# Effect of Thiourea and Dimethylsulphoxide on Phosphorus use efficiency, Dry matter partitioning and Productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.)

ग्वार [ सायमोपसिस टेट्रागोनोलोबा (एल.) टॉब ] की फॉस्फोरस उपयोग क्षमता, शुष्क प्रदार्थ विभाजन एवं उत्पादकता पर थायोयूरिया व डाइमिथाईलसल्फोआक्साईड का प्रभाव

**Thesis**
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**By**
**Narayan Singh Solanki**
**2003**

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR**
**RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR**

## CERTIFICATE –I

Dated 25-02-2003

This is to certify that **Mr. Narayan Singh Solanki** has successfully completed the Preliminary Examination held on 29th May, 2001 as required under the regulation for Doctor of Philosophy in Agriculture.

**(Dr. H.S. Dungarwal)**
Prof. & Head
Department of Agronomy
Rajasthan college of Agriculture
Udaipur (Raj.)

**DEAN**
Rajasthan College of Agriculture
Udaipur

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR**
**RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR**

## CERTIFICATE –II

Dated 25-02-2003

This is to certify that this thesis entitled **"Effect of Thiourea and Dimethylsulphoxide on phosphorus use effeciency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]"** submitted for the degree of **Doctor of Philosophy** in the subject of **Agronomy** embodies bonafide research work carried out by **Mr. Narayan Singh Solanki** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation has been fully acknowledged. The draft of thesis was also approved by the advisory committee on 13th February, 2003.

**(Dr. H.S. Dungarwal)**
Prof. & Head
Department of Agronomy

**(Dr. M.P. Sahu)**
Major Advisor

**(Dr. G.S. Sharma)**
Dean
Rajasthan College of Agriculture,
Udaipur

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR**

**RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR**

## CERTIFICATE -III

Dated : 14/ 6 / 2003

This is to certify that the thesis entitled **"Effect of Thiourea and Dimethylsulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]"** submitted by **Mr. Narayan Singh Solanki** to the Maharana Pratap University of Agriculture and Technology, Udaipur in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** in the subject of **Agronomy** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on this thesis has been found satisfactory, we therefore, recommend that the thesis be approved.

**(Dr. M.P. Sahu)**
Major Advisor

**(Dr. M.S. Shaktawat)**
Advisor

**(Dr. K.B. Shukla)**
Advisor

**(Dr. P.K. Dashora)**
Advisor

**(Dr. H.S. Dungarwal)**
Prof. & Head
Department of Agronomy

**(Dr. H.C.L. Gupta)**
Dean, PGS Nominee

**External Examiner**

DEAN
Rajasthan College of Agriculture
UDAIPUR

APPROVED

**(Dr. L.L. Somani)** 9/7/03
Director Resident Instructions
Maharana Pratap University of Agriculture
and Technology Udaipur (Raj.)

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR**
**RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR**

## CERTIFICATE -IV

Dated : 5/7/2003

This is to certify that **Mr. Narayan Singh Solanki** Student of the Department of **Agronomy**, Rajasthan College of Agriculture, Udaipur has made all corrections/modifications in the thesis entitled **"Effect of Thiourea and Dimethylsulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]"** which were suggested by the external examiner and the advisory committee in the oral examination held on 14.6.2003 The final copies of the thesis duly bound and corrected were submitted on 5.7.03 are enclosed herewith for approval.

**(Dr. M.P. Sahu)**
Major Advisor

Enclosed: one original and two copies of bound thesis. Forwarded to the Director Resident instructions, Maharana Pratap University of Agriculture and Technology, Udaipur through the Dean, Rajasthan College of Agriculture, Udaipur.

**(Dr. G.S. Sharma)**
Dean
Rajasthan College of Agriculture,
Udaipur

**(Dr. H.S. Dungarwal)**
Prof. & Head
Department of Agronomy

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Place : Udaipur

Date : 25.02.2003

**Narayan Singh Solanki**

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# ACRONYMS

| | | |
|---|---|---|
| A | - | Main experiment |
| B | - | -SH compound & -SH blockers trial |
| CGR | - | Crop growth rate |
| cm | - | Centimeter |
| DAS | - | Days after sowing |
| DMA | - | Dry matter accumulation |
| DMD | - | Dry matter distribution |
| DMSO | - | Dimethylsulphoxide |
| DTT | - | Dithiothreitol |
| g | - | Gram |
| ha | - | Hectare |
| IA | - | Iodoacetate |
| kg | - | Kilogram |
| LAI | - | Leaf area index |
| LAR | - | Leaf area ratio |
| m | - | Meter |
| MEA | - | Mercaptoethylamine |
| N | - | Nitrogen |
| NAR | - | Net assimilation rate |
| P | - | Phosphorus |
| PCMBS | - | para-Chlorobenzoicsulphonic acid |
| PM | - | Physiological maturity |
| ppm | - | Part per million |
| S | - | Sulphur |
| -SH | - | Sulphydryl group |
| TU | - | Thiourea |

# 1 INTRODUCTION

Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub], popularly known as guar, is an ancient multipurpose arid legume grown for seed, green fodder, vegetables and green manuring. Besides conventional uses, clusterbean has emerged as an industrial crop because of the presence of galactomannan (guar gum) in its endosperm which constitutes about 30-35 % of seed weight. The most important property of guar gum is its ability to hydrate rapidly in cold water to attain a very high viscosity. Guar gum has diversified uses in textile, paper, petroleum, mining, cosmetic, oil, pharmaceutical, explosives, purification of potash, photography, tobacco and food industries. Maximum guar gum is being used in paper industries, as it ensures a more regular distribution of pulp fiber throughout the sheet, resulting in increased burst strength and tensile strength. For food industries, it is widely used to thicken and stabilize salad dressings, ice-cream, lollipops, bakery products and confectionery items. In textile industry it is used as thickening and sizing agent. Guar gum is also used as a thickening agent in various pharmaceutical preparations. Guar seed meal, a byproduct of guar gum industry, forms concentrated animal feed of immense value as it contains more than 42 % protein against 31 % in guar seed.

Clusterbean is an important foreign exchange earning crop. The export of guar gum was 90530 MT earning Rs. 725 crores during 1998-1999 (Kumar and Singh, 2002). Out of the total global production of guar gum, India is in a leading position with 50 % share, followed by 45 % by Pakistan and 5 % by as many as six countries including USA, Australia, Mexico, Brazil and South Africa.

Being deep rooted and drought hardy, clusterbean has occupied large areas in arid and semi-arid tracts. India has the largest area (23.3 m ha.) and production (10.2 lakh ton) with average productivity of 428 kg/ha. The maximum contribution of the states in respect of area is shared by Rajasthan (19.85 m ha) followed by Gujrat (1.68 m ha.), Haryana (1.47 m ha) and Punjab (0.80 m ha). Rajasthan accounts for about 83 % of country's area and about 59 % of total production, based on last 28 years average (1970-71 to 1997-98). The productivity of guar however, is poorest (average of 28 years, 231 kg/ha) in Rajasthan. Even though the crop is grown largely rainfed, there is great scope for increasing the productivity in good rainfall years. In most of guar growing areas, poor soil fertility is one of the severe constraints limiting expression of potential productivity of the presently available improved varieties.

Phosphorus, next to nitrogen, is the fertilizer nutrient that limits crop yields under most agro-climatic situation. In Indian context, phosphate fertilization assumes great importance as All Indian soil test data (Sarkar and Goswami, 1982) indicate that about 98 %

of the soils are of low to medium fertility in relation to phosphate availability. In the recent past the over all consumption of phosphatic fertilizer and the application rate per unit area has increased. But somehow this has not resulted in any proportionate increase in the yield response particularly in rainfed areas. Commercial phosphatic fertilizer being a non-renewable costly input and much of its demand being met through import every year, its application should take into consideration. The various limiting factors that determine its efficient use by different crops. As the key problems linked with fertilizer phosphorus nutrient are its low utilization by crops, fixation in acid and alkaline soils, interactions with other elements, its management aspect in soil crop system is all the more important. Arid zone soils, being sandy in nature, are poor in fertility. These coarse textured and intensively leached soils also lack in phosphorus reserves. Phosphorus deficiency is usually the most important factor for poor yield of legume crops. In areas where legumes are traditionally grown without phosphorus, poor nodulation is observed with low yield. Phosphorus management, therefore, has an important role to play for increasing productivity of clusterbean. Application of phosphorus at 40 kg $P_2O_5$/ha has been reported to be optimum for clusterbean production under agro-climatic condition of semi-arid and arid zone. (Solanki *et al.*, 1998 and Meena, 2001). However, response of clusterbean to phosphorus application has not been studied in detail under arid agro-climate conditions of Bikaner. It may be noted that with the availability of irrigation water from IGNP, the area under clusterbean cultivation has been increasing in recent years. It was, therefore, thought necessary to assess the response of clusterbean to phosphorus under irrigated condition.

Besides P fertilization, a biotechnological approach for improving productivity of clusterbean could be the use of bioregulators for improving photosynthesis and photo assimilate partitioning. Since clusterbean is largely a crop adapted to limited water environment, the use of bioregulator would prove most rewarding if partitioning of dry matter is hastened for yield formation. Improving crop photosynthesis for larger dry matter production by the use of bioregulators may also help in improving crop yield. Geiger and Giaquinta (1982) pointed out three approaches for improving crop productivity viz., (i) increasing canopy photosynthesis (ii) enhancing efficiency of photosynthetic carbon fixation, and (iii) improving distribution of photosynthate for economic yield. The partitioning of assimilates between their sites of production in photosynthesizing leaves and their site of utilization in harvestable regions is unquestionably a major determinant of crop yield (Gifford and Evans, 1981). The potential of regulating the translocation of assimilates by either plant growth regulators or chemicals (bioregulators) promises substantial opportunities for increasing the yield of crops. Thiourea has been reported to improve dry matter partitioning and grain yield of maize and the effects have been attributed to its - SH content (Sahu and

Solanki, 1991). It is a novel bioregulator with considerable potential for improving productivity of crops. It has also been reported that soil application of thiourea at 5 kg/ha increased phosphorus use efficiency in potato, bringing about a saving of nearly 20 kg $P_2O_5$/ha. The treatment increased tuber yield by 15.2 % (Sud *et al.*, 1991). In view of these observations, it was thought necessary to explore the effects of this bioregulator on phosphorus use efficiency as well as dry matter partitioning of clusterbean under arid environment of Bikaner region. Since thiourea contains both N and S, it is often presumed that the effects of thiourea are nutritional rather than bioregulatory in nature. It was, therefore, also attempted to assess the effects of thiourea by way of comparison with standard sulphydryl compounds and sulphydryl blockers, besides comparing with N and S compounds.

Dimethylsulphoxide (DMSO) is a dipolar aprotic solvent with a high dielectric constant and a tendency to accept protons and has been used as a carrier for many compounds used in cryoprotective studies (Dickinson *et al.*, 1967). Chang and Simon (1968) studied the mechanism by which DMSO protects some biological membrane and the beneficial effects were found through alteration in the permeability characteristics. DMSO has got a property to modulate the level of –SH group and thus improve protein configuration and membrane permeability. Increase in grain yield of several field crops due to DMSO has also been reported by various researchers (Sharma, 1975; Pareek, 1976; Rathore, 1977 and Porwal *et al.*, 1986). It was, therefore, presumed that DMSO might improve productivity of clusterbean either through improvement in phosphorus use efficiency or through improved dry matter partitioning.

Taking cognizance of the facts mentioned above, an investigation entitled "Effect of Thiourea and Dimethylsulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]" was conducted with the following objectives.

(i) to find out response of clusterbean to phosphorus application under arid agro-climatic conditions of Bikaner.

(ii) to improve phosphorus use efficiency with Thiourea and Dimethylsulphoxide application.

(iii) to study the effect of Thiourea and Dimethylsulphoxide on dry matter partitioning and seed yield.

(iv) to study the role of thiourea as an –SH compound.

(v) to arrive at an economically viable recommendation for increasing clusterbean production in Bikaner region.

The present thesis embodies the results of the afore mentioned investigation.

# 2 REVIEW OF LITERATURE

In this chapter, a attempt has been made to compile and collate the experimental findings related to the present investigation entitled "Effect of Thiourea and Dimethysulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub]" . As regards effect of phosphorus on growth and productivity of clusterbean, available research work has been briefly presented. However, no report whatsoever was available on the response of clusterbean to thiourea and DMSO. But the research findings on the effect of thiourea and DMSO in other crops were available still in a limited way. Therefore, these reports on thiourea and DMSO have been suitably presented to highlights the major effects on crop growth and productivity. Further, the experimental evidences related to effects of phosphorus, thiourea and DMSO have been presented under suitable headings in order to elucidate the major trends.

## 2.1 EFFECT OF PHOSPHORUS

### 2.1.1 Growth parameters

Chauhan and Bajpai (1979) reported that on loamy sandy soil of Jobner, clusterbean responded significantly to the application of phosphorus upto 90 kg $P_2O_5$/ha. They tried 0, 30, 60 and 90 kg $P_2O_5$/ha and recorded 14.56, 17.54, 19.06 and 22.44 g dry matter per plant, respectively. In another study, height of clusterbean did not increase at 35, 50 and 65 DAS due to P application but its effect was significant at harvest, wherein 30 kg $P_2O_5$/ha produced 5.1 cm taller plant height compared to control (Nehra, 1980). Wani and Patil (1982) in an experiment on clay loam soil of Rahuri, observed that application of 20 and 40 kg $P_2O_5$/ha significantly increased plant height of clusterbean by 4.5 and 5.5 per cent, respectively over control (99.3 cm).

Raut and Ali (1983) in a field experiment at Jhansi, observed that number of branches and net assimilation rate in clusterbean showed an increasing trend with increasing level of phosphorus (i.e. 0, 20, 40 and 60 kg $P_2O_5$/ha). Application of 20, 40 and 60 kg $P_2O_5$/ha resulted into significantly increased number of branches per plant over control. However, levels of 20, 40 and 60 kg $P_2O_5$/ha were found at par with one another. Regmi (1983) while working with guar-wheat cropping system at IARI, New Delhi found that application of 50 kg $P_2O_5$/ha increased plant height of clusterbean at 60 DAS and harvest over control by 4.7 and 4.7 per cent, respectively. Similarly, dry matter accumulation in 40, 60 DAS and at harvest also significantly increased with the application of 50 kg $P_2O_5$/ha over control.

Kumar (1987) in an experiment on clusterbean with three levels of phosphorus (0, 40 and 80 kg $P_2O_5$/ha) on sandy loam soil at IARI, New Delhi, observed that plant height, dry matter accumulation per plant and LAI at 30, 60 and 90 DAS significantly increased with the application of phosphorus upto 40 kg $P_2O_5$/ha. Application of 40 and 80 kg $P_2O_5$/ha significant increased number of branches per plant by 10.1 and 21.2 per cent, respectively over control. However, levels of 40 and 80 kg $P_2O_5$/ha were at par.

Singh and Singh (1989) reported that on loamy soil at Agra, increasing levels of phosphorus (0, 30 and 60 kg $P_2O_5$/ha) resulted into significant improvement in number of nodules per plant and root length of cluster bean. Number of nodules per plant was significantly increased upto 60 kg $P_2O_5$/ha. Application of 30 and 60 kg $P_2O_5$/ha increased number of nodules by 9.9 and 25.4 and root length by 23.7 and 11.9 per cent, respectively over control.

Meena *et al.* (1991) reported that on loamy sand soil of Jobner (Raj.), number of branches per plant and dry matter per plant of clusterbean increased significantly with application of phosphorus upto 30 kg $P_2O_5$/ha over 20 kg $P_2O_5$/ha. However, phosphorus application did not influence plant height. The maximum number of branches (14.9) and dry matter per plant (26.09 g) was recorded with 40 kg $P_2O_5$/ha but it was at par with 30 kg $P_2O_5$/ha.

Goswami and Naik (1992) reported that chlorophyll a, b and total chlorophyll content of clusterbean were increased by applying 10 % phosphatic effluent solution at Raipur, Chattisgarh. Amar Chand (1994) found that increase in chlorophyll content in clusterbean leaves by 10 % per cent was recorded with 40 kg $P_2O_5$/ha over control.

Tiwana and Tiwana (1994) reported that on sandy loam soil of Bhatinda (Punjab), plant height of clusterbean increased with increasing P levels upto 40 kg $P_2O_5$/ha. Singh and Tiwana (1995) reported that on sandy loam soil of Bhatinda, clusterbean exhibited significantly higher plant height with the application of 30 kg $P_2O_5$/ha by 8.2 per cent over control. However, number of branches per plant remained unaffected due to phosphorus application.

Shivran *et al.* (1996) reported that on loamy sand soil at Jobner (Rajasthan), application of 40 kg $P_2O_5$/ha significantly increased plant height and dry matter/m row length of clusterbean by 5.2 and 14.9 per cent, respectively over 20 kg $P_2O_5$/ha. Bhadoria *et al.* (1997) reported that on sandy loam soil of Gwalior (M.P.), plant height and number of branches significantly increased with successive increase in P levels upto 60 kg $P_2O_5$/ha. Application of 20, 40 and 60 kg $P_2O_5$/ha significantly increased plant height by 10.1, 13.6 and 23.1 per cent and number of branches per plant by 35.0, 37.6 and 59.1 per cent, respectively over control.

Pareek (1995) in an experiment with clusterbean on sandy loam soil of Jobner, compared 20 and 40 kg $P_2O_5$/ha. He observed that application of 40 kg $P_2O_5$/ha significantly increased total dry matter at harvest over 20 kg $P_2O_5$/ha by 6.3 per cent. He also reported that plant height and total chlorophyll content of leaves increased with 40 kg $P_2O_5$/ha in comparison to 20 kg $P_2O_5$/ha. Dadhich (1997) in a trial on loamy sand at Jobner studied the effect of phosphorus on clusterbean. He found that dry matter accumulation/m row length increased significantly due to application of 30 kg $P_2O_5$/ha over control, 10 and 20 kg $P_2O_5$/ha by 25.9, 20.1 and 6.8 per cent, respectively. While, Jat (1997) and Kumawat (1997) at the same location found that application of 60 kg $P_2O_5$/ha significantly increased plant height, dry matter accumulation and number of branches per plant over control and 30 kg $P_2O_5$/ha.

Mand *et al.* (1999) observed that nodulation in clusterbean was improved by phosphorus application as compared to control. Meena (2001) reported that on sandy soil at Bikaner, plant height, number of branches per plant, dry matter accumulation at 30, 60 and at harvest, LAI and total chlorophyll significantly increased with the application phosphorus upto 40 kg $P_2O_5$/ha. However, levels 40 and 60 kg $P_2O_5$/ha were at par. Reager (2001) also found similar results on loamy sand soil at Jobner. Naagar (2001) studied the response of clusterbean to phosphorus (0, 10, 20 and 30 kg $P_2O_5$/ha) on loamy sand soil of Jobner. He observed that plant height, dry matter at 30, 60 DAS and at harvest, number of branches per plant, total chlorophyll and number of nodules/plant increase significantly upto 30 kg $P_2O_5$/ha.

**2.1.2 Yield and yield attributes**

Investigation carried out at Jodhpur and Hisar have shown that clusterbean responded to phosphorus fertilization upto 40 kg $P_2O_5$/ha. Beyond this level the yield attributes were not influenced significantly. (Tomar and Singh, 1976 and Singh & Henery, 1981). Singh (1978) observed significant increase in seed yield of clusterbean at CAZRI, Jodhpur with the application of phosphorus upto 20 kg $P_2O_5$/ha.

Chauhan and Bajpai (1979) in an experiment with four levels of phosphorus viz., 0, 30, 60 and 90 kg $P_2O_5$/ha, on sandy loam soil of Jobner, found that 90 kg $P_2O_5$/ha significantly increased grain yield by 51.8, 21.8 and 14.6 per cent over 0, 30 and 60 kg $P_2O_5$/ha, respectively. Though maximum increase in seed yield was obtained with 60 kg $P_2O_5$/ha but it was at par with 30 kg $P_2O_5$/ha. The maximum straw yield was recorded with 90 kg $P_2O_5$/ha but it did not differ significantly over 60 kg $P_2O_5$/ha. Application of 60 kg $P_2O_5$/ha was at par with 30 kg $P_2O_5$/ha.

Malik *et al.* (1981) tried phosphorus fertilization at 0, 40, 80 and 120 kg $P_2O_5$/ha on clusterbean on sandy loam soil of Hisar. Phosphorus application upto 40 kg $P_2O_5$/ha significantly increased grain yield by 12.9 per cent over control (15.9 q/ha). However, the difference in yield due to different rates of application i.e. 40, 80 and 120 kg $P_2O_5$/ha were not significant. Similarly, Gill and Singh (1981) at the same location found that application of 30 kg $P_2O_5$/ha significantly enhanced the seed yield by 31.4 per cent over control. Levels of 30, 60 and 90 kg $P_2O_5$/ha were at par. Yield attributing characters viz., number of cluster per plant, number of pods per cluster, number of seeds per pod, test weight and seed yield per plant were improved significantly with the application of 30 kg $P_2O_5$/ha.

Wani and Patil (1982) observed that on clay loam soil of Rahuri, number of cluster per plant, number of pods per plant and test weight of clusterbean significantly increased with phosphorus application upto 40 kg $P_2O_5$/ha. The difference between 40 and 80 kg $P_2O_5$/ha did not attain the level of significance. Similar trends were noted in respect of grain yield. Application of 40 kg $P_2O_5$/ha significantly increased grain yield by 43.7 and 23.1 and straw yield by 34.3 and 6.0 per cent over control and 20 kg $P_2O_5$/ha, respectively.

Raut and Ali (1983) reported that on sandy loam soil of IGFRI, Jhansi, phosphorus levels (0, 20, 40 and 60 kg $P_2O_5$/ha) brought about significant influence on number of pods per plant and seed yield during both the years of study. Grain yield increased significantly up to 60 kg $P_2O_5$/ha. The corresponding increases over 0, 20 and 40 kg $P_2O_5$/ha were 57.0, 34.5 and 13.8 per cent, respectively. They also reported that average response to kg/ha $P_2O_5$ applied at 20, 40 and 60 kg $P_2O_5$/ha was 43.9, 25.9 and 9.7 kg seed, respectively.

Dahiya *et al.* (1986) in a study with clusterbean for three consecutive years on loamy sand soil of Hisar found that application of 30 kg $P_2O_5$/ha increased the grain yield significantly over control during all the three years. However, there was no additional benefit with 60 kg $P_2O_5$/ha over 30 kg $P_2O_5$/ha. On an average, 30 kg $P_2O_5$/ha increased the yield by 16.1 per cent over control. Kumar (1987) in a trial on response of clusterbean to phosphorus (0, 40 and 80 kg $P_2O_5$/ha) conducted on sandy loam soil at IARI, New Delhi, found that number of pods, test weight grain yield and straw yield increased significantly with the application of phosphorus upto 40 kg $P_2O_5$/ha. Phosphorus application beyond 40 kg $P_2O_5$/ha did not bring about significant increase in yield attributing character and grain yield. Grain yield increased by 17.7 per cent over control.

Singh and Singh (1989) observed that on sandy loam soil at Agra, application of 60 kg $P_2O_5$/ha significantly increased grain yield by 38.1 and 13.6 per cent over control (13.9 q/ha) and 30 kg $P_2O_5$/ha (16.9 q/ha), respectively. Number of pods also significantly increased with increasing levels of phosphorus upto 60 kg $P_2O_5$/ha. Meena *et al.* (1991) reported that on loamy sand soil of Jobner, increasing levels of phosphorus (20, 30 and 40 kg $P_2O_5$/ha) significantly increased grain yield of clusterbean upto 30 kg $P_2O_5$/ha. Per cent increase due to 30 kg $P_2O_5$/ha over 20 kg $P_2O_5$/ha was 19.4. The harvest index and number of pods per plant remained unaffected due to phosphorus application. Number of grains per pods significantly increased upto 30 kg $P_2O_5$/ha, while test weight increased significantly upto 40 kg $P_2O_5$/ha.

Tiwana and Tiwana (1994) reported on sandy loam soil of Bathinda (Punjab) that all the phosphorus levels (20, 40 and 60 kg $P_2O_5$/ha) produced significantly higher grain yield over 10 kg $P_2O_5$/ha. The grain yield of clusterbean increased significantly with increase in P levels upto 40 kg $P_2O_5$/ha, beyond which a reduction in yield was noticed. The magnitude of increased in yield with 40 kg $P_2O_5$/ha over 10 and 20 kg $P_2O_5$/ha was 16.2 and 9.6 per cent during 1988, and 20.1 and 12.1 per cent during 1989, respectively, similar trend was observed in stover yield. Singh and Tiwana (1995) reported that the phosphorus application (30 and 60 kg $P_2O_5$/ha) increased grain yield of clusterbean over control, but the significant effect was noticed upto 30 kg $P_2O_5$/ha. Grain yield per plant, number of grains per pod and number of pods per plant significantly increased upto 30 kg $P_2O_5$/ha. Application of 30 and 60 kg $P_2O_5$/ha significantly increased grain yield by 50.8 per cent each in 1988 and 27.8 and 31.1 per cent in 1989 respectively over control. However, levels of 30 and 60 kg $P_2O_5$/ha were at par.

Baboo and Rana (1995) reported that on sandy loam soil at Bulandsahar, application of 60 kg $P_2O_5$/ha significantly increased grain yield of clusterbean during 1988 and 1989 over control and 30 kg $P_2O_5$/ha. However, the per kg P response was higher at 30 kg $P_2O_5$/ha. Pareek (1995) at Jobner observed that application of 40 kg $P_2O_5$/ha to clusterbean gave significantly higher number of pods per plant, test weight, seed, straw and biological yields over 20 kg $P_2O_5$/ha. The seed yield significantly increased due to 40 kg $P_2O_5$/ha (8.9 q/ha) by 9.1 per cent over 20 kg $P_2O_5$/ha. He also observed that average response per kg P applied at 20 and 40 kg $P_2O_5$/ha was 46 and 24 kg seed of clusterbean, respectively.

Shivran *et al.* (1996) at Jobner reported that application of 60 kg $P_2O_5$/ha to clusterbean significantly increased number of pods per plant and number of seed per pod over control and 30 kg $P_2O_5$/ha. While, test weight increased significantly upto 30 kg $P_2O_5$/ha. Seed yield, straw yield and harvest index significantly increased due to application of 60 kg $P_2O_5$/ha over control and 30 kg $P_2O_5$/ha. Seed yield increased significantly by 33.1 and 11.3 per cent over control (11.8 q/ha) and 30 kg $P_2O_5$/ha (14.1 q/ha), respectively.

Bhadoria *et al.* (1997) at Gwalior tried 0, 20, 40 and 60 kg $P_2O_5$/ha in clusterbean. He found that application of 60 kg $P_2O_5$/ha significantly increased grain yield by 44.8, 29.5 and 20.9 per cent over control, 20 and 40 kg $P_2O_5$/ha. The average response per kg P applied at 20, 40 and 60 kg $P_2O_5$/ha was 85.2, 45.7 and 36.8 kg seed, respectively.

A field study conducted by Dadhich (1997) at Jobner revealed that seed yield and yield attributes of clusterbean increased significantly with 30 kg $P_2O_5$/ha. However, Jat (1997) at the same location obtained significantly higher seed yield of clusterbean with 45 kg $P_2O_5$/ha. Solanki *et al.* (1998) at Jalore observed that application of 40 kg $P_2O_5$/ha gave significantly higher seed yield of clusterbean over control and 20 kg $P_2O_5$/ha by 38.7 and 24.6

per cent, respectively. The average response per kg P applied at 20 and 40 kg $P_2O_5$/ha was 6.9 and 11.7 kg seed.

Meena (2001) in a trial on response of clusterbean to phosphorus (0, 20, 40 and 60 kg $P_2O_5$/ha), conducted on sandy soil of Bikaner found that yield attributes, yield and harvest index significantly increased with increasing levels of P upto 40 kg $P_2O_5$/ha. Application of 40 kg $P_2O_5$/ha significantly increased seed yield by 31.1 and 13.3 per cent over control and 20 kg $P_2O_5$/ha, respectively.

Naagar (2001) in a study with clusterbean for two years on loamy sand soil at Jobner found that yield attributes viz., number of pods per plant, seeds per plant, length of pod, test weight increased with every increased in P levels (0, 10, 20 and 30 kg $P_2O_5$/ha). Application of 30 kg $P_2O_5$/ha significantly increased seed yield by 40.7, 18.1 and 7.4 per cent over control, 10 and 20 kg $P_2O_5$/ha, respectively. Harvest index remained unaffected.

**2.1.3 Nutrient content and uptake**

The nitrogen content as well as the amount of nitrogen fined in nodules of legume plants were found to be higher with P nutrition (Khare and Rai, 1968). Under field condition of light textured soils of Jobner, phosphorus application at 40 kg significantly increased N and P content in grain and stover of clusterbean by 191.1 and 185.7 &167.59 and 932.5 per cent, respectively. The N and P contents were significantly higher in grains (4.197 and 0.468 per cent) due to fertilization with 30 kg $P_2O_5$/ha over control (3.915 and 0.328 per cent). However, the content in straw were non significant (Nehra, 1980). Gill (1979) reported that application of 30 kg $P_2O_5$/ha significantly increased plant P content of clusterbean.

Patil and Pal (1985) reported that clusterbean seed contained 2.93, 1.38 and 4.27 per cent N in shoot, root and nodules, respectively and the corresponding values of P content were 0.29, 8.51 and 0.35 per cent, respectively. They also reported that total N and P removal were in the order of 4.31 and 4.81 kg/ha, respectively. At New Delhi, Regmi *et al.* (1985) found that phosphorus uptake was 4.6 and 4.9 kg by straw and 16.7 and 16.9 kg/ha by grain at 0 and 50 kg $P_2O_5$/ha, respectively.

Kumar (1987) at IARI observed that P content in clusterbean grain significantly increased due to application of 80 kg $P_2O_5$/ha by 59.9 and 32.8 per cent over control and 40 kg $P_2O_5$/ha, respectively. However P content in stover remained unaffected. N content and total P uptake by the crop significantly increased with the application of phosphorus upto 40 kg $P_2O_5$/ha.

Singh and Singh (1989) at Agra observed that N, P and K uptake by clusterbean were higher under 60 kg $P_2O_5$/ha. The maximum P uptake (11.3 kg/ha) was obtained with 60 kg $P_2O_5$/ha, which was 39.8 and 14.6 per cent higher over control and 30 kg $P_2O_5$/ha, respectively. They also found that a significant positive relationship between nutrient uptake and seed yield.

Sing and Singh (1994) at Agra found that P uptake by clusterbean increased with increasing P rates upto 40 mg P/kg soil. However, P content increased with increasing rates of P upto 40 mg P/kg soil by 17.9 and 6.5 per cent over control and 20 mg P/kg soil, respectively.

Baboo and Rana (1995) reported that P uptake by seed and straw of clusterbean significantly increased with 60 kg $P_2O_5$/ha over control and 30 kg $P_2O_5$/ha during 1988 and 1989. The highest total P uptake of 11.3 kg /ha was obtained with 60 kg $P_2O_5$/ha.

Pareek (1995) reported that the content of N, P and S in seeds and stover were marginally enhanced under the influence of 40 kg $P_2O_5$/ha in comparison to 20 kg $P_2O_5$/ha but their uptake of N, P and S was 10.1, 12.8 and 14.0 per cent higher due to 40 kg $P_2O_5$/ha over 20 kg $P_2O_5$/ha. Bhadoria *et al.* (1997) reported that P content in seed of clusterbean significantly increased with the application of phosphorus upto 40 kg $P_2O_5$/ha. Application of 0, 20 and 40 kg $P_2O_5$/ha gave P content of 0.609, 0.629 and 0.666 per cent, respectively.

Meena (1999) at Jobner while working on clusterbean found that P content in seed and total P uptake by the crop significantly increased with the application of phosphorus upto 45 kg $P_2O_5$/ha. Application of 45 kg $P_2O_5$/ha significantly increased P content in seed (0.348 %) by 24.7, 17.2 and 6.4 per cent and total P uptake by 57.7, 25.9 and 7.8 per cent over control, 15 and 30 kg $P_2O_5$/ha, respectively.

Naagar (2001) at Jobner on clusterbean found that P content of seeds and straw significantly increased with the increasing levels of phosphorus upto 30 kg $P_2O_5$/ha. Application of 30 kg $P_2O_5$/ha significantly increased total P uptake by 63.5, 28.8 and 10.8 per cent over control, 10 and 20 kg $P_2O_5$/ha, respectively.

### 2.2.4 Protein and gum content

Protein content in clusterbean seed had been found to vary from 26.8 to 31.0 per cent (Esser, 1957 and Misra, *et al.*, 1968). Application of 20, 40 and 60 kg $P_2O_5$/ha increased protein content of seeds of clusterbean by 1.2, 2.5 and 2.8 per cent over control at Hisar (Jain *et al.*, 1988). He also found that gum content of seed increased upto 20 kg $P_2O_5$/ha. Higher doses of phosphorus (40 kg $P_2O_5$/ha and 60 kg $P_2O_5$/ha) resulted in the lowering of gum content though it was higher than the control value.

Singh and Singh (1989) reported that protein content and gum content of clusterbean seed significantly increased with the increasing levels of phosphorus upto 60 kg $P_2O_5$/ha. Application of 60 kg $P_2O_5$/ha significantly increased protein content by 13.7 and 5.1 per cent and gum content by 31.6 and 12.2 per cent over control and 30 kg $P_2O_5$/ha respectively. On the contrarily, Madalgeri and Rao (1989) and Malik *et al.* (1981) did not found improvement in seed quality of clusterbean. Protein content of clusterbean seeds improved significantly by 7.2 per cent due to 40 kg $P_2O_5$/ha over 20 kg $P_2O_5$/ha (Amarchand, 1994).

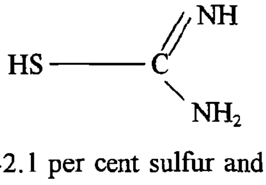
Baboo and Rana (1994) found that application of 60 kg $P_2O_5$/ha significantly increased gum and protein content of clusterbean over control and 30 kg $P_2O_5$/ha during 1988 and 1989. Pareek (1995) found that application of 40 kg $P_2O_5$/ha resulted in 2.3 per cent increase in gum content of clusterbean over 20 kg $P_2O_5$/ha. While protein content did not influence. Bhadoria *et al.* (1997) reported that protein and gum content of clusterbean grains significantly influenced by phosphorus application upto 40 kg $P_2O_5$/ha. However, 40 and 60 kg $P_2O_5$/ha did not differ with each other in this respect. Application of 40 kg $P_2O_5$/ha significantly increased protein content (31.31 %) by 5.3 and 2.1 per cent and gum content (29.0 %) by 2.9 and 1.7 per cent over control and 20 kg $P_2O_5$/ha, respectively.

Dadhich (1997) at Jobner reported that protein and gum content of clusterbean seeds significantly increased with the application of phosphorus upto 30 kg $P_2O_5$/ha. However, Meena (1999) at the same location found that protein and gum content of cluster bean seeds significantly increased upto 45 kg $P_2O_5$/ha. Application of 45 kg $P_2O_5$/ha significantly increased protein content by 10.3, 7.5 and 2.7 per cent and gum content by 13.6, 8.1 and 2.3 per cent over control, 15 and 30 kg $P_2O_5$/ha, respectively.

Naagar (2001) at Jobner reported that protein and gum content of clusterbean seed significantly enhanced due to phosphorus application upto 30 kg $P_2O_5$/ha. Application of 30 kg $P_2O_5$/ha significantly increased protein content of seed by 14.3, 7.5 and 2.3 per cent and gum content by 6.3, 3.1 and 1.3 per cent over control, 10 and 20 kg $P_2O_5$/ha, respectively.

## 2.2 EFFECT OF THIOUREA APPLICATION ON CROP GROWTH AND PRODUCTIVITY

Thiourea is a sulphydryl compound (Jocelyn, 1972). It contains one –SH group besides containing nitrogen in the form of –$NH_2$ as evident from its structural formula given below




Thiourea contains 42.1 per cent sulfur and 36.8 per cent nitrogen. Thus, it behave in the physiology of plant both as a suphydryl compound and as an amino compound like urea. The stimulatory action of thiourea in various physiological processes of plants is well known. Poljakoff Mayber and Mayer (1960) have summarized some of these effects in plants.

Thiourea is chiefly known for it dormancy breaking and germination stimulating effect (Mayer, 1956), Mayer and Poljakoff Mayber (1958) and Poljakoff Mayber *et al.* (1958). It is interesting to note that thiourea promoted growth in cytokinin requiring soybean and tobacco callous tissues in the absence of kinetnin (Erez, 1978). The increase in fresh and dry weights obtained was a result of cell multiplication. Callous tissues grew well when repeatedly sub-cultured in kinetin free medium containing thiourea. Best growth was obtained with $10^{-4}$ to $10^{-3}$ M thiourea. At these concentrations, synergism was demonstrated between thiourea and cytokinin, kinetin, BA and zeatin. Thiourea caused greater growth than diphenyl urea and phenyl thiourea. The possibility that a breakdown product of thiouera was responsible for the enhanced growth was noted excluded. The dormancy breaking effect of thiourea was suggested to be related to its growth enhancing effect. Vassilev and Mashev (1974) tried a number of derivatives of thiourea, using leaf discs of *Raphanus sativus* and concluded that the compounds exhibited cytokinin like activity, the substances with high cytokinin activity also brought about increased accumulation of N in barley seedlings.

**2.2.1 Effect thiourea on crop growth and productivity**

Arkhangelski *et al.* (1975) reported that spraying of seedlings of sugar beet with 0.2 per cent solution of thiourea at the stage of flower buds and seed formation significantly increased seed yield and improved the quality. It was also reported that seeds obtained from the treated plants gave higher yields of roots in comparison to the control harvested from untreated plants. Hoping (1977) reported that application 1.5 % thiourea through foliage 55 weeks before anticipated bud break, increase bud break fruitful shoots and yield per plant of grapevines. Snir (1983) reported that foliar spray of thiourea at 1 % improved bud break and significantly increased yield of red raspberry in comparison to control.

Pareek (1987) observed that foliar spray of thiourea + $FeSO_4$ significantly increased grain yield of sorghum by 21.9 and 46.5 per cent in comparison to $FeSO_4$ and control, respectively. Also thiourea treatment significantly increased N, K and S content of leaves but reduced P content. These results with thiourea were obtained in chlorotic sorghum grown on alkaline calcareous soils of Udaipur.

Narang (1988) observed that foliar spray of 0.1 % thiourea improved LAI, dry matter accumulation per plant and harvest index of gram. The N, K and S, Ca+Mg and Zn contents of leaves significantly increased with thiourea spray in comparison to control but P content remained unaffected. Fe content showed a significant reduction over control. Further, thiourea spray also significantly increased chlorophyll content of leaves by 3.6 per cent and yield by 47.08 per cent.

Sharma (1988) observed that foliar spray of 0.2 % thiourea at grain initiation in pearlmillet significantly increased dry matter accumulation per plant, LAI and number of green leaves per plant over water control. Thiourea spray increased number of grains per ear, 1000- grain weight and grain weight per ear, which jointly resulted in 14.11 per cent increased grain yield with an improved harvest index of 36.03 per cent as against 32.13 per cent in control. The efficacy of thiourea spray was found attributable to improved dry matter partitioning to grain.

Mahavar (1989) in a study assessing the role of thiourea in mustard production, observed that foliar spray of 0.2 % thiourea at flowering significantly increased seed yield by 14.1 per cent over control. Further, thiourea spray increased LAI, dry matter per plant and harvest index of mustard.

Verma (1989) observed that foliar spray of 0.2 % thiourea significantly increased number of pods per plant and number of kernel per pod of groundnut. It had no effect on seed index and shelling percentage. He also observed that thiourea spray significantly increased pod yield by 6.6 per cent over control.

Patel (1991) reported that 0.1 % thiourea spray at flowering significantly increased number of pods per plant, number of grains per pod and seed index of chickpea in comparison to water control. Grain yield increased by 20.4 per cent over control.

Sachan (1991) observed that foliar spray of 500 ppm thiourea increased dry matter accumulation per plant, LAI and number of leaves per plant at physiological maturity of maize. Yield components viz., length of cob, diameter of cob, number of grains per cob and grain weight per cob also increased under this treatment and the grain yield eventually increased by 25.4 per cent over control. Protein content of grain also increased under thiourea treatment.

Seven year study conducted in green house and field trial by Sud *et al.* (1991) on loamy sand soil of Shimla revealed that in green house study the application of thiourea increased potato yield and P uptake by 13.1 and 44.7 %, respectively over control. Continuous application of thiourea and phosphorus significantly increased the soil P by 15 ppm compared with control. In field trial they observed that the combined application of thiourea and phosphorus gave the best results. The increase in seed yield was 10-20 % with 5 kg thiourea, 34-49 % with 44 kg P/ha and 60-70 % with combined application of thiourea and phosphorus. Application of thiourea resulted in better utilization of P from the soil. Thiourea in combination with phosphorus increased uptake of P by 28.4 % compared with P application alone. They reported that application of 5 kg thiourea alone was found to save 22 kg P/ha for potato crop.

Sahu and Solanki (1991) reported that foliar spray of 0.1 % thiourea at grain formation stage significantly increased grain yield of maize by 34.1 % over water control. Since foliar spray of 0.1 % urea did not improve grain yield, it was inferred that the biological activity of thiourea was primarily on account of its –SH group. Increased grain yield of maize with thiourea spray was found to have resulted on account of improvement in harvest index. Saini (1991) reported that 0.1% thiourea spray significantly increased latex and seed yield of opium poppy by 24.6 and 36.0 per cent, respectively over control.

Intodia (1992) observed that foliar spray of 500 ppm thiourea at capsule development of opium poppy significantly improved LAI, DMA, LAD and chlorophyll. N, K and S content of leaves and seeds and their uptake by the crop also increased. Seed and lalex yields increased by 9.9 and 11.5 %, respectively over control.

Moizi (1993) observed that foliar spray of $FeSO_4$ + thiourea significantly increased number of pods per plant, number of kernel per pods, yield per plant and pod yield per hectare of groundnut. $FeSO_4$ + thiourea was found to be significantly more effective than Fe-EDHA in improving these parameters. He also observed that $FeSO_4$ + thiourea spray increased the pod yield by 21.9 per cent over control.

Sahu *et al.* (1993) reported that foliar spray of 0.1 % thiourea at 30 and 45 DAS significantly increased LAI and number of green leaves per plant at physiological maturity in maize. Thiourea spray increased grain yield by 40.6 per cent over control.

Singh *et al.* (1993) observed that foliar spray of thiourea at 2 % resulted in advanced maturity by 3 days in 20 years old pear trees. Intodia & Tomar (1994) reported that foliar spray of 1000 ppm thiourea and 2-mercaptoethanol increased grain yield of foxtail millet over control. Kovacik (1994) reported that soil applied thiourea in radish reduced soil nitrate content only when it applied before sowing. However, it had no significant effect on radish nitrate content.

The result of field trial conducted under AICMIP at Almora centrer revealed that foliar spray of thiourea (0.1%) increased the grain yield of maize by 12.2 per cent over control (21.1 q/ha). Similarly, work carried out at Udaipur centre of ALCMLP further confirmed that foliar spray of 0.1 % thiourea at tassel initiation and grain formation produced significantly higher test weight (244.8 g), grain and stover yields (35.5 and 60.7 q/ha, respectively) over water spray. However, plants treated with thiourea attained a significantly lower plant height over water spray (Anon., 1994).

Similarly, Dadhich (1994) reported that soil application of thiourea at 10 kg/ha in combination with $FeSO_4$ at 25 kg/ha increased the grain yield of soybean by 17 % over $FeSO_4$ alone.

Sahu and Singh (1995) reported that soil application of thiourea at 10 kg/ha significantly increased ears/m row length, grains/ear, weight/grain and harvest index of wheat. The seed yield also significantly increased by 17.3 % over control with the application of thiourea at 10 kg/ha over control. They further reported that foliar spray of thiourea (500 ppm) at tillering and flowering brought about an increase of 24 % in grain yield of wheat grown in heavy soils of Udaipur.

Dhankhar and Singh (1996) reported that maximum number of roots in Aonla at 35 DAS was attained with thiourea spray at 750 ppm. Gutierrez *et al.* (1996) observed that application of thiourea significantly increased the number of shoot and spikes for plant, as well as in the grains number and weight with concentrations of 2 % in wheat.

Rathore (1996) reported that at Udaipur thiourea infusion in maize significantly increased total chlorophyll, LAI, green leaves per plant, number of seed per cob and seed weight/cob over the water control.

Khafi *et al.* (1997) reported that at Udaipur foliar application of 0.1 % thiourea significantly increased the plant height, number of secondary branches per plant siliquae per plant, seeds per siliqua and seed yield per plant of mustard. The harvest index, seed and stover yields were also increased with thiourea foliar spray.

Parihar *et al.* (1997 & 1998) while working at Jodhpur reported that foliar application of 1000 ppm thiourea significantly increased crop growth, dry matter partitioning, yield components and 1000 grain weight compared to water spray in pearl millet. When compared with water spray (188.3 kg/ha), he observed a mean increase in grain yield by 9.6 per cent. Non-significant result with respect to grain and fodder yield were obtained with sprays of 1000 ppm thiourea and water in sorghum under AICSI P centre at Udaipur (Anon, 1995-96).

Sharma (1997) reported that foliar spray of thiourea on maize maintained the higher number of green leaves per plant over water spray. Thiourea enhanced the DMA of cobs by 18.4 per cent and increased LAI, total chlorophyll and number of grains per cob by 17.4, 15.8 and 16.6 per cent, respectively. Further, thiourea also recorded the higher grains per row of cob, 1000 grains weight by 16.6 and 6.6 and 6.6 per cent and harvest index of maize was increased by 13.9 per cent.

Shekhawat (1998) in a study on loamy sand soil of Bikaner observed that foliar spray 0.1 % thiourea significantly increased the LAI, CGR and leaf area duration of mustard but decreased plant height and leaf are ratio. He reported that thiourea spray increased number of siliqua, length of siliqua and number of seeds per siliqua by 9.0, 4.5 and 2.7 per cent, respectively in comparison to water spray. He reported 17.6, 8.8 and 10.7 per cent increase in grain, stover and biological yields, respectively with the application of thiourea spray over water spray.

Singh (1999) in a study under agroclimatic conditions of Bikaner found that seed soaking and foliar spray of thiourea (0.05 %) at pre flowering stage significantly increased grain yield of green gram by 15.8, 10.4, 8.9 and 9.1 per cent over control, seed soaking with TU, foliar spray of TU at branching and foliar spray of TU at 50 % flowering, respectively. He also reported that total chlorophyll content, dry matter accumulation, number of pods per plant, number of grains per pod increased significantly due to this treatment over control.

Positive effects of 0.1 % TU spray in clusterbean at 25 and 45 DAS on net photosynthesis, total chlorophyll, starch and NR activity over control have been observed (Anonymous, 1999). The net photosynthesis increased from 10.30 $\mu$ mol $m^2$ $S^{-1}$ under control to 17.06 $\mu$ mol $m^2$ $S^{-1}$ under 0.1 % TU spray at 25 and 45 DAS. Similarly, chlorophyll content increased from 3.29 mg/g dw to 5-90 mg/g dw, starch from 149.0 mg/g dw to 239.0 mg/g dw and NR activity ($\mu$g $No_2$) from 434.2 mg/g $dwh^{-1}$ to 569.0 mg/g $dwh^{-1}$, respectively.

Chandra and Pandey (1998) at Jorhat (Assam) found that foliar spray of 1.5 % thiourea on pruned tea (*Camellia sinensis* L. 0 Kuntze) significantly increased quality parameters such as caffeine, crude protein, starch, N, carotenoid and ascorbic acid content over control.

Yadava (2000) in a study on sandy soil of Bikaner observed that foliar spray of 0.05 % thiourea at tillering and flowering significantly increased growth and yield attributes of oats under one and two cut treatment. He also reported that foliar spray of 0.05 % thiourea at tillering and flowering increased seed yield of uncut oats crop by 26.7 per cent over control (17.59 q/ha).

Pandey *et al.* (2000) studied the effect of N levels and foliar spray of sulphydryl compounds (thiourea and 2-mercaptoethanol) on maize. The results indicated that spraying of 0.1 % thiourea at 10 and 20 days after tassel emergence gave a yield of 3040 kg/ha compared with 2650 kg/ha from a water control and 2520 kg/ha from 0.1 % mercapto-ethanol.

Jharia (2002) studied the effect of foliar spray of thiourea on clusterbean at Bikaner. The result indicated that foliar spray of 500 ppm thiourea at branching resulted in significant improvement in yield attributes viz., number of pods per plant, number of seeds per pod, seed yield per plant and test weight over control. N, P and gum content of seed also significantly increased due to foliar spray of 500 ppm thiourea. The total P uptake by the crop was 55.5 per cent higher over control. He reported that seed, straw and biological yields and harvest index significantly increased due to foliar spray of 500 ppm thiourea by 22.6, 9.1, 12.7 and 8.7 per cent, respectively over control.

Sharma (2002) on sandy soils of fatehpur (Rajasthan) observed that foliar spray of 500 ppm thiourea gave higher seed yield of clusterbean (11.05 q/ha) over foliar sprays of

DMSO and brassinoloids. Among the foliar applied growth substances maximum protein and gum content of grain (26.8 and 27.8 %) was obtained under foliar spray of 500 ppm thiourea.

## 2.3 EFFECT OF DIMETHYLSULPHOXIDE (DMSO) ON GROWTH AND PRODUCTIVITY

DMSO in a dipolar aprotic solvent with a high dielectric constant and a tendency to accept protons and has been used as a carrier for many compounds used in cryoprotective studies (Dickinson *et al.*, 1967). Chang and Simon (1968) studied the mechanism by which DMSO protects some biological membrane and the beneficial effects were found through alterations in the permeability characteristics. They suggested that the effect of DMSO are primarily due to its ability to alter enzyme reaction rate and possibly the protein configuration. Therefore, it is possible that at low concentration DMSO permits protein molecules to assume more open, less hydrogen bounded configuration. Burns (1974) reported protection of citrus cell against freezing damage by DMSO.

Significant increase in sugar content of leaf and seed yield was observed in opium poppy with DMSO application (Sharma, 1975; Pareek, 1976; Rathore, 1977). Porwal *et al.* (1986), while working on chemical cryoprotective in gram, reported significant increased in water soluble carbohydrate and protein content of leaves. Increase in grain yield was also significant.

Broome and Zimmerman (1976) reported that DMSO proved an excellent solvent for the cytokinins and slightly enhanced their effects. Prikhod et al. (1978) observed that two foliar sprays of 2.5 % DMSO increased root yield of sugar beet by 0.92 to 1.02 t/ha.

Delmer (1979) reported that DMSO acts selectively on the plasma membrane of cultured tobacco cells, rendering it more permeable to small molecules, while having a for smaller effect on the permeability of the vacuolar membrane. Prikhod and Zub (1979) found that sugar beet plants treated with 2.5 % DMSO increased the N accumulation in roots and leaves, permeability of cell wall, non-metabolic absorption of nitrates by roots and utilization of soil N.

Lundberg *et al.* (1986) observed that treatment with 5 % DMSO for 30 minutes resulted in permeabilization of most cells. Dhakar (1986) reported that foliar spray of DMSO significantly increased grain yield and oil content of mustard.

Michalik (1987) reported that 0.01 % DMSO reduced root P influx in maize roots and increased it by 26.9 %. Rao (1987) reported that foliar spray of DMSO brought about increase in chlorophyll, N, K and S contents of leaves of grain, while P content was decreased. Increase in grain yield was 39.6 % over control. Romanenko *et al.* (1987) found that incubation for 9.5 h of root sigment of 3 or 4 day old radish cv. Red Gaint seeding treated with haemoglobin in 5 mg DMSO/ml almost doubled the pinocytotic activity in the root hairs whereas incubation in 20 mg DMSO/ml inhibited pinocytotic activity. In wheat root segment maximum pinocytotic activity occurred with 0.5 mg DMSO/ml

Singh and Khangarot (1987) reported that in a field trial designed to assess the efficacy of certain agro-chemicals, foliar spray of DMSO (78 g/ha) significantly increased the grain yield of gram and that the beneficial effects were mainly on account of increase in the number of pods per plant.

Southwick and Poovalah (1987) studied auxin movement in strawberry fruits corresponding to its growth promoting activity. The results indicated that NAA at $10^{3}$ M concentration plus 2 % DMSO in lanolin paste, applied to apices of unpollinated receptacles, promoted growth and receptacle elongation, resulting in full sized fruit

Narang (1988) reported that foliar spray of DMSO significantly increased chlorophyll a, total chlorophyll of leaf, water soluble carbohydrates, leaf sap, EC, N and K content leaves, pod yield/plant, branches/plant, seeds index and grain yield of gram in comparison to control. The yield increased by 49.85 per cent control due to foliar spray of DMSO over control. Saini (1991) reported that seed yield of opium poppy increased due to foliar spray of DMSO by 16 5 % over control.

Kolupaev (1997) studied the effect of 0 005, 2 0 M DMSO applied before and after heat stress on the resistance of wheat coleoptiles grown at 18 °C for 5 days to heat stress of 45 – 46 °C for 10 h was investigated. DMSO treatment reduced heat damage both during and after exposure It is suggested that the inhibitory effect of DMSO on cell metabolism is responsible for it protection from heat damage.

## 2.4 EFFECT OF MERCAPTOETHYLAMINE, DITHIOTHREITOL, PARA-CHLOROMERCURICBANZOIC SULPHONIC ACID AND IODOACETATE

Giaquinta (1976) suggested that the water soluble, sulfhydryl-specific, chemical modifier p-chloromercuribenzenesulfonic acid reversibly inhibited the accumulation of exogenously supplied $^{14}C$ sucrose into the leaf discs of *Beta valgaris*. PCMBS treatment did not inhibit photosynthesis or respiration or induce membrane leakage to sucrose, indicating that the site of inhibition was the plasmalemma. The active loading of sucrose and $^{14}CO_2$ derived assimilates into the phloem and their thranslocation from the source leaf were inhibited by the non-permeant modifier. Several non-permeant sulfhydryl group modifiers also inhibited sucrose accumulation into leaf discs while two amino reactive reagents had no effect The results indicate that sugars are actively accumulated into the phloem from the apoplast and that membrane sulfhydryl groups may be involved.

Delrot *et al.* (1980) studied the effects of a penetrating (NEM) and a non-penetrating (PCMBS) sulfhydryl- specific reagent on proton extrusion, 86 Rb and ($U^{14}$) sucrose uptake by *Vicia faba* leaves. He concluded that PCMBS (1 mM) exerted a strong inhibition on ($^{14}C$) sucrose uptake but did not inhibit proton extrusion and $^{86}Rb$ uptake. The sensitivity of phloem loading to PCMBS is thought to be consequence of sugar carrier blockage and not of inhibition of the proton pump.

The respiratory metabolism of tobacco callus and its relation to tissue differentiation and bud primordium formation were studied in tobacco by Li and Liang (1990). They found that respiratory rate of callus increased on the 6$^{th}$ day and decreased after 15 day in culture. On the 18$^{th}$ day, there was a second rise in respiratory rate, indicating the start of callus senescence. When treated with inhibitor (iodoacetate, malonate and $Na_3$ $PO_4$), the degree of participation of HMP (hexose monophosphate pathway) was higher than that of EMP (Embden-meyerhoff-parnas pathway) in callus cultured for 6-12 day. On the 18$^{th}$ day in culture, callus respiration was markedly inhibited by iodoacetate, indicating that EMP was the main component of respiratory metabolism in callus at the beginning of senescence.

Farrar and Minchin (1991) tested four hypothesis for the control of partitioning of photoassimitated 11 C between the 2 halves of split root system of young barley plant. They found that import is related to total ability (metabolism plus storage) of the sink to use sucrose. Treatments that would have led to greatly decreased use of sucrose (iodoacetate inhibition) decreased import before those which would have led to a smaller decrease in sucrose use.

Sahu and Solanki (1991) reported that foliar spray of 0.1 % mercaptoethylamine increased grain yield of maize by 29.2 per cent over water spray (control). They also observed significant increase in harvest index due to foliar spray of 0.1 % mercaptoethylamine over control.

Hatch and Agostino (1992) found that hypocotyl protoplasts of cauliflower reduced their mitochondrial contribution to the fusion products with iodoacetate treatment, although it did not affect chloroplast segregation. They studied bilevel disulfide group reduction in the activation of $C_4$ leaf nicotinamide adenine dinucleotide phosphate –malate dehydrogenase of *Zea mays*. They found that the maximum steady rate of activation was increased and the length of the lag in activation decreased, as the concentration of thioredoxin –m, dithiothreitol and KCI were increased. The lag in activation (sigmoidicity) was eliminated by preincubating the inactivated enzyme with 100 millimole 2-mercapto ethanol, this pre treatment did not activate the enzyme.

Thimann *et al.* (1992) studied the effects of different inhibitors on oats coleoptile cell in IAA. They found that growth was inhibited by 2 mm iodoacetate, and short, fragmented, twisted or curled microfilaments occurred in most cells.

Zhang *et al.* (1992) studied improvement of longevity and viability of sperm cells isolated from pollen of *Zea mays*. They observed that cysteine caused a rapid decrease in cell viability and increased lysis, whereas dithiothreitol increased the cell numbers but lowered their viability.

Fieuw and Patrick (1993) studied photosynthate efflux from the vascular region of *Vicia faba* seed coats using was-out experiment after removal of the embryo. Sulphydryl group modifiers reduced 14 C- photosynthate efflux by 40-50 %, while the inhibitory effect was prevented or reduced by dithiothreitol, which competes with these compounds for sulphydryl groups.

Harris and Heber (1993) observed that chlorophyll fluorescence yield in spinach slowly increased only when dithiothreitol or dithionite was added. Hayashi and Chino (1995) reported that active thioredoxin is a major protein translocated in rice sieve tubes. Parry *et al.* (1997) reported that treatment of the S 3-RNase from wild tomato Lycopersicon peruvianum (L.) Mill with iodoacetate at pH 6.1 led to a loss of RNase activity. In presence of a competitive inhibitor, guanosine 3' – monophosphate, (3'-GMP), the rate of RNase inactivation by iodoacetate was reduced significantly.

Nakamura et al. (1999) observed enzyme activity in the leaf extract of *Trillium apetalon* was stimulated by EDTA and dithiothreitol, but strongly inhibited by P-chloromercuribenzoate and iodoacetate.

The signaling process of water stress induced abscisic acid (ABA) accumulation was investigated in maize (*Zea mays* L.) leaf and root tissues by Jia and Zhang (2000). They reported that dithiothreitol, a reducing agent but not a free radical scavenger, significantly inhibited dehydration induced ABA accumulation whereas solely free radical scavenger, dimethylsulphoxide (DMSO), had no effect. Supfhydryl modifier, iodoacetamide (IOA) totally blocked the water stress induced ABA accumulation. Furthermore, an impermeable sulfhydryl modifier, P-chloromercuriphenyl-sulphonic acid (PCMBS), could also inhibit the water stress induced ABA accumulation in the leaf tissues. These results indicate that water stress perception protein (S) or receptor (s) may be located on the plasmalemma and sulpfhydryl group in the extracellular domain is critical to the reactivity of the speculated water stress receptors. Dithiothreitol and IOA did not lead to a decrease of the baseline ABA level, i.e. in non-stress roots.

Malanchuk *et al.* (2000) studied the activity of alpha-galactosidase isolated from culture fluid of cladosporium cludosporioides and how it is affected by cations, anions and specific chemical reagents. Ag + ions competitively inhibited alpha-galactosidase. Pre incubation with galactose did not protect alpha-galactosidase from the inhibitory effects of Ag + or P-ch MB, but thiol compound (L-cysteine, dithiothreitol, beta –mercaptoethanol) restored the enzyme activity. These results imply a role for the histidine imidazole group in catalysis. Sulphydryl groups play an important role in supporting the active conformation of the protein molecule.

Eksittikul *et al.* (2001) developed a leaf disc system to study sucrose uptake in cassava (*Manihot esculenta*). Sucrose uptake was found to be strongly inhibited by sulphydryl reagents, para-chloromercuribenzene sulfonate and iodoacetate.

# 3 MATERIALS AND METHODS

The investigation entitled ' Effect of Thiourea and Dimethylsulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L) Taub.] was conducted during *kharif* season of 1999 and 2000 at the research farm, Agricultural Research Station, Beechwal, Bikaner. In order to achieve the objectives of the study, two separate experiments were conducted. The materials used and techniques adopted during the course of the investigation are described in this chapter.

## 3.1 LOCATION OF EXPERIMENTAL SITE

Bikaner, the experimental location, is situated at an elevation of 234.70 metres above mean sea level with latitude of $28.01^0$ North and longitude of $73.22^0$ East. According to 'Agro-ecological region map' brought out by National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Bikaner falls under Agro-Ecological region No.2 (M9E1) under Arid Ecosystem (Hot Arid Ecoregion with Desert and Saline soils), which is characterized by deep, sandy and coarse loamy, desert soils with low water holding capacity, hot arid climate, and precipitation less than 300 mm. PET in this region ranges between 1500-2000 mm. As per NARP agro- climatic zone, Bikaner falls in Zone 1c, which has recently carved out of the original zone 1a. The newly created zone 1c is known as Hyper Arid Partially Irrigated Western Plains and consists of the districts of Jaisalmer, Bikaner and four tehsil of Churu districts, i.e., Dungargarh, Ratangarh, Sujangarh and Sardarshahar. The soils of zone are mostly sandy in texture and aeolin in nature having high permeability at surface and are very low in fertility and organic matter content.

## 3.2 CLIMATE AND WEATHER

The region has arid climate characterized by moderate winter and harsh summers. Strong southwest winds during summer with frequent dust storms are regular phenomena. The average rainfall of Bikaner is 260 mm, most of which is received during the months of July and August. During the course of the study, weather conditions were, in general, favourable for the growth and development of the crop.

The maximum and minimum temperatures during crop growth period ranged between 30-40.6 $^0$ C and 15.8-30.4 $^0$ C, respectively during 1999. In the year 2000, the maximum and minimum temperature during crop growth period ranged between 32.0-41.0 $^0$ C and 11.3-30.2 $^0$ C, respectively. During crop growth period, 34.0 and 166.3 mm rainfall was recorded in 1999 and 2000 respectively.

**Table 3.1 Mean weekly weather parameters during the crop growth period (1999 & 2000)**

| Std. Week No. | Period | | Mean Temperature ($^{0}C$) | | | | Relative humidity (%) | | | | Rainfall (mm) | | Wind velocity (km/hr) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Maximum | | Minimum | | Maximum | | Minimum | | | | | |
| | From | To | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| 27 | July 02 | July 08 | 40.0 | 41.0 | 30.4 | 30.0 | 58 | 60 | 39 | 33 | 00.0 | 00.0 | 09.2 | 13.3 |
| 28 | July 09 | July 15 | 40.6 | 39.3 | 28.4 | 30.2 | 73 | 68 | 43 | 51 | 04.6 | 11.0 | 10.3 | 14.3 |
| 29 | July 16 | July 22 | 37.7 | 36.3 | 27.4 | 26.7 | 74 | 81 | 57 | 63 | 45.6 | 05.0 | 07.4 | 15.2 |
| 30 | July 23 | July 29 | 38.5 | 35.5 | 28.6 | 26.5 | 69 | 76 | 45 | 42 | 00.0 | 157.8 | 09 5 | 15.2 |
| 31 | July 30 | Aug.05 | 32.3 | 37.0 | 26.3 | 27.1 | 80 | 64 | 61 | 37 | 26.4 | 00.0 | 07.5 | 16.7 |
| 32 | Aug.06 | Aug.12 | 38.0 | 38.2 | 28.4 | 27.2 | 77 | 67 | 47 | 36 | 00.0 | 00.0 | 08.5 | 12.5 |
| 33 | Aug. 13 | Aug.19 | 37.4 | 36.1 | 27.2 | 26.3 | 75 | 79 | 42 | 53 | 00.0 | 07.1 | 08.8 | 13.6 |
| 34 | Aug. 20 | Aug 26 | 37.6 | 38.7 | 26.9 | 27.2 | 70 | 71 | 38 | 40 | 00.0 | 01.4 | 09.9 | 07.1 |
| 35 | Aug 27 | Sept. 02 | 30 0 | 37.2 | 27.5 | 27.3 | 71 | 69 | 44 | 42 | 00.0 | 00.0 | 07 5 | 15.8 |
| 36 | Sept. 03 | Sept. 09 | 38.8 | 37.3 | 27.4 | 26.6 | 71 | 69 | 42 | 40 | 07.6 | 00.0 | 06.1 | 13.4 |
| 37 | Sept.10 | Sept. 16 | 40 1 | 36.4 | 27.4 | 24.4 | 68 | 69 | 30 | 29 | 00.0 | 00.0 | 06.1 | 11.7 |
| 38 | Sept.17 | Sept. 23 | 37.8 | 37.8 | 26.7 | 23.8 | 66 | 63 | 32 | 23 | 00.0 | 00.0 | 07.7 | 09.4 |
| 39 | Sept 24 | Sept.30 | 34 0 | 38.4 | 26.4 | 22.9 | 66 | 58 | 28 | 21 | 00.0 | 00.0 | 06.1 | 09.1 |
| 40 | Oct. 01 | Oct 07 | 36.8 | 39.7 | 23.5 | 22.5 | 77 | 44 | 28 | 16 | 00.0 | 00.0 | 05.3 | 05.6 |
| 41 | Oct. 08 | Oct. 14 | 38.5 | 38.1 | 23.0 | 21.4 | 58 | 51 | 19 | 22 | 00.0 | 00.0 | 04.4 | 06.5 |
| 42 | Oct. 15 | Oct. 21 | 37.7 | 38.2 | 19.9 | 17.4 | 45 | 37 | 21 | 12 | 00.0 | 00.0 | 04.2 | 05.0 |
| 43 | Oct. 22 | Oct. 28 | 37.2 | 37.2 | 18.9 | 18.1 | 47 | 49 | 17 | 14 | 00.0 | 00.0 | 04.0 | 06.0 |
| 44 | Nov. 29 | Nov. 04 | 37.2 | 35.0 | 18.5 | 15.3 | 45 | 47 | 19 | 15 | 00.0 | 00.0 | 03.1 | 04.5 |
| 45 | Nov. 05 | Nov. 11 | 33.3 | 33.5 | 17.0 | 15.3 | 45 | 54 | 18 | 18 | 00.0 | 00.0 | 04.6 | 04.6 |
| 46 | Nov. 12 | Nov 18 | 33.2 | 32.0 | 15.8 | 11.3 | 56 | 58 | 26 | 25 | 00.0 | 00.0 | 03.6 | 04.1 |

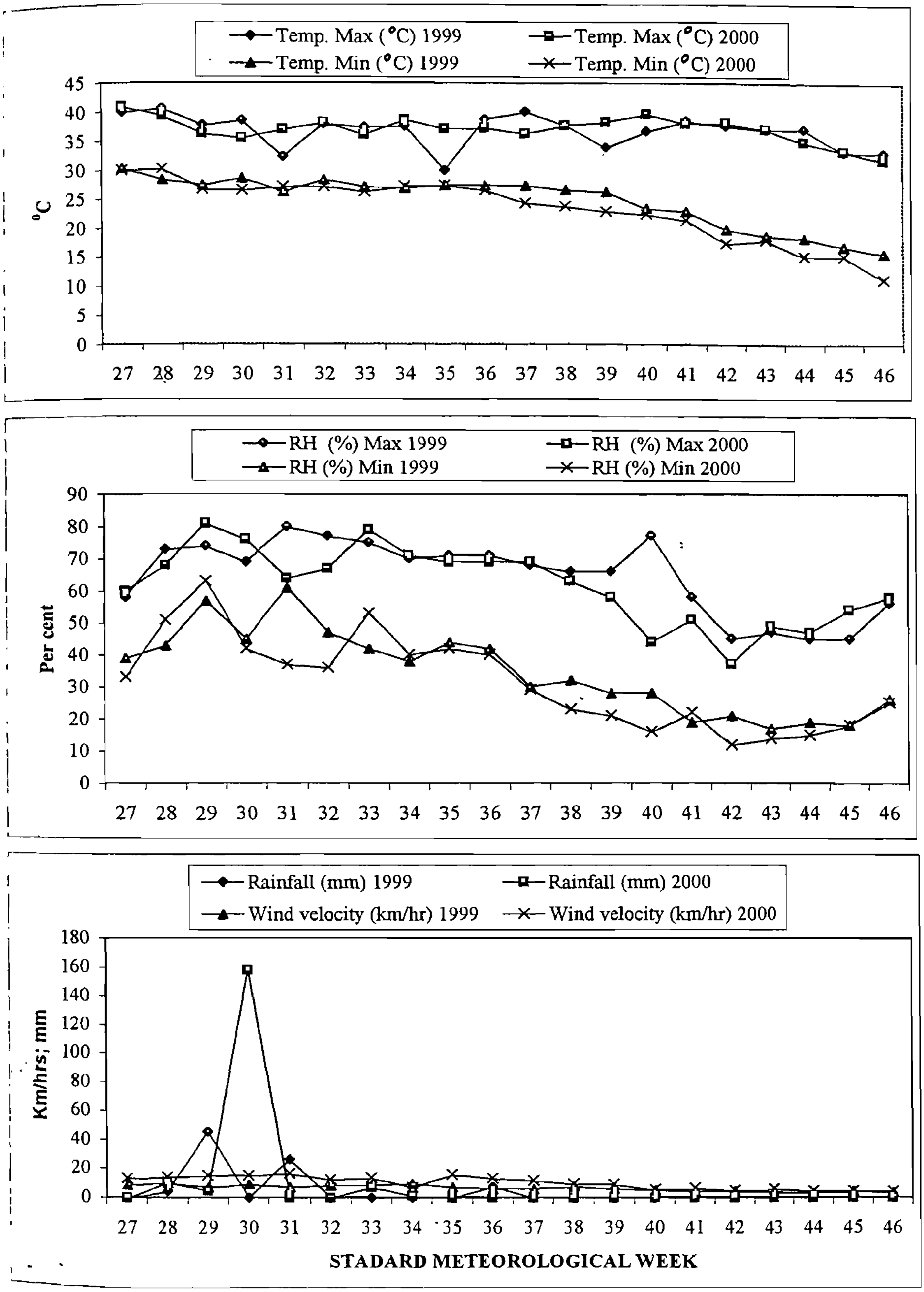



Fig. 3.1 MEAN WEEKLY WEATHER PARAMETERS DURING CROP GROWTH PERIOD(1999 and 2000)

### 3.3 SOIL OF THE EXPERIMENTAL SITE

Soil samples were taken from five different spots from the experimental field at 0-30 cm depth before sowing. Composite samples were prepared by grinding and passing through 2 mm sieve and were analyzed to determine the physico-chemical properties of the soil. The data on physico-chemical properties of soil for both the years of the study are presented in Table 3.2 along with the methods used for analysis. The soil analysis indicated that soils of the experimental field were sandy in texture and alkaline in nature. They are poor in organic matter while low in available nitrogen, phosphorus and potassium.

**Table 3.2 Physico-chemical properties of soils of the experimental site**

| Soil characteristics | Value at 0-30 cm depth | | Reference to Method of Analysis |
|---|---|---|---|
| | 1999 | 2000 | |
| Sand (%) | 90.80 | 91.25 | |
| Silt (%) | 2.60 | 2.64 | International Pipette Method (Piper , |
| Clay (%) | 6.60 | 6.11 | 1950) |
| Texture | Sandy | Sandy | |
| EC (1:2) $dSm^{-1}$ | 0.15 | 0.18 | Conductivity Meter (Jackson, 1973) |
| $p^H$ (1:2) | 8.33 | 8.41 | $p^H$ meter (Jackson, 1973) |
| Organic Carbon (%) | 0.099 | 0.080 | Walkley and Black rapid titration method (1947) |
| Available Nitrogen (kg/ha) | 105.0 | 109.0 | Alkaline $KMnO_4$ method |
| Available $P_2O_5$ (kg/ha) | 18.4 | 16.5 | Olsen's method (Olsen *et al.* 1954) |
| Available $K_2O$ (kg/ha) | 206.0 | 198.0 | Flame photometrically (Jackson, 1973) |

### 3.4 CROPPING HISTORY

Cropping history of experimental field is given in Table 3.3.

**Table 3.3: Cropping history of experimental site**

| 1999 | | | 2000 | | |
|---|---|---|---|---|---|
| YEAR | KHARIF | RABI | YEAR | KHARIF | RABI |
| 1995 | Fallow | Fallow | 1996 | BAJRA | WHEAT |
| 1996 | MOTH | FALLOW | 1997 | BAJRA | GRAM |
| 1997 | MOTH | WHEAT | 1998 | CASTOR | FALLOW |
| 1998 | BAJRA | WHEAT | 1999 | GROUNDNUT | METHI |
| 1999 | GUAR* | | 2000 | GUAR* | |

*Experimental crop

## 3.5 DETAILS OF EXPERIMENTS

### 3.5A EXPERIMENT-1

This experiment entitled" Effect of Thiourea and Dimethyl sulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean (*Cyamopsis tetragonoloba* L. Taub) consisted of 24 treatments. The treatment consisted of three levels of phosphorus and eight chemical treatments of Thiourea and DMSO including control, thus making 24 treatments combinations in all. The details of treatments along with their symbols are given below and are presented in Table 3.4

A. Levels of phosphorus

| | | |
|---|---|---|
| (i) | 0 kg $P_2O_5$/ha | = $P_0$ |
| (ii) | 20 kg $P_2O_5$/ha | = $P_{20}$ |
| (iii) | 40 kg $P_2O_5$/ha | = $P_{40}$ |

B Chemicals

| | | |
|---|---|---|
| (i) | Control | = $C_0$ |
| (ii) | 5 kg thiourea/ha in soil (basal) | = $C_1$ |
| (iii) | 5 kg thiourea/ha in soil ($^1/_2+^1/_2$) | = $C_2$ |
| (iv) | 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | = $C_3$ |
| (v) | 5 kg thiourea/ha + 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | = $C_4$ |
| (vi) | 500 ppm thiourea foliar spray | = $C_5$ |
| (vii) | 100 ppm DMSO foliar spray | =$C_6$ |
| (viii) | 500 ppm thiourea + 100 ppm DMSO foliar spray | = $C_7$ |

#### 3.5A.1 Experimental Design and Layout

The 24 treatment combinations replicated four times were laid out in randomized block design. The plan of layout is shown in Fig. 3.2

#### 3.5A.2 Fertilizer application

A basal dose of nitrogen @ 20 kg /ha and potassium @ 20 kg $K_2O$ was applied. Potassium was supplied through Muriate of potash and basal dose of phosphorus was applied as per treatment through DAP. Application of basal N, P and K was made manually through placement in furrows at 8-10 cm depth below the soil surface. Thereafter, the furrows were covered with soil dropping, leaving a depth of 5-6 cm for the purpose of sowing seeds.

# Fig. 3.2: PLAN OF LAYOUT OF EXPERIMENT NO. 1 ↑ N

1 m PATH

SUB IRRIGATION CHANNEL

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| R4 | $P_{20}C_4$ | $P_0C_7$ | $P_{40}C_4$ | $P_{40}C_7$ | $P_{20}C_1$ | $P_{40}C_5$ | $P_0C_4$ | $P_{20}C_2$ |
| | $P_{20}C_0$ | $P_0C_1$ | $P_{20}C_7$ | $P_0C_2$ | $P_{20}C_6$ | $P_0C_6$ | $P_{40}C_1$ | $P_{40}C_0$ |
| | $P_0C_0$ | $P_{40}C_3$ | $P_{20}C_5$ | $P_{40}C_6$ | $P_0C_5$ | $P_{40}C_2$ | $P_{20}C_3$ | $P_0C_3$ |
| R3 | $P_{20}C_5$ | $P_{40}C_0$ | $P_{20}C_7$ | $P_{40}C_2$ | $P_{40}C_5$ | $P_0C_6$ | $P_{20}C_3$ | $P_{40}C_4$ |
| | $P_{20}C_0$ | $P_0C_1$ | $P_0C_2$ | $P_{20}C_4$ | $P_0C_5$ | $P_0C_7$ | $P_{40}C_6$ | $P_0C_3$ |
| | $P_0C_0$ | $P_{20}C_6$ | $P_{40}C_1$ | $P_{40}C_7$ | $P_{40}C_3$ | $P_{20}C_1$ | $P_0C_4$ | $P_{20}C_2$ |
| R2 | $P_0C_1$ | $P_{20}C_2$ | $P_{40}C_2$ | $P_0C_3$ | $P_{20}C_7$ | $P_0C_4$ | $P_{40}C_7$ | $P_0C_7$ |
| | $P_{20}C_0$ | $P_{40}C_1$ | $P_{20}C_3$ | $P_{40}C_3$ | $P_{40}C_4$ | $P_{20}C_6$ | $P_0C_5$ | $P_{40}C_5$ |
| | $P_{40}C_0$ | $P_{20}C_1$ | $P_0C_2$ | $P_{20}C_4$ | $P_{40}C_6$ | $P_0C_0$ | $P_{20}C_5$ | $P_0C_6$ |
| R1 | $P_0C_1$ | $P_0C_2$ | $P_{20}C_4$ | $P_{20}C_2$ | $P_0C_4$ | $P_{40}C_4$ | $P_{40}C_6$ | $P_{20}C_7$ |
| | $P_{20}C_0$ | $P_{40}C_1$ | $P_0C_3$ | $P_{40}C_3$ | $P_{20}C_5$ | $P_0C_6$ | $P_{20}C_6$ | $P_0C_7$ |
| | $P_0C_0$ | $P_{40}C_0$ | $P_{20}C_1$ | $P_{40}C_2$ | $P_0C_5$ | $P_{20}C_3$ | $P_{40}C_5$ | $P_{40}C_7$ |

**LEGEND**

**(A) Levels of phosphorus**

$P_0$ = 0 kg
$P_{20}$ = 20 kg $P_2O_5$/ha
$P_{40}$ = 40 kg $P_2O_5$/ha

**(B) Chemicals**

$C_0$ = Control
$C_1$ = 5 kg thiourea/ha in soil (basal)
$C_2$ = 5 kg thiourea/ha in soil (1/2+1/2)
$C_3$ = 2 kg DMSO/ha in soil (1/2+1/2)
$C_4$ = 5 kg thiourea/ha+2 kg DMSO/ha in soil (1/2+1/2)
$C_5$ = 500 ppm thiourea foliar spray
$C_6$ = 100 ppm DMSO foliar spray
$C_7$ = 500 ppm thiourea+100 ppm DMSO foliar spray
**NB**: Split application of thiourea and DMSO were made at sowing and 45 days after sowing

**DESIGN** : Randomized Block Design
**Replication** : Four

**Plot size**
Gross : 5m x 3 m
Net : 4m x 1.8 m

**Total treatment Combinations** : 3 x 8 = 24

Table 3.4 **Details of treatment combinations for experiment-1**

| SN | Treatment combinations | Symbol |
|---|---|---|
| 1 | No phosphorus + control | $P_0C_0$ |
| 2 | No phosphorus + 5 kg thiourea/ha in soil (basal) | $P_0C_1$ |
| 3 | No phosphorus + 5 kg thiourea/ha in soil ($^1/_2$+$^1/_2$) | $P_0C_2$ |
| 4 | No phosphorus + 2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | $P_0C_3$ |
| 5 | No phosphorus + 5 kg thiourea/ha+2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | $P_0C_4$ |
| 6 | No phosphorus + 500 ppm thiourea foliar spray | $P_0C_5$ |
| 7 | No phosphorus + 100 ppm DMSO foliar spray | $P_0C_6$ |
| 8 | No phosphorus + 500 ppm thiourea + 100 ppm DMSO foliar spray | $P_0C_7$ |
| 9 | 20 kg $P_2O_5$/ha + control | $P_{20}C_0$ |
| 10 | 20 kg $P_2O_5$/ha + 5 kg thiourea/ha in soil (basal) | $P_{20}C_1$ |
| 11 | 20 kg $P_2O_5$/ha + 5 kg thiourea/ha in soil ($^1/_2$+$^1/_2$) | $P_{20}C_2$ |
| 12 | 20 kg $P_2O_5$/ha + 2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | $P_{20}C_3$ |
| 13 | 20 kg $P_2O_5$/ha +5 kg thiourea/ha+2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | $P_{20}C_4$ |
| 14 | 20 kg $P_2O_5$/ha + 500 ppm thiourea foliar spray | $P_{20}C_5$ |
| 15 | 20 kg $P_2O_5$/ha + 100 ppm DMSO foliar spray | $P_{20}C_6$ |
| 16 | 20 kg $P_2O_5$/ha + 500 ppm thiourea + 100 ppm DMSO foliar spray | $P_{20}C_7$ |
| 17 | 40 kg $P_2O_5$/ha + control | $P_{40}C_0$ |
| 18 | 40 kg $P_2O_5$/ha + 5 kg thiourea/ha in soil (basal) | $P_{40}C_1$ |
| 19 | 40 kg $P_2O_5$/ha + 5 kg thiourea/ha in soil ($^1/_2$+$^1/_2$) | $P_{40}C_2$ |
| 20 | 40 kg $P_2O_5$/ha + 2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | $P_{40}C_3$ |
| 21 | 40 kg $P_2O_5$/ha +5 kg thiourea/ha+2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | $P_{40}C_4$ |
| 22 | 40 kg $P_2O_5$/ha + 500 ppm thiourea foliar spray | $P_{40}C_5$ |
| 23 | 40 kg $P_2O_5$/ha + 100 ppm DMSO foliar spray | $P_{40}C_6$ |
| 24 | 40 kg $P_2O_5$/ha + 500 ppm thiourea + 100 ppm DMSO foliar spray | $P_{40}C_7$ |

### 3.5A.3 Details of crop raising

After seedbed preparation, guar variety " RGC-986 " was sown on 17th and 18th July during 1999 and 2000, respectively. Seeds were sown at 5-6 cm depth in furrows, 30 cm apart. A uniform seed rate of 20 kg/ha was used. In order to obtain uniform plant stand, seeds were weighed for each plot separately in small packets for sowing. Sowing was done manually. Seed was treated with Rhizobium culture. The crop was sown after pre sowing irrigation. The crop was irrigated five times. One weeding and hoeing was done around 20-25 DAS with a view to control weeds in early phase. Details of cultural operations from seedbed to harvesting are given in Table 3.5

**Table 3.5 Details of cultural operations carried out during the course of experimentation-I**

| SN | Operations | 1999 | 2000 |
|---|---|---|---|
| 1 | Pre sowing irrigation | 15-07-1999 | 16-07-2000 |
| 2 | Seedbed preparation | 16-07-1999 | 17-07-2000 |
| 3 | Sowing | 17-07-1999 | 18-07-2000 |
| 4 | Thinning | 02-08-1999 | 03-08-2000 |
| 5 | Hoeing | 08-08-1999 | 10-08-2000 |
| 6 | Harvesting | 10-11-1999 | 11-11-2000 |
| 7 | Threshing | 15-12-1999 | 12-12-2000 |

### 3.5A.4 Treatments application

Phosphorus as per treatments was applied as basal through DAP. As regards soil application of thiourea (basal), thiourea @ 5 kg/ha was mixed with soil and applied in furrow manually at a depth of 8-10 cm and followed by 3-4 cm of soil layering, thus exposing about 5 cm deep furrow for sowing of clusterbean seeds. DMSO was also applied in the same manner. The remaining half dose of thiourea and DMSO was top dressed at 45 days after sowing (DAS) when the crop plants were at flowering stage. While applying the split dose of TU and DMSO through top dressing, care was taken to ensure uniform distribution of TU and DMSO in between the crop rows and light hoeing was done followed by light irrigation.

As regards foliar spray treatments of thiourea and DMSO, 0.5 g thiourea and 0.1 ml DMSO per litre of water was used to achieve 500 ppm and 100 ppm concentration. Laboratory grade thiourea and DMSO were used to prepare spray solutions. In order to improve the spray retention, Labolene, a sticking agent, was mixed into the spray solution @ 0.5 ml/l. Foliar sprays of TU and DMSO were applied at pre flowering i.e. 40 DAS . The subsequent spray was done at pod development stage i.e. 60 DAS. A spray volume of 750 litres per hectare was used to spray the crop. The dates of treatment application for the two years of experimentation are shown in Table 3.6.

**Table 3.6 Schedule of treatment application in experiment-I**

| Treatments | Date of treatment application | |
|---|---|---|
| | 1999 | 2000 |
| Phosphorus (full dose) | 17-07-1999 | 18-07-200 |
| Soil application | | |
| Thiourea (basal) | 17-07-1999 | 18-07-2000 |
| Thiourea (1/2+1/2) | 17-07-1999, 29-08-1999 | 18-07-2000, 30-08-2000 |
| Foliar spray (two) | | |
| Thiourea and DMSO | 28-08-1999, 15-09-1999 | 29-08-2000, 16-09-2000 |

### 3.5A.5 Harvesting

The crop was harvested by cutting with sickles. The harvested produce of each plot was bundled and properly tagged for treatment identification. Central rows forming net plot were harvested leaving two row on each side (lengthwise) and half meter on each side (widthwise) in each plot. The bundles were kept open for sun drying. Threshing was done by beating the plants with thick sticks and thereafter, seed and straw yield per plot was recorded.

**3.5A.6 Treatment evaluation:** Following criteria were adopted for evaluating the effects of the treatments

**Growth studies**

1. Plant height at 60 DAS and at physiological maturity
2. Number of branches per plant at physiological maturity
3. Dry matter accumulation at 30,60,90 and at physiological maturity
4. Dry matter distribution in leaves, stems and pods at 30,60,90 and at physiological maturity
5. Chlorophyll content of leaves at 90 DAS
6. LAI, CGR, LAR and NAR at 60 and 90 DAS
7. Number of green leaves per plant at physiological maturity
8. Root length, root weight and number of nodules per plant at 60 DAS

**Yield attributes**

Number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, number of unfilled pods per plant, number of poorly filled pods per plant, seeds per pod, 1000 seed weight, seed yield per plant, and harvest index were recorded at maturity.

**Yields**

1. Seed yield per hectare
2. Straw and biological yields per hectare

**Bio chemical studies**

1. Protein and gum content of seed
2. N, P and S content of leaves at 90 DAS
3. P distribution(%) in leaves, stem and pods at 60, 90 DAS and at physiological maturity
4. P uptake by seed and straw at harvest
5. Phosphorus recovery
6. Phosphorus harvest index (%)

**Soil studies**

Available P content of soil at 30 and 60 DAS and at harvest.

**Growth studies**

For periodical growth observation, two rows on either side were left. The observations were recorded at 30, 60, 90 DAS and at physiological maturity.

**Plant height**

Plant height was recorded at 60 DAS and at physiological maturity on the basis of the average height of five randomly selected plants from each plot.

**Number branches per plant:**

The branches of five randomly selected plants from side rows were counted at crop maturity. The data were averaged to find out the mean number of branches per plant.

**Dry matter accumulation:**

Five plants were randomly collected from individual plots for estimating dry matter accumulation per plant at 30, 60 and 90 DAS and at physiological maturity. Leaves and pods were then detached from branches. Stems, leaves and pods so separated were kept in paper bags aerated by making several holes over them. These samples were kept in sun for few days and then transferred to hot air oven for drying at 65 $^0$C till a constant weight was achieved. Dry weight of samples was recorded and weight per plant was then calculated.

**Dry matter distribution:**

Dry matter distribution in leaves, stems and pods were calculated from dry matter accumulation in leaves, stems and pods of five randomly selected plants at 30, 60 90 DAS and at physiological maturity.

**Leaf area index:**

As per schedule, leaf area of five plants from each plot was recorded with the help of Laser Area Meter (C1203). All the leaves from plant were detached and inserted in the conveyor belt of the instrument, and the total area measured was recorded. Thereafter, leaf area per plant was obtained. Leaf area index was calculated as per formula suggested by Sestak *et. al.* (1971).

$$\text{Leaf area index} = \frac{\text{Total leaf area}}{\text{Total land area}}$$

**Crop growth rate (CGR) and net assimilation rate (NAR) and leaf area ratio (LAR):**

The crop growth rate was computed by the following formula as given by Redford (1967).

$$\underset{(g/m^2/d)}{\text{CGR}} = \frac{W_2 - W_1}{P\,(t_1 - t_2)}$$

$$\text{NAR }(g/m^2/d) = \frac{W_2 - W_1 \,(L_nL_2 - L_nL_1)}{t_2 - t_1 \,(L_2 - L_1)}$$

$$\text{LAR} = \frac{L_2 - L_1 \,(L_nW_2 - L_nW_1)}{W_2 - W_1 \,(L_nL_2 - L_nL_1)}$$

Where, $W_1$ and $W_2$ are dry weight and $L_1$ and $L_2$ is LAI at time $t_1$ and $t_2$, respectively. $L_n$ is natural log and P is ground area.

**Number of green leaves per plant:** Number of green leaves was recorded at physiological maturity on the basis of the average number of green leaves of five randomly selected plants from each plot.

**Root length, root weight and number of nodules:** Five plants per plot were randomly dug out using *kudali* in a careful manner at 60 DAS. These plants along with the large soil mass enveloping roots were flushed under tap water. The root mass was then separated from plant by cutting with sharp knife. The length of root was measured and nodules were counted. The root mass was then dried between the folds of filter papers. Thereafter, the plant as well as the root samples were placed in an oven and dried at 65 $^0$ C to constant weight

**Yield attributes:** Number of clusters per plant, number of pods per cluster, number of pods per plant, number of unfilled pods per plant and number of poorly filled pods per plant : Ten randomly selected plants at maturity were used for taking observation like cluster per plant, pods per cluster, pods per plant, unfilled and poorly filled pods per plant and seed yield per plant

**Number of seeds per pod:** Total number of seeds of 20 randomly selected pods were counted at crop maturity to determine the average number of seeds per pod.

**Test weight:** Guar seed sample were drawn from the produce of 10 randomly selected plant of each plot after weighing the net plot yield. From this, 1000 seeds were counted and weights recorded on an electric top-pan balance

**Harvest index:** Harvest index was calculated as per formula given by Donald and Hamblin (1976)

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

**Bio-chemical studies**

**Gum content:** The seed samples were analysed for gum content by phenol- sulphuric acid method (Das *et. al* 1977).

**Protein content:** The protein content in seed was calculated by multiplying per cent nitrogen content in seed with the factor 6.25(A.O.A.C., 1960)

**Plant analysis:** The plant samples collected as per schedule from each plot were dried and thereafter ground to a fine powder for estimating nutrient content. Nutrient content in leaves, stems, pods, seeds and stover were estimated by using standard method given below

**Nitrogen:** Nesslar's reagent colorimetric method (Snell and Snell, 1949).

**Phosphorus:** Ammonium vanadate (yellow colour method, Richards, 1968).

**Sulphur:** Turbidimetric method (Tabatabai and Bremner, 1970)

**Chlorophyll:** Chlorophyll content of leaves at 90 DAS was determined by the method advocated by Arnon (1949). Fresh leaves from five plants were picked up from each plot. Composite samples were washed in running tap water, 0.01N HCl and then thoroughly rinsed with distilled water in succession and were dried between folds of blotting paper. One-gram lot from the composite sample was weighed and ground well in 80 % acetone with a pestle and mortar. The material was then filtered through whatman filter paper No. 42 and volume was made to 25 ml. The resultant intensity of colour was measured at 645 and 663 nm wavelength on Spectronic 20 The total chlorophyll content was computed by the following formula.

$$\text{Chlorophyll a} = \frac{12.7\ A_{663}\text{-}2.69\ A_{645}}{A \times 1000 \times W} \times V$$

$$\text{Chlorophyll b} = \frac{22.9\ A_{645}\text{-}4.68\ A_{663}}{A \times 1000 \times W} \times V$$

$$\text{Total chlorophyll (mg/g f.w.)} = \frac{20.2\ A_{645}+8.02\ A_{663}}{A \times 1000 \times W} \times V$$

Where, A = length of path light in the cell, V = volume of the extract in ml, W = fresh weight of the sample in g

**P uptake:** The P uptake in leaves, stems and pods at 60 and 90 DAS and at physiological maturity and seeds and stover was estimated using formula

P uptake (kg/ha) = P content (%) X Dry matter (kg/ha)/100

**P distribution (%)**

The total P uptake at 60 and 90 DAS and at physiological maturity was computed by summing up the P uptake by leaves, stems and pods and for working out P distribution in leaves, stems and pods at 60 and 90 DAS and at physiological maturity, P uptake by leaves, stems and pods were then used to calculate per cent accumulation of P in relation to the total P uptake by the plant.

**Phosphorus use efficiency:** Phosphorus use efficiency indices were estimated using the formulae given by Nova and Loomis (1981)

(a) **Agronomic efficiency** : Refers to effectiveness of P application in increasing grain yield per unit area. This was calculated by subtracting grain yield in control plot from grain yield obtained under various P treatments The increased grain yield under P treatment was divided by the dose of P applied/ ha

$$\text{Agronomic efficiency (Kg grain/ kg applied P/ ha)} = \frac{\text{Kg grain (increase over control)}}{\text{Kg P applied}}$$

(b) **Physiological efficiency** : Refers to the effectiveness of P application in increasing P uptake by the crop. This was calculated by working out increase in grain yield over control (as described earlier) and dividing the same by the increase in P uptake under P treatments in comparison to control.

$$\text{Physiological efficiency (Kg grain/ kg P uptake/ ha)} = \frac{\text{Kg grain (increase over control)}}{\text{Kg P uptake (increase over control)}}$$

(c) **Phosphorus recovery** : This was calculated by working out increase in P uptake under P treatments over control and dividing the same by the dose of P applied/ha This was calculated on percentage basis.

$$\text{Phosphorus recovery (\%)} = \frac{\text{P uptake in treated plot - P uptake in control}}{\text{Dose of P applied}} \times 100$$

(d) **Phosphorus harvest index** : This was worked out by dividing P uptake by the grain (yield/ha) by total P uptake by the crop (grain as well as straw yields/ha). This was computed on percentage basis.

$$\text{Phosphorus harvest index (\%)} = \frac{\text{P uptake by grain}}{\text{Total P uptake by the crop}} \times 100$$

**Soil analysis:** Soil samples upto depths of 0-30 cm were taken from each plot at 30, 60, 90 DAS and at harvest. The samples were analyzed for P as per method mentioned in Table 3 2

### 3.5B EXPERIMNT-II

This experiment on effect of –SH compounds and –SH group blockers on dry matter partitioning and yield of clusterbean was conducted. The details of treatments are presented in Table 3.6.

### 3.5B.1 Experimental design and layout

The 10 treatments replicated four times were laid out in Randomized Block Design. The plan of layout is shown in Fig. 3.3

### 3.5B.2 Fertilizer application:

A basal dose of nitrogen @ 20 kg /ha, phosphorus @ 40 kg $P_2O_5$/ha and potassium @20 kg $K_2O$/ha was applied. Potassium was applied through MOP (Muriate of potash) and phosphorus was applied though DAP in all experimental plots. The amount of nitrogen already supplied through DAP was calculated and accordingly the remaining nitrogen was supplied through urea. It may be noted that application of basal N, P and K was made through placement in furrow at 8-10 cm depth below the soil surface. Thereafter, the furrows were covered with soil dropping, leaving a depth of 5-6 cm for the purpose of sowing seeds.

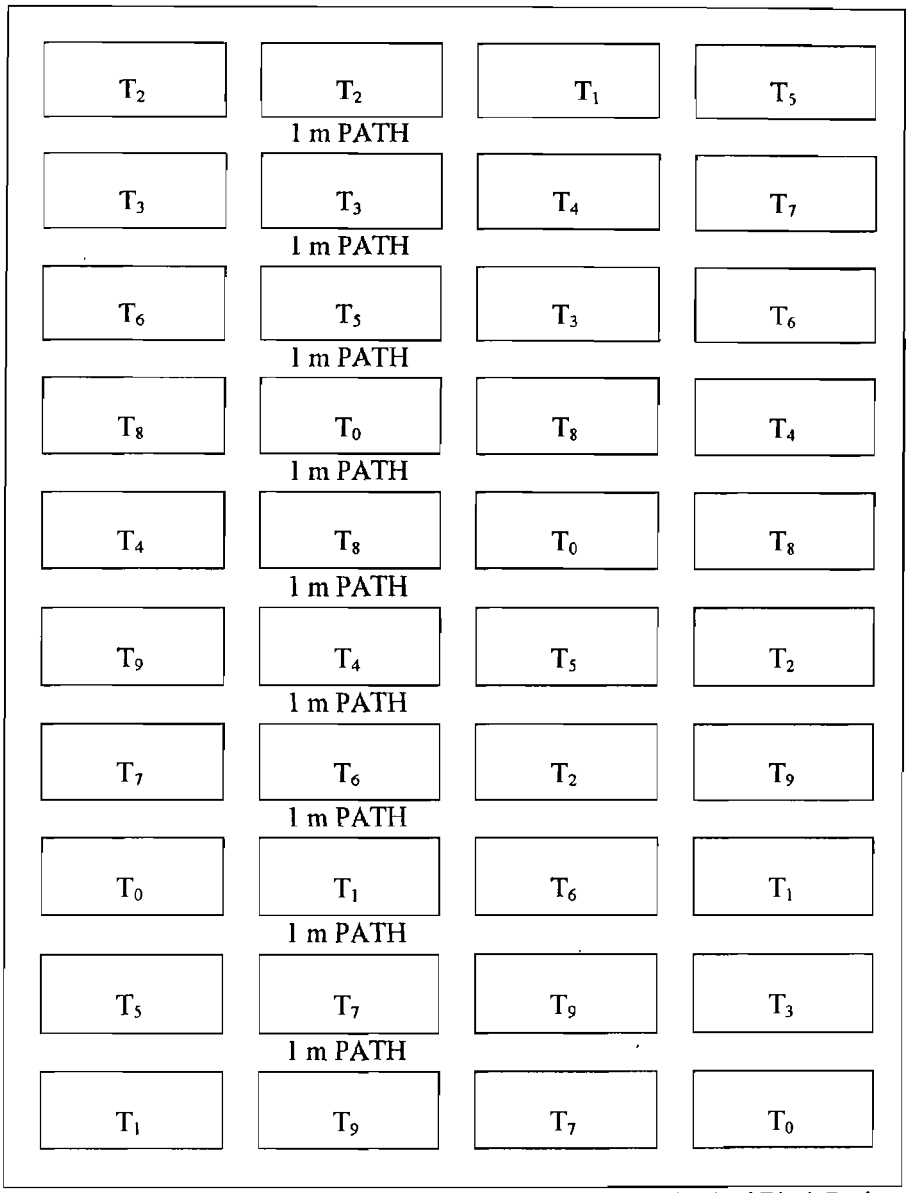
**Table 3.7 The details of treatments along with their symbols for experiment-II**

| | Treatments: Foliar spray of chemicals | Symbol |
|---|---|---|
| (i) | Control (water spray) | $T_0$ |
| (ii) | 500 ppm Thiourea (TU) | $T_1$ |
| (iii) | 500 ppm Mercaptoethyamine (MEA) | $T_2$ |
| (iv) | 10 ppm Dithiothrcitol (DTT) | $T_3$ |
| (v) | 10 ppm para-chloromercurybenzoicsulphonic acid (PCMBS) | $T_4$ |
| (vi) | 10 ppm PCMBS + 500 ppm TU | $T_5$ |
| (vii) | 100 ppm Iodoacetate | $T_6$ |
| (viii) | 100 ppm Iodoacetate + 500 ppm TU | $T_7$ |
| (ix) | 1000 ppm urea | $T_8$ |
| (x) | 1000 ppm Aluminium sulphate | $T_9$ |

### 3.5B.3 Details of crop raising

After seedbed preparation, guar variety RGC-986 was sown on 17th and 18th July during 1999 and 2000, respectively. Other details are same as described under experiment-I. Details of cultural operation from seedbed preparation to harvesting are given in Table 3.7

**Fig. 3.3 PLAN OF LAYOUT OF EXPERIMENT No.2** ↑ N




**LEGEND**

**Foliar spray**

$T_0$ = Control (water spray)
$T_1$ = 500 thiourea (TU)
$T_2$ = 500 ppm Mercaptoetylamine (MEA)
$T_3$ = 100 ppm Dithiothreitol (DTT)
$T_4$ = 10 ppm para-Chloromercurybenzoicsulphonic acid (PCMBS)
$T_5$ = 10 ppm PCMBS + 500 ppm TU
$T_6$ = 100 ppm Iodoactate (IA)
$T_7$ = 100 ppm IA + 500 ppm TU
$T_8$ = 1000 ppm urea
$T_9$ = 1000 ppm aluminum sulphate

**Design:** Randomized Block Design
**Replication:** Four
**Plot size:** Gross: 3m x 2 m
Net: 1.8m x 1 m
**Total treatments:** 10

**Table 3.8 Details of cultural operation carried out during the course of experimentation**

| S.N. | Operations | 1999 | 2000 |
|---|---|---|---|
| 1 | Pre sowing irrigation | 15.07.1999 | 16.07.2000 |
| 2 | Seed bed preparation | 16.07.1999 | 17.07.2000 |
| 3 | Sowing | 17.07.1999 | 18.07.2000 |
| 4 | Thinning | 3.8.199 | 05.08.2000 |
| 5 | Hoeing | 09.08.1999 | 12.08.2000 |
| 6 | Harvesting | 10.11.1999 | 11.11.2000 |
| 7 | Threshing | 15.12.1999 | 12.12.2000 |

### 3.5B.4 Treatment application

For the foliar spray treatment of chemicals, 0.5 g chemical per litre of water was used to achieve 500 ppm concentration and 0.01, 0.1, and 1 g chemical per litre was used for preparation of 10, 100 and 1000 ppm spray solution, respectively. Laboratory grade chemicals were used to prepare spray solution. In order to improve the spray retention, Labolene, a sticking agent, was mixed into the spray solution @ 0.5 ml/l. Foliar sprays of chemicals were applied at pod initiation stage i.e. at 55 DAS. A spray volume of 750 litres per hectare was used to spray the crop. In control plots, water was sprayed. The dates of foliar spray of chemicals during the two years of experimentation are shown in Table 3.8.

**Table 3.9 Schedule of treatment application in experiment-II**

| Treatments | Date of application | |
|---|---|---|
| | 1999 | 2000 |
| $T_0, T_1, T_2, T_3, T_4, T_6, T_8$ and $T_9$ | 10.09.1999 | 11.09.2000 |
| $T_5$ and $T_7$ | 10.09.1999<br>PCMBS and Iodoacetate spray | 11.09.1999<br>PCMBS and Iodoacetate spray |
| | 11.09.199<br>TU spray in $T_5$ and $T_7$ | 12.09.199<br>TU spray in $T_5$ and $T_7$ |

*In treatments No. $T_5$ and $T_7$ where combined application of PCMBS + TU and Iodoacetate + TU, The spray of TU was done just one day after PCMBS and Iodoacetate spray.

### 3.5B.5 Harvesting

Fifty plants from each plot were collected and bundled. Threshing was done by beating the plants with thick stick and thereafter, seed and straw yield per plot was recorded and seed and staw yields (q/ha) was calculated.

**3.5B.6 Treatment evaluation**

Following criteria were adopted for evaluating the effect of the treatments

**Growth studies**

Dry matter accumulation of leaves, stems and pods at 15 days interval after treatment application.

**Yield attributes**

Number of clusters per plant, number of pods per plant, number of pods per plant, pod length, number of unfilled pods per plant, number of poorly filled pods per plant, seeds per plant, test weight, seed yield per plant, ratio of grain and pod husk in lowermost, middle and uppermost cluster of main shoot at physiological maturity.

**Yield:** Grain, straw and biological yields and harvest index

**Bio chemical studies:** N and S content of leaves at 75 DAS.

**Dry matter accumulation by leaves, stems and pods**

Five plants were randomly collected from individual plots for dry matter accumulation at 75, 90 DAS and at physiological maturity. Leaves, stems and pods were then detached from branches. Leaves, stems and pods so separated were kept in paper bags aerated by making several holes over them. These sample were kept in sun for few days and then transferred to hot air oven for drying at 65 $^0$C till a constant weight was achieved. Dry weight of samples was recorded and weight per plant was then calculated for recorded dry matter distribution in leaves, stems and pods.

**Yield attributes**

Ten randomly selected plants at maturity were used for taking observations of yield attributes.

**Number of seeds per pod:** Total number of seeds of 20 randomly selected pods were counted at crop maturity to determine the average number of seeds per pods.

**Pod length:** Twenty 20 pods were randomly collected at crop maturity and used for measuring pod length.

**Test weight:** Guar seed samples were drawn from the produce of each plot after weighing the net plot yield. From this 1000 seeds were counted and weights recorded on electric top pan balance.

**Ratio of grain and pod husk in lowermost, middle and uppermost cluster of main shoot:**

Samples collected for estimating yield attributes per plant at maturity were also used for taking observation pods from lowermost, middle and uppermost cluster were detached from main shoot and kept in paper bags. These samples were kept in sun for few days and then transferred to hot air oven for drying at 65 $^{0}$ C till a constant weight was achieved. Grains were separated manually and weights recorded for grain and pod husk for calculating ratio of grain and pod husk.

**Yields:** Fifty plants collected from individual plots were kept in sun for few days and weights were recorded. Harvesting was done by beating bundles with stick and separated grains and weights recorded. From this weight grain, straw and biological yields for net plot were calculated. These were then converted into yield per hectare.

**Biochemical studies**

**N and S content of leaves at 75 DAS:** leaves samples collected for estimating dry matter accumulation per plant at 75 DAS were also used for estimation of N and S content of leaves.

**STATISTICAL ANALYSIS:** The standard procedures as suggested by Fisher (1949) were employed by applying the techniques of analysis of variance for Randomized Block Design in order to test the significance of results. Wherever " F" test was found significant at 5 per cent level of probability, the critical differences were calculated to assess the significance of difference between the treatments.

**ECONOMICS:** In order to evaluate the effectiveness of different treatments, the expenditure incurred on all cultural operations including inputs applied to each treated plot was computed. The gross returns were worked out on the basis of grain yield and straw yield as per treatment and prevailing selling price. The net returns per hectare were calculated by deducting cost of cultivation from gross returns per hectare for respective treatments. It was done to ascertain the most remunerative treatments. Accordingly, benefit:cost (B:C) ratio was also computed.

# 4 EXPERIMENTAL RESULTS

Data arising out of the present investigation entitled "Effect of Thiourea and Dimethylsulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]" conducted during two consecutive *kharif* season of 1999 and 2000 are presented and described in this chapter. Analysis of variance for the data are provided in Appendices I to XXXVII

As already detailed under Materials and Methods, one experiment was conducted on the effect of Thiourea and DMSO at varying levels of phosphorus, while the second experiment was conducted on the effects of –SH compounds and –SH group blocker on dry matter partitioning and yield of clusterbean. Data in respect of the main effects as well as interaction effects (wherever significant) of the treatments have been suitably presented and described to highlight the finding. It is worth pointing that most of the parameters studied in the experiment concerning first experiment showed interaction effects of TU and DMSO with phosphorus. It was, therefore, consider logical and necessary to present all such data in the interaction mode, of course, simultaneously providing the data for the main effect as well.

## 4A.1 EFFECT OF THIOUREA (TU) AND DIMETHYLSULPHOXIDE (DMSO) AT VARYING LEVELS OF PHOSPHORUS ON GROWTH PARAMETERS

### 4A.1.1 Plant height

Data (Table 4A.1) show that phosphorus application brought about significantly increase in plant height at 60 DAS upto 40 kg $P_2O_5$ /ha in both the year. On the basis of pooled data, application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha. Application of 20 and 40 kg $P_2O_5$/ha significantly increased plant height at 60 DAS by 11.9 and 18.9 per cent, respectively over control.

Soil application of TU and DMSO did not influence plant height at 60 DAS in both the years. Similarly, foliar sprays of TU and DMSO failed to increase plant height at 60 DAS during both the years.

Data (Table 4A.2) reveal that application of 40 kg $P_2O_5$/ha significantly increased plant height at physiological maturity over control during both the years. However, application of 20 and 40 kg $P_2O_5$/ha was at par in this respect in both the years. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased plant height at physiological maturity by 5.5 and 8.5 per cent, respectively over control.

All the soil and foliar applied treatments were ineffective to improve plant height at physiological maturity during either of the years. Similar trends were noticed in pooled data also.

**Table: 4A.1 Effect of thiourea and DMSO on plant height (cm) at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 62.0 | 70.83 | 75.20 | 69.34 |
| 5 kg TU/ha in soil (basal) | 58.95 | 73.32 | 75.12 | 69.12 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 67.60 | 70.83 | 77.10 | 71.81 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 63.20 | 69.52 | 72.50 | 68.41 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 68.17 | 72.17 | 74.58 | 71.64 |
| 500 ppm TU (spray) | 60.09 | 70.17 | 79.65 | 69.97 |
| 100 ppm DMSO (spray) | 67.70 | 72.41 | 72.66 | 70.92 |
| TU+DMSO (spray) | 62.61 | 71.15 | 78.93 | 70.90 |
| Mean | 63.82 | 71.30 | 75.72 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.833 | 1.360 | 2.356 | |
| C.D. (0.05) | 2.308 | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 61.06 | 17.93 | 75.31 | 69.09 |
| 5 kg TU/ha in soil (basal) | 61.13 | 73.26 | 74.96 | 69.78 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 67.07 | 69.77 | 77.71 | 71.52 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 63.24 | 69.58 | 73.23 | 68.68 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 68.25 | 73.01 | 77.53 | 72.93 |
| 500 ppm TU (spray) | 61.59 | 71.21 | 77.72 | 70.17 |
| 100 ppm DMSO (spray) | 63.92 | 71.65 | 72.75 | 69.44 |
| TU+DMSO (spray) | 63.18 | 71.47 | 78.20 | 70.95 |
| Mean | 63.68 | 71.36 | 75.93 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.819 | 1.338 | 2.317 | |
| C.D. (0.05) | 2.270 | NS | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 61.53 | 70.88 | 75.25 | 69.22 |
| 5 kg TU/ha in soil (basal) | 60.04 | 73.29 | 75.04 | 69.46 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 67.34 | 70.30 | 77.41 | 71.68 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 63.22 | 69.55 | 72.86 | 68.54 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 68.21 | 72.59 | 76.06 | 72.28 |
| 500 ppm TU (spray) | 60.84 | 70.69 | 78.69 | 70.07 |
| 100 ppm DMSO (spray) | 65.81 | 72.03 | 72.71 | 70.18 |
| TU+DMSO (spray) | 62.89 | 71.31 | 78.57 | 70.92 |
| Mean | 63.73 | 71.33 | 75.82 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.584 | 0.954 | 1.652 | |
| C.D. (0.05) | 1.619 | NS | 4.580 | |

**Table: 4A.2 Effect of thiourea and DMSO on plant height (cm) at physiological maturity at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 79.32 | 86.79 | 95.49 | 87.20 |
| 5 kg TU/ha in soil (basal) | 86.37 | 88.86 | 89.17 | 88.13 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 88.86 | 90.17 | 93.19 | 90.86 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 85.54 | 90.03 | 88.85 | 88.14 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 87.67 | 92.61 | 96.14 | 92.14 |
| 500 ppm TU (spray) | 80.07 | 88.92 | 92.43 | 87.14 |
| 100 ppm DMSO (spray) | 84.86 | 85.03 | 88.53 | 86.14 |
| TU+DMSO (spray) | 89.23 | 90.22 | 90.94 | 90.13 |
| Mean | 85.24 | 89.08 | 91.89 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.726 | 2.818 | 4.881 | |
| C.D. (0.05) | 4.784 | NS | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 79.09 | 86.28 | 93.10 | 86.56 |
| 5 kg TU/ha in soil (basal) | 85.66 | 89.15 | 90.63 | 88.48 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 89.11 | 90.73 | 94.43 | 91.42 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 85.04 | 89.61 | 89.42 | 88.02 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 85.56 | 93.86 | 95.23 | 91.55 |
| 500 ppm TU (spray) | 80.57 | 89.16 | 92.54 | 87.42 |
| 100 ppm DMSO (spray) | 82.55 | 85.54 | 90.34 | 86.14 |
| TU+DMSO (spray) | 85.07 | 92.70 | 88.09 | 88.62 |
| Mean | 84.08 | 89.63 | 91.87 | 88.53 |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.977 | 3.229 | 5.590 | |
| C.D. (0.05) | 5.479 | NS | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 79.21 | 86.53 | 94.90 | 86.88 |
| 5 kg TU/ha in soil (basal) | 86.01 | 89.00 | 89.90 | 88.31 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 88.96 | 90.45 | 93.99 | 91.14 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 85.29 | 89.82 | 89.13 | 88.08 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 86.62 | 93.24 | 95.68 | 91.85 |
| 500 ppm TU (spray) | 80.32 | 89.04 | 92.48 | 87.28 |
| 100 ppm DMSO (spray) | 83.70 | 85.28 | 89.44 | 86.14 |
| TU+DMSO (spray) | 87.15 | 91.46 | 89.52 | 89.38 |
| Mean | 84.66 | 89.35 | 91.88 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.525 | 2.090 | 1.770 | |
| C.D. (0.05) | 4.229 | NS | NS | |

Data (Table 4A.1) on combined effects of treatments further show that interaction effects were not significant in any of the years. However, in pooled data, interaction effects were found significant. Under no phosphorus, soil application of TU+DMSO ($^1/_2$+$^1/_2$) significantly increased plant height at 60 DAS by 10.8 per cent over control. Rest of the soil and foliar applied treatments were ineffective in this respect. Under 20 and 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective.

### 4A.1.2 Number of branches per plant:

Data (Table 4A.3) reveal that phosphorus application resulted in significant increase in number of branches per plant upto 40 kg $P_2O_5$/ha in both the years. Further, application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha in both the years. On the basis of pooled data application of 20 and 40 kg $P_2O_5$/ha significantly increased number of branches per cent by 25.0 and 32.7 per plant, respectively over control.

Soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$) significantly increased number of branches per pant during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$) resulted in significantly higher number of branches per plant by 28.1 per cent over soil application of TU at 5 kg/ha (basal). Soil application of DMSO at 2 kg/ha ($^1/_2$+$^1/_2$) failed to increase number of branches per plant in both the years. Soil application of TU + DMSO ($^1/_2$+$^1/_2$) significantly increased number of branches per cent in both the years. On the basis of pooled data, soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$) and TU+DMSO ($^1/_2$+$^1/_2$) significantly increased number of branches per plant by 32.7 and 34.5 per cent, respectively over control.

Data further show that foliar spray of 500 ppm TU and TU+DMSO significantly increased number of branches per plant in both the years, foliar spray of 100 ppm DMSO did not influence number of branches per plant significantly. On the basis of pooled data, foliar spray of TU and TU+DMSO significantly increased number of branches per plant by 12.7 per cent in each year over control.

### 4A.1.3 Number of green leaves at physiological maturity

Data (Table 4A.4) show that number of green leaves recorded under the influence of phosphorus application were significantly superior over control upto 20 kg $P_2O_5$/ha in 1999 and upto 40 kg $P_2O_5$/ha in 2000. On the basis of pooled data, application of 40 kg $P_2O_5$/ha significantly increased number of green leaves per plant over 20 kg $P_2O_5$/ha. Application of 20 and 40 kg $P_2O_5$/ha registered 28.9 and 39.2 per cent improvement in number of green leaves per plant over control, respectively.

Soil application of TU at 5 kg/ha (basal) failed to increase number of green leaves per plant in 1999, while significant increase over control was observed in 2000. Soil application

**Table: 4A.3 Effect of thiourea and DMSO on number of branches/plant at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 4.5 | 5.7 | 6.6 | 5.6 |
| 5 kg TU/ha in soil (basal) | 4.9 | 5.9 | 6.6 | 5.8 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 7.1 | 7.5 | 7.7 | 7.4 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 4.9 | 6.2 | 7.0 | 6.0 |
| TU+DMSO in soil (1/2 + 1/2) | 7.5 | 7.6 | 7.5 | 7.5 |
| 500 ppm TU (spray) | 5.2 | 6.7 | 6.7 | 6.2 |
| 100 ppm DMSO (spray) | 4.9 | 5.9 | 6.7 | 5.8 |
| TU+DMSO (spray) | 5.1 | 6.7 | 7.1 | 6.3 |
| Mean | 5.5 | 6.5 | 7.0 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.117 | 0.191 | 0.331 | |
| C.D. (0.05) | 0.324 | 0.529 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 4.3 | 5.4 | 6.8 | 3.5 |
| 5 kg TU/ha in soil (basal) | 4.7 | 5.7 | 6.4 | 5.6 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 5.6 | 7.9 | 8.2 | 7.2 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 4.6 | 5.9 | 6.7 | 5.7 |
| TU+DMSO in soil (1/2 + 1/2) | 5.6 | 8.0 | 8.3 | 7.3 |
| 500 ppm TU (spray) | 5.2 | 6.5 | 6.7 | 6.1 |
| 100 ppm DMSO (spray) | 4.5 | 5.6 | 6.6 | 5.5 |
| TU+DMSO (spray) | 5.2 | 6.5 | 6.8 | 6.2 |
| Mean | 4.9 | 6.4 | 7.0 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.134 | 0.218 | 0.378 | |
| C.D. (0.05) | 0.371 | 0.604 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 4.4 | 5.6 | 6.5 | 5.5 |
| 5 kg TU/ha in soil (basal) | 4.8 | 5.8 | 6.5 | 5.7 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 6.3 | 7.7 | 7.9 | 7.3 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 4.7 | 6.1 | 6.9 | 5.9 |
| TU+DMSO in soil (1/2 + 1/2) | 6.5 | 7.8 | 7.9 | 7.4 |
| 500 ppm TU (spray) | 5.2 | 6.6 | 6.7 | 6.2 |
| 100 ppm DMSO (spray) | 4.7 | 5.7 | 6.6 | 5.7 |
| TU+DMSO (spray) | 5.2 | 6.6 | 6.9 | 6.2 |
| Mean | 5.2 | 6.5 | 6.9 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.089 | 0.145 | 0.251 | |
| C.D. (0.05) | 0.246 | 0.402 | NS | |

**Table: 4A.4 Effect of thiourea and DMSO on number of green leaves / plant at physiological maturity at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 26.7 | 35.9 | 43.2 | 35.3 |
| 5 kg TU/ha in soil (basal) | 28.9 | 42.9 | 47.8 | 39.9 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 53.5 | 87.9 | 97.4 | 79.6 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 34.8 | 42.2 | 44.2 | 40.4 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 73.3 | 96.2 | 95.8 | 88.4 |
| 500 ppm TU (spray) | 68.8 | 81.1 | 84.4 | 78.1 |
| 100 ppm DMSO (spray) | 49.2 | 64.9 | 68.7 | 60.9 |
| TU+DMSO (spray) | 78.9 | 84.5 | 96.4 | 86.6 |
| Mean | 51.8 | 66.9 | 72.2 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 2.08 | 3.39 | 5.88 | |
| C.D. (0.05) | 5.76 | 9.39 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 22.8 | 30.7 | 36.9 | 30.2 |
| 5 kg TU/ha in soil (basal) | 26.1 | 38.7 | 43.1 | 35.9 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 40.7 | 66.8 | 74.1 | 60.5 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 30.3 | 36.7 | 38.6 | 35.2 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 54.5 | 71.6 | 71.4 | 65.8 |
| 500 ppm TU (spray) | 62.4 | 73.5 | 76.6 | 70.8 |
| 100 ppm DMSO (spray) | 30.8 | 40.7 | 43.1 | 38.2 |
| TU+DMSO (spray) | 71.4 | 76.5 | 87.3 | 78.4 |
| Mean | 42.4 | 54.4 | 58.8 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.03 | 1.69 | 2.92 | |
| C.D. (0.05) | 2.86 | 4.68 | 8.09 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 24.8 | 33.3 | 40.1 | 32.73 |
| 5 kg TU/ha in soil (basal) | 27.5 | 40.8 | 45.4 | 37.9 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 47.1 | 77.4 | 85.7 | 70.1 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 32.6 | 39.4 | 41.4 | 37.8 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 63.9 | 83.8 | 83.6 | 77.10 |
| 500 ppm TU (spray) | 65.6 | 77.3 | 80.5 | 74.5 |
| 100 ppm DMSO (spray) | 40.0 | 52.8 | 55.9 | 49.6 |
| TU+DMSO (spray) | 75.2 | 80.5 | 91.8 | 82.5 |
| Mean | 47.1 | 60.7 | 65.5 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.16 | 1.89 | 3.28 | |
| C.D. (0.05) | 3.22 | 5.25 | 9.10 | |

of TU at 5 kg/ha ($^1/_2$+$^1/_2$) and soil application of TU+DMSO ($^1/_2$+$^1/_2$) significantly increased number of green leaves per plant over control during both the years. Pooled data reveal that soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$) and soil application of TU+DMSO ($^1/_2$+$^1/_2$) significantly increased number of green leaves per plant by 114.0 and 135.6 per cent over control, respectively.

Data further show that foliar spray of 500 ppm TU, 100 ppm and TU+DMSO brought about significantly increase in number of green leaves during both the years. On the basis of pooled data, foliar spray of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased number of green leaves per plant by 127.4, 51.4 and 152.1 per cent, respectively over control.

Data (Table 4A.4) show that TU and DMSO interacted significantly with phosphorus in influencing number of green leaves per plant in 2000 only. Under no phosphorus, soil application of TU at 5 kg (1/2+1/2), soil application of TU+DMSO ($^1/_2$+$^1/_2$), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased number of green leaves per plant over control. Under 20 kg $P_2O_5$/ha, except soil application of TU at 5 kg/ha (basal) and soil application of DMSO at 2 kg/ha ($^1/_2$+$^1/_2$), all the soil and foliar applied treatments were effective. Under 40 kg p2p5/ha, soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$), soil application of TU+DMSO ($^1/_2$+$^1/_2$), foliar spray of 500 ppm TU and foliar spray of TU+DMSO proved effective in this respect. Pooled data show that under no phosphorus, soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$), soil application of TU+DMSO ($^1/_2$+$^1/_2$), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased number of green leaves per plant by 89.9, 157.6, 164.5, 61.3 and 203.2 per cent, respectively over control. Similar trends were recorded under 20 and 40 kg $P_2O_5$/ha. The increases were in the order of 132.4, 151.6, 132.1, 58.5 and 141.7 per cent under 20 kg P2O5/ha and 113.7, 108.5, 100.7, 39.4and 128.9 per cent under 40 kg $P_2O_5$/ha.

#### 4A1.4 Dry matter accumulation per plant at 30 DAS

Figure 4.1-4.4 show that dry matter accumulation (DMA) per plant at 30 DAS varied significantly under different levels of phosphorus. Significant improvement in DMA per plant was recorded at 20 kg $P_2O_5$/ha over control in 1999 while, it increased significantly upto 40 kg $P_2O_5$/ha in 2000. On the basis of pooled data, application of 40 kg $P_2O_5$/ha/ha was at par with 20 kg $P_2O_5$/ha. Application of 20 and 40 kg $P_2O_5$/ha registered 27.3 and 32.8 percent improvement in DMA per plant at 30 DAS over control, respectively.

Soil application of TU at 5 kg/ha (basal) significant increased DMA per plant over control during both the years. Soil application of TU at 5kg/ha ($^1/_2$+$^1/_2$) significantly increased DMA per plant in 2000 only. In the pooled data, soil application of TU at 5 kg /ha ($^1/_2$+$^1/_2$) did not differ significantly from that under soil application of TU at 5 kg/ha (basal). Soil application of DMSO at 2kg /ha (½ + ½) significantly increased DMA per plant over control in 1999 only. Soil application of TU+DMSO ($^1/_2$+$^1/_2$) significantly increased DMA /plant over control in both the years. On the basis of pooled data, soil application of TU at 5 kg/ ha (basal), soil application of TU at 5 kg /ha (½+½), soil application of DMSO at 2 kg (½+½) and soil application of TU+DMSO ($^1/_2$+$^1/_2$) significantly increased DMA per plant by 17.0, 12.4,10.5 and 17.5 per over control, respectively.

None of the foliar applied treatments had significant effect on DMA per plant at 30 DAS in either of the years. In pooled data, similar trends were noted.

### 4A.1.5 Dry matter accumulation per plant at 60 DAS

Figure 4.1-4.4 show that phosphorus application brought about significant increase in DMA per plant at 60 DAS upto 40 kg $P_2O_5$/ha during both the years. Pooled data show that 40 kg $P_2O_5$ /ha significantly superior over 20 kg $P_2O_5$/ha. Application of 20 and 40 kg $P_2O_5$/ha significantly increased DMA per plant by 20.5 and 31.1 per cent, respectively over control.

Soil application of TU at 5 kg/ha (½+½) significantly increased DMA per plant over control in 1999 only. Soil application of DMSO at 2 kg/ha (½+½) was in effective during both the years in this respect. Soil application of TU+DMSO brought about significant increase in DMA per plant over control in both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and TU+DMSO (½+½) significantly increased DMA per plant by 11.2 and 17.1 per cent, respectively over control.

Foliar spray of 500 ppm DMSO failed to increase DMA per plant at 60 DAS significantly but foliar spray of TU+DMSO brought about significant increase in DMA per plant during both the years. In pooled data similar trends were observed. Foliar spray of TU+DMSO significantly increased DMA per plant by 8.0 per cent over control.

### 4A.1.6 Dry matter accumulation per plant at 90 DAS

Figure 4.1-4.4 reveal that phosphorus application resulted significant increase in DMA per plant at 90 DAS upto 40 kg $P_2O_5$ /ha in both the years. Pooled data show that DMA per plant under the influence of 20 and 40 kg $P_2O_5$ /ha was higher by 25.1 and 35.4 per cent over control, respectively.

Soil application of TU at 5 kg/ha (basal) significantly increased DMA per plant in 2000 only. However, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO significantly increased DMA per plant over control during both the years. While, soil application of DMSO at 2 kg/ha (½+½) was effective only in 1999. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) significantly increased DMA per plant at

90 DAS by 5.6 per cent over soil application of TU at 5 kg/ha (basal). Soil application of TU at 5 kg/ha (basal), TU at 5 kg/ha (½+½), DMSO at 2 kg/ha (½+½) and TU+DMSO (½+½) significantly increased DMA per plant by 12.4, 18.7, 12.8 and 29.2 per cent, respectively over control.

All the foliar applied treatments of TU and DMSO was found effective in improving DMA per plant during both the years except foliar spray of 100 ppm DMSO in 2000. Pooled data indicate that foliar sprays of 500 ppm, 100 ppm DMSO and foliar spray TU+DMSO significantly increased DMA per plant by 19.0, 14.1 and 22.8 per cent, respectively over control.\

**4A.1.7 Dry matter accumulation per plant at physiological maturity**

Figure 4.1-4.4 show that phosphorus application brought about significant increase in dry matter accumulation (DMA) per plant at physiological maturity up to 40 kg $P_2O_5$ /ha during both the years. In pooled data, application 40 kg $P_2O_5$ /ha proved superior to 20 kg $P_2O_5$ /ha. Application of 20 and 40 kg $P_2O_5$ /ha registered 33.9 and 45.6 per cent improvement in DMA per plant over control, respectively.

Soil application of TU at 5 kg/ha (basal) proved effective only in 1999. Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased DMA per plant over control during both the years. Soil application of DMSO at 2 kg/ha (½+½) significantly increased DMA per plant in 1999 only. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) significantly increased DMA per plant by 11.8 per cent over soil application of TU at 5 kg/ha (basal). The per cent increase in DMA per plant due to soil application of TU at 5 kg/ha (basal) soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg (½+½) and soil application of TU+DMSO (½+½) was to the order of 7.2, 19.8, 8.4 and 31.4 per cent over control, respectively.

All the foliar applied treatments of TU and DMSO was significantly superior to control during both the years except foliar spray 100 ppm DMSO in 2000. Pooled data show that foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased DMA per plant by 14.9, 14.9 and 20.0 per cent, respectively over control.

**4 A.1.8 Dry matter distribution in leaves at 30 DAS**

Data (Table 4A.5) show that application of 40 kg $P_2O_5$ /ha significantly increased dry matter distribution (DMD) in leaves at 30 DAS during 2000 only. In pooled data, phosphorus application did not influence DMD in leaves significantly.

All the soil applied treatments of TU and DMSO were proved ineffective in improving DMA in leaves during 1999. However, in 2000 soil application of TU at 5 kg/ha

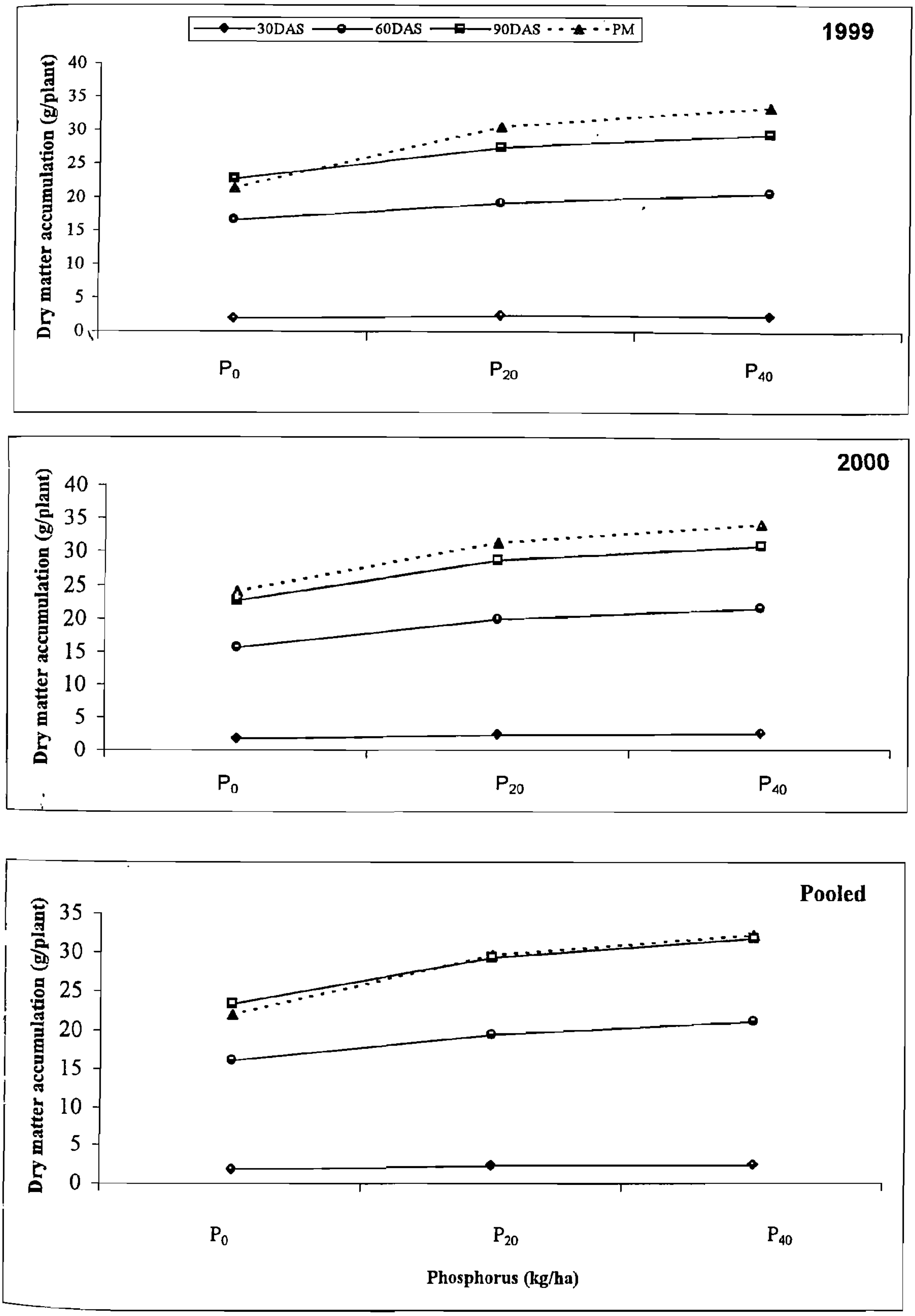



Fig. 4.1 Effect of phosphorurs on dry matter accumulation (g/plant)

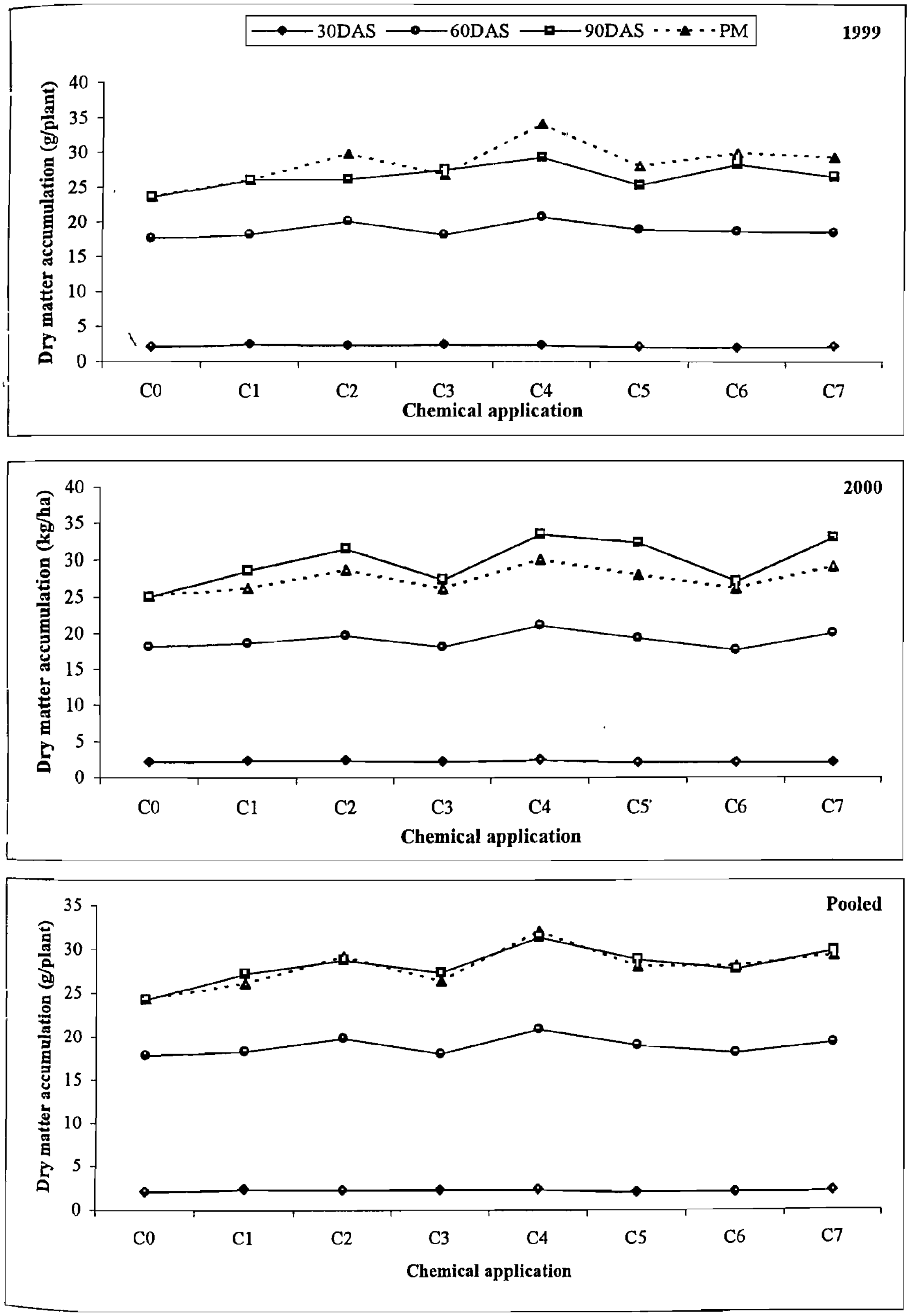



**Fig. 4.2 Effect of thiourea and DMSO on dry matter accumulation (g/plant)**

(½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased DMD in leaves. On the basis of pooled data, only soil application of TU at 5 kg/ha (½+½) was found effective in increasing DMD in leaves by 4.8 and 3.20 per cent over control and soil application of TU at 5 kg/ha (basal), respectively.

All the foliar applied treatments of TU and DMSO were failed to improve DMD in leaves during both the years. However, in pooled data increasing trends were noted due to foliar sprays of 500 ppm TU and 100 ppm DMSO over control.

### 4A.1.9 Dry matter distribution in stem at 30 DAS

Data (Table 4A.6) show that dry matter distribution (DMD) in stem at 30 DAS increased significantly due to application of 20 kg $P_2O_5$/ha in 2000 only. In pooled data phosphorus application failed to increase DMD in stems.

DMD in stems at 30 DAS showed inconsistent effect of soil applied treatments of TU and DMSO. In 1999, none of the soil-applied treatments of TU and DMSO was effective. Whereas in 2000, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly reduced DMD in stems over control. Pooled data show that DMD in stems at 30 DAS reduced significantly under soil application of TU at 5 kg/ha (½+½) over control, whereas soil application of TU at 5 kg/ha (basal), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU +DMSO (½+½) remained unaffected. The magnitude of reduction in DMD in stems was 9.8 per cent due to soil application of TU at 5 kg/ha (½+½) in comparison to control.

None of the foliar applied treatments of TU and DMSO was effective in affecting DMD in stems during both the years. Pooled data also showed similar trends.

### 4A.1.10 Dry matter distribution in leaves at 60 DAS

Data (Table 4A.7) indicate that phosphorus application showed inconsistent effect on DMD in leaves at 60 DAS. In 1999, none of the phosphorus applied treatments proved effective. However, in 2000 phosphorus application significantly increased DMD in leaves per plant upto 20 kg $P_2O_5$/ha. Pooled data show that phosphorus application did not influence DMD in leaves per plant.

DMD in leaves at 60 DAS showed inconsistent effect of soil applied TU and DMSO treatments. In 1999, none of the soil applied treatments of TU and DMSO was effective. Whereas, in 2000 soil application of TU+DMSO (½+½) significantly reduced DMD in leaves. Pooled data show that DMD in leaves at 60 DAS reduced significantly under soil application of TU+DMSO (½+½).

**Table: 4A.5 Effect of thiourea and DMSO on dry matter distribution (%) in leaves at 30 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 69.01 | 69.42 | 68.31 | 68.92 |
| 5 kg TU/ha in soil (basal) | 70.35 | 70.44 | 70.53 | 70.44 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 73.56 | 74.21 | 71.28 | 73.01 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 68.19 | 69.93 | 71.24 | 69.79 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 68.89 | 71.89 | 67.30 | 69.36 |
| 500 ppm TU (spray) | 69.97 | 72.05 | 70.59 | 70.87 |
| 100 ppm DMSO (spray) | 69.81 | 70.78 | 69.35 | 69.98 |
| TU+DMSO (spray) | 64.14 | 70.85 | 72.87 | 69.09 |
| Mean | 69.24 | 71.20 | 70.11 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.416 | 1.153 | 1.997 | |
| C.D. (0.05) | NS | NS | NS | |

| Year 2000 | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 69.59 | 68.42 | 71.03 | 69.68 |
| 5 kg TU/ha in soil (basal) | 69.55 | 70.76 | 70.94 | 70.42 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 72.68 | 71.33 | 76.01 | 72.34 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 72.00 | 71.29 | 70.49 | 71.27 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 72.04 | 71.69 | 71.66 | 71.79 |
| 500 ppm TU (spray) | 69.84 | 69.55 | 71.27 | 70.22 |
| 100 ppm DMSO (spray) | 70.51 | 68.57 | 71.25 | 70.11 |
| TU+DMSO (spray) | 70.40 | 69.02 | 70.44 | 69.95 |
| Mean | 70.83 | 70.08 | 71.26 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.214 | 0.349 | 0.604 | |
| C.D. (0.05) | 0.593 | 0.967 | NS | |

| Pooled | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 69.29 | 28.92 | 69.67 | 69.30 |
| 5 kg TU/ha in soil (basal) | 69.95 | 70.60 | 73.23 | 70.43 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 73.12 | 72.77 | 72.14 | 72.68 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 70.09 | 70.62 | 70.87 | 70.53 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 70.47 | 71.79 | 69.48 | 70.58 |
| 500 ppm TU (spray) | 69.91 | 70.79 | 73.43 | 70.55 |
| 100 ppm DMSO (spray) | 70.16 | 69.67 | 72.80 | 70.04 |
| TU+DMSO (spray) | 67.27 | 69.94 | 71.36 | 69.52 |
| Mean | 70.03 | 70.63 | 70.68 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.369 | 0.602 | 1.043 | |
| C.D. (0.05) | NS | 1.669 | NS | |

**Table: 4A.6 Effect of thiourea and DMSO on dry matter distribution (%) in stems at 30 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 31.02 | 30.64 | 30.55 | 30.74 |
| 5 kg TU/ha in soil (basal) | 29.46 | 29.45 | 28.05 | 28.99 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 26.38 | 25.68 | 30.28 | 27.45 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 31.07 | 29.92 | 28.76 | 29.92 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 30.93 | 28.15 | 32.20 | 30.43 |
| 500 ppm TU (spray) | 30.03 | 28.02 | 29.50 | 29.18 |
| 100 ppm DMSO (spray) | 30.02 | 29.14 | 30.77 | 29.98 |
| TU+DMSO (spray) | 27.66 | 29.08 | 27.62 | 28.12 |
| Mean | 29.57 | 28.76 | 29.72 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.623 | 1.017 | 1.761 | |
| C.D. (0.05) | NS | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 30.42 | 31.59 | 28.97 | 30.32 |
| 5 kg TU/ha in soil (basal) | 30.45 | 29.24 | 29.06 | 29.58 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 27.32 | 28.67 | 26.99 | 27.66 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 27.99 | 28.70 | 29.50 | 28.73 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 27.96 | 28.32 | 28.34 | 28.20 |
| 500 ppm TU (spray) | 30.16 | 30.45 | 28.73 | 29.78 |
| 100 ppm DMSO (spray) | 29.49 | 31.43 | 28.75 | 29.89 |
| TU+DMSO (spray) | 29.59 | 30.98 | 28.57 | 30.05 |
| Mean | 29.17 | 29.92 | 28.74 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.214 | 0.349 | 0.604 | |
| C.D. (0.05) | 0.593 | 0.967 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 30.72 | 31.11 | 29.75 | 30.53 |
| 5 kg TU/ha in soil (basal) | 29.96 | 29.35 | 28.56 | 29.29 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 26.85 | 27.17 | 28.64 | 27.55 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 29.53 | 29.31 | 29.13 | 29.33 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 29.44 | 29.23 | 30.27 | 29.32 |
| 500 ppm TU (spray) | 30.09 | 29.24 | 29.11 | 29.48 |
| 100 ppm DMSO (spray) | 29.75 | 30.29 | 29.76 | 29.93 |
| TU+DMSO (spray) | 28.63 | 30.03 | 28.59 | 29.08 |
| Mean | 29.37 | 29.34 | 29.23 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.329 | 0.537 | 0,931 | |
| C.D. (0.05) | NS | 1.489 | NS | |

TU and DMSO foliar spray treatments also showed inconsistent effect on DMD in leaves at 60 DAS. In 1999, none of the foliar applied treatments of TU and DMSO was effective. However, in 2000 foliar spray of TU+DMSO significantly reduced DMD in leaves over control. Pooled data show that foliar spray of TU+DMSO significantly reduced DMD in leaves by 2.8 per cent over control.

Data (Table 4A.7) show that application of TU and DMSO interacted significantly with phosphorus in influencing DMD in leaves at 60 DAS during 2000 only. Under no phosphorus, 20 and 40 kg $P_2O_5$/ha, all the soil and foliar applied treatments of TU and DMSO proved ineffective in increasing DMD in leaves at 60 DAS over control. However, foliar spray of TU+DMSO under 20 kg $P_2O_5$/ha and soil application of TU at 5 kg/ha (basal) under 40 kg $P_2O_5$/ha significantly increased DMD in leaves at 60 DAS over absolute control. Combined effects of treatments on DMD in leaves at 60 DAS, however, turned out non-significant in pooled data.

### 4A.1.11 Dry matter distribution in stems at 60DAS

Data (Table 4A.8) show that dry matter distribution (DMD) in stems at 60 DAS showed inconsistent effect of phosphorus application treatments. In 1999, phosphorus application did not influence DMD in stems whereas, in 2000 application 20 and 40 kg $P_2O_5$/ha significantly reduced DMD in stems. In pooled data, DMD in stems per plant remained unaffected due to phosphorus application.

Soil application of TU and DMSO showed inconsistent effect on DMD in stems. None of the soil applied treatments of TU and DMSO proved effective in either of the years except soil application of TU+ DMSO (½+½) in 2000. In pooled data, all the soil applied treatments of TU and DMSO were not effective in this respect.

All the foliar applied treatments proved ineffective in affecting DMD in stems per plant during both years. Pooled data also show similar trends.

Data on combined effect of treatments (Table 4A.8) show that interaction effects of TU and DMSO with phosphorus were significant in 2000 only in respect of DMD in stems at 60DAS. Under no phosphorus and 20 kg $P_2O_5$/ha, none of the soil and foliar applied treatments of TU and DMSO proved effective. However, under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly decreased DMD in stems at 60 DAS as compared to control. Under 20 kg $P_2O_5$/ha, maximum reduction of 43.28 per cent was obtained with foliar spray of TU+DMSO followed by soil application of TU at 5 kg/ha (½+½). When compared with absolute control, the decreases in DMD in stems at 60 DAS were of the order of 7.0 and 6.3 per cent, respectively. In pooled data, interaction effects were not significant in this respect.

#### 4A.1.12 Dry matter distribution in pods at 60DAS

Data (Table 4A.9) show that phosphorus application brought about significant increase in dry matter distribution (DMD) per plant at 60DAS over control in 2000 only. Pooled data indicate that application of 20 and 40 kg $P_2O_5$/ha significantly increased DMD in pods at 60 DAS by 7.4 and 14.4 per cent, respectively over control. Application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha in this respect.

Soil application of TU at 5 kg/ha (basal) and soil application of DMSO at 2kg/ha (½+½) did not influence DMD in pods during both years. However, soil application of TU at 5kg/ha (½+½) and soil application TU+DMSO (½+½) significantly increased DMD in pods during 2000 only. On the basis of pooled data, DMD in pods significantly increased by 18.7 per cent due to soil application of TU+DMSO (½+½) over control. Whereas, other soil applied treatments were at par with control.

Foliar sprays of 500 ppm TU and TU+DMSO significantly increased DMD in pods per plant at 60 DAS over control during 2000 only whereas, it remained unaffected in 1999. In pooled data, foliar sprays of 500 ppm TU and TU+DMSO significantly increased DMD in pods by 9.9 and 11.3 per cent, respectively over control. Foliar spray of 100 ppm DMSO was at par with control in this respect.

#### 4A.1.13 Dry matter distribution in leaves at 90 DAS

Data (Table 4A.10) reveal that successive increase in P levels upto 40 kg $P_2O_5$/ha significantly increased dry matter distribution in leaves per plant at 90 DAS during 2000 only. On the basis of pooled data, application of 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha. Application of 20 and 40 kg $P_2O_5$/ha significantly increased DMD in leaves per plant by 10.2 and 13.0 per cent, respectively over control.

Soil application of TU at 5 kg/ha (basal) and DMSO at 2 kg/ha (½+½) significantly increased DMD in leaves during both years. However, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO had significant effect on DMD in leaves during 2000 only. Pooled data show that soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), DMSO at 2 kg/ha (½+½) and TU+DMSO (½+½) significantly increased DMD in leaves by 30.6, 28.4, 20.9 and 25.3 per cent, respectively over control.

Foliar spray of 500 ppm TU, 100 ppm DMSO and TU+DMSO brought about significant increase in DMD in leaves at 90 DAS during both years. On the basis of pooled data the significant increases in DMD in leaves due to foliar sprays of 500 ppm TU, 100 ppm

**Table: 4A.7 Effect of thiourea and DMSO on dry matter distribution (%) in leaves 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 46.87 | 45.58 | 46.22 | 46.22 |
| 5 kg TU/ha in soil (basal) | 48.73 | 44.46 | 47.59 | 46.93 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 46.61 | 44.51 | 45.79 | 45.64 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 45.99 | 41.83 | 45.49 | 44.43 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 43.79 | 47.42 | 44.42 | 45.21 |
| 500 ppm TU (spray) | 46.64 | 45.87 | 45.53 | 46.01 |
| 100 ppm DMSO (spray) | 43.86 | 45.00 | 44.83 | 44.57 |
| TU+DMSO (spray) | 45.83 | 44.34 | 45.18 | 45.12 |
| Mean | 46.04 | 44.88 | 45.63 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.472 | 0.772 | 1.336 | |
| C.D. (0.05) | NS | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 46.15 | 47.24 | 46.40 | 46.59 |
| 5 kg TU/ha in soil (basal) | 46.51 | 46.36 | 47.51 | 46.79 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 45.79 | 46.36 | 46.45 | 46.20 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 46.23 | 46.73 | 46.23 | 46.39 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 44.04 | 44.26 | 46.73 | 45.10 |
| 500 ppm TU (spray) | 46.39 | 45.46 | 46.13 | 45.99 |
| 100 ppm DMSO (spray) | 46.37 | 46.34 | 44.59 | 45.76 |
| TU+DMSO (spray) | 45.14 | 47.35 | 46.09 | 46.19 |
| Mean | 45.83 | 46.26 | 46.27 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.143 | 0.234 | 0.405 | |
| C.D. (0.05) | 0.396 | 0.649 | 1.123 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 46.51 | 46.41 | 46.31 | 46.41 |
| 5 kg TU/ha in soil (basal) | 47.62 | 45.41 | 46.12 | 45.92 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 46.20 | 45.44 | 46.12 | 45.92 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 46.11 | 44.28 | 45.86 | 45.41 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 43.92 | 45.84 | 45.58 | 45.11 |
| 500 ppm TU (spray) | 46.52 | 45.66 | 45.83 | 46.00 |
| 100 ppm DMSO (spray) | 45.12 | 45.67 | 44.71 | 45.17 |
| TU+DMSO (spray) | 45.49 | 45.85 | 45.64 | 45.66 |
| Mean | 45.93 | 45.57 | 45.95 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.247 | 0.403 | 0.698 | |
| C.D. (0.05) | NS | 1.117 | NS | |

**Table: 4A.8 Effect of thiourea and DMSO on dry matter distribution (%) in stems at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 45.42 | 45.63 | 46.23 | 45.76 |
| 5 kg TU/ha in soil (basal) | 43.56 | 46.89 | 44.38 | 44.94 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 45.40 | 46.12 | 45.80 | 45.77 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 46.34 | 48.75 | 45.66 | 46.92 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 45.69 | 43.35 | 46.80 | 45.28 |
| 500 ppm TU (spray) | 45.42 | 44.95 | 45.20 | 45.19 |
| 100 ppm DMSO (spray) | 47.03 | 45.97 | 46.06 | 46.36 |
| TU+DMSO (spray) | 45.98 | 45.75 | 45.81 | 45.85 |
| Mean | 45.61 | 45.93 | 45.74 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.479 | 0.782 | 1.135 | |
| C.D. (0.05) | NS | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 46.65 | 44.23 | 46.15 | 45.68 |
| 5 kg TU/ha in soil (basal) | 46.38 | 45.07 | 44.29 | 45.25 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 46.24 | 45.07 | 45.09 | 45.47 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 46.61 | 44.65 | 44.97 | 45.41 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 46.06 | 43.72 | 44.57 | 44.78 |
| 500 ppm TU (spray) | 46.45 | 43.84 | 44.93 | 45.08 |
| 100 ppm DMSO (spray) | 46.39 | 46.79 | 46.97 | 46.72 |
| TU+DMSO (spray) | 47.61 | 43.38 | 44.97 | 45.32 |
| Mean | 46.55 | 44.59 | 45.28 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.149 | 0.243 | 0.420 | |
| C.D. (0.05) | 0.413 | 0.673 | 1.164 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 46.03 | 44.93 | 46.19 | 45.72 |
| 5 kg TU/ha in soil (basal) | 44.97 | 45.98 | 44.34 | 45.09 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 45.82 | 45.95 | 45.45 | 45.62 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 46.47 | 46.72 | 45.32 | 46.16 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 45.87 | 43.54 | 45.68 | 45.03 |
| 500 ppm TU (spray) | 45.94 | 44.39 | 44.07 | 45.13 |
| 100 ppm DMSO (spray) | 46.71 | 46.38 | 46.52 | 46.54 |
| TU+DMSO (spray) | 43.79 | 44.56 | 45.39 | 45.58 |
| Mean | 46.08 | 45.26 | 45.49 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.251 | 0.409 | 0.709 | |
| C.D. (0.05) | NS | NS | NS | |

**Table: 4A.9 Effect of thiourea and DMSO on dry matter distribution (%) in pods at 60 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 7.70 | 8.78 | 7.54 | 8.01 |
| 5 kg TU/ha in soil (basal) | 7.70 | 8.64 | 8.03 | 8.12 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 7.69 | 9.35 | 8.40 | 8.48 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 7.69 | 9.41 | 8.84 | 8.65 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 10.52 | 9.22 | 8.77 | 9.50 |
| 500 ppm TU (spray) | 7.93 | 9.17 | 9.26 | 8.78 |
| 100 ppm DMSO (spray) | 9.10 | 9.02 | 9.09 | 9.07 |
| TU+DMSO (spray) | 8.18 | 9.90 | 9.01 | 9.03 |
| Mean | 8.31 | 9.19 | 8.62 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.312 | 0.509 | 0.883 | |
| C.D. (0.05) | NS | NS | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 7.21 | 8.55 | 7.45 | 7.73 |
| 5 kg TU/ha in soil (basal) | 7.12 | 8.57 | 8.19 | 7.96 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 8.02 | 9.47 | 8.45 | 8.64 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 6.92 | 9.02 | 8.79 | 8.24 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 9.89 | 8.93 | 8.70 | 9.17 |
| 500 ppm TU (spray) | 7.17 | 9.43 | 8.94 | 8.51 |
| 100 ppm DMSO (spray) | 7.26 | 8.94 | 8.44 | 8.21 |
| TU+DMSO (spray) | 7.25 | 9.31 | 8.93 | 8.49 |
| Mean | 7.60 | 9.02 | 8.49 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.169 | 0.277 | 0.479 | |
| C.D. (0.05) | 0.468 | 0.768 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 7.46 | 8.67 | 7.49 | 7.87 |
| 5 kg TU/ha in soil (basal) | 7.41 | 8.61 | 8.11 | 8.04 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 7.86 | 9.41 | 8.43 | 8.57 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 7.30 | 9.22 | 8.82 | 8.45 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 10.21 | 9.07 | 8.74 | 9.34 |
| 500 ppm TU (spray) | 7.55 | 9.29 | 9.09 | 8.65 |
| 100 ppm DMSO (spray) | 8.18 | 8.98 | 8.77 | 8.64 |
| TU+DMSO (spray) | 7.71 | 9.61 | 8.97 | 8.76 |
| Mean | 7.96 | 9.11 | 8.55 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.178 | 0.289 | 0.502 | |
| C.D. (0.05) | 0.492 | 0.804 | NS | |

DMSO and TU+DMSO over control were to the tune of 47.7, 13.6 and 45.0 per cent, respectively.

Data (Table 4A.10) further show that application of TU and DMSO interacted significantly with phosphorus in influencing DMD in leaves at 90 DAS during 2000 only. All the soil and foliar applied treatments of TU and DMSO, except soil application of TU at 5 kg/ha (basal) under 20 kg $P_2O_5$/ha, significantly increased DMD in leaves at 90 DAS over control under each level of phosphorus. The highest DMD in leaves at 90 DAS (27.59%) was obtained with foliar spray of 500 ppm TU under 20 kg $P_2O_5$/ha. It was significantly superior over rest of the treatment combinations except soil application of TU+DMSO (1/2+1/2) and foliar spray of TU+DMSO under 40 kg $P_2O_5$/ha.

### 4A.1.14 Dry matter distribution in stems at 90 DAS

Data (Table 4A.11) show that phosphorus application brought about significant reduction in DMD in stems per plant at 90 DAS upto 40 kg $P_2O_5$ /ha in 2000, whereas it remained unaffected in 1999. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly reduced DMD in stems per plant by 9.3 and 12.5 per cent, respectively over control. In pooled data, application of 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha in this respect.

Soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO significantly reduced DMD in stems during both the years. Similar trends were noted in pooled data. Soil application of TU at 5kg/ha (½+½) significantly reduced DMD in stems over soil application of TU at 5kg/ha (basal). On the basis of pooled data, significant reduction of 8.8 per cent was recorded due to soil application of TU at 5 kg/ha (½+½) over soil application of TU at 5 kg/ha (basal). In pooled data, soil application of TU at 5kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly reduced DMD in stems over control. The magnitude of reduction in DMD in stems was highest under soil application of TU +DMSO (½+½) but it was at par with soil application of TU at 5 kg/ha (½+½) alone but was superior to soil application of DMSO at 2 kg/ha (½+½) alone.

Foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly reduced DMD in stems over control during both years. Pooled data show that DMD in stems at 90 DAS reduced significantly under foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO over control. The magnitude of reduction in DMD in stems at 90 DAS was highest under foliar spray of TU+DMSO.

Data (Table 4A.11) show that interaction effects on DMD in stems at 90 DAS were significant in both the years. Pooled data show that under no phosphorus, all the soil and foliar applied treatments of TU and DMSO significantly decreased DMD in stems at 90 DAS over control. The maximum reduction in DMD in stems was recorded with foliar spray of TU+DMSO. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (1/2+1/2), soil application of TU+DMSO (1/2+1/2), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly decreased DMD in stems at 90 DAS by 14.7, 12.6, 25.9 and 27.2 per cent, respectively over control. Soil application of TU at 5 kg/ha (basal), soil application of DMSO at 2 kg/ha (1/2+1/2) and foliar spray of 100 ppm DMSO proved ineffective. Under 40 kg $P_2O_5$/ha, all the soil and foliar applied treatments of TU and DMSO proved effective in decreasing DMD in stems at 90 DAS over control. Under 20 kg $P_2O_5$/ha, the highest reduction in DMD in stems was obtained with foliar spray of TU+DMSO (28.1%) and foliar spray of 500 ppm TU (28.6 %). When compared to absolute control, the decreases were of the order of 41.8 and 40.8 per cent, respectively.

### 4A.1.15 Dry matter distribution in pods at 90 DAS

Data (Table 4A.12) indicate that significant increase in dry matter distribution (DMD) in pods at 90 DAS was recorded under 40 kg $P_2O_5$ /ha in 1999, whereas in 2000, application of 20 and 40 kg P2O5 /ha brought about significant increase in DMD in pods over control. In pooled data 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha in respect of DMD in pods. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased DMD in pods by 4.3 and 5.4 per cent, respectively over control.

Soil application of TU at 5 kg/ha (basal) significantly reduced DMD in pods during 1999, whereas in 2000 significant increase in DMD in pods at 90 DAS was noted over control. In pooled data, it was at par with control TU at 5 kg/ha (½+½) and TU+DMSO (½+½) significantly increased DMD in pods during both the years. Soil application of DMSO at 2kg/ha (½+½) was ineffective during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and TU+DMSO (½+½) significantly increased DMD in pods by 7.3 and 10.7 per cent, respectively over control. Soil application of TU at 5 kg/ha (½+½) resulted in significant improvement in DMD in pods over soil application of TU at 5 kg/ha (basal).

Foliar spray of 500 ppm TU+DMSO significantly increased DMD in pods at 90 DAS during both the years. On the basis of pooled data, a significant increase in DMD in pods by 10.7 and 14.5 per cent was recorded due to foliar sprays of 500 ppm TU and TU+DMSO, respectively over control.

**Table: 4A.10 Effect of thiourea and DMSO on dry matter distribution (%) in leaves at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 25.07 | 27.33 | 25.89 | 26.10 |
| 5 kg TU/ha in soil (basal) | 30.95 | 31.13 | 33.26 | 31.78 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 29.37 | 28.44 | 26.65 | 28.15 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 30.82 | 31.00 | 30.58 | 30.80 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 26.44 | 24.79 | 25.35 | 25.53 |
| 500 ppm TU (spray) | 29.93 | 33.24 | 30.69 | 31.29 |
| 100 ppm DMSO (spray) | 27.71 | 27.55 | 29.16 | 28.14 |
| TU+DMSO (spray) | 31.12 | 31.32 | 30.83 | 31.09 |
| Mean | 28.93 | 29.35 | 29.05 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.560 | 0.915 | 1.584 | |
| C.D. (0.05) | NS | 2.535 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 9.237 | 15.038 | 13.598 | 12.624 |
| 5 kg TU/ha in soil (basal) | 16.338 | 19.013 | 21.005 | 18.785 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 18.445 | 22.300 | 23.918 | 21.554 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 11.697 | 16.770 | 19.520 | 15.996 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 18.938 | 23.055 | 27.012 | 23.002 |
| 500 ppm TU (spray) | 23.945 | 27.597 | 26.115 | 25.886 |
| 100 ppm DMSO (spray) | 10.533 | 17.280 | 19.710 | 15.841 |
| TU+DMSO (spray) | 22.902 | 24.740 | 27.562 | 25.068 |
| Mean | 16.504 | 20.724 | 22.305 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.116 | 0.189 | 0.328 | |
| C.D. (0.05) | 0.321 | 0.524 | 0.909 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 17.16 | 21.18 | 19.75 | 19.36 |
| 5 kg TU/ha in soil (basal) | 23.64 | 25.07 | 27.13 | 25.28 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 23.91 | 25.37 | 25.28 | 24.85 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 21.26 | 23.89 | 25.05 | 23.40 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 22.69 | 23.93 | 26.18 | 24.26 |
| 500 ppm TU (spray) | 26.94 | 30.42 | 28.40 | 28.59 |
| 100 ppm DMSO (spray) | 19.12 | 22.42 | 24.43 | 21.99 |
| TU+DMSO (spray) | 27.01 | 28.03 | 29.19 | 28.08 |
| Mean | 22.72 | 25.04 | 25.68 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.285 | 0.467 | 0.808 | |
| C.D. (0.05) | 0.792 | 1.294 | NS | |

**Table: 4A.11 Effect of thiourea and DMSO on dry matter distribution (%) in stems at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 42.03 | 34.47 | 36.34 | 37.61 |
| 5 kg TU/ha in soil (basal) | 35.90 | 37.67 | 32.55 | 35.38 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 35.50 | 32.42 | 31.96 | 33.29 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 34.59 | 34.63 | 34.36 | 34.53 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 35.09 | 36.11 | 34.91 | 35.37 |
| 500 ppm TU (spray) | 25.31 | 26.82 | 27.61 | 26.58 |
| 100 ppm DMSO (spray) | 36.35 | 36.79 | 36.53 | 36.56 |
| TU+DMSO (spray) | 25.83 | 26.35 | 27.46 | 26.55 |
| Mean | 33.83 | 33.16 | 32.71 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.380 | 0.621 | 1.076 | |
| C.D. (0.05) | NS | 1.721 | 2.982 | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 54.58 | 42.76 | 44.69 | 47.34 |
| 5 kg TU/ha in soil (basal) | 44.04 | 38.41 | 35.81 | 39.42 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 42.11 | 33.43 | 29.26 | 34.93 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 47.26 | 41.84 | 42.72 | 43.94 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 36.37 | 31.42 | 26.94 | 31.58 |
| 500 ppm TU (spray) | 35.31 | 30.37 | 27.04 | 30.91 |
| 100 ppm DMSO (spray) | 49.06 | 41.16 | 38.35 | 42.86 |
| TU+DMSO (spray) | 31.98 | 29.87 | 28.22 | 30.02 |
| Mean | 42.58 | 36.15 | 34.13 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.299 | 0.489 | 0.847 | |
| C.D. (0.05) | 0.829 | 1.355 | 2.348 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 48.31 | 38.61 | 40.51 | 42.48 |
| 5 kg TU/ha in soil (basal) | 39.97 | 38.04 | 34.18 | 37.40 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 38.81 | 32.92 | 30.61 | 34.11 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 40.93 | 38.23 | 38.54 | 39.23 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 35.73 | 33.76 | 30.93 | 33.47 |
| 500 ppm TU (spray) | 30.31 | 28.59 | 27.32 | 28.74 |
| 100 ppm DMSO (spray) | 42.71 | 38.98 | 37.44 | 39.71 |
| TU+DMSO (spray) | 28.91 | 28.11 | 27.84 | 28.29 |
| Mean | 38.21 | 34.66 | 33.42 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.242 | 0.395 | 0.685 | |
| C.D. (0.05) | 0.671 | 1.095 | 1.898 | |

**Table: 4A.12 Effect of thiourea and DMSO on dry matter distribution (%) in pods at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus ( kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 32.89 | 38.21 | 37.76 | 36.28 |
| 5 kg TU/ha in soil (basal) | 31.54 | 31.20 | 34.19 | 33.14 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 34.55 | 39.14 | 41.39 | 38.36 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 34.58 | 34.37 | 35.06 | 34.67 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 38.47 | 39.09 | 39.62 | 39.06 |
| 500 ppm TU (spray) | 44.76 | 39.93 | 41.70 | 41.29 |
| 100 ppm DMSO (spray) | 35.94 | 35.65 | 34.31 | 35.29 |
| TU+DMSO (spray) | 43.04 | 42.33 | 41.68 | 42.35 |
| Mean | 36.66 | 37.80 | 38.21 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.436 | 0.712 | 1.233 | |
| C.D. (0.05) | 1.208 | 1.973 | 3.417 | |

| **Year 2000** | Phosphorus ( kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 36.18 | 42.20 | 41.71 | 40.03 |
| 5 kg TU/ha in soil (basal) | 39.62 | 42.58 | 43.19 | 41.79 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 39.45 | 44.27 | 46.82 | 43.51 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 41.04 | 41.39 | 37.77 | 40.06 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 44.69 | 45.53 | 46.05 | 45.42 |
| 500 ppm TU (spray) | 40.74 | 42.03 | 46.85 | 43.21 |
| 100 ppm DMSO (spray) | 40.40 | 41.56 | 42.06 | 41.34 |
| TU+DMSO (spray) | 45.62 | 45.39 | 44.22 | 45.07 |
| Mean | 40.96 | 43.12 | 43.58 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.338 | 0.551 | 0.955 | |
| C.D. (0.05) | 0.937 | 1.527 | 2.647 | |

| **Pooled** | Phosphorus ( kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 34.53 | 40.20 | 39.74 | 38.16 |
| 5 kg TU/ha in soil (basal) | 35.58 | 38.14 | 38.69 | 37.47 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 36.99 | 41.71 | 44.10 | 40.94 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 37.81 | 37.88 | 36.41 | 37.37 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 41.58 | 42.31 | 42.84 | 42.24 |
| 500 ppm TU (spray) | 41.50 | 40.98 | 44.28 | 42.25 |
| 100 ppm DMSO (spray) | 38.17 | 38.61 | 38.19 | 38.32 |
| TU+DMSO (spray) | 44.33 | 43.86 | 42.95 | 43.71 |
| Mean | 38.81 | 40.46 | 40.89 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.276 | 0.450 | 0.779 | |
| C.D. (0.05) | 0.764 | 1.248 | 2.161 | |

Data (Table 4A.12) show that application of TU and DMSO interacted significantly with phosphorus in influencing DMD in pods at 90 DAS during both the years. In 1999, under no phosphorus, soil application of TU at 5 kg/ha (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased DMD in pods at 90 DAS over control. Under 20 kg $P_2O_5$/ha, only foliar spray of TU+DMSO proved effective. Under 40 kg $P_2O_5$/ha, foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased DMD in pods over control. In 2000, under no phosphorus, all treatments proved effective in increasing DMD in pods at 90 DAS over control. Under 20 kg $P_2O_5$/ha, only foliar spray of TU+DMSO proved effective. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of 500 ppm TU proved effective. In pooled data, under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased DMD in pods at 90 DAS by 7.1, 9.5, 20.4, 20.2, 10.5 and 28.4 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, none of the TU and DMSO treatments proved effective. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased DMD in pods at 90 DAS by 10.9, 7.8, 11.4 and 8.1 per cent, respectively over control. The highest DMD in pods at 90 DAS (44.3%) was obtained with foliar spray of TU+DMSO under no phosphorus.

### 4A.1.16 Dry matter distribution in leaves at physiological maturity

Data (Table 4A.13) show that phosphorus application brought about significant reduction in dry matter distribution (DMD) in leaves at physiological maturity in 1999. On the basis of pooled data, significant reduction in DMD in leaves due to 20 and 40 kg $P_2O_5$/ha was recorded over control.

Soil application of TU at 5 kg/ha (basal) significantly increased DMD in leaves during 2000. Soil application of TU at 5 kg/ha (½+½) and TU+DMSO (½+½) significantly increased in DMD in leaves during both the years. Significant increase in DMD in leaves due to soil application of DMSO at 2 kg/ha (½+½) was observed only in 2000. In pooled data, soil application of TU at 5 kg/ha (½+½) proved significantly superior to soil application of TU at 5 kg/ha (basal), giving an increase of 54.1 per cent in DMD in leaves. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and TU+DMSO (½+½) significantly increased in DMD in leaves by 76.5 and 74.7 per cent, respectively over control.

Foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased in DMD in leaves at physiological maturity during both the years. On the basis of pooled data, significant increase in DMD in leaves due to foliar sprays 500 ppm TU, 100 ppm DMSO and TU+DMSO was in the order of 93.9, 32.5 and 102.9 per cent, respectively over control.

Data (Table 4A.13) further show that application of TU and DMSO interacted significantly with phosphorus in influencing DMD in leaves at physiological maturity in 2000 only. All the soil as well as foliar applied treatments of TU and DMSO significantly increased DMD in leaves at physiological maturity over control under each level of phosphorus. Pooled data show that under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased DMD in leaves by 59.1, 82.0, 105.6, 34.0 and 113.3 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased DMD in leaves at physiological maturity by 71.2, 78.7, 83.6, 28.3 and 84.7 per cent, respectively over control. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO, foliar spray of TU+DMSO significantly increased DMD in leaves at physiological maturity by 23.5, 100.6, 79.2, 92.2, 35.2 and 113.3 per cent, respectively over control. The highest DMD in leaves (8.3%) was obtained with foliar spray of TU+DMSO followed by foliar spray of 500 ppm TU (8.0%) under no phosphorus.

#### 4A.1.17 Dry matter distribution in stems at physiological maturity

Data (Table 4A.14) show that phosphorus application brought about significant reduction in dry matter distribution (DMD) in stems at physiological maturity upto 20 kg $P_2O_5$/ha in 1999 and upto 40 kg $P_2O_5$ /ha in 2000. On the basis of pooled data, 20 and 40 kg $P_2O_5$/ha significantly reduced in DMD in stems by 12.4 and 15.2 per cent, respectively over control.

Soil application of TU at 5 kg/ha (basal) significantly reduced in DMD in stems during 1999 only. Soil application of TU at 5 kg/ha (½+½) and TU+DMSO (½+½) significantly reduced in DMD in stems during both the years. However, soil application of DMSO at 2 kg/ha (½+½) did not influence DMD in stems during 2000. In pooled data, soil application of TU at 5 kg/ha (½+½) was significantly superior to soil application of TU at 5 kg/ha (basal), giving 9.5 per cent higher reduction in DMD in stems. Pooled data show that soil application of TU at 5 kg/ha (½+½), DMSO at 2 kg/ha (½+½) and TU+DMSO significantly reduced DMD in stems over control. The highest reduction in DMD in stems was noted under soil application of TU at 5 kg/ha (½+½) alone.

Foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly reduced DMD in stems over control during both the years except 100 ppm DMSO in 2000. Pooled data show that DMD in stems at physiological maturity reduced significantly under foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO over control. Furthermore, magnitude of reduction in DMD in stems was highest under foliar spray of TU+DMSO.

Data (Table 4A.14) further show that application of TU and DMSO interacted significantly with phosphorus in influencing DMD in stems at physiological maturity in 1999 only. Under no phosphorus, all the soil and foliar applied treatments significantly decreased DMD in stems at physiological maturity over control. Under 20 kg P2O5/ha, except soil application of TU at 5 kg/ha (basal), soil application of DMSO at 2 kg/ha (½+½) and foliar spray of DMSO, all the soil and foliar applied treatments significantly decreased DMD in stems. Similar trends were noted under 40 kg $P_2O_5$/ha and pooled data. In pooled data, lowest DMD of 28.9 and 28.9 per cent obtained with foliar spray of TU+DMSO and foliar spray of 500 ppm, respectively, under 20 kg $P_2O_5$/ha. However, they were at par. When compared to absolute control, the decreases were of the order of 34.1 and 34.1 per cent, respectively.

**4A.1.18 Dry matter distribution in pods at physiological maturity**

Data (Table 4A.15) show that phosphorus application brought about significant increase in dry matter distribution (DMD) in pods upto 20 kg $P_2O_5$ /ha during 1999 and upto 40 kg $P_2O_5$/ha during 2000. In pooled data, application of 40 kg $P_2O_5$/ha significantly superior over 20 kg $P_2O_5$/ha in respect of DMD in pods at physiological maturity. Application of 20 and 40 kg $P_2O_5$ /ha resulted in significant increase of 9.2 and 11.5 per cent, respectively over control.

DMD in stems at physiological maturity showed inconsistent effect of soil applied TU and DMSO treatments. In 2000, none of the soil applied TU and DMSO treatments was effective, whereas in 1999, soil application of TU at 5 kg /ha (basal), soil application of TU at 5kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased DMD in pods over control, whereas soil application of DMSO at 2 kg/ha (½+½) proved ineffective. In pooled data, soil application of TU at 5 kg/ha (½+½) significantly increased DMD in pods by 2.2 per cent over soil application of TU at 5 kg/ha (basal). Pooled data show that soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased DMD in pods by 4.9, 2.4 and 3.6 per cent, respectively over control.

Foliar sprays of TU and DMSO treatments also showed inconsistent effects on DMD in pods. In 2000, none of the foliar applied treatments proved effective. However, in 1999 foliar sprays of 500 ppm TU and TU+DMSO significantly increased DMD in pods over

**Table: 4A.13 Effect of thiourea and DMSO on dry matter distribution (%) in leaves at physiological maturity at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 5.09 | 4.23 | 3.88 | 4.40 |
| 5 kg TU/ha in soil (basal) | 4.49 | 4.61 | 4.76 | 4.62 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 7.29 | 7.85 | 8.25 | 7.79 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 4.77 | 4.26 | 4.15 | 4.39 |
| TU+DMSO in soil (1/2 + 1/2) | 7.99 | 7.54 | 6.93 | 7.49 |
| 500 ppm TU (spray) | 8.76 | 7.44 | 7.11 | 7.77 |
| 100 ppm DMSO (spray) | 6.42 | 5.67 | 5.63 | 5.91 |
| TU+DMSO (spray) | 9.14 | 7.61 | 8.06 | 8.27 |
| Mean | 6.74 | 6.15 | 6.10 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.166 | 0.270 | 0.468 | |
| C.D. (0.05) | 0.460 | 0.748 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.73 | 3.47 | 3.35 | 3.18 |
| 5 kg TU/ha in soil (basal) | 3.89 | 4.12 | 4.17 | 4.06 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 5.16 | 5.35 | 6.23 | 5.58 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 3.97 | 3.73 | 3.69 | 3.79 |
| TU+DMSO in soil (1/2 + 1/2) | 6.24 | 6.22 | 6.02 | 6.15 |
| 500 ppm TU (spray) | 7.31 | 6.69 | 6.76 | 6.92 |
| 100 ppm DMSO (spray) | 4.06 | 4.22 | 4.14 | 4.14 |
| TU+DMSO (spray) | 7.55 | 6.61 | 7.21 | 7.12 |
| Mean | 5.12 | 5.05 | 5.19 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.033 | 0.054 | 0.094 | |
| C.D. (0.05) | 0.019 | 0.149 | 0.261 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 3.91 | 3.85 | 3.61 | 3.79 |
| 5 kg TU/ha in soil (basal) | 4.19 | 4.37 | 4.46 | 4.34 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 6.22 | 6.59 | 7.24 | 6.69 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 4.37 | 3.99 | 3.92 | 4.09 |
| TU+DMSO in soil (1/2 + 1/2) | 7.12 | 6.88 | 6.47 | 6.62 |
| 500 ppm TU (spray) | 8.04 | 7.07 | 6.94 | 7.35 |
| 100 ppm DMSO (spray) | 5.24 | 4.94 | 4.88 | 5.02 |
| TU+DMSO (spray) | 8.34 | 7.11 | 7.63 | 7.69 |
| Mean | 5.93 | 5.60 | 5.65 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.084 | 0.138 | 0.239 | |
| C.D. (0.05) | 0.234 | 0.382 | 0.662 | |

**Table: 4A.14 Effect of thiourea and DMSO on dry matter distribution (%) in stems at physiological maturity at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 45.85 | 35.15 | 35.49 | 38.83 |
| 5 kg TU/ha in soil (basal) | 37.97 | 36.66 | 34.33 | 36.32 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 38.20 | 26.91 | 26.73 | 30.61 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 39.56 | 35.56 | 34.31 | 36.47 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 38.36 | 29.95 | 28.22 | 32.17 |
| 500 ppm TU (spray) | 31.07 | 23.89 | 24.37 | 26.44 |
| 100 ppm DMSO (spray) | 39.92 | 33.89 | 33.46 | 35.76 |
| TU+DMSO (spray) | 30.76 | 24.05 | 24.15 | 26.32 |
| Mean | 37.71 | 30.76 | 30.13 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.379 | 0.619 | 1.073 | |
| C.D. (0.05) | 1.050 | 1.716 | 2.974 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 42.09 | 38.97 | 36.39 | 39.15 |
| 5 kg TU/ha in soil (basal) | 38.90 | 38.31 | 35.28 | 37.49 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 38.34 | 35.53 | 34.68 | 36.18 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 39.31 | 37.37 | 35.85 | 37.51 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 38.01 | 34.42 | 34.36 | 35.59 |
| 500 ppm TU (spray) | 37.70 | 34.05 | 34.63 | 35.46 |
| 100 ppm DMSO (spray) | 39.49 | 38.10 | 34.76 | 37.45 |
| TU+DMSO (spray) | 37.29 | 33.87 | 32.42 | 34.53 |
| Mean | 38.89 | 36.33 | 34.79 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.325 | 0.530 | 0.918 | |
| C.D. (0.05) | 0.901 | 1.469 | NS | |

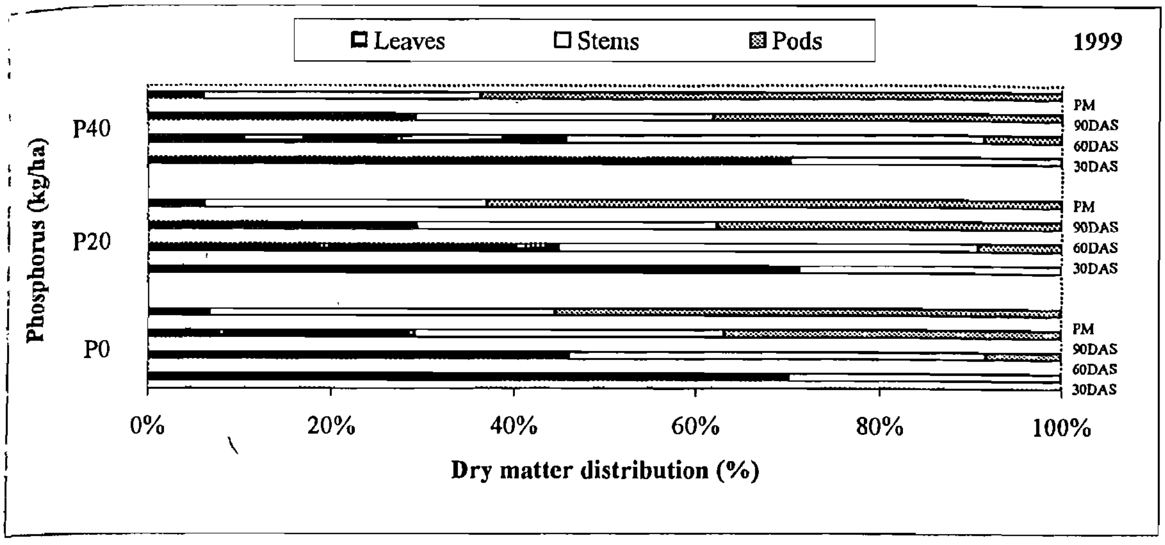
| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 43.97 | 37.06 | 35.94 | 38.99 |
| 5 kg TU/ha in soil (basal) | 38.43 | 37.48 | 34.80 | 36.91 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 38.27 | 31.22 | 30.70 | 33.40 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 39.43 | 36.47 | 35.08 | 36.99 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 38.18 | 32.19 | 31.29 | 33.89 |
| 500 ppm TU (spray) | 34.38 | 28.97 | 29.49 | 30.95 |
| 100 ppm DMSO (spray) | 39.71 | 35.99 | 34.11 | 36.60 |
| TU+DMSO (spray) | 34.03 | 28.96 | 28.29 | 30.42 |
| Mean | 38.30 | 33.54 | 32.46 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.250 | 0.408 | 0.706 | |
| C.D. (0.05) | 0.692 | 1.129 | 1.957 | |

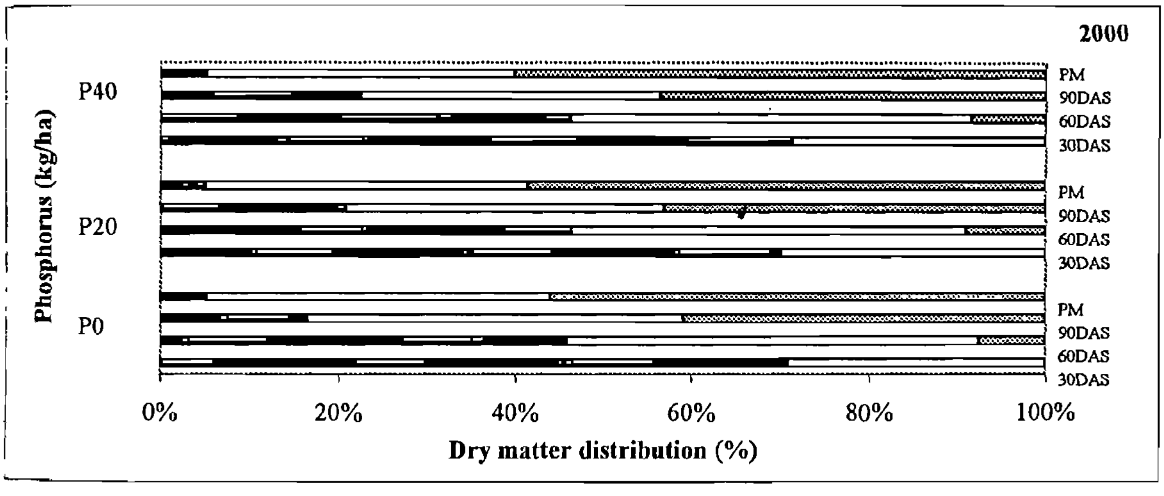
**Table: 4A.15 Effect of thiourea and DMSO on dry matter distribution (%) in pods at physiological maturity at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 49.06 | 60.62 | 60.63 | 56.77 |
| 5 kg TU/ha in soil (basal) | 57.54 | 58.73 | 60.91 | 59.06 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 54.51 | 63.25 | 65.02 | 60.93 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 53.62 | 60.17 | 61.55 | 58.45 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 53.65 | 62.52 | 64.85 | 60.34 |
| 500 ppm TU (spray) | 60.16 | 68.66 | 68.52 | 65.78 |
| 100 ppm DMSO (spray) | 53.66 | 60.47 | 60.91 | 58.35 |
| TU+DMSO (spray) | 60.11 | 68.34 | 67.79 | 65.41 |
| Mean | 55.29 | 62.84 | 63.77 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.470 | 0.768 | 1.329 | |
| C.D. (0.05) | 1.302 | 2.128 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 55.13 | 57.56 | 60.26 | 57.65 |
| 5 kg TU/ha in soil (basal) | 57.21 | 57.57 | 60.56 | 58.45 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 56.50 | 59.13 | 61.69 | 59.11 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 56.73 | 59.00 | 60.46 | 58.73 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 55.75 | 59.36 | 59.62 | 58.24 |
| 500 ppm TU (spray) | 54.99 | 59.26 | 58.61 | 57.62 |
| 100 ppm DMSO (spray) | 56.44 | 57.68 | 61.11 | 58.41 |
| TU+DMSO (spray) | 55.16 | 59.52 | 60.37 | 58.35 |
| Mean | 55.99 | 58.64 | 60.34 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.384 | 0.628 | 1.087 | |
| C.D. (0.05) | 1.064 | NS | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 52.12 | 59.09 | 60.45 | 57.22 |
| 5 kg TU/ha in soil (basal) | 57.37 | 58.15 | 60.74 | 58.75 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 55.51 | 61.19 | 63.36 | 60.02 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 55.17 | 59.59 | 61.00 | 58.59 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 54.70 | 60.94 | 62.24 | 59.29 |
| 500 ppm TU (spray) | 57.57 | 63.96 | 63.56 | 61.70 |
| 100 ppm DMSO (spray) | 55.05 | 59.07 | 61.01 | 58.38 |
| TU+DMSO (spray) | 57.63 | 63.93 | 64.08 | 61.88 |
| Mean | 55.64 | 60.74 | 62.05 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.304 | 0.496 | 0.859 | |
| C.D. (0.05) | 0.842 | 1.374 | NS | |



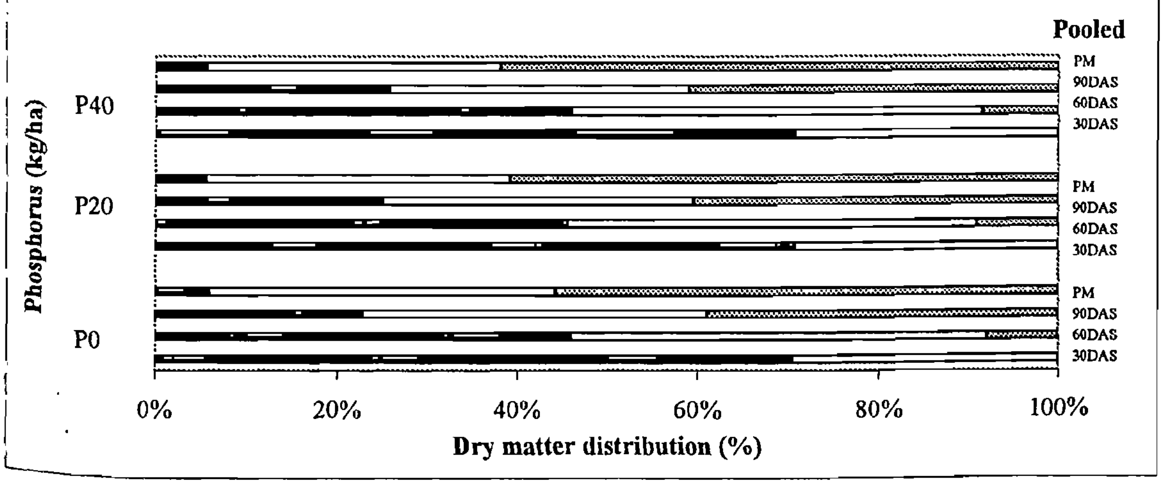




**Fig. 4.3 Effect phosphorus on dry matter distribution (%)**

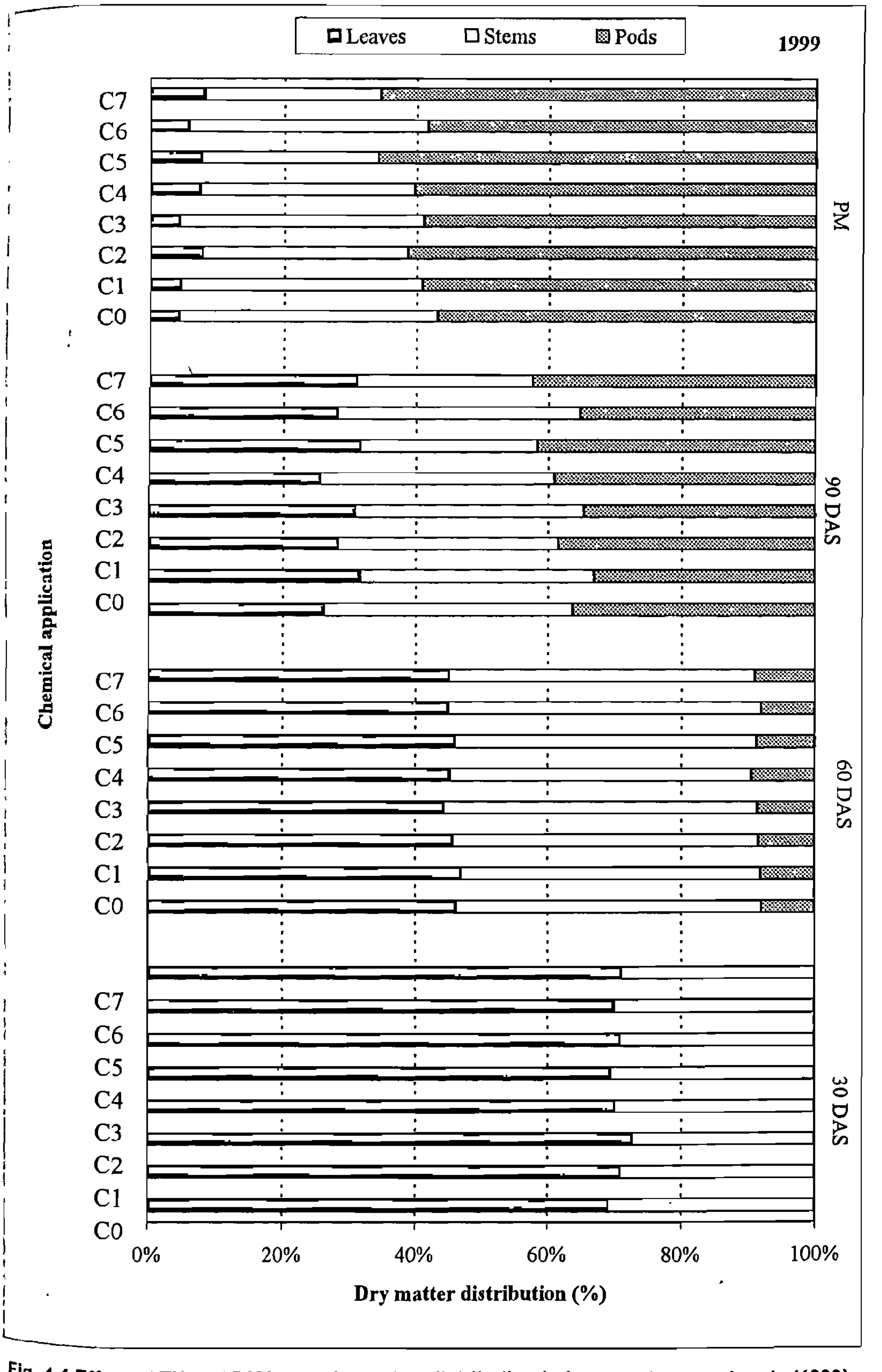



Fig. 4.4 Effect of TU and DMSO on dry matter distribution in leaves, stems and pods (1999)

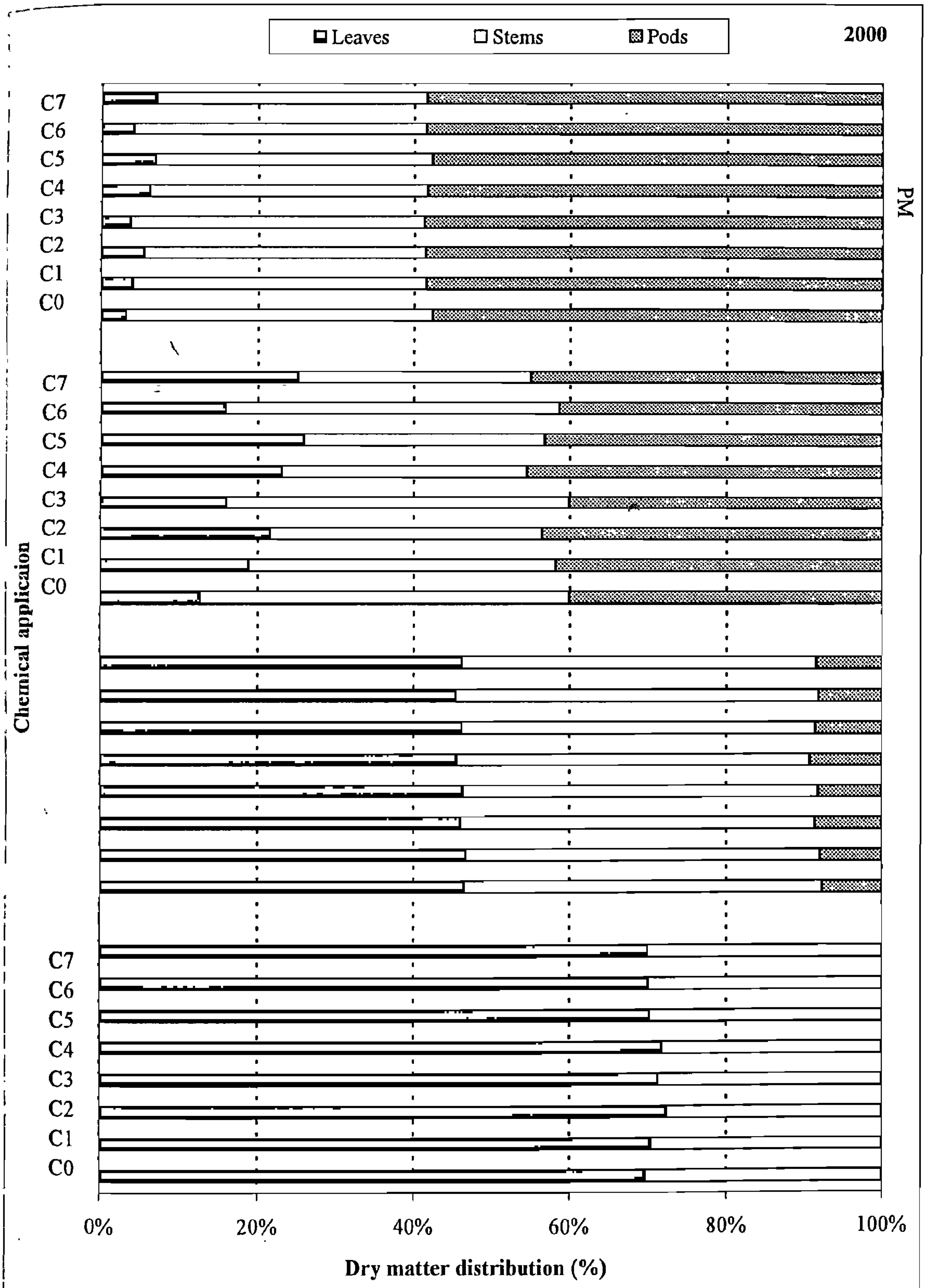



**Fig. 4.5 Effect of TU and DMSO on dry matter distribution in leaves, stems and pods (2000)**

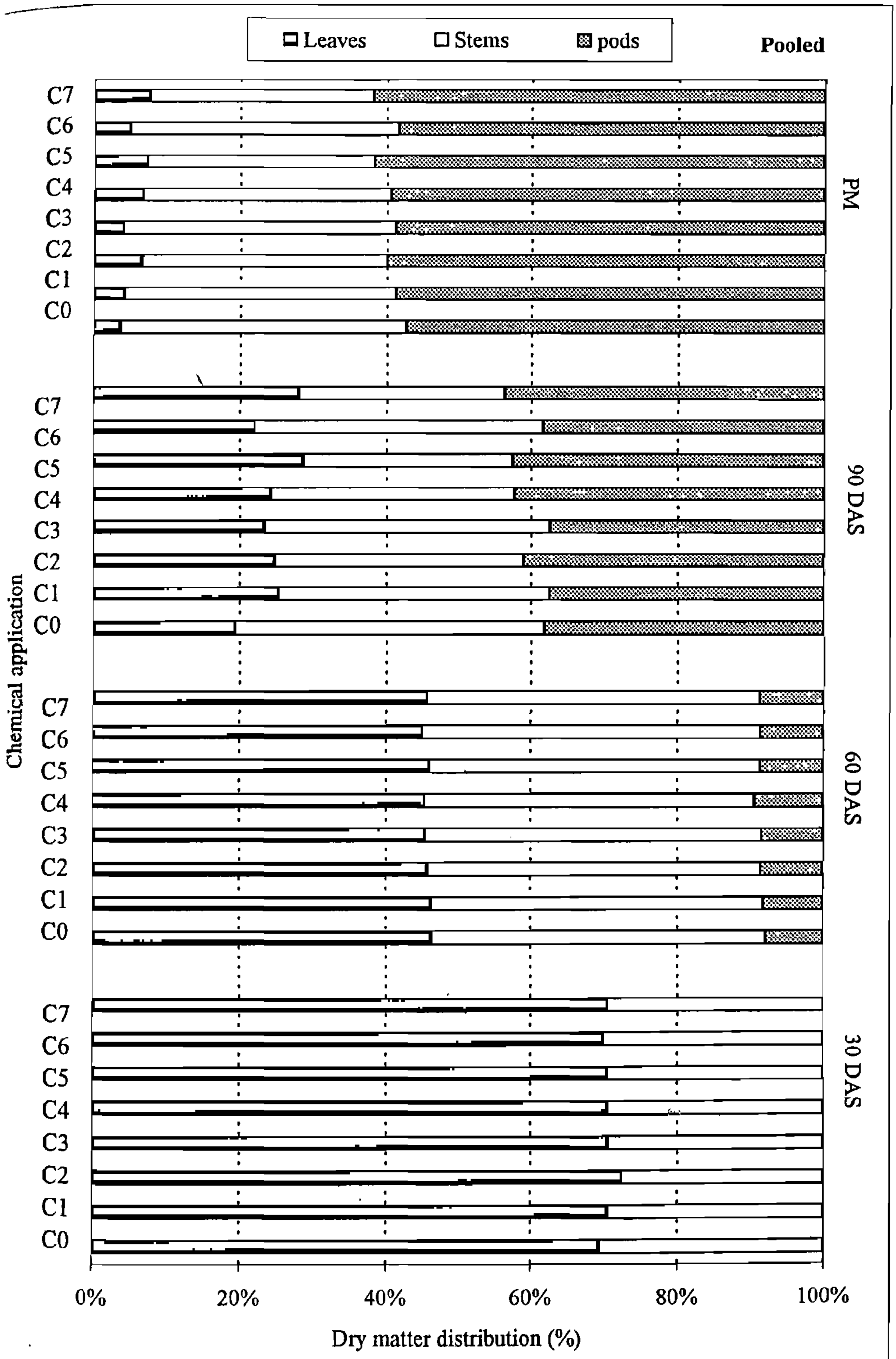



**Fig. 4.6 Effect of TU and DMSO on dry matter distribution in leaves, stems and pods (Pooled)**

control, whereas foliar spray of 100 ppm DMSO proved ineffective. Pooled data show that foliar sprays of 500 ppm TU and TU+DMSO significantly increased DMD in pods at physiological maturity. However, both the treatments were at par in this respect.

**4A.1.19 Chlorophyll content of leaves at 90 DAS**

Data (Table 4A.16) show that phosphorus application brought about significant increase in chlorophyll a, chlorophyll b and total chlorophyll content of leaves at 90 DAS in both the years. In pooled data, application of 20 and 40 kg $P_2O_5$/ha recorded significant increases of 26.3 and 27.1 per cent, respectively in chlorophyll a, 52.9 and 52.9 per cent in chlorophyll b and 30.2 and 31.4 per cent in total chlorophyll content, respectively over control.

Data further show that under no phosphorus, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased chlorophyll a content of leaves during both the years. However, chlorophyll b content of leaves remained unaffected by soil application of DMSO at 2 kg/ha (½+½) in both the years and soil application of TU at 5 kg/ha (½+½) in 2000 only. All the soil applied treatments of TU and DMSO proved effective in improving total chlorophyll content of leaves at 90 DAS except soil application of DMSO at 2 kg/ha (½+½). Pooled data show that increases in chlorophyll a, chlorophyll b and total chlorophyll content of leaves under soil application of TU at 5 kg/ha (basal) were 9.4, 30.9 and 13.0 per cent, respectively over control. The corresponding increases under soil application of TU at 5 kg/ha (½+½) were 39.6, 14.7 and 35.5 per cent and those under soil application of TU+DMSO (½+½) were 18.9, 55.9 and 24.9 per cent. However, soil application of TU at 5 kg/ha (½+½) was significantly superior to 20 and 40 kg $P_2O_5$/ha in respect of chlorophyll a and total chlorophyll content of leaves at 90 DAS.

Data further show that all the foliar spray treatments of TU and DMSO proved effective in increasing chlorophyll a, chlorophyll b and total chlorophyll content of leaves during both the years. In pooled data, foliar spray of 500 ppm TU significantly increased chlorophyll a, chlorophyll b and total chlorophyll content of leaves by 42.2, 60.3 and 45.3 per cent, respectively over control. The corresponding increases under foliar spray of 100 ppm DMSO were 27.1, 39.7 and 29.1 per cent and those under foliar spray of TU+DMSO were 51.5, 76.5 and 55.4 per cent. Data further show that foliar sprays of 500 ppm TU and TU+DMSO was significantly superior to 20 and 40 kg P2O5/ha alone in this respect.

**Table 4A.16 Effect of thiourea, DMSO and phosphorus on chlorophyll content (mg/g fr. wt.) of leaves at 90 DAS**

| Treatments | Chlorophyll a | | | Chlorophyll b | | | Total chlorophyll | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Control | 0.361 | 0.377 | 0.369 | 0.064 | 0.073 | 0.068 | 0.424 | 0.450 | 0.437 |
| Control+5 kg TU/ ha in soil (basal) | 0.409 | 0.399 | 0.404 | 0.090 | 0.089 | 0.089 | 0.500 | 0.488 | 0.494 |
| Control+5 kg TU/ ha in soil ($^1/_2$+$^1/_2$) | 0.529 | 0.499 | 0.515 | 0.076 | 0.079 | 0.078 | 0.606 | 0.579 | 0.592 |
| Control+2 kg DMSO/ ha in soil ($^1/_2$+$^1/_2$) | 0.402 | 0.398 | 0.399 | 0.065 | 0.067 | 0.066 | 0.467 | 0.464 | 0.466 |
| Control + (TU+DMSO) in soil ($^1/_2$+$^1/_2$) | 0.447 | 0.432 | 0.439 | 0.106 | 0.106 | 0.106 | 0.554 | 0.538 | 0.546 |
| Control+500 ppm TU spray | 0.542 | 0.508 | 0.525 | 0.105 | 0.114 | 0.109 | 0.647 | 0.622 | 0.635 |
| Control+100 ppm DMSO spray | 0.461 | 0.476 | 0.469 | 0.093 | 0.098 | 0.095 | 0.555 | 0.574 | 0.564 |
| Control + (TU+DMSO) spray | 0.578 | 0.539 | 0.559 | 0.125 | 0.115 | 0.120 | 0.704 | 0.654 | 0.679 |
| 20 kg $P_2O_5$/ha | 0.461 | 0.472 | 0.466 | 0.105 | 0.103 | 0.104 | 0.565 | 0.575 | 0.569 |
| 40 kg $P_2O_5$/ha | 0.476 | 0.464 | 0.469 | 0.105 | 0.103 | 0.104 | 0.581 | 0.566 | 0.574 |
| S.Em. $\pm$ | 0.0089 | 0.0067 | 0.0056 | 0.0027 | 0.0030 | 0.0020 | 0.0093 | 0.0074 | 0.0059 |
| C.D. (0.05) | 0.0258 | 0.0195 | 0.0158 | 0.0077 | 0.0087 | 0.0057 | 0.0271 | 0.0215 | 0.0168 |

### 4A.1.20 Leaf area index (LAI) at 60 DAS

Data (Table 4A.17) show that phosphorus application resulted into significant increase in LAI at 60 DAS upto 40 kg $P_2O_5$/ha during both the years. On the basis of pooled data, application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha. The magnitude of increase in LAI due to application of 20 and 40 kg $P_2O_5$/ha were to the tune of 24.1 and 40.9 per cent, respectively over control.

Soil application of TU+DMSO (½+½) significantly increased LAI at 60 DAS in 1999 only. Soil application of TU at 5 kg/ha (½+½) significantly increased LAI in both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU +DMSO (½+½) significantly incrcased LAI by 10.5 and 16.3 per cent, respectively over control. Soil application of DMSO at 2 kg/ha (½+½) was ineffective in this respect.

Data further reveal that foliar spray of TU+DMSO significantly increased LAI at 60 DAS during 2000 only, whereas other foliar applied treatments were ineffective in this respect during both the years. On the basis of pooled data, foliar sprays of 500 ppm TU and TU+DMSO significantly increased LAI at 60 DAS by 7.1 per cent each over control.

### 4A.1.21 Leaf area index (LAI) at 90 DAS

Data (Table 4A.18) reveal that phosphorus application brought about significant increase in LAI at 90 DAS upto 40 kg $P_2O_5$/ha during both the years. In pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased LAI by 33.9 and 49.8 per cent, respectively over control. Application of 40 kg $P_2O_5$/ha proved significantly superior over 20 kg $P_2O_5$/ha in this respect.

Soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased LAI in both years. In pooled data, similar trends were recorded and the increases were in the order of 27.4, 47.4, 22.9 and 59.4 per cent over control. Soil application of TU at 5 kg/ha (½+½) significantly increased LAI at 90 DAS by 15.6 per cent over soil application of TU at 5 kg/ha (basal).

Data further show that foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased LAI at 90 DAS in both years. In poled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased LAI at 90 DAS by 62.8, 21.8 and 69.9 per cent, respectively over control.

Data (Table 4A.18) show that TU and DMSO interacted significantly with phosphorus in influencing LAI at 90 DAS 2000 only. Under no phosphorus, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly

**Table: 4A.17 Effect of thiourea and DMSO on LAI at 60 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) 0 | 20 | 40 | Mean |
|---|---|---|---|---|
| Control | 3.87 | 4.46 | 5.44 | 4.59 |
| 5 kg TU/ha in soil (basal) | 3.99 | 4.75 | 5.55 | 4.76 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 4.73 | 4.86 | 5.95 | 5.18 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 3.99 | 4.33 | 5.35 | 4.56 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 4.27 | 5.55 | 6.21 | 5.34 |
| 500 ppm TU (spray) | 4.15 | 5.15 | 5.52 | 4.94 |
| 100 ppm DMSO (spray) | 3.92 | 5.15 | 5.38 | 4.82 |
| TU+DMSO (spray) | 4.00 | 4.64 | 5.66 | 4.76 |
| Mean | 4.11 | 4.86 | 5.63 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.110 | 0.179 | 0.311 | |
| C.D. (0.05) | 0.305 | 0.498 | NS | |

| Year 2000 | Phosphorus (kg/ha) 0 | 20 | 40 | Mean |
|---|---|---|---|---|
| Control | 3.37 | 4.61 | 5.15 | 4.37 |
| 5 kg TU/ha in soil (basal) | 3.44 | 4.82 | 5.26 | 4.50 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 3.81 | 4.77 | 5.55 | 4.71 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 3.50 | 4.43 | 5.12 | 4.35 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 3.92 | 5.46 | 5.86 | 5.08 |
| 500 ppm TU (spray) | 3.84 | 4.85 | 5.29 | 4.66 |
| 100 ppm DMSO (spray) | 3.42 | 4.17 | 4.77 | 4.12 |
| TU+DMSO (spray) | 3.89 | 5.19 | 5.46 | 4.85 |
| Mean | 3.64 | 4.79 | 5.31 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.088 | 0.144 | 0.249 | |
| C.D. (0.05) | 0.243 | 0.398 | NS | |

| Pooled | Phosphorus (kg/ha) 0 | 20 | 40 | Mean |
|---|---|---|---|---|
| Control | 3.62 | 4.53 | 5.29 | 4.48 |
| 5 kg TU/ha in soil (basal) | 3.71 | 4.78 | 5.40 | 4.63 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 4.27 | 4.81 | 5.75 | 4.95 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 3.75 | 4.38 | 5.23 | 4.45 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 4.09 | 5.51 | 6.04 | 5.21 |
| 500 ppm TU (spray) | 4.00 | 5.00 | 5.41 | 4.80 |
| 100 ppm DMSO (spray) | 3.67 | 4.66 | 5.08 | 4.46 |
| TU+DMSO (spray) | 3.94 | 4.91 | 5.56 | 4.80 |
| Mean | 3.88 | 4.82 | 5.47 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.070 | 0.115 | 0.199 | |
| C.D. (0.05) | 0.195 | 0.319 | NS | |

**Table: 4A.18 Effect of thiourea and DMSO on LAI at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.34 | 3.77 | 4.13 | 3.41 |
| 5 kg TU/ha in soil (basal) | 3.36 | 3.95 | 4.27 | 3.86 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 3.71 | 4.13 | 4.31 | 4.05 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 3.83 | 4.18 | 4.15 | 4.05 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 3.75 | 4.22 | 4.38 | 4.12 |
| 500 ppm TU (spray) | 4.08 | 4.65 | 4.58 | 4.43 |
| 100 ppm DMSO (spray) | 3.52 | 4.03 | 4.47 | 4.01 |
| TU+DMSO (spray) | 3.96 | 4.55 | 4.84 | 4.45 |
| Mean | 3.57 | 4.18 | 4.39 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.086 | 0.141 | 0.244 | |
| C.D. (0.05) | 0.239 | 0.390 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 1.28 | 2.13 | 2.32 | 1.91 |
| 5 kg TU/ha in soil (basal) | 2.03 | 3.12 | 3.60 | 2.92 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 2.51 | 4.14 | 4.73 | 3.79 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 1.40 | 2.59 | 3.45 | 2.48 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 2.74 | 4.49 | 5.85 | 4.36 |
| 500 ppm TU (spray) | 3.18 | 4.63 | 4.84 | 4.22 |
| 100 ppm DMSO (spray) | 1.29 | 2.68 | 3.46 | 2.48 |
| TU+DMSO (spray) | 3.24 | 4.74 | 5.82 | 4.60 |
| Mean | 2.21 | 3.56 | 4.26 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.071 | 0.116 | 0.200 | |
| C.D. (0.05) | 0.196 | 0.320 | 0.554 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 1.81 | 2.95 | 3.23 | 2.66 |
| 5 kg TU/ha in soil (basal) | 2.69 | 3.53 | 3.94 | 3.39 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 3.11 | 4.13 | 4.52 | 3.92 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 2.61 | 3.39 | 3.80 | 3.27 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 3.25 | 4.35 | 5.11 | 4.24 |
| 500 ppm TU (spray) | 3.63 | 4.64 | 4.71 | 4.33 |
| 100 ppm DMSO (spray) | 2.40 | 3.36 | 3.97 | 3.24 |
| TU+DMSO (spray) | 3.60 | 4.64 | 5.33 | 4.52 |
| Mean | 2.89 | 3.87 | 4.33 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.056 | 0.091 | 0.156 | |
| C.D. (0.05) | 0.155 | 0.253 | NS | |

increased LAI at 90 DAS over control. Soil application of DMSO at 2 kg/ha (½+½) and foliar spray of 100 ppm DMSO proved ineffective in this respect under no phosphorus. Under 20 kg P2O5/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO proved effective in increasing LAI at 90 DAS over control. Under 40 kg $P_2O_5$/ha, all the soil and foliar applied treatments significantly increased LAI at 90 DAS over control. The LAI obtained with foliar spray of 500 ppm TU and foliar spray of TU+DMSO under no phosphorus proved superior to 20 and 40 kg $P_2O_5$/ha. Combined effect of treatments on LAI at 90 DAS however, turned out non-significant in pooled data.

**4A.1.22 Crop growth rate (CGR) at 60 DAS**

Data (Table 4A.19) show that phosphorus application resulted in significant increase in CGR at 60 DAS upto 40 kg $P_2O_5$/ha during both the years. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased CGR at 60 DAS by 19.8 and 30.9 per cent, respectively over control. Further, application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha.

Soil application of TU at 5 kg/ha (½+½) significantly increased CGR at 60 DAS in 1999 only. Soil application of TU+DMSO (½+½) significantly increased CGR at 60 DAS during both the years. Soil application of DMSO at 2 kg/ha (½+½) failed to increase CGR at 60 DAS during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) significantly increased CGR at 60 DAS by 9.8 per cent over soil application of TU at 5 kg/ha (basal). Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased CGR by 11.0 and 17.1 per cent, respectively over control.

Data further indicate that foliar sprays of 500 ppm TU and 100 ppm DMSO failed to increase CGR at 60 DAS during both the years. However, foliar spray of TU+DMSO significantly increased CGR over control in 2000 only. In pooled data, foliar sprays of 500 ppm TU and TU+ DMSO significantly increased CGR at 60 DAS by 7.4 and 17.1 per cent, respectively over control.

**4A.1.23 Crop growth rate (CGR) at 90DAS**

Data (Table 4A.20) show that phosphorus application brought about significant increase in CGR at 90 DAS upto 20 kg $P_2O_5$/ha during both the years. In pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased CGR by 30.9 and 40.3 per cent, respectively over control. Further, application of 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha in this respect.

**Table: 4A.19 Effect of thiourea and DMSO on crop growth rate ($g/m^2/d$) at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 15.18 | 16.83 | 20.08 | 17.36 |
| 5 kg TU/ha in soil (basal) | 14.85 | 18.15 | 19.40 | 17.45 |
| 5 kg TU/ha in soil ($^1/_2+{}^1/_2$) | 19.15 | 18.75 | 21.58 | 19.83 |
| 2 kg DMSO/ha in soil ($^1/_2+{}^1/_2$) | 16.00 | 17.58 | 18.85 | 17.48 |
| TU+DMSO in soil ($^1/_2+{}^1/_2$) | 18.18 | 20.08 | 23.10 | 20.45 |
| 500 ppm TU (spray) | 16.33 | 19.50 | 20.03 | 18.62 |
| 100 ppm DMSO (spray) | 15.40 | 20.43 | 19.75 | 18.53 |
| TU+DMSO (spray) | 15.78 | 18.18 | 20.68 | 18.21 |
| Mean | 16.36 | 18.68 | 20.43 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.406 | 0.664 | 1.150 | |
| C.D. (0.05) | 1.127 | 1.841 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 14.33 | 18.38 | 20.73 | 17.81 |
| 5 kg TU/ha in soil (basal) | 14.29 | 19.54 | 20.48 | 18.09 |
| 5 kg TU/ha in soil ($^1/_2+{}^1/_2$) | 15.98 | 19.53 | 22.19 | 19.23 |
| 2 kg DMSO/ha in soil ($^1/_2+{}^1/_2$) | 14.89 | 17.92 | 20.23 | 17.68 |
| TU+DMSO in soil ($^1/_2+{}^1/_2$) | 17.27 | 21.80 | 23.19 | 20.75 |
| 500 ppm TU (spray) | 16.18 | 19.84 | 21.55 | 19.19 |
| 100 ppm DMSO (spray) | 14.44 | 17.75 | 19.83 | 17.34 |
| TU+DMSO (spray) | 16.74 | 21.10 | 22.14 | 19.99 |
| Mean | 15.51 | 19.48 | 21.29 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.348 | 0.569 | 0.984 | |
| C.D. (0.05) | 0.965 | 1.577 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 14.76 | 17.60 | 20.40 | 17.59 |
| 5 kg TU/ha in soil (basal) | 14.57 | 18.84 | 19.94 | 17.78 |
| 5 kg TU/ha in soil ($^1/_2+{}^1/_2$) | 17.56 | 19.14 | 21.88 | 19.53 |
| 2 kg DMSO/ha in soil ($^1/_2+{}^1/_2$) | 15.44 | 17.75 | 19.54 | 17.57 |
| TU+DMSO in soil ($^1/_2+{}^1/_2$) | 17.72 | 20.94 | 23.14 | 20.60 |
| 500 ppm TU (spray) | 16.25 | 19.67 | 20.78 | 18.90 |
| 100 ppm DMSO (spray) | 14.92 | 19.09 | 19.79 | 17.93 |
| TU+DMSO (spray) | 16.26 | 19.64 | 21.41 | 19.10 |
| Mean | 15.93 | 19.08 | 20.86 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.267 | 0.437 | 0.757 | |
| C.D. (0.05) | 0.742 | 1.211 | NS | |

**Table: 4A.20 Effect of thiourea and DMSO on crop growth rate ($g/m^2/d$) at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.23 | 8.75 | 9.10 | 6.69 |
| 5 kg TU/ha in soil (basal) | 5.43 | 8.93 | 11.75 | 8.70 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 7.00 | 8.50 | 6.98 | 7.49 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 8.15 | 11.75 | 11.40 | 10.43 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 9.55 | 10.10 | 8.75 | 9.47 |
| 500 ppm TU (spray) | 9.10 | 6.83 | 7.90 | 7.94 |
| 100 ppm DMSO (spray) | 8.93 | 9.93 | 13.18 | 10.68 |
| TU+DMSO (spray) | 8.93 | 9.40 | 8.60 | 8.98 |
| Mean | 7.41 | 9.27 | 9.71 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.530 | 0.865 | 1.499 | |
| C.D. (0.05) | 1.469 | 2.400 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 5.72 | 7.92 | 9.23 | 7.62 |
| 5 kg TU/ha in soil (basal) | 9.36 | 10.92 | 12.98 | 11.08 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 10.04 | 14.96 | 14.29 | 13.09 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 7.93 | 10.48 | 12.34 | 10.25 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 10.35 | 14.09 | 16.68 | 13.71 |
| 500 ppm TU (spray) | 11.85 | 16.51 | 15.09 | 14.48 |
| 100 ppm DMSO (spray) | 7.69 | 11.32 | 12.46 | 10.49 |
| TU+DMSO (spray) | 11.62 | 14.79 | 16.94 | 14.45 |
| Mean | 9.32 | 12.62 | 13.75 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.347 | 0.566 | 0.981 | |
| C.D. (0.05) | 0.962 | 1.569 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 3.97 | 8.33 | 9.16 | 7.16 |
| 5 kg TU/ha in soil (basal) | 7.39 | 9.92 | 12.36 | 9.89 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 8.52 | 11.73 | 10.63 | 10.29 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 8.04 | 11.11 | 11.87 | 10.34 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 9.95 | 12.09 | 12.71 | 11.59 |
| 500 ppm TU (spray) | 10.47 | 11.67 | 11.49 | 11.21 |
| 100 ppm DMSO (spray) | 8.31 | 10.62 | 12.82 | 10.58 |
| TU+DMSO (spray) | 10.27 | 12.09 | 12.77 | 11.71 |
| Mean | 8.36 | 10.95 | 11.73 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.317 | 0.517 | 0.896 | |
| C.D. (0.05) | 0.878 | 1.434 | NS | |

Soil application of TU at 5 kg/ha (basal) and soil application of TU at 5 kg/ha (½+½) significantly increased CGR at 90 DAS in 2000 only. However, soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased CGR at 90 DAS during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), and soil application of TU+DMSO (½+½) significantly increased CGR at 90 DAS by 38.1, 43.7, 44.4 and 61.9 per cent, respectively over control.

All the foliar applied treatments of TU and DMSO superior to control in respect of CGR at 90 DAS during 2000 only, whereas in 1999, only foliar spray of 100 ppm DMSO was effective. In pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased CGR at 90 DAS by 56.5, 47.8 and 63.5 per cent, respectively over control.

**4A.1.24 Leaf area ratio (LAR) at 60 DAS**

Data (Table 4A.21) indicate that phosphorus application brought about significant increase in LAR at 60 DAS upto 40 kg $P_2O_5$/ha during both the years. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased LAR at 60 DAS by 3.9 and 7.9 per cent, respectively over control. Further, application of 40 kg $P_2O_5$/ha proved superior to 20 kg $P_2O_5$/ha.

Soil application of TU and DMSO did not influence LAR at 60 DAS during both the years. Similarly, none of the foliar applied treatments effective in this respect during both the years. Similar trends were recorded in pooled data.

Data (Table 4A.21) show that TU and DMSO interacted significantly with phosphorus in influencing LAR at 60 DAS in 2000 only. Under no phosphorus, soil application of TU at 5 kg/ha (½+½) proved effective in increasing LAR at 60 DAS over control. Under 20 and 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective in this respect. The highest LAR (0.266) was obtained with soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) under 40 kg $P_2O_5$/ha which was at par with soil application of TU+DMSO (½+½) under 20 kg $P_2O_5$/ha but was superior to rest of the treatments under 20 kg $P_2O_5$/ha and no phosphorus. In pooled data, interaction effects were non-significant.

**4A.1.25 Leaf area ratio (LAR) at 90 DAS**

Data (Table 4A.22) show that application of phosphorus upto 40 kg $P_2O_5$/ha significantly increased LAR at 90 DAS during both the years. In pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased LAR at 90 DAS by 8.9 and 13.1 percent, respectively over control. Further, application of 40 kg $P_2O_5$/ha was proved superior to 20 kg $P_2O_5$/ha in respect of LAR at 90-90 DAS.

Soil application of TU at 5 kg/ha (basal) and soil application DMSO at 2 kg/ha (½+½) significantly increased LAR at 90 DAS during both the years. However, soil application TU at 5 kg/ha (½+½) was effective in 2000 only in improving LAR at 90 DAS. In pooled data, soil application TU at 5 kg/ha (basal), soil application TU at 5 kg/ha (½+½), soil application DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased LAR at 90 DAS by 13.5, 16.6, 7.4 and 11.6 per cent, respectively over control.

Data further show that significant increase in LAR at 90 was recorded due to foliar spray of 500 ppm TU in both the years. Whereas, foliar of 100 ppm DMSO and foliar spray of TU +DMSO significantly improved LAR at 90 DAS during 2000 only. In pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased LAR at 90 DAS by 20.2, 3.1 and 18.4 percent, respectively over control.

Data (Table 4A.22) show that TU and DMSO interacted significantly with phosphorus in influencing LAR at 90 DAS in 2000 only. All the soil and foliar applied treatments significantly increased LAR at 90 DAS under no phosphorus, 20 and 40 kg $P_2O_5$/ha except foliar spray of 100 ppm DMSO under no phosphorus. In pooled data, under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU +DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased LAR at 90 DAS by 16.8, 16.8, 24.2, 8.7, 2.0, 10.7 and 22.1 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) and foliar sprays of 500 ppm TU and TU+DMSO significantly increased LAR at 60-90 DAS by 5.8, 7.0, 9.9, 19.3 and 12.9 per cent, respectively over control. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) and foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased LAR at 90 DAS by 18.4, 13.1, 12.5, 19.0, 8.9 and 20.8 per cent, respectively over control. The highest LAR of 0.204 was obtained with foliar spray of 500 ppm TU under 20 kg $P_2O_5$/ha. When compared with absolute control, the increase was 36.9 per cent.

**4 A.1.26 Net assimilation rate (NAR) at 60 DAS**

Data (Table 4A.23) show that phosphorus application resulted significant increase in NAR at 60 during both the years. In pooled data, application of 40 kg $P_2O_5$/ha significant

**Table: 4A.21 Effect of thiourea and DMSO on leaf area ratio at 60 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.259 | 0.270 | 0.276 | 0.269 |
| 5 kg TU/ha in soil (basal) | 0.263 | 0.259 | 0.286 | 0.269 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 0.257 | 0.268 | 0.284 | 0.269 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 0.249 | 0.249 | 0.283 | 0.260 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 0.248 | 0.277 | 0.275 | 0.267 |
| 500 ppm TU (spray) | 0.259 | 0.272 | 0.285 | 0.272 |
| 100 ppm DMSO (spray) | 0.246 | 0.267 | 0.278 | 0.264 |
| TU+DMSO (spray) | 0.249 | 0.268 | 0.284 | 0.267 |
| Mean | 0.254 | 0.266 | 0.281 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0022 | 0.0035 | 0.0061 | |
| C.D. (0.05) | 0.0061 | NS | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.247 | 0.258 | 0.263 | 0.256 |
| 5 kg TU/ha in soil (basal) | 0.248 | 0.257 | 0.266 | 0.257 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 0.253 | 0.257 | 0.266 | 0.258 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 0.249 | 0.258 | 0.264 | 0.257 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 0.245 | 0.262 | 0.266 | 0.257 |
| 500 ppm TU (spray) | 0.252 | 0.256 | 0.261 | 0.256 |
| 100 ppm DMSO (spray) | 0.249 | 0.247 | 0.256 | 0.251 |
| TU+DMSO (spray) | 0.248 | 0.258 | 0.261 | 0.255 |
| Mean | 0.249 | 0.257 | 0.263 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0007 | 0.0012 | 0.0020 | |
| C.D. (0.05) | 0.0020 | NS | 0.0057 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.254 | 0.264 | 0.270 | 0.263 |
| 5 kg TU/ha in soil (basal) | 0.255 | 0.259 | 0.275 | 0.263 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 0.255 | 0.263 | 0.274 | 0.264 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 0.250 | 0.254 | 0.274 | 0.259 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 0.246 | 0.270 | 0.270 | 0.262 |
| 500 ppm TU (spray) | 0.256 | 0.265 | 0.274 | 0.265 |
| 100 ppm DMSO (spray) | 0.248 | 0.258 | 0.266 | 0.257 |
| TU+DMSO (spray) | 0.249 | 0.263 | 0.273 | 0.261 |
| Mean | 0.252 | 0.262 | 0.272 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0011 | 0.0018 | 0.0032 | |
| C.D. (0.05) | 0.0032 | NS | NS | |

**Table: 4A.22 Effect of thiourea and DMSO on leaf area ratio at 90 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.185 | 0.196 | 0.194 | 0.192 |
| 5 kg TU/ha in soil (basal) | 0.206 | 0.204 | 0.226 | 0.212 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.195 | 0.196 | 0.201 | 0.197 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.199 | 0.198 | 0.212 | 0.203 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.179 | 0.189 | 0.193 | 0.187 |
| 500 ppm TU (spray) | 0.199 | 0.216 | 0.214 | 0.209 |
| 100 ppm DMSO (spray) | 0.184 | 0.193 | 0.206 | 0.194 |
| TU+DMSO (spray) | 0.199 | 0.205 | 0.214 | 0.206 |
| Mean | 0.193 | 0.199 | 0.207 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0021 | 0.0034 | 0.0058 | |
| C.D. (0.05) | 0.0058 | 0.0095 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.113 | 0.145 | 0.139 | 0.133 |
| 5 kg TU/ha in soil (basal) | 0.143 | 0.158 | 0.169 | 0.157 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.152 | 0.169 | 0.179 | 0.167 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.124 | 0.149 | 0.164 | 0.145 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.151 | 0.184 | 0.192 | 0.175 |
| 500 ppm TU (spray) | 0.172 | 0.192 | 0.187 | 0.183 |
| 100 ppm DMSO (spray) | 0.119 | 0.147 | 0.160 | 0.142 |
| TU+DMSO (spray) | 0.165 | 0.181 | 0.192 | 0.179 |
| Mean | 0.142 | 0.166 | 0.173 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0008 | 0.0013 | 0.0022 | |
| C.D. (0.05) | 0.0022 | 0.0036 | 0.0062 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.149 | 0.171 | 0.168 | 0.163 |
| 5 kg TU/ha in soil (basal) | 0.174 | 0.181 | 0.199 | 0.185 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.174 | 0.183 | 0.190 | 0.182 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.162 | 0.174 | 0.189 | 0.175 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.165 | 0.188 | 0.193 | 0.182 |
| 500 ppm TU (spray) | 0.185 | 0.204 | 0.200 | 0.196 |
| 100 ppm DMSO (spray) | 0.152 | 0.170 | 0.183 | 0.168 |
| TU+DMSO (spray) | 0.182 | 0.193 | 0.203 | 0.193 |
| Mean | 0.168 | 0.183 | 0.190 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0011 | 0.0018 | 0.0031 | |
| C.D. (0.05) | 0.0031 | 0.0050 | 0.0086 | |

increased NAR at 60 DAS by 8.6 and 6.6 per cent, over control and 20 kg $P_2O_5$/ha, respectively.

None of the soil applied treatments were effective in improving NAR at 60 DAS during both the years. In pooled data also similar trends were observed.

Foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased NAR at 60 DAS over control during 2000 only. In 1999, all the foliar applied treatments were ineffective. In pooled data, all the foliar applied treatments were ineffective in this respect.

**4A.1.27 Net assimilation rate (NAR) at 90 DAS.**

Data (Table 4A.24) show that application of phosphorus did not influence NAR at 90 DAS.

Soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (1/2+1/2), and soil application of TU+DMSO (1/2+1/2), significantly increased NAR at 90 DAS during 2000 only. Whereas soil application of DMSO at 2 kg/ha (½+½) significantly increased NAR at 90 DAS over control during both the years. In pooled data, only soil application of DMSO at 2 kg/ha (½+½) significantly increased NAR at 90 DAS by 24.6 per cent, over control.

Foliar spray of 500 ppm TU and foliar spray of TU+ DMSO significantly increased NAR at 90 DAS over control during in 2000 only, whereas foliar application of 100 ppm DMSO proved effective in improving NAR at 90 DAS during both the years.

In pooled data, foliar spray of 500 ppm TU did not influence NAR at 60-90 DAS, whereas foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased NAR at 90 DAS by 30.8 and 16.9 per cent, respectively over control. Further, foliar spray of TU+DMSO was at par with foliar sprays of 500 ppm TU and 100 ppm DMSO alone.

**4A.1.28 Root length at 60 DAS**

Data (Table 4A.25) indicate that phosphorus application brought about significant increase in root length at 60 DAS upto 40 kg $P_2O_5$/ha during both the years. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased root length at 60 DAS by 14.4 and 24.3 per cent, respectively over control. Further, application of 40 kg $P_2O_5$/ha resulted in significantly increased root length at 60 DAS over 20 kg $P_2O_5$/ha.

Soil application of TU at 5 kg/ha ($^1/_2+^1/_2$) and TU+DMSO ($^1/_2+^1/_2$) significantly increased root length in 2000 only. On the basis of pooled data, soil application of TU at 5 kg/ha ($^1/_2+^1/_2$) was at par with soil application of TU at 5 kg/ha (basal). Soil application of DMSO did not influence root length at 60 DAS during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha ($^1/_2+^1/_2$) and soil application of TU+DMSO ($^1/_2+^1/_2$)

**Table: 4A.23 Effect of thiourea and DMSO on net assimilation rate (g/m²/d) at 60 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.275 | 0.257 | 0.280 | 0.271 |
| 5 kg TU/ha in soil (basal) | 0.233 | 0.258 | 0.260 | 0.250 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 0.275 | 0.259 | 0.285 | 0.273 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 0.237 | 0.269 | 0.287 | 0.264 |
| TU+DMSO in soil (1/2 + 1/2) | 0.273 | 0.246 | 0.304 | 0.274 |
| 500 ppm TU (spray) | 0.263 | 0.271 | 0.287 | 0.274 |
| 100 ppm DMSO (spray) | 0.266 | 0.290 | 0.295 | 0.284 |
| TU+DMSO (spray) | 0.258 | 0.270 | 0.272 | 0.267 |
| Mean | 0.260 | 0.265 | 0.284 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0045 | 0.0073 | 0.0127 | |
| C.D. (0.05) | 0.0127 | NS | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.274 | 0.276 | 0.294 | 0.281 |
| 5 kg TU/ha in soil (basal) | 0.260 | 0.271 | 0.282 | 0.271 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 0.267 | 0.272 | 0.281 | 0.273 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 0.269 | 0.263 | 0.292 | 0.275 |
| TU+DMSO in soil (1/2 + 1/2) | 0.268 | 0.271 | 0.294 | 0.278 |
| 500 ppm TU (spray) | 0.282 | 0.289 | 0.302 | 0.291 |
| 100 ppm DMSO (spray) | 0.276 | 0.286 | 0.294 | 0.285 |
| TU+DMSO (spray) | 0.285 | 0.294 | 0.312 | 0.297 |
| Mean | 0.273 | 0.278 | 0.294 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0017 | 0.0028 | 0.0049 | |
| C.D. (0.05) | 0.0049 | 0.0080 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.275 | 0.266 | 0.288 | 0.276 |
| 5 kg TU/ha in soil (basal) | 0.246 | 0.264 | 0.271 | 0.260 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 0.271 | 0.266 | 0.283 | 0.273 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 0.254 | 0.266 | 0.290 | 0.270 |
| TU+DMSO in soil (1/2 + 1/2) | 0.270 | 0.259 | 0.300 | 0.276 |
| 500 ppm TU (spray) | 0.273 | 0.280 | 0.295 | 0.283 |
| 100 ppm DMSO (spray) | 0.270 | 0.288 | 0.295 | 0.284 |
| TU+DMSO (spray) | 0.271 | 0.281 | 0.293 | 0.282 |
| Mean | 0.266 | 0.271 | 0.289 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0024 | 0.0039 | 0.0068 | |
| C.D. (0.05) | 0.0066 | NS | NS | |

**Table: 4A.24 Effect of thiourea and DMSO on net assimilation rate ($g/m^2/d$) at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.056 | 0.064 | 0.020 | 0.047 |
| 5 kg TU/ha in soil (basal) | 0.062 | 0.059 | 0.045 | 0.055 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 0.044 | 0.057 | 0.036 | 0.046 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 0.066 | 0.076 | 0.063 | 0.069 |
| TU+DMSO in soil (1/2 + 1/2) | 0.054 | 0.064 | 0.072 | 0.063 |
| 500 ppm TU (spray) | 0.047 | 0.042 | 0.048 | 0.046 |
| 100 ppm DMSO (spray) | 0.075 | 0.061 | 0.078 | 0.071 |
| TU+DMSO (spray) | 0.049 | 0.062 | 0.068 | 0.059 |
| Mean | 0.057 | 0.061 | 0.054 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0039 | 0.0064 | 0.0110 | |
| C.D. (0.05) | NS | 0.0180 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.079 | 0.074 | 0.089 | 0.081 |
| 5 kg TU/ha in soil (basal) | 0.086 | 0.084 | 0.102 | 0.091 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 0.084 | 0.100 | 0.097 | 0.094 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 0.087 | 0.092 | 0.103 | 0.094 |
| TU+DMSO in soil (1/2 + 1/2) | 0.085 | 0.069 | 0.095 | 0.083 |
| 500 ppm TU (spray) | 0.086 | 0.095 | 0.098 | 0.093 |
| 100 ppm DMSO (spray) | 0.092 | 0.101 | 0.108 | 0.100 |
| TU+DMSO (spray) | 0.090 | 0.089 | 0.098 | 0.092 |
| Mean | 0.086 | 0.088 | 0.099 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0019 | 0.0032 | 0.0055 | |
| C.D. (0.05) | 0.0055 | 0.0090 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.069 | 0.070 | 0.055 | 0.065 |
| 5 kg TU/ha in soil (basal) | 0.075 | 0.071 | 0.074 | 0.073 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 0.063 | 0.078 | 0.066 | 0.069 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 0.077 | 0.085 | 0.082 | 0.081 |
| TU+DMSO in soil (1/2 + 1/2) | 0.070 | 0.068 | 0.084 | 0.074 |
| 500 ppm TU (spray) | 0.068 | 0.069 | 0.073 | 0.069 |
| 100 ppm DMSO (spray) | 0.084 | 0.080 | 0.093 | 0.085 |
| TU+DMSO (spray) | 0.070 | 0.077 | 0.083 | 0.076 |
| Mean | 0.072 | 0.075 | 0.076 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0022 | 0.0036 | 0.0062 | |
| C.D. (0.05) | NS | 0.0099 | NS | |

significantly increased root length at 60 DAS in the order of 10.8 and 14.2 per cent over control.

Data further reveal that foliar sprays of 500 ppm TU, 100 ppm DMSO and foliar spray of TU + DMSO did not influence root length at 60 DAS in both the years.

**4A.1.29 Dry matter of roots per plant at 60 DAS**

A perusal of data (Table 4A.26) reveals that phosphorus application brought about significantly increase in dry matter of roots per plant at 60 DAS upto 20 kg $P_2O_5$/ha in 1999 and upto 40 kg $P_2O_5$/ha in 2000. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased dry matter of roots per plant at 60 DAS to tune of 39.2 and 48.9 per cent, respectively over control. Further, application of 40 kg $P_2O_5$/ha registered significant improvement in dry matter of roots per plant over 20 kg $P_2O_5$/ha.

Data (Table 4A.26) show that none of the soil applied treatments of TU and DMSO was effective in improving dry matter of roots per plant at 60 DAS in either of the years except soil application of TU+DMSO ($^1/_2$+$^1/_2$) in 1999. However, pooled data show that soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$) and soil application of TU+DMSO ($^1/_2$+$^1/_2$) registered 11.1 and 18.1 per cent significant improvement over control, respectively.

Foliar spray of TU and DMSO alone as well as TU+DMSO did not influence dry matter of roots per plant at 60 DAS in any of the years. Similar trends were observed in pooled data.

Data on combined effects of treatment (Table 4A.26) show that TU and DMSO interacted significantly with phosphorus in influencing dry matter of roots per plant at 60 DAS in 2000 only. Under no phosphorus, soil application of TU+DMSO (½+½) significantly increased dry matter of roots per plant over control, whereas rest of the treatments remained unaffected. However, under 20 and 40 kg $P_2O_5$/ha, soil and foliar applied treatments of TU and DMSO failed to increase dry matter of roots per plant over control. Combined effect of treatments on dry matter of roots per plant at 60 DAS, however, turned out non-significant in pooled data.

**4A1.30 Number of nodules per plant at 60 DAS**

Data ( Table 4A.27) show that phosphorus application brought about significant increase in number of nodules per plant upto 20 kg $P_2O_5$/ha in 1999 and upto 40 kg $P_2O_5$/ha in 2000. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased number of nodules by 38.1 and 47.6 per cent, respectively over control.

Data further show that soil application of TU at 5 kg/ha (½+½) proved effective in improving number of nodules per plant during both the years. Similar trends were noted in pooled data. Foliar spray of TU+DMSO also proved effective in this respect.

**Table: 4A. 25 Effect of thiourea and DMSO on root length (cm) at 60 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 18.0 | 19.50 | 21.51 | 19.67 |
| 5 kg TU/ha in soil (basal) | 17.83 | 21.07 | 23.25 | 20.72 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 19.83 | 21.55 | 22.27 | 21.21 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 19.52 | 20.50 | 22.33 | 20.78 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 20.62 | 22.22 | 23.35 | 22.07 |
| 500 ppm TU (spray) | 18.83 | 20.50 | 21.83 | 20.39 |
| 100 ppm DMSO (spray) | 18.08 | 20.15 | 22.13 | 20.12 |
| TU+DMSO (spray) | 18.63 | 21.07 | 21.73 | 20.48 |
| Mean | 18.92 | 20.82 | 22.30 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.447 | 0.731 | 0.265 | |
| C.D. (0.05) | 1.239 | NS | NS | |

| Year 2000 | Phosphorus ( kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 17.0 | 20.16 | 22.11 | 19.75 |
| 5 kg TU/ha in soil (basal) | 17.34 | 28.86 | 23.27 | 20.48 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 18.37 | 22.73 | 26.31 | 22.47 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 17.91 | 20.66 | 22.34 | 20.30 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 18.92 | 23.29 | 26.58 | 22.93 |
| 500 ppm TU (spray) | 17.62 | 21.09 | 22.23 | 20.31 |
| 100 ppm DMSO (spray) | 17.46 | 20.11 | 21.99 | 19.86 |
| TU+DMSO (spray) | 18.28 | 21.16 | 22.37 | 20.60 |
| Mean | 17.86 | 21.25 | 23.40 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.401 | 0.654 | 1.133 | |
| C.D. (0.05) | 1.111 | 1.813 | NS | |

| Pooled | Phosphorus ( kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 17.5 | 19.83 | 21.81 | 19.71 |
| 5 kg TU/ha in soil (basal) | 17.58 | 20.97 | 23.26 | 20.60 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 19.10 | 22.14 | 24.29 | 21.84 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 18.72 | 20.58 | 22.33 | 20.54 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 19.77 | 22.76 | 24.96 | 22.50 |
| 500 ppm TU (spray) | 18.23 | 20.79 | 22.03 | 20.35 |
| 100 ppm DMSO (spray) | 17.77 | 20.13 | 22.07 | 19.99 |
| TU+DMSO (spray) | 18.45 | 21.12 | 22.05 | 20.54 |
| Mean | 18.39 | 21.04 | 22.85 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.300 | 0.490 | 0.849 | |
| C.D. (0.05) | 0.832 | 1.359 | NS | |

**Table: 4A.26 Effect of thiourea and DMSO on dry matter of root/plant (g) at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 1.114 | 1.564 | 1.488 | 1.389 |
| 5 kg TU/ha in soil (basal) | 1.214 | 1.508 | 1.680 | 1.467 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 1.499 | 1.583 | 1.600 | 1.561 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 1.251 | 1.361 | 1.498 | 1.370 |
| TU+DMSO in soil (1/2 + 1/2) | 1.535 | 1.635 | 1.99 | 1.720 |
| 500 ppm TU (spray) | 1.103 | 1.480 | 1.405 | 1.329 |
| 100 ppm DMSO (spray) | 1.361 | 1.589 | 1.580 | 1.510 |
| TU+DMSO (spray) | 1.203 | 1.499 | 1.890 | 1.531 |
| Mean | 1.285 | 1.527 | 1.641 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.043 | 0.071 | 0.123 | |
| C.D. (0.05) | 0.120 | 0.196 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 1.030 | 1.735 | 1.914 | 1.559 |
| 5 kg TU/ha in soil (basal) | 1.064 | 1.803 | 1.836 | 1.567 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 1.280 | 1.879 | 1.980 | 1.713 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 1.086 | 1.828 | 1.944 | 1.619 |
| TU+DMSO in soil (1/2 + 1/2) | 1.304 | 1.953 | 2.031 | 1.762 |
| 500 ppm TU (spray) | 1.058 | 1.780 | 1.918 | 1.585 |
| 100 ppm DMSO (spray) | 1.053 | 1.775 | 1.922 | 1.583 |
| TU+DMSO (spray) | 1.057 | 1.787 | 1.962 | 1.602 |
| Mean | 1.117 | 1.817 | 1.938 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.033 | 0.054 | 0.093 | |
| C.D. (0.05) | 0.091 | NS | 0.257 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 1.073 | 1.649 | 1.701 | 1.474 |
| 5 kg TU/ha in soil (basal) | 1.139 | 1.655 | 1.759 | 1.517 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 1.390 | 1.731 | 1.790 | 1.637 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 1.169 | 1.595 | 1.721 | 1.495 |
| TU+DMSO in soil (1/2 + 1/2) | 1.419 | 1.794 | 1.010 | 1.741 |
| 500 ppm TU (spray) | 1.080 | 1.630 | 1.661 | 1.457 |
| 100 ppm DMSO (spray) | 1.208 | 1.683 | 1.751 | 1.547 |
| TU+DMSO (spray) | 1.13 | 1.643 | 1.926 | 1.567 |
| Mean | 1.201 | 1.672 | 1.789 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.027 | 0.044 | 0.077 | |
| C.D. (0.05) | 0.075 | 0.123 | NS | |

**Table: 4A.27 Effect of thiourea and DMSO on nodules per plant at 60 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 3.5 | 5.5 | 5.8 | 4.9 |
| 5 kg TU/ha in soil (basal) | 4.0 | 5.3 | 5.7 | 5.0 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 6.0 | 6.0 | 6.1 | 6.0 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 3.9 | 5.4 | 5.8 | 5.0 |
| TU+DMSO in soil (1/2 + 1/2) | 6.1 | 6.2 | 6.4 | 6.2 |
| 500 ppm TU (spray) | 4.1 | 5.8 | 5.7 | 5.2 |
| 100 ppm DMSO (spray) | 3.9 | 5.5 | 5.6 | 5.0 |
| TU+DMSO (spray) | 3.9 | 5.5 | 5.9 | 5.1 |
| Mean | 4.4 | 5.6 | 5.9 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.119 | 0.194 | 0.336 | |
| C.D. (0.05) | 0.329 | 0.539 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.9 | 5.2 | 6.6 | 4.9 |
| 5 kg TU/ha in soil (basal) | 3.4 | 6.1 | 6.1 | 5.2 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 4.7 | 6.9 | 6.7 | 6.1 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 3.7 | 6.0 | 6.3 | 5.3 |
| TU+DMSO in soil (1/2 + 1/2) | 4.8 | 6.4 | 7.0 | 6.1 |
| 500 ppm TU (spray) | 4.0 | 5.8 | 6.6 | 5.5 |
| 100 ppm DMSO (spray) | 3.6 | 5.8 | 6.0 | 5.1 |
| TU+DMSO (spray) | 4.5 | 6.4 | 6.6 | 5.8 |
| Mean | 3.9 | 6.1 | 6.5 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.135 | 0.220 | 0.381 | |
| C.D. (0.05) | 0.374 | 0.610 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 3.2 | 5.3 | 6.2 | 4.9 |
| 5 kg TU/ha in soil (basal) | 3.7 | 5.7 | 5.9 | 5.1 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 5.4 | 6.4 | 6.4 | 6.0 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 3.8 | 5.7 | 6.1 | 5.2 |
| TU+DMSO in soil (1/2 + 1/2) | 5.4 | 6.3 | 6.7 | 6.1 |
| 500 ppm TU (spray) | 4.0 | 5.8 | 6.2 | 5.3 |
| 100 ppm DMSO (spray) | 3.7 | 5.6 | 5.8 | 5.1 |
| TU+DMSO (spray) | 4.2 | 5.9 | 6.2 | 5.4 |
| Mean | 4.2 | 5.8 | 6.2 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.089 | 0.147 | 0.254 | |
| C.D. (0.05) | 0.249 | 0.407 | NS | |

## 4A.2: EFFECT OF TU AND DMSO AT VARYING LEVELS OF PHOSPHORUS ON YIELD PARAMETERS

### 4A.2.1 Number of clusters per plant

Data (Table 4A.28) show that successive increase in phosphorus levels upto 40 kg $P_2O_5$/ha significantly increased number of clusters per plant during 2000, however, it responded significantly upto 20 kg $P_2O_5$/ha during 1999. In pooled data, application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha. Application of 20 and 40 kg $P_2O_5$/ha significantly increased number of clusters per plant by 18.4 and 27.8 per cent, respectively over control.

Soil application of TU at 5 kg/ha (basal) failed to increase number of branches per plant significantly during either of the years. However, soil application of TU at 5 kg/ha (½+½) and soil application of TU +DMSO (½+½) significantly increased number of cluster per plant during both the years, whereas soil application of DMSO at 2 kg/ha (½+½) proved ineffective in this respect. On the basis of pooled data, soil application of 5 kg TU/ha (½+½) significantly increased number of clusters per plant by 18.5 per cent over soil application of TU at 5 kg/ha (basal). In pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased number of clusters per plant by 22.1 and 25.8 per cent, respectively over control.

Foliar sprays 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased number of clusters per plant in 1999. In 2000, foliar sprays of 500 ppm TU and TU+DMSO proved effective in increasing number of clusters per plant. Whereas, foliar spray of 100 ppm DMSO proved ineffective in this respect. Pooled data show that foliar sprays of 500 ppm TU and TU+DMSO significantly increased number of clusters per plant by 18.4 and 19.0 per cent, respectively over control.

### 4A.2.2 Number of pods per cluster

Data (Table 4A.29) reveal that phosphorus application proved ineffective in increasing number of pods per cluster during 1999. While in 2000, phosphorus application brought about significant increase in number of pods per cluster upto 20 kg $P_2O_5$/ha. However, in pooled data, number pods per cluster remained unaffected due to phosphorus application.

Soil applied treatments of TU and DMSO showed inconsistent effect on number of pods per cluster. In 1999, none of the soil applied treatments of TU and DMSO proved effective. However, in 2000 soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased number of pods per cluster over control. Other

**Table: 4A.28 Effect of thiourea and DMSO on number of cluster/plant at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 13.42 | 18.32 | 17.15 | 16.30 |
| 5 kg TU/ha in soil (basal) | 16.60 | 15.00 | 16.75 | 17.45 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 19.10 | 19.50 | 26.60 | 21.73 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 13.32 | 16.42 | 17.75 | 15.83 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 23.75 | 20.72 | 23.25 | 22.57 |
| 500 ppm TU (spray) | 18.15 | 18.62 | 18.95 | 21.07 |
| 100 ppm DMSO (spray) | 18.35 | 18.10 | 20.92 | 19.12 |
| TU+DMSO (spray) | 15.42 | 20.90 | 16.60 | 2047 |
| Mean | 17.20 | 19.64 | 21.12 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.550 | 0.899 | 1.557 | |
| C.D. (0.05) | 1.526 | 2.491 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 13.40 | 17.3 | 18.2 | 16.3 |
| 5 kg TU/ha in soil (basal) | 13.0 | 16.4 | 18.4 | 16.10 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 14.50 | 19.50 | 20.6 | 18.20 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 13.40 | 17.20 | 18.40 | 16.30 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 14.80 | 19.60 | 20.80 | 18.40 |
| 500 ppm TU (spray) | 14.2 | 18.60 | 19.60 | 17.50 |
| 100 ppm DMSO (spray) | 13.20 | 17.40 | 18.30 | 16.30 |
| TU+DMSO (spray) | 14.70 | 19.60 | 20.50 | 18.30 |
| Mean | 13.90 | 18.20 | 19.40 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.332 | 0.543 | 0.941 | |
| C.D. (0.05) | 0.920 | 1.505 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 13.4 | 17.8 | 17.7 | 16.3 |
| 5 kg TU/ha in soil (basal) | 15.1 | 17.7 | 17.6 | 16.8 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 16.8 | 19.5 | 23.6 | 19.9 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 13.4 | 16.8 | 18.1 | 16.1 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 19.3 | 20.2 | 22.0 | 20.5 |
| 500 ppm TU (spray) | 16.2 | 19.9 | 21.8 | 19.3 |
| 100 ppm DMSO (spray) | 15.8 | 17.8 | 19.6 | 17.7 |
| TU+DMSO (spray) | 16.3 | 20.3 | 21.5 | 19.4 |
| Mean | 15.8 | 18.7 | 20.2 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.321 | 0.525 | 0.909 | |
| C.D. (0.05) | 0.891 | 1.455 | NS | |

**Table: 4A.29 Effect of thiourea and DMSO on number pods/cluster at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 3.90 | 3.30 | 3.88 | 3.69 |
| 5 kg TU/ha in soil (basal) | 3.31 | 3.32 | 3.64 | 3.42 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 3.89 | 3.47 | 2.55 | 3.31 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 4.50 | 3.92 | 3.74 | 4.05 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 3.00 | 3.25 | 3.08 | 3.11 |
| 500 ppm TU (spray) | 3.62 | 3.27 | 3.01 | 3.30 |
| 100 ppm DMSO (spray) | 3.23 | 3.33 | 3.36 | 3.31 |
| TU+DMSO (spray) | 3.55 | 3.63 | 3.12 | 3.44 |
| Mean | 3.62 | 3.44 | 3.30 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.126 | 0.206 | 0.356 | |
| C.D. (0.05) | NS | NS | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.80 | 3.10 | 3.20 | 3.03 |
| 5 kg TU/ha in soil (basal) | 2.90 | 3.20 | 3.30 | 3.13 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 3.20 | 3.60 | 3.70 | 3.50 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 3.00 | 3.20 | 3.30 | 3.17 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 3.30 | 3.70 | 3.65 | 3.55 |
| 500 ppm TU (spray) | 3.30 | 3.60 | 3.70 | 3.53 |
| 100 ppm DMSO (spray) | 2.75 | 3.30 | 3.25 | 3.10 |
| TU+DMSO (spray) | 3.20 | 3.50 | 3.55 | 3.42 |
| Mean | 3.06 | 3.40 | 3.46 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.039 | 0.065 | 0.113 | |
| C.D. (0.05) | 0.110 | 0.180 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 3.35 | 3.20 | 3.54 | 3.36 |
| 5 kg TU/ha in soil (basal) | 3.10 | 3.26 | 3.47 | 3.28 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 3.55 | 3.54 | 3.13 | 3.40 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 3.78 | 3.56 | 3.52 | 3.62 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 3.15 | 3.47 | 3.36 | 3.33 |
| 500 ppm TU (spray) | 3.46 | 3.43 | 3.36 | 3.42 |
| 100 ppm DMSO (spray) | 2.99 | 3.32 | 3.30 | 3.20 |
| TU+DMSO (spray) | 3.38 | 3.57 | 3.33 | 3.43 |
| Mean | 3.34 | 3.42 | 3.38 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.066 | 0.108 | 0.187 | |
| C.D. (0.05) | NS | NS | NS | |

soil applied treatments proved ineffective in this respect. In pooled data, none of the soil applied treatments proved effective in respect of number of pods per cluster.

Foliar spray treatments also showed inconsistent effect on number of pods per cluster. In 1999, all the foliar applied treatments of TU and DMSO proved ineffective. However, in 2000 foliar sprays of 500 ppm TU and TU+DMSO significantly increased number of pods per cluster over control. Foliar spray of 100 ppm DMSO proved ineffective in this respect. Pooled data show that none of the foliar applied treatments proved effective in respect of number of pods per cluster.

### 4A.2.3 Number of pods per plant

Data (Table 4A.30) reveal that phosphorus application brought about significant increase in number of pods per plant upto 20 kg $P_2O_5$/ha during 1999 and upto 40 kg $P_2O_5$/ha in 2000. In pooled data, application of 40 kg $P_2O_5$/ha proved significantly superior over 20 kg $P_2O_5$/ha. Further, application 20 and 40 kg $P_2O_5$/ha significantly increased number of pods by 22.1 and 28.8 per cent, respectively over control.

Soil application of TU at 5 kg/ha (½+½) significantly increased number of pods per plant in both the years. Soil application of TU+DMSO also proved effective in this respect, whereas soil application of DMSO at 2 kg/ha (½+½) did not influence number of pods per plant in both years. In pooled data, soil application of TU at 5 kg/ha (½+½) significantly increased number of pods per plant by 22.7 per cent over soil application of TU at 5 kg/ha (basal). Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly superior to control, giving an increase of 23.9 and 25.4 per cent, respectively.

Foliar sprays of 500 ppm TU and TU+DMSO significantly increased number of pods per plant during both the years, whereas foliar spray of 100 ppm DMSO failed to cause significant improvement in this respect. Similar trends were observed in pooled data. On the basis of pooled data, foliar sprays of 500 ppm TU and TU+DMSO significantly increased number of pods per plant by 20.9 and 21.7 per cent, respectively over control.

### 4A.2.4 Number of poorly filled pods per plant

Data (Table 4A.31) show that significant reduction in number of poorly filled pods per plant was recorded due to application of phosphorus upto 40 kg $P_2O_5$/ha during both the years. In pooled data, application of 40 kg $P_2O_5$/ha significantly reduced number of poorly filled pods per plant over 20 kg $P_2O_5$/ha. Pooled data show that 20 and 40 kg $P_2O_5$/ha caused significant reduction in number of poorly filled pods per plant by 31.9 and 40.4 per cent, respectively over control.

Soil application of TU at 5 kg/ha (basal) significantly reduced number of poorly filled pods per plant in 1999, whereas in 2000, it was ineffective. However, soil application of TU at 5 kg/ha (½+½) significantly reduced number of poorly filled pods per plant during both the years. This treatment was superior to soil application of TU at 5 kg (basal) in both the years. Significant reduction in number of poorly filled was recorded due to soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and TU+DMSO (½+½) over control in both the years. Pooled data show that the magnitude of reduction in number of poorly filled pods per plant was highest under soil application of TU +DMSO (½+½).

Foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly reduced number of poorly filled pods per plant over control in 1999. While in 2000, only foliar spray of 100 ppm DMSO proved effective in this respect. Pooled data show that foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly reduced number of poorly filled pods per plant over control. The magnitude of reduction in number of poorly filled pods per plant was highest under foliar spray of TU+DMSO.

Data (Table 4A.31) show that interaction effects of TU and DMSO with phosphorus were significant in both the years. In 1999, under no phosphorus, number of poorly filled pods per plant was significantly decreased under all the soil applied as well as foliar applied treatments of TU and DMSO when compared with control. Similar trends were recorded under 20 and 40 kg $P_2O_5$/ha. In 2000, under no phosphorus, number of poorly filled pods per plant was significantly decreased under all the soil and foliar applied treatments of TU and DMSO over control except soil application of TU at 5 kg/ha (basal). Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal) and foliar spray of 100 ppm DMSO remained unaffected, whereas rest of the treatments caused significant reduction in number of poorly filled pods per plant. Under 40 kg $P_2O_5$/ha, only soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO proved effective in decreasing number of poorly pods per plant when compared to control. However, rests of the treatments were ineffective. Pooled data show that under no phosphorus, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (1/2+1/2), soil application of TU+DMSO (½+½), foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly decreased number of poorly filled pods per plant by 24.7, 51.8, 40.7, 56.8, 64.2, 37.0 and 64.2 per cent, respectively over control. However, foliar spray of TU+DMSO was most effective. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly decreased number of poorly filled pods per plant by 17.1, 26.8, 34.1, 29.3, 17.1 and 21.9 per cent, respectively over control. soil application of DMSO at 2 kg/ha (½+½) proved ineffective

**Table: 4A.30 Effect of thiourea and DMSO on number of pods/plant at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 50.63 | 59.27 | 63.20 | 57.70 |
| 5 kg TU/ha in soil (basal) | 53.13 | 61.22 | 59.42 | 57.92 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 71.38 | 67.52 | 67.72 | 68.87 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 60.2 | 63.5 | 65.17 | 62.96 |
| TU+DMSO in soil (1/2 + 1/2) | 70.00 | 67.25 | 70.00 | 69.08 |
| 500 ppm TU (spray) | 62.55 | 68.87 | 72.45 | 67.96 |
| 100 ppm DMSO (spray) | 59.12 | 60.00 | 67.52 | 62.23 |
| TU+DMSO (spray) | 62.88 | 70.92 | 70.00 | 67.93 |
| Mean | 61.2 | 64.90 | 66.87 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.310 | 2.139 | 3.705 | |
| C.D. (0.05) | 3.631 | 5.929 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 37.73 | 53.88 | 57.85 | 49.82 |
| 5 kg TU/ha in soil (basal) | 38.50 | 52.65 | 60.68 | 50.61 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 46.43 | 70.18 | 76.40 | 64.33 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 40.43 | 54.92 | 60.75 | 52.03 |
| TU+DMSO in soil (1/2 + 1/2) | 48.78 | 72.53 | 75.90 | 65.73 |
| 500 ppm TU (spray) | 46.78 | 67.00 | 72.40 | 62.06 |
| 100 ppm DMSO (spray) | 36.33 | 57.73 | 59.28 | 51.11 |
| TU+DMSO (spray) | 47.13 | 68.78 | 72.88 | 62.93 |
| Mean | 42.76 | 62.21 | 67.02 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.317 | 2.151 | 3.726 | |
| C.D. (0.05) | 3.651 | 5.962 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 44.18 | 56.58 | 60.53 | 53.76 |
| 5 kg TU/ha in soil (basal) | 45.81 | 56.94 | 60.05 | 54.27 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 58.90 | 68.85 | 72.06 | 66.60 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 50.31 | 59.21 | 62.96 | 57.49 |
| TU+DMSO in soil (1/2 + 1/2) | 59.39 | 69.89 | 72.95 | 67.41 |
| 500 ppm TU (spray) | 54.66 | 67.94 | 72.43 | 65.01 |
| 100 ppm DMSO (spray) | 47.73 | 58.86 | 63.40 | 56.66 |
| TU+DMSO (spray) | 55.00 | 69.85 | 71.44 | 65.43 |
| Mean | 52.00 | 63.51 | 66.98 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.929 | 1.517 | 2.627 | |
| C.D. (0.05) | 2.575 | 4.205 | NS | |

**Table: 4A.31 Effect of thiourea and DMSO on number of poorly filled pods/plant at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 8.7 | 4.1 | 4.0 | 5.6 |
| 5 kg TU/ha in soil (basal) | 5.1 | 3.0 | 2.8 | 3.6 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 3.1 | 3.0 | 2.9 | 3.0 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 3.7 | 3.0 | 2.1 | 2.9 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 2.5 | 2.6 | 2.5 | 2.5 |
| 500 ppm TU (spray) | 2.3 | 2.8 | 1.8 | 2.3 |
| 100 ppm DMSO (spray) | 3.7 | 3.0 | 1.8 | 2.8 |
| TU+DMSO (spray) | 2.5 | 2.4 | 1.4 | 2.1 |
| Mean | 3.9 | 2.9 | 2.4 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.074 | 0.122 | 0.211 | |
| C.D. (0.05) | 0.205 | 0.338 | 0.585 | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 7.5 | 4.0 | 3.6 | 5.0 |
| 5 kg TU/ha in soil (basal) | 7.1 | 3.8 | 3.5 | 4.8 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 4.8 | 3.0 | 2.8 | 3.5 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 5.9 | 4.1 | 3.5 | 4.5 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 4.5 | 2.8 | 2.8 | 3.4 |
| 500 ppm TU (spray) | 3.5 | 3.1 | 3.0 | 3.2 |
| 100 ppm DMSO (spray) | 6.5 | 3.8 | 3.7 | 4.7 |
| TU+DMSO (spray) | 3.2 | 2.4 | 2.2 | 2.6 |
| Mean | 5.4 | 3.4 | 3.1 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.007 | 0.120 | 0.208 | |
| C.D. (0.05) | 0.019 | 0.333 | 0.577 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 8.1 | 4.1 | 3.8 | 5.3 |
| 5 kg TU/ha in soil (basal) | 6.1 | 3.4 | 3.2 | 4.2 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 3.9 | 3.0 | 2.9 | 3.3 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 4.8 | 3.6 | 2.8 | 3.7 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 3.5 | 2.7 | 2.7 | 2.9 |
| 500 ppm TU (spray) | 2.9 | 2.9 | 2.4 | 2.8 |
| 100 ppm DMSO (spray) | 5.1 | 3.4 | 2.8 | 3.8 |
| TU+DMSO (spray) | 2.9 | 2.4 | 1.8 | 2.4 |
| Mean | 4.7 | 3.2 | 2.8 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.052 | 0.085 | 0.148 | |
| C.D. (0.05) | 0.145 | 0.237 | 0.410 | |

in this respect. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½) foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly decreased number of poorly filled pods per plant by 15.8, 23.7, 26.3, 28.9, 36.8, 26.3 and 52.6 per cent, respectively over control. Foliar spray of TU+DMSO was the most effective in this respect. The lowest number of poorly filled pods were recorded with foliar spray of TU+DMSO under 40 kg $P_2O_5$/ha which was significantly superior to all other treatment combinations and giving 77.8 per cent reduction in number of poorly filled pods per plant as compared to absolute control.

**4A.2.5 Number unfilled pods per plant.**

Data (Table 4A.32) show that phosphorus application brought about significant reduction in number of unfilled pods per plant upto 40 kg $P_2O_5$/ha in 1999 and upto 20 kg $P_2O_5$/ha in 2000. In pooled data, the magnitude of reduction in number of unfilled pods per plant by 40 kg $P_2O_5$/ha was significantly higher over 20 kg $P_2O_5$/ha. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly reduced number of unfilled pods per plant by 42.7 and 46.3 per cent, respectively over control.

Soil application of TU at 5 kg/ha (basal) significantly reduced number of unfilled pods per plant in 1999, whereas it was ineffective in 2000. Soil application of TU at 5 kg/ha (½+½) significantly reduced number of unfilled pods per plant during both the years. This treatment was significantly superior to soil application of TU at 5 kg/ha (basal) in both the years. Soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and TU+DMSO (½+½) significantly reduced number of unfilled pods per plant over control during both the years. In pooled data, similar trends were noted. The magnitude of reduction in number of unfilled pods per plant was highest under soil application of TU+DMSO (½+½).

Foliar sprays of 500 ppm TU and TU+DMSO significantly reduced number of unfilled pods per plant over control during both the years. Foliar spray of 100 ppm DMSO failed to affect on number of unfilled pods per plant in either of the years. Pooled data show that foliar sprays of 500 ppm TU and TU+DMSO significantly reduced number of unfilled pods per plant over control. The magnitude of reduction in number of unfilled pods per plant was highest under foliar spray of TU+DMSO.

Data on combined effect of treatments (Table 4A.32) show that effects of soil and foliar applied treatments on number of unfilled pods per plant were significant under different levels of phosphorus in both the years. In 1999, under no phosphorus, all the foliar applied treatments proved effective in decreasing number of unfilled pods per plant as compared to control. Under 20 kg $P_2O_5$/ha, except soil application of TU at 5 kg/ha (basal), all the soil and foliar applied treatments proved effective. Under 40 kg $P_2O_5$/ha, soil application of DMSO at 2 kg/ha (1/2+1/2) and foliar spray of 100 ppm DMSO proved ineffective. Whereas, rest of the treatments significantly decreased number of unfilled pods per plant over control. In 2000, soil application of TU at 5 kg/ha (basal) under each level of phosphorus proved ineffective in this respect. Under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (1/2+1/2), soil application of TU+DMSO (½+½), foliar sprays of 500 ppm TU and TU+DMSO significantly decreased number of unfilled pods per plant over control. Foliar spray of 100 ppm DMSO proved ineffective. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly decreased number of unfilled pods per plant over control. Soil application of DMSO at 2 kg/ha (½+½) and foliar spray of 100 ppm DMSO remained unaffected in this respect. Similar trends were recorded under 40 kg $P_2O_5$/ha. Pooled data show that under no phosphorus, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly decreased number of unfilled pods per plant by 17.4, 62.2, 22.7, 63.6, 62.9, 5.3 and 65.9 per cent, respectively over control. Under 20 kg P2O5/ha, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly decreased number of unfilled pods per plant by 55.6, 11.1, 61.1,65.3 and 69.4 per cent, respectively over control. Soil application of TU at 5 kg/ha (basal) and foliar spray of 100 ppm DMSO proved ineffective. Foliar spray of TU+DMSO proved most effective in this respect. However, it was at par with foliar spray of 500 ppm TU and soil application of TU+DMSO (½+½) under 20 and 40 kg $P_2O_5$/ha. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (1/2+1/2), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly decreased number of unfilled pods per plant by 53.0, 60.6, 62.2 and 68.2 per cent, respectively over control. Soil application of TU at 5 kg/ha (basal), soil application of DMSO at 2 kg/ha (½+½) and foliar spray of 100 ppm DMSO remained unaffected. The lowest number of unfilled pods per plant per plant (2.1) were recorded with foliar spray of TU+DMSO under 40 kg $P_2O_5$/ha. However, it was at par with foliar spray of 500 ppm TU, TU+DMSO and soil application of TU+DMSO (½+½) under 20 kg $P_2O_5$/ha, whereas, foliar spray of 500 ppm TU and soil application of TU at 5 kg/ha (½+½) under 40 kg $P_2O_5$/ha.

**4A.2.6 Pod length**

Data (Table 4A.33) reveal that significant increase in pod length was recorded due to phosphorus application upto 40 kg $P_2O_5$/ha in 1999. Whereas, pod length responded

**Table: 4A.32 Effect of thiourea and DMSO on number of unfilled pods/plant at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 14.2 | 7.6 | 6.6 | 9.5 |
| 5 kg TU/ha in soil (basal) | 10.4 | 7.5 | 5.4 | 7.8 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 3.8 | 3.2 | 3.4 | 3.5 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 10.2 | 6.2 | 6.0 | 7.5 |
| TU+DMSO in soil (1/2 + 1/2) | 3.5 | 3.0 | 3.0 | 3.2 |
| 500 ppm TU (spray) | 4.8 | 2.5 | 2.6 | 3.3 |
| 100 ppm DMSO (spray) | 13.2 | 7.6 | 7.2 | 9.3 |
| TU+DMSO (spray) | 4.2 | 2.2 | 2.1 | 2.8 |
| Mean | 8.0 | 4.9 | 4.5 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.103 | 0.169 | 0.292 | |
| C.D. (0.05) | 0.286 | 0.468 | 0.809 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 12.2 | 6.8 | 6.5 | 8.5 |
| 5 kg TU/ha in soil (basal) | 11.5 | 6.2 | 6.2 | 8.0 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 6.2 | 3.1 | 2.8 | 4.0 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 10.2 | 6.5 | 6.4 | 7.7 |
| TU+DMSO in soil (1/2 + 1/2) | 6.0 | 2.5 | 2.2 | 3.6 |
| 500 ppm TU (spray) | 5.1 | 2.4 | 2.3 | 3.3 |
| 100 ppm DMSO (spray) | 11.7 | 6.2 | 6.1 | 8.0 |
| TU+DMSO (spray) | 4.8 | 2.2 | 2.1 | 3.0 |
| Mean | 8.5 | 4.5 | 4.3 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.114 | 0.186 | 0.322 | |
| C.D. (0.05) | 0.316 | 0.516 | 0.892 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 13.2 | 7.2 | 6.6 | 8.9 |
| 5 kg TU/ha in soil (basal) | 10.9 | 6.9 | 6.1 | 7.9 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 5.0 | 3.2 | 3.1 | 3.8 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 10.2 | 6.4 | 6.2 | 7.6 |
| TU+DMSO in soil (1/2 + 1/2) | 4.8 | 2.8 | 2.6 | 3.4 |
| 500 ppm TU (spray) | 4.9 | 2.5 | 2.5 | 3.3 |
| 100 ppm DMSO (spray) | 12.5 | 6.9 | 6.7 | 8.7 |
| TU+DMSO (spray) | 4.5 | 2.2 | 2.1 | 2.9 |
| Mean | 8.2 | 4.7 | 4.4 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.077 | 0.126 | 0.217 | |
| C.D. (0.05) | 0.213 | 0.348 | 0.603 | |

significantly upto 20 kg $P_2O_5$/ha in 2000. In pooled data, application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased pod length by 4.9 and 9.1 per cent, respectively over control.

Soil application of TU at 5 kg (basal), soil application of TU at 5 kg/ha (½+½) and soil application of DMSO at 2 kg/ha (½+½) proved ineffective in respect of pod length during 1999. In 2000, none of the soil applied treatments of TU and DMSO was effective. However, soil application of TU+DMSO (½+½) found effective in increasing pod length over control during 1999. In pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased pod length by 3.9 and 5.0 per cent, respectively over control.

Foliar sprays of 500 ppm TU and TU+DMSO significantly increased pod length during 1999 only. In 2000, none of the foliar applied treatments was effective in this respect. In pooled data, only foliar spray of TU+DMSO (½+½) was significantly superior to control in respect of pod length. The per cent increase due to foliar spray of TU+DMSO was 9.1 over control.

Data (Table 4A.33) on combined effect of treatments further show that effects of soil and foliar applied treatments did not vary significantly under different levels of phosphorus in any of the years. However, in pooled data, interaction effects were found significant. Under no phosphorus and 20 kg $P_2O_5$/ha, none of the soil and foliar applied treatments of TU and DMSO proved effective in influencing pod length. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+ DMSO significantly increased pod length by 6.6, 7.7 and 27.7 per cent, respectively over control. However, soil application of TU+DMSO (½+½) and soil application of TU at 5 kg/ha (½+½) was at par. The maximum pod length (6.63 cm) was recorded with foliar spray of TU+DMSO under 40 kg $P_2O_5$/ha followed by soil application of TU+DMSO (½+½) under the same level and 20 kg $P_2O_5$/ha. When compared with absolute control, the increases were of the order of 32.6, 11.8 and 11.8 per cent, respectively.

### 4A.2.7 Number of seeds per pod

Data (Table 4A.34) show that significant improved in number of grains per pod was recorded upto 20 kg $P_2O_5$/ha over control during both the years. In pooled data, 20 and 40 kg $P_2O_5$/ha were at par in this respect. Application of 20 and 40 kg $P_2O_5$/ha registered 7.9 and 8.7 per cent improvement in number of grains per pod, respectively over control.

Soil application of TU at 5 kg/ha (½+½) significantly increased number of grains per pod in both the years. In pooled data, soil application of TU at 5 kg/ha (½+½) recorded significantly higher number of grains per pods by 8.4 per cent over soil application of TU at 5

**Table: 4A.33 Effect of thiourea and DMSO on pod length (cm) at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 4.85 | 5.31 | 5.13 | 5.20 |
| 5 kg TU/ha in soil (basal) | 4.83 | 5.09 | 5.14 | 5.28 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 5.01 | 5.44 | 5.51 | 5.44 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 4.91 | 5.26 | 5.27 | 5.23 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 5.10 | 5.49 | 5.50 | 5.55 |
| 500 ppm TU (spray) | 5.21 | 5.22 | 5.22 | 5.48 |
| 100 ppm DMSO (spray) | 5.17 | 5.24 | 5.41 | 5.25 |
| TU+DMSO (spray) | 5.02 | 5.14 | 5.45 | 5.55 |
| Mean | 5.04 | 5.45 | 5.62 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.057 | 0.093 | 0.161 | |
| C.D. (0.05) | 0.158 | 0.258 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 5.16 | 5.33 | 5.24 | 5.24 |
| 5 kg TU/ha in soil (basal) | 4.92 | 5.16 | 5.32 | 5.13 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 5.21 | 5.49 | 5.55 | 5.42 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 5.13 | 5.69 | 5.68 | 5.49 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 5.29 | 5.28 | 5.28 | 5.29 |
| 500 ppm TU (spray) | 4.90 | 5.31 | 5.34 | 5.18 |
| 100 ppm DMSO (spray) | 5.15 | 5.29 | 5.47 | 5.30 |
| TU+DMSO (spray) | 5.11 | 5.32 | 5.52 | 5.31 |
| Mean | 5.11 | 5.36 | 5.43 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.063 | 0.103 | 0.179 | |
| C.D. (0.05) | 0.175 | NS | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 5.00 | 5.32 | 5.19 | 5.17 |
| 5 kg TU/ha in soil (basal) | 5.87 | 5.13 | 5.23 | 5.08 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 5.11 | 5.47 | 5.53 | 5.37 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 4.91 | 5.28 | 5.31 | 5.17 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 5.12 | 5.59 | 5.59 | 5.43 |
| 500 ppm TU (spray) | 5.25 | 5.25 | 5.25 | 5.25 |
| 100 ppm DMSO (spray) | 5.16 | 5.26 | 5.44 | 5.29 |
| TU+DMSO (spray) | 5.06 | 5.23 | 6.63 | 5.64 |
| Mean | 5.06 | 5.31 | 5.52 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.043 | 0.069 | 0.120 | |
| C.D. (0.05) | 0.118 | 0.193 | 0.334 | |

kg/ha (basal). Soil application of DMSO at 2 kg/ha (½+½) remained unaffected in this respect in either of years. While, soil application of TU+DMSO (½+½) significantly increased number of grains per pod in both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased number of grains per pod by 9.9 and 11.7 per cent, respectively over control.

Foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO resulted in significant increase in number of grains per pod over control during both the years. In pooled data, similar trends were observed. The per cent increase in grains per pod due to foliar spray 500 ppm TU, 100 ppm DMSO and TU+DMSO over control were to the tune of 7.5, 6.6 and 9.5, respectively.

Data (Table 4A.34) on combined effects of treatments further show that soil and foliar applied treatments of TU and DMSO with phosphorus application did not influence significantly in both the years. However, in pooled data, interaction effects were significant. Under no phosphorus, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased number of grains per pod by 12.1, 25.2, 16.3, 22.2, 19.7, 16.7 and 20.5 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO significantly increased number of grains per pod by 9.6 and 6.9 per cent, respectively over control. Rest of the treatments proved ineffective in this respect. Under 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments of TU and DMSO proved effective. The highest number of grains per pod of 7.84 was obtained with soil application of TU+DMSO (½+½), under 20 kg $P_2O_5$/ha. When compared with absolute control the increase was 31.9 per cent. However, it was at par with soil application of TU at 5 kg/ha (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO under 20 kg $P_2O_5$/ha and all the treatment except soil application of TU at 5 kg/ha (basal) under 40 kg $P_2O_5$/ha in this respect.

**4A.2.8 Test weight**

A perusal of data (Table 4A.35) show that significant increase in test weight was recorded upto 20 kg $P_2O_5$/ha in 2000 only, while during 1999 only increasing trends were observed with increasing rates of phosphorus. On the basis of pooled data, 20 and 40 kg $P_2O_5$/ha were at par in this respect. Significant increase in test weight due to 20 and 40 kg $P_2O_5$/ha was to the extent of 1.9 and 2.3 per cent, respectively over control.

All the soil applied treatments of TU and DMSO failed to improve test weight in 1999. However in 2000, soil application of TU at 5 kg/ha (basal), soil application of TU at 5

**Table: 4A.34 Effect of thiourea and DMSO on number of seeds/ pod at varying levels of phosphorus**

| **Year 1999** | Phosphorus ( kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 6.03 | 7.12 | 7.37 | 6.84 |
| 5 kg TU/ha in soil (basal) | 6.73 | 7.03 | 6.90 | 6.88 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 7.47 | 7.50 | 7.5 | 7.49 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 6.97 | 7.15 | 7.42 | 7.18 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 7.30 | 7.87 | 7.70 | 7.62 |
| 500 ppm TU (spray) | 7.25 | 7.32 | 7.5 | 7.36 |
| 100 ppm DMSO (spray) | 7.02 | 7.30 | 7.62 | 7.32 |
| TU+DMSO (spray) | 7.25 | 7.53 | 7.50 | 7.42 |
| Mean | 7.00 | 7.35 | 7.44 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.078 | 0.128 | 0.222 | |
| C.D. (0.05) | 0.216 | 0.355 | NS | |

| **Year 2000** | Phosphorus ( kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 5.85 | 7.18 | 7.50 | 6.84 |
| 5 kg TU/ha in soil (basal) | 6.60 | 7.20 | 7.18 | 6.99 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 7.40 | 7.65 | 7.60 | 7.55 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 6.85 | 7.23 | 7.42 | 7.17 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 7.23 | 7.80 | 7.92 | 7.65 |
| 500 ppm TU (spray) | 6.97 | 7.47 | 7.57 | 7.34 |
| 100 ppm DMSO (spray) | 6.83 | 7.33 | 7.65 | 7.26 |
| TU+DMSO (spray) | 7.07 | 7.78 | 7.82 | 7.55 |
| Mean | 6.85 | 7.45 | 7.58 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.078 | 0.127 | 0.220 | |
| C.D. (0.05) | 0.216 | 0.352 | NS | |

| **Pooled** | Phosphorus ( Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 5.94 | 7.15 | 7.44 | 6.84 |
| 5 kg TU/ha in soil (basal) | 6.66 | 7.11 | 7.04 | 6.94 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 7.44 | 7.57 | 7.55 | 7.52 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 6.91 | 7.18 | 7.43 | 7.18 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 7.26 | 7.84 | 7.81 | 7.64 |
| 500 ppm TU (spray) | 7.11 | 7.40 | 7.54 | 7.35 |
| 100 ppm DMSO (spray) | 6.93 | 7.30 | 7.64 | 7.29 |
| TU+DMSO (spray) | 7.16 | 7.65 | 7.65 | 7.49 |
| Mean | 6.93 | 7.40 | 7.51 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.059 | 0.096 | 0.167 | |
| C.D. (0.05) | 0.163 | 0.267 | 0.463 | |

kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased test weight over control. In pooled data, an increase of 1.3 per cent was recorded due to soil application of TU at 5 kg/ha (½+½) over soil application of TU at 5 kg (basal). On the basis of pooled data, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased test weight by 3.5, 2.4 and 4.4 per cent, respectively over control.

Data further show that foliar spray of 500 ppm TU significantly increased test weight only in 2000. Foliar spray of 100 ppm DMSO did not influence the test weight during both the years. Foliar spray of TU+DMSO registered significant improvement in test weight during 2000. On the basis of pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO registered significantly higher test weight by 3.4, 2.1 and 4.1 per cent, respectively over control.

**4A.2.9 Seed yield per plant**

Data (Table 4A.36) show that successive increase in phosphorus levels upto 40 kg $P_2O_5$/ha significantly increased seed yield per plant during both the years. Application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$ registered significant increase in seed yield per plant by 35.1 and 47.7 per cent, respectively over control.

Soil application of TU at 5 kg/ha (½+½) significantly increased seed yield per plant in both the years. In pooled data, soil application of TU at 5 kg/ha (½+½) gave significantly higher seed yield per plant by 21.5 per cent over soil application TU at 5 kg/ha (basal). Soil application of DMSO at 2 kg/ha (½+½) failed to improve seed yield per plant in either of the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased seed yield per plant by 30.4 and 41.3 per cent, respectively over control.

Data further show that foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO resulted in significant increase in seed yield per plant during both the years. On the basis of pooled data, significant increase in seed yield per plant was recorded due to foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO over control were in the order of 22.6, 15.1 and 30.2 per cent, respectively.

Data (Table 4A.36) show that TU and DMSO interacted significantly with phosphorus in influencing seed yield per plant in 1999 only. In 2000, interaction effects were not significant. In 1999, under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased seed yield per plant over

**Table: 4A.35 Effect of thiourea and DMSO on test weight (g) at varying levels of phosphorus**

| Year 1999 | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 28.93 | 28.56 | 28.88 | 28.79 |
| 5 kg TU/ha in soil (basal) | 29.22 | 30.55 | 29.16 | 29.64 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 30.29 | 29.39 | 30.29 | 30.01 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 29.13 | 30.36 | 29.92 | 29.8 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 29.71 | 30.42 | 30.29 | 30.14 |
| 500 ppm TU (spray) | 29.67 | 29.65 | 30.65 | 29.99 |
| 100 ppm DMSO (spray) | 30.09 | 29.68 | 29.34 | 29.70 |
| TU+DMSO (spray) | 29.68 | 30.05 | 29.95 | 29.89 |
| Mean | 29.59 | 29.84 | 29.81 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.174 | 0.285 | 0.493 | |
| C.D. (0.05) | NS | NS | NS | |

| Year 2000 | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 28.56 | 29.68 | 29.93 | 29.39 |
| 5 kg TU/ha in soil (basal) | 29.22 | 30.05 | 30.10 | 29.79 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 29.47 | 30.54 | 30.54 | 30.18 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 29.13 | 29.92 | 30.36 | 29.80 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 29.71 | 30.98 | 31.14 | 30.61 |
| 500 ppm TU (spray) | 29.67 | 30.10 | 30.65 | 30.14 |
| 100 ppm DMSO (spray) | 29.34 | 29.59 | 30.09 | 29.67 |
| TU+DMSO (spray) | 29.68 | 31.10 | 31.16 | 31.64 |
| Mean | 29.35 | 30.25 | 30.49 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.156 | 0.255 | 0.442 | |
| C.D. (0.05) | 0.432 | 0.707 | NS | |

| Pooled | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 28.75 | 29.12 | 29.45 | 29.09 |
| 5 kg TU/ha in soil (basal) | 29.22 | 30.29 | 29.63 | 29.72 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 29.88 | 30.00 | 30.41 | 30.10 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 29.13 | 30.13 | 30.14 | 29.80 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 29.71 | 30.70 | 30.71 | 30.37 |
| 500 ppm TU (spray) | 29.67 | 29.88 | 30.65 | 30.07 |
| 100 ppm DMSO (spray) | 29.72 | 29.64 | 29.72 | 29.69 |
| TU+DMSO (spray) | 29.68 | 30.58 | 30.56 | 30.27 |
| Mean | 29.47 | 30.04 | 30.15 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.117 | 0.191 | 0.331 | |
| C.D. (0.05) | 0.325 | 0.530 | NS | |

**Table: 4A.36 Effect of thiourea and DMSO on seed yield/plant (g) at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 7.84 | 11.50 | 12.90 | 10.75 |
| 5 kg TU/ha in soil (basal) | 8.60 | 12.50 | 13.60 | 11.57 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 15.05 | 14.90 | 15.2 | 15.05 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 8.56 | 12.50 | 13.00 | 11.35 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 16.82 | 16.42 | 16.58 | 16.61 |
| 500 ppm TU (spray) | 10.35 | 14.80 | 16.30 | 13.82 |
| 100 ppm DMSO (spray) | 11.85 | 13.80 | 14.50 | 13.38 |
| TU+DMSO (spray) | 11.50 | 15.20 | 16.45 | 14.38 |
| Mean | 11.32 | 13.95 | 14.81 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.300 | 0.490 | 0.849 | |
| C.D. (0.05) | 0.831 | 1.358 | 2.353 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 8.01 | 11.54 | 14.08 | 11.21 |
| 5 kg TU/ha in soil (basal) | 9.04 | 12.63 | 14.39 | 12.02 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 9.83 | 14.24 | 16.70 | 13.59 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 8.93 | 13.37 | 13.55 | 11.95 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 10.03 | 16.12 | 17.11 | 14.42 |
| 500 ppm TU (spray) | 9.05 | 14.01 | 16.24 | 13.10 |
| 100 ppm DMSO (spray) | 8.69 | 12.68 | 14.30 | 11.89 |
| TU+DMSO (spray) | 9.83 | 15.42 | 17.38 | 14.21 |
| Mean | 9.18 | 13.75 | 15.47 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.246 | 0.402 | 0.697 | |
| C.D. (0.05) | 0.682 | 1.114 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 7.93 | 11.52 | 13.49 | 10.98 |
| 5 kg TU/ha in soil (basal) | 8.82 | 12.57 | 13.99 | 11.79 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 12.44 | 14.57 | 15.95 | 14.32 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 8.75 | 12.94 | 13.28 | 11.65 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 13.43 | 16.27 | 16.85 | 15.51 |
| 500 ppm TU (spray) | 9.70 | 14.41 | 16.27 | 13.46 |
| 100 ppm DMSO (spray) | 10.27 | 13.24 | 14.40 | 12.64 |
| TU+DMSO (spray) | 10.67 | 15.31 | 16.92 | 14.30 |
| Mean | 10.25 | 13.85 | 15.14 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.194 | 0.317 | 0.549 | |
| C.D. (0.05) | 0.538 | 0.879 | NS | |

control Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO proved effective in this respect. Under 40 kg $P_2O_5$/ha, only soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO were significantly superior in increasing seed yield per plant over control.

**4A.3 EFFECT OF TU AND DMSO AT VARYING LEVELS OF PHOSPHORUS ON YIELDS**

**4A.3.1 Seed yield :** Seed yields obtained in two years of experimentation appear to have been influenced, through to a lesser extent, by weather parameters, particularly rainfall and temperatures. Higher rainfall during the initial crop establishment phase in 2000 helped the crop in better vegetative and reproductive development more favorably in comparison to the conditions prevailing in 1999. Similarly lower minimum temperatures during grain filling in 2000 also favoured the crop more than the condition in 1999. This is evident from the fact that general yield levels of various treatments were higher in 2000. Whereas, the trends of treatment effects (in case of chemicals) over largely similar in both the years, the effect of 20 and 40 kg $P_2O_5$/ha levels were significantly different in 2000 probably because of better soil moisture and temperature conditions in comparison to those in 1999.

A perusal of data (Table 4A.37) reveal that phosphorus application brought about significant increase in seed yield upto 20 kg $P_2O_5$/ha in 1999 and up to 40 kg $P_2O_5$/ha in 2000 In pooled data, 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased seed yield by 28.7 and 35 9 per cent, respectively over control

Soil application of TU at 5 kg/ha (½+½) significantly increased seed yield in both the years. In pooled data, soil application of TU at 5 kg/ha (½+½) proved significantly superior to soil application of TU at 5 kg/ha (basal), giving an increase of 12 7 per cent in seed yield. Soil application of DMSO at 2 kg/ha (½+½) significantly increased seed yield in 1999 only. Soil application of TU+DMSO (½+½) significantly increased seed yield in both the years On the basis of pooled data, soil application of TU at 5 kg/ha (½+½), soil application on DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased seed yield by 18.9, 6.6 and 19.9 per cent, respectively over control.

Foliar sprays of 500 ppm, 100 ppm DMSO and TU+DMSO significantly increased seed yield over control during both the years. In pooled data, similar trends were noted. On the basis of pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased seed yield by 11.5, 10.4 and 13.9 per cent, respectively over control

Data (Table 4A.37) show that application of TU and DMSO interacted significantly with phosphorus in influencing the seed yield in 1999 only Under no phosphorus. soil application of TU at 5 kg/ha (½+½) , soil application of DMSO at 2 kg/ha (½+½). soil application of TU+DMSO (½+½), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased seed yield by 52.6, 24.6, 48.4, 31.8 and 36.4 per cent, respectively over control. Under 20 kg P2O5/ha, only soil application of TU at 5 kg/ha (½+½) significantly increased seed yield by 14.8 per cent over control. Rests of treatments were not significant. Under 40 kg P2O5/ha, soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of 100 ppm DMSO significantly increased seed yield by 13.7, 16.7 and 12.8 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, seed yield obtained (18.78 q/ha) with soil application of TU at 5 kg/ha (½+½) was significantly superior to 40 kg P2O5/ha alone but was at par with soil application of TU at 5 kg/ha (½+½) under no phosphorus and 40 kg $P_2O_5$/ha and soil application of TU at 5 kg/ha (½+½) under different levels of phosphorus. When compared with absolute control, the increase was 60.8 per cent. Pooled data show that under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg /ha, soil application of TU+DMSO , foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased seed yield by 40.1, 19.0, 39.6, 17.5, 28.1 and 30.8 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO and foliar spray of TU+DMSO significantly increased seed yield by 16.3, 15.9 and 11.3 per cent, respectively. Whereas under 40 kg $P_2O_5$/ha, soil application of TU+DMSO and foliar spray of 500 ppm TU significantly increased seed yield by 11.2 and 9.8 per cent, respectively over control. The seed yield obtained (19.22 q/ha) under 20 kg $P_2O_5$/ha with soil application of TU at 5 kg/ha (½+½) was at par with 40 kg $P_2O_5$/ha alone and other soil and foliar applied treatment of TU and DMSO under 40 kg $P_2O_5$/ha.

**4A.3.2 Straw yield**

It is evident from data (Table 4A.38) that phosphorus application brought about significant increase in straw yield upto 20 kg $P_2O_5$ /ha in both the years. Application of 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased straw yield by 17.9 and 18.1 per cent, respectively over control.

Soil application of TU and DMSO failed to increase straw yield during both the years. Similarly, foliar spray of TU and DMSO also did not influence straw yield in both the years. In pooled data, similar trends were recorded.

Data (Table 4A.38) further indicate that soil and foliar applied treatments of TU and DMSO interacted significantly with phosphorus in 1999 only. Under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO significantly increased straw yield over control. Under 20 and 40 kg $P_2O_5$/ha,

**Table: 4A.37 Effect of thiourea and DMSO on seed yield (q/ha) at Varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 11.68 | 16.36 | 16.57 | 14.87 |
| 5 kg TU/ha in soil (basal) | 12.85 | 17.08 | 16.15 | 15.36 |
| 5 kg TU/ha in soil ($^1/_2+{}^1/_2$) | 17.82 | 18.78 | 18.42 | 18.34 |
| 2 kg DMSO/ha in soil ($^1/_2+{}^1/_2$) | 14.56 | 16.78 | 17.21 | 16.18 |
| TU+DMSO in soil ($^1/_2+{}^1/_2$) | 17.33 | 17.57 | 18.85 | 17.92 |
| 500 ppm TU (spray) | 13.28 | 17.84 | 19.34 | 16.82 |
| 100 ppm DMSO (spray) | 15.40 | 15.83 | 18.70 | 16.64 |
| TU+DMSO (spray) | 15.93 | 17.85 | 17.74 | 17.17 |
| Mean | 14.86 | 17.26 | 17.87 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.256 | 0.417 | 0.723 | |
| C.D. (0.05) | 0.709 | 1.156 | 2.004 | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 10.92 | 16.68 | 19.17 | 15.59 |
| 5 kg TU/ha in soil (basal) | 11.58 | 17.88 | 20.94 | 16.8 |
| 5 kg TU/ha in soil ($^1/_2+{}^1/_2$) | 13.83 | 19.65 | 20.22 | 17.9 |
| 2 kg DMSO/ha in soil ($^1/_2+{}^1/_2$) | 12.34 | 17.39 | 19.17 | 16.30 |
| TU+DMSO in soil ($^1/_2+{}^1/_2$) | 14.22 | 20.73 | 20.91 | 18.62 |
| 500 ppm TU (spray) | 13.28 | 18.20 | 19.91 | 17.13 |
| 100 ppm DMSO (spray) | 13.53 | 18.52 | 18.89 | 16.98 |
| TU+DMSO (spray) | 13.62 | 18.93 | 20.10 | 17.55 |
| Mean | 12.91 | 18.50 | 19.91 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.314 | 0.513 | 0.889 | |
| C.D. (0.05) | 0.870 | 1.42 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 11.30 | 16.52 | 17.87 | 15.23 |
| 5 kg TU/ha in soil (basal) | 12.22 | 17.48 | 18.54 | 16.08 |
| 5 kg TU/ha in soil ($^1/_2+{}^1/_2$) | 15.83 | 19.22 | 19.32 | 18.12 |
| 2 kg DMSO/ha in soil ($^1/_2+{}^1/_2$) | 13.45 | 17.09 | 18.19 | 16.24 |
| TU+DMSO in soil ($^1/_2+{}^1/_2$) | 15.78 | 19.15 | 19.88 | 18.27 |
| 500 ppm TU (spray) | 13.28 | 18.02 | 19.62 | 16.98 |
| 100 ppm DMSO (spray) | 14.47 | 17.18 | 18.79 | 16.81 |
| TU+DMSO (spray) | 14.78 | 18.39 | 18.92 | 17.36 |
| Mean | 13.89 | 17.88 | 18.89 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.203 | 0.331 | 0.573 | |
| C.D. (0.05) | 0.562 | 0.917 | 1.588 | |

**Table: 4A.38 Effect of thiourea and DMSO on straw yield (q/ha) at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 33.85 | 44.24 | 44.70 | 40.93 |
| 5 kg TU/ha in soil (basal) | 33.79 | 45.76 | 41.28 | 40.27 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 44.01 | 39.68 | 46.61 | 43.43 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 39.62 | 39.88 | 40.61 | 40.03 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 41.68 | 41.01 | 38.95 | 40.54 |
| 500 ppm TU (spray) | 33.68 | 44.24 | 43.41 | 40.45 |
| 100 ppm DMSO (spray) | 38.13 | 37.92 | 40.95 | 39.00 |
| TU+DMSO (spray) | 41.15 | 43.31 | 40.40 | 41.62 |
| Mean | 38.24 | 42.00 | 42.11 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.845 | 1.380 | 2.391 | |
| C.D. (0.05) | 2.342 | NS | 6.628 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 31.42 | 45.14 | 45.22 | 40.59 |
| 5 kg TU/ha in soil (basal) | 33.23 | 47.81 | 49.34 | 43.24 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 37.99 | 45.55 | 45.15 | 42.56 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 35.71 | 46.29 | 44.86 | 42.29 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 38.21 | 47.42 | 46.35 | 43.99 |
| 500 ppm TU (spray) | 37.82 | 42.45 | 44.09 | 41.45 |
| 100 ppm DMSO (spray) | 37.13 | 46.67 | 46.95 | 43.58 |
| TU+DMSO (spray) | 37.03 | 43.90 | 44.53 | 41.82 |
| Mean | 36.07 | 45.57 | 45.69 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.664 | 1.084 | 1.878 | |
| C.D. (0.05) | 1.841 | NS | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 32.64 | 44.69 | 44.96 | 40.76 |
| 5 kg TU/ha in soil (basal) | 33.51 | 46.45 | 45.31 | 41.76 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 41.00 | 42.62 | 45.38 | 43.00 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 37.66 | 43.08 | 42.73 | 41.16 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 39.95 | 44.21 | 42.65 | 42.27 |
| 500 ppm TU (spray) | 35.75 | 43.35 | 43.75 | 40.95 |
| 100 ppm DMSO (spray) | 37.63 | 42.29 | 43.95 | 41.29 |
| TU+DMSO (spray) | 39.09 | 43.60 | 42.46 | 41.72 |
| Mean | 37.15 | 43.79 | 43.89 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.537 | 0.877 | 1.519 | |
| C.D. (0.05) | 1.489 | NS | 4.213 | |

none of the soil and foliar applied treatments proved effective. In pooled data, under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased straw yield by 25.6, 15.4 22.4, 15.3 and 19.8 per cent, respectively over control. These treatments were at par with one another. Under 20 and 40 kg $P_2O_5$/ha, all the soil and foliar applied treatments of TU and DMSO proved ineffective in increasing straw yield. The highest straw yield (45.38 q/ha) was obtained with soil application of TU at 5 kg/ha (½+½) under 40 kg $P_2O_5$/ha which was at par with soil application of TU at 5 kg/ha (½+½) under no phosphorus and 20 kg $P_2O_5$/ha.

**4A.3.3 Biological yield**

Data (Table 4A.39) show that phosphorus application significantly responded upto 20 kg $P_2O_5$/ha in respect of biological yield during both the years. Levels 20 and 40 kg $P_2O_5$/ha were at par in this respect. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased biological yield by 20.8 and 23.0 per cent, respectively over control.

Data further show that none of the soil applied treatments of TU and DMSO was effective in improving biological yield in either of the years. Similarly, foliar applied treatments of TU and DMSO also ineffective in this respect. Pooled data also show similar trends.

Data (Table 4A.39) show that TU and DMSO interacted significantly with phosphorus in influencing biological yield in 1999 only. Pooled data show that under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased biological yield over control. However, under 20 and 40 kg $P_2O_5$/ha, soil and foliar applied treatments of TU and DMSO failed to increase biological yield over control. Under 20 kg $P_2O_5$/ha, the highest biological yield of 63.93 and 63.37 q/ha were obtained with soil application of TU at 5 kg/ha (basal) and soil application of TU+DMSO (½+½). When compared with absolute control, the increases were of the order of 45.4 and 44.2 per cent, respectively.

**4A.3.4 Harvest index**

Data (Table 4A.40) show that phosphorus application brought about significant improvement in harvest index upto 40 kg $P_2O_5$/ha during both the years. Application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased harvest index by 6.4 and 12.3 per cent, respectively over control.

Soil application of TU at 5 kg/ha (½+½) significantly increased harvest index during both the years. In pooled data, soil application of TU at 5 kg/ha (½+½) recorded significantly higher harvest index by 7.1 per cent over soil application of TU at 5 kg/ha (basal). Soil application of DMSO at 2 kg/ha (½+½) significantly increased harvest index in 1999 only. Soil application of TU+DMSO (½+½) significantly increased harvest index in both years. Pooled data show that soil application of TU at 5 kg/ha (1/2+ 1/2), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased harvest index by 10.3, 4.3 and 10.7 per cent, respectively over control.

\Data further show that foliar sprays of 500 ppm TU and TU+DMSO resulted in significant increase in harvest index during both the years. While, foliar spray of 100 ppm DMSO significantly increased harvest index only in 1999. On the basis of pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased harvest index by 7.5, 7.9 and 8.3 per cent, respectively over control.

Data on combined effects of treatments (Table 4A.40) show that effects of soil and foliar applied TU and DMSO on harvest index varied significantly under different levels of phosphorus in 1999 only. Under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased harvest index over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of 100 ppm DMSO significantly increased harvest index over control. Under 40 kg $P_2O_5$/ha, except soil application of TU at 5 kg/ha (basal) and soil application of TU at 5 kg/ha (½+½), all other treatments proved effective in increasing harvest index over control. Combined effect of treatments on harvest index, however, turned out non-significant in pooled data.

## 4A.4 EFFECT OF TU AND DMSO AT VARYING LEVELS OF PHOSPHORUS ON AVAILABLE P CONTENT OF SOIL

### 4A.4.1 Available P content of soil at 30 DAS

Data (Table 4A.41) show that phosphorus application brought about significant improvement in available P content of soil at 30 DAS upto 40 kg $P_2O_5$/ha in both the years. In pooled data, 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ ha. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased P content of soil at 30 DAS by 11.0 and 19.0 per cent, respectively over control.

Available P content of soil at 30 DAS showed inconsistent effects of soil applied treatments of TU and DMSO. In 2000, none of the soil applied treatments of TU and DMSO was effective, whereas in 1999, soil application of TU at 5 kg/ha (basal), soil application of

**Table: 4A.39 Effect of thiourea and DMSO on biological yield (q/ha) at varying levels of phosphorus**

| **Year 1999** | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 45.56 | 60.60 | 61.27 | 55.81 |
| 5 kg TU/ha in soil (basal) | 46.64 | 62.84 | 57.43 | 55.64 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 61.84 | 58.47 | 65.03 | 61.78 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 54.17 | 56.66 | 57.82 | 56.22 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 59.02 | 58.58 | 57.79 | 58.46 |
| 500 ppm TU (spray) | 46.98 | 62.09 | 62.75 | 57.27 |
| 100 ppm DMSO (spray) | 53.33 | 53.74 | 59.65 | 55.64 |
| TU+DMSO (spray) | 57.08 | 61.16 | 58.14 | 58.79 |
| Mean | 53.09 | 59.27 | 59.99 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 1.016 | 1.659 | 2.874 | |
| C.D. (0.05) | 2.816 | NS | 7.966 | |

| **Year 2000** | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 42.34 | 61.82 | 64.39 | 56.18 |
| 5 kg TU/ha in soil (basal) | 44.81 | 65.02 | 70.28 | 60.04 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 51.82 | 65.20 | 64.37 | 60.46 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 48.05 | 63.68 | 64.03 | 58.59 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 52.43 | 68.15 | 67.26 | 62.61 |
| 500 ppm TU (spray) | 51.10 | 60.65 | 64.00 | 58.58 |
| 100 ppm DMSO (spray) | 50.66 | 65.19 | 65.84 | 60.56 |
| TU+DMSO (spray) | 50.65 | 62.83 | 64.63 | 59.37 |
| Mean | 48.98 | 64.07 | 65.60 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.886 | 1.447 | 2.506 | |
| C.D. (0.05) | 2.456 | NS | NS | |

| **Pooled** | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 43.95 | 61.21 | 62.83 | 56.00 |
| 5 kg TU/ha in soil (basal) | 45.73 | 63.93 | 63.86 | 57.84 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 56.83 | 61.83 | 64.70 | 61.12 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 51.11 | 60.17 | 60.92 | 57.40 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 55.72 | 63.37 | 62.53 | 60.54 |
| 500 ppm TU (spray) | 49.03 | 61.37 | 63.37 | 57.93 |
| 100 ppm DMSO (spray) | 52.09 | 59.47 | 62.74 | 58.10 |
| TU+DMSO (spray) | 53.87 | 61.99 | 61.39 | 59.08 |
| Mean | 51.04 | 61.67 | 62.79 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.729 | 1.912 | 2.064 | |
| C.D. (0.05) | 2.022 | NS | 5.721 | |

**Table: 4A.40 Effect of thiourea and DMSO on harvest index (%) at varying levels of phosphorus**

| Year 1999 | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 25.58 | 27.02 | 28.07 | 26.89 |
| 5 kg TU/ha in soil (basal) | 27.72 | 27.43 | 29.19 | 28.11 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 31.12 | 32.14 | 28.56 | 30.60 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 26.89 | 29.61 | 30.89 | 29.13 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 28.45 | 28.81 | 31.13 | 29.46 |
| 500 ppm TU (spray) | 28.95 | 29.57 | 33.68 | 30.73 |
| 100 ppm DMSO (spray) | 28.87 | 28.97 | 33.21 | 30.68 |
| TU+DMSO (spray) | 27.97 | 29.21 | 31.51 | 29.56 |
| Mean | 28.19 | 29.22 | 30.78 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.303 | 0.495 | 0.858 | |
| C.D. (0.05) | 0.841 | 1.373 | 2.378 | |

| Year 2000 | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 25.79 | 26.97 | 29.83 | 27.53 |
| 5 kg TU/ha in soil (basal) | 25.77 | 27.46 | 30.47 | 27.90 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 26.70 | 30.11 | 31.39 | 29.40 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 26.02 | 29.91 | 31.23 | 29.05 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 25.71 | 27.31 | 29.13 | 27.65 |
| 500 ppm TU (spray) | 26.86 | 28.33 | 28.72 | 27.97 |
| 100 ppm DMSO (spray) | 27.06 | 30.44 | 31.10 | 29.53 |
| TU+DMSO (spray) | 26.87 | 30.11 | 31.10 | 29.36 |
| Mean | 26.35 | 28.83 | 30.47 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.329 | 0.539 | 0.933 | |
| C.D. (0.05) | 0.912 | 1.494 | NS | |

| Pooled | Phosphorus (Kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 25.69 | 26.99 | 28.95 | 27.21 |
| 5 kg TU/ha in soil (basal) | 26.74 | 27.45 | 29.84 | 28.01 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 28.91 | 31.13 | 29.98 | 30.00 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 26.30 | 28.46 | 30.41 | 28.39 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 27.97 | 30.20 | 32.16 | 30.11 |
| 500 ppm TU (spray) | 27.23 | 29.36 | 31.18 | 29.26 |
| 100 ppm DMSO (spray) | 27.91 | 28.95 | 31.19 | 29.35 |
| TU+DMSO (spray) | 27.42 | 29.66 | 31.31 | 29.46 |
| Mean | 27.27 | 29.02 | 30.63 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.224 | 0.366 | 0.634 | |
| C.D. (0.05) | 0.621 | 1.014 | NS | |

TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased available P content of soil over control. Soil application of DMSO at 2 kg/ha (½+½) proved ineffective in this respect. In pooled data, soil application of TU at 5 kg/ha (basal) failed to increase in available P content. However, soil application of TU at 5 kg/ha (½+½) significantly increased available P content of soil over control but was at par with soil application of TU at 5 kg/ha (basal). On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO significantly increased available P content.

Data further show that all the foliar spray treatments proved ineffective to improve available P content of soil at 30 DAS during both the years. Pooled data also show similar trends.

**4A.4.2 Available P content of soil at 60 DAS**

Data (Table 4A.42) show that significant improvement in available P content of soil at 60 DAS was recorded at 40 kg $P_2O_5$/ha in both the years. Application of 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha registered 17.6 and 24.9 per cent significant improvement in available P content of soil over control, respectively.

Soil application of TU at 5 kg/ha (½+½) significantly increased available P content of soil over control in both the years. Soil application of TU at 5 kg/ha (½+½) proved significantly superior to soil application of TU at 5 kg/ha (basal) in both the years. Soil application of DMSO at 2 kg/ha (½+½) proved ineffective in this respect during either of the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased available P content of soil by 8.5 and 10.3 per cent, respectively over control.

Foliar spray treatments of TU and DMSO failed to improve in available P content of soil at 60 DAS in either of the years. Similar trends were noted in poled data.

**4A.4.3 Available P content of soil at harvest**

Data (Table 4A.43) reveal that available P content of soil at harvest increased significantly with successive increase in phosphorus levels upto 40 kg $P_2O_5$/ha during both the years. 40 kg $P_2O_5$/ha proved superior to 20 kg $P_2O_5$/ha. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased available P content of soil by 18.3 and 27.4 per cent, respectively over control.

Available P content of soil significantly improved due to soil application of TU at 5 kg/ha (½+½). In pooled data, soil application of TU at 5 kg/ha (½+½) proved superior to soil application of TU at 5 kg/ha (basal), giving an increase of 4.9 per cent in available P content

**Table: 4A.41 Effect of thiourea and DMSO on available P content of soil at 30 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 17.92 | 20.12 | 21.98 | 20.01 |
| 5 kg TU/ha in soil (basal) | 18.12 | 21.34 | 21.52 | 20.83 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 19.39 | 22.13 | 22.15 | 21.22 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 18.19 | 20.98 | 21.99 | 20.39 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 19.98 | 22.52 | 22.93 | 21.31 |
| 500 ppm TU (spray) | 18.01 | 20.12 | 21.99 | 20.04 |
| 100 ppm DMSO (spray) | 18.0 | 20.33 | 22.01 | 20.11 |
| TU+DMSO (spray) | 18.0 | 20.42 | 21.39 | 19.94 |
| Mean | 18.45 | 20.99 | 21.99 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.163 | 0.266 | 0.461 | |
| C.D. (0.05) | 0.452 | 0.723 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 15.82 | 17.24 | 18.92 | 17.33 |
| 5 kg TU/ha in soil (basal) | 16.12 | 17.25 | 19.01 | 17.46 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 16.15 | 17.23 | 19.00 | 17.46 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 16.00 | 17.26 | 19.01 | 17.42 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 16.14 | 17.26 | 19.11 | 17.50 |
| 500 ppm TU (spray) | 15.80 | 17.25 | 18.90 | 17.32 |
| 100 ppm DMSO (spray) | 15.88 | 17.15 | 18.89 | 17.31 |
| TU+DMSO (spray) | 15.77 | 17.21 | 18.95 | 17.31 |
| Mean | | | | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.188 | 0.306 | 0.530 | |
| C.D. (0.05) | 0.521 | NS | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 16.87 | 18.68 | 20.45 | 18.67 |
| 5 kg TU/ha in soil (basal) | 17.12 | 19.29 | 20.27 | 18.89 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 17.77 | 19.68 | 20.58 | 19.34 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 17.09 | 19.12 | 20.50 | 18.91 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 18.05 | 19.89 | 21.02 | 19.66 |
| 500 ppm TU (spray) | 16.91 | 18.69 | 20.45 | 18.68 |
| 100 ppm DMSO (spray) | 16.94 | 18.74 | 20.45 | 18.71 |
| TU+DMSO (spray) | 16.89 | 18.52 | 20.17 | 18.62 |
| Mean | 17.21 | 19.11 | 20.48 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.124 | 0.203 | 0.351 | |
| C.D. (0.05) | 0.344 | 0.562 | NS | |

**Table: 4A.42 Effect of thiourea and DMSO on available P content of soil at 60 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 19.84 | 23.42 | 25.46 | 22.91 |
| 5 kg TU/ha in soil (basal) | 19.93 | 23.56 | 25.41 | 22.97 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 21.46 | 25.56 | 26.74 | 24.59 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 20.11 | 24.16 | 25.63 | 23.30 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 21.92 | 25.88 | 27.0 | 24.93 |
| 500 ppm TU (spray) | 19.86 | 23.56 | 25.32 | 22.91 |
| 100 ppm DMSO (spray) | 19.69 | 23.82 | 26.0 | 23.17 |
| TU+DMSO (spray) | 19.70 | 23.62 | 25.56 | 22.96 |
| Mean | 20.31 | 24.20 | 25.89 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.219 | 0.359 | 0.622 | |
| C.D. (0.05) | 0.607 | 0.995 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 18.13 | 21.39 | 22.49 | 20.67 |
| 5 kg TU/ha in soil (basal) | 18.52 | 21.48 | 22.38 | 20.79 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 20.16 | 23.46 | 24.46 | 22.69 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 19.04 | 21.52 | 22.68 | 21.08 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 20.31 | 23.69 | 25.42 | 23.14 |
| 500 ppm TU (spray) | 18.94 | 21.79 | 23.0 | 21.24 |
| 100 ppm DMSO (spray) | 18.22 | 21.41 | 22.40 | 20.68 |
| TU+DMSO (spray) | 18.89 | 21.81 | 23.10 | 21.27 |
| Mean | 19.03 | 22.07 | 23.24 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.243 | 0.396 | 0.686 | |
| C.D. (0.05) | 0.674 | 1.098 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 18.99 | 22.41 | 23.97 | 21.79 |
| 5 kg TU/ha in soil (basal) | 19.23 | 22.52 | 23.89 | 21.88 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 20.81 | 24.51 | 25.60 | 23.64 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 19.58 | 22.84 | 24.16 | 22.19 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 21.12 | 24.79 | 26.21 | 24.04 |
| 500 ppm TU (spray) | 19.4 | 22.67 | 24.16 | 22.08 |
| 100 ppm DMSO (spray) | 18.96 | 22.62 | 24.20 | 21.92 |
| TU+DMSO (spray) | 19.29 | 22.72 | 24.33 | 22.11 |
| Mean | 19.67 | 23.13 | 24.57 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.164 | 0.267 | 0.463 | |
| C.D. (0.05) | 0.454 | 0.741 | NS | |

**Table: 4A.43 Effect of thiourea and DMSO on available P content of soil at harvest at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 16.52 | 20.13 | 22.12 | 19.59 |
| 5 kg TU/ha in soil (basal) | 17.69 | 20.16 | 22.52 | 20.12 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 18.46 | 21.34 | 22.63 | 20.81 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 17.52 | 20.92 | 22.04 | 20.16 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 18.32 | 21.56 | 22.79 | 20.89 |
| 500 ppm TU (spray) | 16.93 | 19.43 | 21.65 | 19.35 |
| 100 ppm DMSO (spray) | 17.0 | 19.53 | 22.11 | 19.55 |
| TU+DMSO (spray) | 16.56 | 19.31 | 20.42 | 18.76 |
| Mean | 17.38 | 20.30 | 22.04 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.239 | 0.391 | 0.677 | |
| C.D. (0.05) | 0.662 | 1.084 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 13.72 | 20.01 | 21.12 | 18.28 |
| 5 kg TU/ha in soil (basal) | 13.99 | 20.51 | 21.62 | 18.71 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 17.42 | 20.42 | 21.96 | 19.93 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 17.51 | 19.13 | 20.99 | 19.21 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 17.51 | 20.52 | 22.13 | 20.05 |
| 500 ppm TU (spray) | 16.56 | 18.45 | 19.63 | 18.21 |
| 100 ppm DMSO (spray) | 16.88 | 18.49 | 19.70 | 18.36 |
| TU+DMSO (spray) | 17.0 | 18.93 | 19.92 | 18.62 |
| Mean | 16.32 | 19.56 | 20.88 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.161 | 0.262 | 0.454 | |
| C.D. (0.05) | 0.446 | 0.726 | 1.258 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 15.12 | 20.07 | 21.62 | 18.94 |
| 5 kg TU/ha in soil (basal) | 15.84 | 20.34 | 22.07 | 19.42 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 17.94 | 20.88 | 22.29 | 20.37 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 17.52 | 20.03 | 21.52 | 19.69 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 17.92 | 21.04 | 22.46 | 20.47 |
| 500 ppm TU (spray) | 16.75 | 18.94 | 20.64 | 18.78 |
| 100 ppm DMSO (spray) | 16.94 | 19.01 | 20.91 | 18.95 |
| TU+DMSO (spray) | 16.78 | 19.12 | 20.17 | 18.69 |
| Mean | 16.85 | 19.93 | 21.46 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.144 | 0.235 | 0.407 | |
| C.D. (0.05) | 0.399 | 0.652 | 1.129 | |

of soil. Soil application of DMSO at 2 kg/ha (½+½) significantly increased available P content of soil only in 2000, whereas soil application of TU+DMSO (½+½) proved significantly superior over control during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased available P content of soil by 7.6, 4.0, and 8.1 per cent, respectively over control.

None of the foliar spray treatments of TU and DMSO proved effective in respect of available P content of soil at harvest during both the years. In pooled data, similar trends were noted.

Data (Table 4A.43) further show that application of TU and DMSO interacted significantly with phosphorus in influencing available P content of soil at harvest in 2000 only. Under no phosphorus, except soil application of TU at 5 kg/ha (basal), all the soil and foliar applied treatments of TU and DMSO significantly increased available P content of soil at harvest over control. Under 20 and 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective in this respect. In pooled data, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased available P content of soil at harvest by 18.6, 15.9, 18.5, 10.8, 12.0 and 10.9 per cent, respectively over control. Soil application of TU at 5 kg/ha (½+½) found most effective. Under 20 and 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective in this respect. Under 40 kg $P_2O_5$/ha, the highest available P content of soil at harvest (22.46 kg/ha) was obtained with soil application of TU+DMSO (½+½). When compared to absolute control, the increase in available P content of soil at harvest was 48.5 per cent.

## 4A.5 EFFECT OF TU AND DMSO AT VARYING LEVELS OF PHOSPHORUS ON NUTRIENT CONTENT OF THE CROP

### 4A.5.1 Gum content of seed

Data (Table 4A.44) reveal that significant increase in gum content of seed was recorded upto 20 kg $P_2O_5$/ha during 1999. However, in 2000, it responded significantly upto 40 kg $P_2O_5$/ha. In pooled data, 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha. Further, application of 20 and 40 kg $P_2O_5$/ha significantly increased gum content of seed by 5.7 and 7.1 per cent, respectively over control.

Soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased gum content of seed over control in 1999 only. None of the soil

**Table: 4A.44 Effect of thiourea and DMSO on gum content (%) in seed at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 25.82 | 27.82 | 27.74 | 27.13 |
| 5 kg TU/ha in soil (basal) | 26.88 | 28.83 | 28.76 | 28.16 |
| 5 kg TU/ha in soil (½+ ½) | 27.52 | 29.55 | 29.56 | 28.95 |
| 2 kg DMSO/ha in soil (½+ ½) | 27.0 | 28.98 | 29.15 | 28.38 |
| TU+DMSO in soil (½+ ½) | 27.62 | 29.71 | 29.59 | 29.05 |
| 500 ppm TU (spray) | 27.12 | 29.47 | 29.45 | 28.76 |
| 100 ppm DMSO (spray) | 27.10 | 29.59 | 29.18 | 28.45 |
| TU+DMSO (spray) | 27.15 | 29.48 | 29.46 | 28.78 |
| Mean | 27.15 | 29.12 | 29.11 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.201 | 0.329 | 0.569 | |
| C.D. (0.05) | 0.557 | 0.912 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 26.10 | 27.10 | 27.89 | 27.03 |
| 5 kg TU/ha in soil (basal) | 26.17 | 27.12 | 27.89 | 27.06 |
| 5 kg TU/ha in soil (½+ ½) | 26.76 | 27.79 | 28.45 | 27.66 |
| 2 kg DMSO/ha in soil (½+ ½) | 26.03 | 27.04 | 28.29 | 27.12 |
| TU+DMSO in soil (½+ ½) | 26.88 | 28.00 | 28.48 | 27.79 |
| 500 ppm TU (spray) | 26.56 | 27.75 | 28.34 | 27.55 |
| 100 ppm DMSO (spray) | 26.03 | 27.04 | 28.32 | 27.13 |
| TU+DMSO (spray) | 26.59 | 28.02 | 28.35 | 27.65 |
| Mean | 26.39 | 27.48 | 28.25 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.218 | 0.335 | 0.616 | |
| C.D. (0.05) | 0.604 | NS | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 25.96 | 27.46 | 27.82 | 27.08 |
| 5 kg TU/ha in soil (basal) | 26.53 | 27.98 | 28.33 | 27.61 |
| 5 kg TU/ha in soil (½+ ½) | 27.27 | 28.67 | 29.00 | 28.31 |
| 2 kg DMSO/ha in soil (½+ ½) | 26.52 | 28.01 | 28.72 | 27.75 |
| TU+DMSO in soil (½+ ½) | 27.38 | 28.85 | 29.03 | 28.42 |
| 500 ppm TU (spray) | 26.96 | 28.61 | 28.89 | 28.16 |
| 100 ppm DMSO (spray) | 26.57 | 28.06 | 28.75 | 27.79 |
| TU+DMSO (spray) | 26.99 | 28.75 | 28.90 | 28.22 |
| Mean | 26.77 | 28.29 | 28.68 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.148 | 0.242 | 0.419 | |
| C.D. (0.05) | 0.411 | 0.671 | NS | |

applied treatments were effective during 2000. In pooled data, soil application of TU at 5 kg/ha (basal) did not influence gum content in seed. However, soil application of TU at 5 kg/ha (½+½) significantly increased gum content in seed by 2.5 per cent over soil application of TU at 5 kg/ha (basal). Soil application of DMSO at 2 kg/ha (½+½) failed to increase gum content of seed in pooled data. Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased gum content of seed by 4.5 and 4.9 per cent, respectively over control.

Foliar sprays of 500 ppm, 100 ppm DMSO and TU+DMSO significantly increased gum content of seed in 1999 only. In pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased gum content of seed by 3.9, 2.6 and 4.2 per cent, respectively over control.

**4A.5.2 Protein content of seed**

Data (Table 4A.45) show that phosphorus application brought about significant increase in protein content of seed upto 20 kg $P_2O_5$/ha during both the years. In pooled data, 40 kg $P_2O_5$/ha was significantly superior to 20 kg $P_2O_5$/ha in this respect. Further, application of 20 and 40 kg $P_2O_5$/ha significantly increased protein content of seeds by 5.9 and 7.9 per cent, respectively over control.

Soil applied as well as foliar spray treatments of TU and DMSO did not bring about significant variation in protein content of seeds in any of the years.

**4A.5.3 N content in leaves at 90 DAS**

Data (Table 4A.46) show that successive increase in P levels upto 40 kg $P_2O_5$/ha significantly increased N content of leaves at 90 DAS during both the years. Levels of 40 kg $P_2O_5$/ha significantly superior to 20 kg $P_2O_5$/ha in both the years. On the basis of pooled data, 20 and 40 kg $P_2O_5$/ha significantly increased N content in leaves by 8.0 and 10.9 per cent, respectively over control.

Soil application of TU and DMSO showed inconsistent effect on N content of leaves at 90 DAS. In 1999, none of the soil applied treatments proved effective. However, in 2000, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased N content of leaves over control, whereas soil application of TU at 5 kg/ha (basal) and soil application of DMSO at 2 kg/ha (½+½) proved ineffective. Pooled data show that soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased N content of leaves by 2.9 and 3.8 per cent, respectively over control. However, both the treatments were at par in this respect.

**Table: 4A.45 Effect of thiourea and DMSO on protein content (%) in seed at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 22.92 | 24.25 | 24.45 | 23.92 |
| 5 kg TU/ha in soil (basal) | 22.99 | 24.27 | 24.46 | 23.96 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 23.23 | 24.44 | 25.01 | 24.23 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 23.0 | 24.19 | 24.85 | 24.01 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 23.25 | 24.65 | 25.04 | 24.35 |
| 500 ppm TU (spray) | 23.01 | 24.40 | 24.90 | 24.11 |
| 100 ppm DMSO (spray) | 23.0 | 24.19 | 24.88 | 24.02 |
| TU+DMSO (spray) | 23.06 | 24.42 | 24.91 | 24.13 |
| Mean | 23.11 | 24.35 | 24.81 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.221 | 0.362 | 0.626 | |
| C.D. (0.05) | 0.613 | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 22.92 | 24.28 | 24.50 | 23.90 |
| 5 kg TU/ha in soil (basal) | 22.92 | 24.30 | 24.48 | 23.89 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 22.96 | 24.47 | 25.05 | 24.16 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 22.85 | 24.20 | 24.87 | 23.98 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 23.11 | 24.71 | 25.06 | 24.29 |
| 500 ppm TU (spray) | 22.81 | 24.42 | 25.00 | 24.08 |
| 100 ppm DMSO (spray) | 22.81 | 24.15 | 24.92 | 23.96 |
| TU+DMSO (spray) | 22.83 | 24.70 | 25.00 | 24.18 |
| Mean | 22.90 | 24.40 | 24.86 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.168 | 0.274 | 0.475 | |
| C.D. (0.05) | 0.465 | NS | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 22.99 | 24.27 | 24.47 | 23.91 |
| 5 kg TU/ha in soil (basal) | 23.03 | 24.28 | 24.47 | 23.93 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 23.10 | 24.46 | 25.03 | 24.19 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 22.93 | 24.19 | 24.86 | 23.99 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 23.23 | 24.68 | 25.05 | 24.32 |
| 500 ppm TU (spray) | 22.92 | 24.41 | 24.95 | 24.09 |
| 100 ppm DMSO (spray) | 22.90 | 24.17 | 24.89 | 23.99 |
| TU+DMSO (spray) | 22.95 | 24.56 | 24.96 | 24.15 |
| Mean | 23.01 | 24.38 | 24.84 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.139 | 0.227 | 0.393 | |
| C.D. (0.05) | 0.385 | NS | NS | |

**Table: 4A.46 Effect of thiourea and DMSO on N content (%) in leaves at 90 DAS varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.520 | 2.743 | 2.855 | 2.706 |
| 5 kg TU/ha in soil (basal) | 2.525 | 2.747 | 2.850 | 2.708 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 2.530 | 2.825 | 2.860 | 2.738 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 2.512 | 2.752 | 2.850 | 2.705 |
| TU+DMSO in soil (1/2 + 1/2) | 2.553 | 2.840 | 2.865 | 2.752 |
| 500 ppm TU (spray) | 2.527 | 2.780 | 2.850 | 2.719 |
| 100 ppm DMSO (spray) | 2.500 | 2.748 | 2.848 | 2.698 |
| TU+DMSO (spray) | 2.533 | 2.805 | 2.855 | 2.731 |
| Mean | 2.525 | 2.780 | 2.854 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0183 | 0.0298 | 0.0516 | |
| C.D. (0.05) | 0.0507 | NS | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.470 | 2.670 | 2.690 | 2.610 |
| 5 kg TU/ha in soil (basal) | 2.480 | 2.680 | 2.750 | 2.637 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 2.600 | 2.780 | 2.820 | 2.733 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 2.500 | 2.610 | 2.710 | 2.607 |
| TU+DMSO in soil (1/2 + 1/2) | 2.610 | 2.800 | 2.880 | 2.763 |
| 500 ppm TU (spray) | 2.550 | 2.520 | 2.780 | 2.617 |
| 100 ppm DMSO (spray) | 2.520 | 2.680 | 2.720 | 2.640 |
| TU+DMSO (spray) | 2.590 | 2.790 | 2.790 | 2.723 |
| Mean | 2.540 | 2.691 | 2.768 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0231 | 0.0379 | 0.0658 | |
| C.D. (0.05) | 0.0640 | 0.1051 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.495 | 2.706 | 2.773 | 2.658 |
| 5 kg TU/ha in soil (basal) | 2.503 | 2.714 | 2.800 | 2.672 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 2.565 | 2.803 | 2.840 | 2.736 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 2.506 | 2.681 | 2.780 | 2.656 |
| TU+DMSO in soil (1/2 + 1/2) | 2.581 | 2.820 | 2.873 | 2.758 |
| 500 ppm TU (spray) | 2.539 | 2.650 | 2.815 | 2.668 |
| 100 ppm DMSO (spray) | 2.510 | 2.714 | 2.784 | 2.669 |
| TU+DMSO (spray) | 2.561 | 2.797 | 2.822 | 2.727 |
| Mean | 2.533 | 2.736 | 2.811 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0147 | 0.0241 | 0.0418 | |
| C.D. (0.05) | 0.0409 | 0.0669 | NS | |

None of the foliar spray treatments proved effective in 1999. However, in 2000 only foliar spray of TU+DMSO significantly increased N content in leaves at 90 DAS over control, whereas foliar spray of 500 ppm TU and 100 ppm DMSO proved ineffective. Pooled data show that foliar spray of TU+DMSO significantly increased N content in leaves by 2.6 per cent over control.

**4A.5.4 S content of leaves at 90 DAS**

Data (Table 4A.47) reveal that phosphorus application did not bring about significant variation in S content of leaves at 90 DAS during both the years. Pooled data also show similar trends.

Soil applied as well as foliar spray treatments of TU and DMSO also did not have significant effects on S content of leaves at 90 DAS in any of the year.

**4A.5.5 P content of leaves at 60 DAS**

Data (Table 4A.48) show that phosphorus application brought about significant improvement in P content of leaves at 60 DAS upto 40 kg $P_2O_5$/ha during both the years. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased P content of leaves by 8.8 and 7.2 per cent, respectively over control.

Soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO significantly increased P content of leaves at 60 DAS over control. Rest of the soil and foliar applied treatments of TU and DMSO proved ineffective in this respect during both the years. Similar trends were recorded in pooled data.

**4A.5.6 P content of stems at 60 DAS**

Data (Table 4A.49) reveal that phosphorus application brought about significant improvement in P content of stems at 60 DAS upto 40 kg $P_2O_5$/ha during both the years. In pooled data similar trends were noted

Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO proved effective in increasing P content of stems at 60 DAS over control during 2000 only. In pooled data similar trends were observed.

**4A5.7 P content of pods at 60 DAS**

Data (4A.50) indicate that phosphorus application brought about significant increase in P content of pods at 60 DAS upto 40 kg $P_2O_5$/ha during both the years as well as in pooled data.

**Table: 4A.47 Effect of thiourea and DMSO on S content (%) in leaves at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.375 | 0.365 | 0.363 | 0.367 |
| 5 kg TU/ha in soil (basal) | 0.360 | 0.368 | 0.355 | 0.361 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 0.378 | 0.370 | 0.358 | 0.368 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 0.373 | 0.375 | 0.378 | 0.375 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 0.368 | 0.373 | 0.375 | 0.372 |
| 500 ppm TU (spray) | 0.380 | 0.375 | 0.378 | 0.378 |
| 100 ppm DMSO (spray) | 0.370 | 0.374 | 0.368 | 0.370 |
| TU+DMSO (spray) | 0.375 | 0.378 | 0.380 | 0.378 |
| Mean | 0.372 | 0.372 | 0.369 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0026 | 0.0043 | 0.0074 | |
| C.D. (0.05) | NS | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.390 | 0.390 | 0.392 | 0.391 |
| 5 kg TU/ha in soil (basal) | 0.390 | 0.392 | 0.391 | 0.391 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 0.393 | 0.402 | 0.410 | 0.402 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 0.389 | 0.395 | 0.400 | 0.395 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 0.391 | 0.401 | 0.402 | 0.398 |
| 500 ppm TU (spray) | 0.391 | 0.401 | 0.407 | 0.400 |
| 100 ppm DMSO (spray) | 0.388 | 0.392 | 0.398 | 0.393 |
| TU+DMSO (spray) | 0.392 | 0.401 | 0.408 | 0.400 |
| Mean | 0.391 | 0.397 | 0.401 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0031 | 0.0050 | 0.0087 | |
| C.D. (0.05) | NS | NS | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.383 | 0.377 | 0.378 | 0.379 |
| 5 kg TU/ha in soil (basal) | 0.375 | 0.380 | 0.375 | 0.376 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 0.385 | 0.386 | 0.384 | 0.385 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 0.381 | 0.385 | 0.389 | 0.385 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 0.379 | 0.387 | 0.389 | 0.385 |
| 500 ppm TU (spray) | 0.385 | 0.388 | 0.393 | 0.389 |
| 100 ppm DMSO (spray) | 0.379 | 0.383 | 0.383 | 0.381 |
| TU+DMSO (spray) | 0.384 | 0.389 | 0.394 | 0.389 |
| Mean | 0.381 | 0.384 | 0.858 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0020 | 0.0033 | 0.0057 | |
| C.D. (0.05) | NS | NS | NS | |

**Table: 4A.48 Effect of thiourea and DMSO on P content (%) in leaves at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.413 | 0.451 | 0.495 | 0.453 |
| 5 kg TU/ha in soil (basal) | 0.415 | 0.452 | 0.495 | 0.454 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 0.444 | 0.494 | 0.497 | 0.476 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 0.416 | 0.453 | 0.496 | 0.455 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 0.453 | 0.495 | 0.498 | 0.482 |
| 500 ppm TU (spray) | 0.422 | 0.459 | 0.496 | 0.459 |
| 100 ppm DMSO (spray) | 0.413 | 0.452 | 0.496 | 0.454 |
| TU+DMSO (spray) | 0.425 | 0.459 | 0.497 | 0.460 |
| Mean | 0.425 | 0.485 | 0.496 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0031 | 0.0051 | 0.0088 | |
| C.D. (0.05) | 0.0086 | 0.0140 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.403 | 0.434 | 0.480 | 0.439 |
| 5 kg TU/ha in soil (basal) | 0.405 | 0.436 | 0.481 | 0.441 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 0.427 | 0.482 | 0.488 | 0.466 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 0.407 | 0.435 | 0.481 | 0.441 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 0.430 | 0.489 | 0.490 | 0.470 |
| 500 ppm TU (spray) | 0.410 | 0.439 | 0.482 | 0.444 |
| 100 ppm DMSO (spray) | 0.404 | 0.434 | 0.483 | 0.440 |
| TU+DMSO (spray) | 0.415 | 0.441 | 0.483 | 0.446 |
| Mean | 0.412 | 0.449 | 0.483 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0035 | 0.0058 | 0.0403 | |
| C.D. (0.05) | 0.0097 | 0.0161 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.408 | 0.443 | 0.488 | 0.446 |
| 5 kg TU/ha in soil (basal) | 0.411 | 0.444 | 0.488 | 0.448 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 0.435 | 0.488 | 0.493 | 0.472 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 0.411 | 0.444 | 0.489 | 0.448 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 0.441 | 0.492 | 0.494 | 0.476 |
| 500 ppm TU (spray) | 0.416 | 0.449 | 0.489 | 0.451 |
| 100 ppm DMSO (spray) | 0.409 | 0.443 | 0.489 | 0.447 |
| TU+DMSO (spray) | 0.420 | 0.450 | 0.489 | 0.453 |
| Mean | 0.419 | 0.456 | 0.489 | 0.455 |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0024 | 0.0038 | 0.0067 | |
| C.D. (0.05) | 0.0065 | 0.0106 | NS | |

**Table: 4A.49 Effect of thiourea and DMSO on P content (%) in stems at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.385 | 0.411 | 0.418 | 0.405 |
| 5 kg TU/ha in soil (basal) | 0.386 | 0.410 | 0.426 | 0.407 |
| 5 kg TU/ha in soil (½ + ½) | 0.392 | 0.421 | 0.429 | 0.414 |
| 2 kg DMSO/ha in soil (½ + ½) | 0.389 | 0.412 | 0.428 | 0.410 |
| TU+DMSO in soil (½ + ½) | 0.396 | 0.426 | 0.429 | 0.417 |
| 500 ppm TU (spray) | 0.390 | 0.418 | 0.426 | 0.411 |
| 100 ppm DMSO (spray) | 0.385 | 0.413 | 0.426 | 0.408 |
| TU+DMSO (spray) | 0.3391 | 0.418 | 0.427 | 0.412 |
| Mean | 0.389 | 0.416 | 0.426 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0025 | 0.0040 | 0.0069 | |
| C.D. (0.05) | 0.0069 | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.371 | 0.396 | 0.405 | 0.391 |
| 5 kg TU/ha in soil (basal) | 0.371 | 0.395 | 0.406 | 0.391 |
| 5 kg TU/ha in soil (½ + ½) | 0.380 | 0.407 | 0.408 | 0.398 |
| 2 kg DMSO/ha in soil (½ + ½) | 0.375 | 0.400 | 0.405 | 0.393 |
| TU+DMSO in soil (½ + ½) | 0.391 | 0.412 | 0.414 | 0.406 |
| 500 ppm TU (spray) | 0.377 | 0.402 | 0.407 | 0.395 |
| 100 ppm DMSO (spray) | 0.372 | 0.399 | 0.404 | 0.392 |
| TU+DMSO (spray) | 0.378 | 0.404 | 0.409 | 0.397 |
| Mean | 0.377 | 0.402 | 0.407 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0019 | 0.0031 | 0.0053 | |
| C.D. (0.05) | 0.0053 | 0.0085 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.378 | 0.404 | 0.411 | 0.398 |
| 5 kg TU/ha in soil (basal) | 0.379 | 0.403 | 0.416 | 0.399 |
| 5 kg TU/ha in soil (½ + ½) | 0.386 | 0.414 | 0.419 | 0.406 |
| 2 kg DMSO/ha in soil (½ + ½) | 0.383 | 0.406 | 0.416 | 0.402 |
| TU+DMSO in soil (½ + ½) | 0.394 | 0.419 | 0.422 | 0.412 |
| 500 ppm TU (spray) | 0.384 | 0.410 | 0.416 | 0.403 |
| 100 ppm DMSO (spray) | 0.379 | 0.406 | 0.415 | 0.400 |
| TU+DMSO (spray) | 0.386 | 0.411 | 0.418 | 0.405 |
| Mean | 0.383 | 0.409 | 0.417 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0015 | 0.0025 | 0.0044 | |
| C.D. (0.05) | 0.0043 | 0.0070 | NS | |

**Table: 4A.50 Effect of thiourea and DMSO on P content (%) in pods at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.489 | 0.522 | 0.545 | 0.519 |
| 5 kg TU/ha in soil (basal) | 0.492 | 0.523 | 0.542 | 0.519 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.532 | 0.546 | 0.547 | 0.542 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.496 | 0.525 | 0.546 | 0.522 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.539 | 0.550 | 0.551 | 0.548 |
| 500 ppm TU (spray) | 0.499 | 0.535 | 0.546 | 0.527 |
| 100 ppm DMSO (spray) | 0.490 | 0.521 | 0.544 | 0.518 |
| TU+DMSO (spray) | 0.501 | 0.537 | 0.546 | 0.528 |
| Mean | 0.504 | 0.532 | 0.546 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0042 | 0.0068 | 0.0119 | |
| C.D. (0.05) | 0.0116 | 0.0188 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.487 | 0.520 | 0.540 | 0.516 |
| 5 kg TU/ha in soil (basal) | 0.499 | 0.521 | 0.542 | 0.521 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.528 | 0.538 | 0.545 | 0.537 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.500 | 0.522 | 0.542 | 0.521 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.518 | 0.545 | 0.548 | 0.537 |
| 500 ppm TU (spray) | 0.501 | 0.530 | 0.542 | 0.524 |
| 100 ppm DMSO (spray) | 0.492 | 0.518 | 0.541 | 0.517 |
| TU+DMSO (spray) | 0.503 | 0.531 | 0.541 | 0.525 |
| Mean | 0.504 | 0.528 | 0.543 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0033 | 0.0053 | 0.0095 | |
| C.D. (0.05) | 0.0091 | 0.0147 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.489 | 0.521 | 0.543 | 0.518 |
| 5 kg TU/ha in soil (basal) | 0.496 | 0.523 | 0.543 | 0.521 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.530 | 0.543 | 0.546 | 0.540 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.498 | 0.524 | 0.544 | 0.522 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.528 | 0.547 | 0.551 | 0.542 |
| 500 ppm TU (spray) | 0.500 | 0.533 | 0.544 | 0.526 |
| 100 ppm DMSO (spray) | 0.491 | 0.520 | 0.543 | 0.518 |
| TU+DMSO (spray) | 0.503 | 0.534 | 0.544 | 0.527 |
| Mean | 0.504 | 0.530 | 0.544 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0031 | 0.0051 | 0.0088 | |
| C.D. (0.05) | 0.0087 | 0.0141 | NS | |

Soil application of TU at 5 kg P2O5/ha (½+½) and soil application of TU+DMSO significantly increased P content of pods over control during both the years.

**4A.5.8 P content in leaves at 90 DAS**

Data (4A.51) show that phosphorus application brought about significant improvement in P content of leaves at 90 DAS upto 40 kg $P_2O_5$/ha during both the years. 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha in both the years. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased P content in leaves by 7.5 and 12.4 per cent, respectively over control.

Soil application of TU at 5 kg/ha (½+½) significantly increased P content of leaves during both the years. In pooled data, soil application of TU at 5 kg/ha (½+½) significantly increased P content in leaves by 4.5 per cent over soil application of TU at 5 kg/ha (basal). Soil application of TU+DMSO (½+½) significantly increased P content in leaves over control during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P content in leaves by 6.3 and 6.7 per cent, respectively over control.

Foliar sprays of 500 ppm TU and TU+DMSO brought about significant improvement in P content of leaves during both the years. Pooled data show that foliar sprays of 500 ppm TU and TU+DMSO significantly increased P content of leaves at 90 DAS by 5.3 per cent each over control.

Data (Table 4A.51) further show that interaction effects on P content of leaves at 90 DAS were significant in 1999 only. In pooled data, under no phosphorus, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P content of leaves at 90 DAS by 5.6 and 5.9 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased P content of leaves at 90 DAS by 10.5, 11.8, 10.5 and 10.8 per cent, respectively over control. However, these treatments were at par with one another. Under 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments of TU and DMSO proved effective in this respect. Under 20 kg $P_2O_5$/ha, the highest P content of leaves (0.456%) was obtained with soil application of TU+DMSO (½+½). However, it was at par with all treatments under 40 kg $P_2O_5$/ha. When compared with absolute control the increase was 16.0 per cent.

**4A5.9 P content of stems at 90 DAS**

Data (Table 4A.52) show that phosphorus application brought about significant increase in P content of stems at 90 DAS upto 40 kg $P_2O_5$/ha during 1999 only. However, in pooled data, P content of stems increased significantly upto 20 kg $P_2O_5$/ha.

**Table: 4A.51 Effect of thiourea and DMSO on P content (%) in leaves at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.394 | 0.414 | 0.461 | 0.423 |
| 5 kg TU/ha in soil (basal) | 0.394 | 0.417 | 0.460 | 0.424 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 0.416 | 0.463 | 0.463 | 0.447 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 0.395 | 0.417 | 0.460 | 0.424 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 0.417 | 0.464 | 0.464 | 0.448 |
| 500 ppm TU (spray) | 0.397 | 0.453 | 0.461 | 0.437 |
| 100 ppm DMSO (spray) | 0.394 | 0.414 | 0.461 | 0.423 |
| TU+DMSO (spray) | 0.397 | 0.454 | 0.461 | 0.437 |
| Mean | 0.400 | 0.437 | 0.461 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0027 | 0.0044 | 0.0076 | |
| C.D. (0.05) | 0.0075 | 0.0122 | 0.0211 | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.391 | 0.400 | 0.433 | 0.408 |
| 5 kg TU/ha in soil (basal) | 0.395 | 0.427 | 0.438 | 0.420 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 0.414 | 0.440 | 0.449 | 0.434 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 0.400 | 0.402 | 0.440 | 0.414 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 0.416 | 0.448 | 0.451 | 0.438 |
| 500 ppm TU (spray) | 0.407 | 0.449 | 0.452 | 0.436 |
| 100 ppm DMSO (spray) | 0.400 | 0.401 | 0.435 | 0.412 |
| TU+DMSO (spray) | 0.410 | 0.450 | 0.451 | 0.437 |
| Mean | 0.404 | 0.427 | 0.444 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0034 | 0.0055 | 0.0096 | |
| C.D. (0.05) | 0.0094 | 0.0152 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.393 | 0.408 | 0.446 | 0.415 |
| 5 kg TU/ha in soil (basal) | 0.395 | 0.421 | 0.449 | 0.422 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 0.415 | 0.451 | 0.456 | 0.441 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 0.398 | 0.410 | 0.450 | 0.419 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 0.416 | 0.456 | 0.458 | 0.443 |
| 500 ppm TU (spray) | 0.403 | 0.451 | 0.456 | 0.437 |
| 100 ppm DMSO (spray) | 0.398 | 0.408 | 0.448 | 0.418 |
| TU+DMSO (spray) | 0.404 | 0.452 | 0.456 | 0.437 |
| Mean | 0.402 | 0.432 | 0.452 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0022 | 0.0035 | 0.0061 | |
| C.D. (0.05) | 0.0060 | 0.0098 | 0.0169 | |

None of the soil and foliar applied treatments of TU and DMSO proved effective in this respect during both the years.

**4A5.10 P content of pods at 90 DAS**

Data (4A.53) show that phosphorus application brought about significantly increase in P content of pods at 90 DAS upto 40 kg $P_2O_5$/ha during both the years. Pooled data also show similar trends.

Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO significantly increased P content of pods at 90 DAS over control during both the years. Foliar sprays of 500 ppm TU and TU+DMSO also significantly increased P content of pods over control during both the years. Pooled data also show similar trends.

Data further show that TU and DMSO interacted significantly with phosphorus in influencing P content of pods at 90 DAS during both the years. Pooled data show that under no phosphorus and 20 kg $P_2O_5$/ha, soil application of TU at 5 kg /ha (½+½), soil application of TU+DMSO, foliar spray of 500 ppm TU and TU+DMSO significantly increased P content of pods over control. Under 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective.

**4A5.11 P content of leaves at physiological maturity**

Data (Table 4A.54) show that phosphorus application brought about significant increase in P content of leaves at physiological maturity over control during both the years. Pooled data also show similar trends.

Soil application of TU at 5 kg /ha (½+½), soil application of TU+DMSO, foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased P content of leaves at physiological maturity during both the years. Rest of the treatments was not significant but exhibited increasing trends over control. Pooled data also show similar trends.

Data further show that TU and DMSO interacted significantly with phosphorus in influencing P content of leaves at physiological maturity during 1999 only. Pooled data show that under no phosphorus, only soil application of TU at5 kg/ha (½+½) and soil application of TU+DMSO proved effective in increasing P content of leaves over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO, foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased P content of leaves at physiological maturity over control. However, under 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective.

**Table: 4A.52 Effect of thiourea and DMSO on P content (%) in stems at 90 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.373 | 0.388 | 0.399 | 0.387 |
| 5 kg TU/ha in soil (basal) | 0.370 | 0.389 | 0.401 | 0.387 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 0.384 | 0.396 | 0.402 | 0.394 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 0.373 | 0.389 | 0.398 | 0.387 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 0.387 | 0.398 | 0.403 | 0.396 |
| 500 ppm TU (spray) | 0.373 | 0.391 | 0.400 | 0.388 |
| 100 ppm DMSO (spray) | 0.373 | 0.388 | 0.398 | 0.386 |
| TU+DMSO (spray) | 0.378 | 0.393 | 0.400 | 0.390 |
| Mean | 0.376 | 0.392 | 0.400 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0021 | 0.0034 | 0.0058 | |
| C.D. (0.05) | 0.0058 | NS | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.365 | 0.372 | 0.378 | 0.372 |
| 5 kg TU/ha in soil (basal) | 0.366 | 0.373 | 0.375 | 0.371 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 0.375 | 0.380 | 0.381 | 0.379 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 0.367 | 0.370 | 0372 | 0.369 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 0.376 | 0.381 | 0382 | 0.380 |
| 500 ppm TU (spray) | 0.367 | 0.380 | 0374 | 0.374 |
| 100 ppm DMSO (spray) | 0.365 | 0.371 | 0371 | 0.369 |
| TU+DMSO (spray) | 0.370 | 0.374 | 0375 | 0.373 |
| Mean | 0.369 | 0.375 | 0376 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0039 | 0.0063 | 0.0110 | |
| C.D. (0.05) | NS | NS | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.369 | 0.380 | 0.389 | 0.379 |
| 5 kg TU/ha in soil (basal) | 0.368 | 0.381 | 0.388 | 0.379 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 0.379 | 0.388 | 0.391 | 0.386 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 0.370 | 0.380 | 0.385 | 0.378 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 0.381 | 0.389 | 0.393 | 0.388 |
| 500 ppm TU (spray) | 0.370 | 0.383 | 0.388 | 0.380 |
| 100 ppm DMSO (spray) | 0.369 | 0.380 | 0.385 | 0.378 |
| TU+DMSO (spray) | 0.374 | 0.384 | 0.388 | 0.382 |
| Mean | 0.373 | 0.383 | 0.388 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0022 | 0.0036 | 0.0062 | |
| C.D. (0.05) | 0.0061 | NS | NS | |

**Table: 4A.53 Effect of thiourea and DMSO on P content (%) in pods at 90 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.470 | 0.507 | 0.538 | 0.505 |
| 5 kg TU/ha in soil (basal) | 0.475 | 0.508 | 0.538 | 0.507 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.528 | 0.537 | 0.539 | 0.535 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.480 | 0.509 | 0.540 | 0.510 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.529 | 0.539 | 0.540 | 0.536 |
| 500 ppm TU (spray) | 0.490 | 0.528 | 0.537 | 0.518 |
| 100 ppm DMSO (spray) | 0.475 | 0.508 | 0.543 | 0.508 |
| TU+DMSO (spray) | 0.499 | 0.536 | 0.537 | 0.524 |
| Mean | 0.493 | 0.521 | 0.538 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0029 | 0.0048 | 0.0083 | |
| C.D. (0.05) | 0.0080 | 0.0133 | 0.0230 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.469 | 0.505 | 0.535 | 0.503 |
| 5 kg TU/ha in soil (basal) | 0.474 | 0.510 | 0.537 | 0.507 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.526 | 0.535 | 0.538 | 0.533 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.473 | 0.508 | 0.538 | 0.506 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.526 | 0.537 | 0.540 | 0.534 |
| 500 ppm TU (spray) | 0.488 | 0.523 | 0.536 | 0.515 |
| 100 ppm DMSO (spray) | 0.473 | 0.506 | 0.535 | 0.504 |
| TU+DMSO (spray) | 0.488 | 0.536 | 0.536 | 0.519 |
| Mean | 0.489 | 0.520 | 0.537 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0017 | 0.0027 | 0.0045 | |
| C.D. (0.05) | 0.0047 | 0.0075 | 0.0124 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.470 | 0.506 | 0.536 | 0.504 |
| 5 kg TU/ha in soil (basal) | 0.475 | 0.509 | 0.538 | 0.507 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.528 | 0.536 | 0.539 | 0.534 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.476 | 0.509 | 0.539 | 0.508 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.528 | 0.538 | 0.540 | 0.535 |
| 500 ppm TU (spray) | 0.489 | 0.525 | 0.536 | 0.517 |
| 100 ppm DMSO (spray) | 0.474 | 0.506 | 0.539 | 0.506 |
| TU+DMSO (spray) | 0.494 | 0.536 | 0.537 | 0.522 |
| Mean | 0.491 | 0.521 | 0.538 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0017 | 0.0027 | 0.0047 | |
| C.D. (0.05) | 0.0047 | 0.0076 | 0.0132 | |

**Table: 4A.54 Effect of thiourea and DMSO on P content (%) in leaves at physiological maturity DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.392 | 0.415 | 0.461 | 0.423 |
| 5 kg TU/ha in soil (basal) | 0.393 | 0.417 | 0.459 | 0.423 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 0.417 | 0.462 | 0.463 | 0.447 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 0.396 | 0.418 | 0.461 | 0.425 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 0.416 | 0.464 | 0.463 | 0.448 |
| 500 ppm TU (spray) | 0.398 | 0.454 | 0.462 | 0.438 |
| 100 ppm DMSO (spray) | 0.393 | 0.414 | 0.460 | 0.422 |
| TU+DMSO (spray) | 0.396 | 0.454 | 0.462 | 0.437 |
| Mean | 0.400 | 0.437 | 0.461 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0025 | 0.0041 | 0.0071 | |
| C.D. (0.05) | 0.0069 | 0.0114 | 0.0197 | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.391 | 0.400 | 0.433 | 0.408 |
| 5 kg TU/ha in soil (basal) | 0.395 | 0.427 | 0.438 | 0.420 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 0.414 | 0.440 | 0.449 | 0.434 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 0.400 | 0.402 | 0.440 | 0.414 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 0.416 | 0.448 | 0.451 | 0.438 |
| 500 ppm TU (spray) | 0.407 | 0.449 | 0.452 | 0.436 |
| 100 ppm DMSO (spray) | 0.400 | 0.401 | 0.435 | 0.412 |
| TU+DMSO (spray) | 0.410 | 0.450 | 0.451 | 0.437 |
| Mean | 0.404 | 0.427 | 0.444 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0044 | 0.0073 | 0.0125 | |
| C.D. (0.05) | 0.0123 | 0.0201 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.392 | 0.407 | 0.447 | 0.415 |
| 5 kg TU/ha in soil (basal) | 0.394 | 0.422 | 0.449 | 0.422 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 0.415 | 0.451 | 0.456 | 0.441 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 0.398 | 0.410 | 0.450 | 0.419 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 0.416 | 0.456 | 0.457 | 0.443 |
| 500 ppm TU (spray) | 0.403 | 0.452 | 0.457 | 0.437 |
| 100 ppm DMSO (spray) | 0.397 | 0.407 | 0.448 | 0.417 |
| TU+DMSO (spray) | 0.403 | 0.452 | 0.457 | 0.437 |
| Mean | 0.402 | 0.432 | 0.452 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0026 | 0.0042 | 0.0072 | |
| C.D. (0.05) | 0.0071 | 0.0115 | 0.0199 | |

### 4A.5.12 P content of stems at physiological maturity

Data (Table 4A.55) indicate that application of 40 kg $P_2O_5$/ha significantly increased P content of stems at physiological maturity over control and 20 kg $P_2O_5$/ha during both the years.

Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO proved effective in improving P content of stems at physiological maturity over control in 2000 only. With regard to foliar spray it can be seen that only foliar spray of TU+DMSO proved effective. Rest of the treatments remained ineffective in this regard. Pooled data also show similar trends

### 4A.5.13 P content of pods at physiological maturity

Data (Table 4A.56) show that phosphorus application brought about significant increase in P content of pods at physiological maturity upto 40 kg $P_2O_5$/ha over control during both the years. Pooled data also show similar trends.

Soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO significantly increased P content of leaves at physiological maturity during both the years. Pooled data also show similar trends. Rest of the soil applied treatments found non significant but an increasing trends was observed over control.

Foliar spray of TU+DMSO proved effective in increasing P content of pods at physiological maturity over control during 2000 only. However, in pooled data, foliar sprays of 500 ppm TU and TU+DMSO significantly increased P content of pods at physiological maturity.

Data further show that TU and DMSO interacted significantly with phosphorus in influencing P content of pods at physiological maturity in 2000 only. Pooled data show that under no phosphorus and 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO, foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased P content of pods over control. However, under 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective.

Soil application of DMSO and foliar spray of 100 ppm DMSO also showed increasing trends over control.

### 4A.5.14 P distribution in leaves at 60 DAS

Data (Table 4A.57) reveal that phosphorus application brought about significant increase in P distribution in leaves at 60 DAS during both the years. In 1999, application of 40 kg $P_2O_5$/ha significantly increased in P distribution in leaves at 60 DAS, while in 2000, level 20 and 40 kg $P_2O_5$/ha proved superior over control. Level of 40 kg

**Table: 4A.55 Effect of thiourea and DMSO on P content (%) in stems at physiological maturity DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.358 | 0.375 | 0.388 | 0.374 |
| 5 kg TU/ha in soil (basal) | 0.360 | 0.377 | 0.388 | 0.375 |
| 5 kg TU/ha in soil $(^1/_2 + ^1/_2)$ | 0.378 | 0.386 | 0.391 | 0.385 |
| 2 kg DMSO/ha in soil $(^1/_2 + ^1/_2)$ | 0:59 | 0.378 | 0.89 | 0.375 |
| TU+DMSO in soil $(^1/_2 + ^1/_2)$ | 0.379 | 0.388 | 0.392 | 0.386 |
| 500 ppm TU (spray) | 0.359 | 0.381 | 0.388 | 0.376 |
| 100 ppm DMSO (spray) | 0.357 | 0.377 | 0.389 | 0.374 |
| TU+DMSO (spray) | 0.373 | 0.383 | 0.389 | 0.381 |
| Mean | 0.365 | 0.380 | 0.389 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0025 | 0.0041 | 0.0072 | |
| C.D. (0.05) | 0.0069 | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.355 | 0.372 | 0.381 | 0.369 |
| 5 kg TU/ha in soil (basal) | 0.358 | 0.372 | 0.380 | 0.370 |
| 5 kg TU/ha in soil $(^1/_2 + ^1/_2)$ | 0.375 | 0.385 | 0.391 | 0.384 |
| 2 kg DMSO/ha in soil $(^1/_2 + ^1/_2)$ | 0.358 | 0.372 | 0.383 | 0.370 |
| TU+DMSO in soil $(^1/_2 + ^1/_2)$ | 0.378 | 0.385 | 0.392 | 0.385 |
| 500 ppm TU (spray) | 0.358 | 0.380 | 0.387 | 0.375 |
| 100 ppm DMSO (spray) | 0.356 | 0.372 | 0.383 | 0.370 |
| TU+DMSO (spray) | 0.365 | 0.383 | 0.386 | 0.378 |
| Mean | 0.363 | 0.378 | 0.385 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0022 | 0.0032 | 0.0062 | |
| C.D. (0.05) | 0.0061 | 0.0088 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.356 | 0.374 | 0.385 | 0.372 |
| 5 kg TU/ha in soil (basal) | 0.357 | 0.375 | 0.384 | 0.373 |
| 5 kg TU/ha in soil $(^1/_2 + ^1/_2)$ | 0.376 | 0.386 | 0.391 | 0.385 |
| 2 kg DMSO/ha in soil $(^1/_2 + ^1/_2)$ | 0.358 | 0.375 | 0.386 | 0.373 |
| TU+DMSO in soil $(^1/_2 + ^1/_2)$ | 0.379 | 0.387 | 0.392 | 0.386 |
| 500 ppm TU (spray) | 0.359 | 0.381 | 0.388 | 0.376 |
| 100 ppm DMSO (spray) | 0.356 | 0.375 | 0.385 | 0.372 |
| TU+DMSO (spray) | 0.369 | 0.383 | 0.388 | 0.379 |
| Mean | 0.364 | 0.379 | 0.387 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0017 | 0.0024 | 0.0048 | |
| C.D. (0.05) | 0.0047 | 0.0066 | NS | |

**Table: 4A.56 Effect of thiourea and DMSO on P content (%) in pods at physiological maturity DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.480 | 0.513 | 0.541 | 0.511 |
| 5 kg TU/ha in soil (basal) | 0.479 | 0.514 | 0.542 | 0.512 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.530 | 0.542 | 0.548 | 0.540 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.495 | 0.514 | 0.542 | 0.517 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.532 | 0.544 | 0.549 | 0.541 |
| 500 ppm TU (spray) | 0.500 | 0.532 | 0.540 | 0.524 |
| 100 ppm DMSO (spray) | 0.481 | 0.513 | 0.540 | 0.511 |
| TU+DMSO (spray) | 0.501 | 0.533 | 0.544 | 0.526 |
| Mean | 0.500 | 0.526 | 0.543 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0036 | 0.0059 | 0.0102 | |
| C.D. (0.05) | 0.0099 | 0.0164 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.470 | 0.506 | 0.537 | 0.504 |
| 5 kg TU/ha in soil (basal) | 0.478 | 0.510 | 0.537 | 0.508 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.528 | 0.536 | 0.538 | 0.534 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.475 | 0.520 | 0.537 | 0.510 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.527 | 0.539 | 0.540 | 0.535 |
| 500 ppm TU (spray) | 0.489 | 0.525 | 0.538 | 0.517 |
| 100 ppm DMSO (spray) | 0.473 | 0.506 | 0.536 | 0.505 |
| TU+DMSO (spray) | 0.493 | 0.536 | 0.538 | 0.522 |
| Mean | 0.491 | 0.521 | 0.538 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0023 | 0.0037 | 0.0065 | |
| C.D. (0.05) | 0.0064 | 0.0148 | 0.0180 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.475 | 0.509 | 0.539 | 0.508 |
| 5 kg TU/ha in soil (basal) | 0.479 | 0.513 | 0.540 | 0.510 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 0.529 | 0.539 | 0.543 | 0.537 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 0.485 | 0.517 | 0.540 | 0.514 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 0.529 | 0.541 | 0.545 | 0.538 |
| 500 ppm TU (spray) | 0.495 | 0.529 | 0.539 | 0.521 |
| 100 ppm DMSO (spray) | 0.478 | 0.510 | 0.538 | 0.508 |
| TU+DMSO (spray) | 0.496 | 0.535 | 0.541 | 0.524 |
| Mean | 0.496 | 0.524 | 0.541 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.0021 | 0.0035 | 0.0060 | |
| C.D. (0.05) | 0.0059 | 0.0097 | 0.0167 | |

$P_2O_5$/ha significantly superior to 20 kg $P_2O_5$/ha in both years. On the basis of pooled data, 40 kg $P_2O_5$/ha significantly increased P distribution in leaves at 60 DAS by 6.7 per cent over control.

Soil and foliar applied treatments of TU and DMSO did not influence the P distribution in leaves at 60 DAS during both the years. In pooled data, similar trends were recorded.

Data on combined effects of treatments (Table 4A.57) show that interaction effect on P distribution in leaves at 60 DAS were significant only in 2000. None of the soil and foliar applied treatments of TU and DMSO proved effective under no phosphorus, 20 and 40 kg $P_2O_5$/ha. Under soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU and DMSO, application of 40 kg $P_2O_5$/ha significantly increased P distribution in leaves at 60 DAS over control. In pooled data, under no phosphorus and 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective. Under 20 kg $P_2O_5$/ha, only soil application of TU+DMSO (½+½) significantly increased P distribution in leaves at 60 DAS by 5.2 per cent over control. The highest P distribution in leaves at 60 DAS (49.97%) was obtained with soil application of TU+DMSO (½+½) under 20 kg $P_2O_5$/ha. It was significantly superior to absolute control by 5.4 per cent.

#### 4A.5.15 P distribution in stems at 60 DAS

Data (Table 4A.58) show that phosphorus application did not influence P distribution in stems at 60 DAS during 1999. However in 2000, P distribution in stems at 60 DAS significantly reduced due to application of 20 and 40 kg $P_2O_5$/ha over control. Level 20 and 40 kg $P_2O_5$/ha were at par in this respect. On the basis of pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly reduced P content in stems at 60 DAS by 2.7 and 4.7 per cent, respectively over control. Application of 20 and 40 kg $P_2O_5$/ha was at par in this respect.

In 1999, none of the soil and foliar applied treatments proved effective in influencing P distribution in stems at 60 DAS. However, in 2000 soil application of TU+DMSO (½+½) significantly reduced P distribution in stems at 60 DAS over control. On the basis of pooled data, significant reduction in P distribution in stems at 60 DAS by 3.4 per cent over control was recorded due to soil application of TU+DMSO (½+½).

#### 4A.5.16 P distribution in pods at 60 DAS

Data (Table 4A.59) show that phosphorus application brought about significant increase in P distribution in pods at 60 DAS upto 20 kg $P_2O_5$/ha in 1999 and upto 40 kg $P_2O_5$/ha in 2000. On the basis of pooled data, application of 20 kg $P_2O_5$/ha significantly increased in P distribution in pods at 60 DAS by 11.3 per cent over control.

Soil application of TU at 5 kg/ha (½+½) significantly increased P distribution in pods at 60 DAS over control only in 2000. Soil application of TU+DMSO (½+½) also significantly increased P distribution in pods during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P distribution in pods by 8.5, 7.9 and 18.0 per cent, respectively over control. Soil application of TU at 5 kg/ha (½+½) resulted in significantly higher P distribution in pods by 6.5 per cent over soil application of TU at 5 kg/ha (basal).

None of the foliar spray treatments proved effective in 1999. However, in 2000 only foliar spray of 500 ppm TU and TU+DMSO brought about significant increase in P distribution over control. On the basis of pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased P distribution in pods by 9.8, 9.4 and 10.8 per cent, respectively over control.

Data (Table 4A.59) show that application of TU and DMSO interacted significantly with phosphorus in influencing P distribution in pods at 60 DAS in 2000 only. Under no phosphorus, only soil application of TU+DMSO (½+½) proved effective in incresing P distribution in pods at 60 DAS over control. Under 20 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective in this respect. Under 40 kg $P_2O_5$/ha, soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO significantly increased P distribution in pods at 60 DAS over control. In pooled data, under no phosphorus, soil application of TU+DMSO (½+½) significantly increased P distribution in pods at 60 DAS by 38.5 per cent over control. Rests of the treatments were not significant. Under 20 kg $P_2O_5$/ha, all the soil and foliar applied treatments of TU and DMSO proved ineffective. Under 40 kg $P_2O_5$/ha, soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased P distribution in pods at 60 DAS by 15.8,15.0, 19.6, 15.3 and 17.7 per cent, respectively over control. The maximum P distribution (12.6%) was obtained with soil application of TU+DMSO (½+½) under no phosphorus. It was significantly superior to all treatment combinations except foliar spray of TU+DMSO under 20 kg $P_2O_5$/ha.

### 4A.5.17 P distribution in leaves at 90 DAS

Data (Table 4A.60) show that phosphorus application brought about significant increase in P distribution in leaves at 90 DAS upto 40 kg $P_2O_5$/ha during 2000 only. On the basis of pooled data, 20 and 40 kg $P_2O_5$/ha significantly increased P distribution in leaves by

**Table: 4A.57 Effect of thiourea and DMSO on P distribution (%) in leaves at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 47.66 | 46.74 | 49.21 | 47.87 |
| 5 kg TU/ha in soil (basal) | 49.51 | 45.84 | 50.34 | 48.56 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 48.65 | 47.27 | 48.41 | 48.11 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 46.68 | 43.07 | 48.06 | 45.93 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 45.47 | 49.65 | 47.02 | 47.38 |
| 500 ppm TU (spray) | 47.62 | 47.01 | 48.13 | 47.58 |
| 100 ppm DMSO (spray) | 44.59 | 46.17 | 47.47 | 46.08 |
| TU+DMSO (spray) | 46.89 | 45.24 | 47.81 | 46.64 |
| Mean | 47.13 | 46.37 | 48.31 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.505 | 0.825 | 1.429 | |
| C.D. (0.05) | 1.400 | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 47.18 | 48.30 | 49.50 | 48.33 |
| 5 kg TU/ha in soil (basal) | 47.56 | 47.60 | 50.47 | 48.54 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 47.30 | 48.31 | 49.60 | 48.40 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 47.18 | 47.18 | 49.18 | 47.85 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 45.01 | 50.29 | 49.66 | 48.31 |
| 500 ppm TU (spray) | 47.41 | 47.48 | 48.86 | 47.92 |
| 100 ppm DMSO (spray) | 47.37 | 45.19 | 47.77 | 46.77 |
| TU+DMSO (spray) | 46.40 | 48.15 | 48.94 | 47.83 |
| Mean | 46.93 | 47.81 | 49.25 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.264 | 0.431 | 0.747 | |
| C.D. (0.05) | 0.732 | NS | 2.070 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 47.42 | 47.52 | 49.35 | 48.10 |
| 5 kg TU/ha in soil (basal) | 48.54 | 46.72 | 50.41 | 48.55 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 47.98 | 47.79 | 49.00 | 48.26 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 46.93 | 45.12 | 48.62 | 46.89 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 45.24 | 49.97 | 48.34 | 47.85 |
| 500 ppm TU (spray) | 47.52 | 47.24 | 48.50 | 47.75 |
| 100 ppm DMSO (spray) | 45.98 | 45.68 | 47.62 | 46.43 |
| TU+DMSO (spray) | 46.64 | 46.70 | 48.38 | 47.24 |
| Mean | 47.03 | 47.09 | 48.78 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.285 | 0.465 | 0.806 | |
| C.D. (0.05) | 0.790 | 1.290 | 2.234 | |

**Table: 4A.58 Effect of thiourea and DMSO on P distribution (%) in stems at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 43.05 | 42.88 | 41.77 | 42.57 |
| 5 kg TU/ha in soil (basal) | 41.22 | 43.87 | 40.39 | 41.82 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 41.76 | 41.74 | 41.81 | 41.77 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 43.95 | 45.93 | 41.67 | 43.85 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 41.51 | 39.51 | 42.66 | 41.22 |
| 500 ppm TU (spray) | 42.86 | 42.01 | 41.07 | 41.98 |
| 100 ppm DMSO (spray) | 44.43 | 43.14 | 41.94 | 43.17 |
| TU+DMSO (spray) | 43.27 | 42.99 | 41.72 | 42.66 |
| Mean | 42.76 | 42.76 | 41.63 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.543 | 0.887 | 1.536 | |
| C.D. (0.05) | NS | NS | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 43.91 | 41.23 | 41.56 | 42.23 |
| 5 kg TU/ha in soil (basal) | 43.72 | 41.90 | 39.80 | 41.81 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 42.51 | 40.45 | 40.31 | 41.09 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 43.83 | 41.79 | 40.28 | 41.97 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 42.81 | 39.15 | 40.01 | 40.65 |
| 500 ppm TU (spray) | 43.64 | 40.92 | 40.43 | 41.66 |
| 100 ppm DMSO (spray) | 43.60 | 43.92 | 42.10 | 43.21 |
| TU+DMSO (spray) | 44.56 | 40.45 | 40.44 | 41.82 |
| Mean | 43.57 | 41.23 | 40.62 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.268 | 0.438 | 0.758 | |
| C.D. (0.05) | 0.743 | 1.214 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 43.48 | 42.05 | 41.67 | 42.40 |
| 5 kg TU/ha in soil (basal) | 42.47 | 42.88 | 40.10 | 41.81 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 42.13 | 41.10 | 41.06 | 41.43 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 43.89 | 43.86 | 40.97 | 42.91 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 42.16 | 39.33 | 41.33 | 40.94 |
| 500 ppm TU (spray) | 43.25 | 41.46 | 40.75 | 41.82 |
| 100 ppm DMSO (spray) | 44.02 | 43.53 | 42.02 | 43.19 |
| TU+DMSO (spray) | 43.92 | 41.72 | 41.08 | 42.24 |
| Mean | 43.16 | 41.99 | 41.12 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.303 | 0.494 | 0.856 | |
| C.D. (0.05) | 0.839 | 1.371 | NS | |

**Table: 4A.59 Effect of thiourea and DMSO on P distribution (%) in pods at 60 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 9.30 | 10.38 | 9.02 | 9.57 |
| 5 kg TU/ha in soil (basal) | 9.27 | 10.33 | 9.28 | 9.62 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 9.58 | 10.99 | 9.77 | 10.11 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 9.38 | 11.27 | 10.26 | 10.30 |
| TU+DMSO in soil (1/2 + 1/2) | 13.02 | 10.86 | 10.32 | 11.40 |
| 500 ppm TU (spray) | 9.53 | 10.99 | 10.81 | 10.45 |
| 100 ppm DMSO (spray) | 10.99 | 10.70 | 10.58 | 10.76 |
| TU+DMSO (spray) | 9.85 | 11.76 | 10.49 | 10.70 |
| Mean | 10.11 | 10.91 | 10.06 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.238 | 0.389 | 0.674 | |
| C.D. (0.05) | 0.661 | 1.079 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 9.91 | 10.45 | 8.95 | 9.44 |
| 5 kg TU/ha in soil (basal) | 8.98 | 10.48 | 9.75 | 9.73 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 10.21 | 11.23 | 10.10 | 10.51 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 8.99 | 11.05 | 10.55 | 10.19 |
| TU+DMSO in soil (1/2 + 1/2) | 12.17 | 10.55 | 10.35 | 11.03 |
| 500 ppm TU (spray) | 9.85 | 11.60 | 10.68 | 10.41 |
| 100 ppm DMSO (spray) | 9.03 | 10.90 | 10.12 | 10.02 |
| TU+DMSO (spray) | 9.04 | 11.40 | 10.65 | 10.36 |
| Mean | 9.54 | 10.96 | 10.14 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.186 | 0.304 | 0.527 | |
| C.D. (0.05) | 0.516 | 0.843 | 1.460 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 9.10 | 10.41 | 8.98 | 9.50 |
| 5 kg TU/ha in soil (basal) | 9.12 | 10.40 | 9.51 | 9.68 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 9.89 | 11.11 | 9.93 | 10.31 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 9.18 | 11.16 | 10.40 | 10.25 |
| TU+DMSO in soil (1/2 + 1/2) | 12.60 | 10.71 | 10.33 | 11.21 |
| 500 ppm TU (spray) | 9.24 | 11.30 | 10.74 | 10.43 |
| 100 ppm DMSO (spray) | 10.01 | 10.80 | 10.35 | 10.39 |
| TU+DMSO (spray) | 9.44 | 11.58 | 10.57 | 10.53 |
| Mean | 9.82 | 10.93 | 10.10 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.151 | 0.247 | 0.428 | |
| C.D. (0.05) | 0.419 | 0.685 | 1.186 | |

12.7 and 16.6 per cent, respectively over control. However, levels 20 and 40 kg $P_2O_5$/ha were at par in this respect.

Soil application of TU at 5 kg/ha (basal) significantly increased P distribution in leaves at 90 DAS in both the years. Soil application of TU at 5 kg/ha (½+½) also significantly increased P distribution in leaves during 2000 only. Soil application of DMSO at 2 kg/ha (½+½) significantly increased P distribution in leaves during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P distribution in leaves by 31.6, 29.9, 21.5 and 25.2 per cent, respectively over control.

Foliar sprays of 500 ppm TU and TU+DMSO significantly increased P distribution in leaves at 90 DAS during both the years. Foliar spray of 100 ppm DMSO was effective in 2000 only. In pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased P distribution in leaves at 90 DAS by 48.0, 13.8 and 44.6 per cent, respectively over control.

Data (Table 4A.60) show that TU and DMSO interacted significantly with phosphorus in influencing P distribution in leaves at 90 DAS during 2000 only. All the soil and foliar applied treatments of TU and DMSO significantly increased P distribution in leaves at 90 DAS over control, under each levels of phosphorus. The highest P distribution in leaves at 90 DAS was recorded with foliar spray 500 ppm TU under 20 kg $P_2O_5$/ha. In pooled data, interaction effects were not significant.

### 4A.5.18 P distribution in stems at 90 DAS

Data (Table 4A.61) show that phosphorus application resulted in significant reduction in P distribution in stems at 90 DAS as compared to control during both the years. On the basis of pooled data, a significant reduction in P distribution in stems by 12.1 and 17.1 per cent over control due to application of 20 and 40 kg $P_2O_5$ha, respectively. Further, application of 40 kg $P_2O_5$/ha recorded significantly higher reduction in P distribution in stems over 20 kg $P_2O_5$/ha.

Soil application of TU at 5 kg/ha (basal) brought about significant reduction in P distribution in stems at 90 DAS during 2000 only. Soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly reduced P distribution in stems as compared to control during both the years. In pooled data, the per cent reduction in P distribution in stems due to soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha

(½+½) and soil application of TU+DMSO (½+½) were in the order of 12.1, 22.5, 8.4 and 24.4.

Foliar spray of 100 ppm DMSO did not influence the P distribution in stems at 90 DAS during 1999 only. However, foliar sprays of 500 ppm TU and TU+DMSO proved effective in this respect during both the years. Pooled data showed that foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly decreased P distribution in stems by 35.3, 7.3 and 36.2 per cent, respectively over control.

Data (Table 4A.61) show that TU and DMSO interacted significantly with phosphorus in influencing P distribution in stems at 90 DAS during both the years. In pooled data, under no phosphorus, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly decreased P distribution in stems at 90 DAS by 16.5, 23.7, 16.7, 30.7, 40.2, 12.8 and 43.0 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 50 ppm TU and foliar spray of TU+DMSO significantly reduced P distribution in stems at 90 DAS by 17.4, 16.3, 29.5 and 30.5 per cent, respectively over control. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly decreased P distribution in stems at 90 DAS by 16.4, 25.9, 24.6, 34.7, 8.5 and 33.2 per cent, respectively over control.

### 4A.5.19 P distribution in pods at 90 DAS

Data (Table 4A.62) show that phosphorus application brought about significant increase in P distribution in pods at 90 DAS during 2000 only. In pooled data, 20 and 40 kg $P_2O_5$/ha significantly increased P distribution in pods by 3.0 and 4.9 per cent, respectively over control. Further, level 20 and 40 kg $P_2O_5$/ha were at par.

Soil application of TU at 5 kg/ha (½+½) significantly increased P distribution in pods during 2000 only. Soil application of TU+DMSO (½+½) proved effective during both the years. However, soil application of DMSO at 2 kg/ha (½+½) proved ineffective in this respect in both the years. In pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P distribution in pods at 90 DAS by 6.7 and 10.0 per cent, respectively over control.

Foliar sprays of 500 ppm TU and TU+DMSO significantly increased P distribution in pods at 90 DAS during both the years. While, foliar spray of 100 ppm DMSO proved ineffective in both the years. On the basis of pooled data, foliar sprays of 500 ppm TU and

**Table: 4A.60 Effect of thiourea and DMSO on P distribution in leaves at 90 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 24.02 | 25.71 | 25.54 | 25.09 |
| 5 kg TU/ha in soil (basal) | 29.64 | 29.97 | 32.70 | 30.77 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 27.77 | 27.93 | 25.95 | 27.22 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 29.28 | 29.44 | 30.17 | 29.63 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 24.50 | 24.52 | 24.83 | 24.62 |
| 500 ppm TU (spray) | 27.47 | 32.36 | 29.79 | 29.87 |
| 100 ppm DMSO (spray) | 26.27 | 26.27 | 28.81 | 27.12 |
| TU+DMSO (spray) | 28.39 | 30.05 | 29.91 | 29.45 |
| Mean | 27.17 | 28.28 | 28.46 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.599 | 0.978 | 1.695 | |
| C.D. (0.05) | NS | 2.713 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 8.92 | 13.88 | 13.08 | 11.96 |
| 5 kg TU/ha in soil (basal) | 15.53 | 18.40 | 20.08 | 18.00 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 17.30 | 21.80 | 22.85 | 20.65 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 11.30 | 15.60 | 19.23 | 15.38 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 14.48 | 22.08 | 25.73 | 21.76 |
| 500 ppm TU (spray) | 22.90 | 27.08 | 25.10 | 25.03 |
| 100 ppm DMSO (spray) | 10.27 | 16.05 | 18.83 | 15.05 |
| TU+DMSO (spray) | 21.20 | 24.53 | 26.63 | 24.12 |
| Mean | 15.61 | 19.93 | 21.44 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.184 | 0.301 | 0.521 | |
| C.D. (0.05) | 0.511 | 0.834 | 1.444 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 16.47 | 19.79 | 19.31 | 18.52 |
| 5 kg TU/ha in soil (basal) | 22.58 | 24.19 | 26.39 | 24.38 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 22.53 | 24.87 | 24.40 | 23.93 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 20.29 | 22.52 | 24.70 | 22.50 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 20.99 | 23.30 | 25.28 | 23.19 |
| 500 ppm TU (spray) | 25.19 | 29.72 | 27.44 | 27.45 |
| 100 ppm DMSO (spray) | 18.27 | 21.16 | 23.82 | 21.08 |
| TU+DMSO (spray) | 24.79 | 27.29 | 28.27 | 26.78 |
| Mean | 21.39 | 24.10 | 24.95 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.313 | 0.512 | 0.887 | |
| C.D. (0.05) | 0.869 | 1.419 | NS | |

**Table: 4A.61 Effect of thiourea and DMSO on P distribution in stems at 90 DAS at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 38.16 | 30.33 | 31.03 | 33.17 |
| 5 kg TU/ha in soil (basal) | 33.89 | 33.50 | 27.95 | 31.78 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 30.87 | 27.51 | 27.05 | 28.41 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 30.90 | 30.67 | 29.29 | 30.29 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 30.22 | 30.64 | 29.88 | 30.25 |
| 500 ppm TU (spray) | 21.85 | 22.47 | 23.21 | 22.51 |
| 100 ppm DMSO (spray) | 32.63 | 32.51 | 31.23 | 32.12 |
| TU+DMSO (spray) | 22.33 | 21.88 | 23.09 | 22.43 |
| Mean | 30.11 | 28.66 | 27.84 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.388 | 0.633 | 1.096 | |
| C.D. (0.05) | 1.075 | 1.755 | 3.039 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 49.16 | 36.82 | 37.47 | 41.15 |
| 5 kg TU/ha in soil (basal) | 38.99 | 32.41 | 29.32 | 33.57 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 35.75 | 28.18 | 23.67 | 29.20 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 41.88 | 35.81 | 35.55 | 37.74 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 30.27 | 25.60 | 21.74 | 25.87 |
| 500 ppm TU (spray) | 30.40 | 24.89 | 21.48 | 25.59 |
| 100 ppm DMSO (spray) | 43.46 | 35.36 | 31.44 | 36.75 |
| TU+DMSO (spray) | 27.42 | 24.79 | 22.65 | 24.95 |
| Mean | 37.17 | 30.48 | 27.91 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.372 | 0.608 | 1.053 | |
| C.D. (0.05) | 1.032 | 1.685 | 2.918 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 43.66 | 35.58 | 34.25 | 37.16 |
| 5 kg TU/ha in soil (basal) | 36.44 | 32.95 | 28.64 | 32.68 |
| 5 kg TU/ha in soil ($^1/_2$+ $^1/_2$) | 33.31 | 27.74 | 25.36 | 28.81 |
| 2 kg DMSO/ha in soil ($^1/_2$+ $^1/_2$) | 36.39 | 33.24 | 32.42 | 34.02 |
| TU+DMSO in soil ($^1/_2$+ $^1/_2$) | 30.25 | 28.12 | 25.81 | 28.06 |
| 500 ppm TU (spray) | 26.13 | 23.68 | 22.35 | 24.05 |
| 100 ppm DMSO (spray) | 38.05 | 33.93 | 31.33 | 34.44 |
| TU+DMSO (spray) | 24.88 | 23.33 | 22.87 | 23.69 |
| Mean | 33.64 | 29.57 | 27.88 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.269 | 0.439 | 0.760 | |
| C.D. (0.05) | 0.745 | 1.216 | 2.107 | |

**Table: 4A.62 Effect of thiourea and DMSO on P distribution in pods at 90 DAS at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 37.82 | 43.95 | 43.43 | 41.73 |
| 5 kg TU/ha in soil (basal) | 36.47 | 36.53 | 39.36 | 37.45 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 41.36 | 44.76 | 47.00 | 44.37 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 39.82 | 39.89 | 40.55 | 40.08 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 45.28 | 44.84 | 45.29 | 45.14 |
| 500 ppm TU (spray) | 50.68 | 45.17 | 47.01 | 47.62 |
| 100 ppm DMSO (spray) | 41.10 | 41.22 | 39.96 | 40.76 |
| TU+DMSO (spray) | 49.28 | 48.07 | 46.99 | 48.11 |
| Mean | 42.73 | 43.05 | 43.70 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.633 | 1.035 | 1.792 | |
| C.D. (0.05) | NS | 2.868 | NS | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 41.92 | 49.31 | 49.48 | 46.90 |
| 5 kg TU/ha in soil (basal) | 45.49 | 49.19 | 50.59 | 48.43 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 46.96 | 50.02 | 53.50 | 50.16 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 46.82 | 48.60 | 45.24 | 46.89 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 52.24 | 52.31 | 52.52 | 52.36 |
| 500 ppm TU (spray) | 46.68 | 48.03 | 53.41 | 49.38 |
| 100 ppm DMSO (spray) | 46.29 | 48.61 | 49.74 | 48.22 |
| TU+DMSO (spray) | 51.36 | 50.68 | 50.75 | 50.93 |
| Mean | 47.22 | 49.58 | 50.65 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.407 | 0.665 | 1.153 | |
| C.D. (0.05) | 1.129 | 1.845 | 3.195 | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 39.87 | 46.63 | 46.46 | 44.32 |
| 5 kg TU/ha in soil (basal) | 40.98 | 42.86 | 44.98 | 42.94 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 44.16 | 47.39 | 50.25 | 47.27 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 43.32 | 44.24 | 42.89 | 43.49 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 48.76 | 48.58 | 48.91 | 48.75 |
| 500 ppm TU (spray) | 48.68 | 46.60 | 50.21 | 48.50 |
| 100 ppm DMSO (spray) | 43.70 | 44.92 | 44.85 | 44.49 |
| TU+DMSO (spray) | 50.32 | 49.38 | 48.87 | 49.52 |
| Mean | 44.97 | 46.33 | 47.18 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em $\pm$ | 0.377 | 0.615 | 1.065 | |
| C.D. (0:05) | 1.044 | 1.705 | 2.954 | |

TU+DMSO significantly increased P distribution in pods by 9.4 and 11.7 per cent, respectively over control.

Data on combined effects of treatments (Table 4A.62) show that TU and DMSO interacted significantly with phosphorus in influencing P distribution in pods at 90 DAS during 2000 only. Under no phosphorus, all the soil and foliar applied treatments of TU and DMSO significantly increased P distribution in pods at 90 DAS over control. Under 20 kg $P_2O_5$/ha, none of the soil and foliar applied treatments of TU and DMSO proved effective. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½) and foliar spray of 500 ppm TU significantly increased P distribution in pods over control. However, rest of the treatments remained unaffected. In pooled data, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (1/2+1/2), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased P distribution in pods at 90 DAS by 10.7, 8.6, 22.3, 22.1, 9.6 and 26.2 per cent, respectively over control. However, soil application of TU at 5 kg/ha (basal) remained unaffected in this respect. Foliar spray of TU+DMSO was most effective. Under 20 kg $P_2O_5$/ha, all the soil and foliar applied treatments of TU+DMSO remained unaffected. However, P distribution in pods at 90 DAS was significantly lower under soil application of TU at 5 kg/ha (basal), when compared with control. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½) and foliar spray of 500 ppm TU significantly increased P distribution in pods at 90 DAS by 8.2 and 7.9 per cent, respectively over control. However, rest of the treatments remained unaffected. The maximum P distribution in pods at 90 DAS (50.32%) was obtained with foliar spray of TU+DMSO under no phosphorus. The increases were of the order of 26.2, 7.9 and 8.3 per cent over no phosphorus, 20 and 40 kg $P_2O_5$/ha, respectively

**4A.5.20 P distribution in leaves at physiological maturity**

Data (Table 4A.63) show that phosphorus application did not influence P distribution in leaves at physiological maturity during both the years. In pooled data, similar trends were noted.

Soil application of TU at 5 kg/ha (basal) significantly increased P distribution in leaves at physiological maturity during 2000 only. Soil application of TU at 5 kg/ha (basal) and soil application of DMSO at 2 kg/ha (½+½) proved ineffective in 1999. Whereas, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (1/2+1/2) proved effective during both the years. In pooled data, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P distribution in leaves at physiological maturity by 14.8, 76.6 and 79.7 per cent, respectively over control. Soil application of DMSO at 2 kg/ha (½+½) did not proved effective in pooled data. Further, in pooled data, soil application of TU at 5 kg/ha (½+½) proved superior to soil application of TU at 5 kg/ha (basal).

Foliar sprays of 500 ppm, 100 ppm DMSO and TU+DMSO significantly increased P distribution in leaves at physiological maturity during both the years. In pooled data, similar trends were recorded. Thus, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased P distribution in leaves by 91.7, 31.7 and 102.5 per cent, respectively over control.

Data on combined effect of treatments (Table 4A.63) show that effects of TU and DMSO on P distribution in leaves at physiological maturity were significant under different levels of phosphorus in 2000 only. Under no phosphorus, all the soil and foliar applied treatments of TU and DMSO proved effective in increasing P distribution in leaves at physiological maturity over control. Under 20 and 40 kg $P_2O_5$/ha, except soil application of DMSO at 2 kg/ha (½+½), all the soil and foliar applied treatments of TU and DMSO proved effective in this respect. In pooled data, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased P distribution in leaves at physiological maturity by 51.5, 73.2, 98.6, 32.2 and 104.8 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased P distribution in leaves by 80.3, 87.2, 92.5, 27.8 and 91.8 per cent, respectively over control. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased P distribution in leaves at physiological maturity by 24.1, 100.3, 79.5, 83.0, 35.4 and 111.0 per cent, respectively over control. Under no phosphorus, the highest P distribution in leaves at physiological maturity (7.56%) was obtained with foliar spray of TU+DMSO followed by foliar spray of 500 ppm TU (7.33%). It was at par with foliar spray of 500 ppm TU under no phosphorus and foliar spray of TU+DMSO under 40 kg $P_2O_5$/ha but was significantly superior to rest of the treatments combinations in this respect.

### 4A.5.21 P distribution in stems at physiological maturity

Data (Table 4A.64) show that phosphorus application brought about significant decreased P distribution in stems at physiological maturity during both the years. In pooled data, 20 and 40 $P_2O_5$/ha significantly decreased P distribution in stems by 14.6 and 18.2 per cent, respectively over control. The significant difference was noted between 20 and 40 kg $P_2O_5$/ha.

**Table: 4A.63 Effect of thiourea and DMSO on P distribution in leaves at physiological maturity at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 4.83 | 3.81 | 3.69 | 4.11 |
| 5 kg TU/ha in soil (basal) | 4.15 | 4.20 | 4.51 | 4.29 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 6.57 | 7.51 | 7.65 | 7.24 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 4.41 | 3.86 | 3.93 | 4.06 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 7.17 | 7.11 | 6.46 | 6.91 |
| 500 ppm TU (spray) | 7.80 | 6.90 | 6.60 | 7.11 |
| 100 ppm DMSO (spray) | 5.93 | 5.06 | 5.34 | 5.44 |
| TU+DMSO (spray) | 8.07 | 7.04 | 7.45 | 7.52 |
| Mean | 6.11 | 5.68 | 5.70 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.166 | 0.271 | 0.469 | |
| C.D. (0.05) | NS | 0.752 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.55 | 3.09 | 3.04 | 2.89 |
| 5 kg TU/ha in soil (basal) | 3.56 | 3.88 | 3.82 | 3.75 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 4.61 | 4.94 | 5.82 | 5.12 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 3.73 | 3.29 | 3.51 | 3.51 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 5.61 | 5.82 | 3.61 | 5.68 |
| 500 ppm TU (spray) | 6.87 | 6.38 | 5.71 | 6.32 |
| 100 ppm DMSO (spray) | 3.85 | 3.76 | 3.76 | 3.79 |
| TU+DMSO (spray) | 7.05 | 6.21 | 6.74 | 6.67 |
| Mean | 4.73 | 6.67 | 4.75 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.071 | 0.116 | 0.201 | |
| C.D. (0.05) | NS | 0.321 | 0.556 | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 3.69 | 3.45 | 3.36 | 3.50 |
| 5 kg TU/ha in soil (basal) | 3.85 | 4.04 | 4.17 | 4.02 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 5.59 | 6.22 | 6.73 | 6.18 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 4.07 | 3.57 | 3.72 | 3.79 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 6.39 | 6.46 | 6.03 | 6.29 |
| 500 ppm TU (spray) | 7.33 | 6.64 | 6.15 | 6.71 |
| 100 ppm DMSO (spray) | 4.88 | 4.41 | 4.55 | 4.91 |
| TU+DMSO (spray) | 7.56 | 6.62 | 7.09 | 7.09 |
| Mean | 5.42 | 5.18 | 5.23 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.090 | 0.147 | 0.255 | |
| C.D. (0.05) | NS | 0.409 | 0.708 | |

**Table: 4A.64 Effect of thiourea and DMSO P distribution in stems at physiological maturity at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 39.26 | 28.65 | 28.48 | 32.13 |
| 5 kg TU/ha in soil (basal) | 31.78 | 30.05 | 27.45 | 29.76 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 31.12 | 21.55 | 20.94 | 24.54 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 33.27 | 29.11 | 27.45 | 29.94 |
| TU+DMSO in soil (1/2 + 1/2) | 31.32 | 23.67 | 22.19 | 25.73 |
| 500 ppm TU (spray) | 24.93 | 18.59 | 19.02 | 20.85 |
| 100 ppm DMSO (spray) | 33.49 | 27.69 | 27.56 | 29.58 |
| TU+DMSO (spray) | 25.35 | 18.74 | 18.80 | 20.96 |
| Mean | 31.31 | 24.75 | 23.99 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.299 | 0.488 | 0.845 | |
| C.D. (0.05) | 0.829 | 1.353 | 2.344 | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 35.67 | 32.23 | 29.12 | 32.34 |
| 5 kg TU/ha in soil (basal) | 32.58 | 31.43 | 28.08 | 30.70 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 31.03 | 28.68 | 28.15 | 29.29 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 33.02 | 30.52 | 29.66 | 31.07 |
| TU+DMSO in soil (1/2 + 1/2) | 30.98 | 27.59 | 27.81 | 28.80 |
| 500 ppm TU (spray) | 31.12 | 27.56 | 27.93 | 28.87 |
| 100 ppm DMSO (spray) | 33.14 | 31.46 | 27.79 | 30.80 |
| TU+DMSO (spray) | 31.04 | 27.09 | 25.95 | 28.03 |
| Mean | 32.32 | 29.57 | 28.06 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.308 | 0.503 | 0.871 | |
| C.D. (0.05) | 0.853 | 1.394 | NS | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 37.47 | 30.44 | 28.80 | 32.24 |
| 5 kg TU/ha in soil (basal) | 32.18 | 30.74 | 27.77 | 30.23 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 31.08 | 25.12 | 24.55 | 26.91 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 33.15 | 29.82 | 28.56 | 30.51 |
| TU+DMSO in soil (1/2 + 1/2) | 31.15 | 25.63 | 25.00 | 27.26 |
| 500 ppm TU (spray) | 28.03 | 23.07 | 23.48 | 24.86 |
| 100 ppm DMSO (spray) | 33.31 | 29.58 | 27.68 | 30.19 |
| TU+DMSO (spray) | 28.20 | 22.92 | 22.38 | 24.50 |
| Mean | 31.82 | 27.16 | 26.03 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.215 | 0.350 | 0.607 | |
| C.D. (0.05) | 0.595 | 0.971 | 1.682 | |

Soil application of TU at 5 kg/ha (basal) significantly decreased P distribution in stems at physiological maturity over control during both the years. Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) also significantly decreased P distribution in stems during both the years. However, soil application of DMSO at 2 kg/ha (½+½) proved effective in 1999 only. In pooled data, all the soil applied treatments proved effective. Soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly decreased P distribution by 6.2, 16.5 5.4 and 15.4 per cent, respectively over control.

Foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly decreased P distribution in stems at physiological maturity during both the years. In pooled data also, similar trends were noted. The per cent decreased in P distribution in stems were in the order of 22.9, 6.4 and 24.0 over control.

Data on combined effects of treatments (Table 4A.64) show that TU and DMSO interacted significantly in influencing P distribution in stems at physiological maturity only in 1999. Under no phosphorus, all the soil and foliar applied treatments of TU and DMSO significantly reduced P distribution in stems at physiological maturity over control. Under 20 and 40 kg $P_2O_5$/ha, P distribution in stems significantly reduced due to soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO. Pooled data also show the similar trends. Further more, under 20 kg $P_2O_5$/ha, magnitude of reduction in P distribution in stems at physiological maturity was highest under foliar spray of TU+DMSO. It was significant with rest of treatment combinations except foliar spray of 500 ppm TU under 20 kg $P_2O_5$/ha and foliar spray of 500 ppm TU and foliar spray of TU+DMSO under 40 kg $P_2O_5$/ha.

#### 4A.5.22 P distribution in pods at physiological maturity

Data (Table 4A.65) reveal that phosphorus application brought about significant increase in P distribution in pods at physiological maturity during both the years. In pooled data, 20 and 40 kg $P_2O_5$/ha significantly increased P distribution in pods by 7.8 and 9.6 per cent, respectively over control. Further, 40 kg $P_2O_5$/ha was superior to 20 kg $P_2O_5$/ha.

All the soil applied treatment significantly increased P distribution in pods at physiological maturity during 1999 only. Whereas, in 2000, none of the soil applied treatments were effective in this respect. In pooled data, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P distribution in pods by

**Table: 4A.65 Effect of thiourea and DMSO on P distribution in pods at physiological maturity at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 55.66 | 67.54 | 67.83 | 63.68 |
| 5 kg TU/ha in soil (basal) | 64.08 | 65.75 | 68.04 | 65.96 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 62.31 | 70.94 | 71.41 | 68.22 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 62.32 | 67.04 | 68.62 | 65.99 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 61.51 | 69.22 | 71.11 | 67.28 |
| 500 ppm TU (spray) | 67.27 | 74.52 | 74.37 | 72.05 |
| 100 ppm DMSO (spray) | 60.59 | 67.25 | 67.85 | 65.23 |
| TU+DMSO (spray) | 66.58 | 74.22 | 73.75 | 71.52 |
| Mean | 62.53 | 69.56 | 70.37 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.381 | 0.622 | 1.078 | |
| C.D. (0.05) | 1.056 | 1.725 | 2.988 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 61.79 | 64.69 | 67.84 | 64.77 |
| 5 kg TU/ha in soil (basal) | 63.86 | 64.70 | 68.10 | 65.55 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 64.36 | 66.38 | 66.03 | 65.59 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 63.25 | 66.18 | 66.83 | 65.42 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 63.41 | 66.59 | 66.58 | 65.53 |
| 500 ppm TU (spray) | 62.01 | 66.06 | 65.69 | 64.59 |
| 100 ppm DMSO (spray) | 63.02 | 64.78 | 68.44 | 65.41 |
| TU+DMSO (spray) | 61.91 | 66.70 | 67.31 | 65.30 |
| Mean | 62.95 | 65.76 | 67.10 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.310 | 0.507 | 0.877 | |
| C.D. (0.05) | 0.860 | NS | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 58.72 | 66.11 | 67.84 | 64.22 |
| 5 kg TU/ha in soil (basal) | 63.97 | 65.22 | 68.07 | 65.75 |
| 5 kg TU/ha in soil ($^1/_2+^1/_2$) | 63.33 | 68.66 | 68.72 | 66.90 |
| 2 kg DMSO/ha in soil ($^1/_2+^1/_2$) | 62.79 | 66.61 | 67.72 | 65.71 |
| TU+DMSO in soil ($^1/_2+^1/_2$) | 62.46 | 67.91 | 68.84 | 66.40 |
| 500 ppm TU (spray) | 64.64 | 70.29 | 70.03 | 68.32 |
| 100 ppm DMSO (spray) | 61.80 | 66.02 | 68.15 | 65.32 |
| TU+DMSO (spray) | 64.24 | 70.46 | 70.53 | 68.41 |
| Mean | 62.74 | 67.66 | 68.74 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.246 | 0.401 | 0.695 | |
| C.D. (0.05) | 0.681 | 1.112 | 1.926 | |

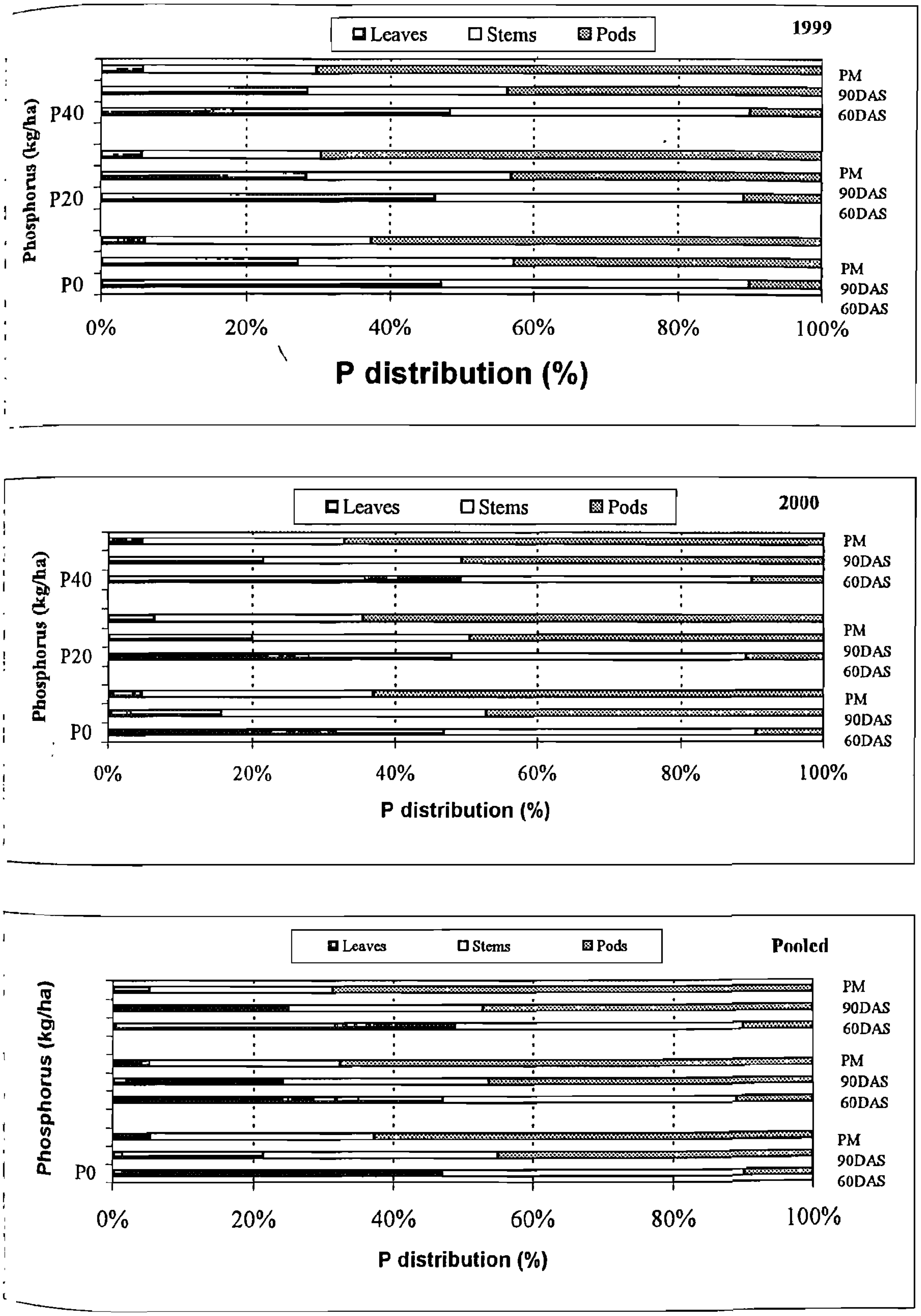



Fig. 4.7 Effect of phosphorus on P distribution (%)

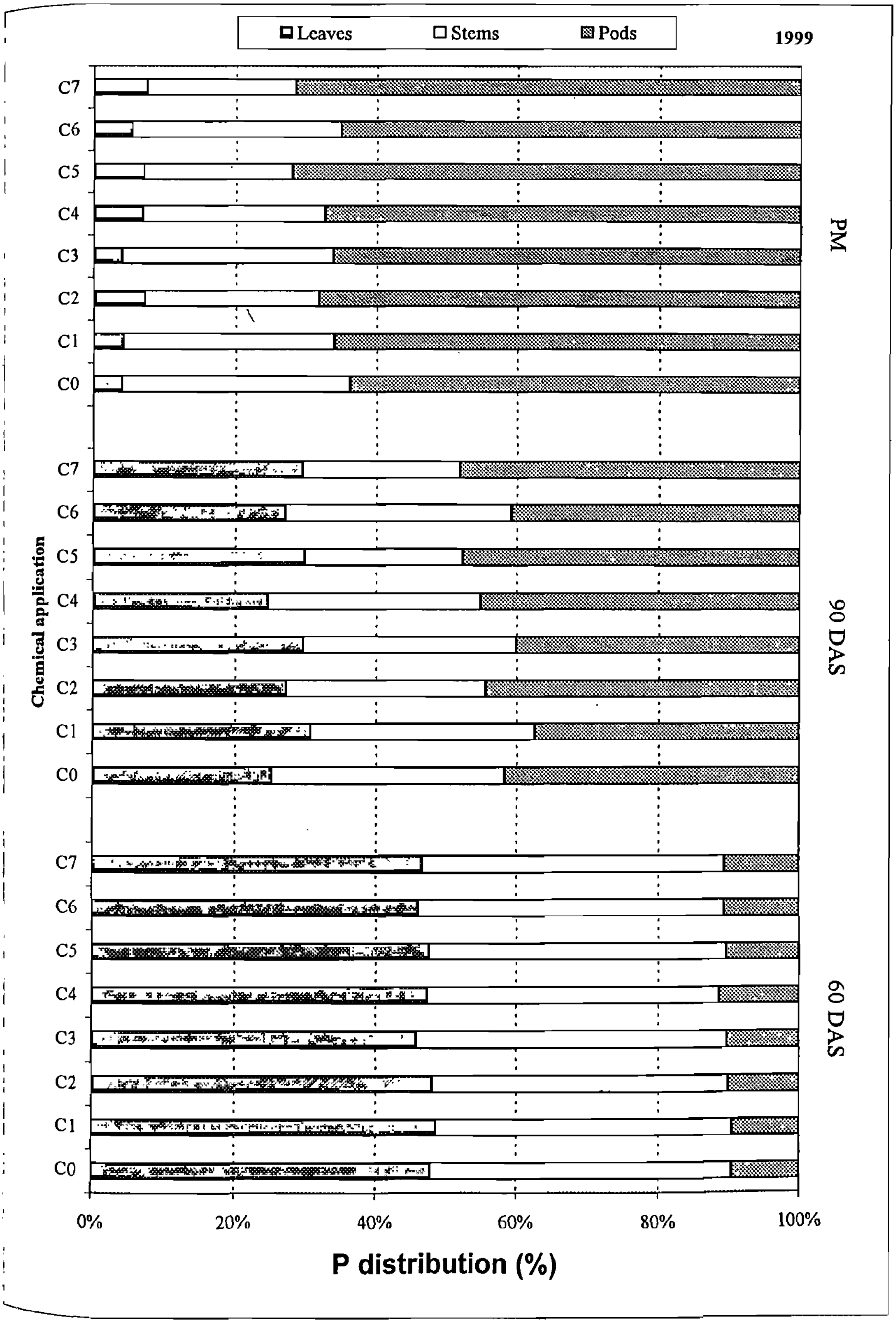



Fig. 4.8 Effect of thiourea and DMSO on P distribution (%) 1999

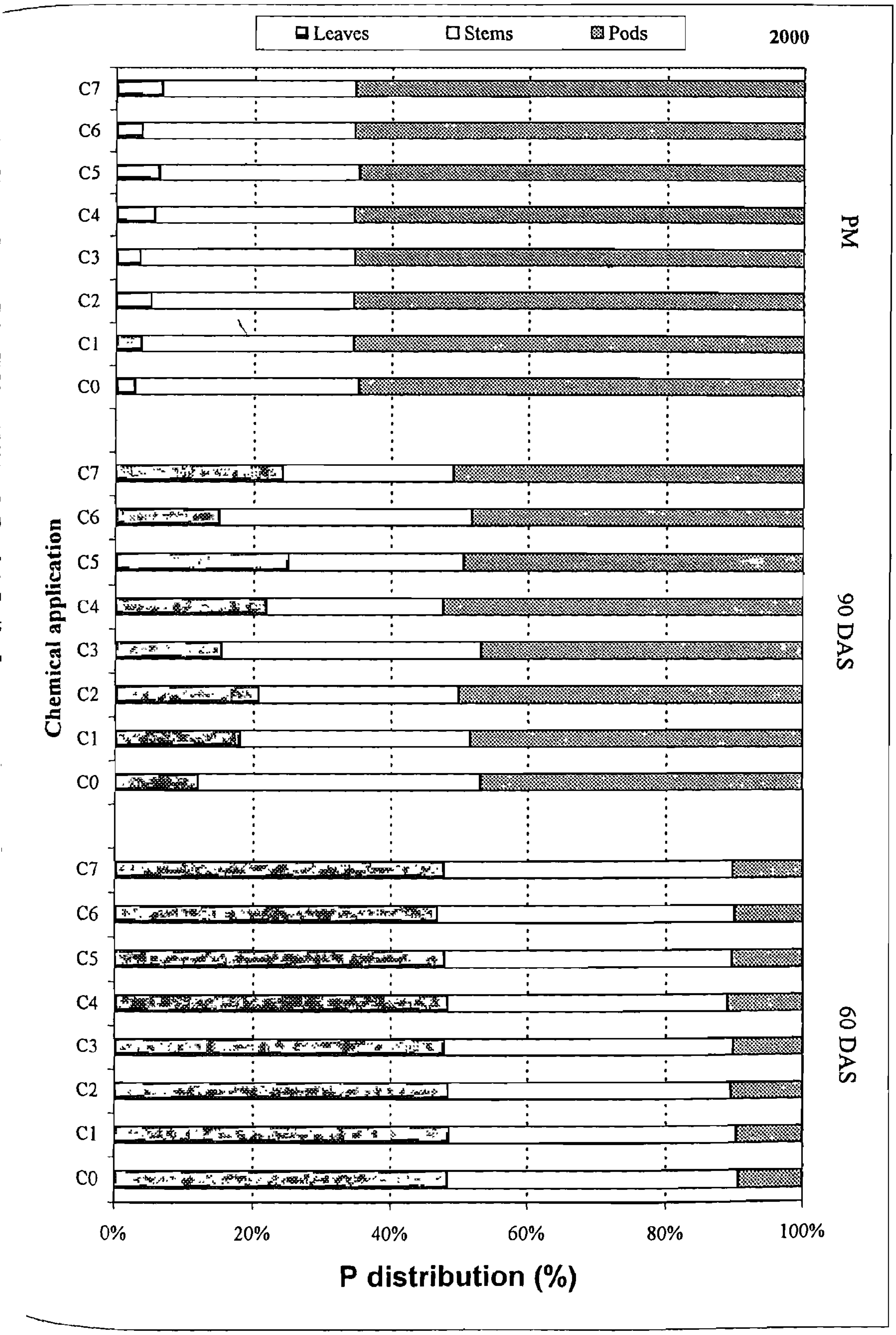



Fig. 4.9 Effect of thiourea and DMSO on P distribution (%) 2000

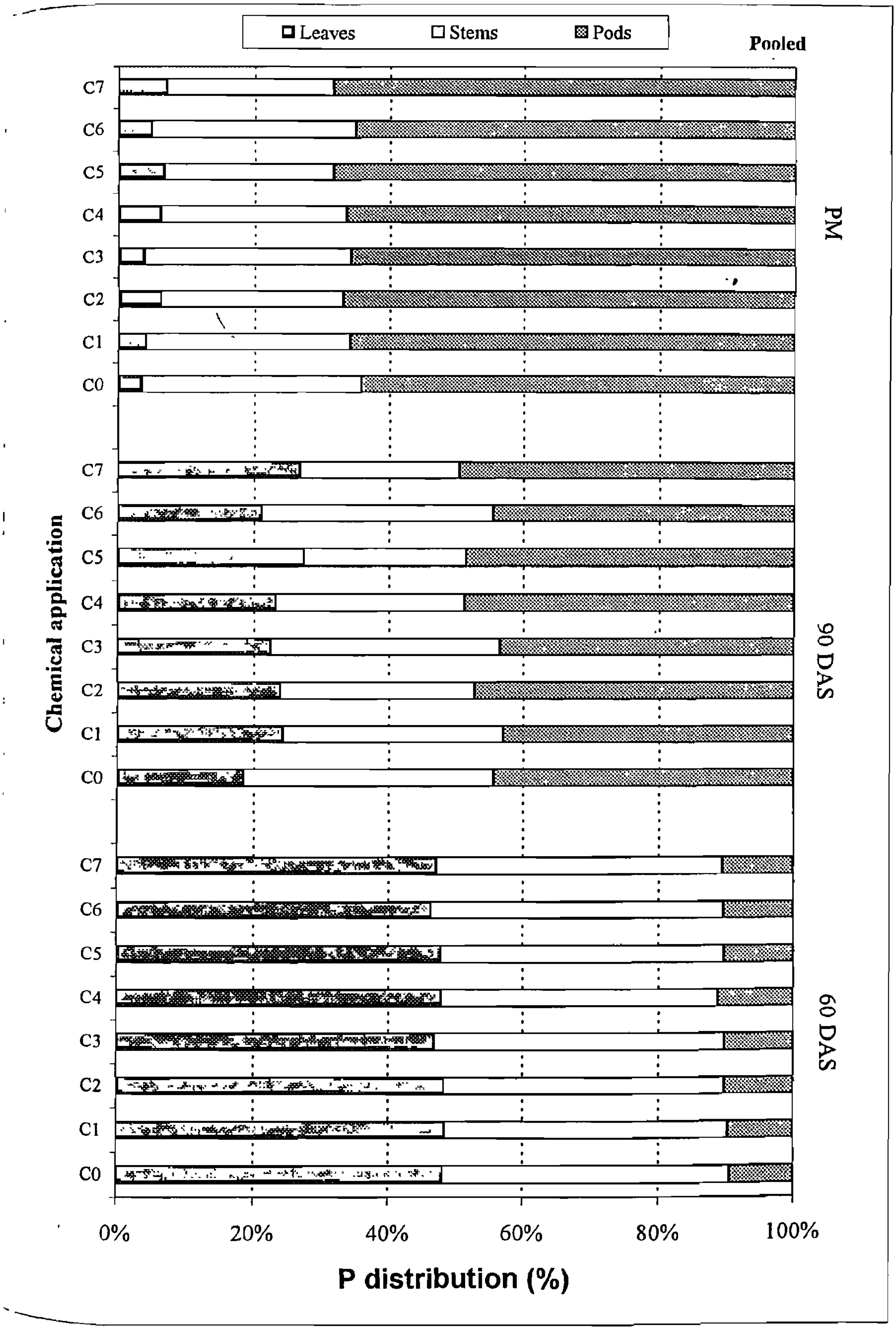



Fig. 4.10 Effect of thiourea and DMSO on P distribution (%) pooled

2.4, 4.2, 2.3 and 3.4 per cent, respectively over control. Soil application of TU at 5 kg/ha (½+½) proved superior to soil application of TU at 5 kg/ha (basal).

Foliar spray of 500 ppm TU and TU+DMSO significantly increased P distribution in pods during 1999 only. However, in 2000, all the foliar spray treatments were ineffective. In pooled data, foliar sprays of 500 ppm TU and TU+DMSO significantly increased P distribution in pods by 6.4 and 6.5 par cent, respectively over control.

Data on combined effects of treatments (Table 4A.65) show that TU and DMSO interacted significantly in influencing P distribution in pods at physiological maturity during 1999 only. Under no phosphorus, all the soil and foliar applied treatments of TU and DMSO significantly increased P distribution in pods at physiological maturity over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased P distribution in pods over control. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO proved effective. In pooled data, all the soil and foliar applied treatments of TU and DMSO significantly increased P distribution in pods at physiological maturity over control under no phosphorus. However, under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO proved effective. Under 40 kg $P_2O_5$/ha, only foliar spray of 500 TU and foliar spray of TU+DMSO proved effective in increasing P distribution in pods at physiological maturity over control. Under 20 kg $P_2O_5$/ha, the highest P distribution in pods at physiological maturity (70.46%) was obtained with foliar spray of TU+DMSO. However, it was at par with soil application of TU at 5 kg/ha (½+½) and foliar spray of 500 ppm TU under 20 kg $P_2O_5$/ha. When compared to absolute control, 20 and 40 kg $P_2O_5$/ha, the increases were of the order of 19.9, 6.8 and 3.9 per cent, respectively.

## 4A.6 EFFECT OF TU AND DMSO AT VARYING LEVELS OF PHOSPHORUS ON P UPTAKE

### 4A.6.1 P uptake by seed

Data (Table 4A.66) show that successive increase in P levels upto 40 kg $P_2O_5$/ha significantly increased P uptake by seed during 1999, however, it responded significantly upto 20 kg $P_2O_5$/ha during 2000. In pooled data, 40 kg $P_2O_5$/ha proved superior to 20 kg $P_2O_5$/ha. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly increased P uptake by 43.7 and 52.4 per cent, respectively over control.

Soil application of TU at 5 kg/ha (½+½) significantly increased P uptake by seed over control during both the years. In pooled data, soil application of TU at 5 kg/ha (½+½) significantly increased P uptake by 15.4 per cent over soil application of TU at 5 kg/ha (basal). Soil application of DMSO at 2 kg/ha (½+½) has significant effect on P uptake during 1999, whereas in 2000 it failed to improve in P uptake. However, soil application of TU+DMSO (½+½) significantly increased P uptake by seed during both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P uptake by 22.2 and 23.9 per cent, respectively over control. However, both the treatments were at par in this respect.

Foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased P uptake by seed during 1999. However, in 2000 foliar spray of 100 ppm DMSO did not cause significant improvement in P uptake by seed. On the basis of pooled data, foliar sprays of 500 ppm TU and TU+DMSO significantly increased P uptake by seed by 12.7 and 15.3 per cent, respectively over control.

Data (Table 4A.66) further show that application of TU and DMSO interacted significantly with phosphorus in influencing P uptake by seed in 1999 only. In 2000, interaction effects were not significant. In 1999, under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased P uptake by seed over control. Under 20 kg $P_2O_5$/ha, only soil application of TU at 5 kg/ha (½+½) proved effective in incresing P uptake by seed over control. Under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of 100 ppm DMSO significantly increased P uptake by seed over control. However, these treatments were at par with soil application of TU at 5 kg/ha (½+½) under 20 kg $P_2O_5$/ha. The highest P uptake of 11.61 kg/ha obtained with soil application of TU at 5 kg/ha (½+½) under 20 kg $P_2O_5$/ha. When compared to absolute control, the increases were of the order of 91.3 per cent. In pooled data, interaction effects were not significant

#### 4A.6.2 P uptake by straw

Data (Table 4A.67) indicate that phosphorus application brought about significant increased P uptake by straw upto 20 kg $P_2O_5$/ha during both the years. In pooled data, 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha in this respect. Pooled data show that application of 20 and 40 kg $P_2O_5$/ha significantly incrcased P uptake by straw by 33.2 and 37.5 per cent, respectively over control.

Effect of soil applied treatments on P uptake by straw were significant in 2000 only. Soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P uptake by straw over control, whereas soil application of TU at 5 kg /ha (basal) and soil application of DMSO at 2 kg /ha (½+½) proved ineffective. In pooled

**Table: 4A66 Effect of thiourea and DMSO on P uptake by seed (kg/ha) at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 6.07 | 9.71 | 10.04 | 8.60 |
| 5 kg TU/ha in soil (basal) | 6.74 | 10.17 | 9.79 | 8.90 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 9.59 | 11.61 | 11.40 | 10.87 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 7.71 | 9.89 | 10.25 | 9.29 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 9.44 | 10.90 | 11.67 | 10.67 |
| 500 ppm TU (spray) | 7.09 | 10.81 | 11.68 | 9.86 |
| 100 ppm DMSO (spray) | 8.03 | 9.43 | 11.09 | 9.52 |
| TU+DMSO (spray) | 8.51 | 10.75 | 10.83 | 10.03 |
| Mean | 7.90 | 10.41 | 10.84 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.152 | 0.249 | 0.431 | |
| C.D. (0.05) | 0.421 | 0.690 | 1.195 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 5.61 | 9.43 | 11.02 | 8.69 |
| 5 kg TU/ha in soil (basal) | 6.02 | 10.13 | 12.09 | 9.41 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 7.35 | 11.52 | 11.95 | 10.27 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 6.43 | 9.84 | 10.89 | 9.05 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 7.62 | 12.33 | 12.34 | 10.76 |
| 500 ppm TU (spray) | 6.97 | 10.47 | 11.47 | 9.64 |
| 100 ppm DMSO (spray) | 6.98 | 10.51 | 10.67 | 9.39 |
| TU+DMSO (spray) | 7.19 | 10.91 | 11.60 | 9.90 |
| Mean | 6.77 | 10.64 | 11.50 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.180 | 0.294 | 0.508 | |
| C.D. (0.05) | 0.502 | 0.814 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 5.84 | 9.57 | 10.53 | 8.65 |
| 5 kg TU/ha in soil (basal) | 6.38 | 10.15 | 10.94 | 9.16 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 8.47 | 11.56 | 11.67 | 10.57 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 7.07 | 9.87 | 10.57 | 9.17 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 8.53 | 11.62 | 12.01 | 10.72 |
| 500 ppm TU (spray) | 7.03 | 10.64 | 11.57 | 9.75 |
| 100 ppm DMSO (spray) | 7.51 | 9.97 | 10.88 | 9.45 |
| TU+DMSO (spray) | 7.85 | 10.83 | 11.22 | 9.97 |
| Mean | 7.33 | 10.53 | 11.17 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.188 | 0.192 | 0.333 | |
| C.D. (0.05) | 0.327 | 0.533 | NS | |

**Table: 4A.67 Effect of thiourea and DMSO on P uptake (kg/ha) by straw at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 9.33 | 13.32 | 14.32 | 12.32 |
| 5 kg TU/ha in soil (basal) | 9.34 | 13.84 | 13.26 | 12.14 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 12.44 | 12.79 | 15.38 | 13.53 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 10.81 | 12.61 | 13.08 | 12.16 |
| TU+DMSO in soil (1/2 + 1/2) | 11.91 | 13.56 | 13.14 | 12.87 |
| 500 ppm TU (spray) | 9.36 | 14.16 | 13.93 | 12.48 |
| 100 ppm DMSO (spray) | 10.31 | 11.75 | 13.96 | 11.67 |
| TU+DMSO (spray) | 11.77 | 13.92 | 13.10 | 12.93 |
| Mean | 10.66 | 13.24 | 13.64 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.303 | 0.495 | 0.857 | |
| C.D. (0.05) | 0.840 | NS | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 8.97 | 14.23 | 14.92 | 12.70 |
| 5 kg TU/ha in soil (basal) | 9.50 | 14.92 | 16.18 | 13.53 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 11.02 | 15.45 | 15.07 | 13.84 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 10.24 | 14.78 | 14.86 | 13.29 |
| TU+DMSO in soil (1/2 + 1/2) | 11.31 | 16.14 | 15.91 | 14.45 |
| 500 ppm TU (spray) | 10.94 | 13.69 | 14.79 | 13.14 |
| 100 ppm DMSO (spray) | 10.43 | 14.76 | 15.55 | 13.58 |
| TU+DMSO (spray) | 10.75 | 14.25 | 15.01 | 13.34 |
| Mean | 10.39 | 14.78 | 15.28 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.266 | 0.434 | 0.752 | |
| C.D. (0.05) | 0.737 | 1.203 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 9.15 | 13.77 | 14.62 | 12.51 |
| 5 kg TU/ha in soil (basal) | 19.42 | 14.38 | 14.72 | 12.84 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 11.70 | 14.12 | 15.22 | 13.89 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 10.52 | 13.69 | 13.97 | 12.73 |
| TU+DMSO in soil (1/2 + 1/2) | 11.61 | 14.85 | 14.52 | 13.66 |
| 500 ppm TU (spray) | 10.15 | 13.93 | 14.36 | 12.81 |
| 100 ppm DMSO (spray) | 10.37 | 13.25 | 14.26 | 12.63 |
| TU+DMSO (spray) | 11.26 | 14.09 | 14.05 | 13.13 |
| Mean | 10.52 | 14.01 | 14.46 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.202 | 0.329 | 0.570 | |
| C.D. (0.05) | 0.559 | NS | NS | |

data, all the soil applied treatments of TU and DMSO did not cause significant improvement in P uptake by straw.

All the foliar spray treatments of TU and DMSO did not bring about significant variation in P uptake by straw during both the years. Pooled data also exhibited similar trends.

#### 4A.6.3 Total P uptake

Data (Table 4A.68) show that phosphorus application resulted in significant increase in total P uptake upto 20 kg $P_2O_5$/ha during 1999 and upto 40 kg $P_2O_5$/ha in 2000. In pooled data, 40 kg $P_2O_5$/ha proved superior to 20 kg $P_2O_5$/ha. Application of 20 and 40 kg $P_2O_5$/ha significantly increased total P uptake by 37.3 and 43.4 per cent, respectively over control.

Soil application of TU at 5 kg /ha (½+½) significantly increased total P uptake over control. In pooled data, significant increase in total P uptake by 10.3 per cent due to soil application of TU at 5 kg /ha (½+½) over soil application of TU at 5 kg /ha (basal). Soil application of DMSO at 2 kg /ha (½+½) also did not influence the total P uptake during both the years, whereas soil application of TU+DMSO (½+½) has significant effect. On the basis of pooled data, soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO (½+½) significantly increased total P uptake by 14.7 and 15.2 per cent, respectively over control.

Foliar sprays of 500 ppm TU and TU+DMSO cause significant effects on total P uptake in 1999, whereas in 2000 all the foliar spray treatments were proved ineffective in this respect. Pooled data show that foliar spray of 500 ppm TU and TU+DMSO significantly increased total P uptake by 6.6 and 9.2 per cent, respectively over control.

Data (Table 4A.68) further show that application of TU and DMSO interacted significantly with phosphorus in influencing total P uptake in 1999 only. In 2000, interaction effects were not significant. In 1999, under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased total P uptake by 43.1, 20.6, 38.7, 19.1 and 31.7 per cent, respectively over control. Under 20 and 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments of TU and DMSO proved effective in this respect. Under 40 kg $P_2O_5$/ha, the highest total P uptake of 26.78 and 25.61 kg/ha was obtained with soil application of TU at 5 kg/ha (1/2+1/2) and foliar spray of 500 ppm TU, respectively over control. However, these treatments were at per with soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm and foliar spray of TU+DMSO under 20 kg $P_2O_5$/ha. Under 20 kg P2O5/ha, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of TU+(½+½), foliar spray of 500 ppm TU and foliar spray of

**Table: 4A.68 Effect of thiourea and DMSO on total P uptake (kg/ha) at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 15.40 | 23.03 | 24.22 | 20.88 |
| 5 kg TU/ha in soil (basal) | 16.08 | 24.00 | 23.04 | 21.04 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 22.03 | 24.40 | 26.78 | 24.40 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 18.58 | 22.50 | 23.32 | 21.47 |
| TU+DMSO in soil (1/2 + 1/2) | 21.36 | 24.46 | 24.81 | 23.54 |
| 500 ppm TU (spray) | 16.44 | 24.97 | 25.61 | 22.34 |
| 100 ppm DMSO (spray) | 18.34 | 21.18 | 24.05 | 21.19 |
| TU+DMSO (spray) | 20.28 | 24.67 | 23.93 | 22.96 |
| Mean | 18.56 | 23.65 | 24.47 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.374 | 0.611 | 1.058 | |
| C.D. (0.05) | 1.037 | 1.694 | 2.933 | |

| **Year 2000** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 14.73 | 23.66 | 25.94 | 21.44 |
| 5 kg TU/ha in soil (basal) | 15.52 | 25.06 | 28.27 | 22.95 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 18.36 | 26.96 | 27.01 | 24.11 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 16.67 | 24.62 | 25.74 | 22.34 |
| TU+DMSO in soil (1/2 + 1/2) | 18.93 | 28.47 | 28.25 | 25.21 |
| 500 ppm TU (spray) | 17.91 | 24.16 | 26.26 | 22.78 |
| 100 ppm DMSO (spray) | 17.42 | 25.27 | 26.22 | 22.97 |
| TU+DMSO (spray) | 17.94 | 25.16 | 26.61 | 23.24 |
| Mean | 17.18 | 25.42 | 26.78 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.410 | 0.670 | 1.160 | |
| C.D. (0.05) | 1.136 | 1.857 | Ns | |

| **Pooled** | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 15.07 | 23.34 | 25.08 | 21.16 |
| 5 kg TU/ha in soil (basal) | 15.79 | 24.53 | 25.66 | 21.99 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 20.19 | 25.68 | 26.89 | 24.26 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 17.62 | 23.56 | 24.53 | 21.91 |
| TU+DMSO in soil (1/2 + 1/2) | 20.14 | 26.46 | 26.53 | 24.38 |
| 500 ppm TU (spray) | 17.18 | 24.57 | 25.94 | 22.56 |
| 100 ppm DMSO (spray) | 17.88 | 23.22 | 25.14 | 22.08 |
| TU+DMSO (spray) | 19.11 | 24.92 | 25.27 | 23.10 |
| Mean | 17.87 | 24.54 | 25.63 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.278 | 0.453 | 0.785 | |
| C.D. (0.05) | 0.769 | 1.257 | NS | |

TU+DMSO significantly increased total P uptake by 55.8, 58.4, 58.8, 62.1 and 60.9 per cent, respectively over absolute control. Combined effects of treatments on total P uptake, however, turned out non-significant in pooled data.

#### 4A.6.4 Agronomic efficiency

Data (Table 4A.69) show that agronomic efficiency decreased with incresing levels of phosphorus during both the years. Mean data show that application of 20 and 40 kg $P_2O_5$/ha gave an agronomic efficiency of 32.9 and 18.9 kg grain/kg applied P/ha, respectively.

All the soil applied treatments proved effective in increasing agronomic efficiency of the crop during both the years. Mean data show that the highest agronomic efficiency of 30.4 kg grain/kg applied P/ha was recorded due to soil application of TU+DMSO followed by soil application of TU at 5 kg/ha (½+½)

Agronomic efficiency increased under all the foliar spray treatments during both the years. Foliar spray of 500 ppm TU, 100 ppm DMSO and TU+DMSO recorded higher agronomic efficiency of 27.2, 24.1 and 27.3 kg grain/kg applied P/ha, respectively in comparison to control (21.3 kg grain/ kg applied P/ ha).

#### 4A.6.5 Physiological efficiency

Data (Table 4A.70) show that physiological efficiency increased with increasing levels of phosphorus during both the years. Mean data show that application of 40 kg $P_2O_5$/ha gave higher physiological efficiency (71.9 kg grain/ kg P uptake/ha) in comparison to 20 kg $P_2O_5$/ha (69.4 kg grain/ kg P uptake/ha).

Physiological efficiency increased due to all the soil applied treatments over control during both the years. On the basis of mean data, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg /ha and soil application of TU+DMSO recorded higher physiological efficiency of 66.8, 71.2, 70.5 and 71.9 kg grain/ kg P uptake/ ha, respectively over control (64.4 kg grain/kg P uptake/ha).

All the foliar spray treatments also proved effective in increasing physiological efficiency over control during both the years. The magnitude of increase in physiological efficiency due to foliar spray treatments was higher in comparison to soil applied treatments. In mean data, the highest physiological efficiency (73.6 kg grain/ kg P uptake/ha) was obtained under foliar spray of 500 ppm TU followed by foliar sprays of 100 ppm DMSO and TU+DMSO (73.3 kg grain/ kg P uptake/ ha).

**Table: 4A.69 Effect of thiourea and DMSO on agronomic efficiency at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 23.4 | 12.2 | 17.8 |
| 5 kg TU/ha in soil (basal) | 27.0 | 11.2 | 19.1 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 35.5 | 16.9 | 26.2 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 25.5 | 13.8 | 19.7 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 29.5 | 17.9 | 23.7 |
| 500 ppm TU (spray) | 30.8 | 19.2 | 25.0 |
| 100 ppm DMSO (spray) | 20.7 | 17.6 | 19.2 |
| TU+DMSO (spray) | 30.8 | 15.2 | 23.0 |
| Mean | 27.8 | 15.5 | |

| Year 2000 | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 28.8 | 20.6 | 24.7 |
| 5 kg TU/ha in soil (basal) | 34.8 | 25.1 | 29.9 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 43.7 | 23.3 | 33.5 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 32.4 | 20.6 | 26.5 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 49.1 | 24.9 | 37.0 |
| 500 ppm TU (spray) | 36.4 | 22.5 | 29.5 |
| 100 ppm DMSO (spray) | 38.0 | 19.9 | 28.9 |
| TU+DMSO (spray) | 40.1 | 22.9 | 31.5 |
| Mean | 37.9 | 22.5 | |

| Pooled | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 26.1 | 16.4 | 21.3 |
| 5 kg TU/ha in soil (basal) | 30.9 | 18.1 | 24.5 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 39.6 | 20.1 | 29.9 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 28.9 | 17.2 | 23.1 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 39.3 | 21.5 | 30.4 |
| 500 ppm TU (spray) | 33.6 | 20.8 | 27.2 |
| 100 ppm DMSO (spray) | 29.4 | 18.7 | 24.1 |
| TU+DMSO (spray) | 35.5 | 19.1 | 27.3 |
| Mean | 32.9 | 18.9 | |

**Table: 4A.70 Effect of thiourea and DMSO on physiological efficiency at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 61.3 | 55.4 | 58.4 |
| 5 kg TU/ha in soil (basal) | 62.8 | 58.5 | 60.7 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 78.9 | 59.2 | 69.1 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 71.8 | 69.8 | 70.8 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 65.0 | 76.2 | 70.6 |
| 500 ppm TU (spray) | 64.4 | 75.0 | 69.7 |
| 100 ppm DMSO (spray) | 71.8 | 81.2 | 76.5 |
| TU+DMSO (spray) | 66.6 | 71.0 | 68.8 |
| Mean | 67.8 | 68.3 | |

| Year 2000 | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 64.5 | 73.6 | 69.1 |
| 5 kg TU/ha in soil (basal) | 67.4 | 74.0 | 70.7 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 71.4 | 75.7 | 73.6 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 65.4 | 74.9 | 70.2 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 71.4 | 73.9 | 72.7 |
| 500 ppm TU (spray) | 77.2 | 77.9 | 77.6 |
| 100 ppm DMSO (spray) | 72.1 | 69.4 | 70.8 |
| TU+DMSO (spray) | 76.8 | 77.3 | 77.1 |
| Mean | 70.8 | 74.6 | |

| Pooled | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 63.1 | 65.6 | 64.4 |
| 5 kg TU/ha in soil (basal) | 65.3 | 68.4 | 66.8 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 74.6 | 67.8 | 71.2 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 68.2 | 72.8 | 70.5 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 68.9 | 74.9 | 71.9 |
| 500 ppm TU (spray) | 70.7 | 76.5 | 73.6 |
| 100 ppm DMSO (spray) | 72.1 | 74.4 | 73.3 |
| TU+DMSO (spray) | 71.9 | 74.7 | 73.3 |
| Mean | 69.4 | 71.9 | |

### 4A.6.6 P recovery

Data (Table 4A.71) show that higher P recovery was recorded under lower dose of phosphorus during both the years. In mean data higher P recovery (47.36 %) was obtained due to 20 kg $P_2O_5$/ha in comparison to 40 kg $P_2O_5$/ha (26.42%).

Soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO increased P recovery over control during both the years. In mean data, the corresponding values were 36.9, 38.99 and 37.86 %. Foliar sprays of 500 ppm TU and TU+DMSO increased P recovery over control during both the years. In mean data, P recovery of 37.34 and 37.86 % was obtained due to foliar sprays of 500 ppm TU and TU+DMSO, respectively in comparison to control (33.22 %).

### 4A.6.7 P harvest index

Data (Table 4A.72) show that phosphorus application brought about significant increase in P harvest index upto 40 kg $P_2O_5$/ha during 2000 only. In pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased P harvest index by 4.6 and 6.3 per cent, respectively over control. Further, 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha in this respect.

Soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P harvest index during both the years. Soil application of DMSO at 2 kg /ha (½+½) proved ineffective during both the years. In pooled data, soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO (½+½) significantly increased P harvest index by 7.3 and 7.9 per cent, respectively over control. Soil application of TU at 5 kg /ha (basal) and soil application of DMSO at 2 kg /ha (½+½) proved ineffective in pooled data.

All the foliar spray treatments proved effective in increasing P harvest index during both the years, except foliar spray of 100 ppm DMSO in 2000. In pooled data, foliar sprays of 500 ppm, 100 ppm DMSO and TU+DMSO significantly increased P harvest index by 6.1, 5.7 and 5.7 per cent, respectively over control.

## 4A.7 ECONOMICS OF THE TREATMENTS

### 4A7.1 Net monetary returns

Data (Table 4A.73) show that phosphorus application resulted in significant increase in net monetary return upto 20 kg $P_2O_5$/ha during 1999 and upto 40 kg $P_2O_5$/ha during 2000. In pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased net monetary returns by Rs 5671 and Rs 6791 per hectare, respectively over control (Rs 13424 per ha). Further, 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha.

**Table: 4A.70 Effect of thiourea and DMSO on P recovery (%) at varying levels of phosphorus**

| **Year 1999** | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 38.15 | 22.05 | 30.10 |
| 5 kg TU/ha in soil (basal) | 43.00 | 19.10 | 31.05 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 45.00 | 28.45 | 32.05 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 35.50 | 19.80 | 27.65 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 45.30 | 23.53 | 34.42 |
| 500 ppm TU (spray) | 47.85 | 25.53 | 36.69 |
| 100 ppm DMSO (spray) | 28.90 | 21.63 | 25.26 |
| TU+DMSO (spray) | 46.35 | 21.33 | 33.84 |
| Mean | 41.26 | 22.68 | |

| **Year 2000** | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 44.65 | 28.03 | 36.34 |
| 5 kg TU/ha in soil (basal) | 51.65 | 33.85 | 42.75 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 61.15 | 30.70 | 45.93 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 49.45 | 27.53 | 38.49 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 68.70 | 33.80 | 51.25 |
| 500 ppm TU (spray) | 47.15 | 28.83 | 37.99 |
| 100 ppm DMSO (spray) | 52.70 | 28.73 | 40.72 |
| TU+DMSO (spray) | 52.15 | 29.70 | 40.93 |
| Mean | 53.45 | 30.15 | |

| **Pooled** | Phosphorus (kg/ha) | | Mean |
|---|---|---|---|
| | 20 | 40 | |
| Control | 41.40 | 25.04 | 33.22 |
| 5 kg TU/ha in soil (basal) | 47.33 | 26.48 | 36.90 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 53.08 | 29.58 | 38.99 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 42.48 | 23.67 | 33.07 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 57.00 | 28.67 | 42.84 |
| 500 ppm TU (spray) | 47.50 | 27.18 | 37.34 |
| 100 ppm DMSO (spray) | 40.80 | 25.18 | 32.99 |
| TU+DMSO (spray) | 49.25 | 25.52 | 37.86 |
| Mean | 47.36 | 26.42 | |

**Table: 4A.72 Effect of thiourea and DMSO on P harvest index (%) at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 39.42 | 42.19 | 41.64 | 41.08 |
| 5 kg TU/ha in soil (basal) | 42.36 | 42.59 | 42.55 | 42.49 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 44.39 | 47.58 | 42.57 | 44.85 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 41.49 | 44.12 | 44.01 | 43.21 |
| TU+DMSO in soil (1/2 + 1/2) | 44.21 | 44.60 | 47.09 | 45.30 |
| 500 ppm TU (spray) | 43.34 | 43.40 | 45.63 | 44.13 |
| 100 ppm DMSO (spray) | 44.19 | 44.64 | 46.25 | 45.03 |
| TU+DMSO (spray) | 42.15 | 43.59 | 45.10 | 43.61 |
| Mean | 42.69 | 44.09 | 44.36 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.533 | 0.871 | 1.508 | |
| C.D. (0.05) | NS | 2.413 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 38.24 | 39.83 | 42.43 | 40.17 |
| 5 kg TU/ha in soil (basal) | 38.75 | 40.45 | 42.74 | 40.65 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 40.07 | 42.68 | 44.19 | 42.31 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 38.65 | 40.02 | 42.29 | 40.32 |
| TU+DMSO in soil (1/2 + 1/2) | 40.25 | 43.37 | 43.71 | 42.44 |
| 500 ppm TU (spray) | 38.99 | 43.35 | 43.85 | 42.06 |
| 100 ppm DMSO (spray) | 40.25 | 41.54 | 40.76 | 40.85 |
| TU+DMSO (spray) | 40.08 | 43.25 | 43.60 | 42.31 |
| Mean | 39.41 | 41.81 | 42.95 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.357 | 0.583 | 1.009 | |
| C.D. (0.05) | 0.989 | 1.615 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 38.83 | 41.01 | 42.04 | 40.63 |
| 5 kg TU/ha in soil (basal) | 40.55 | 41.52 | 42.65 | 41.57 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 42.23 | 45.13 | 43.39 | 43.58 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 40.07 | 42.06 | 43.15 | 41.76 |
| TU+DMSO in soil (1/2 + 1/2) | 42.23 | 43.99 | 45.40 | 43.87 |
| 500 ppm TU (spray) | 41.16 | 43.38 | 44.74 | 43.09 |
| 100 ppm DMSO (spray) | 42.22 | 43.09 | 43.51 | 42.94 |
| TU+DMSO (spray) | 41.11 | 43.42 | 44.35 | 42.96 |
| Mean | 41.05 | 42.95 | 43.65 | |
| | Phosphorus | Chemicals. | Interaction | |
| S.Em ± | 0.277 | 0.453 | 0.785 | |
| C.D. (0.05) | 0.769 | 1.257 | NS | |

Soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO brought about significant increase in net monetary returns over control in 1999 only. On the basis of pooled data, soil application of TU at 5 kg /ha (½+½) significantly increased net monetary returns by Rs 2523 over control (Rs 16426 per ha).

Data further show that all the foliar spray treatments proved effective in increasing net monetary returns per ha in 1999 only. Pooled data show that foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO gave significantly higher net monetary returns by Rs 2014, Rs 1977 and Rs 2569 per ha, respectively over control (Rs16426 per ha).

Data (Table 4A.73) on combined effects of treatments further show that TU and DMSO interacted significantly with phosphorus in influencing net monetary returns per ha in 1999 only. Under no phosphorus, soil application of TU at 5 kg /ha (½+½), soil application of DMSO at 2 kg/ha, soil application of TU+DMSO (1/2+1/2), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO proved effective in increasing net monetary returns. However, under 40 kg $P_2O_5$/ha, only foliar spray of 500 ppm TU significantly increased net monetary returns over control. In pooled data, soil application of TU at 5 kg/ha and foliar spray of 100 ppm DMSO significantly increased net monetary returns under no phosphorus. The highest net returns of Rs 22497 per ha was obtained with foliar spray of 500 ppm TU with 40 kg $P_2O_5$/ha followed by foliar spray of 100 ppm DMSO (Rs 21478 per ha).

**4A7.2 Benefit:cost (B:C) ratio**

Data (Table 4A.74) show that phosphorus application brought about significant increase in B:C ratio upto 20 kg $P_2O_5$/ha during 1999 and upto 40 kg $P_2O_5$/ha during 2000. In pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly larger B:C ratio over control. Further, 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha.

All the soil applied treatments of TU and DMSO caused significant reduction in B: C ratio during both the years. Similar results were noted in pooled data.

None of the foliar spray treatments proved effective in improving B:C ratio during both the years. However, an increasing trends were observed due to foliar applied treatments.

Data (Table 4A.74) on combined effects of treatments show that TU and DMSO interacted significantly with phosphorus in influencing B:C ratio during 1999 only. Under no phosphorus, soil application of TU at 5 kg /ha (½+½), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased B:C ratio over control. Similar trends were recorded in pooled data. However, the highest B: C ratio (2.04) was recorded under foliar spray of 500 ppm TU with 40 kg $P_2O_5$/ha.

**Table: 4A.73 Effect of thiourea and DMSO on net monetary returns (Rs/ha) at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 17726 | 27979 | 28141 | 24615 |
| 5 kg TU/ha in soil (basal) | 17943 | 27324 | 24766 | 23344 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 28920 | 30455 | 29704 | 29693 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 22493 | 26983 | 27615 | 25697 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 26503 | 26668 | 28982 | 27384 |
| 500 ppm TU (spray) | 20291 | 30316 | 33165 | 27924 |
| 100 ppm DMSO (spray) | 25299 | 25884 | 31888 | 27691 |
| TU+DMSO (spray) | 26279 | 30186 | 29491 | 28652 |
| Mean | 23182 | 28224 | 29219 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 575.1 | 939.2 | 1626.7 | |
| C.D. (0.05) | 1594.3 | 2603.5 | 4509.4 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2958 | 9662 | 12087 | 8236 |
| 5 kg TU/ha in soil (basal) | 1405 | 8712 | 11870 | 7329 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 3818 | 10280 | 10518 | 8205 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 2883 | 8649 | 10217 | 7249 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 3006 | 10309 | 10136 | 7817 |
| 500 ppm TU (spray) | 4858 | 10184 | 11829 | 8957 |
| 100 ppm DMSO (spray) | 5316 | 10964 | 11067 | 9115 |
| TU+DMSO (spray) | 5099 | 10965 | 11966 | 9343 |
| Mean | 3368 | 9965 | 11211 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 340.4 | 555.869 | 962.8 | |
| C.D. (0.05) | 943.6 | NS | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 10342 | 18821 | 20114 | 16426 |
| 5 kg TU/ha in soil (basal) | 9674 | 18018 | 18318 | 15337 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 16369 | 20367 | 20111 | 18949 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 12688 | 17816 | 18916 | 16473 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 14754 | 18488 | 19559 | 17601 |
| 500 ppm TU (spray) | 12575 | 20250 | 22497 | 18440 |
| 100 ppm DMSO (spray) | 15307 | 18424 | 21478 | 18403 |
| TU+DMSO (spray) | 15680 | 20575 | 20728 | 18995 |
| Mean | 13425 | 19095 | 20215 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 334.1 | 545.6 | 945.0 | |
| C.D. (0.05) | 926.2 | 1512.5 | 2619.7 | |

**Table: 4A.74 Effect of thiourea and DMSO on B:C ratio at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 1.95 | 2.97 | 2.89 | 2.61 |
| 5 kg TU/ha in soil (basal) | 1.58 | 2.34 | 2.06 | 1.99 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 2.49 | 2.56 | 2.43 | 2.49 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 2.09 | 2.43 | 2.42 | 2.31 |
| TU+DMSO in soil (1/2 + 1/2) | 2.06 | 2.03 | 2.15 | 2.08 |
| 500 ppm TU (spray) | 2.04 | 2.95 | 3.13 | 2.71 |
| 100 ppm DMSO (spray) | 2.6 | 2.58 | 3.08 | 2.75 |
| TU+DMSO (spray) | 2.62 | 2.91 | 2.76 | 2.76 |
| Mean | 2.20 | 2.60 | 2.62 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.053 | 0.086 | 0.151 | |
| C.D. (0.05) | 0.146 | 0.242 | 0.419 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 0.28 | 0.88 | 1.07 | 0.74 |
| 5 kg TU/ha in soil (basal) | 0.11 | 0.65 | 0.87 | 0.54 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 0.29 | 0.75 | 0.75 | 0.60 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 0.23 | 0.68 | 0.78 | 0.56 |
| TU+DMSO in soil (1/2 + 1/2) | 0.21 | 0.69 | 0.67 | 0.52 |
| 500 ppm TU (spray) | 0.42 | 0.85 | 0.96 | 0.74 |
| 100 ppm DMSO (spray) | 0.47 | 0.93 | 0.92 | 0.77 |
| TU+DMSO (spray) | 0.43 | 0.90 | 0.97 | 0.77 |
| Mean | 0.30 | 0.79 | 0.87 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.027 | 0.045 | 0.078 | |
| C.D. (0.05) | 0.076 | 0.125 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 1.11 | 1.93 | 1.99 | 1.68 |
| 5 kg TU/ha in soil (basal) | 0.84 | 1.49 | 1.47 | 1.27 |
| 5 kg TU/ha in soil (1/2 + 1/2) | 1.39 | 1.65 | 1.59 | 1.54 |
| 2 kg DMSO/ha in soil (1/2 + 1/2) | 1.16 | 1.55 | 1.60 | 1.44 |
| TU+DMSO in soil (1/2 + 1/2) | 1.14 | 1.35 | 1.41 | 1.30 |
| 500 ppm TU (spray) | 1.23 | 1.90 | 2.04 | 1.72 |
| 100 ppm DMSO (spray) | 1.53 | 1.75 | 1.99 | 1.76 |
| TU+DMSO (spray) | 1.53 | 1.92 | 1.87 | 1.77 |
| Mean | 1.25 | 1.70 | 1.75 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.029 | 0.049 | 0.084 | |
| C.D. (0.05) | 0.082 | 0.136 | 0.236 | |

### 4A7.3 Gum yield

Data (Table 4A.75) reveal that phosphorus application brought about significant increase in gum yield upto 20 kg $P_2O_5$/ha in 1999 and upto 40 kg $P_2O_5$/ha in 2000 In pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased gum yield by 36.0 and 45.2 per cent, respectively over control. Further, 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha.

Soil application of TU at 5 kg/ha (½+½) significantly increased gum yield in both the years. In pooled data, soil application of TU at 5 kg/ha (½+½) proved significantly superior to soil application of TU at 5 kg/ha (basal), giving an increase of 14.4 per cent in gum yield. Soil application of DMSO at 2 kg/ha (½+½) significantly increased gum yield in 1999 only. Soil application of TU+DMSO (½+½) significantly increased gum yield in both the years. On the basis of pooled data, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased gum yield by 7.5, 22.9, 9.2 and 25.4 per cent, respectively over control.

Foliar sprays of 500 ppm, 100 ppm DMSO and TU+DMSO significantly increased gum yield over control during both the years. In pooled data, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased gum yield by 15.9, 13.5 and 18.6 per cent, respectively over control.

Data (Table 4A.75) further show that application of TU and DMSO interacted significantly with phosphorus in influencing the gum yield. Pooled data show that under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg /ha, soil application of TU+DMSO, foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased gum yield by 47.1, 21.8, 47.4, 22.2, 31.4 and 36.2 per cent, respectively over control. Under 20 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg /ha, soil application of TU+DMSO foliar sprays of 500 ppm TU and foliar spray of TU+DMSO significantly increased gum yield by 21.4, 5.51, 21.6,13.7 and 16.3 per cent, respectively over control. Whereas under 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO, foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased gum yield by 10.3, 16.1, 14.3 and 10.5 per cent, respectively over control. The gum yield obtained (5.50 q/ha) under 20 kg $P_2O_5$/ha with soil application of TU at 5 kg/ha (½+½) was significantly superior to 40 kg $P_2O_5$/ha alone but at par with other soil and foliar applied treatments of TU and DMSO under 40 kg $P_2O_5$/ha.

**4A7.4 Net monetary returns based on gum yield**

Data (Table 4A.76) show that phosphorus application resulted in significant increase in net monetary return upto 20 kg $P_2O_5$/ha during 1999 and upto 40 kg $P_2O_5$/ha during 2000. In pooled data, application of 20 and 40 kg $P_2O_5$/ha significantly increased net monetary returns by Rs 6011 and Rs 7200 per hectare, respectively over control (Rs 9089 per ha). Further, 40 kg $P_2O_5$/ha proved significantly superior to 20 kg $P_2O_5$/ha.

Soil application of TU at 5 kg /ha (½+½) significantly increased net returns in 1999 only. While soil application of TU+DMSO brought about significant increase in net monetary returns over control in both the years. On the basis of pooled data, soil application of TU at 5 kg /ha (½+½) and soil application of TU+DMSO significantly increased net monetary returns by Rs 2787 and Rs4685 per hectare, respectively over control (Rs 12037 per ha).

Data further show that all the foliar spray treatments proved effective in increasing net monetary returns per ha in 1999 only. Pooled data show that foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO gave significantly higher net monetary returns by Rs 1699, Rs 1976 and Rs 3011 per ha, respectively over control (Rs12037per ha).

Data (Table 4A.76) on combined effects of treatments further show that TU and DMSO interacted significantly with phosphorus in influencing net monetary returns per ha in 1999 only. Under no phosphorus, soil application of TU at 5 kg /ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO proved effective in increasing net monetary returns. However, under 40 kg $P_2O_5$/ha, soil application of TU+DMSO (½+½) and foliar spray of 500 ppm TU significantly increased net monetary returns over control. In pooled data, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 100 ppm DMSO and foliar spray of TU+DMSO significantly increased net monetary returns under no phosphorus.

**Table: 4A.75 Effect of thiourea and DMSO on gum yield (q/ha) at varying levels of phosphorus**

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 3.01 | 4.55 | 4 59 | 4.05 |
| 5 kg TU/ha in soil (basal) | 3.44 | 4.93 | 4.64 | 4.34 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 4.93 | 5.55 | 5.19 | 5.22 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 3.93 | 4.87 | 5.02 | 4.61 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 4.82 | 5.22 | 5.57 | 5.21 |
| 500 ppm TU (spray) | 3.63 | 5.26 | 5.71 | 4.86 |
| 100 ppm DMSO (spray) | 4 19 | 4.70 | 5.45 | 4 78 |
| TU+DMSO (spray) | 4.36 | 5.25 | 5 27 | 4.96 |
| Mean | 4 04 | 5.04 | 5.18 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.092 | 0.149 | 0.259 | |
| C.D. (0.05) | 0.254 | 0.414 | NS | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.85 | 4.52 | 5.33 | 4.23 |
| 5 kg TU/ha in soil (basal) | 3.03 | 4 82 | 5.83 | 4.56 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 3 69 | 5 45 | 5 75 | 4 96 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 3 21 | 4.69 | 5 41 | 4.44 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 3.82 | 5.80 | 5.96 | 5.19 |
| 500 ppm TU (spray) | 3.53 | 5 05 | 5.64 | 4 74 |
| 100 ppm DMSO (spray) | 3.52 | 5 00 | 5 35 | 4 62 |
| TU+DMSO (spray) | 3.62 | 5.29 | 5.69 | 4.86 |
| Mean | 3.41 | 5.08 | 5.62 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.079 | 0.129 | 0 223 | |
| C.D. (0.05) | 0.218 | 0.357 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 2.93 | 4.53 | 4.96 | 4 14 |
| 5 kg TU/ha in soil (basal) | 3.23 | 4.88 | 5.23 | 4.45 |
| 5 kg TU/ha in soil ($^1/_2 + ^1/_2$) | 4.31 | 5.50 | 5.47 | 5.09 |
| 2 kg DMSO/ha in soil ($^1/_2 + ^1/_2$) | 3.57 | 4.78 | 5.22 | 4.52 |
| TU+DMSO in soil ($^1/_2 + ^1/_2$) | 4.32 | 5.51 | 5.76 | 5.19 |
| 500 ppm TU (spray) | 3.58 | 5.15 | 5.67 | 4.80 |
| 100 ppm DMSO (spray) | 3.85 | 4.85 | 5.40 | 4.70 |
| TU+DMSO (spray) | 3.99 | 5.27 | 5.48 | 4.91 |
| Mean | 3.72 | 5.06 | 5.40 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 0.060 | 0.099 | 0.171 | |
| C.D. (0.05) | 0.168 | 0.274 | 0.474 | |

Table: 4A.76 Effect of thiourea and DMSO on net returns (Rs/ha) on the basis of gum yield at varying levels of phosphorus

| Year 1999 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 11959 | 21939 | 21883 | 18594 |
| 5 kg TU/ha in soil (basal) | 12327 | 22192 | 19767 | 18095 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 22180 | 25609 | 24946 | 24245 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 14288 | 19995 | 20703 | 18329 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 23281 | 25433 | 27269 | 25328 |
| 500 ppm TU (spray) | 14186 | 24771 | 27258 | 22072 |
| 100 ppm DMSO (spray) | 18802 | 21090 | 26359 | 22084 |
| TU+DMSO (spray) | 19958 | 25452 | 25085 | 23498 |
| Mean | 17122 | 23310 | 24159 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 598.31 | 977.04 | 1692.29 | |
| C.D. (0.05) | 1658.53 | 2708.37 | 4691 03 | |

| Year 2000 | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 647 | 6672 | 9121 | 5480 |
| 5 kg TU/ha in soil (basal) | -1032 | 5444 | 8649 | 4354 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 1185 | 7179 | 7841 | 5401 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | -1839 | 3419 | 5464 | 2348 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 3475 | 10364 | 10511 | 8117 |
| 500 ppm TU (spray) | 1411 | 6510 | 8278 | 5399 |
| 100 ppm DMSO (spray) | 2173 | 7392 | 8263 | 5943 |
| TU+DMSO (spray) | 2426 | 8138 | 9228 | 6597 |
| Mean | 1056 | 6890 | 8419 | |
| | Phosphorus | Chemicals | Interaction | |
| S Em ± | 285.93 | 466 92 | 808 73 | |
| C.D. (0.05) | 792 59 | 1294 29 | NS | |

| Pooled | Phosphorus (kg/ha) | | | Mean |
|---|---|---|---|---|
| | 0 | 20 | 40 | |
| Control | 6303 | 14306 | 15502 | 12037 |
| 5 kg TU/ha in soil (basal) | 5648 | 13818 | 14208 | 11225 |
| 5 kg TU/ha in soil ($^1/_2$ + $^1/_2$) | 11683 | 16394 | 16394 | 14824 |
| 2 kg DMSO/ha in soil ($^1/_2$ + $^1/_2$) | 6225 | 11707 | 13084 | 10339 |
| TU+DMSO in soil ($^1/_2$ + $^1/_2$) | 13378 | 17899 | 18890 | 16722 |
| 500 ppm TU (spray) | 7799 | 15641 | 17768 | 13736 |
| 100 ppm DMSO (spray) | 10488 | 14241 | 17311 | 14013 |
| TU+DMSO (spray) | 11192 | 16795 | 17157 | 15048 |
| Mean | 9089 | 15100 | 16289 | |
| | Phosphorus | Chemicals | Interaction | |
| S.Em ± | 331.56 | 541.44 | 937.80 | |
| C.D. (0.05) | 919.08 | 1500.87 | 2599.58 | |

Note: Cost of gum Rs 6400 per q (1999) and Rs 3400 per q (2000)

EXPERIMENT II

**4B EFFECT OF – SH COMPOUNDS AND –SH GROUP BLOCKERS ON DRY MATTER PARTITIONING AND YIELD OF CLUSTERBEAN**

**4B1 EFFECT OF – SH COMPOUNDS AND –SH GROUP BLOCKER ON GROWTH OF CROP**

**4B.1.1 Dry matter accumulation per plant at 75, 90 DAS and physiological maturity**

Foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased total dry matter accumulation per plant at 75 DAS over control during both the years (Table 4B.1). Foliar sprays of 10 ppm PCMBS and 100 ppm IA had no significant effect on dry matter accumulation plant per plant in both the years. Further, foliar spray of PCMBS+TU and IA+TU also significantly increased total dry matter accumulation per plant at 75 DAS over control during both the years. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly increased total dry matter accumulation per plant at 75 DAS 9.6, 14.3, 7.7, 8.7 and 8.9 per cent, respectively over control. The maximum total dry matter accumulation per plant (25.96 g) was obtained with foliar spray of 500 ppm MEA. Further, it was significantly superior to foliar spray of 500 ppm TU and 10 ppm DTT. However, foliar sprays of 500 ppm TU and 10 ppm DTT was at par in this respect. Foliar sprays of 1000 ppm urea and 1000 ppm aluminum sulphate remained ineffective during both the years as well in pooled data.

In respect of total dry matter accumulation per plant at 90 DAS, it can be seen that foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT brought about significant increase in total dry matter accumulation per plant during both the years, except foliar spray of 500 ppm TU in 2000. Foliar sprays of PCMBS+TU and IA+TU had significant effect on total dry matter accumulation per plant at 90 DAS in 1999 only. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly increased total dry matter accumulation per plant at 90 DAS by 6.5, 12.3, 7.5, 7.5 and 5.5 per cent, respectively over control. Rest of the foliar spray treatments were not effective in this respect. The highest total dry matter accumulation of 27.48 g was recorded with foliar spray of 500 ppm MEA, which was significantly superior to foliar spray of 500 ppm TU and 10 ppm DTT in respect of total dry matter accumulation per plant at 90 DAS.

In respect of total dry matter accumulation per plant at physiological maturity, it is clear from the table that foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased total dry matter accumulation per plant at physiological maturity over control during either of the years. However, foliar spray of 10 ppm PCMBS caused significant reduction in total dry matter accumulation per plant at physiological maturity over control in both the years. Further, when compared with foliar spray of 10 ppm PCMBS alone,

**Table 4B.1 Effect of foliar applied chemicals on dry matter accumulation /plant (g)**

| Treatments | At 75 DAS | | | At 90 DAS | | | At physiological maturity | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 22.79 | 22.64 | 22.71 | 24.38 | 24.57 | 24.48 | 21.88 | 22.82 | 22.35 |
| 500 ppm TU | 24.72 | 25.07 | 24.89 | 26.29 | 25.83 | 26.06 | 25.07 | 25.38 | 25.23 |
| 500 ppm MEA | 25.76 | 26.16 | 25.96 | 27.38 | 27.59 | 27.48 | 28.82 | 28.51 | 28.66 |
| 10 ppm DTT | 24.22 | 24.71 | 24.46 | 26.55 | 26.08 | 26.32 | 24.84 | 24.96 | 24.89 |
| 10 ppm PCMBS | 22.93 | 21.85 | 22.39 | 25.09 | 23.82 | 24.46 | 19.59 | 19.84 | 19.72 |
| PCMBS+TU | 24.60 | 24.76 | 24.68 | 26.64 | 26.00 | 26.32 | 24.17 | 24.41 | 24.28 |
| 100 ppm IA | 23.19 | 22.64 | 22.92 | 24.46 | 23.99 | 24.22 | 21.08 | 23.09 | 22.08 |
| IA+TU | 24.67 | 24.82 | 24.74 | 26.39 | 25.27 | 25.83 | 24.36 | 25.04 | 24.69 |
| 1000 ppm urea | 22.99 | 22.78 | 22.88 | 24.40 | 24.75 | 24.57 | 22.00 | 23.40 | 22.70 |
| 1000 ppm $Al_2(SO_4)_3$ | 23.53 | 22.79 | 23.16 | 24.74 | 24.80 | 24.76 | 22.67 | 22.85 | 22.76 |
| S.Em ± | 0.481 | 0.341 | 0.295 | 0.585 | 0.497 | 0.384 | 0.529 | 0.650 | 0.419 |
| C.D. (0.05) | 1.396 | 0.989 | 0.835 | 1.696 | 1.442 | 1.087 | 1.536 | 1.886 | 1.188 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

foliar spray of PCMBS+TU caused significant increase in total dry matter accumulation per plant during both the years. Foliar spray of 100 ppm IA did not influence total dry matter accumulation per plant but foliar spray of TA+TU had significant effect during both the years. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased total dry matter accumulation per plant at physiological maturity by 12.9, 14.8 and 11.4 per cent, respectively over control. On the contrary foliar spray of 10 ppm PCMBS caused significant reduction in total dry matter accumulation per plant by 11.8 per cent over control. Foliar spray of PCMBS+TU brought about significant increase in total dry matter accumulation per plant by 23.1 and 8.6 per cent over foliar spray of 10 PCMBS alone and control, respectively. Foliar sprays of 100 ppm IA, 1000 ppm urea and 1000 ppm aluminium sulphate were at par in this respect.

**4B.1.2 Dry matter distribution in leaves, stems and pods at 75 DAS**

Data (Table 4B.2) indicate that dry matter distribution (DMD) in leaves, stems and pods at 75 DAS showed significant variations under foliar spray of chemicals.

All the foliar spray treatments proved ineffective in influencing DMD in leaves at 75 DAS during both the years except foliar spray of 10 ppm PCMBS in 2000. DMD in leaves reduced significantly under foliar spray of 10 ppm PCMBS in 2000 only. In pooled data, similar trends were recorded. Per cent reduction in DMD leaves under foliar spray of 10 ppm PCMBS was 4.2 over control.

In respect of DMD in stems, it can be seen that foliar spray of 10 ppm PCMBS proved effective in improving DMD in stems at 75 DAS during both the years. On the contrary, foliar spray of 500 ppm MEA brought about significant reduction in DMD in stems at 75 DAS over control in 1999 only. Rest of foliar spray treatments remained ineffective during both the years. In pooled data, only foliar spray of 10 ppm PCMBS significantly increased DMD in stems over control. On the contrary, foliar spray of 500 ppm MEA significantly reduced DMD in stems over control. Other foliar spray treatments proved ineffective in this respect.

DMD in pods showed significant variations in 2000 only. DMD in pods reduced significantly due to foliar spray of 10 ppm PCMBS over control. Rest of foliar spray treatments had no effect on DMD in pods at 75 DAS during both the years. In pooled data, foliar spray of 10 ppm PCMBS significantly reduced DMD in pods at 75 DAS by 13.2 per cent over control. Rest of the foliar spray treatments proved ineffective in this respect in pooled data.

**Table 4B.2 Effect of foliar applied chemicals on dry matter distribution (%) at 75 DAS**

| Treatments | Leaves | | | Stems | | | Pods | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 38.92 | 38.18 | 38.55 | 40.76 | 40.14 | 40.45 | 20.32 | 21.69 | 21.00 |
| 500 ppm TU | 39.02 | 38.98 | 38.99 | 40.23 | 39.61 | 39.92 | 20.76 | 21.41 | 21.08 |
| 500 ppm MEA | 39.81 | 38.80 | 39.81 | 38.39 | 38.29 | 38.34 | 21.80 | 21.90 | 21.85 |
| 10 ppm DTT | 39.26 | 38.56 | 38.91 | 39.59 | 39.71 | 39.65 | 21.16 | 21.73 | 21.44 |
| 10 ppm PCMBS | 38.77 | 35.08 | 36.92 | 43.44 | 46.09 | 44.76 | 17.79 | 18.83 | 18.31 |
| PCMBS+TU | 39.51 | 38.32 | 38.92 | 40.35 | 39.94 | 40.14 | 20.14 | 21.74 | 20.94 |
| 100 ppm IA | 39.90 | 38.07 | 38.99 | 40.28 | 40.13 | 40.21 | 19.81 | 21.81 | 20.81 |
| IA+TU | 39.01 | 39.13 | 39.07 | 39.98 | 39.43 | 39.70 | 21.01 | 21.44 | 21.23 |
| 1000 ppm urea | 39.10 | 38.06 | 38.58 | 40.49 | 40.09 | 40.29 | 20.42 | 21.84 | 21.13 |
| 1000 ppm $Al_2(SO_4)_3$ | 39.06 | 37.69 | 38.38 | 39.98 | 40.85 | 40.41 | 20.96 | 21.46 | 21.21 |
| S.Em ± | 0.611 | 0.729 | 0.476 | 0.483 | 0.716 | 0.432 | 0.786 | 0.512 | 0.469 |
| C.D. (0.05) | NS | 2.115 | 1.347 | 1.402 | 2.077 | 1.224 | NS | 1.486 | 1.329 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

**4 B.1.3 Dry matter distribution in leaves, stems and pods at 90 DAS**

Data (Table 4B.3) show that none of the foliar spray treatments proved effective during both the years except foliar spray of 10 ppm PCMBS in 1999 only. Foliar spray of 10 ppm PCMBS significantly increased DMD in leaves during 1999. In pooled data, DMD in leaves significantly increased due to foliar spray of 10PPM PCMBS over control. All other foliar applied treatments failed to affect DMD in leaves at 90 DAS.

In respect of DMD in stems at 90 DAS, all the foliar applied treatments proved ineffective during both the years. Similar trends were noted in pooled data.

In respect of DMD in pods at 90 DAS, foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT showed increasing trends during both the years. On the contrary, DMD in pods significantly reduced under foliar spray of 10 ppm PCMBS in 1999 only. Pooled data show that foliar spray of 500 PPM MEA proved effective in improving DMD in pods, where as foliar spray of 10 PPM PCMBS caused significant reduction over control in this respect. Rest of the foliar applied treatments proved ineffective.

**4 B1.4 Dry matter distribution in leaves, stems and pods at physiological maturity**

Data (Table 4 B.4) indicate that foliar sprays of 500 ppm TU, 500 ppm MEA and 10 PPM DTT brought about significant increase in DMD in leaves at physiological maturity over control during both the years. On the contrary, DMD in leaves significantly reduced due to foliar sprays of 10 ppm PCMBS during both the years and 100 ppm IA in 1999 Only. Foliar spray of PCMBS+TU also caused significant reduction in DMD in leaves over control during 2000. Pooled data show that foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and IA+TU brought about significant increase in DMD in leaves over control. On the contrary, foliar sprays of 10 ppm PCMBS, PCMBS+TU and 10 ppm IA caused significant reduction in DMD in leaves over control. The magnitude of reduction in DMD in leaves was highest under foliar spray of 10 ppm PCMBS.

In respect of DMD in stems at physiological maturity, foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT showed decreasing trends in DMD in stems during both the years. On the contrary, foliar sprays of 10 ppm PCMBS and 100 ppm IA showed increasing trends in DMD in stems during both the years but foliar spray of 100 ppm IA could reach the significance level in 1999 only. In pooled data, foliar spray of 10 ppm DTT significantly reduced DMD in stems over control. However, foliar sprays of 500 ppm TU and 500 ppm MEA also showed decreasing trends in DMD in stems when compared with control. On the contrary, foliar sprays of 10 ppm PCMBS and 100 ppm IA caused significant increase in DMD in stems by 6.8 and 5.2 percent, respectively over control.

**Table 4B.3 Effect of foliar applied chemicals on dry matter distribution (%) at 90 DAS**

| Treatments | Leaves | | | Stems | | | Pods | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 19.59 | 20.08 | 19.83 | 40.44 | 39.10 | 39.77 | 39.97 | 40.82 | 40.39 |
| 500 ppm TU | 18.78 | 19.69 | 19.24 | 39.68 | 38.07 | 38.88 | 41.53 | 42.25 | 41.89 |
| 500 ppm MEA | 18.65 | 18.94 | 18.79 | 38.75 | 38.45 | 38.59 | 42.60 | 42.61 | 42.61 |
| 10 ppm DTT | 18.98 | 19.35 | 19.16 | 39.98 | 38.89 | 39.44 | 41.04 | 41.75 | 41.39 |
| 10 ppm PCMBS | 22.03 | 21.74 | 21.88 | 41.29 | 41.41 | 41.35 | 36.67 | 36.85 | 36.76 |
| PCMBS+TU | 19.79 | 20.66 | 20.23 | 40.17 | 38.33 | 39.25 | 40.03 | 41.00 | 40.52 |
| 100 ppm IA | 19.78 | 20.45 | 20.11 | 42.12 | 40.45 | 41.28 | 38.10 | 39.10 | 38.60 |
| IA+TU | 18.34 | 19.17 | 18.75 | 41.82 | 39.15 | 40.48 | 39.84 | 41.68 | 40.76 |
| 1000 ppm urea | 19.69 | 19.79 | 19.74 | 41.36 | 39.76 | 40.56 | 38.95 | 40.45 | 39.69 |
| 1000 ppm $Al_2(SO_4)_3$ | 19.23 | 19.87 | 19.55 | 40.65 | 39.56 | 40.10 | 40.12 | 40.57 | 40.35 |
| S.Em ± | 0.666 | 0.626 | 0.457 | 0.958 | 1.043 | 0.708 | 1.027 | 1.117 | 0.758 |
| C.D. (0.05) | 1.932 | NS | 1.295 | NS | NS | NS | 2.978 | NS | 2.149 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

**Table 4B.4 Effect of foliar applied chemicals on dry matter distribution (%) at physiological maturity**

| Treatments | Leaves | | | Stems | | | Pods | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 7.15 | 7.61 | 7.38 | 46.47 | 45.67 | 46.07 | 46.38 | 46.72 | 46.55 |
| 500 ppm TU | 8.46 | 8.89 | 8.68 | 44.51 | 43.50 | 44.01 | 47.02 | 47.61 | 47.32 |
| 500 ppm MEA | 8.49 | 8.12 | 8.30 | 45.30 | 44.34 | 44.82 | 46.21 | 47.54 | 46.88 |
| 10 ppm DTT | 9.32 | 9.86 | 9.58 | 44.00 | 42.66 | 43.33 | 46.67 | 47.48 | 47.07 |
| 10 ppm PCMBS | 4.93 | 5.45 | 5.19 | 49.14 | 49.25 | 49.19 | 45.92 | 45.31 | 45.61 |
| PCMBS+TU | 5.91 | 6.31 | 6.11 | 46.13 | 45.90 | 46.01 | 47.96 | 47.79 | 47.88 |
| 100 ppm IA | 4.64 | 7.05 | 5.85 | 49.37 | 47.53 | 48.45 | 45.98 | 45.41 | 45.69 |
| IA+TU | 7.59 | 10.45 | 9.03 | 46.20 | 43.23 | 44.72 | 46.20 | 46.31 | 46.26 |
| 1000 ppm urea | 7.42 | 7.61 | 7.51 | 45.99 | 45.83 | 45.91 | 46.59 | 46.56 | 46.57 |
| 1000 ppm $Al_2(SO_4)_3$ | 6.75 | 7.42 | 7.08 | 45.18 | 46.06 | 45.62 | 48.07 | 46.52 | 47.29 |
| S.Em ± | 0.403 | 0.410 | 0.287 | 0.950 | 1.311 | 0.809 | 0.925 | 1.304 | 0.799 |
| C.D. (0.05) | 1.169 | 1.189 | 0.815 | 2.757 | 3.802 | 2.294 | NS | NS | NS |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

In respect of DMD in pods at physiological maturity, none of the foliar applied treatments proved effective during both the years. Similar trends were noted in pooled data.

4.B1.5 Number of branches and number of green leaves per plant.

**Number of branches per plant**

Data (Table 4 B.5) show that foliar spray of 500 ppm MEA proved effective in increasing number of branches per plant in 2000 only. Whereas, number of branches significantly reduced under foliar spray of 10 ppm PCMBS over control during 2000 only. Rest of the foliar applied treatments, remained ineffective during both the years. Pooled data show that foliar spray of 500 ppm MEA significantly increased number of branches per plant by 13.2 per cent over control. On the contrary, foliar spray of 10 ppm PCMBS significantly decreased number of branches per plant by 10.5 percent over control. Further, foliar spray of PCMBS+TU significantly increased number of branches per plant over foliar spray of 10 ppm PCMBS alone. Other foliar applied treatments remained ineffective in pooled data.

**Number of green leaves**

Data (Table 4B.5) show that foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly increased number of green leaves per plant during both the years. On the contrary, foliar spray 10 ppm PCMBS brought about significant reduction in number of green leaves per plant over control during both the years, while foliar spray of 100 ppm IA showed significant reduction in number of green leaves per plant over control in 1999 only. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU brought about significant increase in number of green leaves per plant by 24.6, 31.9, 18.9, 9.0 and 22.2 percent, respectively over control. Number of green leaves per plant significantly reduced under foliar spray of 10 ppm PCMBS and 100 ppm IA by 34.2 and 14.8 per cent, respectively over control. The magnitude of reduction in green leaves per plant under 10 ppm PCMBS was significantly higher as compared to foliar spray of 100 ppm IA. Foliar spray of PCMBS+TU and IA+TU proved significantly superior to foliar spray of 10 ppm PCMBS and 100 ppm IA alone, respectively. Further, the highest number of green leaves (70.2) was obtained under foliar spray of 500 ppm MEA, which was significant superior to foliar spray of 10 ppm DTT but was at par with 500 ppm TU.

## 4B.2 EFFECT OF -SH COMPOUNDS AND –SH GROUP BLOCKERS ON YIELD ATTRIBUTES OF THE CROP

### 4B.2.1 Number of clusters per plant

Data (Table 4B.5) show that foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and IA+TU significantly increased number of clusters per plant over control during 1999 only. However, foliar spray of 100 ppm PCMBS showed significant reduction in number of clusters per plant over control in 1999 only. In 2000, none of the foliar applied

**Table 4B.5 Effect of foliar applied chemicals on number of branches, clusters and green leaves per plant**

| Treatments | Number of branches per plant | | | Number of clusters per plant | | | Number of green leaves per plant | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 7.30 | 7.08 | 7.19 | 10.72 | 10.75 | 10.74 | 52.5 | 53.9 | 53.2 |
| 500 ppm TU | 7.35 | 7.83 | 7.59 | 13.45 | 11.13 | 12.29 | 66.1 | 66.4 | 66.3 |
| 500 ppm MEA | 8.13 | 8.15 | 8.14 | 15.47 | 12.15 | 13.81 | 70.6 | 69.8 | 70.2 |
| 10 ppm DTT | 7.28 | 7.30 | 7.29 | 15.42 | 11.12 | 13.27 | 60.4 | 66.1 | 63.3 |
| 10 ppm PCMBS | 7.13 | 5.73 | 6.43 | 8.80 | 9.95 | 9.38 | 30.9 | 39.1 | 35.0 |
| PCMBS+TU | 7.38 | 7.05 | 7.22 | 11.42 | 10.72 | 11.07 | 40.6 | 58.4 | 49.5 |
| 100 ppm IA | 7.30 | 7.13 | 7.22 | 10.05 | 10.70 | 10.38 | 38.2 | 52.4 | 45.3 |
| IA+TU | 7.70 | 7.82 | 7.76 | 12.80 | 10.92 | 11.86 | 65.6 | 64.5 | 65.0 |
| 1000 ppm urea | 7.35 | 6.90 | 7.13 | 10.65 | 10.74 | 10.69 | 54.6 | 54.1 | 54.3 |
| 1000 ppm $Al_2(SO_4)_3$ | 7.38 | 7.10 | 7.24 | 10.10 | 10.76 | 10.43 | 53.0 | 53.7 | 53.3 |
| S.Em ± | 0.395 | 0.335 | 0.259 | 0.633 | 0.501 | 0.366 | 2.55 | 1.51 | 1.48 |
| C.D. (0.05) | NS | 0.973 | 0.734 | 1.837 | NS | 1.038 | 7.40 | 4.37 | 4.20 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

treatments proved effective in this respect. Pooled data show that foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and IA+TU significantly increased number of clusters per plant by 14.4, 28.6, 23.6 and 10.4 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced number of clusters per plant by 12.7 per cent over control. Foliar spray of PCMBS+TU was significantly superior to foliar spray of 10 ppm PCMBS alone in this respect. However, foliar spray of 100 ppm IA had no significant effect on number of clusters per plant. The highest number of clusters per plant (13.81) was obtained under foliar spray of 500 ppm MEA, which was significantly superior to 500 ppm TU but was at par with 10 ppm DTT. Further, foliar sprays of 1000 ppm urea and 1000 ppm aluminium sulphate had no significant effect on number of clusters per plant during both the years.

**4B.2.2 Number of poorly filled pods, number of unfilled pods and number of pods per plant**

**Number of poorly filled pods per plant**

Data (Table 4B.6) show that foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU brought about significant reduction in number of poorly filled pods per plant over control during both the years. However, under foliar sprays of 10 ppm PCMBS and 100 ppm IA, number of poorly filled pods per plant increased significantly over control in both the years. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly decreased number of poorly filled pods per plant by 38.1, 71.4, 42.9, 38.1 and 33.3 per. The magnitude of reduction in number of poorly filled pods per plant was highest under foliar spray of 500 ppm MEA. Further, foliar sprays of 10 ppm PCMBS and 100 ppm IA recorded significantly higher number of poorly filled pods per plant as compared to control. The corresponding increases were of the order of 90.5 and 23.8 per cent. Foliar sprays of 1000 ppm urea and 1000 ppm aluminium sulphate remained ineffective during both the years.

**Number of unfilled pods per plant**

Data (Table 4B.6) show that foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT brought about significant reduction in number of unfilled pods per plant over control during both years. On the contrary, foliar spray of 10 ppm PCMBS significantly increased number of unfilled pods per plant over control in either of the years. Foliar spray of 100 ppm IA proved effective in increasing number of unfilled pods per plant over control during 1999 only. Pooled data show that foliar spray of 500 ppm TU, 500 MEA and 10 ppm DTT significantly decreased number of unfilled pods per plant by 31.3, 41.7 and 27.1 per cent,

**Table 4B.6 Effect of foliar applied chemicals on yield attributes**

| Treatments | Number of poorly filled pods per plant | | | Number of unfilled pods per plant | | | Number of pods per plant | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 2.0 | 2.2 | 2.1 | 4.5 | 5.2 | 4.8 | 58.47 | 60.58 | 59.53 |
| 500 ppm TU | 1.3 | 1.3 | 1.3 | 3.2 | 3.4 | 3.3 | 74.95 | 65.18 | 70.06 |
| 500 ppm MEA | 0.5 | 0.7 | 0.6 | 2.5 | 3.1 | 2.8 | 72.90 | 69.45 | 71.18 |
| 10 ppm DTT | 1.2 | 1.3 | 1.2 | 3.4 | 3.6 | 3.5 | 71.85 | 64.83 | 68.34 |
| 10 ppm PCMBS | 3.8 | 4.2 | 4.0 | 8.9 | 6.4 | 7.6 | 48.20 | 50.20 | 49.20 |
| PCMBS+TU | 1.2 | 1.5 | 1.3 | 5.6 | 5.8 | 5.7 | 55.80 | 59.95 | 57.88 |
| 100 ppm IA | 2.9 | 2.3 | 2.6 | 7.5 | 5.8 | 6.6 | 48.37 | 60.73 | 54.55 |
| IA+TU | 1.5 | 1.3 | 1.4 | 5.2 | 4.1 | 4.6 | 59.92 | 65.38 | 62.65 |
| 1000 ppm urea | 1.9 | 2.3 | 2.1 | 4.4 | 5.5 | 4.9 | 56.82 | 60.05 | 58.44 |
| 1000 ppm $Al_2(SO_4)_3$ | 1.9 | 2.3 | 2.1 | 4.6 | 5.1 | 4.8 | 60.92 | 59.88 | 60.40 |
| S.Em ± | 0.07 | 0.15 | 0.08 | 0.25 | 0.22 | 0.16 | 2.331 | 0.997 | 1.267 |
| C.D. (0.05) | 0.20 | 0.42 | 0.23 | 0.72 | 0.63 | 0.47 | 6.759 | 2.893 | 3.592 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

respectively over control. Whereas foliar spray of 10 ppm PCMBS, PCMBS+TU and 100 ppm IA significantly increased number of unfilled pods per plant by 58.3, 18.7 and 37.5 per cent, respectively over control. However, foliar spray of IA+TU proved ineffective in this respect. Similarly, foliar spray of 1000 ppm urea and 1000 ppm aluminium sulphate also did not influence number of unfilled pods per plant during both the years.

**Number of pods per plant**

Data (Table 4B.6) show that foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT had significant improvement in number of pods per plant during both the years. On the contrary, number of pods per plant significantly reduced over control under foliar spray of 10 ppm PCMBS during both the years, while under foliar spray of 100 ppm IA significant reduction in number of pods per plant over control was recorded in 1999 only. Foliar spray of PCMBS+TU proved significantly superior to foliar spray of 10 ppm PCMBS alone. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT brought about significant increases of 17.7, 19.6 and 14.8 per cent, respectively over control. On the contrary, number of pods per plant significantly reduced by 17.4 and 8.4 per cent under foliar spray of 10 ppm PCMBS and 100 ppm IA, respectively over control. Rest of the foliar applied treatment remained ineffective in this respect.

### 4B.2.3 Pod length, number of seeds per pod, test weight and seed yield per plant

**Pod length**

Data (Table 4B.7) show that foliar sprays of 500 ppm TU, 500 ppm MEA and 100 ppm DTT brought about significant increase in pod length during both the years except foliar spray of 500 ppm TU in 2000. On the other hand, foliar sprays of 10 ppm PCMBS and 10 ppm IA caused significant reduction in pod length during 1999 only. Pooled data show that foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and PCMBS+TU brought about significant increase of in pod length by 4.8, 9.7, 6.4 and 4.1 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS and 100 ppm IA significantly reduced pod length by 5.4 and 4.8 per cent, respectively over control. The magnitude of reduction was higher under foliar spray of 10 ppm PCMBS as compared to 100 ppm IA. Further, foliar spray of IA+TU, 1000 ppm urea and 1000 aluminum sulphate remained ineffective in influencing pod length during either of the years.

**Number of seeds per pod**

Data (Table 4B.7) show that foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased number of seeds per pod in 1999. While in 2000, only foliar spray of 500 ppm MEA proved effective. In 2000, rest of the foliar applied treatments remained ineffective. On the other hand, foliar sprays of 10 ppm PCMBS and 100 ppm IA significantly reduced number of seeds per plant over control in 1999 only. In pooled data, foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased number of seeds per pod by 8.5, 12.7 and 5.6 per cent, respectively over control. However, foliar sprays of PCMBS+TU and IA+TU proved ineffective. Foliar spray of 500 ppm MEA proved most effective in increasing number of seeds per plant. However it was at par with foliar spray of 500 ppm TU and 10 ppm DTT. On the contrary, foliar spray of 10 ppm PCMBS and 100 ppm IA caused significant reduction of 5.6 per cent each over control. Further, foliar sprays of 1000 ppm urea and 1000 aluminum sulphate proved ineffective in this respect.

**Test weight**

Data (Table 4B.7) show that foliar spray of 500 ppm MEA only proved effective in improving test weight during both the years. Rest of the foliar applied treatments remained ineffective in this respect during both the years. Pooled data show that foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased test weight by 2.8, 9.9 and 2.7 per cent, respectively over control. Rest of the foliar applied treatments did not influence the test weight.

**Seed yield per plant**

Data (4B.7) show that foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased seed yield per plant during 1999. Whereas, in 2000 only foliar spray of 500 ppm MEA proved effective. Similarly, foliar spray of PCMBS+TU proved effective in 1999 only. On the other land, foliar spray of 10 ppm PCMBS significantly reduced seed yield per plant during both the years, whereas foliar spray of 100 ppm IA was effective in reducing seed yield per plant during 1999 only. In pooled data, foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased seed yield per plant by 13.5, 25.8 and 12.2 per cent, respectively over control. Foliar spray of 500 ppm MEA proved most effective in increasing seed yield per plant. It was significantly superior to foliar sprays of 500 ppm TU and 10 ppm DTT. On the other hand, foliar spray of 10 ppm PCMBS caused significant reduction of 15.4 per cent in seed yield per plant over control. However, foliar spray of 100 ppm IA did not influence seed yield per plant in pooled data.

**4B.2.4 Dry matter of pods in lower most, middle and uppermost cluster**

**Dry matter of pods in lowermost cluster**

Data (Table 4B.8) show that foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT brought about significant increase in dry matter of pods in lowermost cluster during

**Table 4B.7 Effect of foliar applied chemicals on yield attributes**

| Treatments | Pod length (cm) | | | Number of seeds per pod | | | Test weight (g) | | | Seed yield per plant (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | | | | |
| Control | 5.13 | 5.18 | 5.16 | 7.0 | 7.1 | 7.1 | 28.80 | 28.79 | 28.80 | 6.06 | 7.55 | 6.81 |
| 500 ppm TU | 5.39 | 5.43 | 5.41 | 7.8 | 7.6 | 7.7 | 29.58 | 29.63 | 29.61 | 7.46 | 8.00 | 7.73 |
| 500 ppm MEA | 5.64 | 5.67 | 5.66 | 8.0 | 8.0 | 8.0 | 31.74 | 31.53 | 31.64 | 8.53 | 8.60 | 8.57 |
| 10 ppm DTT | 5.47 | 5.50 | 5.49 | 7.5 | 7.4 | 7.5 | 29.46 | 29.68 | 29.57 | 7.32 | 7.95 | 7.64 |
| 10 ppm PCMBS | 4.82 | 4.94 | 4.88 | 6.5 | 6.9 | 6.7 | 28.33 | 28.37 | 28.35 | 4.76 | 6.75 | 5.76 |
| PCMBS+TU | 5.45 | 5.29 | 5.37 | 7.4 | 7.3 | 7.4 | 29.13 | 29.20 | 29.17 | 6.77 | 7.75 | 7.26 |
| 100 ppm IA | 4.60 | 5.22 | 4.91 | 6.5 | 6.9 | 6.7 | 28.44 | 28.53 | 28.49 | 5.41 | 7.30 | 6.36 |
| IA+TU | 5.28 | 5.38 | 5.33 | 7.2 | 7.6 | 7.4 | 29.32 | 29.56 | 29.44 | 6.12 | 8.05 | 7.08 |
| 1000 ppm urea | 5.35 | 5.13 | 5.24 | 7.4 | 7.3 | 7.4 | 29.13 | 28.85 | 28.99 | 6.16 | 7.60 | 6.88 |
| 1000 ppm $Al_2(SO_4)_3$ | 5.22 | 5.12 | 5.17 | 7.4 | 7.5 | 7.5 | 29.29 | 28.90 | 29.10 | 6.28 | 7.45 | 6.86 |
| S.Em ± | 0.082 | 0.102 | 0.065 | 0.155 | 0.209 | 0.130 | 0.414 | 0.342 | 0.268 | 0.214 | 0.265 | 0.171 |
| C.D. (0.05) | 0.238 | 0.296 | 0.184 | 0.449 | 0.606 | 0.369 | 1.201 | 0.992 | 0.760 | 0.622 | 0.770 | 0.483 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate ate

1999, whereas only 500 ppm MEA proved effective in 2000. On the contrary, foliar spray of 10 ppm PCMBS brought about significant reduction in dry matter of pods in lowermost cluster during both the years. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA, 100 ppm DTT and IA+TU brought about significant increases of 14.9, 19.7, 11.9 and 12.9 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS and 100 IA significantly decreased dry matter of pods in lowermost cluster by 16.8 and 7.4 per cent, respectively over control. The magnitude of reduction was higher under foliar spray of 10 ppm PCMBS. Further, foliar spray of PCMBS+TU had no significant effect in this respect. Foliar spray of 500 ppm MEA proved most effective. However, it was at par with foliar spray of 500 ppm TU and 10 ppm DTT.

**Dry matter of pods in middle cluster:**

Data (Table 4B.8) show that foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT proved effective in increasing dry matter of pods in middle cluster over control during 1999, whereas in 2000 only foliar spray of 500 ppm MEA proved effective. However, foliar spray of PCMBS+TU and IA+TU proved ineffective during both the years. Foliar spray of 10 ppm PCMBS resulted in significant decrease in dry matter of pods per plant in middle cluster over control during both the years. While, foliar spray of 100 ppm IA significantly reduced dry matter of pods per plant in middle cluster over control in 1999 only. In pooled data, foliar sprays of 500 ppm TU and 500 ppm MEA significantly increased dry matter of pods per plant in middle cluster by 12.7 and 14.5 per cent, respectively over control. On the contrary, foliar sprays of 10 ppm PCMBS and 100 ppm IA significantly decreased dry matter of pods per plant in middle cluster by 24.6 and 10.5 per cent, respectively over control. The magnitude of reduction was higher under foliar spray of 10 ppm PCMBS. However, foliar spray of PCMBS+TU and IA+TU proved effective in increasing dry matter of pods in middle cluster over control.

**Dry matter of pods in uppermost cluster**

Data (Table 4B.8) reveal that foliar spray of 500 ppm TU and 10 ppm DTT significantly increased dry matter of pods in uppermost cluster over control during both the years. However, foliar spray of 500 ppm MEA proved ineffective during both the years. Foliar sprays of PCMBS+TU and IA+TU also proved effective in increasing dry matter of pods in uppermost cluster over control during 2000 only. In pooled data, foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly increased dry matter of pods in uppermost cluster by 37.3, 16.9, 39.8, 17.4 and 16.5 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced dry

**Table 4B.8 Effect of foliar applied chemicals on dry matter accumulation of pods in lowermost, middle and uppermost cluster**

| Treatments | Lowermost cluster | | | Middle cluster | | | Uppermost cluster | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 0.576 | 0.613 | 0.595 | 2.23 | 2.32 | 2.28 | 0.248 | 0.225 | 0.236 |
| 500 ppm TU | 0.677 | 0.689 | 0.684 | 2.55 | 2.59 | 2.57 | 0.341 | 0.308 | 0.324 |
| 500 ppm MEA | 0.710 | 0.715 | 0.712 | 2.58 | 2.64 | 2.61 | 0.280 | 0.273 | 0.276 |
| 10 ppm DTT | 0.660 | 0.673 | 0.666 | 2.26 | 2.35 | 2.31 | 0.355 | 0.305 | 0.330 |
| 10 ppm PCMBS | 0.501 | 0.486 | 0.495 | 1.74 | 1.69 | 1.72 | 0.201 | 0.205 | 0.202 |
| PCMBS+TU | 0.646 | 0.646 | 0.645 | 2.25 | 2.31 | 2.28 | 0.272 | 0.283 | 0.277 |
| 100 ppm IA | 0.508 | 0.595 | 0.551 | 1.95 | 2.14 | 2.04 | 0.237 | 0.228 | 0.232 |
| IA+TU | 0.675 | 0.675 | 0.672 | 2.26 | 2.49 | 2.37 | 0.269 | 0.279 | 0.275 |
| 1000 ppm urea | 0.583 | 0.639 | 0.611 | 2.28 | 2.34 | 2.31 | 0.233 | 0.241 | 0.236 |
| 1000 ppm $Al_2(SO_4)_3$ | 0.579 | 0.615 | 0.597 | 2.23 | 2.28 | 2.25 | 0.247 | 0.255 | 0.251 |
| S.Em ± | 0.0244 | 0.0302 | 0.0193 | 0.096 | 0.998 | 0.069 | 0.0140 | 0.0177 | 0.0113 |
| C.D. (0.05) | 0.0706 | 0.0875 | 0.0549 | 0.280 | 0.290 | 0.195 | 0.0413 | 0.0514 | 0.0321 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

matter of pods in uppermost cluster by 14.4 per cent over control. However, foliar spray of 100 ppm IA proved ineffective in this respect. Foliar spray of 10 ppm DTT proved most effective in increasing dry matter of pods in uppermost cluster. However, it was at par with foliar spray of 500 ppm TU but was superior to foliar spray of 500 ppm MEA.

### 4B.2.5 Dry matter distribution in pods in lowermost, middle, and uppermost cluster

Data (Table 4B.9) indicate that all the foliar applied treatments proved ineffective in influencing dry matter distribution (DMD) in pods in lowermost and middle cluster during both the years. Similar trends were also noted in pooled data. However, foliar spray of 500 ppm TU and 10 ppm DTT significantly increased DMD in pods in uppermost cluster during 1999 only. All the foliar applied treatments proved ineffective in 2000. In pooled data, only foliar spray of 500 ppm TU and 10 ppm DTT proved effective in increasing DMD in pods in uppermost cluster over control. Rest of foliar spray treatments proved ineffective in this respect.

### 4B.2.6 Number of pods in lowermost, middle and uppermost cluster

#### Number of pods per plant in lowermost cluster

Data (Table 4B.10) show that foliar spray treatments had significant effect on number of pods plant in lowermost cluster in 2000 only. Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and IA+TU significantly increased number of pods in lowermost cluster over control in 2000 only. However, foliar spray of 10 ppm PCMBS significantly reduced number of pods in lowermost cluster over control. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased number of pods in lowermost cluster by 16.0, 24.0 and 12.0 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced number of pods in lowermost cluster by 12.0 per cent over control. However, foliar sprays of 100 ppm IA, PCMBS+TU and IA+TU proved ineffective.

#### Number of pods in middle cluster

Data (Table 4B.10) indicate that only foliar spray of 500 ppm TU and 500 ppm MEA brought about significant increase in number of pods in middle cluster over control during both the years. However, foliar spray of IA+TU proved effective in this respect during 2000 only. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced number of pods in middle cluster over control during both the years. While, foliar spray of 100 ppm IA proved ineffective. Pooled data show that foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased number of pods in middle cluster by 8.1, 22.9 and 6.8 per cent,

**Table 4B.9 Effect of foliar applied chemicals on dry matter distribution (%) in pods in lowermost, middle and uppermost cluster**

| Treatments | Lowermost cluster | | | Middle cluster | | | Uppermost cluster | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 5.71 | 5.75 | 5.73 | 22.03 | 21.83 | 21.93 | 2.44 | 2.13 | 2.29 |
| 500 ppm TU | 5.89 | 5.85 | 5.87 | 22.21 | 21.97 | 22.08 | 2.96 | 2.63 | 2.79 |
| 500 ppm MEA | 5.64 | 5.59 | 5.61 | 20.47 | 20.57 | 20.52 | 2.21 | 2.11 | 2.16 |
| 10 ppm DTT | 5.69 | 5.69 | 5.69 | 19.48 | 19.82 | 19.65 | 3.06 | 2.58 | 2.82 |
| 10 ppm PCMBS | 5.55 | 5.41 | 5.48 | 19.37 | 19.04 | 19.20 | 2.24 | 2.28 | 2.26 |
| PCMBS+TU | 5.59 | 5.52 | 5.56 | 19.56 | 19.89 | 19.73 | 2.35 | 2.43 | 2.39 |
| 100 ppm IA | 5.25 | 5.70 | 5.47 | 20.10 | 20.51 | 20.31 | 2.45 | 2.17 | 2.31 |
| IA+TU | 6.01 | 5.84 | 5.93 | 20.05 | 21.56 | 20.80 | 2.40 | 2.42 | 2.41 |
| 1000 ppm urea | 5.71 | 5.89 | 5.80 | 22.23 | 21.62 | 20.93 | 2.27 | 2.22 | 2.24 |
| 1000 ppm $Al_2(SO_4)_3$ | 5.32 | 5.79 | 5.55 | 20.50 | 21.42 | 20.96 | 2.27 | 2.42 | 2.34 |
| S.Em ± | 0.276 | 0.314 | 0.209 | 1.086 | 1.272 | 0.836 | 0.128 | 0.188 | .0114 |
| C.D. (0.05) | NS | NS | NS | NS | NS | NS | 0.371 | NS | 0.322 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

**Table 4B.10 Effect of foliar applied chemicals on number of pods in lowermost, middle and uppermost cluster**

| Treatments | Lowermost cluster | | | Middle cluster | | | Uppermost cluster | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 2.6 | 2.5 | 2.5 | 7.4 | 7.5 | 7.5 | 2.2 | 2.2 | 2.2 |
| 500 ppm TU | 2.9 | 2.9 | 2.9 | 8.1 | 8.0 | 8.0 | 2.9 | 2.8 | 2.8 |
| 500 ppm MEA | 3.1 | 3.1 | 3.1 | 9.8 | 8.3 | 9.1 | 2.7 | 3.0 | 2.8 |
| 10 ppm DTT | 2.9 | 2.8 | 2.9 | 7.9 | 7.8 | 7.9 | 2.7 | 2.6 | 2.6 |
| 10 ppm PCMBS | 2.3 | 2.1 | 2.2 | 6.5 | 6.9 | 6.7 | 1.9 | 2.0 | 1.9 |
| PCMBS+TU | 2.8 | 2.6 | 2.7 | 7.2 | 7.9 | 7.5 | 2.6 | 2.8 | 2.7 |
| 100 ppm IA | 2.6 | 2.6 | 2.6 | 7.3 | 7.5 | 7.4 | 2.0 | 2.3 | 2.1 |
| IA+TU | 2.6 | 2.8 | 2.7 | 7.3 | 8.0 | 7.6 | 2.5 | 2.8 | 2.6 |
| 1000 ppm urea | 2.5 | 2.6 | 2.6 | 7.3 | 7.6 | 7.4 | 2.0 | 2.3 | 2.1 |
| 1000 ppm $Al_2(SO_4)_3$ | 2.7 | 2.7 | 2.7 | 7.3 | 7.4 | 7.3 | 2.0 | 2.4 | 2.2 |
| S.Em $\pm$ | 0.17 | 0.11 | 0.10 | 0.20 | 0.16 | 0.13 | 0.13 | 0.11 | 0.09 |
| C.D. (0.05) | NS | 0.32 | 0.29 | 0.58 | 0.47 | 0.36 | 0.37 | 0.32 | 0.24 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

respectively over control. However, foliar spray of PCMBS+TU and IA+TU remained ineffective. Further, foliar spray of 10 ppm PCMBS significantly reduced number of pods in middle cluster by 9.5 per cent over control. However, foliar spray of 100 ppm IA proved ineffective. Further, foliar spray of 500 ppm MEA proved most effective in increasing number of pods in middle cluster over control. However, it was significantly superior to foliar sprays of 500 ppm TU and 10 ppm DTT.

**Number of pods in uppermost cluster**

Data (Table 4B.10) reveal that foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly increased number of pods in uppermost cluster over control during both the years, except foliar spray of IA+TU in 1999. However, foliar spray of 10 ppm PCMBS and 100 ppm IA proved in effective during the years. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly increased number of pods in uppermost cluster by 31.8, 27.3, 18.2, 22.7 and 18.2 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced number of pods in uppermost cluster by 13.6 per cent over control. However, foliar spray of 100 ppm IA proved ineffective. Further, foliar spray of 500 ppm TU proved most effective in increasing number of pods in uppermost cluster, which was significantly superior to foliar spray of 10 ppm DTT but was at par with 500 ppm MEA.

**4B.2.7 Ratio of grain: pod husk in lowermost, middle and uppermost cluster**

**Grain: Pod husk in lowermost cluster**

Data (Table 4B.11) indicate that foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased grain: pod husk ratio in lowermost cluster over control during both the years. However, foliar sprays of 10 ppm PCMBS, 100 ppm IA, PCMBS+TU and IA+TU had no significant effect in comparison to control during both the years. In pooled data, foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, and IA+TU significantly increased grain: pod husk ratio in lowermost cluster by 17.4, 28.7 17.4 and 15.7 per cent, respectively over control. Rest of the foliar spray treatments proved in effective. The highest grain: pod husk ratio of 1.48 was obtained under foliar spray of 500 ppm MEA, which was significantly superior to foliar sprays of 500 ppm TU and 10 ppm DTT.

**Grain: pod husk ratio in middle cluster**

Data (Table 4B.11) indicate that all the foliar spray treatments proved ineffective in 1999. While, in 2000, only foliar spray of 500 ppm MEA proved effective in increasing grain: pod husk ratio in middle cluster. However, foliar spray of 10 ppm PCMBS proved effective in

**Table 4B.11 Effect of foliar applied chemicals on ratio of grain : pod husk in lower most, middle and uppermost cluster at physiological maturity**

| Treatments | Lowermost cluster | | | Middle cluster | | | Uppermost cluster | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | |
| Control | 1.14 | 1.15 | 1.15 | 1.20 | 1.24 | 1.22 | 2.61 | 2.83 | 2.72 |
| 500 ppm TU | 1.32 | 1.37 | 1.35 | 1.29 | 1.36 | 1.33 | 3.45 | 3.30 | 3.38 |
| 500 ppm MEA | 1.46 | 1.49 | 1.48 | 1.32 | 1.39 | 1.36 | 5.01 | 4.55 | 4.78 |
| 10 ppm DTT | 1.32 | 1.37 | 1.35 | 1.27 | 1.24 | 1.26 | 3.79 | 3.55 | 3.67 |
| 10 ppm PCMBS | 1.02 | 1.03 | 1.03 | 1.06 | 1.03 | 1.05 | 6.67 | 3.40 | 5.04 |
| PCMBS+TU | 1.19 | 1.20 | 1.20 | 1.27 | 1.33 | 1.30 | 4.74 | 3.30 | 4.02 |
| 100 ppm IA | 1.07 | 1.10 | 1.09 | 1.09 | 1.16 | 1.13 | 7.22 | 3.05 | 5.14 |
| IA+TU | 1.29 | 1.36 | 1.33 | 1.16 | 1.28 | 1.22 | 4.25 | 3.28 | 3.77 |
| 1000 ppm urea | 1.08 | 1.13 | 1.11 | 1.17 | 1.24 | 1.21 | 2.85 | 2.98 | 2.92 |
| 1000 ppm $Al_2(SO_4)_3$ | 1.10 | 1.13 | 1.12 | 1.19 | 1.20 | 1.20 | 2.98 | 3.15 | 3.07 |
| S.Em ± | 0.061 | 0.063 | 0.043 | 0.070 | 0.067 | 0.048 | 0.332 | 0.238 | 0.020 |
| C.D. (0.05) | 0.176 | 0.183 | 0.122 | NS | 0.194 | 0.137 | 0.963 | 0.691 | 0.057 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

decreasing grain: pod husk ratio in middle cluster during 2000 only. In pooled data, foliar spray of 500 ppm MEA significantly increased grain: pod husk ratio in middle cluster by 14.0 per cent over control. Whereas, foliar spray of 10 ppm PCMBS brought about significant reduction of 13.9 per cent over control. Rest of the foliar spray treatments proved ineffective in this respect.

**Grain: pod husk ratio in uppermost cluster**

Data (Table 4B.11) show that foliar spray treatments significantly influenced grain: pod husk ratiò inconsistently. In 1999, foliar sprays of 500 ppm MEA, 10 ppm DTT, 10 ppm PCMBS, PCMB+TU, 100 ppm IA and IA+TU significantly increased grain; pod husk ratio in uppermost cluster over control. While, in 2000, only foliar sprays 500 ppm MEA and 10 ppm DTT proved effective in increasing grain: pod husk ratio in uppermost cluster over control. Foliar sprays of 500 ppm TU proved ineffective during both the years. In pooled data, all the foliar spray treatments proved effective in increasing grain: pod husk ratio in uppermost cluster over control.

## 4B.3 EFFECT OF –SH COMPOUND AND –SH GROUP BLOCKER ON YIELD OF CROP

### 4B.3.1 SEED, STRAW AND BIOLOGICAL YIELDS AND HARVEST INDEX

**Seed yield**

Data (Table 4B.12) show that foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased seed yield over control during 1999. However, in 2000, only foliar spray of 500 ppm MEA proved effective in increasing seed yield over control. Further, foliar sprays of 500 ppm TU and 10 ppm DTT exhibited increasing trends over control. On the other hand, foliar spray of 10 ppm PCMBS significantly decreased seed yield over control in either of the years. However, foliar spray of 100 ppm IA proved ineffective in both the years. Foliar spray of PCMBS+TU significantly increased seed yield over control in 1999 only. Pooled data show that foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and PCMBS+TU significantly increased seed yield by 13.6, 27.5, 12.2 and 9.9 per cent, respectively over control (18.89 q/ha). On the contrary, foliar spray of 10 ppm PCMBS significantly decreased seed yield by 14.7 per cent, over control. PCMBS+TU proved effective over PCMBS, and the effects were at par with control. However, foliar sprays of 100 ppm IA, IA+TU, 1000 ppm urea and 1000 aluminum sulphate remain ineffective in respect of seed yield

**Straw yield**

Data (Table 4B.12) show that foliar spray of 500 ppm MEA significantly increased straw yield over control in 1999 only, while foliar spray of 10 ppm PCMBS brought about significant reduction in straw yield over control during 1999 only. Rest of the foliar spray treatments proved ineffective during both the years. In pooled data, foliar spray of 500 ppm MEA significantly increased straw yield by 9.2 per cent over control. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced straw yield by 8.9 percent over control. Rest of the foliar spray treatments proved in effective.

**Biological yield**

Data (Table 4B.12) reveal that foliar spray of 500 ppm TU and 500 ppm MEA significantly increased biological yield over control in 1999 only. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced biological yield over control in 1999 only. Rest of the foliar spray treatments proved ineffective in 1999. However, in 2000 all the foliar spray treatments proved ineffective. In pooled data, only foliar spray of 500 ppm MEA brought about significant increase in biological yield by 14.5 per cent over control. On the contrary, foliar spray of 10 ppm PCMBS significantly decreased biological yield by 9.0 per cent over control. Rest of the foliar spray treatments proved ineffective.

**Harvest index**

Data (Table 4B.12) indicate that foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and PCMBS+TU significantly increased harvest index over control in 1999, whereas in 2000 only foliar spray of 500 ppm MEA proved effective in increasing harvest index. However, foliar spray of 500 ppm TU and 10 ppm DTT showed increasing trend over control. Foliar spray of 10 ppm PCMBS significantly decreased harvest index in 2000 only. In pooled data, foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and PCMBS+TU significantly increased harvest index by 7.7, 11.7, 8.8 and 5.9 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced harvest index by 5.8 per cent over control. Foliar spray of TU+PCMBS proved effective over 10 ppm PCMBS and control. However, foliar spray of 100 ppm IA, IA+TU, 100 ppm urea and 1000 ppm aluminum sulphate proved ineffective.

## 4B.4 EFFECT OF -SH COMPOUND AND- SH GROUP BLOCKER ON NUTRIENT CONTENT OF THE CROP

### 4B.4.1 N and S content of leaves at 75 DAS

Data (Table 4B.13) show that all the foliar spray treatments had no significant effect on N and S content of leaves at 75 DAS during both the years. Similar trends were recorded in pooled data.

**Table 4B.12 Effect of foliar applied chemicals on yields and harvest index**

| Treatments | Seed yield (q/ha) | | | Straw yield (q/ha) | | | Biological yield (q/ha) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | | | | | | | |
| Control | 16.82 | 20.97 | 18.89 | 44.44 | 49.16 | 46.80 | 61.26 | 70.13 | 65.69 | 27.44 | 29.89 | 28.67 |
| 500 ppm TU | 20.70 | 22.22 | 21.46 | 46.80 | 49.30 | 48.05 | 67.50 | 71.52 | 69.51 | 30.68 | 31.07 | 30.88 |
| 500 ppm MEA | 23.67 | 24.51 | 24.09 | 50.90 | 51.31 | 51.11 | 74.57 | 75.82 | 75.19 | 31.74 | 32.29 | 32.02 |
| 10 ppm DTT | 20.31 | 22.08 | 21.20 | 45.40 | 48.19 | 46.80 | 65.71 | 71.27 | 67.99 | 30.96 | 31.44 | 31.20 |
| 10 ppm PCMBS | 13.21 | 19.03 | 16.12 | 36.32 | 48.95 | 42.64 | 49.53 | 69.99 | 59.76 | 26.62 | 27.40 | 27.01 |
| PCMBS+TU | 19.98 | 21.53 | 20.76 | 45.64 | 49.02 | 47.33 | 65.62 | 70.55 | 68.09 | 30.34 | 30.43 | 30.39 |
| 100 ppm IA | 15.01 | 20.27 | 17.64 | 41.38 | 49.85 | 45.62 | 56.39 | 70.13 | 63.26 | 26.59 | 28.91 | 27.75 |
| IA+TU | 16.98 | 22.36 | 19.67 | 43.37 | 49.58 | 46.48 | 60.35 | 73.60 | 66.98 | 28.13 | 30.40 | 29.27 |
| 1000 ppm urea | 17.09 | 21.11 | 19.10 | 43.96 | 50.13 | 47.05 | 61.05 | 71.24 | 66.15 | 27.99 | 29.61 | 28.80 |
| 1000 ppm $Al_2(SO_4)_3$ | 17.43 | 20.69 | 19.06 | 44.87 | 49.86 | 47.37 | 62.29 | 70.55 | 66.42 | 27.96 | 29.30 | 28.63 |
| S.Em $\pm$ | 0.734 | 0.653 | 0.491 | 1.449 | 1.276 | 0.965 | 2.14 | 2.274 | 1.561 | 0.329 | 0.571 | 0.329 |
| C.D. (0.05) | 2.131 | 1.895 | 1.391 | 4.203 | NS | 2.736 | 6.21 | NS | 4.423 | 0.955 | 1.655 | 0.932 |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

**Table 4B.13 Effect of foliar applied chemicals on N and S content of leaves at 75 DAS**

| Treatments | N content (%) | | | S content (%) | | |
|---|---|---|---|---|---|---|
| | 1999 | 2000 | Pooled | 1999 | 2000 | Pooled |
| Foliar spray | | | | | | |
| Control | 2.70 | 2.66 | 2.68 | 0.421 | 0.430 | 0.426 |
| 500 ppm TU | 2.80 | 2.69 | 2.75 | 0.422 | 0.432 | 0.427 |
| 500 ppm MEA | 2.84 | 2.67 | 2.76 | 0.425 | 0.431 | 0.428 |
| 10 ppm DTT | 2.79 | 2.69 | 2.74 | 0.423 | 0.429 | 0.426 |
| 10 ppm PCMBS | 2.71 | 2.70 | 2.70 | 0.421 | 0.428 | 0.425 |
| PCMBS+TU | 2.77 | 2.65 | 2.71 | 0.422 | 0.430 | 0.426 |
| 100 ppm IA | 2.67 | 2.66 | 2.67 | 0.428 | 0.431 | 0.430 |
| IA+TU | 2.79 | 2.68 | 2.74 | 0.426 | 0.429 | 0.428 |
| 1000 ppm urea | 2.71 | 2.69 | 2.70 | 0.423 | 0.430 | 0.427 |
| 1000 ppm $Al_2(SO_4)_3$ | 2.71 | 2.67 | 2.69 | 0.429 | 0.431 | 0.430 |
| S.Em ± | 0.037 | 0.039 | 0.027 | 0.005 | 0.007 | 0.004 |
| C.D. (0.05) | NS | NS | NS | NS | NS | NS |

TU = Thiourea, MEA = Mercaptoethylamine, DTT = Dithiothreitol,
PCMBS = para-Chloromercurybenzoicsulphonic acid, IA = Iodoacetate

# 5 DISCUSSION

While presenting the results of the present investigation entitled "Effect of thiourea and Dimethylsulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] in the preceding chapter, significant variations were noted in number of crop parameters due to effects of different treatments tried in the two years of experimentation. In this chapter, an attempt has been made to critically assess the effects of different treatments on all such crop parameters and present a conceptual framework for better understanding of the treatment effects. Wherever felt necessary, experimental reports of other workers have been cited to support the findings of the present investigation. Since the present investigation comprised two separate experiments, the results of these experiments are discussed accordingly in sequence in the following sections.

## 5.1 EXPERIMENT I: EFFECT OF THIOUREA AND DIMETHYLSULPHOXIDE ON PHOSPHORUS USE EFFICIENCY, DRY MATTER PARTITIONING AND PRODUCTIVITY OF CLUSTERBEAN

## 5.1 EFFECT OF PHOSPHORUS LEVELS

### 5.1.1 Growth parameters

The results indicated that increasing level of P application upto 40 kg $P_2O_5$/ha significantly improved morphological and physiological parameters of clusterbean (Table 4A.1 - 4A.4 and fig.4.1 & 4.2). Thereby capacitating the plants to accumulate significantly higher amount of dry matter at successive stage of crop growth with the increased P application. Root length and dry matter of roots at 60 DAS also increased significantly with 40 kg $P_2O_5$/ha over control and 20 kg $P_2O_5$/ha.

In general the overall improvement in growth of clusterbean with increased P could be ascribed to its pivotal role in several physiological and biochemical processes which are of vital importance for growth and development of plant. The influence of increased P application was noticed on better root length (Table 4A.25), root nodules (Table 4A.27 ) and availability of P from soil (Table 4A.41-4A.43). This seems to have provided congenial nutritional environment in the plants. It is also evident from the estimates of nutrient concentration, which showed a significant enhancement in N and P content of plant parts at successive stages of crop growth (Table 4A. 46-4A.56). Such improvement under increased P application might have increased metabolic processes in plant resulting in greater meristamatic activities and apical growth, thereby improving plant height, branches per plant and higher number of green leaves per plant ultimately resulting in improved photosynthetic surface of the plant. This is evident from increase in LAI at 60 and 90 DAS (Table 4A.17-18).

Since the status of native phosphorus in soil was low (18.4 and 16.5 kg $P_2O_5$/ha), application of soluble phosphorus increased the availability of phosphorus to plant parts. Thus, increased supply of labile phosphorus might have helped in early root ramification and establishment of the crop, thereby leading to increased growth parameters. Singh and Singh (1989) observed stimulating effect of phosphorus application on root growth and root nodules of clusterbean. Increase in chlorophyll content of leaves at 90 DAS was observed with application of 40 kg $P_2O_5$/ha (Table 4A.16). The beneficial effect of phosphorus fertilization on chlorophyll content of leaves might be due to the availability of higher energy in the form of ATP molecules which might have favoured the multiplication of cells and increased the chlorophyll content of leaf tissues (Pareek, 1995)

P application at 20 and 40 kg $P_2O_5$/ha significantly improved growth parameters in comparison to no P application. Beneficial effects of P on growth of clusterbean have been reported by several workers. Wani and Patil (1982) reported significant increase in plant height and number of branches per plant in clusterbean due to application of P upto 80 kg $P_2O_5$/ha. Increase in number of branches and NAR of clusterbean was also recorded with 40 kg $P_2O_5$/ha over control (Raut and Ali, 1983). Singh and Singh (1989) reported significant increase in nodules/plant and root dry weight of clusterbean due to P application upto 60 kg $P_2O_5$/ha over control and 30 kg $P_2O_5$/ha. While, Pareek (1995) reported that application of 40 kg $P_2O_5$/ha significantly improved dry matter accumulation/plant and chlorophyll content of leaves in clusterbean. Thus, the results of these workers corroborate the finding obtained in the present investigation. The larger canopy development as evidenced by increase in LAI and LAR under the influence of 40 kg $P_2O_5$/ha seems to have increased absorption and utilization of radiant energy resulting into higher dry matter accumulation per plant

The P distribution to leaves stems and pods is an important factor to increase dry matter accumulation This is evidenced from increased P content in different parts of the crop under the influence of P application (Table 4A.48-4A.56). When P supply is limited, the availability of P and N to chloroplast becomes limited ultimately affect the photosynthetic processes as well as photosynthates supply to nodules. Thus, interdependence of these processes in plant on P supply show effect of P on plant growth process which resulted in greater accumulation of biomass of individual plant through increase in assimilatory apparatus (LAI) and other growth efficiency parameters viz., CGR, LAR and NAR These results are in close accordance with results reported that Raut and Ali (1983)

**5.1.2 Yield attributes and yield :**

Application of 40 kg $P_2O_5$/ha significantly increased clusters per plant, pods per plant, pod length and seed yield per plant over control and 20 kg $P_2O_5$/ha (Table 4A.28, 29, 33, 36). However, number of seeds per pod and test weight significantly increased upto 20 kg $P_2O_5$/ha (Table 4A.34 & 4A.35). On the contrary, number of poorly filled pods and unfilled pods per plant significantly decreased with the application of 40 kg $P_2O_5$/ha over control and 20 kg $P_2O_5$/ha (Table 4A.31-32). Seed yield and harvest index also significantly increased with increasing levels of P upto 40 kg $P_2O_5$/ha. However, straw and biological yields responded upto 20 kg $P_2O_5$/ha (Table 4A.38 & 39).

The beneficial effect of increased P levels appears to be a result of growth of individual plant as reflected through increased plant height, branching per plant, number of green leaves, LAI, CGR, LAR and NAR and ultimately dry matter accumulation per plant at successive stage of the crop growth. The favourable effect of phosphate fertilization on yield attributes might be due to the fact that phosphorus plays a key role in the root development, energy transformation and various vitally important metabolic processes in plant.

The significant increase in yield attributes observed under phosphorus application seems to have resulted on account of improved nutritional condition inside the plant. It was observed that phosphorus applications at 40 kg $P_2O_5$/ha significantly increased P content of different parts at different growth stages (Table 4A.48-56). All these effects observed with phosphorus application suggest that same sort of nutrient balance was necessary for proper functioning of photosynthetic apparatus and growth of crop plants. This is further evidenced from the fact that there was significant increase in dry matter accumulation at different growth stages which finally reflected in significant improvement in biological yield. Improvement in yield attributes due to increased P application were also reported by Singh and Singh (1989), Tiwana and Tiwana (1994), Shivran *et al.* (1996) and Naagar (2001).

The significant increase in test weight due to 20 kg $P_2O_5$/ha might be due to better uptake and translocation of photosynthate, thus increasing the size and weight of grains. This is evidenced from the fact that dry matter translocation toward the sink increased significantly under the influence of P application (fig. 4.3) and better P status in pods.

A significant increase in seed yield of clusterbean due to application of 40 kg $P_2O_5$/ha could be ascribed to the fact that yield of the crop is a function of yield attributes which are dependent on complementary interactions between vegetative and reproductive growth of the crop. Their overall effects reflect in the form of yield. This is also evidenced from the fact that number of poorly filled pods and number of unfilled pods per plant significantly decreased due to 40 kg $P_2O_5$/ha over control and 20 kg $P_2O_5$/ha (Table 4A.31-32). A positive and significant relationship was observed between seed yield and yield attributes, while negative relationship was observed with number of poorly filled pods and number of unfilled pods per plant (Table 5.1 and 5.2). The observed relationship is in close agreement with findings of Pareek (1995) and Naagar (2001).

In the preceding paragraph it has been emphasized that increased P fertilization played a vital role in improving yield determinants viz., number of green leaves per plant and

**Table 5.1 Correlation coefficient and regression equation showing relationship between independent variable (X) and dependent (Y) variable on Mean basis in clusterbean crop**

| S.N. | Dependent variable (Y) | Independent variable (X) | Correlation coefficient "r" | Regression equation |
|---|---|---|---|---|
| 1 | Seed yield (q/ha) | DMA at physiological maturity | 0.953 ** | Y =3.56 + 0.477 X |
| 2 | Seed yield (q/ha) | LAI at 60 DAS | 0.919 ** | Y = 2.07 + 3.137 X |
| 3 | Seed yield (q/ha) | LAI at 90 DAS | 0.828 ** | Y = 8.31 + 2.321 X |
| 4 | Seed yield (q/ha) | Root length (cm) at 60 DAS | 0.917 ** | Y = -5.52 + 1.079 X |
| 5 | Seed yield (q/ha) | Root nodules at 60 DAS | 0.966 ** | Y = 4.40 + 2.312 X |
| 6 | Seed yield (q/ha) | Cluster/plant | 0.868 ** | Y = 1.92 + 0.82 X |
| 7 | Seed yield (q/ha) | Pods/plant | 0.919 ** | Y = 0.86 + 0.263 X |
| 8 | Seed yield (q/ha) | Poorly filled pods/plant | - 0.800 ** | Y = 22.08 – 1.461 X |
| 9 | Seed yield (q/ha) | Unfilled pods/plant | - 0.761 ** | Y = 20.31 – 0.586 X |
| 10 | Seed yield (q/ha) | Pod length (cm) | 0.581 * | Y = - 5.45 + 4.216 X |
| 11 | Seed yield (q/ha) | Grains/pod | 0.859 ** | Y = - 20.62 + 5.152 X |
| 12 | Seed yield (q/ha) | Test weight (g) | 0.768 ** | Y = - 87.03 +3.477 X |
| 13 | Seed yield (q/ha) | Seed yield/plant (g) | 0.951 ** | Y = 5.26 + 0.889 X |
| 14 | Seed yield (q/ha) | Soil available P at 30 DAS | 0.900 ** | Y = - 13.56 + 1.605 X |
| 15 | Seed yield (q/ha) | Soil available P at 60 DAS | 0.924 ** | Y = - 6.48 + 1.038 X |
| 16 | Seed yield (q/ha) | Soil available P at maturity | 0.916 ** | Y = - 3.75 + 1.063 X |
| 17 | Seed yield (q/ha) | P content of leaves at 60 DAS | 0.912 ** | Y = - 14.64 + 69.277 X |
| 18 | Seed yield (q/ha) | P content of stems at 60 DAS | 0.958 ** | Y = - 46.29 + 156.708 X |
| 19 | Seed yield (q/ha) | P content of pods at 60 DAS | 0.944 ** | Y = - 44.32 + 116.235 X |

Note: The above mentioned regression equations are operative under certain statistical assumptions where X is not always zero

**Table 5.2 Correlation coefficient and regression equation showing relationship between independent variable (X) and dependent (Y) variable on Mean basis in clusterbean crop**

| S.N. | Dependent variable (Y) | Independent variable (X) | Correlation coefficient "r" | Regression equation |
|---|---|---|---|---|
| 20 | Seed yield (q/ha) | P content of leaves at 90 DAS | 0.907 ** | Y = - 21.98 + 90.572 X |
| 21 | Seed yield (q/ha) | P content of stems at 90 DAS | 0.954 ** | Y = - 99.87 + 306.181 X |
| 22 | Seed yield (q/ha) | P content of pods at 90 DAS | 0.915 ** | Y = - 30.88 + 92.549 X |
| 23 | Seed yield (q/ha) | P content of leaves at physiological maturity | 0.906 ** | Y = - 21.31 + 89.029 X |
| 24 | Seed yield (q/ha) | P content of stems at physiological maturity | 0.954 ** | Y = - 58.38 + 199.721 X |
| 25 | Seed yield (q/ha) | P content of pods at physiological maturity | 0.922 ** | Y = -33.80 + 97.592 X |
| 26 | P uptake by seed (kg/ha) | Biological yield (q/ha) | 0.954 ** | Y = - 7.50 + 0.294 X |
| 27 | P uptake by straw (kg/ha) | Biological yield (q/ha) | 0.984 ** | Y = - 5.10 + 0.309 X |
| 28 | Total P uptake (kg/ha) | Biological yield (q/ha) | 0.976 ** | Y = - 12.48 + 0.601 X |
| 29 | Root length at 60 DAS | Soil available P at 30 DAS | 0.950 ** | Y = - 6.57 + 1.44 X |
| 30 | Root length at 60 DAS | Soil available P at 60 DAS | 0.966 ** | Y = 0.01 + 0.922 X |
| 31 | Root nodules at 60 DAS | Soil available P at 30 DAS | 0.894 ** | Y = - 7.25 + 0.666 X |
| 32 | Root nodules at 60 DAS | Soil available P at 60 DAS | 0.933 ** | Y = - 4.45 + 0.438 X |
| 33 | DMA at 60 DAS | LAI at 60 DAS | 0.986 ** | Y = 3.59 + 3.254 X |
| 34 | DMA at 90 DAS | LAI at 90 DAS | 0.907 ** | Y = 12.52 + 4.242 X |
| 35 | Biological yield (q/ha) | DMA at physiological maturity | 0.867 ** | Y = 28.77 + 1.064 X |
| 36 | DMA at 60 DAS (g) | CGR at 60 DAS | 0.997 ** | Y = 0.21 + 1.007 X |
| 37 | DMA at 90 DAS (g) | CGR at 90 DAS | 0.922 ** | Y = 9.68 + 1.790 X |

Note: The above mentioned regression equations are operative under certain statistical assumptions where X is not always zero

LAI for increase photosynthesis, root length and root dry matter for increased nutrient absorption and nodulation, strong sink strength for higher translocation of assimilates and development of reproductive structures as evidenced from increased number of pods per plant due to application of 40 kg $P_2O_5$/ha. These effects culminated in maintaining source-sink balance to a larger extent, thereby resulting in higher seed yield with 40 kg $P_2O_5$/ha. P content of leaves, stems and pods at different growth stages and seed yield were found positively correlated (Table 5.1 and 5.2). The results are in the line of findings of Naagar (2001). Further more, significantly higher number of nodules due to 40 kg $P_2O_5$/ha would likely to retard senescence as evidenced by increased number of green leaves per plant due to 40 kg $P_2O_5$/ha. This all might have increased yield as a result of a longer filling period. Significantly higher seed yield of cluster bean with the application of 40 kg $P_2O_5$/ha was also reported by Pareek (1995) and Solanki *et al.* (1998).

Significant increase in stover yield with 20 kg $P_2O_5$/ha over control could be attributed to conducive effect on roots and growth of plant, which in turn increased morphological parameters viz., plant height, number of green leaves per plant, number of branches per plant and finally dry matter accumulation (Table 4A.1-4 and fig. 4.1). Baboo and Rana (1995) and Shivran *et al.* (1996) also observed significant increase in stover yield of clusterbean with phosphorus application. Increase in biological yield with P application at both 20 and 40 kg $P_2O_5$/ha levels could be attributed to beneficial effects of phosphorus on both vegetative and reproductive growth of the crop, as biological yield is a function of seed and stover yields. Harvest index increased significantly due to 40 kg $P_2O_5$/ha over control and 20 kg $P_2O_5$/ha (Table 4A.40). The dry matter distribution in pods increased significantly from 60 DAS to physiological maturity under the influence of phosphorus application (fig. 4.3). The probable reason for increased harvest index might be due to improved dry matter partitioning due to P application. Shivran *et al.* (1996) and Meena (1999) also observed significant increase in harvest index with P application.

### 5.1.3 Quality parameters

Gum content of seed increased significantly with increasing P levels upto 20 kg $P_2O_5$/ha. The increase in gum content might be perhaps due to augmented carbohydrates and fat syntheses in seeds due to application of phosphorus. Thus, boldness of the seed increased by more accumulation of carbohydrates in seeds resulting in more gum content in clusterbean seeds. Significant improvement in protein content of seed was recorded with increasing levels of P upto 40 kg /ha (Table 4A.45). Improvement in protein content is ascribed to significant enhancement in N content of seed and leaves due to increasing P supply (Table 4A.46). The results are in close agreement with those of Wani and Patil (1982), Jain *et al.* (1988) and

Bhadoria *et al.* (1997). They also reported that application of 40 kg $P_2O_5$/ha significantly increased gum and protein content of seed.

**5.1.4 Nutrient content and P uptake**

Application of 40 kg $P_2O_5$/ha brought about significant improvement in P content of different parts of clusterbean at successive stages of crop growth over control and 20 kg $P_2O_5$/ha (Table 4A.48-56).The improvement in P content in different plant parts with the application of P seems to be on account of its pivotal role in formation of roots, their proliferation and improvement in their functional activities. This might have induced high extraction of nutrients from soil environment for longer duration and their efficient translocation in the plant system. It could be relevant to call into attention that increased P fertilization also resulted in increased soil available P at 60, 90 DAS and harvest (Table 4A. 41-43), which might be easily absorbed by the plants. Increase of P influx with added P seems to have maintained critical concentration at cellular level in order to cope-up with their need and subsequent efficient translocation towards source and sink i.e. leaves and pods or seed resulting in higher concentration in all the plant parts. (Meena, 1999)

As regards the status of P content in different part of clusterbean at successive stages of crop growth, though it increased with increase in P application in the order of pods > leaves > stems, the highest P content was estimated in pods and lowest in stems indicating maximum amount of P was allocated to clusterbean seed probably for formation of seed itself, protein and gum. Similar findings were reported by Bhadoria *et al.* (1997), Kumawat (1997) and Meena (1999). Significant increase in uptake of P by seed and stover (Table 4A. 66-67) of clusterbean recorded in the present investigation might be partly due to increased content in seed and stover under the influence of 40 kg $P_2O_5$/ha over control and 20 kg $P_2O_5$/ha. Apart from this, the total amount of nutrient uptake by the crop is largely determined by total dry matter production. The correlation studies showed significant and positive correlation between P uptake by seed, stover and total P uptake, and biological yield ($r$ = 0.954, 0.984 and 0.976). The results are in close accordance with those of Kumar (1987), Singh and Singh (1989), Baboo and Rana (1995) and Naagar (2001).

P harvest index significantly increased with increasing P application upto 20 kg $P_2O_5$/ha (Table 4A. 72). This might be due to the fact that translocation of P towards pods at physiological maturity was significantly higher due to P application (Table 65). Agronomic efficiency and P recovery decreased with 40 kg $P_2O_5$/ha as compared to 20 kg $P_2O_5$/ha.(Table 69 & 71). Dubey (2000) also found that phosphorus use efficiency was superior under lower dose as compared to higher dose of phosphorus. However, physiological efficiency showed reverse trends (Table 4A.70). It may be further noted that while agronomic efficiency indicates kg grain/kg P applied/ha and P recovery represents kg P absorbed/kg P applied. Higher levels of both these parameter at 20 kg $P_2O_5$/ha thus indicates that critical requirement for phosphorus was met at this level, and beyond 20 kg $P_2O_5$/ha, phosphorus application did not benefit the crop so remarkably both in terms of P uptake and seed yield. On the other hand physiological efficiency of P levels indicated reverse trends i.e. kg grain/kg P uptake/ha increased with increasing P application upto 40 kg $P_2O_5$/ha. This means that absorbed phosphorus was utilized well in grain production with increasing levels of P application. Decrease in agronomic efficiency and P recovery with increasing levels of P application, therefore, indicate that much of P applied was not absorbed by the crop plants and that P absorption was nearly sufficient upto 20 kg $P_2O_5$/ha, beyond which absorbed P was less effective in grain production. Decrease in agronomic efficiency and P recovery with increasing levels of P application were reported by Khiriya *et al.* (2001) in fenugreek grown on sandy loam soil of Hisar.

## 5.2 EFFECT OF THIOUREA

### 5.2.1 Growth parameters

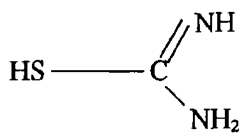
Soil and foliar application of TU brought about significant variations in number of growth parameters in comparison to control. However, it was generally observed that the effect of soil application of TU at 5 kg/ha ($^1/_2 + ^1/_2$) and foliar spray of 500 ppm TU proved superior to control in improving most of the growth parameters. Soil application of TU at 5 kg/ha (basal) also proved superior to control in influencing growth of plants, but the effects were not very consistent (Table 4A.1-4). Further, it was noted that split application of TU in soil proved superior to basal application of TU. A reference to table 4A.3-4 & fig. 4.2 would reveal that significant improvement in branches per plant, number of green leaves per plant, dry matter accumulation at 60, 90 DAS and physiological maturity, LAI and CGR at 60 and 90 DAS was noted on account of split application of TU in soil at 5 kg/ha ($^1/_2 + ^1/_2$) and foliar spray of 500 ppm TU. Almost all these parameters were equally improved by both soil as well as foliar applied TU. However, root length and number of nodules per plant at 60 DAS significantly increased with soil application of TU at 5 kg/ha ($^1/_2 + ^1/_2$) only. In light of these observations it is fairly conceivable that TU might have stimulated the photosynthetic carbon fixation mechanism and hence might have increased canopy photosynthesis (Sahu et. al. 1993). Significant increases in LAI and eventually dry matter accumulation obtained with the TU treatment provide ample support to such effects. Since TU exhibits cytokinin like activity (Vassilev and Mashev, 1974 and Erez, 1978) and cytokinins are well known for delaying leaf senescence (Woolhouse, 1974), TU might have resulted in the creation of larger photosynthetically active leaf surface during the grain filling. That, this is so evidenced by the fact that larger number of green leaves per plant and significant increase in chlorophyll content of leaves was recorded in TU treatment. The larger canopy development as evidenced by number of green leaves and LAI under the influence of TU treatment seems to have increased absorption and utilization of radiant energy resulting into higher DMA per plant.

### 5.2.2 Dry matter partitioning and productivity

when the effects of TU treatment are assessed in respect of dry matter distribution (DMD), it was noted that only soil application of TU at 5 kg/ha ($^1/_2$ +$^1/_2$) proved effective in improving DMD in leaves at 30 DAS ( Table 4A.5 & fig. 4.6). While at 60, 90 DAS and physiological maturity all the TU treatments including TU (basal) and TU (spray) were effective in improving DMD in leaves and pods (fig.4.4 & 4.6). However, the magnitude of increasing DMD in leaves and pods was higher under soil application of TU at 5 kg/ha ($^1/_2$ +$^1/_2$) and foliar spray of 500 ppm TU in comparison to soil application of TU (basal). On the contrary, DMD in stems at 90 DAS and physiological maturity significantly decreased with soil and foliar applied treatments of TU. With regard to yield attributes and yield it was noted that soil application of TU (basal) did not prove effective in influencing yield attributes as well as seed yield in comparison to control. However, almost all the yield attributing parameters, except number of pods per cluster significantly improved with soil application of TU (split) and foliar spray of TU. Both soil and foliar treatment of TU increased the number of pods, seeds per pod and test weight, indicating an improving storage capacity. It may, thus, be noted that while split application of TU in soil worked well in influencing growth parameters significantly over control. Basal application of TU did not show consistent effects. Obviously, persistence of soil applied TU appears to be more under split application in soil then when TU applied basal. This seems to have rejected on account of the highly permeable characteristics of the sandy soils of the experimental sites in the two years of the experimentation. The soils contain 90.8 and 91.25 % sand, and therefore much of TU when applied entirely basal might have leached down beyond root zone during rains or supplemental irrigation given to the crop. On the other hand, under split application despite leaching of some TU in the initial stage TU applied at flowering initiation stage was consistently available in the root zone for absorption and utilization in formation of yield organs including persistence of photosynthetically active more number of leaves. This is convincing as in extremely sandy soils leaching of fertilizer nutrients and reduced fertilizer use efficiency is a well known effect of fertilizer treatments applied to the soil.

It was also evident from the result discussed earlier that split application of TU proved significantly superior to foliar spray of TU in improving crop yield. A reference to data (Table 4A.3, 4A.34 and 4A.30) would reveal that split application of TU resulted in significantly larger number of branches, number of seeds per pod and a consistent increase in number of pods per plant during both the years of experimentation. Also, number of poorly filled pods as well as unfilled pods were lower under this treatment in comparison to foliar applied TU. On the other hand, foliar applied TU significantly increased number of green leaves, LAI, CGR and LAR over split applied TU in soil. Foliar applied TU also resulted in significantly larger test weight as compared to that under split applied TU. It may be noted that foliar spray of TU was made at 45-50 DAS when the crop was at flower initiation stage. Thus, even though post flowering, crop photosynthesis was improved under foliar spray of TU, the pre flowering effect under soil applied TU provided advantage through increased formation of storage capacity i.e. number of seeds and pods per plant besides more number of branches per plant. Thus, while sink capacity was larger under soil applied TU, sink strength was greater under foliar applied treatment and former was more dominant in improving number of seeds and hence yield. It, therefore, appears that early pre flowering stimulation of crop growth through -SH enrichment is necessary for maximizing crop productivity.

In this context, it is noteworthy that TU, containing -SH group, is a non biological thiol (Jocelyn, 1972), stimulates dark fixation of $CO_2$ in embroyonic axes of chickpea (Hernandtez-Nestal *et al.*, 1983). Because of the -SH group, TU may play several bioregulatory roles in crop plants, as the -SH group has diverse biological activity and having the following structural formula (Jocelyn, 1972).




Involvement of SH group in phloem transport of sucrose has been suggested (Giaquinta, 1976; Giaquinta, 1977). This is evidenced by increasing DMD in pods. For illustration of these points related to possible role of TU in photosynthate translocation, a brief note on the mechanism of assimilate transport via phloem loading of sucrose, the major photosynthetic metabolite, appears to be a necessary pre requisite. Giaquinta (1977) stated that for plant to grow, sugar and other assimilates must constantly be transported from the leaves to growing or storage region. This essential transport function takes place in the highly specialized phloem tissue which consists of a net work of inter connecting sieve tubes. In spite of its obvious agronomic importance, little is known about the first step of sugar entry (loading) into the sieve tubes. The model proposed by the author formulates several of the established but difficult to reconcile characteristics of the sieve tubes into a unifying model for sugar uptake. These characteristics include the alkaline sap (pH 8-8.5) with a high potassium ion and ATP concentrations, the presence of electrical gradient and the considerable ATPase activity of the sieve tube plasmalemma. According to this model, sucrose leaves the site of synthesis in the mesophyll cells and enters the free space or apoplast, which has a pH of 5-6. The sucrose is then accumulated into alkaline sieve tubes by an active process involving membrane sulphydryl groups. In this model, the proton gradient of nearly 3 pH units across the sieve tube plasmalemma provides the driving force of sucrose uptake (fig. 5.1). In this regard it is interesting to point out that TU has been observed to activate proton pump in germinating seeds of chickpea (Hernandez – Nistal *et al.*, 1983).

Giaquinta (1976) employed chemical probes to characterize phloem loading at the membrane level. Further, the study showed that sugars are accumulated into the phloem from the apoplost by an energy dependant process which was associated with membrane bound -SH group. Komar *et al.* (1978) also reported that sugar translocating carrier protein possesses a suphydryl group that is essential for its function. Since the -SH group is essential at the substrate binding site of the amino acid carrier (Mc Cormick and Johnstone, 1990), foliar spray of TU in the present might have enhanced formation of the ternary complex, sucrose - $H^+$ carrier, thus improving phloem loading of sucrose and hence translocation of photosynthates. This contention on the possible role of TU in improving translocation of photosynthate via improved phloem loading is substantiated by the effect of TU treatments on dry matter partitioning and yield components, particularly pods per plant and grain weight.

It was noted that not only accumulation of dry matter increased due to effects of TU treatments, but translocation of dry matter was also found to be higher under TU treatment. At 90 DAS and physiological maturity, dry matter distribution in stems decreased and in pods it was increased. Thus, TU treated crop showed significant relocation (partitioning) of dry matter from stems and leaves for pod development. This indicates that there was improved phloem loading of assimilates and hence greater translocation of photosynthate under the influence of TU treatment, most probably on account of the – SH group present in the TU molecule. The role of TU as a sulphydryl compound and eventual effect of – SH supply on crop growth productivity are further borne out by the fact that TU treatments had no significant effect on sulphur content of leaves at 90 DAS when the crop was at grain development phase. Thus, it is clear that content of sulphur was not important but it was the – -SH configuration, which was a factor in yield differences observed due to treatment. Therefore, TU has bio-regulatory effects, chiefly through mobilization of dry matter and translocation of photosynthate for improved yield formation. This in further evidenced from the fact that number of cluster per plant and number of pods per plant increased significantly under TU treatments. On the other hand, higher allocation of dry matter of storage organ resulted in lesser number of poorly and unfilled pods per plant under the influence of TU treatments. These parameters showed significant and negative correlation with seed yield

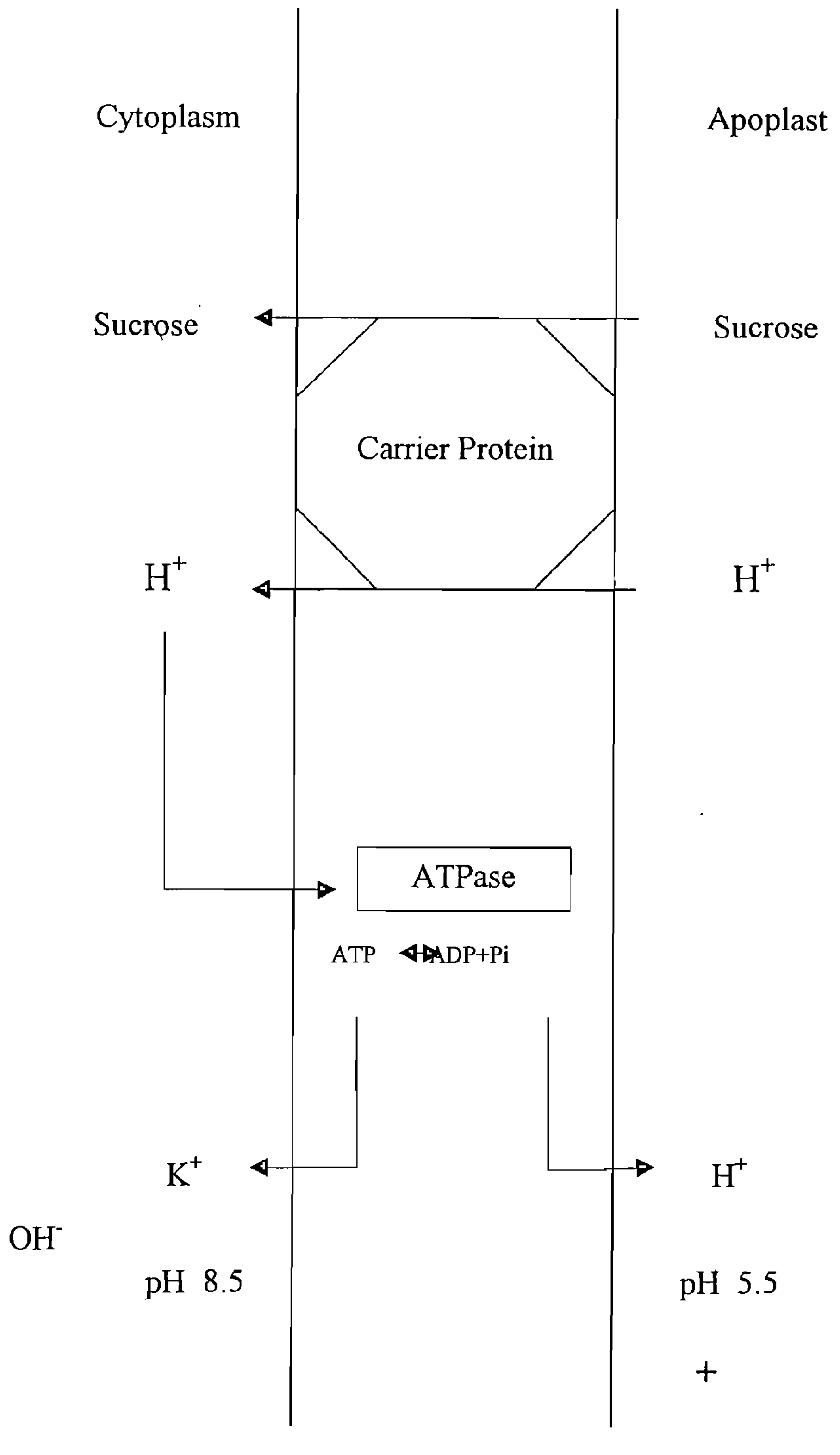



**Fig. 5.1 : Model of transport of assimilates (sucrose) in sieve tubes (phloem)**

(Table 5.1) Harvest index increased significantly due to TU treatment, (Table 4 A 40) Eventually seed yield increased significantly under TU treatments, but straw yield did not This clearly indicates that TU treatment in the present study improved seed yield chiefly on account of improved assimilate partitioning and transport during grain development.

The role of TU in improving dry matter partitioning has been reported in various crops by different workers Sahu and Solanki (1991) noted significant improvement in harvest index with foliar spray of 0.1 % TU in maize Parihar *et al* (1998) observed that dry matter distribution in leaves and stems of bajra decreased due to foliar spray of TU but increase in DMD in ears.

**5.2.3 Phosphorus use efficiency**

Soil application of TU both as basal and split doses increased P harvest index as well as agronomic efficiency of P. Physiological efficiency of P was also increased by these TU treatments Thus, it appears that TU has a role in improving P absorption and utilization inside the plants Since TU is a sulphydryl compound, the effects of TU on root growth and activity might be a result of the metabolic role of – SH group in root physiology and biochemistry. It is also possible that the direct effect of TU on soil phenomenon like solubilizing of native P and P availability due to reduced P fixation might also be factors responsible for increased P use efficiency due to soil application of TU Sud *et al.* (1991) while reporting the effect of TU on P use efficiency by potato in brown hill soils of Shimla suggested three possibilities : (i) it helps in better root growth, (ii) anti-bacterial effect on soil micro-flora to prevent nutrient fixation (De Ritis and Scalfi, 1946) and (iii) sulphur present in thiourea and applied near seed tuber solubilized more soil P compared with inactive form of S from calcium sulphate.

The biological environment of root is essentially manifested by a preferential colonization of soil microbes in the rhizosphere. The proliferation of these microbes is affected by secretion from the root a wide range of readily available organic compound called 'exudates'. The interactions of these microbes with plant root gives rise to a modified and localised biogenic milieu surrounding the root which dissolves many essential plant nutrients from relatively insoluble sources. (Sarkar and Goswami, 1982).

In the present study root length and root dry matter increased with soil application of TU. Perhaps TU might have created better microbial population in soil, which resulted in higher available P in soil. This is also evidenced by the increasing number of nodules under the influenced of TU treatments (Table 4A.27).

Soil application of TU at 5 kg/ha ($^1/_2+^1/_2$) significantly increased available P content of soil at 30, 60 DAS and maturity (Table 4A.22-24). This might be due to the fact that TU has beneficial effect on solubilizing native as well as applied phosphorus in the soil and better root growth. This is evidenced by more root length and root dry matter at 60 DAS under the influence of soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$).

Since the availability of P increased, there was better root growth, which led to their deep penetration into soil to extract more nutrient P by the crop. This is evidenced by the fact that P content increased in different parts of plant at successive growth stages of the crop due to TU treatments (Table 4A.48-56). Increase in P content in different parts of the crop at successive stages of crop growth was observed on account of soil application of TU at 5 kg/ha (1/2 + 1/2). This could probably be due to increase in available P content of soil at successive stages of the crop growth and better root growth under the influence of split application of TU in soil (Table 4A.25-26). This might have induced high extraction of nutrients from the soil environment for longer duration and their efficient translocation in the plant system. The P distribution in pods at 60, 90 DAS and physiological maturity was higher as compared to leaves and stems indicating better sink strength for importing assimilates. Split application of TU in soil significantly increased P uptake by the crop (Table 4 A 68). The nutrient mass in plants is dependent on concentration in plant tissues and dry matter accumulation. Hence, improvement in both of these components under TU treatment resulted in higher P uptake. The regression analysis supports the positive and significant relationship between biological yield and total uptake of P (r = 0.976). Sud *et al.* (1991) observed in green house and field study that application of TU in soil had positive effect on potato yield and P uptake as compared to control. Foliar spray of 500 ppm TU increased P harvest index as well as agronomic efficiency of applied P. These parameters increased by 6.1 & 27.7 % respectively over control due to foliar spray of TU. Such improvement in P use efficiency under TU spray made at flower initiation seems to have rejected on account of physiological improvement in P utilization during seed development in the crop. Increase in P recovery as well as physiological efficiency of applied P strongly supports this contention. Since TU spray treated plants had higher P content in pods, leaves and in stems, it can be assumed that P absorption mechanism also got stimulated under the influence of TU. This is understandable as TU provided – SH groups to functional root and shoot systems, which became metabolic more active and hence showed greater accumulation of P. Because of the role of – SH group in metabolite partitioning as already discussed, there was improved partitioning of absorb P for utilization in seed development.

It was noted that P allocation in pods increased whereas P allocation in stems decreased under foliar spray of TU. P uptake by the crop also significantly increased under the influence of TU spray. Thus, foliar spray of TU play a significant role in improving P accumulation and utilization inside the crop plants, which eventually showed increased P use efficiency.

## 5.3 EFFECT OF DMSO

### 5.3.1 Growth parameters

Soil and foliar application of DMSO showed inconsistent effect on growth parameters. It was noted that number of green leaves per plant significantly increased due to foliar spray of DMSO only. (Table 4A.4). Dry matter accumulation at 90 DAS and physiological maturity and growth indices viz., LAI, CGR, LAR and NAR at 90 DAS also significantly increased under the influence of soil as well as foliar application of DMSO. Improvement in these growth parameters due to DMSO indicates that it acts like growth regulator. Almost all these growth parameters were equally improved by both soil as well as foliar applied DMSO. DMSO might have stimulated the photosynthetic carbon fixation mechanism and hence might have increased canopy photosynthesis (Narang, 1988). Significant increases in LAI and CGR and finally dry matter accumulation obtained with DMSO treatments provide support to such effects. foliar spray of DMSO might have resulted to maintain larger photosynthetically active leaf surface during crop growth. This is evidenced by the fact that significant increase in green leaves per plant and chlorophyll content of leaves was recorded in foliar spray of DMSO. Larger LAI under the influence of DMSO treatment seems to have resulted due to utilization of radiant energy resulting into higher DMA per plant.

### 5.3.2 Dry matter partitioning and productivity

With regard to dry matter distribution, it was observed that dry matter distribution in pods at 90 DAS and physiological maturity increased with soil and foliar applied DMSO (fig. 4.4-4.6). On the contrary, DMD in stem at 90 and physiological maturity significantly decreased with soil and foliar applied DMSO. With regard to yield attributes and yield it was noted that a consistent increase in number of pods per plant was recorded under both soil and foliar application of DMSO. Number of seeds per pod and test weight were also significantly increased due to soil and foliar application of DMSO. Thus, soil application as well as foliar spray of DMSO significantly increased seed yield.

DMSO is a chemical which has got a property to modulate the level of – SH group and thus improve protein configuration and membrane permeability (Chang and Simon, 1968). DMSO is known to be an excellent solvent for many chemicals and to increase plant absorption of chemicals dissolved in it. It improved solubilization of the cytokinins and slightly enhanced their effect (Oliva and Zimmerman, 1976).

It would be evident from the data (Table 4A.12) that dry matter allocation to pods at 90 DAS and physiological maturity increased under the influence of soil and folior applied DMSO. It was interesting to note that DMD in stems at 90 DAS and physiological maturity decreased with soil and foliar application of DMSO. This indicates that there was improved phloem loading of assimilates and hence greater translocation of photosynthate under the influence of DMSO treatments. It was most probably on account of better permeability of cell for translocation of assimilates under the influence of DMSO treatments. DMSO acts selectively on plasma membrane of cells, rendering it more permeable to small molecules (Delmer, 1979). He also indicated that treatment of intact plant cell or tissues with DMSO may be used to assess the distribution of metabolites between cytoplasmic and vacuolar compartments. DMSO has bio-regulatory effects, chiefly in mobilization of dry matter and translocation of photosynthate for improving yield. This is further evidenced from the fact that number of pods, seeds per pod and test weight increased under DMSO treatments.

Harvest index also showed significant improvement. Finally seed yield increased under DMSO treatment without affecting the straw yield. This indicates that DMSO treatment improved seed production chiefly on account of improved assimilate partitioning and transport during grain formation. Some workers have also reported favorable effect of DMSO *spray on grain yield of gram (Singh and Khangarot, 1987 and Narang, 1988). Correlation* studies also reveal that all these growth and yield attributing parameters were significantly positively correlated with seed yield (Table 5.1 and 5.2). Further, harvest index also showed significant positive correlation with seed yield. This substantiates the role of DMSO in improving assimilate partitioning and transport.

**5.3.3 Phosphorus use efficiency**

Soil and foliar applications of DMSO increased P harvest index as well as agronomic efficiency of applied P (Table 4A.72 & 69). However, there was no effect on P recovery but physiological efficiency of P increased under DMSO treatments. This indicates that the major effects of DMSO, either applied to soil or to foliage, lies in improving physiological characteristics like plasmamembrane property for increased transport and utilization of P absorbed from the root environment. That is why P distribution for better seed development was significantly improved under both soil and foliar applied DMSO. This is evidenced due to fact that P allocation to pods significantly increased, whereas P allocation to stems showed significant reduction at physiological maturity (Table 4A.14 & fig. 4.6).

It may be noted that soil application of DMSO brought about significant improvement in available P content of soil measured at harvest. Also, soil applied DMSO significantly increased P content of pods at physiological maturity. Thus, it appears that DMSO has a role *in mobilizing* soil P *and improving* P absorption and accumulation inside the plants. Since DMSO is strong solvent for many organic compounds (Keil, 1965), it is conceivable that the solvent property of DMSO might have aided dissolution of more quantity of organic P inside the soil and thus increased available P in soil at maturity and P content in plant.

## 5.4 EFFECT OF TU+ DMSO

### 5.4.1 Growth parameters

Soil application of TU+ DMSO and foliar spray of TU+ DMSO brought about significant improvement in many growth parameters, viz., number of branches, number of green leaves, dry matter at 60, 90 DAS and physiological maturity, LAI, CGR and LAR. By and large, soil application of TU+ DMSO was at par with soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$) in most of parameters. This shows that addition of DMSO in TU has no additional advantage for improving growth parameters over split application of TU. Similarly in case of foliar spray, it was noted that addition of DMSO in TU had not advantages over foliar spray of TU alone. Improvement in growth parameters due to soil application of TU+ DMSO and foliar spray TU+ DMSO was similar to those obtained under split application of TU and foliar spray of 500 ppm TU. This might be due to role of TU as already discussed in the preceding paragraphs.

### 5.4.2 Dry matter partitioning and productivity

It was noted that only soil application of TU+ DMSO proved effective in improving DMD in leaves at 30 DAS (fig. 4.4-4.6). While at 60, 90 DAS and physiological maturity, soil and foliar application of TU+ DMSO proved effective in improving DMD in leaves and pods. However, the magnitude of increasing DMD in leaves and pods was higher under foliar spray of TU+ DMSO as compared to soil application of TU+ DMSO. On the contrary, DMD in stems at 90 DAS and physiological maturity significantly decreased with soil and foliar application of TU+ DMSO over control. However, mixture of TU+ DMSO in soil was as effective as soil applied TU (split). Similarly in case of foliar spray, mixture of TU+ DMSO was not more effective over foliar spray of TU alone.

With regard to yield attributes and yield it was noted that almost all the yield attributing parameters significantly improved with soil application of TU+ DMSO and foliar spray of TU+ DMSO. Increase in number of pods, seeds per pod and test weight due to soil and foliar application of TU+ DMSO showed an improving storage capacity. However, soil application of TU+ DMSO and foliar spray of TU+ DMSO was at par with soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$) and foliar spray of 500 ppm TU, respectively in improving yield attributes and yield. This indicates that DMSO had no synergestic effect when mixed into TU. Partitioning of dry matter was found to be higher under soil and foliar application of TU+ DMSO. At 90 DAS and physiological maturity, dry matter distribution in stems reduced and DMD in pods it was increased. Further, harvest index of the crop was also improved significantly under TU+ DMSO treatments but was at par with soil and foliar application of TU. This indicates that TU alone was responsible for improving DMD and yield of the crop.

Since addition of DMSO did not prove effective in improving the effects of TU applied soil or through foliage, it can be assumed that the properties of TU are not only similar to those of DMSO but they are of much stronger in effectiveness. Since TU is a sulphydryl compound and since the effect of DMSO is reported to occur via –SH amelioration (Chang and Simon, 1968), these is enough reason to believe that TU alone should be as much effective as TU+ DMSO.

It may be noted that soil applied TU+ DMSO was more effective than foliar applied TU+ DMSO in respect of seed yield as well as yield attributes like number of pods per plant and number of seed per pod. As already explain under the efficacy of TU treatments, and soil applied TU and DMSO were more consistently available to plants not only upto pre flowering stage but also during post-flowering period. On the other hand foliar applied TU+ DMSO improved crop growth and yield formation during post flowering phase only and this made the difference in yield.

### 5.4.3 Phosphorus use efficiency

Soil applied TU+ DMSO increased P harvest index as well as agronomic efficiency of applied P. Similarly, physiological efficiency and P recovery were also increased by soil applied TU+ DMSO. However, this treatment came out at par with TU alone applied to soil. Foliar applied TU+ DMSO, on the other hand, improved P harvest index and physiological efficiency of applied P, this was again at par with foliar spray of TU alone. Thus, by and larger, soil applied TU+ DMSO and foliar applied TU+ DMSO were similar to soil applied TU ($^1/_2$ + $^1/_2$) and foliar spray of 500 ppm TU, respectively.

It may be noted that soil applied TU+ DMSO was more effective in improving P use efficiency as compared to foliar applied TU+ DMSO. There was significant increase in P uptake as well as P recovery due to soil applied TU+ DMSO. This is convincing, as both TU and DMSO have role in mobilization of soil P and improving P availability to plant as already discussed in proceeding paragraph. This is evidenced the fact that available P content of soil at 30, 60 DAS and harvest showed significant increased under soil treatments of TU+ DMSO in comparison to foliar treatment of TU+ DMSO (Table 4A.41-43).

The gum content significantly increased by soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$), soil application of TU+ DMSO, foliar sprays of 500 ppm TU and 100 ppm DMSO and TU+ DMSO. The improvement might presumably be due to increased rate to carbon assimilation which may have produced greater concentration of intermediate products acting as precursors in the synthesis of gum. TU and DMSO have enhanced the pace of vital activities going on within the plant cells.

## 5. 5 ROLE OF SULPHYDRYL COMPOUNDS IN IMPROVING PRODUCTIVITY OF CLUSTERBEAN

While studying the effects of TU and DMSO on growth and yield of clusterbean in the present investigation, and an attempt was also made to study in more detail the effects of standard sulphydryl blockers on dry matter partitioning and yield of the crop. The sulphydryl compounds studied were 2 mercaptoethylamine and dithiothreitol including thiourea. Similarly, the sulphydryl blockers were para-chloromercuribenzoic sulphonic acid (PCMBS) and Iodoacetate. It may be noted that PCMBS has a property of acting on the plasma membrane itself (Giaquinta, 1976), whereas Iodoacetate has the property of acting into cytosol (walter and Earle, 1993).

A reference to table 4B.1 would reveal that MEA, DTT and TU significantly increased dry matter accumulation per plant at 75, 90 DAS and physiological maturity and the effects of 500 ppm MEA were most marked. These chemicals also significantly influenced dry matter distribution (Table 4B.2- 4B.4). Dry matter distribution in leaves increased whereas dry matter distribution in stems decreased. Increasing trends in DMD in pods were also observed. Significant increase in yield attributes viz., number of pods, number of seeds per pod, length of pod and test weight were observed due to effects of sulphydryl compounds and the magnitude of increase was most marked with foliar spray of 500 ppm MEA (Table 4B.5 and 4B.7). As a result, seed yield increased significantly. Foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT increased the seed yield by 13.6, 27.5 and 12.2 per cent, respectively over control (Table 4B.12). It is noteworthy that there was significant increase in harvest index, a trait indicative of assimilate partitioning and transport to seed during reproductive phase of the crop. This means that the sulphydryl compounds influenced assimilate transport (translocation of photosynthate) during seed development, most probably by influencing the process of phloem loading which is known to be inhibited by – SH blockers, PCMBS (Giaquinta, 1976). Giaquinta (1976) reported that in *Beta vulgaris* the active loading of sucrose and $^{14}CO_2$ derived assimilates into phloem and their translocation from the source leaf were reversibly inhibited by the water soluble, suphydryl specific, chemical modifier, para-chloromercuribenzenesulphonic acid. Several non-permeant sulphydryl group modifiers also inhibited the sucrose assimilation into leaf discs. He concluded that sugars are actively accumulated into the phloem from the apoplast and that membrane – SH group might be involved.

In the present study foliar spray of 10 ppm PCMBS significantly decreased harvest index as well as seed yield besides decreasing straw and biological yields (Table 4B.12). DMD in leaves and pods decreased, whereas DMD in stems increased under PCMBS treatment. Similarly, yield attributing parameters viz., number of pods per plant and number of seeds per pod also significantly decreased. This indicates that the reduction in yield and yield attributes occurred most probably because PCMBS inhibited phloem loading by affecting the activity of sucrose transport protein. Since foliar spray of TU after the spray of PCMBS largely reversed the inhibiting effects on most of the parameters studied (Table 4B.5 – 4B.7). In some cases for e.g. DMA, pod length and test weight this treatment combination not only nullified the inhibition caused by PCMBS but it also brought about significant increased over control.

Effect of – SH compounds and PCMBS on pattern of pod filling were also studied. It was observed that the effects were more marked on pod development in uppermost clusters. This indicates that the transport of photosynthates to the developing uppermost pods was limiting, and the supply of – SH group improved the functioning of sucrose transport protein, which ultimately contributed toward supplying assimilate for seed development. It was interesting to note that foliar spray of 10 ppm PCMBS markedly decreased number of pods as well as pod dry matter in uppermost cluster. It was also observed that while the – SH compounds, TU, MEA and DTT decreased the number of poorly filled pods and unfilled pods, the – SH blockers PCMBS, on the other hand, increased the number of poorly filled pods as well as unfilled pods in comparison to control (Table 4B.6). This further proved that the filling of seed enhanced pod development was mainly influenced by – SH compounds and the – SH blocker, most probably through effects on phloem loading and assimilate transport.

It is pertinent to point out here that another – SH blocker, iodoacetate, was also tested in the present study, and the effects were found largely inconsistent. No significant reduction in seed yield as well as harvest index was observed due to foliar spray of 100 ppm iodoacetate (Table 4B.12), though there were decreasing trends. However, significant reduction in number of pods per plant and number of seeds per pod. Similarly number of unfilled pods also showed significant increased under 100 ppm iodoacetate spray (Table 4B.6). But since the effects on seed yield and harvest index were non-significant, it is difficult to conceive that phloem transport of photosynthate was specifically inhibited by this – SH blockers, which has property of entering into the cysoplasm and affecting – SH group of proteins and other biomolecules (Walter and Earle, 1993).

In light of above observations it may be stated that foliar sprays of –SH compounds viz., 500 ppm TU, 500 ppm MEA and 10 ppm DTT most probably improved phloem loading and transport of photoassimilates (sucrose) and thus improve seed yield. The effect of TU can not be attributed to its N and S content, as no significant differences in N and S contents of leaves at 75 DAS were observed under the 500 ppm TU spray treatment (Table 4B.13). Sahu and Singh (1995) also suggested that since the – SH group is essential at the substrate-binding site of the amino acid carrier (Mc Cormick and Jhonstone, 1990). TU may also enhance formation of the ternary complex, sucrose $H^+$- carrier, thus improving phloem loading of sucrose and hence translocation of photosynthate.

# 6 SUMMARY AND CONCLUSION

In this chapter, results of the two experiments, one concerning the effect of thiourea and DMSO at varying levels of phosphorus and the other concerning the effect of –SH compounds and –SH group blockers on clusterbean productivity are summarized. In the first section of this chapter, the major finding on effect of thiourea and DMSO on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean are briefly described. In the second section the results of second experiment "Effect of –SH compounds and –SH group blockers on dry matter partitioning and yield of clusterbean" are summarized. Conclusions derived from the results of these experiments are also presented in this chapter.

## 6.1 Effect of thiourea and DMSO on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean

- Application of 20 and 40 kg $P_2O_5$/ha significantly increased plant height at 60 DAS and physiological maturity over control. Application of 40 kg $P_2O_5$/ha proved superior to 20 kg $P_2O_5$/ha in respect of plant height at 60 DAS, whereas 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha in respect of plant height at physiological maturity. Application of 20 and 40 kg $P_2O_5$/ha significantly increased number of branches per plant over control. Further, 40 kg $P_2O_5$/ha was superior to 20 kg $P_2O_5$/ha in respect of number of branches per plant.

- It was noted that total dry matter accumulation per plant at 30, 60 90 and physiological maturity was significantly increased due to application of 20 and 40 kg $P_2O_5$/ha over control. 40 kg $P_2O_5$/ha was superior to 20 kg $P_2O_5$/ha.

- Dry matter distribution in different plant parts was also computed at 30, 60, 90 and at physiological maturity. It was observed that at 30 DAS, dry matter allocated to leaves and stems was not affected due to phosphorus application. Similarly, at 60 DAS, DMD in leaves and stems were also not affected due to phosphorus application but dry matter allocated to pods was significantly highest under 20 kg $P_2O_5$/ha. At 90 DAS, dry matter allocated to leaves was significantly increased with 20 and 40 kg $P_2O_5$/ha over control. However, they were at par with each other. On the contrary, dry matter allocated to stems not affected due to phosphorus application. Similarly, at 60 DAS, DMD in leaves and stems were also not affected due to phosphorus application but dry matter allocated to pods was significantly highest under 20 kg $P_2O_5$/ha. At 90 DAS, dry matter allocated to leaves was significantly increased with 20 and 40 kg $P_2O_5$/ha over control. However, they were at par with each other. On the contrary, dry matter allocated to stems at 90 DAS was significantly decreased with 20 and 40 kg $P_2O_5$/ha over control. Levels 20 and 40 kg

$P_2O_5$/ha were at par. However, dry matter allocated to pods at 90 DAS was significantly increased with 20 and 40 kg $P_2O_5$ over control but 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha. While, dry matter allocated to leaves and stems at physiological maturity was significantly decreased with 20 and 40 kg $P_2O_5$/ha over control. However the effect of 40 kg $P_2O_5$/ha was at par with 20 kg $P_2O_5$/ha in respect of DMD in leaves but was superior to 20 kg $P_2O_5$/ha in respect of DMD in stems at physiological maturity. However, dry matter collected to pods at physiological maturity was significantly increased with 20 and 40 kg $P_2O_5$/ha over control. Further, 40 kg $P_2O_5$/ha was superior to 20 kg $P_2O_5$/ha. On the whole, at 60 DAS the magnitude of DMD in leaves, stems and pods was 45.93, 46.08 and 7.96 per cent under control; 45.57, 45.26 and 9.11 per cent under 20 kg $P_2O_5$/ha a and 45.95, 45.49 and 8.55 per cent under40 kg $P_2O_5$/ha, respectively. At 90 DAS, it was 22.72, 38.21 and 38.81 per cent under control; 25.04, 34.66 and 40.46 per cent, respectively under 20 kg $P_2O_5$/ha and 25.68, 33.42 and 40.89 per cent under 40 kg $P_2O_5$/ha.

- Chlorophyll a, chlorophyll b and total chlorophyll content of leaves at 90 DAS were significantly increased due to application of 20 and 40 kg $P_2O_5$/ha. Leaf area index, crop growth rate and leaf area ratio at 60 and 90 DAS significantly increased due to application of 20 and 40 kg $P_2O_5$/ha except crop growth rate at 90 DAS, where it was at par with 20 kg $P_2O_5$/ha. Crop growth rate under control, 20 and 40 kg $P_2O_5$/ha was 15.93, 19.08 and 20.86 g/m$^2$/d at 60 DAS and 8.36, 10.95 and 11.73 g/m$^2$/d- at 90 DAS, respectively. Leaf area ratio under control, 20 and 40 kg $P_2O_5$/ha was 0.252, 0.262 and 0.272 at 60 DAS and 0.168, 0.183 and 0.190 at 90 DAS, respectively. Net assimilation rate was significantly increased with phosphorus application at 60 DAS.

- Root length, dry matter of root/plant and number of nodules/plant at 60 DAS were significantly increased with the application of 20 and 40 kg $P_2O_5$/ha. Further, the effect of 40 kg $P_2O_5$/ha also proved superior to 20 kg $P_2O_5$/ha in respect of these parameters.

- All yield attributing parameters, except number of pods per cluster, showed significant improvement due to application of 20 and 40 kg $P_2O_5$/ha over control. On the contrary, the least number of poorly filled pods per plant (2.8) and number of unfilled pods per plant (4.4) were obtained under 40 kg $P_2O_5$/ha, which were significant less than obtained at 20 kg $P_2O_5$/ha and control.

- Seed yield obtained under 40 kg $P_2O_5$/ha was highest (18.89 q/ha) which was significantly higher by 5.6 and 35.9 per cent over 20 kg $P_2O_5$/ha and control, respectively. Straw and biological yields significantly increased with the application of phosphorus upto 20 kg $P_2O_5$/ha. Harvest index was significantly improved due to application of 20 and 40 kg $P_2O_5$/ha over control. 40 kg $P_2O_5$/ha proved superior over 20 kg $P_2O_5$/ha.

- It was observed that available P content of soil at 30, 60 and at harvest was significantly increased with the application of 20 and 40 kg $P_2O_5$/ha over control. However, 40 kg $P_2O_5$/ha proved superior to 20 kg $P_2O_5$/ha in above parameters.

- Gum content of seed significantly increased due to application of phosphorus upto 20 kg $P_2O_5$/ha. Further, increased in P level had no effect on gum content of seed. Whereas, protein content of seed was significantly increased due to phosphorus application upto 40 kg $P_2O_5$/ha. Application 20 and 40 kg $P_2O_5$/ha significantly increased gum content by 5.7 and 7.1 per cent, respectively and protein content by 5.9 and 7.9 per cent, respectively over control.

- N and P content of leaves at 90 DAS significantly increased with the application of 20 and 40 kg $P_2O_5$/ha over control. However, N content of leaves significantly increased upto 20 kg $P_2O_5$/ha, whereas P content of leaves significantly increased upto 40 kg $P_2O_5$/ha. S content of a leaves at 90 DAS remained unaffected due to phosphorus application.

- Application of 40 kg $P_2O_5$/ha brought about significant increase in P distribution in leaves at 60 DAS over control and 20 kg $P_2O_5$/ha. On the contrary, P distribution in stems at 60 DAS significantly decreased due to phosphorus application. While, P distribution in pods at 60 DAS was highest under 20 kg $P_2O_5$/ha. At 90 DAS, P distribution in leaves significantly increased with the application of phosphorus upto 20 kg $P_2O_5$/ha over control but significant decrease in P distribution in stems was noted due to 20 and 40 kg $P_2O_5$/ha over control. However, P distribution in pods at 90 DAS significantly increased with phosphorus application upto 20 kg $P_2O_5$/ha. At physiological maturity, phosphorus application proved ineffective in influencing P distribution in leaves. However, phosphorus application brought about significant reduction in P distribution in stems. The magnitude of reduction in P distribution was highest under 40 kg $P_2O_5$/ha. While, P distribution in pods significantly increased with the application of phosphorus upto 40 kg $P_2O_5$/ha.

- It was noted that P uptake by seed, straw and P uptake by crop significantly increased with the application of phosphorus. P uptake by seeds and total P uptake by crop significantly increased upto 20 kg $P_2O_5$/ha over control. Application of 20 and 40 kg $P_2O_5$/ha significantly increased P uptake of seed by 43.6 & 52.4 and total P uptake of the crop 37.3 & 43.4 per cent, respectively over control (7.33 & 17.87 kg/ha). Application of 20 kg $P_2O_5$/ha significantly increased P uptake by straw by 33.2 per cent over control (10.52 kg/ha).

- Agronomic efficiency of the crop decreased with 40 kg $P_2O_5$/ha as compared to 20 kg $P_2O_5$/ha. However, physiological efficiency showed reverse trends.

- The maximum P recovery of 47.36 kg/ha was obtained with the application of 20 kg $P_2O_5$/ha followed by 40 kg $P_2O_5$/ha (26.42 kg/ha). P harvest index was significantly improved with the application of 20 and 40 kg $P_2O_5$/ha over control. But level 20 and 40 kg $P_2O_5$/ha was at par. P harvest index under control, 20 and 40 kg $P_2O_5$/ha was 41.05, 42.95 and 43.65 per cent, respectively.

- It was noted that soil and foliar applied treatments did not affect plant height at 60 DAS and at physiological maturity. However, under no phosphorus, soil application of TU+DMSO (½+½) significantly increased plant height at 60 DAS over control.

- Soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased number of branches per plant over control. While all these treatments in addition to foliar spray of 100 ppm DMSO also proved effective in increasing number of green leaves at physiological maturity. Under no phosphorus, all the soil and foliar applied treatment, except soil application of TU at 5 kg/ha (basal) and soil application of DMSO at 2 kg/ha (½+½), proved effective in increasing number of green leaves per plant. Under 20 and 40 kg $P_2O_5$/ha also similar trends were noted.

- Soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha (½+½), soil application of DMSO at 2 kg/ha (½+½) and soil application of TU+DMSO (½+½) brought about significant increase in dry matter accumulation (DMA) per plant over control at 30 DAS. While, none of the foliar applied treatments of TU and DMSO proved effective. AT 60 DAS, DMA per plant significantly increased due to soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO over control. While at 90 DAS and at physiological maturity, all the soil and foliar applied treatments of TU and DMSO proved effective in increasing of DMA per plant over control.

- Dry matter distribution (DMD) in leaves, stems and pods at 30, 60, 90 DAS and at physiological maturity was computed in order to assess the effect of TU and DMSO treatments on relative allocation of dry matter in clusterbean plants. At 30 DAS, it was found that only soil application of TU at 5 kg/ha (½+½) proved effective in increasing DMD in leaves and stems over control. At 60 DAS, soil application of TU+DMSO (½+½) and foliar spray of 100 ppm DMSO brought about significant reduction in DMD in leaves over control. With regards to DMD in stems, none of the soil and foliar applied treatments could bring a significant change in DMD in stems. However, DMD in pods significantly increased due to soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO over control.

- Soil and foliar applied treatments of TU and DMSO significantly influenced dry matter distribution (DMD) in leaves, stems and pods at 90 DAS. It was noted that DMD in leaves and pods showed increasing trends, whereas DMD in stems showed decreasing trends under soil and foliar applied treatments of TU and DMSO. All the soil and foliar applied treatments of TU and DMSO significantly increased DMD in leaves over control. These treatments were found to bring about corresponding decrease in DMD in stems. DMD in leaves due to soil application of TU+DMSO (½+½) was at par with soil application of TU at 5 kg/ha (½+½) and soil application of DMSO at 2 kg/ha (½+½) alone. Similarly, DMD in leaves due to foliar spray of TU+DMSO was at par with foliar spray of 100 ppm DMSO alone. The magnitude of reduction in DMD in stems was larger in foliar sprays of TU+DMSO and 500 ppm TU alone in comparison to other treatments. Effectiveness of different TU and DMSO treatment when assessed under different phosphorus levels, showed significant interactions. Under no phosphorus, all the soil and foliar applied treatments of TU and DMSO significantly decreased DMD in stems at 90 DAS. Similarly, in case of DMD in pods significantly increased due to all the soil and foliar applied treatments. Under 20 kg $P_2O_5$/ha, all the treatments, except soil application of TU at 5 kg/ha (basal), soil and foliar applied of DMSO, significantly decreased DMD in stems over control. But under 40 kg $P_2O_5$/ha, all the treatments showed decreasing trends in DMD in stems.

- Soil and foliar applied treatments of TU and DMSO significantly influenced DMD in leaves, stems and pods at physiological maturity. It was observed that DMD in leaves and pods showed increasing trends, whereas DMD in stems showed decreasing trends under soil and foliar applied treatments of TU and DMSO. However, except soil application of DMSO at 2 kg/ha (½+½) all the soil and foliar applied treatments of TU and DMSO proved effective in increasing DMD in leaves. The maximum DMD in leaves was recorded with foliar spray of TU+DMSO under no phosphorus. On the contrary, DMD in stems significantly decreased due to all the soil and foliar applied treatments. Similar trends were noted under no phosphorus. The magnitude or reduction in DMD in stems was highest due to foliar spray of TU+DMSO under 40 kg $P_2O_5$/ha. With regards to DMD in pods, it was noted that all the soil and foliar applied treatments of TU and DMSO except foliar spray of 100 ppm DMSO resulted in significant increase in DMD in pods at physiological maturity. The highest DMD in pods was recorded with foliar spray of TU+DMSO followed by foliar spray of 500 ppm TU alone.

- It was noted that chlorophyll a, chlorophyll b and total chlorophyll content of leaves at 90 DAS significantly increased due to soil and foliar applied treatments of TU and DMSO under no phosphorus.

- Soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO, foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased leaf area index (LAI) at 60 DAS over control. Whereas at 90 DAS, all the soil and foliar applied treatments significantly increased LAI over control. Furthermore, foliar spray TU+DMSO proved most effective at 90 DAS, while at 60 DAS, soil application of TU+DMSO proved most effective. Crop growth rate at 60 DAS significantly increased due to soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO over control. However, at 90 DAS, all the soil and foliar applied treatment significantly increased crop growth rate. Soil application of TU+DMSO at 60 DAS and foliar spray of TU+DMSO at 90 DAS proved most effective. It was noted that soil and foliar applied treatments of TU and DMSO did not influenced leaf area ratio (LAR) at 60 DAS. While at 90 DAS it showed significant variations. All the soil and foliar applied treatments significantly increased LAR at 90 DAS over control. Foliar spray of 500 ppm TU proved most effective. With regards to net assimilation rate (NAR) it was observed that foliar spray of TU+DMSO, foliar spray DMSO and soil application of DMSO at 2 kg/ha (½+½), proved effective at 90 DAS only. NAR remained unaffected due to soil and foliar applied treatments of TU and DMSO at 60 DAS.

- Soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased root length and dry matter of root per plant at 60 DAS over control. All the foliar sprays of TU and DMSO failed to affect these parameters at 60 DAS. However, number of nodules/plant of 60 DAS significantly increased over control due to soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO.

- Soil and foliar applied treatment of TU and DMSO had significant effect on number of cluster per plant and number of pods per plant. However, no response of these treatments was found over number of pods per cluster. Soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased number of cluster per plant and number of pods per plant over control. Soil application of TU+DMSO proved most effective. However, these treatments were at par with one another.

- Soil and foliar applied treatments of TU and DMSO had significant effect on number of poorly filled pods per plant and number of unfilled pods per plant. It was noted that all the soil and foliar applied treatments of TU and DMSO proved effective in decreasing the number of poorly filled pods per plant over control. Similar trends were observed in respect to number of unfilled pods per plant except foliar spray of 100 ppm DMSO. Foliar spray of TU+DMSO proved most effective in decreasing number of poorly filled and unfilled pods per plant which is closely followed by foliar spray of 500 ppm TU alone.

- Soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO significantly increased pod length over control. When effectiveness of different soil and foliar applied treatments of TU and DMSO was assessd under different levels of phosphorus, showed that in 40 kg $P_2O_5$/ha, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO proved effective in increasing pod length over control. Under no phosphorus and 20 kg $P_2O_5$/ha, none of the TU and DMSO treatments proved effective.

- Soil and foliar applied treatments of TU and DMSO had significant effect on number of grains per pods over control. Effectiveness of different TU and DMSO treatments varied significantly under different phosphorus levels. Under no phosphorus, all the soil and foliar applied treatments of TU and DMSO significantly increased number of grains per pod over control. While, under 20 kg $P_2O_5$/ha, only soil application of TU+DMSO (½+½) only soil application of TU+DMSO and foliar spray of TU+DMSO proved effective in increasing number of grains per pods. However, under 40 kg $P_2O_5$/ha, none of the soil and foliar applied treatments proved effective. Soil application of TU at 5 kg/ha (½+½) under no phosphorus and soil application of TU+DMSO under 20 kg $P_2O_5$/ha proved most effective.

- Soil and foliar applied treatments of TU and DMSO had significant effect on test weight All the soil and foliar applied treatments of TU and DMSO significantly increased test weight over control. Test weight was highest under soil application of TU+DMSO (½+½). However, it was at par with that under soil application of TU at 5 kg/ha (½+½) alone, foliar spray of 500 ppm TU and foliar spray of TU+DMSO but was superior to soil application of TU at 5 kg/ha (basal)

- All the soil and foliar applied treatments of TU and DMSO, except soil application of TU at 5 kg/ha (basal) and soil application of DMSO at 2 kg/ha (½+½) significantly increased seed yield per plant over control. The highest seed yield per plant (15 5/g) was recorded with soil application of TU+DMSO (½+½). It was significantly superior to soil application of TU at 5 kg/ha (½+½) alone. Among the foliar sprays, TU+DMSO was most effective. However, it was at par with foliar spray of 500 ppm TU alone but was superior to foliar spray of 100 ppm DMSO alone.

- Soil and foliar applied treatments of TU and DMSO significantly influenced seed yield of clusterbean. In pooled data, all the soil and foliar applied treatments of TU and DMSO, except soil application of TU at 5 kg/ha (basal) caused a significant increasing in seed yield over control. Soil application of 5 kg/ha TU ($^1/_2$ + $^1/_2$ ) with 20 kg $P_2O_5$/ha was the most effective treatment combination, as it gave seed yield of 19.22 q/ha, which was at par with yield obtained with 5 kg/ha TU ($^1/_2$ + $^1/_2$ ) with 40 kg $P_2O_5$/ha.

- Gum yield obtained under 20 kg $P_2O_5$/ha (5 50 q/ha) with soil application of TU at 5 kg/ha ($^1/_2$ + $^1/_2$ ) was significantly superior to 40 kg $P_2O_5$/ha alone. Under this treatments combinations the net returns based on gum yield was Rs. 16394 per ha.

- Soil and foliar applied treatments of TU and DMSO did not influence straw and biological yields. However, their effectiveness under different levels of phosphorus was significant. Under no phosphorus, all the soil and foliar applied treatments of TU and DMSO significantly increased the straw yield over control.

- Soil and foliar applied treatments of TU and DMSO had significant effect on harvest index. All the soil and foliar applied treatments of TU and DMSO except soil application of TU at 5 kg/ha (basal), significantly increased harvest index over control. The highest harvest index (30.11%) was obtained with soil application of TU+DMSO (½+½). However, it was at par with soil application of TU at 5 kg/ha (½+½) but was superior to soil application of DMSO at 2 kg/ha (½+½) alone. Further, among foliar spray treatments TU+DMSO proved most effective. However, it was at par with foliar sprays of 500 ppm TU and 100 ppm DMSO alone.

- ❖ It was noted that soil application of TU at 5 kg/ha (½+½) and soil application of TU+DMSO (½+½) significantly increased available P content of soil over control at 30 and 60 DAS. However, at the harvest, all the soil applied treatment of TU and DMSO, except soil application of TU at 5 kg/ha (basal), proved effective in increasing available P content of soil. But, none of the foliar sprays of TU and DMSO had a significant change in improving available. P content of soil at any stage of plant growth.

- ❖ All the soil and foliar applied treatments of TU and DMSO, except soil application of TU at 5kg/ha (basal) and soil application of DMSO at 2 kg/ha (½+½), significantly increased gum content (28.42%) of seed over control. The highest gum content was obtained with soil application of TU+DMSO (½+½). However, it was at par with soil application of TU at 5 kg/ha (½+½) alone but was superior to soil application of DMSO at 2 kg/ha (½+½) alone. Among the foliar sprays, TU+DMSO proved most effective. However, it was at par with foliar sprays of 500 ppm TU and 100 ppm DMSO alone. Protein content of seed did not influenced by different soil and foliar applied treatments of TU and DMSO.

- ❖ Soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and foliar spray of TU+DMSO significantly increased N content of leaves at 90 DAS over control. In addition to above treatments, foliar spray of 500 ppm TU was also effective in increasing P content of leaves at 90 DAS over control. However, S content of leaves at 90 DAS remained unaffected due to all the soil and foliar applied treatments of TU and DMSO.

- ❖ Soil and foliar applied treatments of TU and DMSO had significant effect on P distribution in leaves and pods under different levels of phosphorus at 60 DAS. Under 20 kg $P_2O_5$/ha, only soil application of TU+DMSO (½+½) proved effective in increasing P distribution in leaves. With regards to P distribution in pods, it was noted that all the soil and foliar applied treatments of TU and DMSO, except soil application of TU at 5 kg/ha (basal), significantly increased P distribution. However, under no phosphorus, only soil application of TU+DMSO (½+½) significantly improved P distribution in pods over control. Under 40 kg $P_2O_5$/ha, all treatments, except soil application of TU at 5 kg/ha (basal) and soil application of TU at 5 kg/ha (½+½), had the significant effect. However, soil application of TU+DMSO significantly decreased P distribution in stems over control.

- ❖ All the soil and foliar applied treatments of TU and DMSO significantly increased P distribution in leaves at 90 DAS. The highest P distribution in leaves (27.45%) was recorded with foliar spray of 500 ppm TU. On the contrary, all the soil and foliar applied treatments of TU and DMSO showed significantly decreasing trends in respect of P distribution in stems over control. The magnitude of reduction was highest under foliar spray of TU+DMSO. When effectiveness of TU and DMSO was assessed under different levels of phosphorus, it was noted that all the treatments proved effective in decreasing P distribution in stems under no phosphorus. Whereas, under 20 kg $P_2O_5$/ha, foliar spray of TU+DMSO was most effective, while under 40 kg $P_2O_5$/ha, foliar spray of 500 ppm TU was most effective in decreasing P distribution in stems. P distribution in pods significantly increased due to soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO, foliar spray of 500 ppm TU and foliar spray of TU+DMSO.

- At harvest, all the soil and foliar applied treatments of TU and DMSO except soil application of DMSO at 2 kg/ha (½+½) significantly increased P distribution in leaves. When the effectiveness of TU and DMSO was assessed under different levels of phosphorus, it was noted that under no phosphorus, soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½) and all the foliar spray treatments significantly increased P distribution in leaves. The highest P distribution (7.56%) was obtained with foliar spray of TU+DMSO followed by foliar spray of 500 ppm TU under no phosphorus. On the contrary, P distribution in stems showed decreasing trends due to soil and foliar applied treatments. The magnitude of reduction was highest under foliar spray of TU+DMSO with 40 kg $P_2O_5$/ha followed by foliar spray of TU+DMSO with 20 kg $P_2O_5$/ha followed by foliar spray of TU+DMSO with 20 kg $P_2O_5$/ha. In pods, P distribution significantly increased with all the soil and foliar applied treatments of TU and DMSO, except foliar spray of 100 ppm DMSO, over control.

- Soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased P uptake by seed over control by 22.2, 23.9, 12.7 and 15.3 per cent, respectively. The highest P uptake by seed (10.72 kg/ha) was obtained with soil application of TU+DMSO (½+½). However, it was at par with soil application of DMSO at 2 kg/ha (½+½) alone. The magnitude of increase in P uptake by seed was larger under soil applied TU and DMSO as compared to foliar sprays. However, P uptake by straw due to soil and foliar applied treatments remain unaffected. With regards to total P uptake by the crop, it was noted that soil and foliar applied treatments showed increasing trends. Soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar spray of 500 ppm TU and foliar spray of TU+DMSO significantly increased total P uptake by the crop over control by 14.6, 15.2, 6.6 and9.2 per cent, respectively. The highest total P uptake (24.38 kg/ha) was recorded under soil application of TU+DMSO (½+½) followed by foliar spray of TU+DMSO (23.10 kg/ha).

- Soil and foliar application of TU and DMSO increased agronomic as well as physiological efficiency of applied phosphorus.

- Soil and foliar applied treatments of TU and DMSO showed increasing trends in phosphorus recovery. Maximum phosphorus recovery (42.84%) was obtained with soil application of TU+DMSO (½+½) followed by soil application of TU at 5 kg/ha (½+½) (38.95%). Under foliar sprays, phosphorus recovery of 37.86, 33.07 and 32.99% was noted due to foliar sprays of TU+DMSO, 500 ppm TU and 100 ppm DMSO, respectively.

- Soil application of TU at 5 kg/ha (½+½), soil application of TU+DMSO (½+½), foliar sprays of 500 ppm TU, 100 ppm DMSO and TU+DMSO significantly increased P harvest index by 7.3, 7.9, 6.1, 5.7 and 5.7 per cent, respectively over control. However, these treatments were at par with one another.

- In terms of net monetary returns and B:C ratio, it was found that application of 40 kg $P_2O_5$/ha gave the highest monetary returns (Rs. 20215 per ha) and B:C ratio (1.75). When effectiveness of TU and DMSO was assessed under different levels of phosphorus, it was found that the maximum net monetary return (Rs. 22497 per ha) and B:C ratio (2.04) obtained under foliar spray of 500 ppm TU with 40 kg $P_2O_5$/ha. However, it was at par with soil application of TU at 5 kg/ha (½+½) with 20 kg $P_2O_5$/ha.

**6.2 Effect of –SH compounds and –SH group blockes on dry matter partitioning and productivity of clusterbean**

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU caused significant increase in total dry matter accumulation per plant at 75 DAS over control. Foliar spray of 500 ppm MEA proved most effective. It was significantly superior over foliar sprays of 500 ppm TU and 10 ppm DTT.

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly increased total dry matter accumulation per plant at 90 DAS by 6.5, 12.3, 7.5, 7.5 and 5.5 per cent, respectively over control. Rest of the foliar spray treatments were not significant.

- In respect of total dry matter accumulation per plant at physiological maturity, it was noted that foliar spray of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased total DMA/plant by 12.9, 14.8 and 11.4 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS caused significant reduction in total DMA/plant by 11.8 per cent over control.

- All the foliar sprays treatments proved ineffective in influencing DMD in leaves at 75 DAS except foliar spray of 10 ppm PCMBS. It was not noted that foliar spray of 10 ppm PCMBS caused significant reduction in DMD in leaves by 4.2 per cent over control.

- In respect of DMD in stems, it was found that foliar spray of 500 ppm MEA brought about significant reduction in DMD in stems at 75 DAS over control. On the contrary, foliar spray of 10 ppm PCMBS significantly increased DMD in stems over control.

- Foliar spray of 10 ppm PCMBS significantly reduced DMD in pods at 75 DAS by 13.2 per cent over control. However, rest of the foliar spray treatments proved ineffective.

- DMD in leaves at 90 DAS significantly increased due to foliar spray of 10 ppm PCMBS over control. Rest of the foliar spray treatments failed to affect DMD in leaves at 90 DAS.

- Foliar spray of 500 ppm MEA proved effective in improving DMD in pods at 90 DAS, whereas foliar spray of 10 ppm PCMBS caused significant reduction over control.

- Foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and IA+TU brought about significant increase in DMD in leaves at physiological maturity over control. On the contrary foliar sprays of 10 ppm PCMBS, PCMBS+TU and 10 ppm IA caused significant reduction in DMD in leaves over control.

- Foliar spray of 500 ppm MEA significantly increased number of branches per plant by 13.2 per cent over control. However, foliar spray of 10 ppm PCMBS significantly decreased number of branches per plant by 10.5 per cent over control.

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU brought about significant increased number of green leaves per plant by 24.6, 31.9, 18.9, 9.0 and 22.2 per cent, respectively over control. While, number of green leaves per plant significantly reduced under foliar spray of 10 ppm PCMBS and 100 ppm IA by 34.2 and 14.8 per cent, respectively over control.

- Foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and IA+TU significantly increased number of cluster per plant by 14.4, 28.6. 23.6 and 10.4 per cent, respectively over control. However, foliar spray of 10 ppm PCMBS significantly reduced number of cluster per plant by 12.7 per cent over control.

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly decreased number of poorly filled pods per plant over control. But in respect of number of unfilled pods per plant, foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT proved effective in decreasing number of unfilled pods per plant over control. Further, foliar sprays of 10 ppm PCMBS and 100 ppm IA caused significantly higher number of poorly filled and unfilled pods per plant over control.

- Number of pods per plant was significantly increased due to foliar spray of 500 ppm TU, 500 ppm MEA, 10 ppm DTT over control. However, number of pods per plant significantly reduced by 17.4 and 8.4 per cent under foliar spray of 10 ppm PCMBS and 100 ppm IA, respectively over control.

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and PCMBS+TU brought about significant increase in pod length by 4.8, 9.7, 6.4 and 4.1 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS and 100 ppm IA significantly reduced pod length over control.

- Foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased number of seeds per pod by 8.5, 12.7 and 5.6 per cent, respectively over control. Foliar spray of 500 ppm MEA proved most effective. While, foliar spray of 10 ppm PCMBS and 100 ppm IA caused a significant reduction of 5.6 per cent each over control.

- Foliar sprays of 500 ppm TU, 500 ppm MEA significantly increased test weight over control. Rest of the foliar spray treatments did not influence test weight.

- Foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased seed yield per plant by 13.5, 25.8 and 12.2 per cent, respectively over control. However, foliar spray of 10 ppm PCMBS caused significant reduction of 15.4 per cent in seed yield per plant over control.

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 100 ppm DTT and IA+TU significantly increased dry matter of pods in lowermost cluster over control. Similarly, in respect of dry matter of pods in middle cluster, only 500 ppm TU and 500 ppm MEA proved effective. on the contrary, foliar spray of 10 ppm PCMBS and 100 ppm IA significantly decreased dry matter of pods in lowermost and middle cluster over control. However, foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT, PCMBS+TU and IA+TU significantly increased dry matter of pods per plant in uppermost cluster over control. Foliar spray of 10 ppm PCMBS significantly reduced dry matter of pods in upper most cluster over control.

- Foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT significantly increased number of pods in lowermost, middle and uppermost cluster over control. However, foliar sprays of PCMBS+TU and IA+TU also effective in respect of number of pods in uppermost cluster. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced number of pods in lowermost, middle and uppermost cluster over control.

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and IA+TU significantly increased grain: pod husk ratio in lowermost cluster over control. While in middle cluster, only foliar spray of 500 ppm MEA proved effective. However, all the foliar spray treatments proved effective in increasing grain : pod husk ratio in lowermost cluster over control. Foliar spray of 10 ppm PCMBS brought about significant reduction in grain: pod husk ratio in middle cluster over control. However, it was ineffective in uppermost cluster.

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and PCMBS+TU significantly increased seed yield by 13.6, 27.5, 12.2 and 9.9 per cent, respectively over control (18.89 q/ha). On the contrary, foliar spray of 10 ppm PCMBS significantly decreased sced yield over control.

- In respect of straw yield, it was noted that only foliar spray of 500 ppm MEA proved effective in increasing straw yield by 9.2 per cent over control. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced straw yield over control. Similar trends were noted in respect to biological yield.

- Foliar sprays of 500 ppm TU, 500 ppm MEA, 10 ppm DTT and PCMBS+TU significantly increased harvest index by 7.7, 11.7, 8.8 and 5.9 per cent, respectively over control. On the contrary, foliar spray of 10 ppm PCMBS significantly reduced harvest index by 5.8 per cent over control.

- None of the foliar spray treatments proved effective in influencing N and S content of leaves at 75 DAS.

# CONCLUSION

On the basis of the results of the investigation entitled "Effect of Thiourea and Dimethylsulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L) Taub.]" conducted for two consecutive years (1999 and 2000), it can be concluded that soil application of thiourea at 5 kg/ha can improve phosphorus use efficiency and crop productivity to a considerable extent. Split application of 5 kg/ha thiourea, half at sowing and other half at 45 days after sowing, along with 20 kg $P_2O_5$/ha gave average seed yield of 19.22 q/ha as against 19.32 q/ha obtained with 5 kg/ha thiourea along with 40 kg $P_2O_5$/ha. Thus, thiourea application brought about a saving of 20 kg $P_2O_5$/ha. Effects of thiourea on phosphorus use efficiency as well as crop productivity appeared to be on account of its sulphydryl content, which played a bioregulatory role inside the crop plants.

Split application of 5 kg/ha thiourea with 20 kg $P_2O_5$/ha gave net returns of Rs. 20367 per ha, which was larger by Rs. 10025 per ha over absolute control (Rs. 10342 per ha). Thus, split application of 5 kg/ha thiourea with 20 kg $P_2O_5$/ha is recommended for increasing productivity of clusterbean under agro climatic conditions of Bikaner region in arid western Rajasthan.

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# EFFECT OF THIOUREA AND DIMETHYLSULPHOXIDE ON PHOSPHORUS USE EFFICIENCY, DRY MATTER PARTITIONING AND PRODUCTIVITY OF CLUSTERBEAN [*Cyamopsis tetragonoloba (L.) Taub*]

**N.S. Solanki** **Dr. M.P. Sahu***
**Research scholar** **Major Advisor**

## ABSTRACT

A field experiment entitled "Effect of Thiourea and Dimethylsulphoxide on phosphorus use efficiency, dry matter partitioning and productivity of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.]" was conducted during two consecutive *kharif* season of 1999 and 2000 at Agricultural Research station, Beechwal-Bikaner. Two field experiments were conducted, one concerning the effect of thiourea and DMSO at varying levels of phosphorus and the other concerning the effect of sulphydryl group and sulphydryl group blockers on clusterbean. The first experiment involved studies on effect of thiourea (TU) and dimethylsulphoxide (DMSO) at varying levels of phosphorus (0, 20 and 40 kg $P_2O_5$/ha) and eight treatments of chemical application viz., control, soil application of TU at 5 kg/ha (basal), soil application of TU at 5 kg/ha ($^1/_2$+$^1/_2$), soil application of DMSO at 2 kg/ha ($^1/_2$+$^1/_2$), soil application of TU + DMSO ($^1/_2$+$^1/_2$), foliar spray of 500 ppm TU, foliar spray of 100 ppm DMSO and foliar spray of TU + DMSO. The second experiment involved studies on the role of sulphydryl groups and sulphydryl group blockers, consisting of ten foliar spray treatments viz., control (water spray), 500 ppm thiourea, 500 ppm mercaptoethylamine (MEA), 10 ppm dithiothreitol (DTT), 10 ppm para- chloromercurybanzoicsulphonic acid (PCMBS), 10 ppm PCMBS+500 ppm TU, 100 ppm iodoacetate (IA), 100 ppm IA+500 ppm TU, 1000 ppm urea and 1000 ppm aluminium sulphate. The treatments were replicated four times in randomized block design in both the experiments. Clusterbean variety RGC- 986 was used.

The results revealed that phosphorus application upto 40 kg $P_2O_5$/ha significantly increased plant height, number of branches per plant, number of green leaves per plant, dry matter accumulation at 30, 60, 90 DAS and physiological maturity, chlorophyll content of leaves, root length, root dry matter and nodules per plant at 60 DAS. Dry matter allocation to leaves and pods at successive growth stages of crop also significantly increased due to 20 and 40 kg $P_2O_5$/ha. Growth indices viz., LAI, CGR, LAR and NAR also improved with phosphorus application.

* Director Research, RAU, Bikaner (Raj.).

Application of phosphorus upto 40 kg $P_2O_5$/ha significantly increased yield attributing parameters. However, test weight and number of grains per pod increased significantly upto 20 kg $P_2O_5$/ha. The gum content increased significantly due to phosphorus application upto 20 kg $P_2O_5$/ha. Agronomic efficiency as well as P recovery decreased with 40 kg $P_2O_5$/ha as compared to 20 kg $P_2O_5$/ha. However, physiological efficiency showed reverse trends. Total P uptake and P harvest index increased significantly with phosphorus application upto 20 kg $P_2O_5$/ha

Soil application of TU at 5 kg/ha ($^1/_2+^1/_2$), soil application of TU+DMSO, foliar spray of 500 ppm TU and foliar spray of TU+DMSO proved effective in improving growth and yield attributing parameters. Foliar spray of 100 ppm DMSO proved effective in improving number of green leaves, dry matter accumulation at 90 DAS and at physiological maturity and LAI, CGR, LAR and NAR. Number of poorly filled pods and unfilled pods per plant significantly decreased with all the soil and foliar applied treatments in comparison to control. Dry matter allocation to leaves and pods increased due to soil and foliar applied TU and DMSO.

Soil application of TU at 5 kg/ha ($^1/_2+^1/_2$) and soil application of TU+DMSO significantly increased available P content of soil over control at 30, 60 DAS and harvest. Soil application of DMSO at 2 kg/ha proved effective in increasing available P content of soil at harvest only. Gum content also increased significantly due to all soil and foliar applied treatments except soil application of TU at 5 kg/ha (basal) and soil application of DMSO at 2 kg/ha.

By and large, P content in different parts of the plant increased under the influence of all soil and foliar applied treatments. P distribution in leaves and pods also increased significantly over control due to soil and foliar applied treatments. Soil and foliar applied TU treatments proved effective in improving P uptake by the crop. Agronomic as well as physiological efficiency and P recovery and P harvest index of the crop showed increasing trends over control under the influence of soil and foliar applied treatments except soil and foliar applied DMSO.

Application of 40 kg $P_2O_5$/ha produced significantly higher seed yield (18.89 q/ha) and registered increase of 35.9 and 5.6 per cent over control and 20 kg $P_2O_5$/ha, respectively. However, straw and biological yields increased significantly upto 20 kg $P_2O_5$/ha. Soil application of TU at 5 kg/ha ($^1/_2+^1/_2$) and foliar spray of 500 ppm TU brought about significant improvement in seed yield by 18.9 and 11.5 per cent, respectively over control (15.23 q/ha). Harvest index increased significantly due to soil and foliar applied TU and DMSO treatments. Soil application of 5 kg/ha ($^1/_2+^1/_2$) with 20 kg $P_2O_5$/ha was the most effective treatment, as it gave seed yield of 19.22 q/ha, which was at par with yield obtained with 5 kg/ha TU with 40 $P_2O_5$/ha. Thus, thiourea application brought about a saving of 20 kg $P_2O_5$/ha. Thus split application of 5 kg/ha thiourea with 20 kg $P_2O_5$/ha is recommended for increasing productivity of clusterbean under agro-climatic condition of Bikaner region.

Studies conducted to assess the role of thiourea as a sulphydryl bioregulator revealed that foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT caused significant improvement in growth and yield attributing parameters. Dry matter allocation to leaves and pods at successive stage of crop growth also increased due to foliar spray of sulphydryl compounds over control. On the contrary, foliar spray of 10 ppm PCMBS significantly decreased growth and yield attributing parameters. N and S contents of leaves at 75 DAS were not affected due to foliar applied sulphydryl compounds. Foliar sprays of 500 ppm TU, 500 ppm MEA and 10 ppm DTT produced significantly higher seed yield and registered increase of 13.6, 27.5 and 12.2 per cent, respectively over control. Similar trends were noted in respect of harvest index. Foliar spray of 10 ppm PCMBS, -SH group blocker, significantly decreased seed yield over control.

# ग्वार [ सायमोपसिस टेट्रागोनोलोबा (एल.) टॉब ] की फॉस्फोरस उपयोग क्षमता, शुष्क प्रदार्थ विभाजन एवं उत्पादकता पर थायोयूरिया व डाइमिथाईलसल्फोआक्साईड का प्रभाव

एन.एस. सोलंकी
शोधकर्ता

डां0 एम.पी. साहु
मूख्य सलाहकार

## अनुक्षेपण

कृषि अनुसंधान केन्द्र, बीछवाल, बीकानेर पर "ग्वार [सायमोपसिस टेट्रागोनोलोबा (एल.) टॉब] की फॉस्फोरस उपयोग क्षमता, शुष्क प्रदार्थ विभाजन एवं उत्पादकता पर थायोयूरिया व डाइमिथाईलसल्फोआक्साईड का प्रभाव" शीर्षक के अन्तर्गत एक क्षेत्र परीक्षण लगातार दो वर्षो 1999 एवं 2000 की खरीफ मौसम में प्रतिपादित किया गया। दो क्षेत्र परीक्षण, एक जो फॉस्फोरस के विभिन्न स्तरो पर थायोयूरिया एवं डी.एम.एस.ओ. का प्रभाव और अन्य जो सल्फाहाइड्रील समूह व सल्फाहाइड्रील समूह अवरोधक का ग्वार पर प्रभाव से सम्बन्धित थे। प्रथम परीक्षण जो फॉस्फोरस के विभिन्न स्तरो पर थायोयूरिया (टी.यू.) एवं डाईमिथाईलसल्फोआक्साईड (डी.एम.एस.ओ.) का प्रभाव से सम्बन्धित, जिसमें फोस्फोरस के तीन स्तर (0,20 व 40 किग्रा. प्रति हैक्टर) एवं आठ रसायन अनुप्रयोग उपचार अर्थात् नियंत्रित, 5 किग्रा.. प्रतिहैक्टर टी.यू. का मृदा में प्रयोग (आधारीय), 5 किग्रा.. प्रति हैक्टर टी.यू. का मृदा में प्रयोग (½+½), 2 किग्रा. प्रति हैक्टर डी. एम. एस. ओ. का मृदा में प्रयोग (½+½), टी.यू.+डी.एम.एस.ओ. का मृदा में प्रयोग (½+½), 500 पीपीएम टी.यू. का पर्णीय छिटकाव, 100 पीपीएम डी.एम.एस.ओ. का पर्णीय छिटकाव व टी.यू.+डी.एम.एस.ओ. का पर्णीय छिटकाव सम्मिलित है। द्वितीय परीक्षण जो सल्फाहाइड्रील समूह व सल्फाहाइड्रील समूह अवरोधक की ग्वार पर भूमिका से सम्बन्धित है जिसमे दस पणीय छिटकाव उपचार अर्थात् नियंत्रित (जल छिटकाव), 500 पीपीएम थायोयूरिया, 500 पीपीएम मरकेप्टोइथाईलएमाईन (एम.ई.ए.), 10 पीपीएम पारा –क्लोरोमरक्यूरिकबेन्जोईकसल्फोनिक अम्ल (पी.सी.एम.बी.एस.), 10 पीपीएम पी.सी.एम.बी.एस. 500 पीपीएम. टी.यू., 10 पीपीएम डाईथायोथ्रिटोल (डी.टी. टी.), 10 पीपीएभ आयोडोएसीटेट (आई.ए.), 100 पीपीएम आई.ए.+500 पीपीएम टी.यू. , 1000 पीपीएम यूरिया व 1000 पीपीएम एल्यूमिनियम सल्फेट सम्मिलित किये गये।

दोनो परीक्षणों में उपचारो को यादृच्छिकृत अभिकल्पना के चार पुनरावृतियों में प्रतिपादित किया गया। ग्वार की आर. जी.सी.–986 किस्म का प्रयोग किया गया।

परिणाम दर्शाते है कि प्रति हैक्टर 40 किग्रा. फॉस्फोरस तक देने से पौधे की ऊचाई, शाखाओं की सख्या प्रति पौधा, हरी पत्तियो की सख्या प्रति पौधा, बुवाई के 30, 60, 90 दिन बाद व शरीरक्रियात्मक परिपक्वता पर शुष्क प्रदार्थ का संचय, पर्णहरित की मात्रा, जड की लम्बाई, जड का शुष्क प्रदार्थ व बुवाई के 60 दिन बाद ग्रंथियों की सख्या प्रति पौधा में सार्थक वृद्धि हुई। 20 व 40 किग्रा. प्रति हैक्टर फॉस्फोरस देने से फसल की उत्तरोत्तर प्रक्रम वृद्धि अवस्था पर पत्तियों व फलीयों में शुष्क प्रदार्थ के बटवारे में सार्थक वृद्धि हुई। वृद्धि अक्षांक अर्थात् पर्ण क्षेत्र सूचकांक, फसल वृद्धि दर, पर्ण–क्षेत्र अनुपात व सकल संचयन दर में भी फॉस्फोरस देने से उन्नति हुई।

40 किग्रा. प्रति हेक्टर तक फॉस्फोरस देने से उपज कारक प्राचलों में सार्थक वृद्धि हुई। तथापि, एक हजार दानो के भार एवं दानो की सख्या प्रति फली में 20 किग्रा. प्रति हैक्टर फॉस्फोरस तक ही सार्थक वृद्धि हुई। 20 किग्रा. प्रति हैक्टर तक फॉस्फोरस देने से गोंद की मात्रा में सार्थक वृद्धि हुई। 20 किग्रा. फॉस्फोरस की तुलना में 40 किग्रा. प्रति हेक्टर फॉस्फोरस देने से सस्य विज्ञान दक्षता व फॉस्फोरस प्रत्यादान में कमी हुई। तथापि, शरीर क्रियात्मक दक्षता ने विपरीत प्रवृति दर्शायी है। कुल फोस्फोरस उदग्रहण व फास्फोरस कटाई सूचकांक में 20 किग्रा.प्रति हैक्टर फास्फोरस देने से सार्थक वृद्धि हुई।

वृद्धि एवं उपज कारक प्राचलों की उन्नति में 5 किग्रा. प्रति हैक्टर थायोयूरिया का मृदा में प्रयोग (½+½), टी.यू.+ डी.एम.एस. ओ. का मृदा में प्रयोग, 500 पीपीएम टी.यू. का पर्णीय छिटकाव व टी.यू.+डी.एम.एस.ओ. का पर्णीय छिटकाव प्रभावी सिद्ध हुए।

हरी पत्तियों की सख्या, बुवाई के 90 दिन बाद व शरीरक्रियात्मक परिपक्वता पर शुष्क प्रदार्थ का संचय, पर्ण क्षेत्र सूचाकांक, फसल वृद्धि दर, पर्ण–क्षेत्र अनुपात व सकल संचयन दर की उन्नति में 100 पीपीएम डी.एम.एस.ओ का पर्णीय छिटकाव प्रभावी रहा। नियत्रित की तुलना में मृदा एवं पर्णीय उपचारों का प्रयोग से अल्पपूरित फलीयों की संख्या व अपूरित फलीयों की सख्या में सार्थक कमी हुई। टी.यू.एवं डी.

एम.एस. ओ. के मृदा एवं पर्णीय प्रयोग से पत्तियों व फलीयों में शुष्क प्रदार्थ के बटवारे में वृद्धि हुई।

बुवाई के 30 व 60 दिन बाद व कटाई पर मृदा में प्राप्य फॉस्फोरस की मात्रा में नियत्रिंत की तुलना में 5 किग्रा. प्रति हैक्टर टी. यू. का मृदा में प्रयोग (½+½) एवं टी.यू.+डी.एम.एस.ओ. का मृदा में प्रयोग से सार्थक वृद्धि हुई। केवल कटाई पर ही मृदा में प्राप्य फॉस्फोरस को बढाने में 2 किग्रा. प्रति हैक्टर डी.एम.एस.ओ. का मृदा में प्रयोग प्रभावी सिद्ध हुआ। 5 किग्रा. प्रति हैक्टर टी.यू. का मृदा में प्रयोग (आधारीय)व 2 किग्रा. प्रति हैक्टर डी.एम.एस.ओ. का मृदा में प्रयोग के अतिरिक्त सभी मृदा व पर्णीय प्रयोग उपचारों से गोंद की मात्रा में भी सार्थक वृद्धि हुई।

सामान्यतया, सभी मृदा व पर्णीय प्रयोग उपचारो के प्रभाव से पौधे के विभिन्न भागो में फॉस्फोरस की मात्रा में वृद्धि हुई। नियंत्रित की तुलना में मृदा व पर्णीय प्रयोग उपचारों से पत्तियों व फलीयों में फॉस्फोरस के वितरण में सार्थक वृद्धि हुई। फसल द्वारा फॉस्फोरस उद्ग्रहण की उन्नति में टी.यू.के मृदा व पर्णीय प्रयोग उपचार प्रभावी सिद्ध हुए। नियत्रिंत की तुलना में मृदा व पर्णीय प्रयोग उपचारों के प्रभाव (डी. एम.एस.ओ. के मृदा व पर्णीय प्रयोग के अतिरिक्त) से सस्य विज्ञान दक्षता, शरीरक्रियात्मक दक्षता, फॉस्फोरस प्रत्यादान व फॉस्फोरस कटाई सूचकांक वर्धमान प्रवृति दर्शाते है।

40 किग्रा.प्रति हैक्टर फॉस्फोरस देने से सार्थक अधिक बीज उत्पादन (18.89 क्वि. प्रति हैक्टर) हुआ एवं नियंत्रित व 20 किग्रा. प्रति हैक्टर फॉस्फोरस से क्रमशः. 35.9 व 5.6 प्रतिशत वृद्धि पंजीयित की गयी। तथापि, भूसा व जैव उपज में सार्थक वृद्धि 20 किग्रा. प्रति हैक्टर फॉस्फोरस तक हुई। बीज उपज में 5 किग्रा. प्रति हैक्टर टी.यू. के मृदा में प्रयोग (½+½) एवं 500 पीपीएम टी.यू. का पर्णीय छिटकाव से क्रमशः 18.9 व 11.5 प्रतिशत सार्थक उन्नति नियंत्रित के उपर हुई। टी.यू. व डी. एम. एस.ओ. के मृदा व पर्णीय प्रयोग उपचारों से कटाई सूचकांक में भी सार्थक वृद्धि हुई। 20 किग्रा. प्रति हैक्टर फॉस्फोरस के साथ 5 किग्रा. प्रति हैक्टर का मृदा में प्रयोग (½+½) सबसे अधिक प्रभावशाली उपचार था। इस उपचार ने 19.22 क्वि. प्रति हैक्टर बीज उत्पादन दिया जो 40 किग्रा. प्रति हैक्टर फॉस्फोरस के साथ मृदा में 5 किग्रा. प्रति हैक्टर थायोयूरिया (½+½) से उत्पादित बीस से सममूल्य पर था।

इस प्रकार थायोयूरिया का मृदा में प्रयोग से 20 किग्रा. प्रति हैक्टर फॉस्फोरस की बचत हुई। अतः बीकाने क्षेत्र की कृषि जलवायु परिस्थिति में ग्वार की उत्पादकता बढ़ाने के लिए 20 किग्रा. प्रति हैक्टर फॉस्फोरस के साथ 5 किग्रा. प्रति हैक्टर थायोयूरिया का मृदा में विपाटित प्रयोग अभिस्ताव किया जाता है। 500 पीपीएम. टी. यू. के साथ 40 किग्रा. प्रति हैक्टर फॉस्फोरस से अधिकतम सकल लाभ रू. 22497 व लाभ–लागत अनुपात 2.04 प्राप्त किया गया।

थायोयूरिया का कार्य एक सल्फाहाईड्रील जैविक नियामक के रूप में निर्धारण हेतू संचालित अध्ययन यह प्रकट करता है कि वृद्धि एवं उपज कारक प्राचलो में 500 पीपीएम.टी.यू., 500 पीपीएम.ई.ए. व 10 पीपीएम डी.डी.टी. से सार्थक उन्नति हुई। सल्फाहाइड्रील यौगिको से फसल की उत्तरोत्तर प्रक्रम में पत्तियों व फलीयों में शुष्क प्रदार्थ वितरण में भी नियंत्रित से वृद्धि हुई। इसके विपरीत, वृद्धि व उपज कारक प्राचलों में 10 पीपीएम. पी.सी.एम.बी.एस. के पर्णीय छिटकाव से सार्थक कमी हुई। सल्फाहाइड्रील यौगिको के पर्णीय छिकाव से बुवाई के 75 दिन बाद पत्तियों मे नत्रजन व गन्धक की मात्रा प्रभावित नही हुई। 500 पीपीएम टी.यू., 500 पीपीएम एम. ई.ए. व 10 पीपीएम डी.डी.टी. से बीज उपज में सार्थक वृद्धि हुई एवं नियंत्रित से क्रमशः 13.6, 27.5 व 12.2 प्रतिशत वृद्धि पंजीयित की गयी। कटाई सूचकांक में भी समान प्रवृति अवलोक की गई। नियंत्रित के उपर 10 पीपीएम पी.सी.एम.बी.एस., सल्फाहाइड्रील समूह अवरोधक से बीज उपज में सार्थक कमी हुई

# APPENDIX –I

**Analysis of variance for plant height at 60 DAS and physiological maturity, number of branches/plant, number of green leaves/plant**

| Source of Variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Plant height (cm) at 60 DAS | | Plant height (cm) at physiological maturity | | No. of branch/plant | | No. of green leaves/plant | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 11.615 | 21.152 | 255.001 | 150.643 | 0.700 | 0.972 | 146.841 | 6.406 |
| Phosphorus (P) | 2 | 11.57.502** | 1225.941** | 356.378* | 514.824* | 18.294** | 35.963** | 3611.071** | 2325.255** |
| Chemicals (C) | 7 | 19.068 | 23.791 | 52.131 | 48.974 | 6.402** | 6.952** | 6031.508** | 4322.05** |
| P x C | 14 | 24.572 | 15.463 | 30.690 | 26.015 | 0.677 | 0.415 | 139.934 | 75.937* |
| Error | 69 | 22.208 | 21.482 | 95.285 | 125.121 | 0.437 | 0.572 | 138.336 | 34.146 |

# APPENDIX –II

**Analysis of variance for dry matter accumulation/plant (g) at 30, 60, 90 DAS and physiological maturity**

| Source of Variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | At 30 DAS | | At 60 DAS | | At 90 DAS | | Physiological maturity | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.319 | 0.017 | 1.025 | 0.595 | 5.400 | 3.685 | 5.929 | 0.694 |
| Phosphorus (P) | 2 | 1.886** | 5.235** | 136.604** | 300.203** | 373.331** | 844.184** | 1252.068** | 568.41** |
| Chemicals (C) | 7 | 0.403* | 00.714* | 13.032* | 16.680** | 38.019** | 123.101** | 118.019** | 36.742** |
| P x C | 14 | 0.137 | 0.007 | 2.885 | 0.637 | 8.810 | 1.973 | 4.939 | 1.827 |
| Error | 69 | 0.144 | 0.076 | 4.511 | 4.127 | 9.389 | 12.474 | 7.223 | 8.288 |

# APPENDIX –III

**Analysis of variance for dry matter distribution (%) in leaves, stems and pods at 30 and 60 DAS**

| Source of Variation | d.f. | M.SS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | At 30 DAS | | | | At 60 DAS | | | | | |
| | | Leaves | | Stems | | Leaves | | Stems | | Pods | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 40.257 | 2.543 | 10.360 | 2.536 | 2.799 | 0.436 | 1.618 | 1.093 | 1.400 | 1.067 |
| Phosphorus (P) | 2 | 30.064 | 11.484** | 8.499 | 11.490** | 11.128 | 2.026 | 0.827 | 31.657** | 6.294 | 16.504** |
| Chemicals (C) | 7 | 20.779 | 11.087** | 15.584 | 11.085** | 8.706 | 3.654** | 5.004 | 3.944** | 3.012 | 2.342* |
| P x C | 14 | 13.420 | 2.428 | 7.317 | 2.427 | 7.909 | 2.946** | 5.289 | 2.369** | 1.543 | 1.487 |
| Error | 69 | 15.958 | 1.160 | 12.404 | 1.460 | 7 144 | 0.656 | 7.334 | 0.707 | 3.117 | 0.919 |

# APPENDIX –IV

**Analysis of variance for dry matter distribution (%) in leaves, stems and pods at 90 DAS and physiological maturity**

| Source of Variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | At 90 DAS | | | | | | At physiological maturity | | | | | |
| | | Leaves | | Stems | | Pods | | Leaves | | Stems | | Pods | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 20.824 | 0.314 | 5.086 | 0.814 | 10.077 | 0.867 | 2.171 | 0.059 | 5.984 | 10.553* | 7.732 | 10.350 |
| Phosphorus (P) | 2 | 1.514 | 287.746** | 10.036 | 624.42** | 20.772* | 62.34** | 4.120* | 0.167* | 566.305** | 137.118** | 692.739** | 153.227** |
| Chemicals (C) | 7 | 72.709** | 275.613** | 222.889** | 534.23** | 127.626** | 52.32** | 34.089** | 27.66** | 271.732** | 26.727** | 131.824** | 2.982 |
| P x C | 14 | 5.185 | 8.068** | 14.904** | 15.54** | 11.885* | 16.79** | 0.904 | 0.484** | 13.077** | 2.697 | 11.544 | 3.126 |
| Error | 69 | 10.037 | 0.431 | 4.627 | 2.872 | 6.078 | 3.649 | 0.877 | 0.035 | 4.603 | 3.372 | 7.071 | 4.718 |

## APPENDIX –V

**Analysis of variance for chlorophyll content of leaves at 90 DAS**

| Source | df | MSS | | | | | |
|---|---|---|---|---|---|---|---|
| | | Chlorophyll content of leaves at 90 DAS | | | | | |
| | | a | | b | | Total | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.00016 | 0.0002 | $4.5x10^{-5}$ | $2.8x10^{-5}$ | 0.0002 | 0.00038 |
| Treatments | 9 | 0.0184* | 0.0115** | 0.0016** | 0.0011** | 0.0274** | 0.0175** |
| Error | 27 | 0.00032 | 0.00018 | $2.8x10^{-5}$ | $3.62x10^{-5}$ | 0.00035 | 0.00022 |

## APPENDIX –VI

**Analysis of variance for LAI at 60 and 90 DAS, CGR at 60 and 90 DAS, LAR at 60 and 90 DAS**

| Source of Variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAI at 60 DAS | | LAI at 90 DAS | | CGR at 60 DAS( $g/m^2/d$ ) | | CGR at 90 DAS($g/m^2/d$) | | LAR at 60DAS | | LAR at 90DAS | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.241 | 0.055 | 0.186 | 0.017 | 0.286 | 0.556 | 5.349 | 2.797 | 0.000078 | 0.0000112 | 0.000388 | 0.0000134 |
| Phosphorus | 2 | 18.408** | 23.029** | 5.869** | 34.875** | 133.682** | 279.499** | 47.505** | 169.692** | 0.006066** | 0.001554** | 0.001598** | 0.008152** |
| Chemical | 7 | 0.902* | 1.131** | 1.297** | 12.54** | 15.554* | 17.856** | 23.249* | 71.223** | 0.000159 | 0.000074** | 0.000935** | 0.00428** |
| P x C | 14 | 0.214 | 0.091 | 0.233** | 0.438** | 3.599 | 0.762 | 14.123 | 2.996 | 0.000177 | 0.0000376 | 0.000095 | 0.000133 |
| Error | 69 | 0.382 | 0.247 | 0.238 | 0.168 | 5.290 | 3.879 | 8.996 | 3.852 | 0.0001506 | 0.0000164 | 0.000135 | 0.0000194 |

# APPENDIX –VII

**Analysis of variance for NAR at 60 and 90 DAS, root length at 60 DAS, root weight at 60 DAS and number of nodules/plant**

| Source of Variation | d.f. | MSS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NAR at 60 DAS ($g/cm^2/d$) | | NAR at 90 DAS ($g/cm^2/d$) | | Root length (cm) at 60 DAS | | Root weight (g) at 60 DAS | | No of nodules/plant at 60 DAS | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.001093** | 0.000108 | 0.000635 | 0.000123 | 2.227 | 1.113 | 0.053 | 0.004 | 0.485 | 0.118 |
| Phosphorus (P) | 2 | 0.005039** | 0.003981** | 0.000364** | 0.001455** | 91.974** | 249.375** | 1.059** | 6.302** | 19.468** | 58.614** |
| Chemicals (C) | 7 | 0.0011600** | 0.001000** | 0.001313** | 0.000448** | 6.309 | 17.018** | 0.189** | 0.065 | 3.172** | 2.411** |
| P x C | 14 | 0.000713 | 0.0000657 | 0.000550 | 0.000133 | 1.180 | 2.344 | 0.057 | 0.073* | 0.816 | 0.457 |
| Error | 69 | 0.000643 | 0.0000965 | 0 000486 | 0.000123 | 6.406 | 5.138 | 0.060 | 0.034 | 0.453 | 0.581 |

# APPENDIX –VIII

**Analysis of variance for number of clusters/plant, number of pods/cluster, number of pods/plant, number of poorly filled pods/plant and number of unfilled pods/plant**

| Source of Variation | d.f. | MSS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No of clusters/plant | | No of pods/cluster | | No of pods/plant | | No of poorly filled pods | | No of unfilled pods/plant | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 12.923 | 0.829 | 0.184 | 0.016 | 19.562 | 22.172 | 0.213 | 0.242 | 0.681 | 0.414 |
| Phosphorus (P) | 2 | 125.503** | 257.622** | 0.870 | 1.500** | 261.876* | 5278.081** | 19.311** | 48.335** | 116.375** | 175.711** |
| Chemicals (C) | 7 | 78.249** | 12.383* | 1.038 | 0.561** | 27.535** | 585.864** | 14.746** | 9.616** | 102.83** | 73.031** |
| P x C | 14 | 10.871 | 0.597 | 0.430 | 0.014 | 42.00 | 21.050 | 3.546 | 1.782** | 8.23** | 2.033** |
| Error | 69 | 9.694 | 3.543 | 0.507 | 0.051 | 54.933 | 55.541 | 0.177 | 0.173 | 0.342 | 0.414 |

## APPENDIX –IX

**Analysis of variance for pod length, seed/pod, test weight and seed yield/plant**

| Source of Variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Pod length (cm) | | No of seeds/pod | | Test weight (g) | | Seed yield/plant (g) | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.127 | 0.049 | 0.378 | 0.577* | 1.085 | 1.578 | 0.5669 | 0.365 |
| Phosphorus (P) | 2 | 2.866** | 0.886** | 1.715** | 4.864** | 0.502 | 11.686** | 106.051** | 338.794** |
| Chemicals (C) | 7 | 0.253* | 0.170 | 0.942** | 0.983** | 2.121 | 2.386* | 49.243** | 17.23** |
| P x C | 14 | 0.016 | 0.051 | 0.216 | 0.2 | 1.009 | 0.190 | 6.446* | 1.669 |
| Error | 69 | 0.104 | 0.128 | 0.197 | 0.194 | 0.974 | 0.783 | 2.8869 | 1.942 |

## APPENDIX –X

**Analysis of variance for seed, straw and biological yields and harvest index**

| Source of Variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Seed yield (q/ha) | | Straw yield (q/ha) | | Biological yield (q/ha) | | Harvest index (%) | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 1.961 | 1.001 | 11.147 | 6.82 | 9.767 | 11.997 | 4.843 | 0.721 |
| Phosphorus (P) | 2 | 81.278** | 388.147** | 155.749** | 975.100** | 458.483** | 2698.91** | 54.409** | 137.94* |
| Chemicals (C) | 7 | 16.833** | 10.590** | 20.435 | 15.705 | 55.444 | 42.36 | 22.154** | 8.933* |
| P x C | 14 | 5.437** | 9.125** | 51.062* | 19.521 | 81.851 | 25.85 | 7.714** | 2.181 |
| Error | 69 | 2.089 | 3.163 | 22.860 | 14.103 | 43.04 | 25.120 | 2.943 | 3.483 |

## APPENDIX –XI

**Analysis of variance for available P content (kg/ha) of soil at 30, 60 DAS and harvest, gum and protein content of seed**

| Source of Variation | d.f. | MSS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Available P content of soil at 30 DAS | | Available P content of soil at 60 DAS | | Available P content of soil at harvest | | Gum content of seed (%) | | Protein content of seed (%) | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 1.689 | 2.082 | 3.249 | 3.976 | 3.515 | 1.550 | 1.425 | 1.364 | 3.923 | 1.802 |
| Phosphorus (P) | 2 | 106.820** | 73.253** | 261.560** | 151.454** | 177.896** | 176.051** | 41.049** | 27.954** | 24.800** | 33.656** |
| Chemicals (C) | 7 | 5.487** | 0.079 | 7.967** | 10.718** | 6.406** | 6.437** | 4.567** | 1.209 | 0.245 | 0.253 |
| P x C | 14 | 0.630 | 0.026 | 0.228 | 0.229 | 0.581 | 5.356** | 0.030 | 0.140 | 0.064 | 0.097 |
| Error | 69 | 0.849 | 1.125 | 1.547 | 1.884 | 1.831 | 0.825 | 1.296 | 1.516 | 1.569 | 0.901 |

## APPENDIX –XII

**Analysis of variance for N, S content (%) of leaves at 90 DAS, P content of leaves, stem and pods at 60 DAS**

| Source of Variation | d.f. | MSS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N content of leaves at 90 DAS | | S content of leaves at 90 DAS | | P content ofleaves at 60 DAS | | P content of stems at 60 DAS | | P content of pods at 60 DAS | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.0211 | 0.0148 | 0.0003 | 0.000023 | 0.0005 | 0.0004 | 0.0003 | 0.0001 | 0.0011 | 0.0005 |
| Phosphorus (P) | 2 | 0.9535** | 0.4291** | 0.00009 | 0.00089 | 0.0404** | 0.0401** | 0.0116** | 0.0084** | 0.0142** | 0.0124** |
| Chemicals (C) | 7 | 0.0044 | 0.0478* | 0.00038 | 0.00023 | 0.0016** | 0.0017** | 0.0002 | 0.0003 | 0.0015* | 0.0008* |
| P x C | 14 | 0.0013 | 0.0091 | 0.00011 | 0.000042 | 0.0004 | 0.0004 | 0.00002 | 0.00002 | 0.0003 | 0.00015 |
| Error | 69 | 0.0106 | 0 0173 | 0.0002 | 0.00030 | 0.0003 | 0.0004 | 0.0002 | 0.0001 | 0.0006 | 0.0003 |

## APPENDIX -XIII

**Analysis of variance for P content (%) of leaves, stems and pods at 90 DAS and physiological maturity**

| Source of Variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | At 90 DAS | | | | | | At physiology maturity | | | | | |
| | | Leaves | | Stems | | Pods | | Leaves | | Stems | | Pods | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.0003 | 0.0006 | 0.0003 | 0.0002 | 0.0006 | 0.0001 | 0.0002 | 0.0006 | 0 0003 | 0.00029 | 0.00081 | 0.00026 |
| Phosphorus (P) | 2 | 0.0301** | 0.0125** | 0.0047** | 0.0005 | 0.0169** | 0.0159** | 0.0302 | 0.0126 | 0.0048** | 0.00417** | 0.01532** | 0.01533** |
| Chemicals (C) | 7 | 0.0014** | 0.0019** | 0.0002 | 0.0002 | 0.0019** | 0.0024** | 0.0014 | 0.0019 | 0.0003 | 0.00047* | 0.00185** | 0.00231** |
| P x C | 14 | 0.0005* | 0.0003 | 0.00002 | 0.000006 | 0.0006 | 0.0006** | 0.0005 | 0.0036 | 0.00007 | 0.00004 | 0.00036 | 0.00054** |
| Error | 69 | 0.0002 | 0.0004 | 0.0001 | 0.0005 | 0.0003 | 0.00009 | 0.0002 | 0.0006 | 0.0002 | 0.00016 | 0.00042 | 0.00017 |

## APPENDIX -XIV

**Analysis of variance for P distribution (%) in leaves, stems and pods at 60 and 90 DAS**

| Source of Variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P distribution in leaves (%) at 90 DAS | | P distribution in stems (%) at 90 DAS | | P distribution in pods (%) at 90 DAS | | P distribution in leaves (%) at 60 DAS | | P distribution in stems (%) at 60 DAS | | P distribution in pods (%) at 60 DAS | |
| | | ·1999 | 2000 | ·1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 26.373 | 1.404 | 1.829 | 1.955 | 23.878 | 2.888 | 8.181 | 0.615 | 4.267 | 0.805 | 2.517 | 1.917 |
| Phosphorus (P) | 2 | 15.76 | 292.49** | 42.143** | 729.985** | 7.846 | 98.856** | 30.307* | 43.941** | 13.582 | 77.853** | 7.195** | 16.3** |
| Chemicals (C) | 7 | 63.805** | 260.87** | 211.794** | 476.00** | 170.817** | 44.758** | 11.065 | 3.812 | 8.693 | 6.903** | 4.441 | 2.885 |
| P x C | 14 | 5.823 | 6.666** | 14.972** | 12.584** | 17.316 | 17.313** | 8.829 | 4.801* | 5.977 | 2.528 | 2.417 | 2.257 |
| Error | 69 | 11.491 | 1.086 | 4.809 | 4.433 | 12.849 | 5.314 | 8.163 | 2.231 | 9.435 | 2.301 | 1.818 | 1.11 |

## APPENDIX –XV

**Analysis of variance for P distribution (%) in leaves, stems and pods at physiological maturity and P uptake by seed and straw (kg/ha)**

| Source of Variation | d.f. | MSS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P distribution in leaves at physiological maturity | | P distribution in stems at physiological maturity | | P distribution in pods at physiological maturity | | P uptake by seed | | P uptake by straw | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 1.936 | 0.054 | 4.982 | 6.88 | 8.976 | 7.101 | 0.936 | 0.337 | 1.026 | 0.317 |
| Phosphorus (P) | 2 | 1.891 | 0.055 | 519.06** | 149.23** | 593.65** | 143.65** | 80.879** | 203.294** | 87.178** | 231.536** |
| Chemicals (C) | 7 | 27.847** | 24.058** | 223.58** | 25.464** | 106.04** | 1.726 | 7.690** | 5.294** | 4.022 | 3.189 |
| P x C | 14 | 0.801 | 0.0619 | 9.827** | 3.603 | 10.500* | 4.504 | 1.477* | 0.776 | 3.979 | 1.414 |
| Error | 69 | 0.883 | 0.160 | 2.859 | 3.033 | 4.647 | 3.080 | 0.744 | 1.034 | 2.941 | 2.262 |

## APPENDIX –XVI

**Analysis of variance for total P uptake (kg/ha), P harvest index (%), net monetary returns (Rs/ha) and B:C**

| Source of Variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total P uptake | | P harvest index | | Net returns | | B:C ratio | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 5.673 | 0.952 | 13.288 | 1.010 | 8729983 | $1x10^6$ | 0.0659 | 0.007 |
| Phosphorus (P) | 2 | 327.854** | 863.874** | 25.524** | 104.488** | $3.35 x10^8$** | $5 x10^8$** | 1.949** | 3.057** |
| Chemicals (C) | 7 | 20.353** | 15.370* | 24.607** | 11.552* | 54997573** | $8x10^6$* | 1.113* | 0.1449* |
| P x C | 14 | 8.696* | 3.363 | 6.806 | 2.913 | 27987655** | $3 x10^6$ | 0.272 | 0.0198 |
| Error | 69 | 4.480 | 5.386 | 9.093 | 4.074 | 10585370 | $4x10^6$ | 0.0915 | 0.024 |

# APPENDIX –XVII

**Analysis of variance (pooled data) for plant height at 60 DAS and physiological maturity, number of branches/plant, number of green leaves/plant and dry matter accumulation/plant (g) at 30, 60, 90 DAS and physiological maturity**

| Source of variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Dry matter accumulation | | | |
| | | Plant height at 60 DAS | Plant height at physiological maturity | No. of branches per plant | No of green leaves per plant | At 30 DAS | At 60 DAS | At 90 DAS | Physiological maturity |
| Year (Y) | 1 | 0.121 | 2.092 | 1.900 | 6657.585** | 0.0075 | 3.583 | 500.263** | 47.649* |
| Replication | 6 | 16.383 | 215.484 | 0.837 | 76.623 | 0.1685 | 0.811 | 4.542 | 3.311 |
| Phosphorus (P) | 2 | 2389.507** | 859.093** | 52.451** | 5865.563** | 6.6616** | 419.748** | 1169.969** | 1753.452** |
| Chemical (C) | 7 | 38.578 | 98.347 | 13.199** | 9949.777** | 0.5968** | 26.455** | 104.863** | 131.857** |
| P x C | 14 | 45.631* | 52.258 | 0.305 | 208.702** | 0.0793 | 1.852 | 4.131 | 4.757 |
| P x Y | 2 | 0.406 | 12.109 | 1.550** | 70.763 | 0.4612* | 17.059* | 47.546* | 66.911** |
| C x Y | 7 | 3.880 | 2.758 | 0.034 | 403.790** | 0.1059 | 3.257 | 58.259** | 22.876** |
| P x C x Y | 14 | 3.721 | 4.448 | 0.809 | 7.170 | 0.0643 | 1.671 | 6.653 | 2.016 |
| Error | 138 | 21.845 | 148.989 | 0.505 | 86.241 | 0.1102 | 4.319 | 10.932 | 7.756 |

# APPENDIX –XVIII

**Analysis of variance (pooled data) for dry matter distribution (%) in leaves, stems and pods at 30, 60, 90 DAS and physiological maturity**

| Source of variation | d.f. | MSS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | At 30 DAS | | At 60 DAS | | | At 90 DAS | | | At physiological maturity | | |
| | | Leaves | Stems | Leaves | Stems | Pods | Leaves | Stems | Pods | Leaves | Stems | Pods |
| Year (Y) | 1 | 13.981 | 0.250 | 17.334* | 4.296 | 5.427 | 4120.238** | 925.148** | 1198.700** | 70.313** | 695.097** | 257.08** |
| Replication | 6 | 21.400* | 6.448 | 1.618 | 1.356 | 1.234 | 10.569 | 2.949 | 5.472 | 1.115* | 8.269 | 9.039 |
| Phosphorus (P) | 2 | 8.468 | 0.375 | 2.944 | 11.312 | 21.101** | 155.511** | 395.172** | 77.393** | 2.037* | 617.55** | 734.329** |
| Chemical (C) | 7 | 25.217** | 17.285 | 8.889* | 6.871 | 4.841* | 220.131** | 643.218** | 151.851** | 59.816** | 229.05** | 64.007** |
| P x C | 14 | 6.543 | 4.545 | 4.503 | 4.473 | 2.795 | 7.797 | 24.492** | 23.793** | 1.141** | 10.301** | 10.017 |
| P x Y | 2 | 33.782 | 19.614 | 10.209 | 21.173** | 1.697 | 133.750** | 239.289** | 5.721 | 5.913** | 85.872** | 111.637** |
| C x Y | 7 | 6.850 | 9.385 | 3.471 | 2.077 | 0.514 | 128.191** | 113.906** | 28.097** | 1.933** | 69.411** | 70.805** |
| P x C x Y | 14 | 9.205 | 5.196 | 6.352 | 3.185 | 0.235 | 5.456 | 5 955 | 4.880 | 0.447 | 5.473 | 4.654 |
| Error | 138 | 8.709 | 6.932 | 3.900 | 4.021 | 2.018 | 5.234 | 3.749 | 4.864 | 0.456 | 3.987 | 5.900 |

## APPENDIX –XIX

**Analysis of variance (pooled data) for LAI at 60 and 90 DAS, CGR at 60 and 90 DAS, LAR at 60 and 90 DAS, NAR at 60 and 90 DAS, root length (cm) at 60 DAS, root weight at 60 DAS and number of nodules at 60 DAS**

| Source of variation | d.f. | MSS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAI | | CGR | | LAR | | NAR | | Root length at 60 DAS | Root weight at 60 DAS | Number of nodules at 60 DAS |
| | | 60 DAS | 90 DAS | 60 DAS | 90 DAS | 60 DAS | 90 DAS | 60 DAS | 90 DAS | | | |
| Year (Y) | 1 | 3.996** | 23.786** | 3.523 | 461.466** | 0.0059** | 0.07481** | 0.00689** | 0.05603** | 1.194 | 0.9357** | 1.900 |
| Replication | 6 | 0.148 | 0.102 | 0.421 | 4.073 | $4.48 \times 10^{-5}$ | 0.000201* | 0.00060 | 0.00038 | 1.670 | 0.0281 | 0.301 |
| Phosphorus (P) | 2 | 40.803** | 34.617** | 398.239** | 198.175** | 0.00660** | 0.00827** | 0.00933** | 0.00032 | 321.869** | 6.223** | 72.820** |
| Chemical (C) | 7 | 1.728** | 10.242** | 28.764** | 50.035** | 0.00016 | 0.00313** | 0.00146** | 0.001096** | 21.179** | 0.2149** | 5.124** |
| P x C | 14 | 0.189 | 0.186 | 2.318 | 5.982 | 0.00012 | 0.000177** | 0.000438 | 0.000331 | 1.478 | 0.0359 | 0.856 |
| P x Y | 2 | 0.635 | 6.126** | 14.942* | 19.022 | 0.00018** | 0.001576** | $3.489 \times 10^{-5}$ | 0.00183** | 19.479* | 1.1390** | 5.261** |
| C x Y | 7 | 0.304 | 3.595** | 4.645 | 44.436** | $7.73 \times 10^{-5}$ | 0.002067** | 0.00365 | 0.000601 | 2.148 | 0.0401 | 0.459 |
| P x C x Y | 14 | 0.116 | 0.486** | 2.042 | 11.137 | 0.000101 | $6.65 \times 10^{-5}$ | 0.000352 | 0.001184** | 2.046 | 0.0281 | 0.417 |
| Error | 138 | 0.317 | 0.199 | 4.584 | 6.424 | $8.347 \times 10^{-5}$ | $7.761 \times 10^{-5}$ | 0.00037 | 0.000304 | 5.773 | 0.0473 | 0.517 |

## APPENDIX –XX

**Analysis of variance (pooled data) for number of clusters/plant, pods/cluster, pods/plant, poorly filled pods/plant, unfilled pods/plant, pod length, seeds/pod, test weight, seed yield, seed yield, straw yield biological yield**

| Source of variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No of clusters/ plant | No of pods/ cluster | No of pods/ plant | No of poorly filled pods/plant | No of unfilled pods/plant | Pod length (cm) | No. seeds/pod | Test weight (g) | Seed yield/plant (g) | Seed yield (q/ha) | Straw yield (q/ha) | Biological yield (q/ha) |
| Year (Y) | 1 | 221.88** | 1.031 | 2355.08** | 34.340** | 0.403 | 1.661** | 0.038 | 3.794* | 15.300* | 9.443 | 131.804** | 211.575* |
| Replication | 6 | 6.876 | 0.100 | 20.867 | 0.227 | 0.547 | 0.089 | 0.452 | 1.331 | 0.465 | 1.481 | 8.984 | 10.882 |
| Phosphorus (P) | 2 | 330.379** | 0.087 | 3936.165** | 63.165** | 288.581** | 3.381** | 6.177** | 8.637** | 411.701** | 448.422** | 955.091** | 2690.941** |
| Chemical (C) | 7 | 72.730** | 0.359 | 811.912** | 21.095** | 173.066** | 0.768** | 1.900** | 4.008** | 59.627** | 25.658** | 13.213 | 67.728 |
| P x C | 14 | 6.928 | 0.237 | 10.581 | 4.631** | 8.235** | 0.648** | 0.399* | 0.699 | 3.456 | 4.670* | 42.094 | 65.138* |
| P x Y | 2 | 27.789* | 2.234** | 1607.89** | 4.481** | 3.506** | 0.453* | 0.402 | 3.625* | 32.888** | 71.092** | 175.759** | 466.416** |
| C x Y | 7 | 17.901* | 1.231** | 49.485 | 3.268** | 2.795** | 0.471** | 0.025 | 0.505 | 6.782** | 1.765 | 22.927 | 30.077 |
| P x C x Y | 14 | 8.104 | 0.209 | 51.884 | 0.697** | 2.027** | 0.417** | 0.016 | 0.511 | 4.697* | 3.860 | 25.759 | 42.553 |
| Error | 138 | 6.618 | 0.2789 | 55.237 | 0.175* | 0.3783 | 0.116 | 0.224 | 0.878 | 2.415 | 2.626 | 18.482 | 34.080 |

# APPENDIX –XXI

**Analysis of variance (pooled data) for harvest index, available P content (kg/ha) at 30, 60 DAS and harvest, gum and protein content of leaves, N and S content (%) of leaves at 90 DAS**

| Source of variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Harvest index (%) | Available P content of soil | | | Gum content of seed (%) | Protein content of seed (%) | N content in leaves at 90 DAS | S content in leaves at 90 DAS |
| | | | At 30 DAS | At 60 DAS | At harvest | | | | |
| Year (Y) | 1 | 34.535 | 458.927** | 196.182** | 46.374** | 58.539** | 0.062 | 0.1371** | 0.03010** |
| Replication | 6 | 2.782 | 1.885 | 3.612 | 2.533 | 1.395 | 2.863* | 0.0179 | 0.00014 |
| Phosphorus (P) | 2 | 180.402** | 173.537** | 405.465** | 348.902** | 65.343** | 58.052** | 1.3264** | 0.00024 |
| Chemical (C) | 7 | 24.663** | 3.341** | 18.145** | 10.833** | 4.788* | 0.491 | 0.0393 | 0.00049 |
| P x C | 14 | 3.622 | 0.299 | 0.157 | 3.928** | 0.127 | 0.153 | 0.0052 | $8.58 \times 10^{-5}$ |
| P x Y | 2 | 11.948* | 6.537** | 7.549* | 0.638 | 3.661 | 0.358 | 0.0562* | 0.00074 |
| C x Y | 7 | 6.425 | 2.226* | 0.541 | 0.905 | 0.989 | 0.0081 | 0.0129 | 0.00013 |
| P x C x Y | 14 | 6.272* | 0.356 | 0.300 | 2.573* | 0.043 | 0.008 | 0.0053 | $7.134 \times 10^{-5}$ |
| Error | 138 | 3.213 | 0.987 | 1.716 | 1.328 | 1.845 | 1.235 | 0.0134 | 0.00026 |

# APPENDIX –XXII

**Analysis of variance (pooled data) for P content (%) of leaves, stems and pods at 60 and 90 DAS and physiological maturity**

| Source of variation | d.f. | MSS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | At 60 DAS | | | At 90 DAS | | | At physiological maturity | | |
| | | Leaves | Stems | Pods | Leaves | Stems | Pods | Leaves | Stems | Pods |
| Year (Y) | 1 | 0.0088** | 0.01104** | 0.00042 | 0.0029** | 0.01248** | 0.00067 | 0.0029** | 0.00047 | 0.0025** |
| Replication | 6 | 0.0052** | 0.00023 | 0.00083 | 0.00040 | 0.00024 | 0.00033 | 4.398** | 0.00030 | 0.00053 |
| Phosphorus (P) | 2 | 0.0805** | 0.01986** | 0.02665** | 0.04077** | 0.00403** | 0.03279** | 0.0409** | 0.00893** | 0.03056** |
| Chemical (C) | 7 | 0.0033** | 0.00047** | 0.00221** | 0.00321** | 0.000348 | 0.00419** | 0.0032 | 0.000785** | 0.00404** |
| P x C | 14 | 0.0007* | $2.953 \times 10^{-5}$ | 0.000406 | 0.00082** | $2.283 \times 10^{-5}$ | 0.00109** | 0.00081 | 0.00010 | 0.00083** |
| P x Y | 2 | $4.75 \times 10^{-5}$ | 0.00017 | $4.469 \times 10^{-5}$ | 0.00187** | 0.001148** | $6.81 \times 10^{-5}$ | 0.0019 | $1.154 \times 10^{-5}$ | $8.89 \times 10^{-5}$ |
| C x Y | 7 | $5.5 \times 10^{-6}$ | $1.885 \times 10^{-5}$ | $7.96 \times 10^{-5}$ | 0.00018 | $5.30\,9 \times 10^{-6}$ | 0.000105 | 0.00016 | $1.27 \times 10^{-5}$ | 0.00012 |
| P x C x Y | 14 | $4.93 \times 10^{-5}$ | $1.346 \times 10^{-5}$ | $4.516 \times 10^{-5}$ | $9.86 \times 10^{-5}$ | $9.95 \times 10^{-6}$ | $8.858 \times 10^{-5}$ | $8.84 \times 10^{-5}$ | $1.126 \times 10^{-5}$ | $6.9 \times 10^{-5}$ |
| Error | 138 | 0.000356 | 0.00015 | 0.000624 | 0.000299 | 0.00031 | 0.00018 | 0.000416 | 0.00018 | 0.00029 |

## APPENDIX –XXVIII

**Analysis of variance (pooled data) for P distribution (%) in leaves, stems, pods at 60, 90 DAS and physiological maturity**

| Source of variation | d.f. | MSS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | At 60 DAS | | | At 90 DAS | | | At physiological maturity | | |
| | | Leaves | Stems | Pods | Leaves | Stems | Pods | Leaves | Stems | Pods |
| Year (Y) | 1 | 25.201* | 15.835 | 1.104 | 3869.123** | 427.392** | 1726.68** | 60.021** | 522.951** | 236.629** |
| Replication | 6 | 4.398 | 2.536 | 2.217 | 13.888* | 1.892 | 13.383 | 0.995 | 5.931 | 8.039 |
| Phosphorus (P) | 2 | 62.842** | 67.172** | 21.291** | 221.486** | 560.684** | 78.980** | 1.063 | 603.045** | 653.125** |
| Chemical (C) | 7 | 12.613* | 13.379* | 6.629** | 202.390** | 595.049** | 165.982** | 50.049** | 195.208** | 50.653** |
| P x C | 14 | 9.690* | 5.728 | 4.306** | 7.100 | 21.936** | 26.352** | 1.139* | 8.165** | 9.117** |
| P x Y | 2 | 11.405 | 24.264* | 2.202 | 86.760** | 211.444** | 27.723 | 0.884 | 65.254** | 84.189** |
| C x Y | 7 | 2.264 | 2.218 | 0.697 | 122.287** | 92.745** | 49.594** | 1.855** | 53.841** | 57.114** |
| P x C x Y | 14 | 3939 | 2.778 | 0.368 | 5.389 | 5.621 | 8.277 | 0.282 | 5.265* | 5.887 |
| Error | 138 | 5.197 | 5.868 | 1.464 | 6.288 | 4.621 | 9.082 | 0.522 | 2.946 | 3.864 |

## APPENDIX –XXIV

**Analysis of variance (pooled data) for P uptake by seed, straw and total P uptake (kg/ha), P harvest index, net monetary returns (Rs/ha) and B:C**

| Source of variation | d.f. | MSS | | | | | |
|---|---|---|---|---|---|---|---|
| | | P uptake by seed | P uptake by straw | Total P uptake | P harvest index | Net returns | B:C ratio |
| Year (Y) | 1 | 0.297 | 45.231** | 38.997** | 259 377** | $1.66 \times 10^{10}$** | 157.705** |
| Replication | 6 | 0.637 | 0.672 | 3.312 | 3.312 | 4970565 | 0.043 |
| Phosphorus | 2 | 270.237** | 297.402** | 1128.049** | 115.891** | $8.48 \times 10^{8}$** | 4.775** |
| Chemical | 7 | 12.359** | 4.937 | 31.855** | 29.838** | $1.05 \times 10^{8}$** | 2.016** |
| P x C | 14 | 0.967 | 2.776 | 6.049 | 3.273 | 15372106* | 0.154** |
| P x Y | 2 | 13.936** | 18.313** | 63.679** | 14.091 | 10421584 | 0.091 |
| C x Y | 7 | 0.625 | 2.274 | 3.668 | 6.356 | 18467298* | 0.359** |
| P x C x Y | 14 | 1.287 | 2.618 | 6.009 | 160.229** | 16011909** | 0.123* |
| Error | 138 | 0.889 | 2.601 | 4.934 | 4.934 | 7144928 | 0.057 |

## APPENDIX-XXV

**Analysis of variance for total dry matter accumulation/plant at 75, 90 DAS and physiological maturity and dry matter distribution (%) in leaves, stems and pods at 75 DAS**

| Source of variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total dry matter accumulation/plant (g) | | | | | | Dry matter distribution (%) at 75 DAS | | | | | |
| | | At 75 DAS | | At 90 DAS | | At physiological maturity | | leaves | | Stems | | Pods | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 1.970 | 1.993 | 1.534 | 2.728 | 2.769 | 0.741 | 1.793 | 2.282 | 0.488 | 0.245 | 1.912 | 1.890 |
| Treatments | 9 | 3.973** | 8.243** | 5.088** | 5.161** | 26.84** | 20.29** | 0.586 | 6.319* | 6.435** | 17.574** | 4.706 | 3.350** |
| Error | 27 | 0.925 | 0.464 | 1.367 | 0.988 | 1.22 | 1.691 | 1.493 | 2.126 | 0.934 | 2.051 | 2.471 | 1.049 |

## APPENDIX-XXVI

**Analysis of variance for dry matter distribution (%) in leaves, stems and pods at 90 DAS and physiological maturity**

| Source of variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | At 90 DAS | | | | | | At physiological maturity | | | | | |
| | | Leaves | | Stems | | Pods | | Leaves | | Stems | | Pods | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 6.984* | 11.488** | 8.638 | 0.543 | 16.887 | 15.405 | 0.444 | 00.199 | 12 022 | 13.668 | 14.763 | 11.348 |
| Treatments | 9 | 4.227** | 2.701 | 4.312 | 4.200 | 11.487* | 11.428* | 15.077** | 12.516** | 12 606** | 16.540* | 4.773 | 2.746 |
| Error | 27 | 1.774 | 1.569 | 3.670 | 4.348 | 4.216 | 4.990 | 0.649 | 0.672 | 3.613 | 6.871 | 3.422 | 6.801 |

## APPENDIX –XXVII

**Analysis of variance for number of branches/plant, clusters/plant, number of green leaves/plant, number of poorly filled pods/plant, number of unfilled pods/plant and number of pods/plant**

| source of variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of branches/plant | | Number of clusters/plant | | Number of green leaves/plant | | No. poorly filled pods/plant | | No. of unfilled pods/plant | | No. of pods/plant | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.765 | 0.253 | 1.725 | 0.259 | 2.376 | 9.368 | 0.038 | 0.193 | 0.297 | 0.246 | 58.703 | 0.554 |
| Treatments | 9 | 0.322 | 1.783** | 21.271** | 9.833** | 728.721** | 337.373** | 3.359** | 3.757** | 15.41** | 5.368** | 368.38** | 106.186** |
| Error | 27 | 0.623 | 0.450 | 1.603 | 0.544 | 26.048 | 9.116 | 0.0187 | 0.085 | 0.248 | 0.191 | 21.731 | 3.977 |

## APPENDIX –XXVIII

**Analysis of variance for pod length, number of seeds/pod, test weight and seed yield/plant**

| source of variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Pod length (cm) | | Number of seeds/pod | | Test weight (g) | | Seed yield/plant (g) | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.058 | 0.03 | 0.138 | 0.081 | 0.231 | 0.977 | 0.021 | 0.217 |
| Treatments | 9 | 0.351** | 0.179** | 0.801** | 0.503** | 3.572** | 3.279** | 4.668** | 0.998** |
| Error | 27 | 0.027 | 0.042 | 0.096 | 0.178 | 0.686 | 0.467 | 0.814 | 0.282 |

## APPENDIX –XXIX

**Analysis of variance for dry matter accumulation of pods in lowermost, middle and uppermost cluster**

| source of variation | d.f. | MSS | | | | | |
|---|---|---|---|---|---|---|---|
| | | Lowermost cluster | | Middle cluster | | Uppermost cluster | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.005 | 0.0003 | 0.0165 | 0.0361 | 0.0008 | 0.0014 |
| Treatments | 9 | 0.021** | 0.0165** | 0.2455** | 0.2767** | 0.0091** | 0.0049** |
| Error | 27 | 0.002 | 0.0036 | 0.0374 | 0.0399 | 0.0008 | 0.0012 |

## APPENDIX –XXX

**Analysis of variance for dry matter distribution (%) in pods in lowermost, middle and uppermost cluster, and number of pods in lowermost, middle and uppermost cluster**

| source of variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dry matter distribution in pods in | | | | | | Number of pods in | | | | | |
| | | Lowermost cluster | | Middle cluster | | Uppermost cluster | | Lowermost cluster | | Middle cluster | | Uppermost cluster | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 1.348 | 0.300 | 3.514 | 2.839 | 0.250 | 0.289 | 0.174 | 0.075 | 0.206 | 0.098 | 0.006 | 0.083 |
| Treatments | 9 | 0.216 | 0.096 | 5.198 | 4.026 | 0.362** | 2.304** | 0.193 | 0.262** | 3.124** | 0.662** | 0.526** | 0.414** |
| Error | 27 | 0.305 | 0.393 | 4.721 | 6.468 | 0.065 | 0.109 | 0.118 | 0.047 | 0.160 | 0.104 | 0.066 | 0.048 |

# APPENDIX -XXXI

**Analysis of variance for ratio of grain : pod husk in lowermost, middle and uppermost cluster, and seed and straw yields (q/ha)**

| source of variation | d.f. | MSS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ratio of grain : Pod husk in | | | | | | Seed yield (q/ha) | | Straw yield (q/ha) | |
| | | Lowermost cluster | | Middle cluster | | Uppermost cluster | | | | | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.0332 | 0.051 | 0.0435 | 0.013 | 0.276 | 0.066 | 3.698 | 0.244 | 20.580 | 0.376 |
| Treatments | 9 | 0.0812** | 0.094** | 0.0293 | 0.047* | 10.019** | 0.902** | 37.346** | 8.153** | 56.168** | 2.815 |
| Error | 27 | 0.0148 | 0.016 | 0.018 | 0.018 | 0.441 | 0.226 | 2.150 | 1.706 | 8.404 | 6.519 |

# APPENDIX -XXXII

**Analysis of variance for biological yield (q/ha), harvest index (%), N content of leaves at 75 DAS and S content of leaves at 75 DAS**

| source of variation | d.f. | MSS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Biological yield (q/ha) | | Harvest index (%) | | N content (%) of leaves at 75 DAS | | S content (%) of leaves at 75 DAS | |
| | | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 41.254 | 10.013 | 0.365 | 0.233 | 0.0011 | 0.0032 | 0.00004 | 0.00013 |
| Treatments | 9 | 179.811** | 14.414 | 14.425** | 7.712** | 0.0117 | 0.0013 | 0.00004 | 0.00001 |
| Error | 27 | 18.327 | 20.673 | 0.434 | 1.301 | 0.0056 | 0.0060 | 0.00011 | 0.00017 |

## APPENDIX -XXXIII

**Analysis of variance of (pooled data) for total dry matter accumulation/plant at 75, 90 DAS and physiological maturity, and dry matter distribution (%) in leaves, stems and pods at 75, 90 DAS and physiological maturity**

| source of variation | d.f. | MSS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total dry matter accumulation /plant | | | Dry matter distribution at 75 DAS | | | Dry matter distribution at 90 DAS | | | Dry matter distribution at physiological maturity | | |
| | | At 75 DAS | At 90 DAS | At physiological maturity | Leaves | Stems | Pods | Leaves | Stems | Pods | Leaves | Stems | Pods |
| Year | 1 | 0.279 | 2.663 | 6.763* | 22.008** | 0.126 | 18.764* | 4.768 | 34.337** | 13.508 | 13.203** | 13.928 | 0.018 |
| Replication | 6 | 1.982 | 2.131 | 1.755 | 2.037 | 0.367 | 1.902 | 9.236** | 4.591 | 16.146** | 0.322 | 12.846 | 13.055 |
| Treatment | 9 | 11.661** | 9.618** | 46.167** | 4.371** | 21.970** | 7.318** | 6.635** | 7.269 | 22.290** | 25.517** | 26.809** | 6.179 |
| Year x Treat | 9 | 0.555 | 0.631 | 0.959 | 2.535 | 2.038 | 0.738 | 0.293 | 1.243 | 0.626 | 2.077** | 2.336 | 1.340 |
| Error | 54 | 0.695 | 1.178 | 1.406 | 1.809 | 1.492 | 1.761 | 1.672 | 4.009 | 4.603 | 0.661 | 5.242 | 5.112 |

## APPENDIX -XXXIV

**Analysis of variance of (pooled data) for number of branches/plant, number of cluster/plant, number of green leaves/plant, number of poorly filled pods/plant, number of unfilled pods/plant, number of pods/plant, pod length, number of seeds/pod, test weight and seed yield/plant**

| source of variation | d.f. | MSS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. branches /plant | No. clusters /plant | No. of green leaves /plant | No. of poorly filled pods /plant | No. unfilled pods /plant | No. of pods /plant | Pod length (cm) | No. of seeds /plant | Test weight (g) | Seed yield /plant (g) |
| Year | 1 | 0.968 | 1.596 | 482.16 | 0.025 | 0.648 | 12.736 | 0.030 | 0.200 | 0.010 | 29.427** |
| Replication | 6 | 0.509 | 0.994 | 5.871 | 0.116 | 0.272 | 29.628 | 0.044 | 0.109 | 0.604 | 0.118 |
| Treatment | 9 | 1.604** | 29.107** | 954.95** | 6.835** | 18.012** | 392.362** | 0.446** | 1.319** | 6.764** | 4.808** |
| Year x Treat | 9 | 0.502 | 1.997 | 111.150** | 0.280 | 2.767** | 82.204** | 0.085* | 0.073 | 0.087 | 0.857** |
| Error | 54 | 0.537 | 1.074 | 17.582 | 0.052 | 0.219 | 12.854 | 0.034 | 0.136 | 0.576 | 0.233 |

## APPENDIX –XXXV

**Analysis of variance of (pooled data) for dry matter accumulation in pods in lowermost, middle and uppermost cluster, and dry matter distribution (%) in pods in lowermost, middle and uppermost cluster, and number of pods in lowermost, middle and uppermost cluster**

| source of variation | d.f. | MSS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Dry matter accumulation (g) in pods in | | | Dry matter distribution in pods in | | | Number of pods in | | |
| | | Lowermost cluster | Middle cluster | Uppermost cluster | Lowermost cluster | Middle cluster | Uppermost cluster | Lowermost cluster | Middle cluster | Uppermost cluster |
| Year | 1 | 0.011 | 0.123 | 0.001 | 0.089 | 3.587 | 0.315 | 0.013 | 0.113 | 0.648* |
| Replication | 6 | 0.002 | 0.026 | 0.007 | 0.824* | 3.176 | 0.255 | 0.125 | 0.153 | 0.045 |
| Treatment | 9 | 0.035** | 0.499** | 0.119** | 0.208 | 7.064 | 0.405** | 0.418** | 3.007** | 0.879** |
| Year x Treat | 9 | 0.002 | 0.522 | 0.008 | 0.104 | 2.158 | 0.089 | 0.037 | 0.779 | 0.062 |
| Error | 54 | 0.003 | 0.039 | 0.006 | 0.349 | 5.594 | 0.104 | 0.083 | 0.132 | 0.057 |

## APPENDIX –XXXVI

**Analysis of variance of (pooled data) for ratio of grain : husk in lowermost, middle and uppermost cluster, and seed, straw and biological yields (q/ha), and harvest index, N and S content (%) of leaves at 75 DAS**

| source of variation | d.f. | MSS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ratio of grain : pod husk in | | | Seed yield (q/ha) | Straw yield (q/ha) | Biological yield (q/ha) | Harvest index (%) | N content of leaves at 75 DAS | S content of leaves at 75 DAS |
| | | Lowermost cluster | Middle cluster | Uppermost cluster | | | | | | |
| Year | 1 | 0.019 | 0.038 | 0.207** | 225.79** | 546.580** | 1602.85** | 30.037** | 0.112 | 0.00039 |
| Replication | 6 | 0.042 | 0.028 | 0.001 | 2.112 | 10.470 | 25.63 | 0.299 | 0.0022 | 0.00009 |
| Treatment | 9 | 0.174** | 0.068** | 0.062** | 38.515** | 35.089** | 192.94** | 20.550* | 0.0065 | 0.00005 |
| Year x Treat | 9 | 0.002 | 0.004 | 0.047 | 6.984** | 23.890** | 65.59** | 1.580* | 0.0065 | 0.00003 |
| Error | 54 | 0.015 | 0.019 | 0.003 | 1.928 | 7.461 | 19.50 | 0.867 | 0.0058 | 0.000139 |

## Appendix XXXVII

Cost of cultivation of treatments (Rs/ha)

| SN | Treatment combinations | 1999 | 2000 |
|---|---|---|---|
| 1 | No phosphorus + control | 9089 | 10625 |
| 2 | No phosphorus + 5 kg thiourea/ha in soil (basal) | 11379 | 12995 |
| 3 | No phosphorus + 5 kg thiourea/ha in soil ($^1/_2$+$^1/_2$) | 11599 | 13295 |
| 4 | No phosphorus + 2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | 10781 | 12477 |
| 5 | No phosphorus + 5 kg thiourea/ha+2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | 12851 | 14547 |
| 6 | No phosphorus + 500 ppm thiourea foliar spray | 9945 | 11641 |
| 7 | No phosphorus + 100 ppm DMSO foliar spray | 9728 | 11424 |
| 8 | No phosphorus + 500 ppm thiourea + 100 ppm DMSO foliar spray | 10039 | 11735 |
| 9 | 20 kg $P_2O_5$/ha + control | 9407 | 10943 |
| 10 | 20 kg $P_2O_5$/ha + 5 kg thiourea/ha in soil (basal) | 11697 | 13313 |
| 11 | 20 kg $P_2O_5$/ha + 5 kg thiourea/ha in soil ($^1/_2$+$^1/_2$) | 11917 | 13613 |
| 12 | 20 kg $P_2O_5$/ha + 2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | 11099 | 12795 |
| 13 | 20 kg $P_2O_5$/ha +5 kg thiourea/ha+2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | 13169 | 14865 |
| 14 | 20 kg $P_2O_5$/ha + 500 ppm thiourea foliar spray | 10263 | 11959 |
| 15 | 20 kg $P_2O_5$/ha + 100 ppm DMSO foliar spray | 10046 | 11742 |
| 16 | 20 kg $P_2O_5$/ha + 500 ppm thiourea + 100 ppm DMSO foliar spray | 10357 | 12053 |
| 17 | 40 kg $P_2O_5$/ha + control | 9725 | 11261 |
| 18 | 40 kg $P_2O_5$/ha + 5 kg thiourea/ha in soil (basal) | 12015 | 13631 |
| 19 | 40 kg $P_2O_5$/ha + 5 kg thiourea/ha in soil ($^1/_2$+$^1/_2$) | 12235 | 13931 |
| 20 | 40 kg $P_2O_5$/ha + 2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | 11417 | 13113 |
| 21 | 40 kg $P_2O_5$/ha +5 kg thiourea/ha+2 kg DMSO/ha in soil ($^1/_2$+$^1/_2$) | 13487 | 15183 |
| 22 | 40 kg $P_2O_5$/ha + 500 ppm thiourea foliar spray | 10581 | 12277 |
| 23 | 40 kg $P_2O_5$/ha + 100 ppm DMSO foliar spray | 10364 | 12060 |
| 24 | 40 kg $P_2O_5$/ha + 500 ppm thiourea + 100 ppm DMSO foliar spray | 10675 | 12371 |

### Cost of inputs

| | 1999 | 2000 |
|---|---|---|
| Cost of $P_2O_5$ | 17.50 Rs/kg | 17.50 Rs/kg |
| Cost of N | 4.10 Rs/ha | 4.10 Rs/ha |
| Cost of thiourea | 207 Rs/500 g | 207 Rs/500 g |
| Cost of DMSO | 313 Rs/500 ml | 313 Rs/500 ml |
| Cost of labolene(sticking agent) | 168 Rs/ lit | 168 Rs/ lit |
| Cost of guar grain | 2150 Rs/ha | 1100 Rs/ha |
| Price of straw | 50 Rs/q | 50 Rs/q |
| Labour cost | 44 Rs/day | 60 Rs/day |

# APPENDIX –XXXVIII

**Analysis of variance for gum yield (q/ha) and net returns (Rs./ha) based on gum yield**

| source of variation | d.f. | MSS | | | |
|---|---|---|---|---|---|
| | | Gum yield (q/ha) | | Net returns (Rs./ha) on gum yield basis | |
| | | 1999 | 2000 | 1999 | 2000 |
| Replication | 3 | 0.185 | 0.206 | 5780990 | 2767154 |
| Phosphorus (P) | 2 | 12.37** | 42.558** | $4.72 \times 10^{8}$** | $4.83 \times 10^{8}$** |
| Chemicals (C) | 7 | 2.009** | 1.125** | 97597714* | 33428286** |
| P x C | 14 | 0.45 | 0.132 | 1927277 | 1859081 |
| Error | 69 | 0.268 | 0.198 | 11455445 | 2616153 |

**Analysis of variance (pooled data) for gum yield (q/ha) and net returns (Rs./ha) based on gum yield**

| source of variation | d.f. | MSS | |
|---|---|---|---|
| | | Gum yield | Net returns on gum yield based |
| Year (Y) | 1 | 0.820* | 38693696* |
| Replication | 6 | 0.195 | 4274072 |
| Phosphorus | 2 | 50.257** | $4.99 \times 10^{8}$** |
| Chemical | 7 | 2.954** | 66552134** |
| P x C | 14 | 0.571* | 19473881* |
| P x Y | 2 | 0.242 | 10201908 |
| C x Y | 7 | 0.321 | 7739378 |
| P x C x Y | 14 | 0.124 | 8654032 |
| Error | 138 | 0.234 | 7035795 |