Effect of Phosphorus Nutrition and Agrochemicals on the Productivity of Soybean [*Glycine max* (L.) Merrill]

फॉस्फोरस पोषण एवं कृषिरसायनों का सोयाबीन [*ग्लाइसिन मेक्स* (एल.) मेरिल] की उत्पादकता पर प्रभाव

Thesis
Submitted to the
Maharana Pratap University of Agriculture and Technology, Udaipur
in partial fulfillment of the requirement for the degree of
Doctor of Philosophy in Agriculture
(Agronomy)

By

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2006

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This is to certify that the thesis entitled "**Effect of phosphorus nutrition and agrochemicals on the productivity of soybean [*Glycine max* (L.) Merrill]**" submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Agronomy**, embodies bonafide research work carried out by **Mr. Yogesh Kanojia** 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 have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 5/09/06.

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Date : 28/12/06

Place : Udaipur

(YOGESH KANOJIA)

ACRONYMS

%	Per cent	m	Metre
/	Per	M	Mole
@	At the rate of	m eq	Milli equivalant
'r'	Correlation coefficient	Max.	Maximum
$^{-1}$	per	Mg	Magnesium
ATP	Adenosine triphosphate	Mg m^{-3}	Mega gramme per cubic metre
B:C	Benefit cost ratio	Mha	Million hectare
BA	Benzyladenine	Min.	Minimum
BAP	Benzylaminopurine	mm	Millimetre
Br	Brassinolide	mM	Milli mole
Ca	Calcium	mRNA	Messenger Ribonucleic acid
CD	Critical difference	MS	Mean square
CEC	Cation exchange capacity	N/N_2	Nitrogen
CGR	Crop growth rate	NAA	Naphthalene acetic acid
cm	Centimetre	NaCl	Sodium chloride
Cmol/kg	Centimol per kilogram	NAR	Net assimilation rate
CO_2	Carbon dioxide	NR	Nitrate reductase
cv.	Cultivar	NS	Not significant
d.f.	Degree of freedom	°C	Degree celsius
DAP	Di-ammonium phosphate	°E	Degree East
DAS	Days after sowing	°N	Degree North
DAT	Days after transplanting	P/P_2O_5	Phosphorus/phosphate
DMA	Dry matter accumulation	pH	Negative log of H^+ ion activity
DNA	Deoxyribonucleic acid	ppm	Parts per million
dSm^{-1}	deci Simon per metre	PR (18/150)	Low grade rock phosphate
EC	Electrical conductivity	PR (34/74)	High grade rock phosphate
et al.	(*et alibi*) or and others	PROM	Phosphate Rich Organic Manure
etc.	Etcetra	PSB	Phosphorus solubilizing bacteria
Fig.	Figure	q	Quintal
FYM	Farm yard manure	R.H.	Relative humidity
g	Gramme	RGR	Relative growth rate
GA	Gibberalic acid	RNA	Ribonucleic acid
H_2CO_3	Bicarbonate	RP	Rock phosphate
ha	Hectare	Rs.	Rupees
HI	Harvest index	RWC	Relative water content
hr	Hour	SEm ±	Standard error of mean
i.e.	that is	SSP	Single super phosphate
K/K_2O	Potassium/potash	t	Tonnes
KCl	Potassium chloride	var.	Variety
kg	Kilogram	*viz.*	(Videlicet) Namely
LAI	Leaf area index		

1. INTRODUCTION

India occupies premier position in global oilseed scenario, accounting for about 19 per cent of area and 9 per cent production. Oilseeds are rich source of energy and nutrition. Edible oils and oil meals play an important role in preventing malnutrition and fulfill caloric requirement of human beings.

Among oil seeds, soybean is one of the important crop of India. It has also been termed as miracle bean because it contains about 40 per cent protein well balanced in essential amino acids, 20 per cent oil rich in poly unsaturated fatty acids, specially omega 6 and omega 3 fatty acids, 6-7 per cent total minerals, 5-6 per cent crude fibre and 17-19 per cent carbohydrates. Besides, it has good amount of iron, vitamin B-complex and isoflavones such as daidzein, genistein and glycitn (Chauhan and Joshi, 2005). It is also used for preparation of soyamilk, antibiotics, cattle and poultry feed, improves soil fertility etc. Presently, the national average yield of soybean is 1210 kg ha^{-1} (Hegde, 2006) and Rajasthan is 1400 kg ha^{-1} (Govt. of Rajasthan, 2006), which is much below than the realizable yield of 30-35 q ha^{-1}. This suggests a tremendous scope to increase the productivity of this crop and a need to work out sustained and location specific production technology, which can help to increase its production.

Now, to increase agricultural production from land of fixed area, attempts should be made to increase nutrition in correct amount and also in correct form, which is readily available to the crop plants. It is beyond doubt that higher yield potential can't be achieved without adequate fertilization. After nitrogen, phosphorus is considered to be the most important nutrient in the crop production. Phosphorus is one of the limiting plant nutrients, affecting soybean productivity (Wadokar *et al.*, 1996). Soybean is well responsive to phosphorus application and takes up in higher amounts. Phosphorus performs a vital role in the life cycle of plant and is an important constituent of genetic material (Khasawneh *et al.*, 1986). It is also known to control photosynthesis, breakdown of carbohydrates and transfer of energy through metabolic transformations. It stimulates proper seed filling and setting (Tisdale *et al.*, 1995). Phosphorus is an important constituent of major biochemical products in plant itself and plays key role in balanced nutrition of crop. Phosphorus is also involved in better root growth, enzymatic and biochemical reactions and also in N-metabolism (Tisdale *et al.*, 1995). It's adequate supply improves oil content of soybean (Vara *et al.*, 1994 and Jat and Nepalia, 1995). Therefore, phosphorus is of prime importance in formation and translocation of carbohydrates, fatty acids, glyceroids and other essential intermediate compounds.

With the intensification of agriculture owing to population pressure, there has been a large increase in the fertilizer use during last 2-3 decades to achieve higher productivity of crops. However, self reliance in the fertilizer production has not yet been achieved in the country and still considerable foreign exchange goes for import of needed material for fertilizer manufacture. This has lead to rapid escalation in the cost of conventional fertilizers particularly phosphatic fertilizers like DAP, SSP and nitrophosphates that has restricted their use by sizable poor farming community. This has made imperative to solubilize the "Interlocked P" for plant availability.

The use of indigenous rock phosphate has thereby, become imperative to save precious foreign exchange. With the development of technology for production of phosphorus rich organic manure (PROM) and various composts, the scope for use of indigenous rock phosphate has increased by many folds and has made cheap, eco-friendly and equally effective as water soluble sources of phosphorus, irrespective of soil types (Prasad and Biswas, 2000). India has a huge deposites of rock phosphate. The total phosphate rock deposites in India are estimated to be about 260 mt, of which only 15.27 mt can be rated suitable for production of conventional phosphatic fertilizers (Narayanasamy and Biswas, 1998). The remaining can be directly used in acidic soils (Marwaha, 1992). However, research has shown that with certain amendments finely ground rock phosphates can be used in neutral to alkaline soils also. Some successful proportions among them are mixing rock phosphates with SSP, organic manures and use of phosphate solublizing microorganisms (Johnston, 1952; Gaur, 1990 and Gopalakrishnan and Palaniappan, 1992). The various grades of phosphate rocks may be manipulated with variety of organic and inorganic acid producing materials to make it "Partially acidulated" in order to solubilize the "Interlocked P" for plant availability. The acid producing solubilizers are found very effective and economic in high phosphorus fixing calcareous soils (Hagin and Katz, 1985) because it contains both, slow release citrate soluble as well as fast release water soluble forms of phosphorus (Trivedi, 1993). Further leguminous crops are considered better feeders of rock phosphates (Narayansamy and Biswas, 1998).

In modern agriculture, production practices mostly emphasized the wide spread use of chemical fertilizers for realizing higher production but at the same time evidences reveal deterioration in soil productivity and ecological degradation with their continuous and non-judicious use. The role of soil organic matter e.g., FYM in maintaining soil fertility and productivity is well recognized. It increases soil microbial activities, plays key role in transformation, recycling and availability of nutrients to the crop (Tisdale *et al.*, 1995). It also improves the physical properties of soil like structure, reduces compaction and crusting of soil and increases water holding capacity of the soil. The availability of micronutrients from native sources also increases due to incorporation of organic matter might be due to release of organic acids. FYM exhibits a potent role in solubilization, transformation and availability of nutrients particularly phosphorus in soil (Sinha *et al.*, 1981) and increases phosphorus use efficiency to the extent of 48 to 64 per cent (Patiram, 1994).

The importance of micro-organisms in soil nutrients cycling and their role in plant nutrition has been realized for a long time. Phosphate solubilizing bacteria (PSB) *viz*., *Bacillus megatherium* is known for inducing solubilizing effect on rock phosphates and thereby releasing available phosphorus (Yadav and Singh, 1991). Aforesaid positive impact of organic matter and ever increasing cost of chemical fertilizers coupled with their limited availability, organic fertilization through locally available source is again regaining importance in crop production and for maintenance of soil productivity on sustainable basis. Thus, combined use of rock phosphate, organic manure and PSB is of special significance under crop production.

In recent years, on account of ecological imbalances in Rajasthan particularly in Udaipur region, the total annual precipitation has been drastically reduced. In comparison to annual rainfall of 624 mm in the region, the rainfall during last 6-7 years remained around 400 mm. This is causing serious threat to agricultural production system of the region during round the year. Hence, to sustain production system under such environmental conditions, calls for development of appropriate technologies for promoting the productivity of crops.

It has been recognized that some agrochemicals play an important role in the growth, development and productivity of crops under normal as well as stressed environmental agro-ecosystem. Their exogenous application in different crops revealed that they help in improving photosynthetic activity and photosynthates assimilation, modify various metabolic and physiological processes in plants and develop economic source-sink relationship. Application of agrochemical is also known to increase flowering, fruit setting, grain filling and test weight in different crops (Pandey, 1975 and Reddy, 1979).

Among agrochemicals, brassinolide comprising a complex mixture of lipids purified from pollens of rape (*Brassica napus* L.) has been found promising. Brassinolide is attributed due to its role in stimulating cell division, elongation by enhancing carbohydrate activity in stem and leaves. Besides this, its application also helps to over-come environmental stresses, thereby improving stress tolerance and disease resistance (Takemastu *et al.*, 1983). In many crops, brassinolide enhances the growth under varied environmental conditions (Mandava, 1988).

The effects of the application of benzyladenine indicated that it was antagonistic to moisture stress (Virk *et al.*, 1985). Although low concentration of benzyladenine (4×10^{-5} M) accelerated the senescence of cut cornation flowers, higher concentration ($1\text{-}2 \times 10^{-4}$ M) retarded senescence, thus increasing flower longevity (Van Staden and Joughim, 1988). In plants, potassium chloride also has been linked to a variety of physiological processes. Potassium ion (K^+) plays significant role in plants, since it governs an important role in osmoregulation. There appears to be a good correlation between K^+ content of guard cells and stomatal aperture. Potassium has a general role in the regulation of water in plant cells. Under water stressed conditions potassium being absorbed selectively by preventing the plants from losing water (Mukherji and Ghosh, 1996).

In the light of premises cited above and the paucity of findings on these aspects, a field experiment entitled "Effect of Phosphorus Nutrition and Agrochemicals on the Productivity of Soybean [*Glycine max* (L.) Merrill]" was planned to conduct during *kharif* seasons of 2003 and 2004 at the Instructional Farm, Rajasthan College of Agriculture, Udaipur with the following objectives:

1. To study the effect of phosphorus nutrition on growth, yield and quality of soybean.
2. To evaluate suitability of phosphorus carriers for soybean.
3. To select most suitable agrochemical to enhance soybean productivity and its quality.
4. To select economically viable treatment combination.

2. REVIEW OF LITERATURE

A brief review pertaining to research findings on the effect of phosphorus sources, its levels and agrochemicals on different aspects of growth and development, yield attributes and yield, quality parameters, nutrient content and uptake by soybean are presented in this chapter. Since, the work done in alkaline calcareous soils on the studied aspects in soybean crop is meager, wherever deemed necessary findings on other crops are also included.

2.1 EFFECT OF PHOSPHORUS SOURCES

2.1.1 Effect of DAP

2.1.1.1 Growth parameters

At Akola, Anokar *et al.* (1995) conducted a field experiment and observed that phosphorus application through DAP proved significantly superior in increasing plant height of soybean over control. It was also found significantly superior with regards to dry matter production. Similarly, Nagaraju and Yadahalli (1996) at Karnataka conducted a trial and found that application of phosphorus through DAP registered higher plant height (43.07 cm) of cowpea as compared to SSP (42.95 cm). In an another study in M.P., Singh *et al.* (1999) reported that phosphorus nutrition through DAP significantly increased the LAI at 30 and 60 DAS and dry matter production of soybean at harvest as compared to control. The increase in these parameters was found upto 40.41, 106.21 and 35.50 per cent, respectively over control. This treatment also significantly increased number of roots per plant, length of roots (cm), number of nodules per plant, fresh weight of nodules and dry weight of nodules per plant over untreated control. Likewise, at Bapatla, Kavitha and Veeraraghavaiah (2001) conducted a field experiment and found that recommended dose of phosphorus through DAP significantly increased dry matter accumulation of soybean at 25 and 50 DAS. This treatment was also found superior in increasing nodule dry weight per plant at 75 DAS and at maturity, when compared with the controlled plots. Similarly at Udaipur, Soni and Aery (2001) found that by applying DAP, there was a significant enhancement in shoot length and dry weight of cowpea. The treatment showed 64.51 and 69.67 per cent enhancement over control (15.39 cm and 0.652 g, respectively). In an another experiment at Udaipur, Ameta (2002) reported that application of DAP significantly increased the plant height, primary & secondary branches and dry matter accumulation of soybean as compared to control. While Meena (2003) conducted a two years field trial and observed that pegionpea fertilized with DAP registered significantly higher dry matter accumulation as compared to control and remained at par with RP (34/74) + FYM (1:3) + ES (25 kg ha^{-1}). At Udaipur in another study, Meena (2005) reported that application of DAP to soybean registered significantly higher plant height, number of primary and secondary branches and dry matter accumulation at 30 and 60 DAS and at harvest over control and PR (34/74) alone.

2.1.1.2 Yield attributes and yield

Singh *et al.* (1993) at ARS, Durgapura reported that basal application of DAP significantly increased pod yield of groundnut over control (16.33 q ha^{-1}). The increment in pod yield was found upto 48.98 per cent over control. At Indore, Jain and Kushwaha (1993) conducted a two years field trial and revealed that P_2O_5 through DAP registered higher number of pods $plant^{-1}$, pod weight $plant^{-1}$, seed weight $plant^{-1}$ and test weight of soybean as compared to SSP. It was also found superior over SSP in increasing seed, straw and biological yield. Similarly, Singh *et al.* (1994) at RCA, Udaipur conducted a two years successive trial and revealed that application of phosphorus through DAP significantly increased the number of pods $plant^{-1}$, pod weight, kernal pod^{-1} and seed index of groundnut over control during both the years. However, the number of unfilled pods $plant^{-1}$ was significantly reduced upto 8.86 and 10.45 per cent during both the years. The pod yield was also increased significantly by 18.61 and 17.51 per cent over control during both the successive years. In another study, Anokar *et al.* (1995) at Akola concluded that in DAP applied plots all the yield attributing characters *viz.*, number of pods plant (68.9), seeds $pods^{-1}$ (2.3), grain yield $plant^{-1}$ (21.0 g) and test weight (129.5 g) were significantly higher over control (53.7, 1.9, 12.8 and 12.5 g, respectively). Thus, the seed and stover yield of soybean in these plots were also increased by 29.0 and 6.0 per cent over control (17.62 & 21.63 q ha^{-1}, respectively). At Hyderabad, Reddy and Surekha (1996) conducted an experiment and observed that phosphorus applied through DAP produced significantly higher pod and haulm yield of groundnut as compared to control. The pod yield through this source was increased by 18.51 per cent over control (16.43 q ha^{-1}).

At Nagpur, it was reported that in soybean DAP application for phosphorus nutrition significantly increased seed and stover yield over control. The magnitude of increment in both yields was found upto 51.59 and 26.50 per cent, respectively over control (Chafle *et al.*, 1999). Likewise, Menaria (2001) at Udaipur reported that in soybean phosphorus fertilization through DAP significantly increased number of pods plant^{-1}, seeds pod^{-1}, seed index and seed yield plant^{-1} as compared to control. This treatment, thus finally increased seed, stover and biological yield significantly by 37.35, 29.74 and 29.48 per cent, when compared with control (14.99, 18.09 and 33.07 q ha^{-1}, respectively). Same results were also shown by Kavitha and Veeraraghavaiah (2001) in soybean crop. They found significant increase in pods plant^{-1} (23.1) and seed yield (1097 kg ha^{-1}) as compared to absolute control (20.1 & 988 kg ha^{-1}, respectively). Similarly, Sharma *et al.* (2001) at RCA, Udaipur applied DAP to soybean and found that seed, straw and biological yields were significantly increased by 31.38, 36.73 & 11.89 per cent, when compared with control (11.47, 22.73 and 34.21 q ha^{-1}, respectively). While at Udaipur, Meena (2003) conducted two years trial and observed that application of DAP to pigeon pea recorded significantly higher number of pods plant^{-1}, number of seeds pod^{-1}, seed weight pod^{-1} and seed yield plant^{-1} over control and RP (18/150) + FYM (1:3) + PSB (2 kg ha^{-1}). Further he also reported that seed, stover and biological yields were also increased significantly through DAP. The magnitude of increase in these yields was 54.63, 40.23 and 43.37 per cent, respectively over control. Likewise Meena (2005) reported that application of DAP to soybean registered significantly higher yield attributes viz., number of pods plant^{-1}, number of seeds pod^{-1}, seed index and seed yield plant^{-1} as compared to absolute control as well as PR (34/74) alone, PR (34/74) + mahua cake, PR (34/74) + castor cake and PR (34/74) + karanj cake. The increase in seed, stover and biological yields through DAP was 67.61, 58.75 and 63.12 per cent, respectively over control.

2.1.1.3 Nutrient content and uptake

Ankoar *et al.* (1995) at Akola, found that phosphorus nutrition through DAP significantly increased total P uptake by soybean as compared to control. Total phosphorus uptake was found 41.34 per cent higher as compared to control (8.49 kg ha^{-1}). Chafle *et al.* (1999) observed that application of phosphorus through DAP significantly increased total N, P and K uptake by soybean over control. Similarly phosphorus through DAP to the soybean crop significantly increased the phosphorus uptake at 25, 50 and 75 DAS by 50.0, 52.3 and 41.23 per cent, as compared to control (Kavitha and Veeraraghavaiah, 2001). Masih *et al.* (2001) at ARS, Durgapura found that application of DAP to the groundnut was superior than direct application of PR (34/74) in increasing N & P content of groundnut pod. In an another study, Menaria (2001) at Udaipur reported that DAP significantly improved N and P content of soybean seed and stover over that of no fertilization. The N content in seed and straw was increased by 9.04 and 19.70 per cent, respectively and P content in seed and straw also increased by 15.58 and 19.89 per cent, respectively over control. Meena (2003) at Udaipur reported that P fertilization through DAP significantly increased N and P content and uptake by pigeon pea over control and found at par with RP (34/74) + FYM (1:3) + ES (25 kg ha^{-1}). Likewise Meena (2005) conducted a trial and reported that application of DAP to soybean registered significantly higher N&P content and uptake by seed and stover as compared to control, PR (34/74) alone, PR (34/74) + mahua cake, PR (34/74) + castor cake and PR (34/74) + karanj cake.

2.1.1.4 Quality parameters

At ARS, Durgapura, Singh *et al.* (1993) conducted an experiment and reported that basal application of phosphorus through DAP significantly increased oil and protein content of groundnut kernels over no fertilization (control). They further reported that on the pooled basis, oil and protein content was increased upto 4.06 & 8.96 per cent, respectively over control. Similarly, at Nagpur, Chafle *et al.* (1999) reported that application of DAP as a source of phosphorus was found significantly superior over control with 7.46 and 8.99 per cent increase in protein and oil content of soybean, respectively over control. Ameta (2002) conducted an experiment at Udaipur and reported that phosphorus application through DAP registered significantly higher oil and protein content of soybean and their yields over absolute control. It was also found significantly superior in increasing oil content and yield over PROM. Likewise, Meena (2003) conducted a two years field experiment and concluded that phosphorus fertilization through DAP registered significantly higher protein content and yield of pigeon pea over absolute control as well as PR (34/74) + FYM (1:3) during both the years of experiment. In an another study, Meena (2005) at Udaipur reported that DAP significantly improved oil and protein content of soybean seed over that of no fertilization, PR (34/74) alone, PR (34/74) + mahua cake, PR (34/74) + castor cake and PR (34/74) + karanj cake and remained at par with PR (34/74) + mahua cake + 4 t FYM ha^{-1}. The oil and protein content and yield was increased by 51.40 & 11.21 and 153.74 & 88.45 per cent, respectively.

2.1.2 Effect of PROM

2.1.2.1 Growth parameters

At Bhavanisagar, Ramamoorthy and Arokiaraj (1997) reported that application of MRP + phosphobacteria to greengram significantly increased plant height (9.1 cm), nodules plant^{-1} (27.4) and dry matter production at 25 DAS (1220 kg ha^{-1}) as compared to control (6.9 cm, 5.1 & 282 kg ha^{-1}, respectively). Similarly, Kulkarni *et al.* (2000) at Dharwad carried out an investigation and revealed that application of Mussoorie rock phosphate (MRP) + FYM + PSB proved significantly superior over control with respect to dry matter production and number & weight of nodules plant^{-1} at 30 & 60 DAS. In an another study, at Udaipur in 2001, Soni and Aery found that PR (34/74) + FYM + PSB combination showed significant positive results in cowpea. This treatment significantly increased shoot length and shoot dry weight per plant by 69.23 and 53.13 per cent over control (15.39 cm and 0.6523 g, respectively). They also concluded that this treatment was found to be even superior over DAP. From IISS, Bhopal, Singh (2002) reported that phosphocompost application in soybean crop significantly increased nodules plant^{-1}, nodule dry weight and shoot dry weight over control. Similar observations were also reported by Soni and Aery (2002) as they concluded that PR (34/74) along with FYM and PSB showed significant enhancement in shoot and root dry weight of cowpea over control. Likewise, at IARI, New Delhi, Shivakumar *et al.* (2004) conducted an experiment and reported that Gafsa rock phosphate (GRP) applied to chick pea significantly increased plant height and number of branches plant^{-1} over SSP. While Meena (2005) conducted an experiment and reported that application of PR (34/74) + castor cake + 4 t FYM ha^{-1} significantly increased plant height, number of primary & secondary branches, dry matter at 30, 60 DAS and at harvest over control and PR (34/74) alone and found at par with DAP.

2.1.2.2 Yield attributes and yield

Paularaj and Velayudham (1995) at TNAU, Coimbatore conducted a field experiment and reported that MRP + FYM + PSB produced significantly higher grain and straw yield of rice. The effect of this treatment was also pronounced on the yield of succeeding black gram. While conducting a two years experiment at Bhawanisagar, Ramamoorthy and Arokiaraj (1997) reported that application of phosphorus through Mussoorie rock phosphate + phosphobacteria significantly increased number of pods plant^{-1}, pod length and seeds pod^{-1} of greengram as compared to untreated control. The increments in these parameters were found by 323.36, 50.90 and 95.23 per cent, respectively over control.

At Dharwad, Kulkarni *et al.* (2000) revealed that combination of MRP+FYM+PSB showed significantly positive results in chick pea. This treatment significantly increased the number of pods plant^{-1} by 95.60 per cent over control (21.40). This treatment was also found to increase seed and straw yield significantly by 14.00 & 23.01 per cent as compared to control (13.57 and 17.60 q ha^{-1}, respectively). In an another study, Malewar *et al.* (2000) at Parbhani concluded on pooled basis that phosphorus application through MRP + FYM to the cotton significantly increased the dry matter yield and seed cotton yield as compared to DAP. Shaktawat and Sharma (2001), at Udaipur, reported that PR (34/74) + FYM + PSB, significantly increased seed, straw and biological yields of soybean as compared to absolute control. The increment in these yields was 60.79, 66.76 and 64.68 per cent over control (7.27, 13.57 and 22.14 q ha^{-1}, respectively). Similarly, Masih *et al.* (2001) at ARS, Durgapura concluded that the composted high grade rock phosphate with PSB increased the pod yield of groundnut significantly over direct use of rock phosphate. In an another experiment, Sharma *et al.* (2002) found that PROM + PSB + rest N, K produced significantly higher seed, straw and biological yields of soybean by 30.77, 35.89 & 31.11 per cent as compared to absolute control (11.47, 22.73 & 34.21 q ha^{-1}, respectively). Ameta (2002) found that PROM + PSB + *Azotobacter* significantly increased pods plant^{-1}, seeds pod^{-1}, test weight and finally seed, straw and biological yields of soybean over control. Likewise, Meena (2005) at Udaipur reported that application of PR (34/74) + castor cake + 4 t FYM ha^{-1} to soybean registered significantly higher number of pods plant^{-1}, number of seeds pod^{-1}, seed index and seed yield plant^{-1} over control, PR (34/74) alone, PR (34/74) + mahua cake, PR (34/74) + castor cake, PR (34/74) + karanj cake, PR (34/74) + mahua cake + 2t FYM ha^{-1}, PR (34/74) + castor cake + 2t FYM ha^{-1} and PR (34/74) + karanj cake + 2t FYM ha^{-1}. He further reported that this treatment increase seed, stover and biological yields by 67.40, 60.57 and 62.85 per cent, respectively over control.

2.1.2.3 Nutrient content and uptake

Shaktawat and Sharma (2001) at Udaipur conducted an experiment on soybean and reported that application of PR (34/74) alongwith FYM recorded significantly higher total N and P uptake over control. However, it was found at par with SSP. In an another experiment, Kavitha and Veeraraghavaiah (2001) at Baptala observed that application of PR (34/74) along with 5 t FYM ha^{-1} recorded the highest P uptake at 25 DAS and found significantly superior over control. Similarly, Ameta (2002) at Udaipur found that 75 kg P_2O_5 ha^{-1} through PR (34/74) + FYM + PSB + *Azotobacter* significantly increased N, P & K content and uptake by soybean seed and stover over control. Likewise, Shivakumar *et al.* (2004) at IARI, New Delhi conducted a two years trial and concluded that application of phosphorus through Gafsa rock phosphate (GRP) significantly increased the P uptake of chickpea over control. Similarly, Meena (2005) at Udaipur reported that application of PR (34/74) + FYM (1:3) + castor cake + 4 t FYM ha^{-1} to soybean registered significantly higher oil and protein content and their yield over control, PR (34/74) alone, PR (34/74) + mahua cake, PR (34/74) + castor cake, PR (34/74) + karanj cake, PR (34/74) + mahua cake + 2t FYM ha^{-1}, PR (34/74) + castor cake + 2t FYM ha^{-1} and PR (34/74) + karanj cake + 2t FYM ha^{-1}. He further reported that this treatment was found at par with DAP.

2.2 EFFECT OF PHOSPHORUS LEVEL

2.2.1 Growth Parameters

At Pantnagar, Bisht and Chandel (1996) concluded in two years experiment that application of 80 kg P_2O_5 ha^{-1}, significantly increased the biomass of soybean at harvest by 44.83 and 70.07 per cent over no phosphorus fertilization (39.7 and 28.4 g $plant^{-1}$, respectively) during both the years. From Udaipur, Jat *et al.* (1996) in two years field trial reported that application of 40 kg P_2O_5 ha^{-1} to soybean significantly increased nodule count $plant^{-1}$ and nodule dry weight $plant^{-1}$ in both the years over control. Similarly, Srivastva *et al.* (1998) at IARI, New Delhi revealed that application of 60 kg P_2O_5 ha^{-1} in pea significantly increased nodule dry weight, CGR, NAR and LAI as compared to no phosphorus and 30 kg P_2O_5 ha^{-1}. In an another study at Hisar, Kumar *et al.* (1999) reported that 80 kg P_2O_5 ha^{-1} significantly increased plant height (51.91 cm) and total dry matter (10.71 q ha^{-1}) of soybean at 60 DAS over no phosphorus fertilization. Ramasamy *et al.* (2000) observed that all the growth parameters of soybean were explicitly increased with increasing level of phosphorus in the entire set of experiments and significantly higher plant height, root length and number of branches $plant^{-1}$ were observed at 80 kg P_2O_5 ha^{-1} over control. However, it was at par with 60 kg P_2O_5 ha^{-1}. Field experiment conducted at Pantnagar showed that higher dose of phosphorus (90 kg P_2O_5 ha^{-1}) significantly increased the plant growth and root characteristics of soybean *viz.*, number of branches (5.71), number of leaves (30.37), root length (18.75 cm), fresh weight of root (1.80 g) and number of nodules (20.51) per plant at flowering stage as compared to control and its lower doses 30 & 60 kg P_2O_5 ha^{-1} (Singh *et al.*, 2001). While, Ramasamy and Sankaran (2001) at NPRC, TNAU, Vamban conducted a two years experiment and observed that there was an appreciable increase in physiological attributes of soybean with the increasing levels of phosphorus from 0 to 80 kg P_2O_5 ha^{-1}. Phosphorus application at 80 kg ha^{-1} being at par with 60 kg ha^{-1} produced significantly higher dry matter at harvest (3380 & 3590 kg ha^{-1}) and LAI (1.522 & 1.639) over control during both the years. Likewise, phosphorus application at 60 kg P_2O_5 ha^{-1} significantly influenced number of branches $plant^{-1}$, LAI and root dry weight of groundnut over 20 kg P_2O_5 ha^{-1}. The increment was found to the tune of 9.30, 8.62 and 8.33 per cent over 20 kg P_2O_5 ha^{-1} (Rao and Shaktawat, 2001). Similarly, Sharma *et al.* (2002) at RCA, Udaipur carried out an experiment on soybean and reported that application of 60 kg P_2O_5 ha^{-1} significantly improved plant height, branches $plant^{-1}$, nodules $plant^{-1}$, nodule weight $plant^{-1}$ and dry matter accumulation at harvest over 30 kg P_2O_5 ha^{-1}. Further increase in phosphorus level did not show any significant increase in these parameters. Results of field experiment conducted at IARI, New Delhi revealed that the growth parameters *viz.*, LAI, NAR and total dry matter accumulation of groundnut were favoured by the application of phosphorus upto 40 kg P_2O_5 ha^{-1}. The LAI was increased upto 28.94, 33.55 and 23.80 per cent at 30, 60 & 90 DAS, respectively as compared to control through this treatment (Maity *et al.*, 2003). Meena *et al.* (2006) at IARI, New Delhi reported that on pooled basis 60 kg P_2O_5 ha^{-1}, significantly increased dry matter accumulation of chick pea at harvest over 30 kg P_2O_5 ha^{-1} and control.

2.2.2. Yield Attributes and Yield

Tuteja *et al.* (1995) noticed that application of 60 kg P_2O_5 ha^{-1} significantly increased number of pods $plant^{-1}$, seeds pod^{-1} and test weight of soybean. In comparison to seed yield of 14.0 q ha^{-1} under control, application of 60 kg P_2O_5 ha^{-1} increased it upto 20.7 per cent. At Udaipur, Jat and Nepalia (1995) reported that response of soybean to phosphorus in terms of yield attributes and yield was significant upto 60 kg P_2O_5 ha^{-1}. Further increase in phosphorus did not influence these characters and yield. The increase in pods $plant^{-1}$, seeds pod^{-1}, test weight and seed and stover yield was 13.85, 6.56, 20.27 and 31.36 & 27.42 per cent, respectively over control. Agrawal *et al.* (1996) noticed a significant increase in seed index of soybean at 60 kg P_2O_5 ha^{-1} over control, whereas seed weight per plant, harvest index and seed yield of soybean increased significantly at 80 kg P_2O_5 ha^{-1}. Similarly, the seed yield of soybean was significantly influenced over control when crop was fertilized with phosphorus at 60 kg P_2O_5 ha^{-1}. The increase in seed yield was found 20.52 per cent over control (19.0 q ha^{-1}) (Sarkar and Tripathi, 1996). At Nainital, Bisht and Chandel, 1996 conducted a two years experiment and observed that application of 80 kg P_2O_5 ha^{-1} to soybean registered significantly higher number of pods $plant^{-1}$ (103.5 & 91.9) and test weight (17.6 & 12.9 g) as compared to no fertilization (74.2 & 67.4 and 12.6 & 10.9 g, respectively) during both years of experimentation. Due to the increase in yield attributes the seed yield was also increased by 34.54 & 12.23 per cent over control (22.0 & 18.8 q ha^{-1}, respectively) with the same dose of phosphorus during both the years. Likewise, Srivastva *et al.*, 1998 at IARI, New Delhi conducted an experiment and revealed that application of 60 kg P_2O_5 ha^{-1} in pea significantly increased seed yield by 15.64 per cent over control (14.7 q ha^{-1}). The decrease in P_2O_5 level also decreased the yield of pea. Nimje and Potkile (1998) at Nagpur reported that seed yield of soybean was significantly increased from 9.8 per cent to 36.2 per cent over control with the application of 25 to 125 kg P_2O_5 ha^{-1}, respectively. Similarly, Rani (1999) also noted 9.58 per cent increase in seed yield of soybean in response to 60 kg P_2O_5 ha^{-1} over control (13.15 q ha^{-1}). Chafle *et al.* (1999) at Nagpur observed that 75 kg P_2O_5 ha^{-1} produced significantly higher seed (12.06 q ha^{-1}) and straw (23.60 q ha^{-1}) yield of soybean over control (7.23 & 16.60 q ha^{-1}, respectively). However, it was found at par with 50 kg P_2O_5 ha^{-1}. Likewise at Hisar, Kumar *et al.* (1999) found that application of 80 kg P_2O_5 ha^{-1} produced significantly higher seed yield (21.08 q ha^{-1}) of soybean over control. In an another study, Ramasamy *et al.* (2000) at Vamban, Tamil Nadu observed differential response due to various levels of phosphorus on seed yield. Phosphorus application at 60 kg P_2O_5 ha^{-1} recorded significantly higher seed yield of soybean over control and 40 kg P_2O_5 ha^{-1}. However, it was found at par with P_2O_5 at 80 kg ha^{-1}. Five year studies at GAU, Targhadia demonstrated that application of P_2O_5 at 60 kg ha^{-1} to the soybean significantly increased seed (8.16 q ha^{-1}) and stover yield (21.85

q ha^{-1}) over no fertilization of phosphorus (7.27 and 17.42 q ha^{-1}, respectively) on pooled basis. However, it was found at par with 40 kg P_2O_5 ha^{-1} (Akbari *et al.*, 2001). During two successive years of study at TNAU, Vamban, Ramasamy and Sankaran (2001) reported that being at par with 60 kg P_2O_5, higher level (80 kg P_2O_5 ha^{-1}) significantly influenced the seed yield of soybean by 10.57 and 10.66 per cent as compared to control (1050 & 1285 kg ha^{-1}, respectively). In an another field study of two consecutive years, Rao and Shaktawat (2001) observed a positive relationship in pod and biological yield with increased level of phosphorus. They found that 60 kg P_2O_5 ha^{-1} registered significantly higher pod & biological yield of groundnut (18.54 & 50.93 q ha^{-1}) over 20 kg P_2O_5 ha^{-1} (16.32 & 46.56 q ha^{-1}, respectively). Tanwar (2002) at Udaipur reported that application of 90 kg P_2O_5 ha^{-1} in soybean provided significantly higher number of pods $plant^{-1}$, seeds pod^{-1}, test weight, seed yield, stover yield and biological yield than the plots treated with 30 kg P_2O_5 ha^{-1}. However, it remained at par with 60 kg P_2O_5 ha^{-1}. Similarly, at Udaipur, application of 60 kg P_2O_5 ha^{-1} registered significantly higher seed yield (15.06 & 13.79 q ha^{-1}) during both the years over 30 kg P_2O_5 ha^{-1}. However, higher dose (90 kg P_2O_5 ha^{-1}) did not improve the yield significantly over 60 kg P_2O_5 ha^{-1} (Sharma *et al.*, 2002).

At IARI, New Delhi, Shivakumar *et al.* (2004) conducted a two years experiment and found that application of phosphorus at 80 kg P_2O_5 ha^{-1} significantly increased pod weight $plant^{-1}$, pods $plant^{-1}$, grain pod^{-1} and grain weight $plant^{-1}$ of chickpea over 40 kg and 0 kg P_2O_5 ha^{-1}. This level also significantly increased the seed and stover yield of chickpea over 40 and 0 kg P_2O_5 ha^{-1} during both the experimental years. While at IARI, New Delhi, Meena *et al.* (2006) conducted a two years trial and concluded that on pooled basis crop fertilized with 60 kg P_2O_5 ha^{-1} significantly increased number of pods $plant^{-1}$, test weight of seed and at last seed yield of chickpea over control and 30 kg P_2O_5 ha^{-1}. The increase in yield was 1.94 per cent over 30 kg P_2O_5 ha^{-1}.

2.2.3 Nutrient Content and Uptake

At Udaipur, Jat and Nepalia (1994) reported that increasing rates of P application from 0 to 60 kg P_2O_5 ha^{-1} significantly enhanced N and P content of seed and stover of soybean. While, Anokar *et al.* (1995) conducted an experiment and found that total uptake of phosphorus by soybean was significantly higher in plots receiving 75 kg P_2O_5 ha^{-1}, with the increase by 49.23 per cent as compared to no phosphorus (8.49 q ha^{-1}). Jat and Nepalia (1995) from Udaipur reported that in soybean the total uptake of NPK was found 35.36, 59.75 & 33.44 per cent higher over control (87.1, 8.2 & 57.4 kg ha^{-1}, respectively), when crop was fertilized with 60 kg P_2O_5 ha^{-1}. In another experiment, at Raipur, Sarkar and Tripathi (1996) revealed that application of 60 kg P_2O_5 ha^{-1} to soybean significantly increased N content of leaf (2.09 %), stem (1.94 %), pod wall (2.13 %), nodule (2.10 %) and seed (7.61 %) over control (1.72, 1.51, 1.84, 1.75 and 7.34 per cent, respectively). Thus, the total N uptake was found significantly higher by 9.85 per cent over control (183 kg ha^{-1}). During two years study, Bisht and Chandel (1996) at Pantnagar reported that application of 80 kg P_2O_5 ha^{-1} significantly increased the NPK and Zn uptake by soybean over control. The increase in NPK and Zn uptake was 85.81 & 159.6, 184.78 & 165.62, 102.36 & 148.70 and 100 & 119.31 per cent, respectively over no phosphorus fertilization during both the years. Similarly, Patel and Chandravanshi (1996) recorded increase in N and P content of soybean upto application of 90 kg P_2O_5 ha^{-1} but the magnitude of response was higher on P content as compared to N content. Nimje and Potkile (1997) reported significant increase in total N, root nodule N, plant N, P and K content of soybean with applied P rates of 0 to125 kg ha^{-1}. Likewise, at Agra, Singh *et al.* (1997) conducted a pot experiment and found that application of 100 kg P_2O_5 ha^{-1} to soil registered maximum N, P and K content of grain and straw of soybean over control and other lower doses. The N, P and K content of grain and straw were increased by 6.10 & 22.29, 38.46 & 121.42 and 4.32 & 4.54 per cent, respectively over control. In an another experiment 90 kg P_2O_5 ha^{-1} registered significantly higher NPK uptake by soybean with 81.32, 70.60 and 50.41 per cent increment over control (Chafle *et al.*, 1999). In five years study at GAU, Targhadia, Akbari *et al.* (2001) on the basis of pooled analysis reported that NPK uptake by soybean was significantly increased (106.4, 8.22 & 45.1 kg ha^{-1}) when the crop was fertilized with 60 kg P_2O_5 ha^{-1} over no phosphorus fertilization (88.9, 6.44 & 35.2 kg ha^{-1}, respectively). While, Singh *et al.* (2001) reported that N and P content of soybean seed was significantly increased with the application of 90 kg P_2O_5 ha^{-1}. The N and P content of seed was increased by 103.27 & 36.04 per cent, respectively over control. At Udaipur, an increment of 90.01 and 129.96 per cent in N and P uptake by soybean seed was registered by the application of 90 kg P_2O_5 ha^{-1} over control (Shaktawat *et al.*, 2002). Similarly at IARI, New Delhi, Shivakumar *et al.* (2004) conducted a two years field experiment and reported that chickpea fertilized with 80 kg P_2O_5 ha^{-1} significantly increased P uptake by seed and stover over its lower levels (0 and 40 kg P_2O_5 ha^{-1}).

2.2.4 Quality Parameters

At Udaipur, Jat and Nepalia (1995) reported that with the application of phosphorus at 60 kg P_2O_5 ha^{-1}, there was significant increase in oil yield of soybean seed over control. The oil yield was increased by 42.85 per cent over control (196 kg ha^{-1}). However, further increase in phosphorus level did not significantly increase the oil yield. Similarly at Pantnagar, Nainital, Bisht and Chandel (1996) during two years study observed that significant higher oil content of soybean seed was recorded with 80 kg P_2O_5 ha^{-1} giving 16.30 & 10.27 per cent increase over control (18.4 & 18.5 per cent) during both the years of experiment, respectively. In 1997, at Udaipur, Singh and Nepalia reported that application of 80 kg P_2O_5 ha^{-1} to soybean registered significantly higher oil yield over control. In an another experiment, Chafle *et al.* (1999) at Nagpur noticed that 90 kg P_2O_5 ha^{-1} registered significantly higher protein and oil content of soybean seed with 34.07 and 19.56 per cent, respectively over control. However, it was found at par with lower level of phosphorus (75 kg P_2O_5 ha^{-1}). Study at Udaipur demonstrated that application of 60 kg P_2O_5 ha^{-1} significantly increased oil and protein content of groundnut as compared to 20 kg P_2O_5 ha^{-1}. The increase in oil and protein contents were found by 5.18 and 5.19 per cent as compared to phosphorus level at 60 kg P_2O_5 ha^{-1} (Rao and Shaktawat, 2001). Similarly, at Akola, Umale *et al.* (2002) conducted an experiment and found that there was a significant increase in protein and oil content of soybean seed, when crop was fertilized with 50 kg P_2O_5 ha^{-1}. However, higher dose of P_2O_5 (75 kg P_2O_5 ha^{-1}) was found statistically at par with 50 kg P_2O_5. While working at IARI, New Delhi, Meena *et al.* (2006) reported that application 60 kg P_2O_5 ha^{-1} significantly increased protein content of seed over 30 kg P_2O_5 ha^{-1} and control. The increase in protein content was 24.54 kg ha^{-1} over control.

2.3 EFFECT OF AGROCHEMICALS

2.3.1 Effect of Brassinolide

2.3.1.1 Physiological parameters

At IARI, New Delhi, Sairam, 1994 conducted a field experiment and observed that foliar spray of homobrassinolide @ 0.1 & 1.0 ppm at 30 and 32 DAS in wheat cv.

C-306 significantly increased relative water content of leaves under water stressed condition, when it was compared with control (stressed plants). Sairam (1994) again at New Delhi conducted an experiment and found that homobrassinolide @ 0.01 and 0.05 ppm either as seed treatment or foliar spray on two contrasting wheat varieties *viz.*, C-306 (drought tolerant) and HD-2329 (drought susceptible) resulted in significant increase in relative water content of leaves under both irrigated as well as rainfed conditions as compared to untreated control. In another experiment, Kumawat (1996) observed that foliar spray of brassinosteroid @ 0.4 ppm significantly increased relative water content of mustard leaves over water spray. He further reported that this treatment markedly reduced free proline content and electrical conductivity of leaves. Maibangsa *et al.* (2000) conducted a pot culture experiment and revealed that brassinosteroids @ 0.5 ppm provided maximum soluble protein content. Studies at Hisar demonstrated that brassinolide @ 0.5 to 3.0 μM increased soluble proteins and decrease proline in rice in NaCl induced stress condition over control (Anuradha and Rao, 2002). Senthil *et al.* (2003) at TNAU, Coimbatore reported that foliar spray of brassinosteroids @ 0.5 ppm registered significantly higher soluble protein in soybean. The increment due to the application of brassinosteroid was 10.02 and 15.18 per cent, respectively over control during two successive years.

2.3.1.2 Growth and developmental characters

Ameta (1993) reported that foliar application of brassinosteroid @ 0.5 ppm significantly increased growth parameters of mustard over control *viz.*, plant height, primary branches $plant^{-1}$ and dry matter accumulation $plant^{-1}$. Similarly, Fang *et al.* (1994) reported that brassinosteroid spray in cotton increased dry matter accumulation in water logged plants than that of control. At IARI, New Delhi, Sairam (1994) carried out an experiment and reported that foliar application of homobrassinolide @ 0.01 ppm to two wheat varieties *viz.*, C-306 and HD-2329 under both rainfed as well as irrigated conditions significantly increased leaf area and biomass production as compared to untreated control. In another experiment, Kumawat (1996) reported that application of brassinosteroid @ 0.4 ppm on mustard significantly increased growth parameters as compared to control *viz.*, plant height, dry matter accumulation $plant^{-1}$ and LAI. At Udaipur, foliar spray of brassinosteroids @ 0.4 ppm in pea significantly increased the dry matter accumulation of leaf, stem and pods over control (pure water). The total dry matter accumulation at harvest due to the application of brassinosteroid was increased by 14.37, 17.36 and 20.39 per cent over control (11.28, 14.76 and 12.59 g plant^{-1}, respectively) (Mehta 1998). Senthil *et al.* (2003) at Coimbatore observed that foliar application of brassinolide @ 0.1 ppm increased root and shoot length of rice than control.

2.3.1.3 Yield attributes and yield

At IARI, New Delhi, Sairam (1994) found that foliar spray of homobrassinolide @ 0.1 and 1.0 ppm at 30 and 32 DAS registered significantly higher grain yield plant^{-1} of wheat cv. C-306 under water stressed condition over control. The increase in yield plant^{-1} was 34.13 and 24.01 per cent, respectively over control (5.83 g plant^{-1}). He further concluded that the increase in grain yield was found due to the significant increase in yield attributing characters *viz.*, ear plant^{-1}, grains ear^{-1} and test weight over control. He also reported that application of homobrassinolide @ 0.01 & 0.05 ppm as seed treatment and foliar spray to the two wheat varieties, drought resistant and drought susceptible under irrigated as well as rainfed condition significantly influenced the yield attributes and yield of wheat. Yield attributes *viz.*, ears m^{-1} row, grains ear^{-1}, test weight and harvest index were found significantly higher over control due to the treatment application. He further reported that due to the enhancement of these yield attributes the yields of both wheat varieties were also found significantly higher under treated plots than untreated plots. Likewise, at PAU, Ludhiana, Bhatia and Kaur (1997) conducted a field experiment and observed that homobrassinolide @ 0.1 & 0.5 μg ml^{-1} at 15 and 30 DAS significantly increased the yield attributes of mung bean *viz.*, length of pod, number of pods plant^{-1}, seeds pod^{-1} and test weight as compared to control. Due to increase in yield attributes, both the concentrations of homobrassinolide significantly increased seed yield plant^{-1} by 59.88 and 46.50 per cent, respectively over control (5.01 g plant^{-1}). In another experiment, Kumawat *et al.* (1997) revealed that foliar application of brassinosteroid @ 0.4 ppm on mustard significantly increased seed yield by 15 per cent over control (water spray). Foliar spray of different concentrations of 28-homobrassinolide significantly increased grain yield of wheat, rice and mustard, pod yield of groundnut, tuber yield of potato and seed yield of cotton over control (Ramraj *et al.*, 1997). Krishnan *et al.* (1999) at Goa, reported that foliar application of brassinosteroid at vegetative, panicle initiation and anthesis stages resulted in increased number of fertile tillers, number of spikelets, number of filled spikelets, fresh weight of 100 grains and dry weight of 100 grains of rice by 68.7, 48.5, 64.2, 23.2 & 26.4 per cent, respectively over control. Similarly, brassionsteroid sprayed plants recorded the highest percentage of spikelet fertility (86.9 %) and number of spikelets panicle^{-1} (140). This resulted in a significant increase in grain yield of rice over control (Maibangsa *et al.*, 2000). Studies at Coimbatore demonstated that foliar application of brassinolide @ 0.1 ppm at 40 and 60 DAS to sunflower cultivar Co-4 recorded 0.79 per cent increase in yield over control (Velu, 2002). Sivakumar *et al.*(2002) noticed that brassinosteroid sprayed plants recorded maximum yield of pearl millet (3591 kg ha^{-1}), while control plots recorded yield only 3018 kg ha^{-1}. The yield in this treatment was found 18.98 per cent higher over control.

At RCA, Udaipur, Purbey and Sen (2005) conducted a two years experiment and found that foliar spray of brassinosteroid at 0.50 ppm significant increased number of pods plant^{-1}, pod length, seed pod^{-1}, test weight, seed and straw yield of fenugreek as compared to water spray. The increase in seed yield on pooled basis was found to the extent of 26.71 per cent over water spray.

2.3.1.4 Quality parameters

Kumawat *et al.* (1997) reported that application of brassinosteroid @ 0.4 ppm significantly increased oil content (38.43 %) and oil yield (5.82 q ha^{-1}) of mustard as compared to control (water spray). In an another experiment, Sivakumar *et al.* (2002) observed increased protein content (9.87 %) as compared to control (9.45 %), when brassionsteroid was sprayed on pearl millet. While conducting a two years trial at Udaipur, Purbey and Sen (2005) reported that with the foliar spray of brassinosteroid at 0.25 and 0.50 ppm N, P and protein content of fenugreek was found significantly superior over control (water spray). Further, they also found that brassinosteroid at 0.50 ppm increased N, P and protein content of fenugreek by 3.94, 5.34 and 3.66 per cent, respectively over control (water spray).

2.3.2 Effect of Benzyladenine

2.3.2.1 Physiological parameters

At Jobner, Yadev *et al.* (1997) conducted an experiment on two gram genotypes, 'C-235' (susceptible) and 'RSG-143-1' (moderately tolerant to water stress) grown in earthen pots and found that foliar spray of benzyladenine @ 465 μM alleviated the adverse effect of water stress partly, in both the genotypes especially in

'RSG143-1' by stimulating the accumulation of proline, amino acids and total soluble sugars in the leaves. The amino acid content of leaves at 55 DAS was found significantly higher in both the genotypes over untreated stressed plants, when plants were treated with benzyladenine @ 465 μM. Similarly, Patil *et al.* (2002) at Nagpur found that foliar spray of 6-benzyladenine @ 50 ppm increased leaf chlorophyll by 10.1 and 13.8 per cent as compared to control (1.170 and 1.252 mg g^{-1}) at 45 and 60 DAS, respectively. Likewise, Menaria (2005) conducted a two years trial and concluded that foliar application of benzyladenine at 10 ppm significantly increased protein content and volatile oil content of fennel over water spray.

2.3.2.2 Growth and developmental characters

Samuel *et al.* (2000) at IARI, New Delhi found that foliar spray of benzyladenine increased biomass of normal as well as late planted wheat as compared to control. While, at Coimbatore, Ramesh and Thirumurugan (2001) conducted a two years field experiment and observed that during both the years benzyladenine @ 25 ppm produced tallest plants of soybean with 71.93 and 73.98 cm, respectively. This treatment also greatly influenced the dry matter production of soybean at harvest during both the years over control. Likewise, Patil *et al.* (2002) revealed that foliar application of 6- benzyladenine in soybean recorded significant improvement in all the morpho-physiological parameters. This treatment at 50 ppm concentration showed maximum plant height, number of branches, dry matter production and leaf area over water spray and control. RGR and NAR were also found significantly higher in plots treated with 200 ppm concentration of 6- benzyladenine over control. While at Udaipur, Menaria (2005) conducted a two years experiment and observed that foliar application of benzyladenine at 10 ppm significantly increased dry matter of fennel at 80, 120 DAT and at harvest over water spray during both years of study. Primary, secondary and tertiary branches were also increased significantly through benzyladenine spray as compared to water spray.

2.3.2.3 Yield attributes and yield

At Goa, Krishnan *et al.* (1999) conducted an experiment on IR-50 Indica rice and found that application of benzylaminopurine significantly increased the yield attributes *viz*., number of fertile tillers, total number of spikelets, number of filled spikelets, fresh and dry weight of 100 grains by 22.5, 15.4, 27.3, 16.9 and 20.9 per cent, respectively over control. Similarly, Patil *et al.* (2002) at Nagpur carried out an experiment and found that 6-benzyladenine had effectively improved all the yield parameters governing yield in soybean. Foliar application of 50 ppm 6- benzyladenine significantly increased pods plant^{-1}, seeds pod^{-1} and seed yield plant^{-1} than water spray and control. Hence, a considerable improvement to the extent of 36.0 per cent increase in yield was achieved by 50 ppm concentration of 6- benzyladenine over control (10.69 q ha^{-1}). Likewise, Menaria (2005) conducted a two years investigation and reported that foliar application of benzyladenine 10 ppm significantly increased number of umbels plant^{-1}, umbel-lets umbel^{-1}, seeds umbel-lets^{-1}, seed yield plant^{-1}, weight of 1000 seeds, seed, stover and biological yields of fennel over water spray during both the years of research.

2.3.3 Effect of Potassium Chloride (KCl)

2.3.3.1 Physiological parameters

Umar *et al.* (1993) reported that potassium (K) enhanced RWC of leaves coupled with reduction in water loss expectedly. Thus, enhanced RWC helped plants to perform various physiological processes like photosynthesis, enzyme activity and biochemical metabolism to continue more efficiently even under low soil moisture condition developed by scarcity of water. At Hisar, Singh *et al.* (1997) reported that RWC of leaves got enhanced (12.0 %) with the increased concentration of K over control. Thakur *et al.* (2000) concluded that foliar spray of KCl @ 0.5 and 1.0 % maintained significantly higher water use efficiency of bell pepper var. California wonder over untreated stressed plants. While, at CAZRI, Jodhpur, Vyas *et al.* (2001) revealed that the decline in leaf relative water content and plant water potential of cluster bean due to water stress was found less in plants grown in the plots which were foliarly sprayed with potassium @ 200 ppm. They also concluded that potassium spray helped plants in maintaining favourable internal tissue water and metabolic activities under water stress condition.

2.3.3.2 Growth and developmental characters

At Gurgoan, Umar *et al.* (1997) reported that K application upto 3 meq litre^{-1} through KCl significantly increased the dry matter yield of groundnut over control. Singh *et al.* (1997) at Hisar reported that when compared with control, K at 120 ppm concentration significantly increased the dry weight of leaves, stem and root per plant and leaf area of chickpea at different stages of life cycle. In an another study, Thakur *et al.* (2000) observed that single spray of KCl 1 % maintained significantly higher LAI as compared to untreated plants upto 75 % water deficit level. The LAI in treated plants ranged between 2.33 to 4.07 as compared to only 1.88 in untreated plants. Similarly, conducting an experiment at TNAU, Coimbatore, Radhamani *et al.* (2001) revealed that application of KCl @ 0.5 % along with basal application of 20 kg sulphur registered significantly higher dry matter production and plant height of sesame at harvest over control. The increment in dry matter production and plant height was found 34.36 and 98.42 per cent over control (1.91 kg ha^{-1} and 77.4 cm, respectively). Likewise, Velu (2002) found that foliar spray of KCl @ 1 % at 40 and 60 DAS in sunflower produced 3.38 per cent more total dry matter production $plant^{-1}$ as compared to no spray (109.2 g) and found at par with control. They also found that seed set percentage was also increased by 1.28 per cent over control (85.9 %). Field study at TNAU, Coimbatore demonstrated that foliar spray of KCl @ 1 % along with salicyclic acid, DAP and NAA significantly influenced the total dry matter production of mungbean at 40, 45, 50, 55, 60 and 65 DAS over control (Chandrashakar and Bangarusamy, 2003). Similarly, at Gayespur (W.B.), Moinuddin and Goswami (2004) conducted an experiment and observed that foliar spray of potassium sulphate significantly increased the dry matter production of wheat over control. The increment was found upto 17.40 per cent over control.

2.3.3.3 Yield attributes and yield

At Gurgoan, pod yield of groundnut was significantly increased over control in plots, where K upto 3 meq $litre^{-1}$ through potassium chloride (KCl) was sprayed (Umar *et al.*, 1997). Significant positive results of KCl @ 0.5 and 1.0 % spray was reported by Thakur *et al.* (2000) with an increase in yield of bell pepper var. California wonder under water stressed condition. They also found that bell pepper var. Yolo wonder also produced higher fruit yield when the plants were treated with both doses of KCl @ 0.5 and 1.0 %. Similarly, Ramesh and Thirumurugam (2001) revealed that KCl at 1 % tank mixed with DAP at 1 % foliar spray produced higher seed yield of soybean over control and considered as efficient practice in improving seed yield of soybean. While Radhamani *et al.* (2001) at TNAU, Coimbatore reported that foliar spray of KCl 0.5 % to seasame along with basal dose of 20 kg sulphur ha^{-1} provided significantly higher number of capsules $plant^{-1}$ (88) and seeds $capsule^{-1}$ (42)

over control (61 and 31, respectively). This treatment also increased the test weight, thus significantly increased the seed yield by 45.81 per cent over control (502 kg ha^{-1}). In another experiment, Velu (2002) reported that foliar spray of KCl 1 % on sunflower var. Co-4 increased number of filled seed $head^{-1}$, total number of seeds $head^{-1}$, seed index, harvest index and at last grain yield was also increased by 6.8 per cent over control (1166 kg ha^{-1}). Kalpana and Krishnarajan (2003) at TNAU, Coimbatore conducted an experiment and observed that combined spray of KCl 1 % with DAP 2 % significantly influenced the yield and yield components of soybean. This treatment increased the number of pods $plant^{-1}$, seeds pod^{-1}, test weight, seed and stover yield by 34.63, 17.88, 30.22, 14.26 and 21.16 per cent, respectively over control. At TNAU, Coimbatore, Chandrasekhar and Bangarusamy (2003) conducted a field experiment and found that spray of KCl 1% alongwith salicyclic acid, DAP and NAA produced significantly higher number of pods $cluster^{-1}$ (19.45) of mungbean over control (13.20) and rest of the treatments. However, in case of number of flowers $plant^{-1}$, this treatment produced higher number of flowers $plant^{-1}$ (48.12) over control. The maximum grain yield was also registered through this treatment. In a field study at Gayespur (W.B.), Moinuddin and Goswami (2004) reported that foliar application of potassium sulphate at 3 % significantly increased the grain yield of wheat over control. The magnitude of increase in grain yield was found upto 9.09 per cent as compared to control.

2.3.3.4 Nutrient content and uptake

Sharma and Agarwal (2002) from Gwalior reported that potassium content of leaf and root of *Cicer arietinum* at 60 DAS was found higher in the plants sprayed with KCl @ 0.1 M. Phosphorus content of leaf and root also increased by 34.98 and 77.97 per cent, respectively as compared to control (No spray). N content of leaves also increased through the application of this treatment over control.

2.3.3.5 Quality parameters

Radhamani *et al.* (2001) at TNAU, Coimbatore conducted an experiment and reported that spray of KCl @ 0.5 % alongwith basal dose of 20 kg sulphur provided significantly higher oil content of sesame over control. The increase in oil content was found by 1.60 per cent over control.

3. MATERIALS AND METHODS

The field experiment entitled "Effect of phosphorus nutrition and agrochemicals on the productivity of soybean [*Glycine max* (L) Merrill]" was conducted during *kharif* seasons of 2003 and 2004. The details of experimental procedures, techniques followed, materials used and criteria adopted for treatment evaluation during the course of investigation are described in this chapter under appropriate headings.

3.1 EXPERIMENTAL SITE

The experiment was laid out during both years in the Plot no. C-6 at the Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur, which is situated in the step foot of Aravalli hills at 24° 35' N latitude and 72° 42' E longitude, at an altitude of 579.5 metres above mean sea level. This region falls under agro-climatic zone IVa "Sub-humid Southern Plain" of Rajasthan.

3.2 CLIMATIC AND WEATHER CONDITIONS

This region has a typical semi-arid and sub-tropical climate characterized by mild winter and moderate summers, associated with high relative humidity. The average annual rainfall of Udaipur is 637 mm, most of which (90 %) is contributed by south-west monsoon from July to mid September.

The mean weekly meteorological data during the crop period were recorded from the Meteorological Observatory, Instructional Farm, RCA, Udaipur and are presented in Appendix I and depicted in Fig. 3.1. Data reveal that during soybean crop period, maximum temperature ranged between (33.3°C and 34.0°C), while minimum temperature ranged between (12.7°C and 13.0°C) during *kharif* 2003 and 2004, respectively. The rainfall received during crop growth period in the 2003 and 2004 was 465.9 and 569.6 mm, respectively. However, the distribution varied in both years.

3.3 PHYSICO-CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOIL

The soil samples from 15 cm depth were drawn randomly from experimental field prior to sowing during each year and composite soil sample was prepared after proper mixing, drying and sieving. This composite soil sample was analyzed for

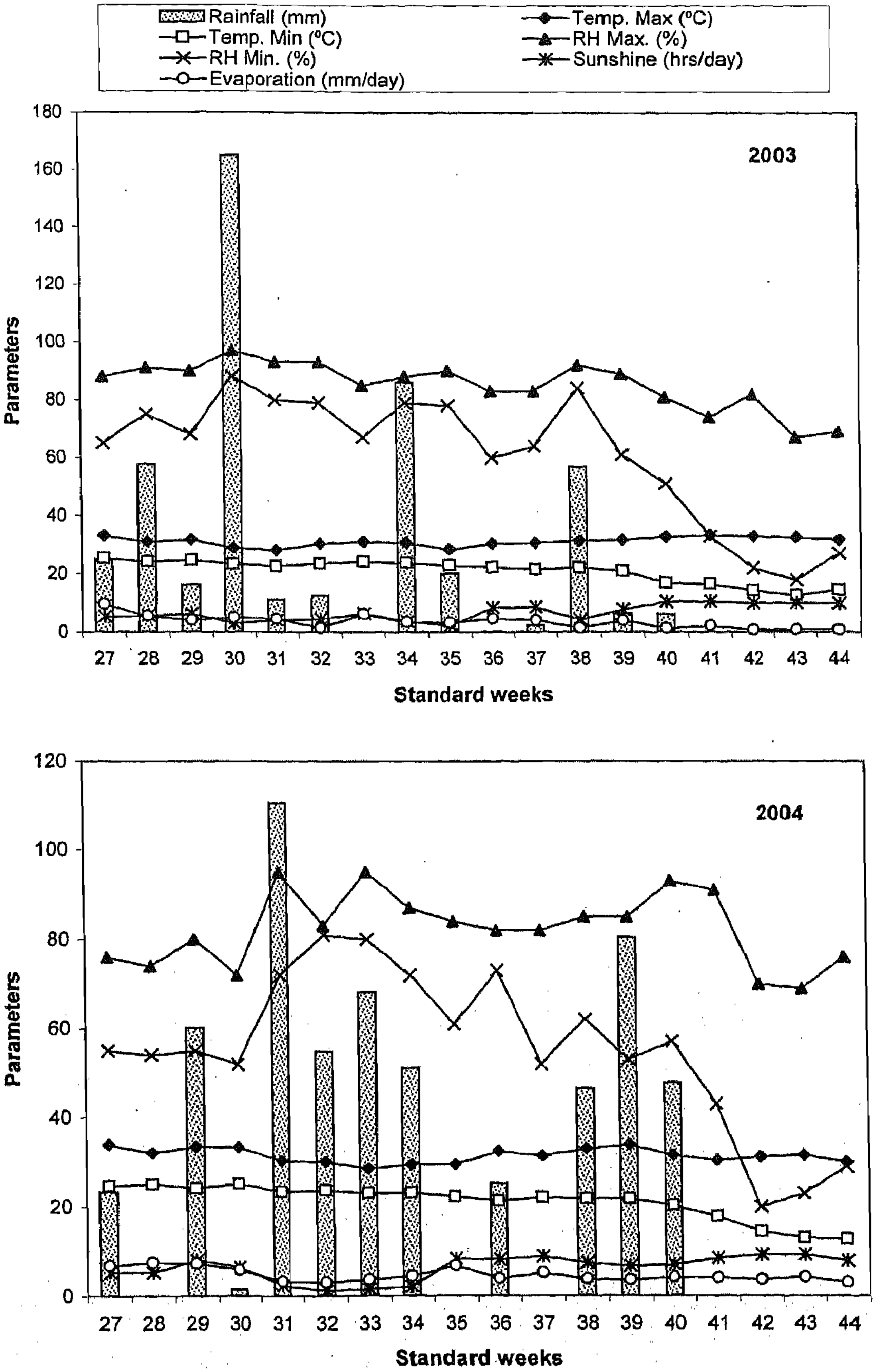


Fig. 3.1 : Mean weekly meteorological parameters during crop growing season (2003 & 2004)

Table 3.1 Physico-chemical properties of experimental soils

	Soil Properties	Value		Reference
		2003	2004	
A.	**Mechanical Analysis**			
	Sand (%)	39.28	39.10	Hydrometer method (Bouyoucos, 1962)
	Silt (%)	26.10	26.20	
	Clay (%)	34.62	34.70	
	Textural class	Clay loam	Clay loam	Triangular diagram (Brady, 1983)
B.	**Physical Parameters**			
	Bulk density (Mg m^{-3})	1.38	1.37	Core sampler method (Piper, 1950)
	Particle density (Mg m^{-3})	2.63	2.65	Black (1965)
	Porosity (%)	47.83	47.62	Black (1965)
C.	**Chemical Parameters**			
	Organic carbon (%)	0.70	0.72	Rapid titration method (Walkley and Black, 1947)
	Organic matter	1.18	1.21	By factor (1.724)
	Available N (kg ha^{-1})	275.7	278.8	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
	Available P (kg ha^{-1})	21.3	22.4	Olsen's method (Olsen *et al.*, 1954)
	Available K (kg ha^{-1})	390	392	Flame photometer method (Richards, 1968)
	Calcium carbonate (%)	3.50	3.58	Rapid titration method (Piper, 1950)
	EC (dSm^{-1} at 25°C)	1.12	1.06	Conductivity bridge method (Richards, 1968)
	CEC Cmol (+) kg ha^{-1}	22.21	22.11	Ammonium acetate method (Piper, 1950)
	Soil pH (1:2.5 soil water suspension)	7.9	7.8	Blackman's pH method (Jackson, 1973)

mechanical, physical and chemical characteristics of the experimental soils. The results of analysis are presented in Table 3.1 along with the methods followed. The soil of experimental field was clay loam in texture, slightly alkaline in reaction (pH 7.9 and 7.8). The soil was medium in available nitrogen (275.7 and 278.8 kg ha^{-1}) and phosphorus (21.3 and 22.4 kg ha^{-1}) and high in available potassium (390 and 392 kg ha^{-1}) during the year 2003 and 2004, respectively.

3.4 CROPPING HISTORY

The experimental fields were under continuous cropping during both the seasons for the last many years. The commercial maize and wheat were grown on the experimental area in *kharif* and *rabi* seasons with recommended practices, respectively during 2001-02 and 2002-03, followed by the present experiment during *kharif* seasons of 2003 and 2004.

3.5 EXPERIMENTAL DETAILS

3.5.1 Treatment Details

The experiment consisted of 24 treatment combinations comprising 2 phosphorus sources *viz.*, DAP and PR (34/74) + cow dung (1 : 3 ratio) + PSB, 3 levels *viz.*, 40, 60 and 80 kg P_2O_5 ha^{-1} and 4 agrochemicals *viz.*, brassinolide, benzyladenine, KCl and control (water spray).

The details of treatments are :

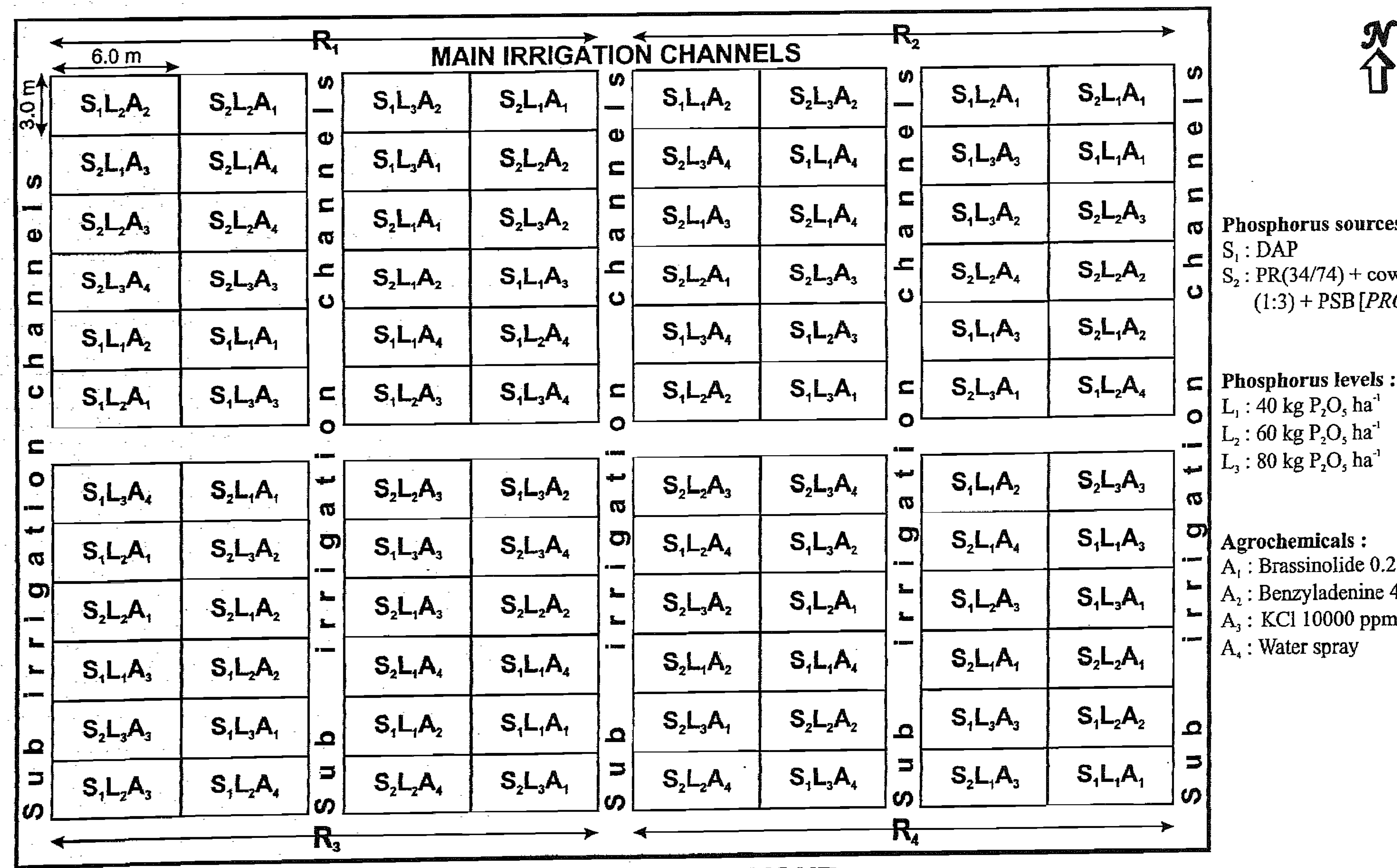
(A)	**Phosphorus sources**	**Symbol**
(i)	DAP	S_1
(ii)	[{PR (34/74)* + cow dung}(in 1 : 3 ratio)] + PSB **(PROM)**	S_2

* Phosphate rock that analyzed + 34 % P_2O_5 and 90 % of the particles finer than 74 microns.

(B)	**Phosphorus levels**	
(i)	40 kg P_2O_5 ha^{-1}	L_1
(ii)	60 kg P_2O_5 ha^{-1}	L_2
(iii)	80 kg P_2O_5 ha^{-1}	L_3

Table 3.2 Details of treatment combinations

S. No.	Symbol used	Treatments		
		Phosphorus sources	Phosphorus levels (kg P_2O_5 ha^{-1})	Agrochemicals
1.	$S_1L_1A_1$	Di-ammonium Phosphate	40	Brassinolide
2.	$S_1L_1A_2$	Di-ammonium Phosphate	40	Benzyladenine
3.	$S_1L_1A_3$	Di-ammonium Phosphate	40	KCl
4.	$S_1L_1A_4$	Di-ammonium Phosphate	40	Water spray
5.	$S_1L_2A_1$	Di-ammonium Phosphate	60	Brassinolide
6.	$S_1L_2A_2$	Di-ammonium Phosphate	60	Benzyladenine
7.	$S_1L_2A_3$	Di-ammonium Phosphate	60	KCl
8.	$S_1L_2A_4$	Di-ammonium Phosphate	60	Water spray
9.	$S_1L_3A_1$	Di-ammonium Phosphate	80	Brassinolide
10.	$S_1L_3A_2$	Di-ammonium Phosphate	80	Benzyladenine
11.	$S_1L_3A_3$	Di-ammonium Phosphate	80	KCl
12.	$S_1L_3A_4$	Di-ammonium Phosphate	80	Water spray
13.	$S_2L_1A_1$	PR (34/74) + cow dung (1:3) + PSB	40	Brassinolide
14.	$S_2L_1A_2$	PR (34/74) + cow dung (1:3) + PSB	40	Benzyladenine
15.	$S_2L_1A_3$	PR (34/74) + cow dung (1:3) + PSB	40	KCl
16.	$S_2L_1A_4$	PR (34/74) + cow dung (1:3) + PSB	40	Water spray
17.	$S_2L_2A_1$	PR (34/74) + cow dung (1:3) + PSB	60	Brassinolide
18.	$S_2L_2A_2$	PR (34/74) + cow dung (1:3) + PSB	60	Benzyladenine
19.	$S_2L_2A_3$	PR (34/74) + cow dung (1:3) + PSB	60	KCl
20.	$S_2L_2A_4$	PR (34/74) + cow dung (1:3) + PSB	60	Water spray
21.	$S_2L_3A_1$	PR (34/74) + cow dung (1:3) + PSB	80	Brassinolide
22.	$S_2L_3A_2$	PR (34/74) + cow dung (1:3) + PSB	80	Benzyladenine
23.	$S_2L_3A_3$	PR (34/74) + cow dung (1:3) + PSB	80	KCl
24.	$S_2L_3A_4$	PR (34/74) + cow dung (1:3) + PSB	80	Water spray



Phosphorus sources :
S_1 : DAP
S_2 : PR(34/74) + cow dung (1:3) + PSB [*PROM*]

Phosphorus levels :
L_1 : 40 kg P_2O_5 ha^{-1}
L_2 : 60 kg P_2O_5 ha^{-1}
L_3 : 80 kg P_2O_5 ha^{-1}

Agrochemicals :
A_1 : Brassinolide 0.25 ppm
A_2 : Benzyladenine 45 ppm
A_3 : KCl 10000 ppm
A_4 : Water spray

FIG. 3.2 : PLAN OF LAYOUT

(C) Agrochemicals*

(i)	Brassinolide 0.25 ppm	A_1
(ii)	Benzyladenine 2 x 10^{-4} M (45 ppm)	A_2
(iii)	KCl 1 % (10000 ppm)	A_3
(iv)	Control (Water spray)	A_4

*Spraying of agrochemicals were done at 30 and 60 DAS

The details of treatment combinations are given in Table 3.2 and the plan of layout along with treatment allocation is depicted in Fig. 3.2.

3.5.2 Other Experimental Details

(i)	Total treatment combinations	:	2 x 3 x 4 = 24
(ii)	Experimental design	:	Factorial Randomized Block Design (FRBD)
(iii)	Replications	:	4
(iv)	Plot size	:	
	(a) Gross	:	6 m x 3 m = 18 m^2
	(b) Net	:	5 m x 2.4 m = 12 m^2

3.6 DETAILS OF CROP RAISING

The schedule of field operations carried out for soybean crop during both the years are given in Table 3.3.

3.6.1 Variety

Soybean variety JS 335 was used as experimental material developed at Sehore (M.P.) by crossing JS 78-77 x JS 71-05. It is early to medium in maturity (98-102 days) having yield potential of about 30 q ha^{-1}. Its test weight ranges between 95 to 120 g. It has purple flowers and seeds are bright yellow. This variety is resistant to bacterial pustules and bacterial blight.

3.6.2 Field Preparation

The experimental field was prepared by ploughing once with tractor drawn disc plough followed by cross harrowing and planking. As per layout of plan, plots were demarcated with provision of irrigation channels.

Table 3.3 Schedule of field operations carried out during crop growth period

S. No.	Operations	Date/Month/Year	
		I Year	II Year
1.	PR composting along with solubilizers	07.06.2003	02.06.2004
2.	Field preparation	04.07.2003	30.06.2004
3.	Layout and bunding	06.07.2003	01.07.2004
4.	Furrow opening and composting incorporation	07.07.2003	03.07.2004
5.	Fertilizer placement and sowing	08.07.2003	04.07.2004
6.	Herbicide application	09.07.2003	05.07.2004
7.	Thinning and gap filling	05.08.2003	31.07.2004
8.	Hoeing and weeding	06.08.2003	10.08.2004
9.	First foliar spay of agrochemicals	08.08.2003	03.08.2004
10.	Second foliar spray of agrochemicals	08.09.2003	03.09.2004
11.	Pesticide spray (I)	05.08.2003	07.08.2004
12.	Pesticide spray (II)	25.08.2003	28.08.2004
13.	Life saving irrigation	15.08.2003 & 20.09.2003	20.07.2004
14.	Harvesting	15.10.2003	12.10.2004
15.	Threshing	25.10.2003	20.10.2004
16.	Winnowing	30.10.2003	24.10.2004

3.6.3 Treatment Application Techniques

(A) Fertilizer/PROM application

(i) Nitrogen : A uniform dose of 30 kg N ha^{-1} was made at sowing through DAP and urea as per treatment.

(ii) Phosphorus : Phosphorus application was made as per treatments (sources and levels). The DAP alone @ 40, 60 and 80 kg P_2O_5 ha^{-1}, in respective plots was applied at the time of sowing, in furrows at 2 to 3 cm below the seeds while PROM @ 40, 60 and 80 kg P_2O_5 ha^{-1} was also incorporated in furrows before sowing, in the respective plots. Salient features of Jamarkotda rock phosphate concentrate quoted from An Approach 1999, RSMML, Udaipur is given in Table 3.4.

Table 3.4. Chemical composition of rock phosphate

Constituents	Content (%)
P_2O_5	+ 34.0
SiO_2	4-7
MgO	1-2.5
R_2O_3	1-2
LOI	5.0-6.0
F	2.8-3.1
CaO	47-51

(iii) Methodology for acidulation : During acidulation PR (34/74), as per phosphorus levels was mixed separately with solubilizer *viz.*, cow dung (in 1:3 ratio), 30 days prior to the application in the field. For making each composting mixture upto 20 kg weight, soil was used as a filler. After 5-6 days, PSB was also incubated in these composting treatments. These composting materials were filled in separate gunny bags according to the treatments. Periodically water was sprinkled to ensure sufficient amount of moisture in the incubating mixtures. *Bacillus megatherium* micro-organism culture was used for composting the treatments. The acidulated material or final product is known as PROM.

(iv) Cow dung : As per treatment, cow dung was used as solubilizer for composting rock phosphate on the basis of 1 : 3 ratios.

3.6.4 Agrochemicals

(i) Brassinolide (Br) : Two foliar sprays of brassinolide 0.25 ppm were done at 30 and 60 DAS (pre and post flowering) during both the years as per treatment.

(ii) Benzyladenine (BA) : Two foliar sprays of benzyladenine 2 x 10^{-4} M (45 ppm) were applied at 30 and 60 DAS (pre and post flowering stage) during both the years as per treatment.

(iii) Potassium chloride (KCl) : Two foliar sprays of KCl 1 % (10000 ppm) solution were applied at 30 and 60 DAS during both the years as per treatment.

(iv) Water spray : Water sprays were also done at 30 and 60 DAS according to the treatment during both the years.

Brassinolide and potassium chloride were directly dissolved in water, however, benzyladenine was first solubilized in alcohol and then it was dissolved in water. All the agrochemicals were sprayed through knapsac sprayer fitted with flat fan nozzle, using 500 litres of water per hectare. In order to make the spray more effective, teepol, a sticking agent was mixed at 0.5 ml $litre^{-1}$ of spray solution.

3.6.5 Seed Treatment and Sowing

The seeds of soybean variety JS 335 were treated with Bavistin @ 2 g kg^{-1} seed in order to avoid fungal infection. *Rhizobium* culture inoculation was also done uniformly @ 5 g kg^{-1} seed just before the sowing. The sowing was done in furrows 30 cm apart and seeds were placed at a depth of 2 to 3 cm using seed rate of 80 kg ha^{-1}.

3.6.6 Weed Management

Pre-emergence application of alachlor granules @ 1.5 kg a.i. ha^{-1} was done in order to minimize weed infestation. One hoeing was also done at 30-35 DAS.

3.6.7 Plant Protection

In order to minimize the infestation of crop pests, sprays of monocrotophos 36 SL at 0.06 % was done during both the years. The details are given in the Table 3.3.

3.6.8 Irrigation

Whenever, long dry spell occurred, life saving irrigation was applied to the crop. The detail about the irrigation has been mentioned in Table 3.3.

3.6.9 Harvesting and Threshing

The crop was harvested from the individual plots, when pods turned yellow and before shattering started. The produce from each net plot area was dried for 7-10 days. Thereafter, threshing of individual plots was done by thresher using appropriate sieve. Seeds plot^{-1}, thus collected, were winnowed, cleaned and weighed.

3.7 TREATMENT EVALUATION

In order to evaluate effect of treatments on growth, yield components, yields, nutrient content and uptake and other aspects of the soybean crop, incubation and soil aspects, observations were recorded for each parameter as per below mentioned methodology.

3.7.1 Plant Population

Numbers of plants in one metre row length from five randomly selected points in each experimental unit were counted at 20 DAS and at crop maturity. These were averaged and expressed in lakh ha^{-1}.

3.7.2 Growth Parameters

(i) Plant height (cm) : Height of five randomly selected plants in each experimental plot was measured from base to the tip of main axis at harvest and averaged out.

(ii) Branches plant^{-1} : Total number of branches were counted from five randomly selected plants from each plot at harvest. The average was worked out and expressed as number of branches plant^{-1}.

(iii) Dry matter accumulation (g plant^{-1}) : Five randomly selected plants from each plot at 30, 40 and 70 DAS and at harvest were separated and taken in paper bags separately and thereafter dried in sunlight. Later on, these sun dried samples were kept in an oven at 70°C temperature for 72 hours (till achieved constant weight). The average dry matter was computed and expressed as g plant^{-1}.

(iv) Growth indices : Crop growth rate and relative growth rate were computed by the following formulae as given by Redford (1967).

$$CGR\ (g\ m^{-2}\ day^{-1}) = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

$$\text{RGR (g g}^{-1}\text{ day}^{-1}) = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where,

W_1 and W_2 are dry matter yields, t_1 and t_2 are time, respectively and P represents the ground area.

3.7.3 Yield Attributes

(i) Number of pods plant^{-1} : Fully matured pods were counted from five representative plant samples of each plots. The average number of pods was worked out and expressed as pods plant^{-1}.

(ii) Seeds pod^{-1} : Twenty five pods were randomly taken from total pods of sampled plant and then seeds were counted. The average was worked out and expressed as number of seeds pod^{-1}.

(iii) Seed index (g) : For seed index, 100 seeds were taken from produce of each net plot and expressed in g.

(iv) Seed yield plant^{-1} (g) : All the sun dried pods of five randomly selected plants from each plot were threshed and their seeds were weighed and expressed in seed yield plant^{-1} (g).

(v) Harvest index (%) : The harvest index was obtained by dividing the economic yield by total biological yield and expressed as percentage (Donald and Hamblin, 1976).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (q ha}^{-1})}{\text{Biological yield (q ha}^{-1})} \times 100$$

3.7.4 Yield

(i) Seed yield (q ha^{-1}) : Weight of sun dried seeds from each net plot was recorded and expressed in terms of q ha^{-1}.

(ii) Stover yield (q ha^{-1}) : Stover yield was obtained by subtracting the seed yield per net plot from the respective biological yield per net plot and finally expressed in terms of stover yield in q ha^{-1}.

(iii) Biological yield (q ha^{-1}) : The weight of thoroughly sun dried plants of net plot alongwith pods were recorded and expressed as biological yield in q ha^{-1}.

3.7.5 Water Relation Studies

(i) Relaive water content of leaf : Relative water content (RWC) of fresh leaves at 40 and 70 DAS was determined by Weatherley's method (1950). It was calculated by using the following formula :

$$\text{RWC (\%)} = \frac{\text{Fresh weight of leaves} - \text{Oven dry weight of leaves}}{\text{Weight of turgid leaves} - \text{Oven dry weight of leaves}}$$

3.7.6 Biochemical Analysis

(i) Estimation of proline content : Free proline from leaves (randomly collected from individual plots) was extracted in aqueous sulfosalicyclic acid and its concentration was measured using ninhydrin method (Bates *et al.*, 1973). The proline concentration in the leaf tissue was determined from a standard curve prepared with synthetic proline and its amount was calculated on fresh weight basis using the following formula :

$$\text{Proline } (\mu \text{ moles g}^{-1} \text{ fresh weight}) = \frac{(\mu\text{g proline ml}^{-1} \text{ X ml toluene}) / 115.5\ \mu\text{g } \mu^{-1} \text{ mole}}{\text{g sample}/5}$$

3.7.7 Chemical Analysis of Plant

(i) Nutrient content in plants : The plant samples collected at 30, 40 and 70 DAS and seed and stover at harvest were oven dried at constant temperature of 70°C for 72 hours. The dried samples were finely ground and passed through 40 mm mesh sieve and used for determination of nutrient content (N and P) as per method furnished in Table 3.5 and expressed in per cent in dry matter.

Table 3.5. Chemical methods for plant nutrient analysis

S. No.	Nutrient	Method	Reference
1.	Nitrogen	Nesseler's reagent colorimetric method	Lindner (1944)
2.	Phosphorus	Vanadomolybdo phosphoric yellow colour method	Richards (1968)

(ii) Nutrient uptake (kg ha^{-1}) : The uptake of N and P at 30, 40 and 70 DAS was estimated by multiplying dry matter yield (kg ha^{-1}) with per cent nutrient content and expressed as nutrient uptake (kg ha^{-1}). Similarly, for estimating nutrient uptake (N and P) by seed and stover at harvest, seed and stover yields were multiplied by respective nutrient content and expressed as nutrient uptake in kg ha^{-1}.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) in dry matter/seed/stover} \times \text{Dry matter/seed/stover yield (kg ha}^{-1}\text{)}}{100}$$

(iii) Oil content (%) : Oil content in seed was determined by rapid non-destructive pulse nuclear magnetic resonance (NMR) spectrometer as given by Tiwari *et al.* (1974).

(iv) Oil yield (kg ha^{-1}) : Oil yield was estimated by using the following formula :

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{Oil content in seed (\%)} \times \text{Seed yield (kg ha}^{-1}\text{)}}{100}$$

(v) Protein content (%) : The protein content of seed was calculated by multiplying per cent nitrogen content in seed with constant factor 6.25 as reported by Gupta *et al.* (1972).

(vi) Protein yield (kg ha^{-1}) : Protein yield was estimated by using the following formula :

$$\text{Protein yield (kg ha}^{-1}\text{)} = \frac{\text{Protein content in seed (\%)} \times \text{Seed yield (kg}^{1}\text{)}}{100}$$

3.8 SOIL ANALYSIS

(i) Available phosphorus : Soil samples were drawn from each experimental plots upto 15 cm depth with the help of screw type auger in zig-zag pattern from four different sites of each plot before and after harvesting of crop. Samples from each experimental plot were mixed thoroughly. These were dried, ground and passed through 2 mm sieve in order to analyze for available phosphorus as per method given in Table 3.1.

3.9 NUTRIENT BALANCE SHEET

Based on apparent gain or loss of nutrients, an attempt was made to establish fate of nutrient available in soil, added through treatments and crop removals were duly taken into account during the course of investigation. The nutrient balance sheet was worked out as follows:

Expected nutrient balance (D) = (A + B) – C

Where,

A = Initial nutrient status of the soil,

B = Nutrient added to the soil as per treatment, and

C = Nutrient taken by crop

Apparent gain / loss (F) = E – D

Where,

E = Actual nutrient balance i.e., the available nutrient status of soil after harvesting the crop.

Actual gain / loss (G) = E – A

3.10 ECONOMICS

In order to assess economic viability of various treatments, treatment wise cost of cultivation and net returns were worked out. On this basis benefit to cost (B:C) ratio was also calculated for different treatments.

3.11 STATISTICAL ANALYSIS

In order to test the significance of variation in experimental data obtained from various treatment effects, data were statistically analyzed. The critical differences were calculated to assess the significance of treatment mean, whenever the F test was found significant at 5 per cent level. To estimate interrelation between various characters, correlation coefficient was computed. Further, in order to establish cause and effect relationship, regression equations were calculated. All these estimates were computed by standard statistical procedure (Panse and Sukhatme, 1989).

4. EXPERIMENTAL RESULTS

The results of field experiment entitled "Effect of phosphorus nutrition and agrochemicals on the productivity of soybean [*Glycine max* (L) Merrill]" conducted during two consecutive years 2003 and 2004 are being presented in this chapter. Data pertaining various criteria used for evaluation of treatments were statistically analysed and analysis of variance for these data have been furnished in Appendices (II to XXXIV). The results of the main effects are being presented in succeeding paragraphs. The interaction effect of phosphorus sources, levels and agrochemicals did not significantly influence any of the studied parameters.

EFFECT OF TREATMENTS ON

4.1 PLANT POPULATION (Lakh ha^{-1})

Data presented in Table 4.1 reveal that number of plants ha^{-1} recorded at 20 DAS and at harvest during both the years of experimentation as well as in pooled analysis did not differ significantly under the influence of various phosphorus sources, levels and agrochemicals. Observations for agrochemicals at 20 DAS were not recorded as they were sprayed at 30 DAS.

4.2 GROWTH PARAMETERS

4.2.1 Plant height at harvest (cm)

Phosphorus sources

It is evident from data (Table 4.2) that both phosphorus sources applied to crop failed to exhibit any significant effect on plant height at harvest during both years of experimentation as well as in pooled analysis.

Phosphorus levels

Data (Table 4.2) show that there was no significant increase in plant height due to the increasing levels of phosphorus during either year of investigation as well as in pooled analysis of data.

Agrochemicals

It is explicit from data (Table 4.2) that during the year of 2003 as well as in 2004, all the agrochemicals were found at par in increasing plant height. However, in

Table 4.1: Effect of phosphorus sources, levels and agrochemicals on plant population

Treatments	Plant population (lakh ha^{-1})					
	20 DAS			At harvest		
	2003	2004	Pooled	2003	2004	Pooled
P Sources						
DAP	3.28	3.25	3.26	3.25	3.18	3.21
PROM	3.27	3.25	3.26	3.25	3.20	3.22
S Em ±	0.01	0.01	0.01	0.01	0.01	0.01
CD 5%	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})						
40	3.26	3.25	3.25	3.23	3.19	3.21
60	3.28	3.26	3.27	3.26	3.20	3.23
80	3.28	3.26	3.27	3.26	3.18	3.22
S Em ±	0.01	0.01	0.01	0.01	0.01	0.01
CD 5%	NS	NS	NS	NS	NS	NS
Agrochemicals*						
Brassinolide	-	-	-	3.27	3.21	3.24
Benzyladenine	-	-	-	3.25	3.20	3.23
KCl	-	-	-	3.23	3.18	3.20
Water	-	-	-	3.25	3.17	3.21
S Em ±	-	-	-	0.01	0.02	0.01
CD 5%	-	-	-	NS	NS	NS

* No effect of agrochemicals as they were sprayed at 30 DAS

Table 4.2: Effect of phosphorus sources, levels and agrochemicals on growth parameters

Treatments	Growth parameters					
	Plant height at harvest (cm)			Number of branches $plant^{-1}$		
	2003	2004	Pooled	2003	2004	Pooled
P Sources						
DAP	49.26	47.58	48.42	5.07	6.06	5.56
PROM	49.40	47.74	48.57	5.17	6.22	5.69
S Em ±	0.76	0.67	0.51	0.09	0.11	0.07
CD 5%	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})						
40	48.28	46.97	47.63	5.00	5.96	5.48
60	49.91	48.11	49.01	5.21	6.28	5.74
80	49.81	47.90	48.85	5.15	6.19	5.67
S Em ±	0.93	0.82	0.62	0.11	0.14	0.09
CD 5%	NS	NS	NS	NS	NS	NS
Agrochemicals						
Brassinolide	51.04	48.80	49.92	5.36	6.38	5.87
Benzyladenine	50.63	47.60	49.12	5.23	6.27	5.75
KCl	47.58	46.87	47.23	4.90	5.98	5.44
Water	48.08	47.35	47.72	4.99	5.93	5.46
S Em ±	1.08	0.95	0.72	0.12	0.16	0.10
CD 5%	NS	NS	2.01	0.35	NS	0.28

pooled analysis, foliar application of brassinolide significantly increased plant height over water spray and KCl. Further, it was found at par with benzyladenine. While, in pooled analysis, it was also observed that benzyladenine, KCl and water spray were found at par with each other. On pooled basis, brassinolide increased plant height by 4.61, 5.69 and 1.63 per cent as compared to water spray, KCl and benzyladenine, respectively.

4.2.2 Branches plant^{-1}

Phosphorus sources

It is apparent from data (Table 4.2) that no significant enhancement in number of branches per plant was observed under the influence of phosphorus sources during both the years of study as well as in pooled analysis.

Phosphorus levels

It is inferred from data (Table 4.2) that there was no significant increase in number of branches per plant due to the increasing levels of phosphorus during either year of investigation as well as in pooled analysis of data.

Agrochemicals

It is evident from data (Table 4.2) that foliar spray of brassinolide significantly increased number of branches plant^{-1} over water spray and KCl during 2003 as well as in pooled analysis. However, it was found at par with benzyladenine. Further, during 2003, application of benzyladenine also found at par with water spray and KCl. Moreover, in pooled analysis KCl and water spray remained at par with each other. On pooled basis, brassinolide increased number of branches by 7.51, 7.90 and 2.09 per cent as compared to water spray, KCl and benzyladenine, respectively.

4.2.3 Dry matter accumulation (g plant^{-1})

4.2.3.1 30 days after sowing

Phosphorus sources

Data (Table 4.3) indicate that during both years as well as in pooled analysis phosphorus sources were found non-significant with regards to dry matter accumulation.

Table 4.3: Effect of phosphorus sources, levels and agrochemicals on dry matter accumulation at various stages

Treatments	Dry matter accumulation (g plant^{-1})											
	30 DAS			40 DAS			70 DAS			At harvest		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources												
DAP	2.11	2.35	2.23	4.08	4.56	4.32	10.86	12.27	11.56	16.47	19.97	18.22
PROM	2.17	2.39	2.28	4.19	4.62	4.41	10.88	12.16	11.52	16.86	20.17	18.51
S Em ±	0.03	0.05	0.03	0.09	0.11	0.07	0.18	0.17	0.13	0.26	0.31	0.20
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})												
40	1.85	2.06	1.96	3.84	4.23	4.03	10.00	11.28	10.64	15.58	18.50	17.04
60	2.32	2.55	2.43	4.33	4.81	4.57	11.42	12.70	12.06	17.41	21.04	19.23
80	2.26	2.50	2.38	4.24	4.74	4.49	11.19	12.66	11.93	17.00	20.66	18.83
S Em ±	0.04	0.06	0.03	0.11	0.13	0.09	0.22	0.21	0.15	0.32	0.38	0.25
CD 5%	0.11	0.16	0.09	0.32	0.38	0.25	0.63	0.60	0.43	0.90	1.08	0.70
Agrochemicals												
Brassinolide	2.14	2.38	2.26	4.59	4.91	4.75	11.84	13.31	12.58	18.21	21.52	19.87
Benzyladenine	2.14	2.37	2.26	4.15	4.69	4.42	11.06	12.69	11.87	17.00	20.52	18.76
KCl	2.16	2.36	2.26	3.88	4.41	4.15	10.26	11.45	10.85	15.67	19.19	17.43
Water	2.13	2.38	2.25	3.93	4.36	4.14	10.32	11.42	10.87	15.77	19.05	17.41
S Em ±	0.04	0.06	0.04	0.13	0.15	0.10	0.26	0.25	0.18	0.37	0.44	0.29
CD 5%	NS	NS	NS	0.37	0.44	0.28	0.73	0.70	0.50	1.04	1.25	0.80

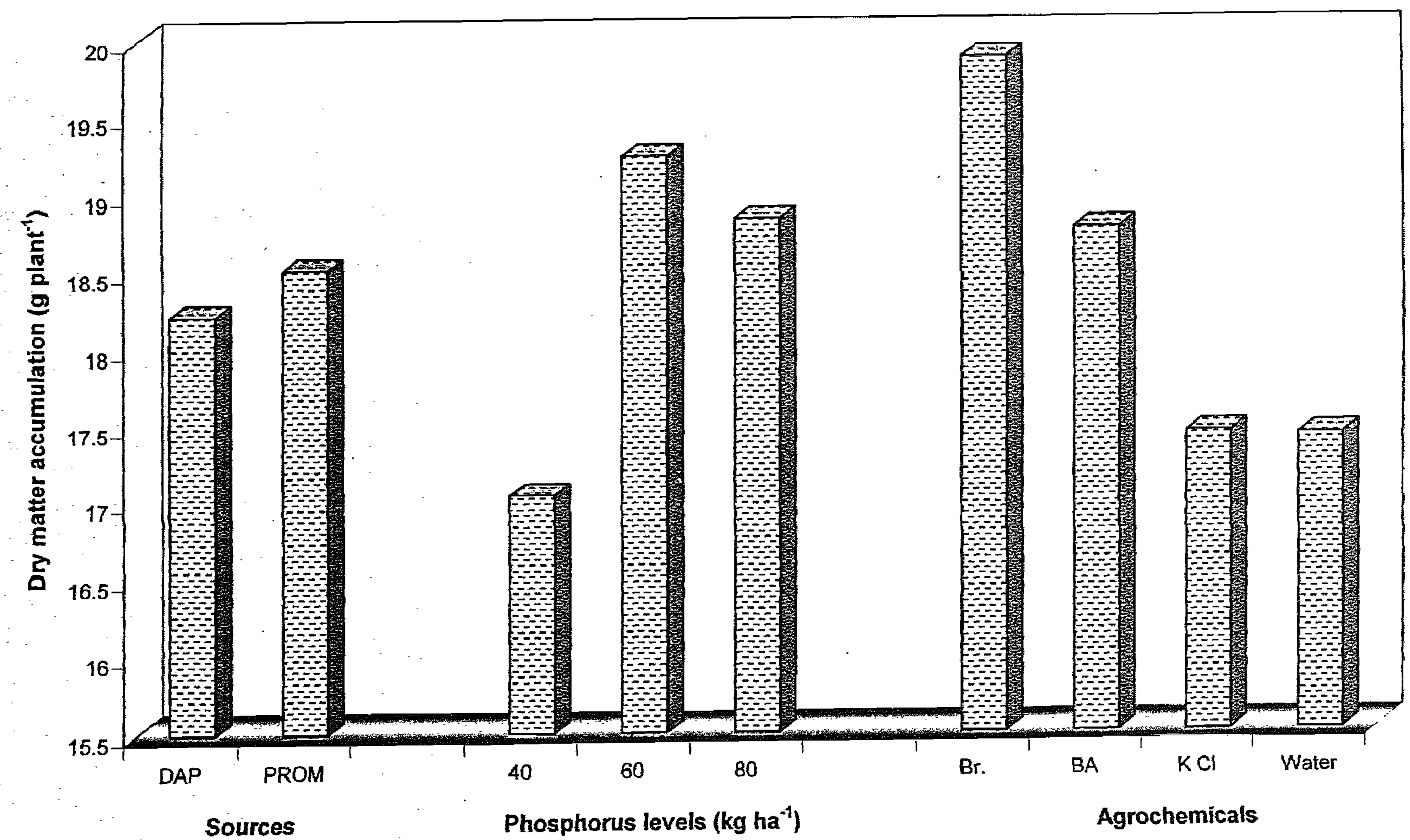


Fig. 4.1 : Effect of phosphorus sources, levels and agrochemicals on dry matter accumulation at harvest (pooled)

Phosphorus levels

A perusal of data (Table 4.3) reveal that application of 60 kg P_2O_5 ha^{-1} recorded maximum dry mater accumulation at 30 DAS during both the years as well as in pooled analysis, and found significantly superior over 40 kg P_2O_5 ha^{-1}. Further increase in phosphorus level up to 80 kg P_2O_5 ha^{-1} decreased dry matter accumulation but found statistically at par with 60 kg P_2O_5 ha^{-1}, but it remained significantly superior over 40 kg P_2O_5 ha^{-1}. On pooled basis, 60 kg P_2O_5 ha^{-1} showed an increase of 23.97 and 2.10 per cent over dry mater 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data pertaining to dry matter accumulation by soybean plant at 30 DAS, presented in Table 4.3 reveal that agrochemicals had non-significant effect during both the years as well as in pooled analysis.

4.2.3.2 40 days after sowing

Phosphorus sources

Data (Table 4.3) reveal that both phosphorus sources did not influence dry matter accumulation by soybean plant significantly at 40 DAS during both years as well as in pooled analysis of data.

Phosphorus levels

Data presented in Table 4.3 reveal that application of 60 kg P_2O_5 ha^{-1} accumulated significantly higher dry matter by soybean at 40 DAS over 40 kg P_2O_5 ha^{-1}. Further increase in phosphorus level up to 80 kg P_2O_5 ha^{-1} decreased dry matter accumulation, but, it remained at par with 60 kg P_2O_5 ha^{-1} during both years of experimentation as well as in pooled analysis, however, it was also found significantly superior as compared to 40 kg P_2O_5 ha^{-1}. On pooled basis, the increase in dry matter through 60 kg P_2O_5 ha^{-1} was of the order of 13.39 and 1.78 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data (Table 4.3) show that foliar application of brassinolide significantly increased dry matter accumulation at 40 DAS during both years of experimentation as well as in pooled analysis over rest of the agrochemicals, however, it was found at par with benzyladenine during 2004. Further, benzyladenine, KCl and water spray remained at par during either year of investigation as well as in pooled analysis. On pooled basis the magnitude of increase through brassinolide was of the order of 14.73, 14.45 and 7.46 per cent as compared to water spray, KCl and benzyladenine, respectively

4.2.3.3 70 days after sowing

Phosphorus sources

Data presented in Table 4.3 show that phosphorus sources had non-significant effect on dry matter accumulation per plant at 70 DAS during either year of investigation as well as in pooled analysis.

Phosphorus levels

Data (Table 4.3) indicate that significant increase in dry matter at 70 DAS was noticed upto 60 kg P_2O_5 ha^{-1} during both the years as well as in pooled analysis. However, further increase in phosphorus level upto 80 kg P_2O_5 ha^{-1} decreased dry matter accumulation but it remained at par with 60 kg P_2O_5 ha^{-1}. Further, crop fertilized with 80 kg P_2O_5 ha^{-1} also registered significantly higher dry matter as compared to 40 kg P_2O_5 ha^{-1} during both the years as well as in pooled analysis. On pooled basis, the magnitude of increase with 60 kg P_2O_5 ha^{-1} was found of the order of 13.34 and 1.09 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is evident from data (Table 4.3) that during the year of 2003 as well as in pooled analysis, foliar application of brassinolide significantly increased dry matter of soybean at 70 DAS over rest of the agrochemicals. However during 2004, it was found at par with benzyladenine. Further, during both the years as well as in pooled analysis, benzyladenine, also found significantly superior over water spray and KCl. While, water spray and KCl remained at par with each other with regards to DMA. On pooled basis, brassinolide increased 15.73, 15.94 and 5.98 per cent dry matter over water spray, KCl and benzyladenine, respectively.

4.2.3.4 At harvest

Phosphorus sources

Data presented in Tale 4.3 reveal that both phosphorus sources applied to soybean failed to exhibit any significant effect on dry matter accumulation at harvest during both the years as well as in pooled analysis of data.

Phosphorus levels

A perusal of data (Table 4.3) indicate that with the increasing levels of phosphorus, dry matter accumulation was also increased significantly up to 60 kg P_2O_5 ha^{-1} as compared to 40 kg P_2O_5 ha^{-1}. Further, phosphorus application up to 80 kg P_2O_5 ha^{-1} decreased the dry matter accumulation, when compared with 60 kg P_2O_5 ha^{-1} during both the years as well as in pooled analysis, but it was found significantly superior over 40 kg P_2O_5 ha^{-1}, however, it remained at par with 60 kg P_2O_5 ha^{-1}. On pooled basis, the magnitude of increase in dry matter with 60 kg P_2O_5 ha^{-1} was found to the tune of 12.85 and 2.12 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

An analysis of data (Table 4.3) show that during both the years as well as in pooled analysis of data, foliar spray of brassinolide significantly increased dry matter accumulation of soybean plant at harvest over rest of the agrochemicals. However, it remained at par with benzyladenine during the year of 2004. Further, benzyladenine was also found significantly superior as compared to KCl and water spray. While, KCl and water spray remained at par with each other during either year as well as in pooled analysis. On pooled basis, brassinolide produced 14.13, 13.99 and 5.92 per cent higher dry matter over water spray, KCl and benzyladenine, respectively.

4.2.4 Crop Growth Rate (g m^{-2} day^{-1})

4.2.4.1. Between 40 to 70 days after sowing

Phosphorus sources

It is apparent from data (Table 4.4) that both phosphorus sources applied to the crop did not registered any significant increase in crop growth rate between 40 to 70 DAS during both the years as well in pooled analysis.

Table 4.4: Effect of phosphorus sources, levels and agrochemicals on crop growth rate and relative growth rate at successive growth stages

Treatments	Crop growth rate (g m^{-2} day^{-1})						Relative growth rate (g g^{-1} day^{-1})					
	Between 40-70 DAS			Between 70 DAS - harvest			Between 40-70 DAS			Between 70 DAS - harvest		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources												
DAP	7.349	8.171	7.760	6.072	8.172	7.122	0.0329	0.0332	0.0330	0.0139	0.0163	0.0151
PROM	7.245	8.041	7.643	6.491	8.525	7.508	0.0319	0.0324	0.0321	0.0146	0.0168	0.0157
S Em ±	0.171	0.194	0.129	0.256	0.285	0.192	0.0007	0.0008	0.0005	0.0006	0.0005	0.0004
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})												
40	6.624	7.504	7.064	6.018	7.668	6.843	0.0319	0.0330	0.0325	0.0148	0.0165	0.0157
60	7.697	8.415	8.056	6.509	8.889	7.699	0.0325	0.0325	0.0325	0.0141	0.0169	0.0155
80	7.571	8.400	7.985	6.317	8.488	7.403	0.0326	0.0328	0.0327	0.0139	0.0163	0.0151
S Em ±	0.210	0.237	0.158	0.314	0.349	0.235	0.0008	0.0010	0.0006	0.0007	0.0006	0.0005
CD 5%	0.591	0.670	0.443	NS	0.985	0.657	NS	NS	NS	NS	NS	NS
Agrochemicals												
Brassinolide	7.895	8.982	8.438	6.944	8.766	7.855	0.0317	0.0334	0.0326	0.0144	0.0160	0.0152
Benzyladenine	7.502	8.533	8.018	6.444	8.376	7.410	0.0329	0.0335	0.0332	0.0144	0.0160	0.0152
KCl	6.869	7.444	7.157	5.820	8.194	7.007	0.0326	0.0319	0.0322	0.0141	0.0173	0.0157
Water	6.922	7.467	7.194	5.917	8.059	6.988	0.0322	0.0324	0.0323	0.0142	0.0170	0.0156
S Em ±	0.242	0.274	0.183	0.363	0.403	0.271	0.0010	0.0011	0.0007	0.0008	0.0007	0.0005
CD 5%	0.683	0.773	0.511	NS	NS	NS	NS	NS	NS	NS	NS	NS

Phosphorus levels

Data (Table 4.4) show that during both the years as well as in pooled analysis, crop growth rate was significantly increased when crop was fertilized with 60 and 80 kg P_2O_5 ha^{-1} as compared to 40 kg P_2O_5 ha^{-1}. However, application of 60 and 80 kg P_2O_5 ha^{-1} were found at par with each other. On pooled basis, application 60 kg P_2O_5 ha^{-1} increased CGR by 14.04 and 8.89 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

A perusal of data (Table 4.4) reveal that during both the years as well as in pooled analysis, foliar application of brassinolide significantly increased crop growth rate between 40 to 70 DAS over KCl and water spray. However, it was found at par with benzyladenine. Further, in the year 2003, benzyladenine, KCl and water spray remained statistically at par with each other, while during 2004 and in pooled analysis, benzyladenine was found significantly superior over KCl and water spray. Moreover, water spray and KCl remained at par with each other. On pooled basis, brassinolide increased CGR by 17.29, 17.90 and 5.24 per cent as compared to water spray, KCl and benzyladenine, respectively.

4.2.4.2 Between 70 days after sowing to harvest

Phosphorus sources

It is evident from data (Table 4.4) that CGR between 70 DAS to harvest was not increased significantly due to the application of phosphorus sources.

Phosphorus levels

A critical examination of data (Table 4.4) shows that during 2003, all the levels of phosphorus were found at par with each other. While during 2004 and in pooled analysis, application of 60 kg P_2O_5 ha^{-1} registered significantly higher CGR as compared to 40 kg P_2O_5 ha^{-1} but remained at par with 80 kg P_2O_5 ha^{-1}. However, 80 and 40 kg P_2O_5 ha^{-1} were also found statistically at par with each other. On pooled basis, 60 kg P_2O_5 ha^{-1} registered 12.50 and 4.00 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data pertaining to CGR, presented in Table 4.4 reveal that agrochemicals had non-significant effect during both the years as well as in pooled analysis.

4.2.5 Relative Growth Rate (g g^{-1} $plant^{-1}$)

Data presented in Table 4.4 show that during both the years of investigation as well as in pooled analysis of data all treatments failed to alter relative growth rate of soybean plant significantly between 40 to 70 DAS and between 70 DAS to harvest.

4.3 YIELD ATTRIBUTES

4.3.1 Pods $plant^{-1}$

Phosphorus sources

It is evident from data (Table 4.5) that application of both phosphorus sources could not significantly alter number of pods $plant^{-1}$ during both the experimental years as well as in pooled analysis.

Phosphorus levels

Data presented in Table 4.5 reveal that significant increase in number of pods $plant^{-1}$ was noticed when crop was fertilized with 60 kg P_2O_5 ha^{-1} as compared to 40 kg P_2O_5 ha^{-1} during both the experimental years as well as in pooled analysis. However, further increase in phosphorus level up to 80 kg P_2O_5 ha^{-1} reduced the number of pods $plant^{-1}$ as compared to 60 kg P_2O_5 ha^{-1} but it remained statistically significant over 40 kg P_2O_5 ha^{-1} during both the years as well as in pooled analysis. On pooled basis, 60 kg P_2O_5 ha^{-1} increased 12.34 and 0.80 per cent pods $plant^{-1}$ over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is explicit from the data (Table 4.5) that foliar spray of brassinolide significantly increased number of pods $plant^{-1}$ during the year of 2003 as well as in pooled analysis among all of the agrochemicals, however, in pooled analysis, it was found at par with benzyledenine. While benzyladenine was also found significantly superior over KCl and water spray during 2003 as well in pooled analysis. Further, during the year 2004, there was non-significant difference among all the agrochemicals. It was also found that foliar application of water spray and KCl

Table 4.5: Effect of phosphorus sources, levels and agrochemicals on yield attributes

Treatments	Yield attributes											
	Number of pods plant^{-1}			Number of seeds pod^{-1}			Seed index (g)			Seed yield plant^{-1} (g)		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources												
DAP	30.40	34.48	32.44	2.12	2.31	2.21	8.78	9.28	9.03	5.07	6.20	5.63
PROM	31.28	34.66	32.97	2.14	2.31	2.22	8.88	9.31	9.09	5.24	6.29	5.77
S Em ±	0.49	0.57	0.38	0.02	0.01	0.01	0.08	0.09	0.06	0.08	0.10	0.06
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})												
40	28.10	32.50	30.30	2.08	2.25	2.16	8.55	8.81	8.68	4.51	5.88	5.20
60	32.40	35.69	34.04	2.16	2.35	2.26	9.00	9.55	9.28	5.60	6.49	6.05
80	32.02	35.53	33.77	2.15	2.32	2.24	8.93	9.54	9.24	5.36	6.36	5.86
S Em ±	0.60	0.70	0.46	0.02	0.01	0.01	0.09	0.11	0.07	0.10	0.12	0.08
CD 5%	1.70	1.98	1.29	0.05	0.04	0.03	0.27	0.30	0.20	0.27	0.35	0.22
Agrochemicals												
Brassinolide	33.53	35.92	34.73	2.20	2.38	2.29	9.34	9.67	9.50	5.61	6.67	6.14
Benzyladenine	31.49	35.31	33.40	2.17	2.33	2.25	9.01	9.38	9.19	5.29	6.32	5.81
KCl	29.00	33.69	31.35	2.07	2.27	2.17	8.38	9.10	8.74	4.77	6.06	5.41
Water	29.32	33.36	31.34	2.08	2.25	2.16	8.59	9.05	8.82	4.95	5.93	5.44
S Em ±	0.70	0.81	0.53	0.02	0.02	0.01	0.11	0.12	0.08	0.11	0.14	0.09
CD 5%	1.96	NS	1.50	0.06	0.05	0.04	0.31	0.34	0.23	0.31	0.40	0.25

remained at par during both the years of investigation as well as in pooled analysis. On pooled basis, brassinolide increased number of pods plant^{-1} by 10.81, 10.78 and 3.98 per cent over water spray, KCl and benzyladenine, respectively.

4.3.2 Seeds pod^{-1}

Phosphorus sources

Data (Table 4.5) show that during either year as well as in pooled analysis, both phosphorus sources were found statistically at par with each other with regard to number of seeds pod^{-1}.

Phosphorus levels

A critical examination of data (Table 4.5) reveal that crop fertilized with 60 kg P_2O_5 ha^{-1} significantly increased number of seeds pod^{-1} over 40 kg P_2O_5 ha^{-1} during both the years as well as in pooled analysis. While, with the application of 80 kg P_2O_5 ha^{-1}, number of seeds pod^{-1} were reduced as compared to 60 kg P_2O_5 ha^{-1} but remained statistically superior over 40 kg P_2O_5 ha^{-1} and at par with 60 kg P_2O_5 ha^{-1}. Further, on pooled basis, the increment with 60 kg P_2O_5 ha^{-1} was found to the tune of 4.63 and 0.89 per cent as compared to 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is evident from data (Table 4.5) that among the agrochemicals, foliar spray of brassinolide significantly increased number of seeds pod^{-1} over KCl and water spray during both the years of experimentation as well as in pooled analysis. However, it was found at par with benzyladenine. Further, benzyladenine was also found significantly superior over KCl and water spray. While, KCl and water spray remained at par with each other during either years of study as well as in pooled analysis. On pooled basis, brassinolide increased number of seeds pod^{-1} by 6.02, 5.53 and 1.77 per cent over water spray, KCl and benzyladenide, respectively.

4.3.3 Seed index (g)

Phosphorus sources

Data presented in Table 4.5 show that both the phosphorus sources failed to exhibit any significant effect on seed index during both the years as well as in pooled analysis of data.

Phosphorus levels

A reference to data (Table 4.5) indicate that application of 60 and 80 kg P_2O_5 ha^{-1} significantly improved seed index over 40 kg P_2O_5 ha^{-1}, however, 60 kg P_2O_5 ha^{-1} registered higher seed index as compared to 80 kg P_2O_5 ha^{-1} but both remained statistically at par with each other during both the years as well as in pooled analysis. The pooled data show that 60 and 80 kg P_2O_5 ha^{-1} increased seed index by 6.91 and 6.45 per cent, respectively over 40 kg P_2O_5 ha^{-1}.

Agrochemicals

Data (Table 4.5) reveal that foliar spray of brassinolide found significantly superior in increasing seed index among all the agrochemicals during both the years of experimentation as well as in pooled analysis. However, it remained at par with benzyladenine during the year 2004. Further, benzyladenine was also found significantly superior over KCl and water spray during 2003 as well as in pooled analysis, while, in 2004, it remained at par with KCl and water spray. Moreover, KCl and water spray remained at par with each other during both the years as well as in pooled analysis. On pooled basis, brassinolide increased seed index by 7.71, 8.69 and 3.37 per cent over water spray, KCl and benzyladenine, respectively.

4.3.4 Seed yield plant^{-1} (g)

Phosphorus sources

A perusal of data (Table 4.5) indicate that both phosphorus sources could not bring about any significant variation in seed yield plant^{-1} during either year as well as in pooled analysis.

Phosphorus levels

Data (Table 4.5) reveal that phosphorus fertilization with 60 kg P_2O_5 ha^{-1} registered significantly higher seed yield plant^{-1} over 40 kg P_2O_5 ha^{-1} during both the years as well as in pooled analysis. While, 80 kg P_2O_5 ha^{-1} also produced significantly higher seed yield plant^{-1} over 40 kg P_2O_5 ha^{-1} but it produced less seed yield plant^{-1} than 60 kg P_2O_5 ha^{-1}. Further, it remained at par with 60 kg P_2O_5 ha^{-1}. On pooled basis, with the application of 60 kg P_2O_5 ha^{-1}, per cent increase was of the order of 16.34 and 3.24 as compared to 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

A reference to data (Table 4.5) show that during both the experimental years as well as in pooled analysis brassinolide significantly increased seed yield plant^{-1} over rest of the agrochemicals. However, during the year 2004, it remained at par with benzyladenine. Further, benzyladenine also found significantly superior over KCl and water spray during 2003 and in pooled analysis, however, it remained at par with KCl and water spray during 2004. While KCl and water spray remained at par with each other during both years as well as in pooled analysis. On pooled basis, foliar spray of brassinolide increased seed yield plant^{-1} to the tune of 12.86, 13.49 and 5.67 per cent over water spray, KCl and benzyladenine, respectively.

4.4 YIELDS AND HARVEST INDEX

4.4.1 Seed yield (q ha^{-1})

Phosphorus sources

Data (Table 4.6) reveal that phosphorus sources had non-significant effect on seed yield of soybean during both the years of experimentation as well as in pooled analysis.

Phosphorus levels

A perusal of data (Table 4.6) show that significant increase in seed yield was recorded with the application of 60 and 80 kg P_2O_5 ha^{-1} over 40 kg P_2O_5 ha^{-1}. However, increasing rate of phosphorus from 60 and 80 kg P_2O_5 ha^{-1} reduced the seed yield but both 60 and 80 kg P_2O_5 ha^{-1} remained at par with each other during both the years of study as well as in pooled analysis of data. Further, on pooled basis, 60 and 80 kg P_2O_5 increased seed yield by 9.14 and 7.18 per cent, respectively over 40 kg P_2O_5 ha^{-1}.

Agrochemicals

A reference to data presented in Table 4.6 reveal that during the year of 2003 as well as in pooled analysis, foliar spray of brassinolide significantly increased seed yield among all of the agrochemicals. Further benzyladenine was also found significantly superior over KCl and water spray. While during the year of 2004, brassinolide remaining at par with benzyladenine, found significantly superior over KCl and water spray. However, KCl and water spray remained at par during both

Table 4.6: Effect of phosphorus sources, levels and agrochemicals on yields and harvest index

Treatments	Yields (q ha^{-1})									Harvest index (%)		
	Seed			Stover			Biological					
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources												
DAP	12.04	14.76	13.40	29.29	34.46	31.87	41.33	49.22	45.27	29.16	29.98	29.57
PROM	12.34	14.85	13.59	29.78	34.60	32.19	42.12	49.44	45.78	29.32	30.06	29.69
S Em ±	0.19	0.22	0.14	0.42	0.46	0.31	0.47	0.55	0.36	0.43	0.37	0.28
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})												
40	11.64	13.97	12.80	28.46	33.05	30.75	40.10	47.02	43.56	29.05	29.71	29.38
60	12.67	15.26	13.97	30.09	35.38	32.74	42.76	50.65	46.70	29.56	30.18	29.87
80	12.26	15.17	13.72	30.04	35.16	32.60	42.31	50.33	46.32	29.10	30.17	29.64
S Em ±	0.23	0.27	0.18	0.52	0.57	0.39	0.58	0.68	0.45	0.52	0.45	0.35
CD 5%	0.65	0.76	0.50	1.47	1.60	1.08	1.64	1.91	1.25	NS	NS	NS
Agrochemicals												
Brassinolide	13.33	15.87	14.60	31.74	36.05	33.90	45.07	51.93	48.50	29.49	30.57	30.03
Benzyladenine	12.48	15.11	13.80	30.02	35.39	32.71	42.50	50.50	46.50	29.52	30.01	29.76
KCl	11.44	14.17	12.80	28.09	33.39	30.74	39.53	47.56	43.55	28.97	29.82	29.40
Water	11.51	14.05	12.78	28.27	33.28	30.78	39.78	47.34	43.56	28.97	29.68	29.33
S Em ±	0.27	0.31	0.20	0.60	0.66	0.44	0.67	0.78	0.52	0.60	0.52	0.40
CD 5%	0.75	0.88	0.57	1.69	1.85	1.24	1.89	2.20	1.44	NS	NS	NS

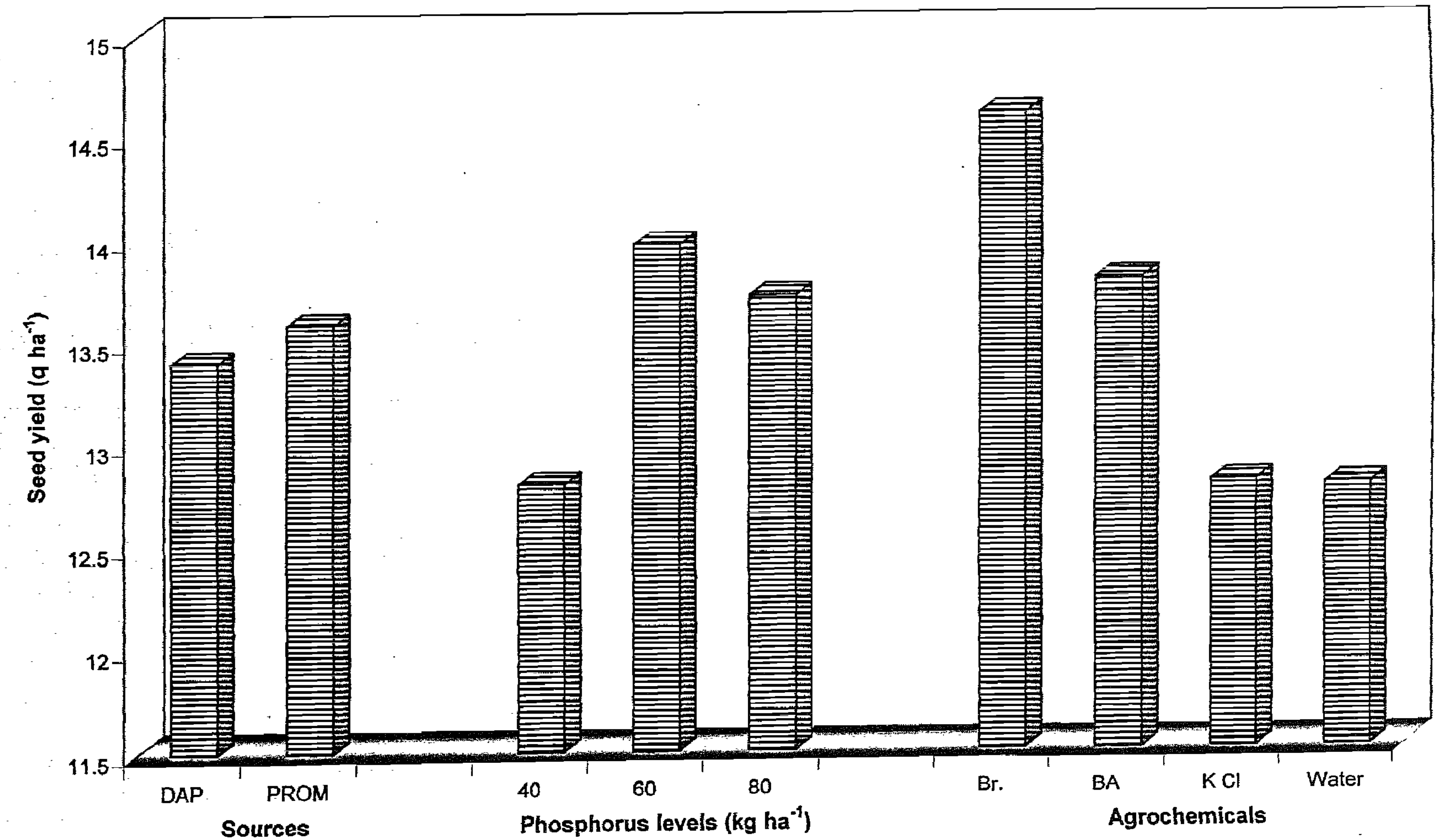


Fig. 4.2 : Effect of phosphorus sources, levels and agrochemicals on seed yield (pooled)

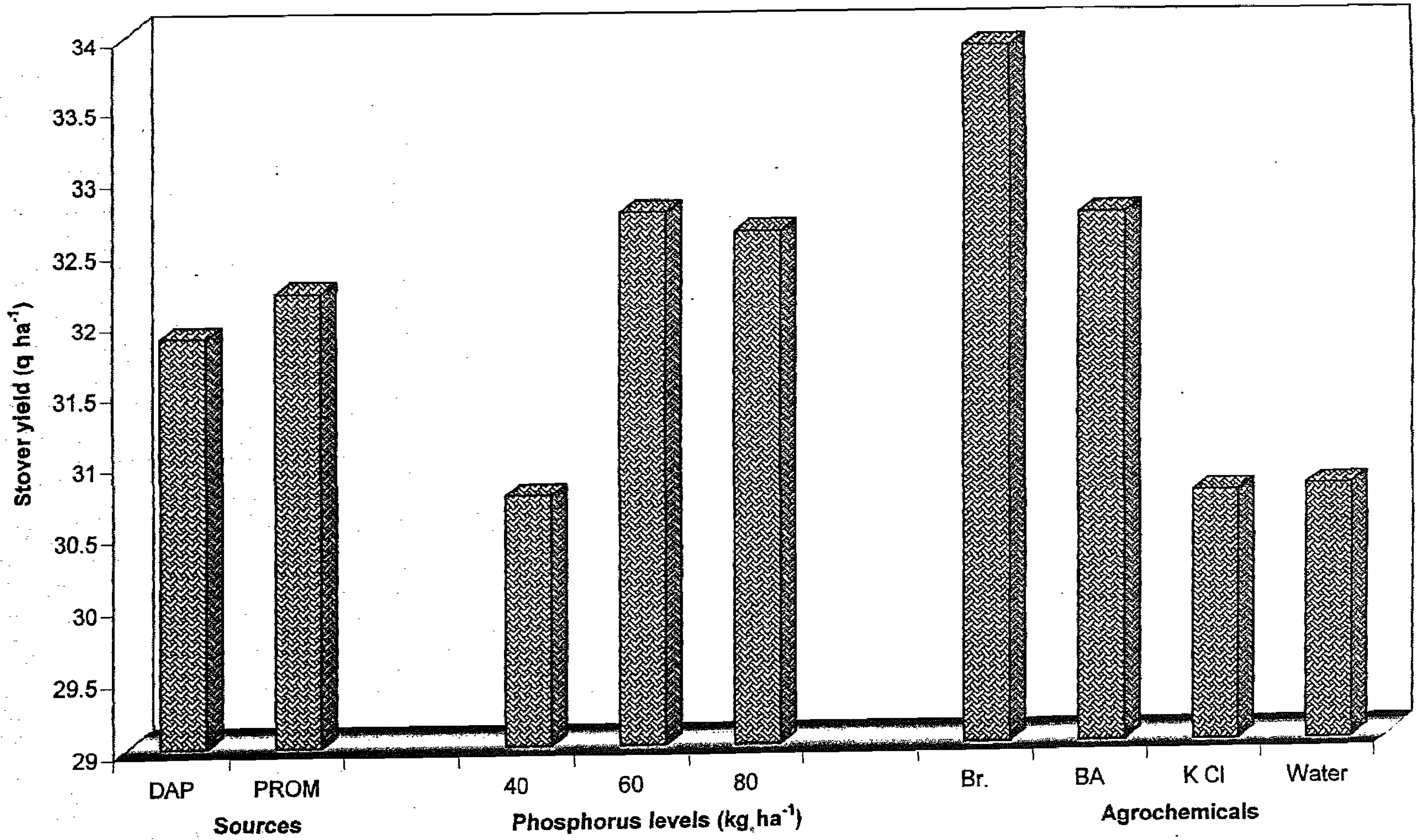


Fig. 4.3 : Effect of phosphorus sources, levels and agrochemicals on stover yield (pooled)

years of study and in pooled analysis. On pooled basis, the per cent increase with brassinolide was found to the magnitude of 14.24, 14.06 and 5.79 over water spray, KCl and benzyladenine, respectively.

4.4.2 Stover yield (q ha^{-1})

Phosphorus sources

Data (Table 4.6) clearly indicate that stover yield remained fairly stable under the influence of phosphorus sources during both the years of study as well as in pooled analysis.

Phosphorus levels

It is evident from data (Table 4.6) that increasing level of phosphorus from 40 to 60 kg P_2O_5 ha^{-1} significantly increased stover yield of crop but further increase in phosphorus level from 60 to 80 kg P_2O_5 ha^{-1} failed to exhibit any advantage during both the years as well as in pooled analysis but both higher phosphorus levels were found at par with each other. On pooled basis, the extent of increase, with 60 and 80 kg P_2O_5 ha^{-1} was gained by 6.47 and 6.02 per cent, respectively over 40 kg P_2O_5 ha^{-1}.

Agrochemicals

Data (Table 4.6) demonstrate that foliar application of brassinolide significantly increased stover yield over rest of the agrochemicals during both the years of experimentation as well as in pooled analysis, however, it remained at par with benzyladenine during the year of 2004 as well as in pooled analysis. Further during both years of study and in pooled analysis, benzyladenine also found significantly superior over KCl and water spray, while KCl and water spray were found at par with each other. On pooled basis, brassinolide increased seed yield by 10.14, 10.27 and 3.64 per cent as compared to water spray, KCl and benzyladenine, respectively.

4.4.3 Biological yield (q ha^{-1})

Phosphorus sources

Across the years as well as in pooled analysis, data (Table 4.6) show that both phosphorus sources failed to produce significant impact on biological yield.

Phosphorus levels

A perusal of data (Table 4.6) reveal that during either year of experimentation as well as in pooled analysis, phosphorus fertilization upto 80 kg P_2O_5 ha^{-1} significantly enhanced biological yield as compared to 40 kg P_2O_5 ha^{-1} but significant response was found only upto 60 kg P_2O_5 ha^{-1} and further increase in phosphorus level up to 80 kg P_2O_5 ha^{-1} reduced biological yield as against 60 kg P_2O_5 ha^{-1}. Further, 60 and 80 kg P_2O_5 ha^{-1} levels were found at par with each other. On pooled basis, 60 kg P_2O_5 ha^{-1} recorded 7.21 and 0.82 per cent higher biological yield over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

A reference to data (Table 4.6) show that during the year 2003, and in pooled analysis, foliar spray of brassinolide registered significantly higher biomass of crop among all of the agrochemicals. However, during 2004, it was found at par with benzyladenine. Further benzyladenine was also found significantly superior over KCl and water spray. It was also observed that KCl and water spray remained at par between them across the years as well as in pooled analysis. On pooled basis, brassinolide increased biological yield by 11.34, 11.36 and 4.30 per cent over water spray, KCl and benzyladenine, respectively.

4.4.4 Harvest index (%)

A perusal of data (Table 4.6) show that during each year of experimentation as well as in pooled analysis, harvest index failed to show any significant variation under the influence of various treatments.

4.5 BIOCHEMICAL CONSTITUENTS OF LEAVES

4.5.1 Relative water content (%)

4.5.1.1 40 days after sowing

Phosphorus sources

An examination of data (Table 4.7) reveal that both phosphorus sources had non-significant effect on relative water content of leaves at 40 DAS during both the experimental years as well as in pooled analysis.

Table 4.7: Effect of phosphorus sources, levels and agrochemicals on relative water content and proline content

Treatments	Relative water content (%)						Proline content (μ mole g^{-1} fresh weight)					
	40 DAS			70 DAS			40 DAS			70 DAS		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources												
DAP	76.74	79.00	77.87	77.02	79.21	78.11	2.23	2.13	2.18	2.49	2.19	2.34
PROM	76.83	79.17	78.00	77.06	79.39	78.23	2.22	2.11	2.16	2.47	2.18	2.32
S Em ±	0.64	0.54	0.42	0.71	0.78	0.53	0.01	0.01	0.01	0.01	0.01	0.01
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})												
40	75.63	78.80	77.22	76.59	78.74	77.66	2.23	2.14	2.19	2.50	2.19	2.35
60	77.45	79.28	78.37	77.32	79.72	78.52	2.21	2.10	2.16	2.46	2.18	2.32
80	77.27	79.18	78.23	77.21	79.44	78.32	2.22	2.12	2.17	2.47	2.18	2.32
S Em ±	0.79	0.66	0.52	0.87	0.96	0.65	0.02	0.01	0.01	0.02	0.01	0.01
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Agrochemicals												
Brassinolide	79.71	80.87	80.29	80.03	81.63	80.83	2.14	2.07	2.11	2.40	2.13	2.27
Benzyladenine	76.62	79.29	77.96	77.02	79.71	78.37	2.22	2.11	2.17	2.47	2.18	2.33
KCl	76.40	78.94	77.67	76.29	78.02	77.15	2.24	2.14	2.19	2.48	2.19	2.34
Water	74.42	77.23	75.83	74.81	77.85	76.33	2.28	2.17	2.22	2.56	2.23	2.39
S Em ±	0.91	0.76	0.60	1.01	1.11	0.75	0.02	0.02	0.01	0.02	0.02	0.01
CD 5%	2.57	2.16	1.66	2.84	NS	2.09	0.06	0.04	0.04	0.06	0.05	0.04

Phosphorus levels

It is evident from data (Table 4.7) that different phosphorus levels applied to crop failed to exhibit any significant effect on relative water content of leaves at 40 DAS during both the years of experimentation as well as in pooled analysis of data.

Agrochemicals

Data (Table 4.7) reveal that during the year 2003 as well as in pooled analysis, foliar application of brassinolide significantly increased RWC of leaves at 40 DAS among all of the agrochemicals. However, in the year of 2004, it was found at par with benzyladenine and KCl. Further, during 2003 and 2004, benzyladenine, KCl and water spray found statistically at par among themselves. While in pooled analysis benzyladenine remained at par with KCl. In pooled analysis, all the agrochemicals remained significantly superior over water spray. On pooled basis, brassinolide increased RWC of leaves by 5.88, 3.37 and 2.99 per cent over water spray, KCl and benzyladenine, respectively.

4.5.1.2 70 days after sowing

Phosphorus sources

Data (Table 4.7) show that phosphorus sources failed to enhance RWC of leaves significantly during both the years of study as well as in pooled analysis of data.

Phosphorus levels

A close examination of data (Table 4.7) indicate that during either years of experimentation as well as in pooled analysis, increasing levels of phosphorus increased RWC of leaves but were found statistically at par among themselves.

Agrochemicals

A perusal of data (Table 4.7) show that during the year 2003 as well as in pooled analysis, foliar application of brassinolide significantly increased RWC of leaves over rest of the agrochemicals. Further, benzyladenine, KCl and water spray were found statistically at par with each other. However, during the investigation year 2004, all the agrochemicals were found statistically at par among themselves. On pooled basis, brassinolide increased RWC of leaves by 5.89, 4.77 and 3.14 per cent over water spray, KCl and benzyladenine, respectively.

4.5.2 Proline content (μ mole g^{-1} fresh weight of leaf)

4.5.2.1 40 days after sowing

Phosphorus sources

Data (Table 4.7) reveal that during each year as well as in pooled analysis of data, both phosphorus sources were found statistically at par with each other with regard to proline content.

Phosphorus levels

Data (Table 4.7) show that during either year as well as in pooled analysis, all the phosphorus levels were found statistically non-significant with each other with regard to reducing proline content at 40 DAS.

Agrochemicals

It is evident from data (Table 4.7) that during both the years as well as in pooled analysis, foliar spray of brassinolide significantly reduced proline content among all of the agrochemicals. However, during 2004, it was found at par with benzyladenine. Further, during 2003, benzyladenine, KCl and water spray remained at par with each other. While during 2004 and in pooled analysis, benzyladenine and KCl as well as KCl and water spray were found at par with each other. On pooled basis, brassinolide reduced proline content by 4.95, 3.65 and 2.76 per cent as compared to water spray, KCl and benzyladenine, respectively.

4.5.2.2 70 days after sowing

Phosphorus sources

A reference to data (Table 4.7) show that phosphorus sources failed to exhibit any significant reduction in proline content of leaves during either years of experimentation as well as in pooled analysis of data.

Phosphorus levels

It is explicit from data (Table 4.7) that during both the years of investigation as well as in pooled analysis, both phosphorus levels were found at par among themselves in reducing proline content.

Agrochemicals

Data (Table 4.7) pertaining to proline content reveal that during both the experimental years as well as in pooled analysis, foliar application of brassinolide significantly reduced proline content of leaves, among all of the agrochemicals. However, it remained at par with benzyladenine during the year 2004. Further, during 2003 and in pooled analysis, benzyladenine and KCl were found at par with each other. However, during 2004 benzyladenine, KCl and water spray remained at par among them. On pooled basis, brassinolide reduced proline content of leaves by 5.34, 3.08 and 2.73 per cent as compared to water spray, KCl and benzyladenine, respectively.

4.6 QUALITY PARAMETERS

4.6.1 Oil content of seed (%)

Phosphorus sources

Data (Table 4.8) show that phosphorus sources failed to alter oil content significantly during both years of experimentation as well as in pooled analysis.

Phosphorus levels

Data presented in Table 4.8 indicate that crop fertilized with 60 and 80 kg P_2O_5 ha^{-1} significantly increased oil content of seed over 40 kg P_2O_5 ha^{-1} during both the years of study as well as in pooled analysis. However, both phosphorus levels 60 and 80 kg P_2O_5 ha^{-1} were found at par with each other during either year of investigation but 60 kg P_2O_5 ha^{-1} registered higher oil content. Further, in pooled analysis 60 kg P_2O_5 ha^{-1} was found significantly superior over 40 and 80 kg P_2O_5 ha^{-1}. On pooled basis, the extent of increase in oil content with 60 kg P_2O_5 ha^{-1} was 9.90 and 1.59 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is explicit from data (Table 4.8) that foliar spray of brassinolide significantly increased oil content of seed among all of the agrochemicals during either year of

Table 4.8: Effect of phosphorus sources, levels and agrochemicals on quality parameters

Treatments	Quality parameters											
	Oil content (%)			Oil yield (kg ha^{-1})			Protein content (%)			Protein yield (kg ha^{-1})		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources												
DAP	18.53	19.49	19.01	223.85	288.60	256.22	39.71	40.87	40.29	479.03	603.96	541.50
PROM	18.64	19.60	19.12	230.28	291.73	261.01	39.78	40.95	40.36	491.46	607.93	549.70
S Em ±	0.09	0.13	0.08	3.75	4.95	3.10	0.21	0.23	0.15	8.01	9.02	6.03
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})												
40	17.64	18.33	17.98	205.14	256.27	230.70	39.09	40.27	39.68	454.63	562.92	508.78
60	19.16	20.36	19.76	243.42	311.24	277.33	40.20	41.33	40.77	510.59	631.02	570.81
80	18.94	19.95	19.45	232.63	302.99	267.81	39.95	41.13	40.54	490.53	623.89	557.21
S Em ±	0.12	0.16	0.10	4.59	6.06	3.80	0.25	0.28	0.19	9.81	11.05	7.39
CD 5%	0.33	0.45	0.28	12.96	17.09	10.63	0.71	0.78	0.52	27.68	31.18	20.67
Agrochemicals												
Brassinolide	19.06	19.96	19.51	254.61	317.90	286.25	40.53	41.63	41.08	540.50	661.27	600.89
Benzyladenine	18.61	19.65	19.13	232.43	297.58	265.01	40.28	41.45	40.86	502.85	626.31	564.58
KCl	18.57	19.32	18.94	212.55	274.05	243.30	38.99	40.30	39.65	446.15	571.34	508.75
Water	18.09	19.26	18.68	208.66	271.13	239.90	39.18	40.26	39.72	451.49	564.86	508.18
S Em ±	0.13	0.18	0.11	5.30	7.00	4.39	0.29	0.32	0.22	11.33	12.76	8.53
CD 5%	0.38	0.52	0.32	14.97	19.74	12.28	0.83	0.90	0.61	31.96	36.00	23.87

experimentation as well as in pooled analysis, however, in 2004, it remained at par with benzyladenine. While, benzyladenine, KCl and water spray were also found at par among themselves in 2004. While, in 2003 and in pooled analysis benzyladenine and KCl were found statistically non-significant with each other and both remained significantly superior over water spray. Moreover, in pooled analysis, KCl and water spray were found at par with each other. On pooled basis, the magnitude of increase in oil content with brassinolide was of the order of 4.44, 3.01 and 1.99 per cent over water spray, KCl and benzyladenine, respectively.

4.6.2 Oil yield (kg ha^{-1})

Phosphorus sources

A critical examination of data (Table 4.8) reveal that no significant difference was seen between phosphorus sources with regards to oil yield during each year as well as in pooled analysis.

Phosphorus levels

It is evident from data (Table 4.8) that during both years of investigation phosphorus fertilization with 60 kg P_2O_5 ha^{-1} proved significantly superior with regard to oil yield over 40 P_2O_5 ha^{-1}, but further increase in phosphorus level at 80 kg P_2O_5 ha^{-1}, oil yield was reduced as compared to 60 kg P_2O_5 ha^{-1}, however, 80 kg P_2O_5 ha^{-1} was found at par with 60 kg P_2O_5 ha^{-1}. On pooled basis, 60 kg P_2O_5 ha^{-1} increase oil yield of the order of 20.21 and 3.55 per cent as compared to 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data (Table 4.8) reveal that foliar application of brassinolide significantly increased oil yield over rest of the agrochemicals during each experimental year as well as in pooled analysis. Further benzyladenine was also found significantly superior over KCl and water spray. While KCl and water spray remained at par with each other during each year of study and in pooled analysis also. On pooled basis, brassinolide yielded 19.32, 17.65 and 8.10 per cent higher oil as compared to water spray, KCl and benzyladenine, respectively.

4.6.3 Protein content of seed (%)

Phosphorus sources

Data (Table 4.8) demonstrate that application of phosphorus through any source under study had no significant effect on protein content during both the years of study as well as in pooled analysis.

Phosphorus levels

It is inferred from data (Table 4.8) that phosphorus fertilization with 60 and 80 kg P_2O_5 ha^{-1} significantly increased protein content of seed during either year of experimentation as well as in pooled analysis over 40 kg P_2O_5 ha^{-1}. Though, 60 and 80 kg P_2O_5 ha^{-1} were found statistically at par with each other but 60 kg P_2O_5 ha^{-1} recorded maximum protein content of seed. Further, on pooled basis, 60 kg P_2O_5 ha^{-1} increased protein content by 2.75 and 0.57 per cent, respectively over 40 and 80 kg P_2O_5 ha^{-1}.

Agrochemicals

During both the years as well as in pooled analysis, data (Table 4.8) show that significantly higher protein content was recorded with the foliar spray of brassinolide over KCl and water spray. However, it was found at par with benzyladenine. Further, benzyladenine was also found significantly superior over KCl and water spray. While during each year as well as in pooled analysis, KCl and water spray remained at par with each other. On pooled basis, brassinolide registered 3.42, 3.60 and 0.54 per cent higher protein content over water spray, KCl and benzyladenine, respectively.

4.6.4 Protein yield (kg ha^{-1})

Phosphorus sources

A reference to data (Table 4.8) reveals that phosphorus fertilization through both sources had non-significant effect on protein yield during both the years of investigation as well as in pooled analysis of data.

Phosphorus levels

It is apparent from data (Table 4.8) that application of 60 and 80 kg P_2O_5 ha^{-1} registered significantly higher protein yield over 40 kg P_2O_5 ha^{-1} during both the experimental years as well as in pooled analysis. Further, with the increasing level of phosphorus from 60 to 80 kg P_2O_5 ha^{-1} protein yield was reduced but found statistically non-significant. On pooled basis, protein yield with 60 kg P_2O_5 ha^{-1} was increased by 12.19 and 2.44 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is explicit form data (Table 4.8) that during both experimental years as well as in pooled analysis, foliar application of brassinolide significantly increased protein yield among all of the agrochemicals. However during 2004, it was found at par with benzyladenine. Further, benzyladenine was also found significantly superior over KCl and water spray, while KCl and water spray remained at par with each other during either year as well as in pooled analysis. On pooled basis, brassinolide produced 18.24, 18.11 and 6.43 per cent higher protein as compared to water spray, KCl and benzyladenine, respectively.

4.7 NUTRIENT CONTENT AND UPTAKE

4.7.1 Nitrogen Content (%)

4.7.1.1 30 days after sowing

Phosphorus sources

Data (Table 4.9) pertaining to N content at 30 DAS reveal that phosphorus sources had non-significant effect during both the years as well as in pooled analysis.

Phosphorus levels

A perusal of data presented in Table 4.9 reveal that application of both 60 and 80 kg P_2O_5 ha^{-1} significantly increased N content during both the years as well as in pooled analysis as compared to 40 kg P_2O_5 ha^{-1} and both remained at par with each other. However, N content was reduced, when crop was fertilized with 80 kg P_2O_5 ha^{-1} as compared to 60 kg P_2O_5 ha^{-1}. On pooled basis, 60 kg P_2O_5 ha^{-1} increased N content by 2.57 and 0.54 per cent over 40 and 80 kg ha^{-1}, respectively.

Agrochemicals

Data (Table 4.9) reveal that different agrochemicals did not influence N content of plant in any of the years of study and in pooled analysis.

Table 4.9: Effect of phosphorus sources, levels and agrochemicals on nitrogen content of plants at various stages

Treatments	Nitrogen content (%)								
	30 DAS			40 DAS			70 DAS		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources									
DAP	3.835	3.883	3.859	3.422	3.495	3.459	2.746	2.735	2.740
PROM	3.853	3.893	3.873	3.433	3.500	3.467	2.771	2.740	2.756
S Em ±	0.011	0.017	0.010	0.011	0.016	0.010	0.012	0.016	0.010
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})									
40	3.798	3.817	3.807	3.381	3.422	3.401	2.715	2.686	2.701
60	3.874	3.937	3.905	3.455	3.542	3.498	2.792	2.778	2.785
80	3.858	3.910	3.884	3.447	3.530	3.488	2.768	2.749	2.758
S Em ±	0.014	0.021	0.013	0.014	0.020	0.012	0.014	0.019	0.012
CD 5%	0.039	0.060	0.036	0.039	0.055	0.033	0.040	0.055	0.034
Agrochemicals									
Brassinolide	3.848	3.890	3.869	3.468	3.540	3.504	2.791	2.801	2.796
Benzyladenine	3.828	3.886	3.857	3.453	3.532	3.492	2.779	2.765	2.772
KCl	3.852	3.888	3.870	3.384	3.469	3.426	2.720	2.700	2.710
Water	3.846	3.888	3.867	3.405	3.450	3.428	2.743	2.685	2.714
S Em ±	0.016	0.024	0.015	0.016	0.023	0.014	0.016	0.022	0.014
CD 5%	NS	NS	NS	0.045	0.064	0.039	0.046	0.063	0.039

4.7.1.2 40 days after sowing

Phosphorus sources

Data presented in Table 4.9 show non-significant difference in N content of plant due to the phosphorus sources during both the years as well a in pooled analysis.

Phosphorus levels

Data related to N content at 40 DAS presented in Table 4.9 reveal that increasing levels of phosphorus significantly increased N content upto 60 kg P_2O_5 ha^{-1} during either year of investigation as well as in pooled analysis. Further increase in phosphorus level upto 80 kg P_2O_5 ha^{-1} had no significant effect in increasing N content as compared to 60 kg P_2O_5 ha^{-1} and N content was reduced than 60 kg P_2O_5 ha^{-1}, however, it was found at par with 60 kg P_2O_5 ha^{-1}. On pooled basis, 60 kg P_2O_5 ha^{-1} increased N content to the tune of 2.85 and 0.29 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

A perusal of data (Table 4.9) show that among the agrochemicals, foliar spray of brassinolide registered significantly higher N content over water spray and KCl, however, it was found at par with benzyladenine during both the years of experimentation as well as in pooled analysis of data. During 2004, benzyladenine remained at par with KCl also. Further, KCl and water spray were also found statistically at par with each other during either year as well as in pooled analysis. On pooled basis, brassinolide increased N content by 2.21, 2.27 and 0.34 per cent over water spray, KCl and benzyladenine, respectively.

4.7.1.3 70 days after sowing

Phosphorus sources

A reference to data presented in Table 4.9 reveal that during both years as well as in pooled analysis, both phosphorus sources were failed to increase N content significantly over each other.

Phosphorus levels

Data (Table 4.9) show that compared to 40 kg P_2O_5 ha^{-1} crop fertilized with 60 and 80 kg P_2O5 ha^{-1} had significantly higher N content during each experimental year as well as in pooled analysis. Further, 60 and 80 kg P_2O_5 ha^{-1} remained at par with each other. However, 60 kg P_2O_5 ha^{-1}registered higher N content as compared to 80 kg P_2O_5 ha^{-1}. On pooled basis, it increased N content by 3.10 ad 0.98 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is explicit from data (Table 4.9) that during both the years of investigation as well as in pooled analysis, foliar application of brassinolide proved significantly superior over KCl and water spray with regard to N content, however, it remained at par with benzyladenine. Further, benzyladenine was found at par with water spray during 2003, however during the year 2004 and in pooled analysis, it was found statistically superior over KCl and water spray. While KCl was found at par with water spray during both years as well as in pooled analysis. On pooled basis, the magnitude of increase in N content, with the foliar spray of brassinolide was recorded by 3.02, 3.17 and 0.87 per cent over water spray, KCl and benzyladenine, respectively.

4.7.1.4 In seed at harvest

Phosphorus sources

It is evident from the data (Table 4.10) that during each year of investigation as well as in pooled analysis phosphorus sources failed to alter N content of seed significantly.

Phosphorus levels

It is inferred from data (Table 4.10) that N content of seed was significantly increased with 60 and 80 kg P_2O_5 ha^{-1} as compared to 40 kg P_2O_5 ha^{-1}. However, both higher levels remained at par during both the experimental years as well as in pooled analysis but 60 kg P_2O_5 ha^{-1} registered higher N content than 80 kg P_2O_5 ha^{-1}. On pooled basis, 60 kg P_2O_5 ha^{-1} registered 2.76 and 0.57 per cent higher N content of seed over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

A reference to data (Table 4.10) reveal that foliar application of brassinolide registered significantly higher N content in seed over KCl and water spray, however, it remained at par with foliar spray of benzyladenine during both the years as well as

Table 4.10: Effect of phosphorus sources, levels and agrochemicals on nitrogen content of seed and stover

Treatments	Nitrogen content (%)					
	Seed			Stover		
	2003	2004	Pooled	2003	2004	Pooled
P Sources						
DAP	6.354	6.539	6.447	1.409	1.448	1.428
PROM	6.364	6.552	6.458	1.414	1.430	1.422
S Em ±	0.033	0.036	0.024	0.009	0.007	0.006
CD 5%	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})						
40	6.254	6.443	6.348	1.399	1.413	1.406
60	6.433	6.614	6.523	1.423	1.455	1.439
80	6.391	6.580	6.486	1.412	1.448	1.430
S Em ±	0.041	0.044	0.030	0.011	0.009	0.007
CD 5%	0.114	0.125	0.084	NS	0.026	0.020
Agrochemicals						
Brassinolide	6.485	6.661	6.573	1.434	1.461	1.448
Benzyladenine	6.445	6.632	6.538	1.430	1.453	1.442
KCl	6.239	6.448	6.344	1.389	1.425	1.407
Water	6.269	6.441	6.355	1.394	1.416	1.405
S Em ±	0.047	0.051	0.035	0.013	0.011	0.008
CD 5%	0.132	0.144	0.097	0.037	0.030	0.023

in pooled analysis. Further, benzyladenine was also found significantly superior over water spray and KCl. While, KCl and water spray were also found statistically at par with each other during either year of study as well as in pooled analysis. On pooled basis, brassinolide registered 3.43, 3.60 and 0.54 per cent higher N content in seed over water spray, KCl and benzyladenine, respectively.

4.7.1.5 In stover at harvest

Phosphorus sources

Data (Table 4.10) show that phosphorus sources applied to soybean crop failed to increase N content in stover significantly during any year of experimentation as well as in pooled analysis.

Phosphorus levels

It is inferred from data (Table 4.10) that N content in stover significantly increased with 60 and 80 kg P_2O_5 ha^{-1} over 40 kg P_2O_5 ha^{-1} during 2004 as well as in pooled analysis, however, 80 kg P_2O_5 ha^{-1} registered less N content in stover but found at par with 60 kg P_2O_5 ha^{-1}. Further, during 2003, all levels of P_2O_5 remained non-significant. On pooled basis, 60 kg P_2O_5 ha^{-1} increased N content to the tune of 2.34 and 0.63 per cent as compared to 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data presented in Table 4.10 show that foliar spray of brassinolide registered maximum N content in stover and found significantly superior over KCl and water spray, however, it was found at par with benzyladenine during both year as well as pooled analysis. Further, during 2003, benzyladenine remained at par with water spray and during 2004, it was found at par with KCl. While in pooled analysis, it was found significantly superior over water spray and KCl. Moreover, during both experimental years and in pooled analysis water spray and KCl were found statistically at par with each other. On pooled basis, brassinolide increased N content by 3.06, 2.91 and 0.42 per cent over water spray, KCl and benzyladenine, respectively.

4.7.2 Phosphorus Content (%)

4.7.2.1 30 days after sowing

Phosphorus sources

A perusal of data (Table 4.11) reveal that phosphorus sources did not influence P content significantly during both the years of experimentation as well as in pooled analysis.

Phosphorus levels

Data (Table 4.11) reveal that during either year as well as in pooled analysis, 80 and 60 kg P_2O_5 ha^{-1} significantly increased P content of soybean over 40 kg P_2O_5 ha^{-1}. However, 80 kg P_2O_5 ha^{-1} registered maximum P content but was found at par with 60 kg P_2O_5 ha^{-1} with regards to P content. Further, on pooled basis, it increased P content to the extent of 5.67 and 0.73 per cent over 40 and 60 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is evident from the data (Table 4.11) that all agrochemicals were found at par among themselves during either year as well as in pooled analysis with regard to P content in soybean.

4.7.2.2 40 days after sowing

Phosphorus sources

Across the years as well as in pooled analysis data (Table 4.11)show that both sources failed to show significant impact on P content.

Phosphorus levels

It is inferred from the data (Table 4.11) that at 40 DAS of crop growth, phosphorus fertilization upto 80 kg P_2O_5 ha^{-1} significantly increased P content over 40 and 60 P_2O_5 ha^{-1} during both the years of investigation as well as in pooled analysis. Further, 60 kg P_2O_5 was also found significantly superior over 40 kg P_2O_5 ha^{-1} with regard to P content during both the years and pooled analysis. On pooled basis, the magnitude of increase with 80 kg P_2O_5 ha^{-1} was registered by 7.36 and 3.26 per cent, respectively.

Table 4.11: Effect of phosphorus sources, levels and agrochemicals on phosphorus content of plants at various stages

Treatments	Phosphorus content (%)								
	30 DAS			40 DAS			70 DAS		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources									
DAP	0.392	0.413	0.403	0.357	0.374	0.365	0.298	0.307	0.302
PROM	0.391	0.410	0.400	0.359	0.376	0.367	0.300	0.309	0.305
S Em ±	0.001	0.002	0.001	0.001	0.002	0.001	0.002	0.002	0.001
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})									
40	0.379	0.397	0.388	0.345	0.361	0.353	0.287	0.301	0.294
60	0.396	0.418	0.407	0.359	0.376	0.367	0.301	0.308	0.305
80	0.399	0.421	0.410	0.369	0.388	0.379	0.309	0.316	0.312
S Em ±	0.001	0.002	0.001	0.002	0.002	0.001	0.002	0.002	0.001
CD 5%	0.003	0.006	0.003	0.005	0.006	0.004	0.006	0.006	0.004
Agrochemicals									
Brassinolide	0.392	0.412	0.402	0.366	0.379	0.372	0.306	0.316	0.311
Benzyladenine	0.390	0.412	0.401	0.358	0.377	0.367	0.302	0.313	0.307
KCl	0.392	0.411	0.402	0.351	0.374	0.362	0.293	0.303	0.298
Water	0.391	0.411	0.401	0.356	0.371	0.363	0.295	0.302	0.298
S Em ±	0.001	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002
CD 5%	NS	NS	NS	0.006	NS	0.004	0.007	0.007	0.005

Agrochemicals

Data (Table 4.11) demonstrate that foliar application of brassinolide significantly increased P content over rest of the agrochemicals during the year 2003 as well as in pooled analysis. However, during 2004, all agrochemicals were found non-significant among themselves. Further, benzyladenine also found significantly superior over KCl but remained at par with water spray during the year 2003 and in pooled analysis. While KCl and water spray were also at par with each other. On pooled basis, brassinolide increased P content by 2.48, 2.76 and 1.36 per cent over water spray, KCl and benzyladenine, respectively.

4.7.2.3 70 days after sowing

Phosphorus sources

An appraisal of data presented in Table 4.11 indicate that both phosphorus sources failed to increase P content of plant significantly during both the years of investigation as well as in pooled analysis.

Phosphorus levels

A reference to data presented in Table 4.11 show that with increasing levels of phosphorus, P content of crop also increased significantly upto 80 kg P_2O_5 ha^{-1}. During both the years of investigation as well as in pooled analysis application of 80 kg P_2O_5 ha^{-1} significantly increased P content of plant over 40 and 60 kg P_2O_5 ha^{-1}. Further, 60 kg P_2O_5 was also found significantly superior over 40 kg P_2O_5 ha^{-1} with regard to P content. On pooled basis, 80 kg P_2O_5 ha^{-1} registered 6.12 and 2.29 per cent higher P content over 40 and 60 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is clear from the data (Table 4.11) that foliar spray of brassinolide significantly increased P content of plant over KCl and water spray, however, it remained at par with benzyladenine during both the years as well as in pooled analysis. Further, benzyladenine also found significantly superior over KCl and water spray during 2004 and in pooled analysis, however, in the year of 2003, it remained at par with water spray. While, in either year as well as in pooled analysis, KCl and water spray remained statistically at par with each other. On pooled basis, brassinolide provided 4.36, 4.36 and 1.30 per cent higher P content over water spray, KCl and benzyladenine, respectively.

4.7.2.4 In seed at harvest

Phosphorus sources

It is apparent from data (Table 4.12) that both phosphorus sources could not cause significant increase of P content in seed at harvest during both the years of investigation as well as in pooled analysis.

Phosphorus levels

It is explicit from the data (Table 4.12) that P content of seed was significant increased with increasing level of phosphorus upto 80 kg P_2O_5 ha^{-1}. During either experimental year as well as in pooled analysis, 80 and 60 kg P_2O_5 ha^{-1} were found significantly superior over 40 kg P_2O_5 ha^{-1}. However, 80 kg P_2O_5 was also found significantly superior over 60 kg P_2O_5 ha^{-1}. Further, on pooled basis, it increased P content of seed by 6.82 and 2.39 per cent as compared to 40 and 60 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data (Table 4.12) show that maximum P content in seed was recorded with foliar spray of brassinolide. Remaining at par with benzyladenine, it was found significantly superior over KCl and water spray during each experimental year as well as in pooled analysis. However, during the year of 2004, benzyladenine remained at par with KCl. Further KCl and water spray were also found at par with each other during both the years and in pooled analysis. On pooled basis, the increase in P content of seed with brassinolide spray was found of the order of 3.25, 3.42 and 0.79 per cent over water spray, KCl and benzyladenine, respectively.

4.7.2.5 In stover at harvest

Phosphorus sources

A perusal of data (Table 4.12) reveal that during each experimental years as well as in pooled analysis both phosphorus sources had non-significant effect on P content of stover.

Table 4.12: Effect of phosphorus sources, levels and agrochemicals on phosphorus content of seed and stover

Treatments	Phosphorus content (%)					
	Seed			Stover		
	2003	2004	Pooled	2003	2004	Pooled
P Sources						
DAP	0.618	0.625	0.621	0.194	0.204	0.199
PROM	0.622	0.629	0.626	0.195	0.206	0.200
S Em ±	0.003	0.003	0.002	0.001	0.001	0.001
CD 5%	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})						
40	0.595	0.607	0.601	0.186	0.194	0.190
60	0.626	0.629	0.627	0.195	0.203	0.199
80	0.639	0.646	0.642	0.203	0.217	0.210
S Em ±	0.004	0.004	0.003	0.001	0.002	0.001
CD 5%	0.012	0.010	0.008	0.003	0.005	0.003
Agrochemicals						
Brassinolide	0.631	0.638	0.635	0.201	0.209	0.205
Benzyladenine	0.628	0.633	0.630	0.195	0.206	0.201
KCl	0.608	0.621	0.614	0.190	0.203	0.197
Water	0.613	0.618	0.615	0.192	0.201	0.196
S Em ±	0.005	0.004	0.003	0.001	0.002	0.001
CD 5%	0.013	0.012	0.009	0.004	0.005	0.003

Phosphorus levels

Irrespective of years, data (Table 4.12) show that 80 kg P_2O_5 ha^{-1} significantly increased P content of stover over all of the levels during either year of experimentation as well as in pooled analysis. Further, 60 kg P_2O_5 ha^{-1} was also found significantly superior over 40 kg P_2O_5 ha^{-1} during both years and in pooled analysis. On pooled basis, under 80 kg P_2O_5 ha^{-1}, P content was increased by 10.53 and 5.53 per cent over 40 and 60 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data (Table 4.12) show that during the year 2003 and in pooled analysis foliar spray of brassinolide significantly increased P content of stover among all of the agrochemicals. However, in the year of 2004, it was found at par with benzyladenine. Further in the year of 2003, benzyladenine was found at par with water spray. While, in the year of 2004, benzyladenine, KCl and water spray remained at par with each other. However, in pooled analysis, it was found significantly superior over water spray and KCl. Foliar spray of KCl and water spray were also found at par with each other during either year of experimentation and in pooled analysis. On pooled basis, the increase in P content, through foliar application of brassinolide was found of the order of 4.59, 4.06 and 1.95 per cent over water spray, KCl and benzyladenine, respectively.

4.7.3 Nitrogen uptake (kg ha^{-1})

4.7.3.1 30 days after sowing

Phosphorus sources

Data (Table 4.13) show that both phosphorus sources failed to increase N uptake significantly over each other during both the years as well as in pooled analysis

Phosphorus levels

Data (Table 4.13) demonstrate that during both experimental years as well as in pooled analysis, 60 and 80 kg P_2O_5 ha^{-1} proved significantly superior over 40 kg P_2O_5 ha^{-1} with regard to N uptake. However, 60 and 80 kg P_2O_5 ha^{-1} were found at par between them but 60 kg P_2O_5 ha^{-1} provided higher N uptake than 80 kg P_2O_5 ha^{-1}.

Table 4.13: Effect of phosphorus sources, levels and agrochemicals on nitrogen uptake by plants at various stages

Treatments	Nitrogen uptake (kg ha^{-1})								
	30 DAS			40 DAS			70 DAS		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources									
DAP	8.111	9.160	8.636	13.980	16.000	14.990	29.871	33.607	31.739
PROM	8.369	9.305	8.837	14.408	16.205	15.307	30.172	33.412	31.792
S Em ±	0.122	0.182	0.110	0.327	0.403	0.259	0.532	0.525	0.374
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})									
40	7.035	7.877	7.456	13.004	14.514	13.759	27.201	30.344	28.773
60	8.983	10.035	9.509	14.964	17.041	16.003	31.869	35.353	33.611
80	8.703	9.785	9.244	14.615	16.752	15.684	30.994	34.832	32.913
S Em ±	0.149	0.223	0.134	0.401	0.493	0.318	0.651	0.644	0.458
CD 5%	0.422	0.629	0.375	1.130	1.392	0.889	1.837	1.816	1.280
Agrochemicals									
Brassinolide	8.237	9.284	8.761	15.929	17.403	16.666	33.090	37.266	35.178
Benzyladenine	8.213	9.216	8.715	14.321	16.636	15.479	30.759	35.099	32.929
KCl	8.327	9.178	8.752	13.140	15.327	14.233	27.914	30.972	29.443
Water	8.185	9.252	8.718	13.388	15.044	14.216	28.323	30.702	29.513
S Em ±	0.173	0.257	0.155	0.463	0.570	0.367	0.752	0.743	0.529
CD 5%	NS	NS	NS	1.305	1.608	1.027	2.121	2.096	1.478

Further, on pooled basis, 60 and 80 kg P_2O_5 ha^{-1} increased N uptake of the order of 27.53 and 23.86 per cent, respectively over 40 kg P_2O_5 ha^{-1}.

Agrochemicals

Data (Table 4.13) reveal that all the agrochemicals had non-significant increase in N uptake by soybean during both years of study as well as in pooled analysis.

4.7.3.2 40 days after sowing

Phosphorus sources

Data (Table 4.13) show that N uptake was not increased significantly with phosphorus sources during either year of investigation as well as in pooled analysis.

Phosphorus levels

A perusal of data (Table 4.13) reveals that with the increasing levels of phosphorus upto 60 kg P_2O_5 ha^{-1}, N uptake by soybean was significantly increased. Further increased in phosphorus level from 60 to 80 kg P_2O_5 ha^{-1}, however registered significantly higher N uptake than 40 kg P_2O_5 ha^{-1} but provided less N uptake as compared to 60 kg P_2O_5 ha^{-1}. Further, both higher levels of phosphorus were found statistically non-significant during both the years of experimentation as well as in pooled analysis. On pooled basis, the per cent increase with 60 and 80 kg P_2O_5 ha^{-1} was found of the order of 16.28 and 13.95, respectively over 40 kg P_2O_5 ha^{-1}.

Agrochemicals

Data presented in Table 4.13 show that during both the years as well as in pooled analysis, foliar application of brassinolide significantly increased N uptake by crop among all of the agrochemicals. However, it was found at par with benzyladenine during the year of 2004. Further, during both the years, benzyladenine remained at par with KCl and water spray, while in pooled analysis, it was found significantly superior over KCl and water spray. It was also noticed that in each experimental year as well as in pooled analysis, KCl and water spray remained at par with each other. On pooled basis, brassinolide increased N uptake of the order of 17.23, 17.15 and 7.69 per cent over water spray, KCl and benzyladenine, respectively.

4.7.3.3 70 days after sowing

Phosphorus sources

It is explicit from data (Table 4.13) that phosphorus sources failed to exert significant effect on N uptake during both the years of experimentation as well as in pooled analysis.

Phosphorus levels

A perusal of data (Table 4.13) reveal that crop fertilized with 60 and 80 kg P_2O_5 ha^{-1} significantly increased N uptake over 40 kg P_2O_5 ha^{-1}. However 60 and 80 kg P_2O_5 ha^{-1} remained at par with each other during each year of research as well as in pooled analysis but 60 kg P_2O_5 ha^{-1} registered maximum N uptake among all of the levels. Further, on pooled analysis 60 and 80 kg P_2O_5 ha^{-1} increased N uptake by 16.85 and 14.39 per cent, respectively over 40 kg P_2O_5 ha^{-1}.

Agrochemicals

Data (Table 4.13) indicate that during both the years of investigation as well as in pooled analysis, foliar application of brasssinolide significantly increased N uptake by crop over rest of the agrochemicals. Further, benzyladenine was also found significantly superior over water spray and KCl during both the years and in pooled analysis. Moreover, in each year and in pooled analysis, water spray and KCl remained statistically at par with each other. On pooled basis, brassinolide increased N uptake by 19.21, 19.49 and 6.83 per cent over water spray, KCl and benzyladenine, respectively.

4.7.3.4 By seed at harvest

Phosphorus sources

Data presented in Table 4.14 reveal that N uptake by soybean seed was not significantly increased with both phosphorus sources during both the years as well as in pooled analysis.

Phosphorus levels

Across the years, as well as in pooled analysis, data (Table 4.14) indicate that 60 kg P_2O_5 ha^{-1} registered maximum N uptake by seed among all the levels and found significantly superior over 40 kg P_2O_5 ha^{-1}. Further, increase in phosphorus level upto

Table 4.14: Effect of phosphorus sources, levels and agrochemicals on nitrogen uptake by seed and stover

Treatments	Nitrogen uptake (kg ha^{-1})					
	Seed			Stover		
	2003	2004	Pooled	2003	2004	Pooled
P Sources						
DAP	76.646	96.634	86.640	41.328	49.928	45.628
PROM	78.634	97.268	87.951	42.093	49.514	45.803
S Em ±	1.282	1.444	0.965	0.641	0.710	0.478
CD 5%	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})						
40	72.740	90.068	81.404	39.829	46.757	43.293
60	81.694	100.963	91.329	42.820	51.466	47.143
80	78.485	99.822	89.154	42.481	50.940	46.710
S Em ±	1.570	1.768	1.182	0.785	0.869	0.586
CD 5%	4.429	4.989	3.307	2.216	2.453	1.639
Agrochemicals						
Brassinolide	86.481	105.803	96.142	45.509	52.686	49.098
Benzyladenine	80.456	100.210	90.333	42.911	51.418	47.165
KCl	71.384	91.414	81.399	39.016	47.613	43.315
Water	72.239	90.377	81.308	39.405	47.167	43.286
S Em ±	1.813	2.042	1.365	0.907	1.004	0.676
CD 5%	5.114	5.760	3.819	2.559	2.832	1.892

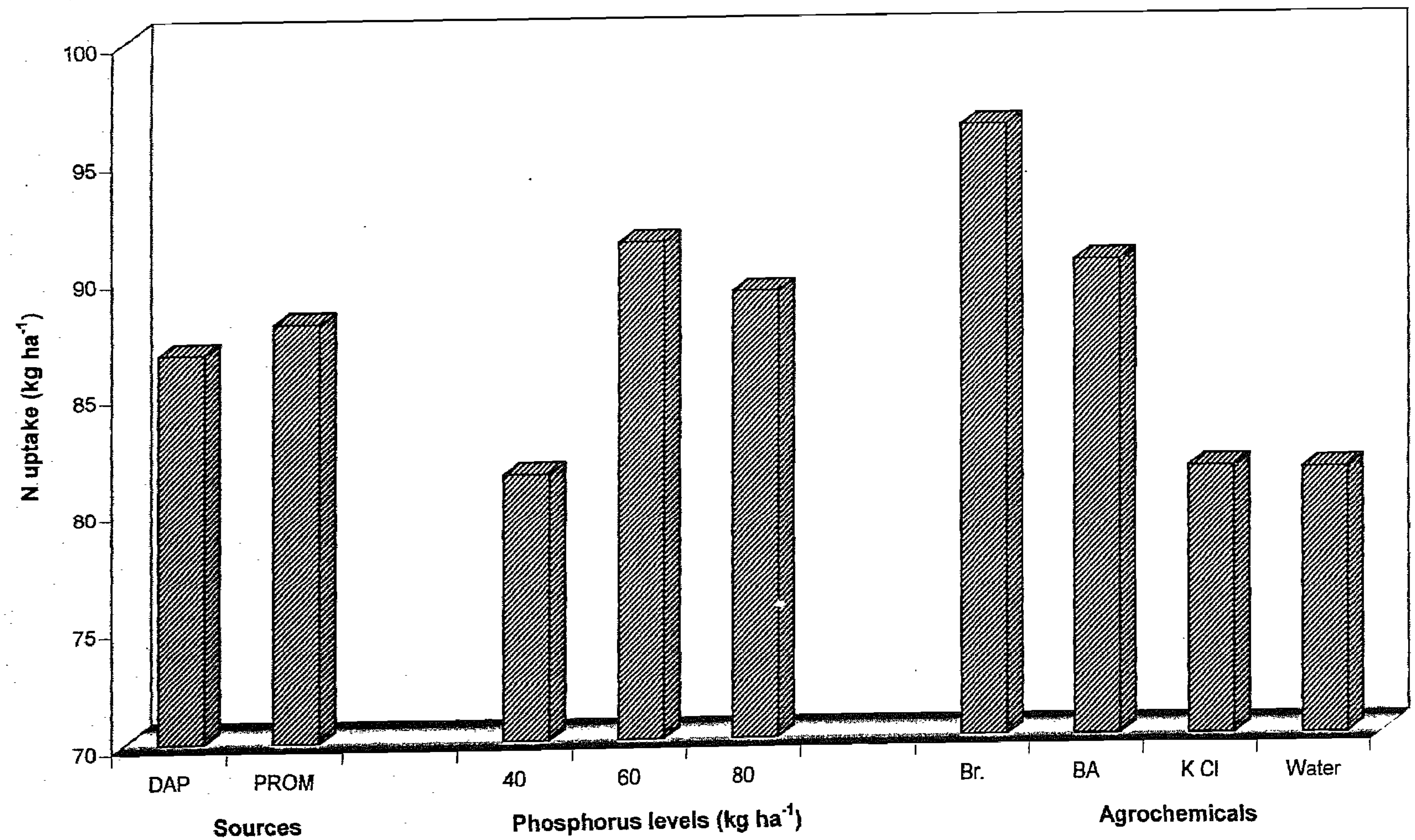


Fig. 4.4 : Effect of phosphorus sources, levels and agrochemicals on nitrogen uptake of seed (pooled)

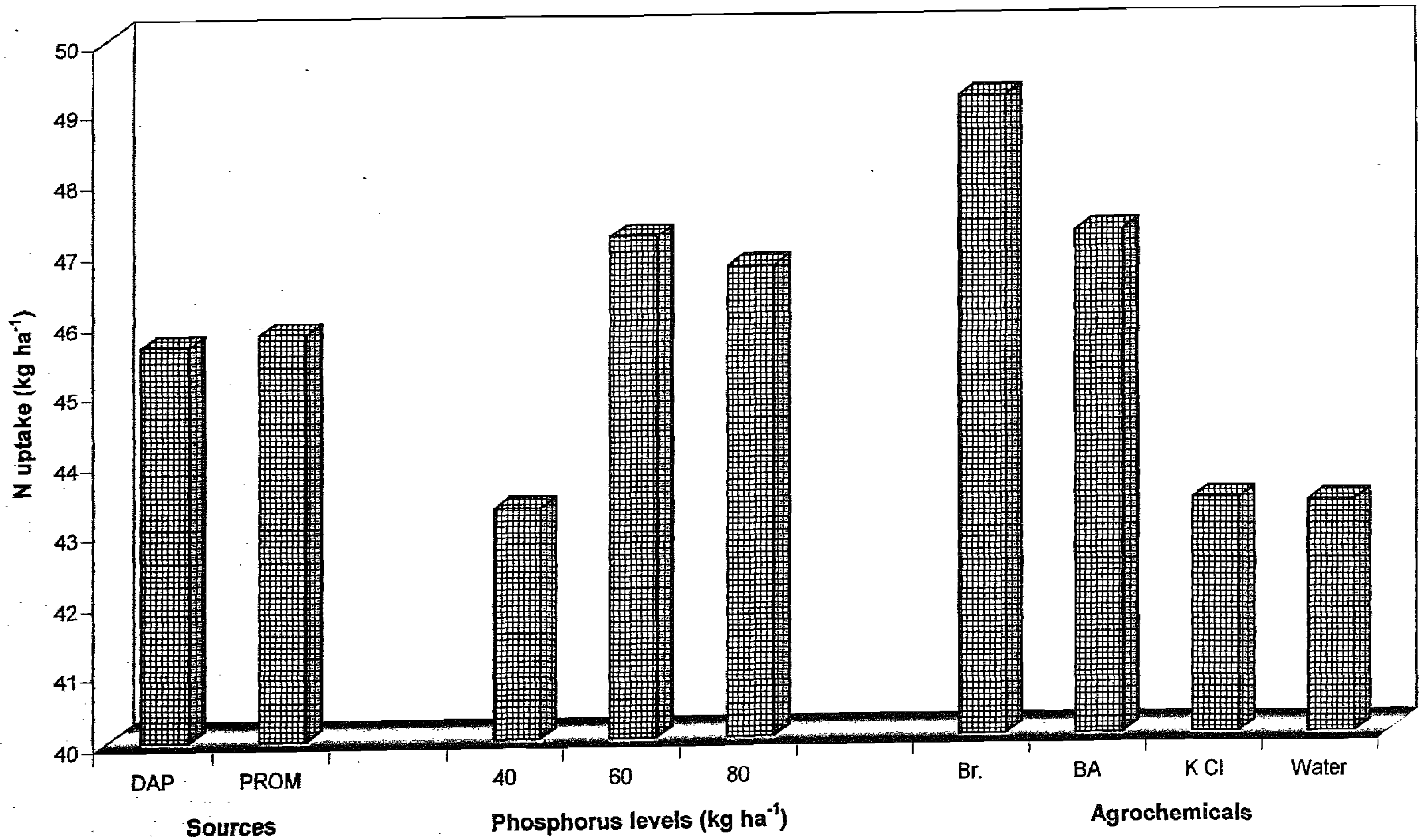


Fig. 4.5 : Effect of phosphorus sources, levels and agrochemicals on nitrogen uptake of stover (pooled)

80 kg P_2O_5 ha^{-1}, however found significantly superior over 40 kg P_2O_5 ha^{-1} but registered less N uptake as compared to 60 kg P_2O_5 ha^{-1}. Moreover, both the higher levels were found statistically non-significant with each other. On pooled basis, the magnitude of increase in N uptake with 60 kg P_2O_5 ha^{-1} was found of the order of 12.20 and 2.44 per cent over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is evident from data (Table 4.14) that during both the years of experimentation as well as in pooled analysis, foliar application of brassinolide significantly increased N uptake by seed over rest of the agrochemicals, however it was found at par with benzyladenine during the year of 2004. Further, benzyladenine was also found significantly superior over KCl and water spray during both years as well as in pooled analysis. While, KCl and water spray remained statistically at par with each other. On pooled basis, foliar application of brassinolide increased N uptake of the order of 18.24, 18.11 and 6.43 per cent over water spray, KCl and benzyladenine, respectively.

4.7.3.5 By stover at harvest

Phosphorus sources

Data (Table 4.14) show that both the phosphorous sources were found at par with each other with regard to N uptake by stover during both the years of investigation as well as in pooled analysis.

Phosphorus levels

A reference to data (Table 4.14) reveal that N uptake by stover was significantly increased with the fertilization of crop at 60 and 80 kg P_2O_5 ha^{-1} as compared to 40 kg P_2O_5 ha^{-1}. However, both higher levels of phosphorus remained at par between them during either experimental year as well as in pooled analysis but at 80 kg P_2O_5 ha^{-1} N uptake by stover was found less than 60 kg P_2O_5 ha^{-1}. Further, on pooled basis, 60 and 80 kg P_2O_5 ha^{-1} increased N uptake by 8.89 and 7.90 per cent, respectively over 40 kg P_2O_5 ha^{-1}.

Agrochemicals

Across the years as well as in pooled analysis, data (Table 4.14) show that foliar application of brassinolide registered significantly higher removal of N by stover among all of the agrochemicals, however during the year 2004, it was found at par with benzyladenine. Further benzyladenine was also found significantly superior in removing N over KCl and water spray during 2003, 2004 and in pooled analysis. While, water spray and KCl remained at par with regard to N uptake during each experimental year as well as in pooled analysis. On pooled basis, brassinolide increased N uptake of the order of 13.42, 13.34 and 4.09 per cent over water spray, KCl and benzyladenine, respectively.

4.7.4 Phosphorus uptake

4.7.4.1 30 days after sowing

Phosphorus sources

Data presented in Table 4.15 show that phosphorus sources could not bring about any significant variation in P uptake by crop during both the years as well as in pooled analysis.

Phosphorus levels

A close examination of data (Table 4.15) reveal that crop fertilized with 60 kg P_2O_5 ha^{-1} provided significantly higher P uptake over 40 kg P_2O_5 ha^{-1} during 2003 and 2004 as well in pooled analysis and remained at par with 80 kg P_2O_5 ha^{-1}. Further, 80 kg P_2O_5 ha^{-1} was also found significantly superior over 40 kg P_2O_5 ha^{-1} during each year of study and in pooled analysis. On pooled basis, 60 kg P_2O_5 ha^{-1} removed 30.52 & 1.64 per cent higher P over 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data (Table 4.15) indicate that various agrochemicals did not significantly influence P uptake by crop at 30 DAS during either experimental year as well as in pooled analysis.

Table 4.15: Effect of phosphorus sources, levels and agrochemicals on phosphorus uptake by plants at various stages

Treatments	Phosphorus uptake (kg ha^{-1})								
	30 DAS			40 DAS			70 DAS		
	2003	2004	Pooled	2003	2004	Pooled	2003	2004	Pooled
P Sources									
DAP	0.830	0.976	0.903	1.458	1.710	1.584	3.240	3.779	3.510
PROM	0.850	0.982	0.916	1.507	1.742	1.625	3.273	3.770	3.522
S Em ±	0.012	0.019	0.011	0.035	0.043	0.028	0.055	0.061	0.041
CD 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})									
40	0.701	0.818	0.760	1.327	1.523	1.425	2.867	3.404	3.136
60	0.918	1.066	0.992	1.556	1.810	1.683	3.442	3.915	3.679
80	0.900	1.052	0.976	1.565	1.845	1.705	3.461	4.005	3.733
S Em ±	0.015	0.023	0.014	0.043	0.052	0.034	0.068	0.075	0.050
CD 5%	0.043	0.066	0.039	0.123	0.147	0.095	0.191	0.211	0.141
Agrochemicals									
Brassinolide	0.840	0.986	0.913	1.681	1.867	1.774	3.624	4.206	3.915
Benzyladenine	0.838	0.979	0.908	1.488	1.770	1.629	3.347	3.969	3.658
KCl	0.849	0.971	0.910	1.363	1.650	1.506	3.009	3.475	3.242
Water	0.833	0.980	0.906	1.398	1.617	1.507	3.046	3.449	3.247
S Em ±	0.018	0.027	0.016	0.050	0.060	0.039	0.078	0.086	0.058
CD 5%	NS	NS	NS	0.141	0.170	0.110	0.220	0.243	0.163

4.7.4.2 40 days after sowing

Phosphorus sources

A perusal of data (Table 4.15) reveal that both phosphorus levels failed to increase P uptake by crop significantly over each other during both the years as well as in pooled analysis.

Phosphorus levels

It is apparent from data (Table 4.15) that during both the years of study as well as in pooled analysis, crop fertilized with 80 kg P_2O_5 ha^{-1} removed significantly higher quantity of P over 40 kg P_2O_5 ha^{-1}. However, it remained at par with 60 kg P_2O_5 ha^{-1}. Further, 60 kg P_2O_5 ha^{-1} was also found significantly superior over 40 kg P_2O_5 ha^{-1}during both the years as well as in pooled analysis. On pooled basis, 80 kg P_2O_5 ha^{-1} increased P uptake of the order of 19.58 and 1.78 per cent over 40 and 60 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data (Table 4.15) reveal that foliar spray of brassinolide significantly increased P uptake by crop as compared to rest of the agrochemicals during the year 2003 as well as in pooled analysis, while in the year of 2004, it was found at par with benzyladenine and removed significantly higher quantity of P over KCl and water spray. Further, during the year 2003 and 2004, benzyladenine was found at par with KCl and water spray, however in pooled analysis, it was also found significantly superior over KCl and water spray. Moreover, KCl and water spray was remained statistically at par with each other during both years and in pooled analysis. On pooled basis, brassinolide increased 17.22, 17.22 and 8.59 per cent higher P uptake by crop over water spray, KCl and benzyladenine, respectively.

4.7.4.3 70 days after sowing

Phosphorus sources

It is evident from the data (Table 4.15) that both sources failed to remove P significantly over each other during both the years as well as in pooled analysis.

Phosphorus levels

It is explicit from data (Table 4.15) that crop fertilized with 80 kg P_2O_5 ha^{-1} significantly increased P uptake over 40 kg P_2O_5 during both the years of experimentation, as well as in pooled analysis. Further, it was found at par with 60 kg P_2O_5 ha^{-1}. However, during 2003, 2004 as well as in pooled analysis 60 kg P_2O_5 ha^{-1} was also found significantly superior over 40 kg P_2O_5 ha^{-1}, with regard to P uptake. On pooled basis, 80 kg P_2O_5 ha^{-1} removed 18.79 and 1.36 per cent higher P over 40 and 60 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

Data presented in Table 4.15 reveal that foliar application of brassinolide registered significantly higher P uptake among all the agrochemicals during 2003, 2004 and in pooled analysis. However, it was found at par with benzyladenine during the year 2004. Further during either year of experimentation as well as in pooled analysis, benzyladenine was also found significantly superior over KCl and water spray. While, KCl and water spray remained at par with each other. On pooled basis, brassinolide increased higher P uptake by 20.60, 20.98 and 7.10 per cent as compared to water spray, KCl and benzyladenine, respectively.

4.7.4.4 By seed at harvest

Phosphorus sources

Data (Table 4.16) show that both phosphorus sources failed to significantly increase P uptake by seed during both the experimental years as well as in pooled analysis.

Phosphorus levels

Data (Table 4.16) reveal that crop fertilized with 80 kg P_2O_5 ha^{-1} registered significantly higher P uptake by seed over 40 kg P_2O_5 ha^{-1} during each year of study as well as in pooled analysis. However, it was found at par with 60 kg P_2O_5 ha^{-1}. Further during both years as well as in pooled analysis, 60 kg P_2O_5 ha^{-1} was also found significantly superior over 40 kg P_2O_5 ha^{-1}. On pooled basis, 80 kg P_2O_5 ha^{-1} increased P uptake by 14.54 and 0.46 per cent over 40 and 60 kg P_2O_5 ha^{-1}, respectively.

Table 4.16: Effect of phosphorus sources, levels and agrochemicals on phosphorus uptake by seed and stover

Treatments	Phosphorus uptake (kg ha^{-1})					
	Seed			Stover		
	2003	2004	Pooled	2003	2004	Pooled
P Sources						
DAP	7.444	9.240	8.342	5.701	7.034	6.367
PROM	7.688	9.360	8.524	5.806	7.286	6.546
S Em ±	0.118	0.149	0.095	0.089	0.109	0.070
CD 5%	NS	NS	NS	NS	NS	NS
P Levels (kg ha^{-1})						
40	6.925	8.481	7.703	5.282	6.410	5.846
60	7.938	9.612	8.775	5.859	7.201	6.530
80	7.835	9.806	8.821	6.119	7.868	6.994
S Em ±	0.145	0.182	0.116	0.109	0.133	0.086
CD 5%	0.409	0.514	0.326	0.308	0.375	0.241
Agrochemicals						
Brassinolide	8.428	10.139	9.283	6.373	7.571	6.972
Benzyladenine	7.835	9.576	8.706	5.869	7.297	6.583
KCl	6.951	8.807	7.879	5.353	6.793	6.073
Water	7.050	8.676	7.863	5.419	6.979	6.199
S Em ±	0.167	0.210	0.134	0.126	0.154	0.099
CD 5%	0.472	0.593	0.376	0.356	0.433	0.278

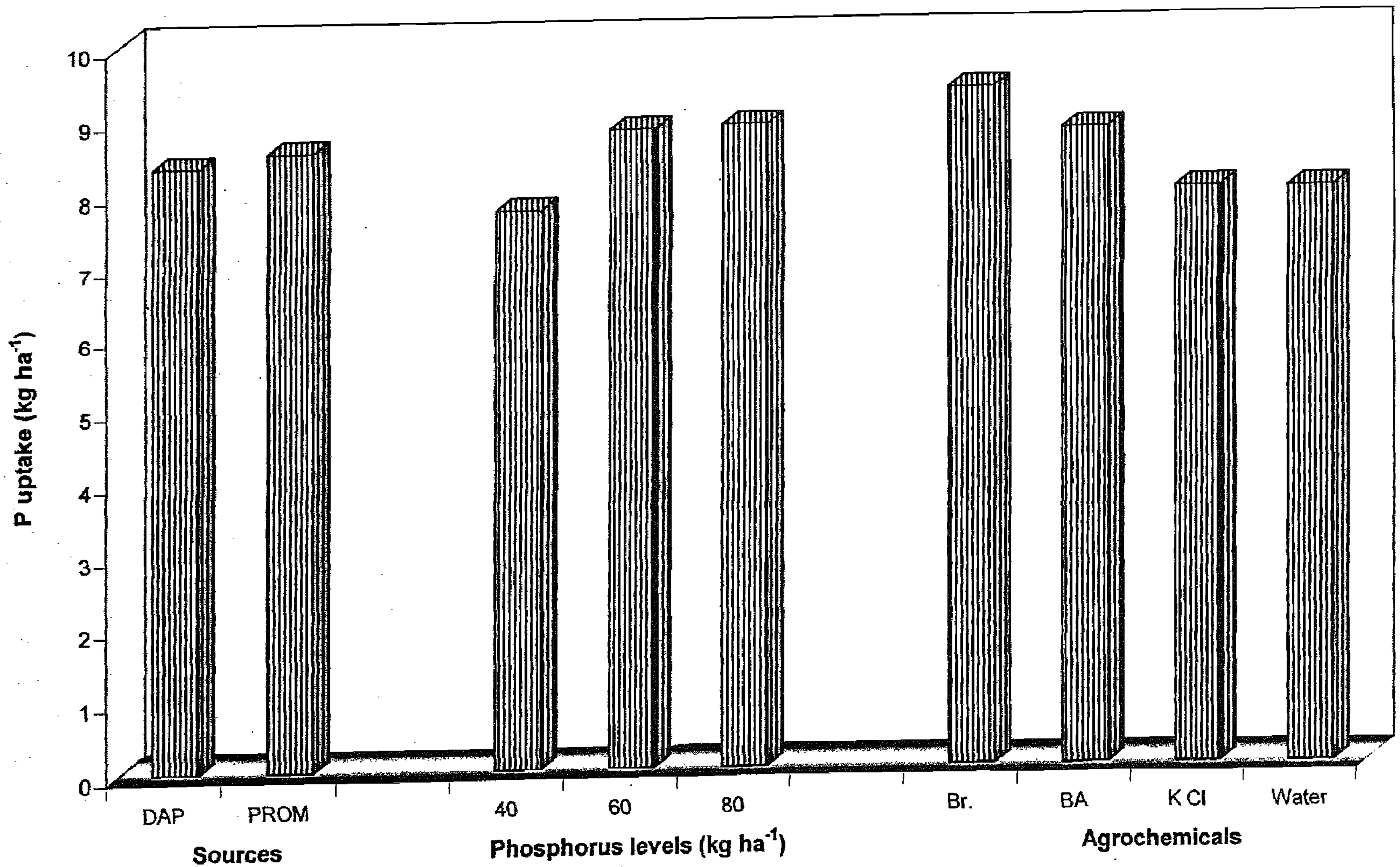


Fig. 4.6 : Effect of phosphorus sources, levels and agrochemicals on phosphorus uptake of seed (pooled)

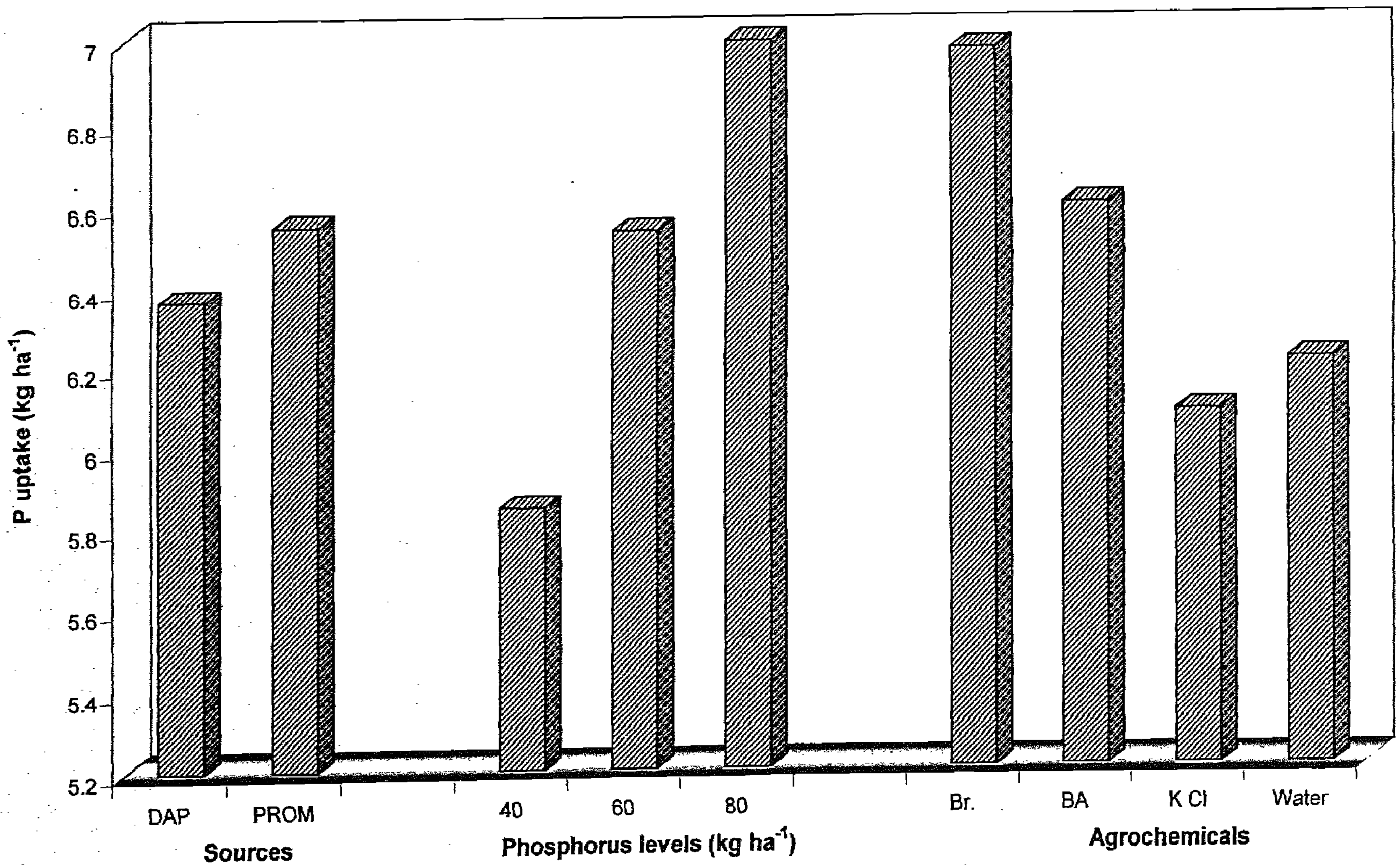


Fig. 4.7 : Effect of phosphorus sources, levels and agrochemicals on phosphorus uptake of stover (pooled)

Agrochemicals

A perusal of data (Table 4.16) show that during either year of experimentation as well as in pooled analysis foliar application of brassinolide was found significantly superior over rest of the agrochemicals with regards to increasing P uptake by seed, however it was found at par with benzyladenine during the year of 2004. Further, benzyladenine was also found significantly superior over KCl and water spray. Moreover, during both the years and in pooled analysis, KCl and water spray remained at par with each other. On pooled basis, brassinolide increased P uptake by seed of the order of 18.07, 17.77 and 6.54 per cent as compared to water spray, KCl and benzyladenine, respectively.

4.7.4.5 By stover at harvest

Phosphorus sources

Data presented in Table 4.16 reveal that phosphorus sources had no significant effect in increasing P uptake by stover during each experimental year as well as in pooled analysis.

Phosphorus levels

Data (Table 4.16) reveal that crop fertilized with 80 kg P_2O_5 ha^{-1} significantly increased P uptake by stover over 40 and 60 kg P_2O_5 ha^{-1}, during 2004 as well as in pooled analysis. However, during 2003, it was found at par with 60 kg P_2O_5 ha^{-1}. Further 60 kg P_2O_5 ha^{-1} was also found significantly superior over 40 kg P_2O_5 ha^{-1} during each year and in pooled analysis. On pooled basis, increase in P uptake with 80 kg P_2O_5 was found of the order of 19.49 and 7.04 per cent over 40 and 60 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

A critical examination of data (Table 4.16) reveal that during the year 2003 as well as in pooled analysis, foliar application of brassinolide was found significantly superior with regard to P uptake by stover over rest of the agrochemicals. Further, benzyladenine was also found significantly superior over KCl and water spray during 2003 and in pooled analysis. However, during the year 2004, brassinolide was found at par with benzyladenine, while benzyladenine was also found at par with water spray. However, during both the years and in pooled analysis, KCl and water spray remained at par with each other. On pooled basis, brassinolide increased P uptake by 12.42, 14.83 and 5.92 per cent over water spray, KCl and benzyladenine, respectively.

4.8 NUTRIENT STATUS OF SOIL AFTER HARVEST

4.8.1 Available phosphorus (kg ha^{-1})

Phosphorus sources

Data (Table 4.17) show that phosphorus sources did not vary significantly among themselves with regard to available P in soil after harvesting of crop during either experimental year as well as in pooled analysis.

Phosphorus levels

It is explicit from data (Table 4.17) that plots fertilized with 80 and 60 kg P_2O_5 ha^{-1} had significantly higher available phosphorus in soil after crop harvesting, as compared to 40 kg P_2O_5 ha^{-1} during both the experimental years as well as in pooled analysis. Further 80 and 60 kg P_2O_5 ha^{-1} were at par with each other during each year and in pooled analysis. On pooled basis, 80 and 60 kg P_2O_5 ha^{-1} had 7.98 and 7.10 per cent increase in available phosphorus, respectively over 40 kg P_2O_5 ha^{-1}.

Agrochemicals

During each year of experimentation as well as pooled analysis, data (Table 4.17) show that all the agrochemicals had no influence on phosphorus content of soil after harvest of crop.

4.9 PHOSPHORUS BALANCE SHEET

A perusal of data (Table 4.18) reveals that there was a build up of available P in treated plots after harvest of soybean crop (column G). Almost similar build up of available P occurred due to both phosphorus sources with a slightly higher build up under PROM with 2.1 kg P ha^{-1} as compared to DAP (1.8 kg P ha^{-1}). Application of 80 kg P_2O_5 ha^{-1} resulted in a build up of 2.6 kg P ha^{-1} in soil after the harvest of soybean, which was 225 per cent higher over the gain under 40 kg P_2O_5 ha^{-1}. Further amongst the agrochemicals, almost similar enhancement 1.9, 2.0, 2.0 and 2.0 kg P ha^{-1} was recorded with brassinolide, benzyladenine, KCl and water spray, respectively.

Table 4.17: Effect of phosphorus sources, levels and agrochemicals on available phosphorus of soil after harvest

Treatments	Available P after harvest (kg ha^{-1})		
	2003	2004	Pooled
P Sources			
DAP	23.1	24.3	23.7
PROM	23.4	24.5	23.9
S Em ±	0.1	0.1	0.1
CD 5%	NS	NS	NS
P Levels (kg ha^{-1})			
40	22.2	23.1	22.7
60	23.7	24.8	24.3
80	23.9	25.1	24.5
S Em ±	0.2	0.2	0.1
CD 5%	0.4	0.5	0.3
Agrochemicals			
Brassinolide	23.2	24.3	23.8
Benzyladenine	23.3	24.4	23.8
KCl	23.3	24.4	23.8
Water	23.4	24.3	23.8
S Em ±	0.2	0.2	0.1
CD 5%	NS	NS	NS

Table 4.18: Phosphorus balance sheet during crop seasons

Treatments	Phosphorus balance sheet (kg ha^{-1})																				
	Initial status (A)			Nutrient added (B)			Crop uptake (C)			Expected balance (D)=A+B-C			Actual balance (E)			Apparent gain loss^{-1} (F)=E-D			Actual gain/loss (G)=E-A		
	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean
P Sources																					
DAP	21.3	22.4	21.9	60.0	60.0	60.0	13.1	16.3	14.7	68.2	66.1	67.1	23.1	24.3	23.7	-45.0	-41.9	-43.5	1.8	1.9	1.8
PROM	21.3	22.4	21.9	60.0	60.0	60.0	13.5	16.6	15.1	67.8	65.8	66.8	23.4	24.5	23.9	-44.4	-41.3	-42.8	2.1	2.1	2.1
P Levels (kg ha^{-1})																					
40	21.3	22.4	21.9	40.0	40.0	40.0	12.2	14.9	13.5	49.1	47.5	48.3	22.2	23.1	22.7	-26.9	-24.4	-25.6	0.9	0.7	0.8
60	21.3	22.4	21.9	60.0	60.0	60.0	13.8	16.8	15.3	67.5	65.6	66.5	23.7	24.8	24.3	-43.8	-40.8	-42.3	2.4	2.4	2.4
80	21.3	22.4	21.9	80.0	80.0	80.0	14.0	17.7	15.8	87.3	84.7	86.0	23.9	25.1	24.5	-63.5	-59.6	-61.5	2.6	2.7	2.6
Agrochemicals																					
Brassinolide	21.3	22.4	21.9	60.0	60.0	60.0	14.8	17.7	16.3	66.5	64.7	65.6	23.2	24.3	23.8	-43.3	-40.4	-41.8	1.9	1.9	1.9
Benzyladenine	21.3	22.4	21.9	60.0	60.0	60.0	13.7	16.9	15.3	67.6	65.5	66.6	23.3	24.4	23.8	-44.3	-41.1	-42.7	2.0	2.0	2.0
KCl	21.3	22.4	21.9	60.0	60.0	60.0	12.3	15.6	14.0	69.0	66.8	67.9	23.3	24.4	23.8	-45.7	-42.4	-44.1	2.0	2.0	2.0
Water	21.3	22.4	21.9	60.0	60.0	60.0	12.5	15.7	14.1	68.8	66.7	67.8	23.4	24.3	23.8	-45.5	-42.4	-44.0	2.1	1.9	2.0

4.10 ECONOMICS OF TREATMENTS

4.10.1 Net returns (Rs. ha^{-1})

Phosphorus sources

Data presented in Table 4.19 show that both sources had non-significant difference between them during the year 2004 but during the year of 2003 as well as in pooled analysis, PROM provided significantly higher net returns as compared to DAP. On pooled basis, it recorded Rs. 810 ha^{-1} more as compared to DAP (Rs. 13267 ha^{-1}).

Phosphorus levels

It is evident from the data (Table 4.19) that 60 kg P_2O_5 ha^{-1} registered significantly higher net returns over 40 kg P_2O_5 ha^{-1}. However, it was found at par with 80 kg P_2O_5 ha^{-1} during either year of experimentation as well as in pooled analysis. Further in 2003, 80 kg P_2O_5 ha^{-1} remained at par with 40 kg P_2O_5 ha^{-1}. While in 2004 and in pooled analysis, it was found significantly superior over 40 kg P_2O_5 ha^{-1}. On pooled basis, 60 kg P_2O_5 fetched net returns of Rs. 14439 ha^{-1} as compared to 40 and 80 kg P_2O_5 ha^{-1} (Rs. 12720 ha^{-1} and Rs. 13857 ha^{-1}, respectively).

Agrochemicals

It is evident from data (Table 4.19) that during either year of investigation as well as in pooled analysis, foliar application of brassinolide provided significantly higher net returns among all of the agrochemicals. Further KCl and water spray were also found significantly superior over benzyladenine. However KCl and water spray remained at par with each other with regards to net returns. On pooled basis, brassinolide registered a net returns of Rs. 17174 ha^{-1}, which was found higher by 17.86, 19.70 and 99.79 per cent over water spray, KCl and benzyladenine, respectively.

4.10.2 B:C ratio

Phosphorus sources

Data (Table 4.19) reveal that application of PROM provided significantly higher B:C ratio as compared to DAP during both the years of experimentation as well as in pooled analysis. On pooled basis, it provided B:C ratio of 1.39 as compared to DAP (1.25).

Table 4.19: Effect of phosphorus sources, levels and agrochemicals on net returns and B:C ratio

Treatments	Net returns (Rs. ha^{-1})			B:C ratio		
	2003	2004	Pooled	2003	2004	Pooled
P Sources						
DAP	9781	16753	13267	0.94	1.56	1.25
PROM	10760	17393	14077	1.08	1.70	1.39
S Em ±	264	340	215	0.03	0.03	0.02
CD 5%	744	NS	602	0.08	0.09	0.06
P Levels (kg ha^{-1})						
40	9599	15840	12720	0.98	1.56	1.27
60	10987	17891	14439	1.08	1.70	1.39
80	10227	17487	13857	0.98	1.63	1.30
S Em ±	323	417	264	0.03	0.04	0.03
CD 5%	912	1176	738	NS	0.11	0.07
Agrochemicals						
Brassinolide	13818	20529	17174	1.40	2.07	1.74
Benzyladenine	5114	12078	8596	0.30	0.70	0.50
KCl	10887	17807	14347	1.14	1.84	1.49
Water	11264	17878	14571	1.21	1.90	1.55
S Em ±	373	481	305	0.04	0.05	0.03
CD 5%	1053	1358	852	0.11	0.13	0.08

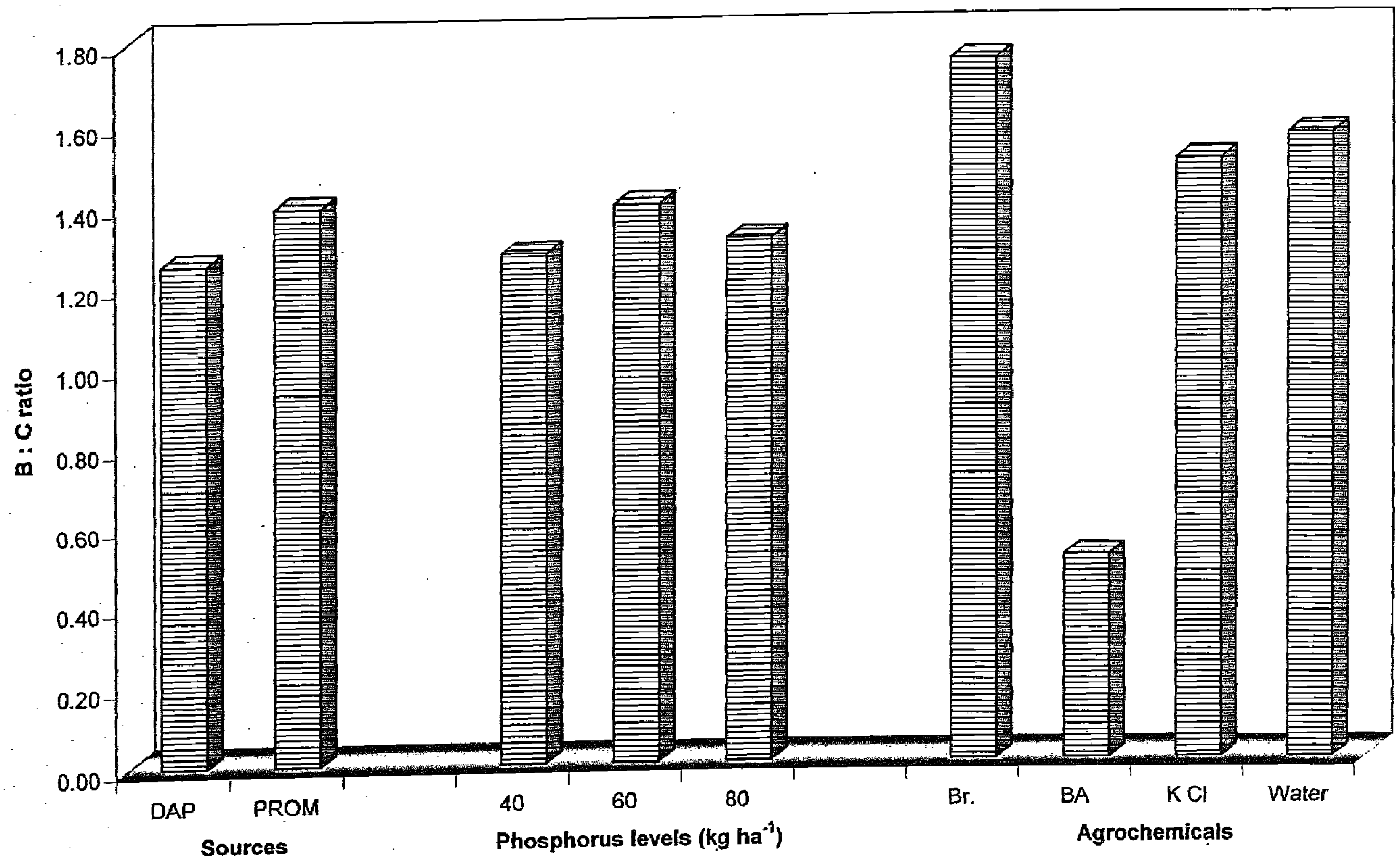


Fig. 4.8 : Effect of phosphorus sources, levels and agrochemicals on B :C ratio (pooled)

Phosphorus levels

It is clear from data (Table 4.19) that during the year 2003, all the phosphorus levels were found statistically non-significant among them. While in 2004, 60 kg P_2O_5 ha^{-1} provided significantly higher B:C ratio over 40 kg P_2O_5 ha^{-1} but found at par with 80 kg P_2O_5 ha^{-1} , however, 80 kg P_2O_5 ha^{-1} level was also found at par with 40 kg P_2O_5 ha^{-1} during this year. Further in pooled analysis, 60 kg P_2O_5 ha^{-1} was found significantly superior over 40 and 80 kg P_2O_5 ha^{-1}, while 40 and 80 kg P_2O_5 ha^{-1} remained at par with each other. On pooled basis, 60 kg P_2O_5 ha^{-1} registered B:C ratio of 1.39 as compared to 1.27 and 1.30 with 40 and 80 kg P_2O_5 ha^{-1}, respectively.

Agrochemicals

It is apparent from the data (Table 4.19) that during either year of investigation as well as in pooled analysis, foliar application of brassinolide provided significantly higher B:C ratio among all of the agrochemicals. Further water spray and KCl were found significantly superior as compared to benzyladenine, however, water spray and KCl remained at par with each other with regard to B:C ratio. On pooled basis, brassinolide registered B:C ratio of 1.74 as compared to 1.55, 1.49 and 0.50 with water spray, KCl and benzyladenine, respectively.

5. DISCUSSION

During the course of presenting the results of field experiment entitled "Effect of phosphorus nutrition and agrochemicals on the productivity of soybean [*Glycine max* (L) Merrill]" significant variations in the criteria used for evaluation were observed due to the effect of different treatments. In the ensuing pages such variations and those having uniform trend are discussed to establish cause and effect relationship by existing evidences and possible explanations based on available literature.

5.1 OVER ALL PERFORMANCE OF SOYBEAN CROP

The results indicated that the productivity of soybean in term of seed, stover and biological yield was higher by 21.41, 16.92 and 18.23 per cent, respectively during the year of 2004 as compared to 2003.

In general as the crop grown under identical management conditions and input levels, the observed variations in the productivity of soybean crop between the years seems to be due to variation in climatic conditions, which prevailed during various stages of crop growth. The profound influence of environmental factors on crop productivity is well documented. Mavi (1986) stated that plant can realize its genetic potential or complete its genetically programmed phasic development under certain range of environment, while Mistry and Patel (1977) opined that weather is principle input parameter, which brings year to year variation in crop productivity despite consistency of other input parameters and practices of crop husbandry. The mean weekly weather parameters recorded during crop growth period showed marked variation in amount and distribution of rainfall and sunshine hours between the years (Appendix-I), while differences in other parameters were marginal. During the second year of experimentation (2004), the total rainfall recorded during soybean growing season was higher (569.6 mm) and was well distributed across various stages. But during the first year (2003) the rainfall received during rainy season was comparatively lower (465.9 mm), that too ill distributed. Despite of life saving irrigation the crop during the year of 2003 encountered shortage of moisture particularly atmospheric and to some extent in the rooting zone (soil moisture). While comparatively higher quantum of rainfall with proper distribution in the year 2004 seems to have congenital conditions for proper growth and development of soybean plants. However, relative humidity (min. & max.) and evaporation demand in 2003 were better but due to the cloudiness for longer duration crop was suffered for solar energy and light subsequently photosynthesis rate was severely affected ultimately this weather condition reduced the crop yield compared to year 2004. Overall growth and development parameters were better during 2004 compared to the year 2003.

It is an established fact that adequate supply of metabolites, moisture and nutrients is pre-requisites for proper growth and development of each yield components. The adequate supply of these inputs during the year 2004 ultimately reflected in improvement of each yield component. Since, seed yield is artifact of several yield components, the marked increase in yield components during 2004 manifested in realization of higher seed yield by 21.41 per cent over that recorded during the year 2003. The increased stover yield during the second year compared to first year of study seems to be on account of better growth of crop as evidenced from increase in morphological parameters along with dry matter accumulation by the plants. Since biological yield is sum of seed and stover yield, so that increase in both these led to realized higher biological yield during the year 2004 compared to the year 2003. Likewise, during second year though the rainfall was normal but in the month of September ample rainfall (152.0 mm) coincided with peak flowering and initiation of poding, while in first year only 66.0 mm rains were received at these stages.

5.2 EFFECT OF PHOSPHORUS FERTILIZATION

It is well known fact that phosphorus is considered to be most reactive in soil system as it is absorbed quickly on soil particles after reaction with soil constituents and only a little part of inherent soil P remains for plant utilization. Thus, it becomes imperative to supplement P in soil media through composting as per soil, crop / cropping sequence, moisture conditions and other agronomic factors those favour the growth and development of plants (Kanwar, 1976). Phosphorus performs a vital role in the life cycle of plant and is an important constituent of genetic material (Khasawneh *et al.*, 1986). It is also known to control photosynthesis, breakdown of carbohydrates and transfer of energy through metabolic transformations. In fact, it is considered to be an energy currency within plant system (Tisdale *et al.*, 1995). Soybean is well responsive to fertilizer application especially to phosphorus. It is the inability of native P to cope up with the demand of soybean for P unless inorganic phosphate is added. In the absence of inorganic applied P (control), phosphorus deficiency has been shown to decrease the unit leaf area and photosynthesis activity (Morison and Batten, 1986) and severely restrict the nodulation process in legumes (Bethlenfalvay and Yoder, 1981 and Israel, 1987) resulting in poor growth and functioning of plant life processes and ultimately decreased the yield components and yield of soybean. Lauer and Belvins (1989) and Crafts-Brander (1992) also postulated that P deficiency led to a proportional decrease in number of pods plant^{-1}. In the light of above facts, the favourable effects of phosphorus are expressed through enhanced root growth, atmospheric N-fixation efficiency, pods plant^{-1} and thereby yield of soybean under the influence of applied phosphorus sources. The results are in close agreement with Meena (2005). Before embarking on the results of effectiveness of phosphorus sources and related discussion, it might be well to state certain premises. Chemical and physical properties of phosphatic fertilizers along with the release pattern of phosphorus are important from agronomic point of view for maintaining adequate concentration of P ions in solution and for minimizing P fixation in soil (Wild, 1950). Choice of appropriate phosphorus sources for agronomic response depends not only on desired P release pattern but also on soil properties such as pH and/or degree of Ca-saturation, P fixing capacity etc. (Marwaha, 1992).

5.3 EFFECT OF PHOSPHORUS SOURCES AND SOLUBILIZERS

5.3.1 Growth Parameters

It is explicit from the result that application of PROM was found non-significant with DAP in improving various growth parameters *viz.*, plant height at harvest, total number of branches plant^{-1} and dry matter accumulation plant^{-1} at various growth stages.

It is well established fact that incorporation of organics not only act as store house of various nutrients but also known to influence favourably the physical, chemical and biological properties of the soil. Besides, it also solubilizes applied P as a result of enhanced activity of soil microbes which in turn, increase availability of nutrients to plants. FYM exhibits a potent role in solubilization, transformation and availability of nutrients, particularly P (as applied) in soils and increases P use efficiency. Organic material, while decomposing release CO_2, citric, malonic, humic, fulvic and other organic acid, which in turn attack tricalcium phosphate (insoluble in water and 2 % citric acid) in the rock phosphate to convert some of the phosphate content into water and citric acid soluble forms. Effect of FYM on plant growth and productivity may be ascribed to its direct and indirect involvement in the availability of nutrients due to increasing CEC of soil to crop plants. Increasing organic matter in soil due to organic matter was subjected to microbial decomposition leading to production of H_2CO_3 and other organic acids (Singh and Lal, 1976). This might have reduced the soil pH (Patel and Patel, 1996) and led to increased availability of phosphorus and other nutrients to crop plants through the process of chelation due to the formation of humus, for proper growth and development. It is relevant to point out here that soil pH has considerable impact on availability of most of the essential plant nutrients. Further, it is pertinent here to call into attention that phosphate solubilizing organisms (including PSB) have been reported to solubilize inorganic form of P by excreting organic acids (Gaur, 1990). Further, it is possible that microorganisms might have produced biologically active substances and played a role in the plant responses with the addition of these organisms (Kucey *et al.*, 1989). However, use of microbial culture would be beneficial to crop, if it is incubated, established and multiplied in the root zone.

It is well documented that in alkaline calcareous soils, where the reactivity of available phosphate rock is inadequate for acceptable short term yield and where the phosphorus retention capacity of the soil quickly renders soluble phosphorus fertilizers unavailable to plants. Under that conditions, partially acidulated rock phosphate can be feasible alternative. Finelly ground rock phosphate incubated for 30 days contain more available phosphorus to plants (Tisdale *et al.*, 1990).

Improvement in plant height could be ascribed to better nutritional environment of plants under addition of PROM. It seems to have enhanced metabolic activities in plants resulting in higher meristemic activities leading towards increased division, enlargement and elongation of cells, which might have helped in attaining higher plant height (Table 4.2) under its influence. Likewise, these improvements at cellular level might have enhanced dry matter accumulation by crop (Table 4.3). The observed improvement in dry matter production seems to be due to balanced nutritional environment. It is further clear from correlation studies that a positive and significant correlation existed between DMA at harvest and plant height at harvest ($r = 0.894$), total number of branches and DMA at harvest ($r = 0.891$) (Table 5.1). Under present experiment, improvement in branches plant^{-1} with the application of PROM seems to be on account of its pivotal role in formation of roots, their proliferation and improvement in their functional activities (Dart, 1977). This might

Table 5.1: Correlation coefficient and regression equation showing relationship between independent variable (X) and dependent variable (Y) on pooled basis

S. No.	Dependent (Y)	Independent (X)	Correlation coefficient (r)	Regression equation (Y = a+ bX)
1	Branches plant^{-1}	DMA at harvest	0.891	Y= 2.835 + 0.152 X
2	DMA at harvest	Plant height at harvest	0.894	Y=-27.560 + 0.947 X
3	DMA at harvest	Branches plant^{-1}	0.891	Y= -11.007 + 5.218 X
4	Pods plant^{-1}	DMA at 70 DAS	0.949	Y= 7.198 + 2.210 X
5	Pods plant^{-1}	Branches plant^{-1}	0.849	Y= -12.349 + 8.003 X
6	Pods plant^{-1}	DMA at 30 DAS	0.759	Y= 14.684 + 7.985 X
7	Pods plant^{-1}	DMA at 40 DAS	0.972	Y= 5.102 + 6.324 X
8	Pods plant^{-1}	DMA at 70 DAS	0.949	Y= 7.198 + 2.210 X
9	Pods plant^{-1}	Branches plant^{-1}	0.849	Y= -12.349 + 8.003 X
10	Pods plant^{-1}	DMA at harvest	0.975	Y= 3.873 + 1.570 X
11	Seed yield	DMA at 30 DAS	0.518	Y= 8.003 + 2.434 X
12	Seed yield	DMA at 40 DAS	0.877	Y= 2.383 + 2.546 X
13	Seed yield	DMA at 70 DAS	0.894	Y= 2.767 + 0.929 X
14	Seed yield	DMA at 70 DAS	0.894	Y= 2.767 + 0.929 X
15	Seed yield	DMA at harvest	0.891	Y= 1.735 + 0.640 X

S. No.	Dependent (Y)	Independent (X)	Correlation coefficient (r)	Regression equation (Y = a+ bX)
16	Seed yield	Pods plant^{-1}	0.821	Y= 1.508 + 0.367 X
17	Seed yield	Seed pod^{-1}	0.908	Y= -16.657 + 13.594 X
18	Seed yield	Seed index	0.884	Y= -5.986 + 2.150 X
19	Seed yield	Seed yield plant^{-1}	0.890	Y= 2.737 + 1.887 X
20	Seed yield	Branches plant^{-1}	0.844	Y= -6.514 + 3.555 X
21	Seed yield	N uptake by seed	0.996	Y= 2.718 + 0.123 X
22	Seed yield	P uptake by seed	0.977	Y= 3.568 + 1.177 X
23	Seed yield	Oil yield	0.965	Y= 4.773 + 0.034 X
24	Stover yield	Plant height at harvest	0.818	Y= -20.156 + 1.076 X
25	Stover yield	DMA at 30 DAS	0.519	Y= 22.531 + 4.209 X
26	Stover yield	DMA at 40 DAS	0.908	Y= 12.162 + 4.552 X
27	Stover yield	DMA at 70 DAS	0.907	Y= 13.222 + 1.630 X
28	Stover yield	DMA at harvest	0.882	Y= 11.910 + 1.095 X
29	Stover yield	N uptake by stover	0.992	Y= 7.066 + 0.546 X
30	Stover yield	P uptake by stover	0.929	Y= 14.526 + 2.726 X
31	Biological yield	DMA at 30 DAS	0.530	Y= 30.534 + 6.643 X
32	Biological yield	DMA at 40 DAS	0.916	Y= 14.545 + 7.098 X
33	Biological yield	DMA at 70 DAS	0.922	Y= 15.990 + 2.559 X

S. No.	Dependent (Y)	Independent (X)	Correlation coefficient (r)	Regression equation (Y = a+ bX)
34	Biological yield	DMA at harvest	0.905	Y= 13.645 + 1.736 X
35	Biological yield	Seed yield	0.963	Y= 10.840 + 2.570 X
36	Seed index	N content in seed	0.950	Y= -10.711 + 3.065 X
37	Seed index	P content in seed	0.868	Y= -2.563 + 18.645 X
38	Oil content	N content in seed	0.797	Y= -14.395 + 5.186 X
39	Oil content	P content in seed	0.848	Y= -3.847 + 36.743 X
40	Oil content	Oil yield	0.885	Y= 12.428 + 0.026 X
41	Oil yield	Seed yield	0.965	Y= -114.162 + 27.622 X
42	Protein yield	Seed yield	0.996	Y= -131.768 + 50.191 X
43	Protein yield	Protein content	0.933	Y= -1836.019 + 59.057 X
44	Protein content	P content in seed	0.799	Y= 19.591 + 33.256 X
45	Proline at 40 DAS	RWC at 40 DAS	-0.930	Y= 4.209 + -0.026 X
46	Proline at 70 DAS	RWC at 70 DAS	-0.904	Y= 4.325 + -0.026 X
47	N uptake by seed	Seed yield	0.996	Y= -21.083 + 8.031 X
48	P uptake by seed	Seed yield	0.977	Y= -2.509 + 0.811 X

have increased solubility and availability of P, inducted higher extraction of nutrients from environment for longer duration and their efficient translocation in the plant system. At the same time better root development might facilitated more area for infection of microbes thus, increased nodulation. These improvement (greater nutrient availability and biological N_2 fixation) probably provided congenial environment for active cell division and elongation in apical region, thereby improved number of branches plant^{-1}. Another possible reason may be that symbiosis nitrogen fixation and ultimately the formation of amino acids into the nodules, which are transferred to the host resulted into formation of more number of branches plant^{-1} and dry matter accumulation (Somani, 1984). The results are in close accordance with the findings of Shaktawat and Sharma (2001), Ameta (2002) and Meena (2003).

The results of present investigation, further revealed that DAP is also a good source of phosphorus as it was found at par with the application of PROM in all growth parameters of soybean. Tisdale and Nelson (1975) have supported this investigation and mentioned that when soluble phosphate and ammonium nitrogen are applied in band, plant roots proliferate extensively in that area.

5.3.2 Yield Attributes and Yield

Results of present investigation indicated that application of both phosphorus sources had pronounced effect on yield attributes *viz*., number of pods plant^{-1}, number of seeds pod^{-1}, seed index, seed yield plant^{-1} and yields (seed, stover and biological in q ha^{-1}) during both the years and found at par with each other.

It has already been emphasized that application of PROM resulted in overall improvement in growth and development of the crop by the virtue of congenial nutritional environment and perhaps by higher N-fixation. This might be attributed to enhancement in yield components of crop such as number of pods plant^{-1}, number of seeds pod^{-1}, seed index and seed yield plant^{-1}. This improvement suggests that during growth and development of each reproductive structure, greater availability of metabolites and nutrients synchronized with the demand. Similarly, the combined application of PROM might have enhanced all the components of growth and development because of solubilization of both organic as well as inorganic P in soil. These results are in close conformity with those of Nimje and Seth (1987), Bisht and Chandel (1996), Sharma *et al.* (2001) and Tanwar (2002). Further, an increase in various yield components with PROM seems not only due to adequate supply of assimilate nutrients but also to its pivotal role in enhancing physico-chemical and biological properties of the soil, which has greater impact on growth of roots. Thus, enhanced root activities under P fertilization might have increased vegetative and reproductive growth of the plants.

Application of PROM increased all the yield attributing characters, which indicates production of bolder seeds due to better phosphate utilization. The increased number of pods plant^{-1} and seed index might be attributed due to higher translocation of carbohydrates to reproductive parts during maturity. The results of present investigation are in accordance with Kulkarni *et al.* (2000) and Kavitha and Veeraraghavaiah (2001). Thus, the results clearly suggest that seed yield is artifact of several yield attributes, which are dependent on source (photosynthates/metobolites) and sink (yield components) relationship and overall improvement in all these aspects under the influence of PROM resulted in realization of higher productivity in terms of seed yield (Table 4.6). Further, another possible reason may be that the addition of organic matter alongwith PR (34/74) not only produces organic acids, but also work as a substrate for microorganisms causing release of phosphorus. Mandal (1975) pointed out that *Bacillus megatherium* var. *phosphaticum* was also found to be effective in solubilizing phosphate, when FYM was applied. Thus, cowdung + PSB in incubation caused higher dissolution of PR (34/74) due to enhancement of PSB activity alongwith acid production and chelating action of organic matter, resulted in increased availability and higher absorption of phosphorus by plants and its translocation to the economic sink (i.e., seed) resulting in higher seed yield.

Stover and biological yield with application of PROM seems to be on account of increased photosynthetic efficiency and greater development of vegetative structures. Since, biological yield is a sum of seed and stover yield, which are dependent on profused growth of vegetative and reproductive plant parts. In the present investigation increase in both these parameters ultimately led to realization of higher biological yield under above said treatment. Significant and positive correlations between pods plant^{-1} and branches plant^{-1} ($r = 0.849$), pods plant^{-1} and DMA at harvest ($r = 0.975$) and biological yield and seed yield ($r = 0.963$) also corroborate these contentions. These findings are also in close conformity with those of Sharma *et al.* (1990), Shivran (1998), Tanwar (2002), Ameta (2002), Mahala (2003) and Meena and Sharma (2005).

The results of present investigation also revealed that DAP is also a better source of phosphorus as PROM, and both remained at par with each other in increasing all yield attributes and yields. Tisdale and Nelson (1975) have supported this investigation and mentioned that when soluble phosphate and ammonium nitrogen are applied in a band, plant roots proliferate extensively in that area.

5.3.3 Quality Parameters

Present investigation also reveals that on pooled basis, PROM found better source of phosphorus in increasing content and yield of protein and oil in seed as compared to DAP. However, it was found at par with DAP. These improvements could be attributed to greater availability of nitrogen and phosphorus. The pivotal role of P and N in protein synthesis is well documented. Nitrogen is a constituent of amino acid, a basic unit of protein. While, phosphorus increases protein content indirectly as it is required in two processes of protein synthesis *viz.*, activation of amino acid and termination of carbon in mRNA of polypeptide releasing factors (Lehninger, 1990). It would be pertinent to recall here that addition of PROM improved soil conditions through improvement in physico-chemical and biological properties of soil conductive for adequate nutrient availability for proper vegetative and reproductive growth of the plant as well as for development of profuse root system. As a result, various bio-chemical reactions and functional activities responsible for mobilization and better translocation of water soluble carbohydrate and biosynthesis might have accelerated leading to reproductive organ (particularly in pods) during maturity.

Improvement in N content of seed due to both sources resulted in increased protein content of soybean seed because N plays an important role in amino acid synthesis thereby increased protein content in seed. As in every stage of protein synthesis considerable free energy is needed and higher energy phosphate compound ATP provides this energy for protein synthesis. Thus, phosphorus play an important role in protein synthesis through channeling of ATP energy in biosynthesis pathway. Increase in seed N and P content support the above findings. Further, in case of relative water content (RWC) and proline content both sources were found at par with each other. In present investigation, significant and positive correlations between protein content and N content in seed ($r = 1.0$), protein content and P content in seed ($r = 0.799$) and protein yield and protein content ($r = 0.933$) corroborate the aforesaid contention. The results are also substantiated by findings of Joshi *et al.* (1982), Honale (1996) and Ameta (2002). Further positive correlation between oil content and oil yield ($r = 0.885$), seed yield and oil yield ($r = 0.965$) was also found.

5.3.4 Nutrient Content and Uptake

The results indicated that nutritional composition of soybean seed in terms of N and P content and their uptake by seed and stover and at various growth stages of soybean was found slightly higher under PROM as a P source, but it was found at par with DAP (Table 4.9 to 4.16).

In general, the root system of legumes have a capacity to solubilize soil phosphorus through the extraction of amino acids and encourage the growth and multiplication of P solubilizing bacteria (Shivran and Ahlawat, 2000). The enhanced concentration of aforesaid nutrients in plant revealed by the positive influence of phosphorus on account of its pivotal role in root formation, proliferation and their functional activities (Dart, 1977). This might have induced higher extraction of nutrients from soil media for longer duration. Enhanced nutritional status of plant under PROM coupled with improved physical, chemical and biological properties of soil leading to higher growth of roots, which might have resulted in increased absorption, N_2 fixation and efficient translocation of nutrients towards plant system during vegetative growth. Data indicates the positive influence of phosphorus fertilization on nutrient content in soybean at 30, 40 and 70 DAS and in seed and stover appears to be due to improved availability of nutrients coupled with higher absorption by the plant (due to extensive and well developed root system) led to their deposition in vegetative parts later on translocated to reproductive parts ultimately increased N and P content. The results of present investigation are in close agreement with the findings of Patel (1988), Nimje and Seth (1988), Vyas (1989), Tomar *et al.* (1997), Ameta (2002) and Meena (2005).

It is well documented that besides, soil and climatic conditions, nutrient uptake by the crop largely depends on dry matter accumulation and concentration of nutrient in the plant parts at cellular level. The concomitant increase in both these components resulted in higher uptake of these nutrients by seed and stover. Higher uptake by seed and stover may be due to the increased availability of P in the soil due to solubilization of added phosphorus by P solubilizers through the production of organic acids etc. The availability of phosphorus might stimulate the activity of micro-organisms in soil and due to this reason, the fixation of atmostpheric nitrogen is increased. Hence, the uptake of N was increased. It is evident from significant correlation observed between total biomass accumulation and uptake of nutrients (Table 5.1). The results are in close agreement with Singh *et al.* (2002), Tanwar (2002), Mehta (2002), Ameta (2002) and Meena (2003).

Further DAP was found statistically non-significant with regards to dry matter accumulation. Tisdale and Nelson (1975) have supported this investigation and mention that when soluble phosphate alongwith ammonical nitrogen are applied as band placement, plant roots proliferate extensively in that area. There is also a greater uptake of phosphorus by crop, which is not observed if nitrate nitrogen is used instead of ammonium form.

5.3.5 Nutrient Status of Soil

Improvement in available phosphorus of soil after harvest was recorded by the application of PROM as well as with DAP. Though PROM registered higher available P of soil at harvest but remained at par with DAP (Table 4.17).

It is well documented that in neutral and calcareous soils, the availability of RP-P, generally has been found to increase with an increase in soil acidity (organic). Application of RP in conjunction with organic matter and PSB to alkaline soil is generally a good source of 'P', appear to be that the evolution of CO_2 and production of organic acids during the decomposition of the organic matter would solubilize some of the RP and increased its availability. Secondly, it is well established that phosphorus availability to plants is significantly increased by the action of soil organisms, which dephosphorylate phosphorus bearing organic compounds and also by bringing about favourable changes in soil reactions in the soil micro-environment leading to solubilization of inorganic phosphate. Besides, metabolic by-products of soil microorganism, such as organic acids and humic acid substances primarily emanating form organic matter decomposition from complex with iron and aluminium compounds, thereby reducing inorganic phosphate fixation to a remarkable degree and thus, increasing its availability indirectly (Chhonkar, 1994). The phenolic and aliphatic compounds are regularly produced in soils due to microbial decomposition of organic materials, which due to their solvent action activate the dissolution of RP resulted in increased available P in soil solution (Singh and Datta, 1974). Further, in an incubation study of rock phosphate revealed that FYM augmented significantly aerobic non-symbiotic nitrogen fixing bacteria and phosphate solublizing microorganism as well as increased their population in the rhizosphere and stimulated the activity of native rhizobial strains resulting in dissolution of phosphate rocks, ultimately increased availability of P in soil solution and significant increase in nodulation of legumes and plant growth (Singh, 1994). Further, FYM application improves the microbial population resulting in dissolution of both organics as well as inorganic non-available phosphorus, thus substantiating the increased available P under PROM source. The results are in accordance with the findings of Nimje and Seth (1987), Rao *et al.* (1995), Tanwar *et al.* (2002) and Ameta (2002).

5.4 EFFECT OF PHOSPHORUS LEVELS

5.4.1 Growth Parameters

It was observed that application at 60 kg P_2O_5 ha^{-1} significantly increased various growth parameters *viz.*, dry matter accumulation and CGR at various growth stages over 40 kg P_2O_5 ha^{-1}. Though 80 kg P_2O_5 ha^{-1} also increased significantly these growth parameters over 40 kg P_2O_5 ha^{-1} but it was found at par with 60 kg P_2O_5 ha^{-1}.

A marked improvement in growth parameters with the application of phosphorus seems to be on account of its pivotal role in formation of roots, their proliferation and improvement in their functional activities (Dart, 1977). This might have induced higher extraction of nutrients from soil environment for longer duration and their efficient translocation in the plant system. At the same time, better root development might facilitate more area for infection of microbes and increased nodulation. These improvements (greater nutrient availability and biological nitrogen fixation) probably provided congenial environment for active cell division and elongation in apical region, thereby enhanced the formation of new and broader leaves per plant ultimately resulted in higher dry matter accumulation. As noted by Fredeen *et al.* (1989), P deficiency reduced the rate of expansion of individual leaf even upto 85 per cent, which clearly emphasize the role of phosphorus fertilization in improving larger canopy development. The increased canopy development seems to have increased absorption and utilization of radiant energy resulting in higher dry matter accumulation. The rate of P absorption and translocation to the leaves is an important factor to increase dry matter and N_2- fixation. 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 had shown the effect of P on plant growth processes resulting in greater accumulation of biomass by individual plant through increase in assimilatory apparatus. Similar findings were also reported by Kumar and Rao (1991), Prasad *et al.* (1991), Prasad *et al.* (1993), Ameta (2002) and Meena (2005).

5.4.2 Effect of Yield Attributes and Yield

It is explicit from the results that application of phosphorus upto 60 kg P_2O_5 ha^{-1} significantly improved yield components *viz.*, number of pods $plant^{-1}$, number of seed pod^{-1}, seed index and seed yield $plant^{-1}$. This level of phosphorus increased number of pod $plant^{-1}$, number of seed pod^{-1}, seed index and seed yield $plant^{-1}$ by 12.34, 4.63, 6.91 and 16.34 per cent over 40 kg P_2O_5 ha^{-1}, respectively (Table 4.5). Crop productivity estimates *viz.*, seed, stover and biological yield increased significantly upto 60 kg P_2O_5 ha^{-1}. Further increase in P level upto 80 kg ha^{-1} decreased the yield as compared to 60 kg P_2O_5 ha^{-1} level. The pooled seed, stover and biological yield of 13.97, 32.74 and 46.70 q ha^{-1} were achieved under 60 kg P_2O_5 ha^{-1}, which were 9.14, 6.47 and 7.21 per cent higher over 40 kg P_2O_5 ha^{-1}, respectively.

It is an established fact that photosynthesis together with availability of assimilates (source) and storage organs (sink) exert an important regulative function on the complex processes of yield formation. The balanced source and sink components to a larger extent influenced by adequate mineral nutrition of the plant. In many legumes (soybean being no exception to it) poor sink capacity is attributed to low retention of flowers to form pods. Three possible explanation have been postulated, first being traditional favorite-hormones, the second assumes that other organs compete with flowers for want of metabolites and nutrients and last being limitation of vascular system for adequate and rapid supply of growth inputs from source to sink (Jeswani, 1986). The later assumption clearly suggests that plant can't be considered as a pool of carbon from which all sinks can draw it equally. This emphasizes need for higher production of metabolites during active reproductive phase. Hence, the increased number of pods $plant^{-1}$ with the addition of P suggests greater formation of flowers and their retention due to adequate supply of nutrients / metabolites. The correlation studies also subscribe positive interrelationship of pods $plant^{-1}$ with growth components like DMA at 30, 40 and 70 DAS ($r = 0.759$, 0.972 and 0.949), respectively.

Besides above ground plant development, increased P application also improved root development, which are considered primary sites for formation of hormones "Cytokinin" which promotes flower formation (Zeevart, 1976). Improvement in yield components of soybean due to increased P application was also reported by Prasad *et al.* (1993) and Tanwar (2002). The significant increase in seed yield of soybean due to the application of 60 kg P_2O_5 ha^{-1} could also be ascribed to the fact that yield of a crop is a function of yield components, which are dependent upon complementary interaction between vegetative and reproductive growth of the crop. The P fertilization improved both vegetative and reproductive parts. The dependence of seed yield on various growth and yield parameters was very well emphasized by the positive correlation of seed yield with dry matter accumulation at harvest ($r = 0.891$), number of pods $plant^{-1}$ ($r = 0.821$), number of seeds pod^{-1} ($r = 0.908$) and seed index ($r = 0.884$). Significantly higher seed yield of soybean with the application of 60 kg P_2O_5 ha^{-1} was also reported by Singh and Bajpai (1990), Prasad *et al.* (1993), Dashora and Jain (1994), Tuteja *et al.* (1995) and Tanwar (2002).

At 80 kg P_2O_5 the yield was slightly reduced as compared to 60 kg P_2O_5 due to the deficiency of micro-nutrients in plant specially Zn, Fe and Mn, as the result of interaction of phosphorus with these micro-nutrient. Thus the yield and the other parameters were reduced with 80 kg P_2O_5. Significant increase in stover yield with increased P application could be attributed to conducive effect on root and shoot growth of the plant, which in turn had occurred from increased morphological parameters *viz.*, plant height, number of branches $plant^{-1}$ CGR and finally DMA (Table 4.2 to 4.4). The results are in close conformity with Upadhyay *et al.* (1988), Patel and Chandravanshi (1996), Vara *et al.* (1994), Ameta (2002) and Meena (2005). Since, biological yield is a function of seed and stover yield representing both vegetative and reproductive growth of crop. The foregoing discussion had already attempted to demonstrate the profound influence of P fertilization on both these yields and consequently upon biological yield.

5.4.3 Quality Parameters

Application of phosphorus upto 60 kg P_2O_5 ha^{-1} significantly increased oil and protein content of soybean seeds. Due to the fact that protein content of seed is a direct effect of its N content, since P fertilization upto 60 kg P_2O_5 ha^{-1} significantly influenced N content (Table 4.9 and 4.10) hence protein content of seeds also increased significantly. The results are in close agreement with finding of Prasad *et al.* (1993), Ameta (2002) and Meena (2005).

Phosphorus plays role in energy transformations inside the plant as it is indispensable for the synthesis of ATP molecules, thus it is convincing to believe that improved energy status of plant fertilized with phosphorus might have enhanced the process of oil synthesis in developing seeds. The results are substantiated by corroborative findings of Fazal and Sisodia (1990) and Tanwar (2002).

5.4.4 Nutrient Content and Uptake

It was observed that the P concentration in soybean plant at 30, 40 & 70 DAS and in seed and stover at harvest increased significantly upto 80 kg P_2O_5 ha^{-1}. However, N content increased significantly only upto 60 kg P_2O_5 ha^{-1} (Table 4.9 to 4.12).

The marked increment in content of P alongwith N in plants with the application of increased P seems to be on account of its pivotal role in formation of roots, their proliferation and improvement in the functional activities (Dart, 1977). 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 mention here that increased P fertilization also resulted in increased soil available P after harvest (Table 4.17), which might be easily absorbed by the plants. At the same time, better root development might have facilitated more area for infection, thereby increased nodulation and subsequent nitrogen fixation. The findings of the present investigation are in close agreement with Jat and Nepalia (1994), Patel and Chandravanshi (1996), Ameta (2002) and Tanwar (2002).

Data on uptake of nutrients (Table 4.13 to 4.16) under the influence of P fertilization showed that increasing rates of P application from 40 to 60 kg P_2O_5 ha^{-1} caused significant increase in N and P uptake by the crop estimated at 30, 40 and 70 DAS and at harvest. Further, increase in P level upto 80 kg P_2O_5 ha^{-1}, however, significantly increased N and P uptake over 40 kg P_2O_5 ha^{-1} but remained at par with 60 kg P_2O_5 ha^{-1}. The nutrient accumulation is dependent on their concentration at cellular level and dry matter accumulation. Hence, improvement in both the components under P fertilization reflected in higher uptake of N and P by the crop. The regression analysis well narrated the positive and significant relationship between N uptake and seed yield (r = 0.966) and P uptake and seed yield (r = 0.977). The results are in close accordance with Reddy *et al.* (1990), Tuteja *et al.* (1995), Tanwar (2002) and Meena (2003).

5.4.5 Nutrient Status of Soil

Application of phosphorus upto 80 kg P_2O_5 ha^{-1} significantly increased available P status of soil after harvesting of crop during both the years of investigation.

Significant improvement of P status of soil with the fertilization of phosphorus might be due to build up of more phosphorus in soil. In the experimental findings P fertilization remarkably improved the available P at harvest to the tune of 3.65, 10.95 and 11.87 per cent over initial available P of soil with the application of 40, 60 and 80 kg P_2O_5 ha^{-1}, respectively. It would be relevant to state here that the gain in available P generally related to P input and P output. In present study, soybean removed relatively less P in the proportion of added P, thus leaving behind more P in soil at higher levels of P application. Besides, on addition of fertilizer P to the soil, there might be some sort of triggering action on native soil P resulting in increased availability. In some cases this being more than the quantity applied through fertilizers. Progressive build up of soil available P with increasing P rates have also been reported by Nimje and Seth (1987), Rao *et al.* (1995) and Tanwar (2002).

5.5 EFFECT OF AGROCHEMICALS

5.5.1 Brassinolide

5.5.1.1 Growth parameters

Application of brassinolide [a polyhydroxy-steroidal lactone with remarkable plant growth promoting activity (Grove *et al.*, 1979)] significantly enhanced various growth parameters of soybean like plant height, number of branches $plant^{-1}$ and dry matter accumulation at 40, 60 & 70 DAS and at harvest over KCl and water spray and in case of dry matter accumulation over benzyladenine also (Table 4.2 to 4.4). The favorable effect of brassinolide on over all growth of soybean could be ascribed to increased metabolic activities in the plant system as well as cell elongation, bending, division, reproductive & vascular development, membrane polarization, proton pumping in plants (Mandava & Thompson, 1983, Mandava, 1988, and Agarwal and Gehlot, 2000).

Takeno and Pharis (1982) postulated that brassinosteroid has growth promoting effects similar to auxins and GA. Thus, in the present investigation improvement in growth of crop with foliar application of brassinolide appears to be on account of increased photosynthetic efficiency of plant by virtue of improvement in chlorophyll content, LAI, maintaining higher RWC, reducing proline content ultimately results in increasing plant height, number of branches plant^{-1} and dry matter accumulation. Mandava and Thompson (1983) also reported significant improvement in crop growth under the influence of brassinolide due to its positive impact on both cell division and elongation resulting in elongation, swelling, curvature and splitting of the second internode. According to Mandava (1988) the primary effect of brassinosteroid is on growth region of the plant that would lead the growth. The increase in dry matter might be due to increase in leaf chlorophyll, soluble protein (Sairam, 1994), increase in photosynthesis (Shen *et al.,* 1990), increase in activity on nitrate reductase in roots and leaves (Singh *et al.,* 1993). Brassinolide application also proved to be promotory and enhanced chlorophyll content at every growth stage thus increased photosynthetic rate and dry matter (Hao *et al.,* 1990 and Bhatia and Kaur, 1997).

A significant increase in dry matter could be observed from positive correlation exhibited between DMA at harvest and plant height at harvest (r= 0.894) and total number of branches plant^{-1} (r= 0.891), respectively. The significant increase in crop growth as a result of brassinolide application under the present investigation is in close agreement with findings of Mitchell and Gregory (1972), Galstone (1983), Braun and Wild (1984), Ameta (1993), Fang *et al.* (1994), Kumawat (1996) and Mehta (2004).

5.5.1.2 Yield Attributes and Yield

Significant improvement in yield attributes such as number of pods plant^{-1}, number of seeds pod^{-1}, seed index and seed yield plant^{-1} and yields (seed and stover yield) were observed due to the foliar application of brassinolide over benzyladenine, KCl and water spray. The magnitude of increase in seed yield was obtained to the extent of 15.81 and 12.95 per cent during the year of 2003 and 2004, respectively over control (water spray).

The marked improvement in various yield attributes of soybean with the application of brassinolide could be ascribed to over all improvement in growth of the crop, estimated in terms of DMA at various growth stages as well as attainment of higher growth efficiency between peak duration. Increase in productivity of soybean (seed yield) under the influence of this agrochemical was also found due to improvement in number of pods plant^{-1}, number of seeds pod^{-1} and seed index.

Since, soybean is indeterminate in growth habit, at later stages of crop, vegetative and reproductive growth competes with each other for want of nutrients, moisture and metabolites. Foliar application of brassinolide increased dry matter accumulation plant^{-1} and minimized competition for photosynthates within the plants, resulting better development of reproductive structures of the crop, eg. number of pods plant^{-1}, number of seeds pod^{-1} and seed index. Brassinolide application is reported to increase translocation resulting in increased yield attributes, which contributed to higher seed yield (Grove *et al.*, 1979 and Petzold *et al.*, 1992). It also maintains source-sink relationship through proper partitioning.

Brassinolide application before anthesis has also been shown to enhance crop yield by improving fruit set and seed filling (Luo *et al.*, 1986). This finding was very much in agreement with those of Nakaseko and Yoshida (1989). It was also realized by Bhatia and Kaur (1997) that brassinolide presumably enhance the photosynthetic efficiency of leaves and also mobilization of metabolites to the reproductive sinks, thus regulating plant productivity. Further, it is also possible that brassinosteroid induced increase in soluble (enzyme) protein results in increased rate of photosynthesis, NR activity, chlorophyll content and ultimately seed yield (Sasse, 1985, Kalinich *et al.*, 1985 and Sairam, 1994). It is also believed that brassinolide action is mediated through endogenous auxin and in many cases it acts in a synergistic manner with auxin (Mandava, 1988). Li *et al.*, 1993 and Ramraj *et al.*, 1997 reported that brassinolide promotes the transport of assimilates to developing seeds leading to higher yield through improvement in pod set and also pod and seed sizes. Another possible reason might be due to brassinolide increased leaf water balance as indicated by increased RWC and reduction in proline content (Kulaeva *et al.*, 1991 and Sairam, 1994). It is also possible that brassinosteroid application is also reported to affect various metabolic activities, enhance water and mineral (nitrogen) uptake resulting in protein synthesis, growth and finally yield (Shen *et al.*, 1990, Kulaeva *et al.*, 1991 and Schilling *et al.*, 1991). Thus it is possible that brassinolide act on carbon reduction cycle of plant and increased the net CO_2 fixation of the plant leaves and consequently photosynthetic rate of the plant. These improvements ultimately led to better source and sink relationship, which increased the productivity of the crop.

Correlation studies carried out in the present investigation showed positive association between seed yield and number of pod plant^{-1} (r=0.821), number of seeds pod^{-1} (r=0.908) and seed index (r=0.884). The results of present study corroborate with the findings of Cerana *et al.* (1983), Meudt *et al.* (1984), Yokota and Takahashi (1986), Ameta (1993), Kumawat (1996) and Mehta (2004). At last, it may be concluded that application of brassinolide to soybean increased all the growth and developmental parameters, yield attributes and yields.

5.5.1.3 Quality parameters and nutrient uptake

Significant increase in oil and protein yield due to foliar application of brassinolide over rest of the treatments could be ascribed due to increase in oil and protein content as well as seed yield. This was due to increased N uptake (Mai *et al.*, 1989) and enhancement of various metabolic activities, water and mineral (nitrogen) uptake resulting in increased protein synthesis (Shen *et al.*, 1990, Kulaeva *et al.*, 1991, Schilling *et al.*, 1991 and Sairam, 1994). The improvement in quality of soybean seed as a result of brassinolide spray could be attributed to their pivotal role in creating congenial nutritional environment, greater availability of essential nutrients and regular supply of metabolites for protein synthesis through improved translocation of metabolites from source to sink (seed). The increase in protein content of seed seems to be due to increased nitrate reductase activity, which led nitrogen uptake and protein yield. Significant improvement in oil and protein yield due to application of brassinolide is in close conformity with the work of Ameta (1993), Kumawat *et al.* (1997), Salvi (1997), Mehta (1998) and Mehta (2004).

In the present investigation significant increase in the uptake of N and P as a result of foliar spray of brassinolide appears to be due to significant increase in seed, stover and total biomass production at harvest, as nutrient uptake to a greater extent is a function of dry matter production and to the lesser degree by per cent nutrient content. Foliar application of brassinolide enabled the plant to fix greater amount of CO_2 in dark reaction of photosynthesis, which might have led to the production of reasonable higher biomass as compared to that of produced by rest of the agrochemicals, eventually higher uptake of nutrients. The results are in cognizance with the findings of Sairam (1994), Ramraj *et al.* (1997) and Mehta (2004).

5.5.2 Benzyladenine

5.5.2.1 Growth parameters

It is generally accepted that cytokinin group of hormones is directly involved in large number of physiological and metabolic processes like auxin. It has also been observed from data (Table 4.2 to 4.4) that foliar spray of benzyladenine (BA) increased plant growth parameters viz., plant height, number of branches plant^{-1} and dry matter accumulation plant^{-1} over KCl and water spray.

In the present investigation, the beneficial effects of foliar applied benzyladenine appear to be on account of formation of SH compound and its cytokinin like activities and thus increased number of leaves and dry matter (Samuel *et al.*, 2000). The profound beneficial effect might be as a result of regulation of all organization of plant in the presence of cytokinin (BA). Adedipe *et al.* (1971) observed that the increase in dry matter and leaves was associated with increase in chlorophyll content of leaves and photosynthetic activity in leaves. This view is in close cognizance with the findings of Micheal and Beringer (1980), Williams and Cartwright (1980), Krishnan *et al.* (1999) and Samuel *et al.* (2000), who recorded increase in sink capacity, CGR, RGR and dry matter production with the foliar spray of benzyladenine. The increased vegetative growth and higher assimilate partitioning towards sink was also noticed by Panwar *et al.* (1990), Bhattacharjee *et al.* (1999) and Menaria (2005).

5.5.2.2 Yield attributes and yield

A significant increase in yield attributes and seed and stover yield of soybean was recorded as a result of foliar application of benzyladenine over that of KCl and water spray (Table 4.5 to 4.6). Application of benzyladenine increased the pooled seed yield by 7.98 per cent over water spray. Significant increase in seed yield of soybean could be ascribed to cumulative effect of yield components viz., number of pods plant^{-1}, number of seeds pod^{-1} and seed index, which increased seed yield plant^{-1} and ultimately led to greater seed production per unit area. As it is clear that pooled seed yield was found positively correlated with the yield attributes with correlation coefficient of 0.821, 0.908 and 0.884, respectively in the order named above. These results are in cognizance with the findings of Williams and Cartwright (1980), Crosby *et al.* (1981), Krishnan *et al.* (1999), Samuel *et al.* (2000) and Pandey *et al.* (2001)

who reported higher yield attributes and yield with the foliar application of benzyladenine in different crops.

Further, part of benevolence on soybean seed yield perhaps resulted on account of delicate interaction of auxin and cytokinin (BA) might have led to increased mobilization of metabolites and its partitioning towards seed development. This contention appears to be quite logical, as foliar applied benzyladenine in this study brought about significant increase in number of pods plant^{-1}, number of seeds pod^{-1}, seed index and seed yield plant^{-1} over KCl and water spray. This view is in close cognizance with the findings of Micheal and Beringer (1980), Williams and Cartwright (1980), Krishnan *et al.* (1999), Samuel *et al.* (2000) and Patil *et al.* (2002), who recorded increase in sink capacity, seed set, yield attributing characters and seed filling percentage as the source was not limiting factor. The increased vegetative growth and higher assimilate partitioning towards sink was also noticed by Panwar *et al.* (1990) and Patil *et al.* (2002).

5.3.2.3 Quality parameters and nutrient uptake

In the present investigation benzyladenine application significantly improved the quality of soybean seed assessed as protein and oil yield over KCl and water spray. Cytokinin (BA) may stimulate protein synthesis by stimulating the recruitment of previously untranslated mRNA into polysomes (Singh, 2004). This finding is in association with Pandey *et al.* (2001) and Patil *et al.* (2002), who recorded a remarkable improvement in protein content of seed. Further, significant improvement in oil content of seed might be due to increased transformation of stored translocated metabolites under the influence of favourable enzymatic activity created by BA application. While oil yield increased due to the increase in seed yield. These results are in close conformity with Samuel *et al.* (2000), Patil *et al.* (2002) and Vani *et al.* (2004). Patil *et al.* (2002) reported that foliar spray of benzyladenine increased nutrient uptake with concomitant increase in dry matter production. This is also clearly indicated by the positive correlation between nutrients uptake and yield of soybean.

6. SUMMARY

The results of field experiment entitled "Effect of phosphorus nutrition and agrochemicals on the productivity of soybean [*Glycine max* (L.) Merrill]" presented and discussed in the preceding chapters are summarized below:

6.1 EFFECT OF PHOSPHORUS SOURCES

- Application of PROM and DAP proved equally effective with respect to the growth parameters viz., plant height, number of branches plant^{-1} and dry matter accumulation at 30, 40, 70 DAS and at harvest during both the years as well as in pooled analysis. Both sources were also found at par with respect to crop growth rate (CGR) and relative growth rate (RGR) between 40 to 70 DAS and 70 DAS to harvest.
- Phosphorus application through PROM, however increased different yield attributes viz., number of pod plant^{-1}, number of seeds pod^{-1}, seed index and seed yield plant^{-1} as compared to DAP but both phosphorus sources remained at par with each other with regard to these yield attributes during both the years of experimentation as well as in pooled analysis.
- Improvement in yields (seed, stover and biological) of soybean was recorded due to PROM over DAP during either year of research as well as in pooled analysis but both phosphorus sources were found statistically at par.
- Application of both phosphorus sources viz., PROM and DAP were found statistically at par with each other with regard to increasing relative water content (RWC) of leaves at 40 and 70 DAS as well as in reducing proline content of leaves at 40 and 70 DAS during both the years as well as in pooled analysis.
- PROM and DAP both proved equally effective with respect to oil and protein content and their yield of seed during both the years of study as well as in pooled analysis and remained at par with each other.
- Phosphorus fertilization either through PROM or DAP was found statistically equally effective with regard to N and P content at 30, 40, 70 DAS and in seed and stover at harvest during both the years and in pooled analysis.

- Application of PROM registered a trend of higher N and P uptake by crop at 30, 40, 70 DAS and by seed and stover as compared to DAP but both sources of phosphorus remained at par with each other during each experimental year as well as in pooled analysis.
- Among phosphorus sources, PROM build up higher soil available P at harvest but it remained at par with DAP during either experimental year as well as in pooled analysis.
- The economic evaluation revealed that during the year 2003 as well as in pooled analysis, phosphorus fertilization through PROM registered significantly higher net returns (Rs. 10,760 and 14,077 ha^{-1} respectively) as compared to DAP, while in the year of 2004, both sources of phosphorus remained at par with each other. Similarly, the B:C ratio was found significantly higher under PROM, when compared with DAP during both the years of investigation as well as in pooled analysis. On pooled basis, PROM registered B:C ratio of 1.39 as compared to DAP (1.25).

6.2 EFFECT OF PHOSPHORUS LEVELS

- Application of 60 kg P_2O_5 ha^{-1} registered significantly higher dry matter accumulation $plant^{-1}$ at 30, 40, 70 DAS and at harvest, when compared with 40 kg P_2O_5 ha^{-1} during both the years of study as well as in pooled analysis. Further increase in P level up to 80 kg P_2O_5 ha^{-1} failed to increase dry matter as compared to 60 kg P_2O_5 ha^{-1} but found statistically superior over 40 kg P_2O_5 ha^{-1}. However, it remained at par with 60 kg P_2O_5 ha^{-1}. The dry matter accumulation $plant^{-1}$ increased by 2.40, 13.39, 13.34 and 12.85 per cent with the application of 60 kg P_2O_5 ha^{-1} over 40 kg P_2O_5 ha^{-1} at 30, 40, 70 DAS and at harvest, respectively. No significant variation was found with regard to plant height at harvest and number of branches $plant^{-1}$ with the application of different phosphorus levels. Whereas crop fertilized with 60 and 80 kg P_2O_5 ha^{-1} significantly increased CGR between 40 to 70 DAS and 70 DAS to harvest of crop during either year as well as in pooled analysis over 40 kg P_2O_5 ha^{-1}, except in the year of 2003 with regard to CGR between 70 DAS to harvest. Both higher levels were found at par with each other at aforesaid time interval.

- Significant improvement in yield attributes of soybean viz., number of number of pods plant^{-1}, number of seeds pod^{-1}, seed index and seed yield plant^{-1} was recorded with 60 and 80 kg P_2O_5 ha^{-1} over 40 kg P_2O_5 ha^{-1} during both the years of study as well as in pooled analysis but at 80 kg P_2O_5 ha^{-1} yield attributes decreased as compared to 60 kg P_2O_5 ha^{-1}, however both higher levels (60 and 80 kg P_2O_5 ha^{-1}) were found at par with each other. On pooled basis, application of 60 kg P_2O_5 ha^{-1} increased number of pods plant^{-1}, number of seeds pod^{-1}, seed index and seed yield plant^{-1} by 12.34, 4.62, 6.91 and 16.34 per cent, respectively over 40 kg P_2O_5 ha^{-1}.
- Application of 60 kg P_2O_5 ha^{-1} increased seed, stover and biological yields of soybean significantly over 40 kg P_2O_5 ha^{-1}. Further elevation in P level up to 80 kg P_2O_5 ha^{-1} decreased these yields during each experimental year as well as in pooled analysis as compared to 60 kg P_2O_5 ha^{-1} but remained significantly superior over 40 kg P_2O_5 ha^{-1}. The pooled seed, stover and biological yields of 13.97, 32.74 and 46.70 q ha^{-1} were registered with 60 kg P_2O_5 ha^{-1}, which were 9.14, 6.47 and 7.72 per cent higher over 40 kg P_2O_5 ha^{-1}, respectively.
- Increase in P level from 40 to 80 kg P_2O_5 ha^{-1} failed to gain any significant increase in RWC at 40 and 70 DAS. Further, no significant difference with regard to proline content at 40 and 70 DAS was observed during both the years of study as well as in pooled analysis.
- Application of 60 and 80 kg P_2O_5 ha^{-1} significantly increased oil and protein content of seed over 40 kg P_2O_5 ha^{-1} during both the years of experimentation as well as in pooled analysis. Oil and protein yields were significantly higher with these levels as compared to 40 kg P_2O_5 ha^{-1}. Further 60 and 80 kg P_2O_5 ha^{-1} remained at par with each other. On pooled basis, the increase in oil and protein yield with 60 kg P_2O_5 ha^{-1} was found of the order of 20.21 and 12.19 per cent, respectively over 40 kg P_2O_5 ha^{-1}.
- Phosphorus fertilization at 60 kg P_2O_5 ha^{-1} significantly increased N content of soybean at 30, 40, 70 DAS and in seed and stover at harvest over 40 kg P_2O_5 ha^{-1} during either year of investigation as well as in pooled analysis. However, in the year 2003, all the P levels were found statistically at par with each other in increasing N content of stover. While significant improvement in P content

at 40, 70 DAS and in seed and stover was observed up to 80 kg P_2O_5 ha^{-1} as compared to 40 and 60 kg P_2O_5 ha^{-1}. While, at 30 DAS, significant response was found only up to 60 kg P_2O_5 ha^{-1}.

- Significant enhancement in N uptake at 30, 40, 70 DAS and in seed and stover was recorded up to 60 kg P_2O_5 ha^{-1} as compared to 40 kg P_2O_5 ha^{-1} during each experimental year as well as in pooled analysis. Further increase in P level (80 kg P_2O_5 ha^{-1}), however, decreased N uptake but remained at par with 60 kg P_2O_5 ha^{-1}. While phosphorus uptake was also increased with increasing P levels but significant response was found only up to 60 kg P_2O_5 ha^{-1}. Further increase in P level up to 80 kg P_2O_5 ha^{-1} failed to bring any significant increase in P uptake and found at par with 60 kg P_2O_5 ha^{-1}, However, in the year 2004 and in pooled analysis, P uptake by stover was found significant up to 80 kg P_2O_5 ha^{-1}.
- Application of 60 and 80 kg P_2O_5 ha^{-1} significantly improved available P status of soil after harvesting of the crop over 40 kg P_2O_5 ha^{-1} during both experimental years as well as in pooled analysis. On pooled analysis, the available P status of soil was 24.5 kg P ha^{-1} under 80 kg P_2O_5 ha^{-1}, while 40 and 60 kg P_2O_5 ha^{-1} recorded 22.7 and 24.3 kg available P ha^{-1} in soil, respectively.
- Phosphorus fertilization through 60 and 80 kg P_2O_5 ha^{-1} was found equally profitable and both gained statistically higher net returns over 40 kg P_2O_5 ha^{-1}. On pooled basis, 60 kg P_2O_5 ha^{-1} registered highest net returns of Rs.14439 ha^{-1} as compared to 40 and 80 kg P_2O_5 ha^{-1} with Rs. 12720 and 13857 ha^{-1}, respectively. With regards to the B:C ratio, there was no significant difference in the year 2003, among all the levels of phosphorus, however, in the year 2004, 60 kg P_2O_5 ha^{-1} application was found at par with 80 kg P_2O_5 ha^{-1} and registered significantly higher B:C ratio as compared to 40 kg P_2O_5 ha^{-1}. While in pooled analysis, it was found significantly superior with B:C ratio of 1.39 in pooled analysis over 40 and 80 kg P_2O_5 ha^{-1} (1.27 and 1.30, respectively).

6.3 EFFECT OF AGROCHEMICALS

- Foliar application of brassinolide brought about a significant increase in growth parameters viz., plant height at harvest on pooled basis, number of branches $plant^{-1}$ in the year of 2003 and in pooled analysis over KCl and water spray and remained at par with benzyladenine. It was also found significantly superior over benzyladenine, KCl and water spray during the year 2003 as well as in pooled analysis with respect to dry matter accumulation at 40 and 70 DAS and at harvest. However, in 2004, it was found at par with benzyladenine with respect to DMA. While on pooled basis, foliar spray of benzyladenine was also found significantly superior over KCl and water spray in increasing dry matter $plant^{-1}$ at 70 DAS and at harvest. Further, being at par with benzyladenine, foliar spray of brassinolide was again found significantly superior over KCl and water spray in increasing crop growth rate (CGR) between 40 to 70 DAS. No significant response was observed in relative growth rate (RGR) between 40 to 70 DAS and CGR and RGR between 70 DAS to harvest among all the agrochemicals.
- Amongst all the agrochemicals, on pooled basis foliar spray of brassinolide significantly increased the yield attributes *viz.*, number of pods $plant^{-1}$, number of seeds pod^{-1}, seed index and seed yield $plant^{-1}$ over rest of the agrochemicals. However, it was found at par with benzyladenine with regard to number of pods $plant^{-1}$ and number of seeds pod^{-1}. However, during 2004, no significant difference was found among agrochemicals with regard to number of pods per $plant^{-1}$. Foliar spray of KCl and water were at statistically par with each other.
- Significant enhancement in yield (seed, stover and biological) of soybean on pooled basis was recorded due to foliar spray of brassinolide over rest of the treatments. However, in case of seed and biological yield during 2004 and in stover yield during the year 2004 and in pooled analysis, it was found at par with benzyladenine. Foliar spray with benzyladenine also produced significantly higher seed, stover and biological yields over KCl and water spray. While KCl and water spray remained at par with each other with respect to all type of yields during each experimental year as well as in pooled analysis. The pooled increase in these yields with foliar spray of brassinolide

was found of the order of 14.24, 10.13 and 11.34 per cent, respectively over water spray.

- Significant improvement in relative water content (RWC) of leaves at 40 and 70 DAS was estimated during the year 2003 as well as in pooled analysis, under the influence of foliar spray of brassinolide over rest of the agrochemicals. During 2004 benzyladenine and KCl were found at par with each other with regard to RWC at 40 DAS. While application of brassinolide reduced proline content of leaves at 40 and 70 DAS over rest of the agrochemicals during both the years of experimentation as well as in pooled analysis except in the year 2004, where it was found at par with benzyladenine.
- Foliar spray of brassinolide significantly increased oil content of seed over rest of the applied agrochemicals except in 2004, where it was found at par with benzyladenine. Protein content was also increased significantly through foliar spray of brassinolide and benzyladenine during both the years as well as in pooled analysis over KCl and water spray. Further, foliar spray of brassinolide also registered significantly higher oil and protein yield of seed over rest of the agrochemicals during both the experimental years as well as in pooled analysis. However in 2004, where it remained at par with benzyladenine in increasing protein yield.
- Significant improvement in N content at 40 and 70 DAS and in seed and stover was noticed during both the years as well as in pooled analysis over KCl and water, when foliar spray of brassinolide was done. On pooled basis, application of benzyladenine also found significantly superior over KCl and water spray. Significant increase in P content at 40 DAS of crop stage and in stover was also recorded during the year 2003 and in pooled analysis with foliar spray of brassinolide over rest of the agrochemicals, however, in 2004, it was found at par with benzyladenine in increasing P content of stover. While foliar spray of both brassinolide and benzyladenine registered significantly higher P content at 70 DAS and in seed over KCl and water spray and found at par with each other during either year of research as well as in pooled analysis.
- Foliar spray of brassinolide significantly increased N and P uptake at 40 and 70 DAS and by seed and stover at harvest over rest of the agrochemicals

during the year 2003 and in pooled analysis. However, during 2004, it was found at par with benzyladenine. While on pooled basis, benzyladenine also registered significantly higher N and P uptake over KCl and water spray. Further, KCl and water spray remained at par with each other in removing N and P from the soil.

- Foliar application of agrochemicals did not have any significant bearing on available P of soil after harvest of crop.
- Significantly higher net returns (Rs. 13818, 20529 and 17174 ha^{-1}) with B:C ratio (1.40, 2.07 and 1.74) was recorded through the foliar application of brassinolide during both the experimental years as well as in pooled analysis, respectively over rest of the agrochemicals. However, water spray and KCl also found significantly superior over benzyladenine in this regard.

7. CONCLUSION

On the basis of results emanated from the present investigation entitled "Effect of phosphorus nutrition and agrochemicals on the productivity of soybean [*Glycine max.* (L.) Merrill]" under prevailing agroclimatic conditions, revealed that both phosphorus sources remained at par with each other with regards to productivity. However, on pooled basis PROM registered significantly higher net returns of Rs. 14077 ha^{-1} with B : C ratio of 1.39 as compared to DAP. Further, 60 kg P_2O_5 ha^{-1} proved significantly superior over 40 kg ha^{-1} for enhancing the productivity of soybean, as it gave maximum net returns (Rs. 14439 ha^{-1}) and B : C ratio (1.39) on pooled basis. Among the agrochemicals foliar application of brassinolide proved significantly superior to enhance soybean productivity, as it obtained significantly higher net returns (Rs. 17174 ha^{-1}) with B : C ratio (1.74). Thus, it is inferred that PROM @ 60 kg P_2O_5 ha^{-1} and brassinolide @ 0.25 ppm are recommended for enhancing the productivity of soybean in Zone IV a.

Since, this is two years' study, further investigations are required for conforming the results and incorporation of these techniques in package of practices to the farmers of Rajasthan (Zone IVa).

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Effect of Phosphorus Nutrition and Agrochemicals on the Productivity of Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

A field experiment entitled "Effect of phosphorus nutrition and agrochemicals on the productivity of soybean [*Glycine max* (L.) Merrill]" was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur during two consecutive years of 2003 and 2004. The objectives were to study the effect of phosphorus nutrition on growth, yield and quality of soybean, to evaluate suitability of phosphorus carriers, to select most suitable agrochemical to enhance soybean productivity and finally to select economic viable treatment combination.

The soil of experimental field was clay loam in texture with medium fertility status and alkaline in reaction. The experiment consisted of 24 treatment combinations of 2 phosphorus sources [DAP and PROM] with 3 phosphorus levels (40, 60 and 80 kg ha^{-1}) and 4 agrochemicals (Brassinolide, benzyladenine, KCl and water spray). These were evaluated under factorial randomized block design with four replications.

The results indicated that application of both phosphorus sources viz., DAP and PROM remained statistically at par with each other during both experimental years as well as in pooled analysis with respect to various growth parameters, yield attributes and yields, quality parameters and nutrient uptake. The economic evaluation revealed that on pooled basis PROM registered significantly higher net returns of Rs. 14077 ha^{-1} with B:C ratio of 1.39 as compared to DAP (Rs. 10760 ha^{-1} and 1.25, respectively).

On pooled basis, it was found that crop fertilized with 60 kg P_2O_5 ha^{-1} significantly improved dry matter accumulation at various growth stages and at harvest of the crop over 40 kg P_2O_5 ha^{-1}. Further, it recorded significant improvement in yield attributes *viz*., number of pods $plant^{-1}$, number of seeds pod^{-1}, seed index and seed yield $plant^{-1}$ and thereby increased seed, stover and biological yields, protein and oil content and their yield over 40 kg ha^{-1}. While plant analysis recorded significant

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improvement in N content and its uptake by seed, stover and by crop at various growth stages. Significant improvement in P content was found through 80 kg P_2O_5 ha^{-1} over 40 and 60 kg ha^{-1} at various growth stages and in seed and stover. The highest P content in soil after harvest was also recorded with 80 kg P_2O_5 ha^{-1}.

The maximum net returns of Rs. 10987, Rs. 17891 and Rs. 14439 ha^{-1} was recorded under the application of 60 kg P_2O_5 ha^{-1} during 2003 and 2004 as well as on pooled basis, respectively, which was found significantly superior over 40 kg ha^{-1} and found at par with 80 kg P_2O_5 ha^{-1}. Phosphorus balance of soil at the end of the crop indicate that all levels of phosphorus left a positive balance of phosphorus, whereas, the highest mean build up of soil available phosphorus (2.6 kg ha^{-1}) was registered with 80 kg P_2O_5 ha^{-1}.

Among agrochemicals, on pooled basis, foliar spray of brassinolide significantly improved various growth parameters and yield attributes of soybean over rest of the agrochemicals. Brassinolide significantly increased dry matter accumulation per plant at 40 and 70 DAS and at harvest. It also significantly increased crop growth rate between 40 to 70 DAS. Brassinolide significantly enhanced soybean productivity in terms of seed, stover, biological, protein and oil yield. On pooled basis, it increased seed, stover, biological, protein and oil yield by 14.24, 10.14, 11.34, 19.32 and 18.24 per cent, respectively over water spray. Significant reduction in proline content and increase in relative water content were also recorded with brassinolide. Further, in pooled analysis application of brassinolide significantly increased N and P content and uptake by crop at 40 and 70 DAS and at harvest and in seed & stover over KCl and water spray. The economic analysis proved significant economic viability of brassinolide over rest of the agrochemicals as it fetched highest net returns ha^{-1} of Rs. 13818, 20529 and 17174 ha^{-1} with B : C ratio of 1.40, 2.07 and 1.74 during 2003 and 2004 as well as in pooled analysis, respectively.

फॉस्फोरस पोषण एवं कृषिरसायनों का सोयाबीन [*ग्लाइसिन मेक्स* (एल.) मेरिल] की उत्पादकता पर प्रभाव

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शोधकर्त्ता मुख्य सलाहकार

अनुक्षेपण

राजस्थान कृषि महाविद्यालय, उदयपुर के प्रशिक्षणात्मक प्रक्षेत्र पर लगातार दो वर्ष खरीफ 2003 एवं 2004 में एक क्षेत्र संपरीक्षण "फॉस्फोरस पोषण एवं कृषिरसायनों का सोयाबीन [*ग्लाइसीन मेक्स* (एल.) मेरिल] की उत्पादकता पर प्रभाव" प्रायोजित किया गया। इस परिक्षण के मुख्य उद्देश्य फॉस्फोरस पोषण का सोयाबीन की वृद्धि, उत्पादकता एवं गुणवत्ता पर प्रभाव, फॉस्फोरस वाहक की अनुकूलता का मूल्यांकन, सोयाबीन की उत्पादकता को बढ़ाने वाले सर्वाधिक उपयुक्त कृषिरसायन का चयन तथा आर्थिक चल उपचार संयोग का अध्ययन करना था।

प्रायोगिक प्रक्षेत्र की मृदा संरचना चिकनी दोमट, मध्यम उर्वरता स्तर तथा क्षारिय क्रिया वाली थी। परीक्षण में कुल चौबीस उपचार संयोजन किये गये, जिसमें फॉस्फोरस के दो स्त्रोतों [डी.ए.पी. तथा प्रोम] साथ में तीन फॉस्फोरस स्तर (40, 60 तथा 80 किलो प्रति हैक्टर) एवं चार कृषिरसायनों (ब्रासीनोलायड, बेन्जाइलएडीनिन, पोटेशियम क्लोराइड तथा जल छिड़काव) थे। इस परीक्षण को यादृच्छिकृत खण्ड अभिकल्पना में चार अभिआवृत्तियों के साथ मूल्यांकित किया गया।

परिणाम दर्शाते है कि दोनों फॉस्फोरस स्त्रोत [डी.ए.पी. तथा प्रोम] दोनों प्रायोगिक वर्षों तथा एकीकृत विश्लेषण में विभिन्न वृद्धि परिमापों, उपज परिमापों एवं उपजों, गुणवत्ता परिमापों तथा पोषक तत्व उदग्रहण के सम्बन्ध में संख्यिकी रूप से आपस में एक समान पाये गये। आर्थिक मूल्यांकन दर्शाता है कि एकीकृत आधार पर प्रोम ने डी.ए.पी की तुलना में (10766 रूपयें प्रति हैक्टर तथा 1.25) सर्वाधिक सार्थक शुद्ध आय क्रमशः 14077 रूपयें प्रति हैक्टर तथा लाभ लागत अनुपात 1.39 दर्ज किया।

एकीकृत आधार पर पाया गया कि फसल में 60 किलो फॉस्फोरस प्रति हैक्टर के प्रयोग से विभिन्न अवस्थाओं पर एवं कटाई पर शुष्क पदार्थ संग्रहण में 40 किलों फॉस्फोरस प्रति हैक्टर के प्रयोग की तुलना में सार्थक वृद्धि हुई। इसके बाद भी उपज परिमापों जैसे फलियों की संख्या प्रति पौधा, बीजों की संख्या प्रति फली, बीज सूचकांक तथा बीज उपज प्रति पौधा और

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इसी कारण से बीज, भूसा तथा जैव उपजों, प्रोटीन एवं तेल मात्रा तथा उनकी उपज 40 किलों फॉस्फोरस की तुलना में सार्थक रूप से बढ़ी। जबकि पौधों के विश्लेषण से बीज, भूसा एवं फसल की विभिन्न अवस्थाओं पर नत्रजन की मात्रा तथा उसके उदग्रहण में सार्थक सुधार पाया गया। 80 किलो फॉस्फोरस प्रति हैक्टर की दर से प्रयोग करने पर विभिन्न अवस्थाओं पर तथा बीज एवं भूसे में फॉस्फोरस की मात्रा में 40 व 60 किलो फॉस्फोरस प्रति हैक्टर की अपेक्षा सार्थक सुधार हुआ।

सर्वाधिक शुद्ध आय 10,987, 17,891 एवं 14,439 रूपये प्रति हैक्टर क्रमशः 2003, 2004 एवं एकीकृत आधार पर 60 किलो फॉस्फोरस प्रति हैक्टर के अनुप्रयोग से पायी गयी जो कि 40 किलो प्रति हैक्टर से सार्थक रूप से एवं 80 किलो प्रति हैक्टर के लगभग समान थी। फसल की समाप्ति पर मृदा में फॉस्फोरस स्थिति चित्रण दर्शाता है कि सभी फॉस्फोरस स्तर ने फॉस्फोरस पर धनात्मक स्तर छोड़ा, जबकि 80 किलो फॉस्फोरस प्रति हैक्टर के द्वारा मृदा में उपलब्ध फॉस्फोरस का सर्वाधिक माध्य (2.6 किलो प्रति हैक्टर) निर्माण पाया गया।

एकीकृत आधार पर सभी कृषिरसायनों में से ब्रासिनोलॉयड के पर्णिय छिड़काव से सोयाबीन के विभिन्न वृद्धि परिमापों एवं उपज परिमापों पर शेष सभी कृषिरसायनों की तुलना में सार्थक वृद्धि पायी गयी। बुवाई के 40 व 70 दिन बाद तथा कटाई पर ब्रासिनोलॉयड से शुष्क पदार्थ संग्रहण प्रति पौधा सार्थक रूप से बढ़ा। इसके प्रयोग से बुवाई के 40 से 70 दिनों के मध्य में फसल वृद्धि दर भी सार्थक पायी गयी। ब्रासिनोलॉयड से सोयाबीन की उत्पादकता में बीज, भूसा, जैव, प्रोटिन एवं तेल के उपज के क्रम में सार्थक सुधार हुआ। एकीकृत आधार पर इससे बीज, भूसा, जैव, प्रोटिन एवं तेल उपज में जल छिड़काव की तुलना में 14.24, 10.14, 11. 34, 19.32 एवं 18.24 प्रतिशत की वृद्धि पायी गई। ब्रासिनोलॉयड़ के छिड़काव से प्रोलिन मात्रा में कमी व सापेक्षित जल मात्रा में वृद्धि भी सार्थक दर्ज की गयी। इसके अलावा एकीकृत आधार पर ब्रासिनोलॉयड के अनुप्रयोग ने पोटेशियम क्लोराइड एवं जल छिड़काव की अपेक्षा फसल द्वारा बुवाई के 40 व 70 दिन बाद तथा कटाई पर एवं बीज व भूसा में नत्रजन व फॉस्फोरस की मात्रा व उदग्रहण को सार्थक बढ़ाया। आर्थिक विश्लेषण सत्यापित करता है कि अन्य बाकी कृषिरसायनों की तुलना में ब्रासिनोलॉयड की आर्थिक जीवन योग्यता सार्थक पायी गयी, जैसा कि इसके द्वारा क्रमशः वर्ष 2003 व 2004 एवं एकीकृत विश्लेषण के आधार पर सर्वाधिक शुद्ध आय 13,818, 20,529 एवं 17,174 रूपये प्रति हैक्टर के साथ 1.40, 2.07 एवं 1.74 का लाभ : लागत अनुपात भी प्राप्त हुआ।

APPENDIX –I

Mean weekly meteorological parameters during crop growing season (2003 & 2004)

Std. week No.	Dates	Temperature (^0C)				R.H. (%)				Sunshine (hrs day^{-1})		Evaporation (mm day^{-1})		Rainfall (mm)	
		Max.		Min.		Max.		Min.							
		2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
27	Jul., 02-Jul., 08	33.2	34.0	25.4	24.7	88	76	65	55	5.4	5.3	9.7	6.8	25.0	23.4
28	Jul., 09-Jul., 15	31.0	32.1	24.2	25.1	91	74	75	54	5.8	5.3	5.6	7.5	57.7	0.0
29	Jul., 16-Jul., 22	31.8	33.5	24.7	24.2	90	80	68	55	6.4	8.1	4.2	7.3	16.3	60.1
30	Jul., 23-Jul., 29	28.9	33.4	23.4	25.2	97	72	88	52	3.1	6.5	5.2	5.9	164.9	1.5
31	Jul., 30-Aug., 05	28.2	30.3	22.7	23.4	93	95	80	72	4.2	2.4	4.7	3.3	11.2	110.6
32	Aug.,06-Aug., 12	30.4	30.1	23.6	23.7	93	83	79	81	4.6	1.2	1.5	3.1	12.6	54.8
33	Aug.,13-Aug., 19	31.1	28.6	24.2	23.1	85	95	67	80	6.5	1.6	6.3	3.7	0.0	68.2
34	Aug.,20-Aug., 26	30.8	29.5	23.8	23.2	88	87	79	72	3.9	2.1	3.5	4.5	85.9	51.2
35	Aug.,27-Sept.,02	28.4	29.5	22.9	22.3	90	84	78	61	2.3	8.3	3.3	6.8	20.1	0.0
36	Sept.,03-Sept.,09	30.4	32.5	22.3	21.3	83	82	60	73	8.4	8.2	4.7	3.9	0.2	25.2
37	Sept.,10-Sept.,16	30.8	31.4	21.6	22.1	83	82	64	52	8.7	8.9	4.3	5.2	2.4	0.0
38	Sept.,17-Sept.,23	31.5	33.0	22.2	21.8	92	85	84	62	4.4	7.4	1.5	3.8	56.8	46.4
39	Sept.,24-Sept.,30	31.7	33.9	21.0	21.8	89	85	61	53	7.9	6.7	4.1	3.6	6.6	80.4
40	Oct.,01-Oct.,07	32.8	31.5	16.9	20.3	81	93	51	57	10.5	7.0	1.4	4.2	6.2	47.8
41	Oct.,08-Oct.,14	33.3	30.4	16.6	17.8	74	91	33	43	10.6	8.5	2.3	4.1	0.0	0.0
42	Oct.,15-Oct.,21	33.0	31.2	14.4	14.4	82	70	22	20	10.1	9.2	0.9	3.7	0.0	0.0
43	Oct.,22-Oct.,28	32.6	31.6	12.7	13.0	67	69	18	23	10.2	9.3	1.0	4.3	0.0	0.0
44	Oct.,29-Nov.,04	31.8	30.0	14.6	12.7	69	76	27	29	10.0	7.9	1.0	3.1	0.0	0.0

Source : Agromet observatory, Rajasthan College of Agriculture, Udaipur

APPENDIX-II

Analysis of variance for growth parameters

Source of variance	d.f.	MSS							
		Growth parameters							
		Plant population (lac ha^{-1})				Plant height (cm)		Branches $plant^{-1}$	
		20 DAS		At harvest					
		2003	2004	2003	2004	2003	2004	2003	2004
Rep.	3	0.00437	0.00206	0.00080	0.01369	55.28038	2.00944	0.43819	0.08708
Treatment	23	0.00151	0.00055	0.00283	0.00298	13.29337	4.87406	0.27003	0.29476
S	1	0.00220	0.00001	0.00008	0.00683	0.49594	0.63375	0.26042	0.57042
L	2	0.00511	0.00108	0.00888	0.00307	26.43510	11.86698	0.37095	0.86792
A	3	0.00404	0.00124	0.00610	0.00695	73.75038	16.22833	1.06153*	1.16819
S X L	2	0.00003	0.00114	0.00076	0.00282	3.15656	5.07469	0.14042	0.00792
S X A	3	0.00043	0.00008	0.00183	0.00059	3.06122	2.66931	0.19708	0.15264
L X A	6	0.00129	0.00019	0.00116	0.00148	1.96413	0.65281	0.09319	0.04903
S X L X A	6	0.00017	0.00053	0.00249	0.00305	0.64142	2.82941	0.09875	0.03347
Error	69	0.00309	0.00463	0.00465	0.00554	27.80263	21.60365	0.36892	0.62100
Total	95	0.08688	0.11270	0.12937	0.16386	796.65663	536.26111	10.99355	16.62986

* Significant at 5 % level of significance

APPENDIX-III

Pooled analysis of variance for growth parameters

Source of variance	d.f.	MSS			
		Growth parameters			
		Plant population (lac ha^{-1})		Plant height (cm)	Branches plant^{-1}
		20 DAS	Harvest		
Year	1	0.0155880*	0.1800750*	134.5025521*	50.0208333*
Rep.	6	0.0032130	0.0072427	28.6449132	0.2626389
Treatment	23	0.0014543	0.0041630	14.8544361	0.4861681
S	1	0.0009630	0.0042188	1.1254688	0.8008333
L	2	0.0054396	0.0061505	36.7401563	1.1865583
A	3	0.0048255	0.0113132	74.1261632*	2.1816667*
S X L	2	0.0006896	0.0008203	6.0360938	0.1064583
S X A	3	0.0001005	0.0009576	4.6771354	0.0513889
L X A	6	0.0006729	0.0023137	1.4625174	0.0664583
SXLXA	6	0.0002354	0.0044821	1.6315104	0.1161806
TXY	23	0.0006054	0.0016402	3.3129869	0.0786246
SXY	1	0.0012505	0.0027000	0.0042188	0.0300000
LXY	2	0.0007521	0.0057953	1.5619271	0.0523083
AXY	3	0.0004533	0.0017389	15.8525521	0.0480556
SXLXY	2	0.0004771	0.0027609	2.1951562	0.0418750
SXAXY	3	0.0004130	0.0014583	1.0533854	0.2983333
LXAXY	6	0.0008049	0.0003280	1.1544271	0.0757639
SXLXAXY	6	0.0004646	0.0010589	1.8393229	0.0160417
Error	138	0.0038558	0.0050923	24.7031378	0.4949577

* Significant at 5 % level of significance

APPENDIX – IV

Analysis of variance for dry matter accumulation at various stages

Source of variance	d.f.	MSS							
		Dry matter accumulation (g plant^{-1})							
		30 DAS		40 DAS		70 DAS		At harvest	
		2003	2004	2003	2004	2003	2004	2003	2004
Rep.	3	0.01209	0.11587	0.20835	0.60347	0.21546	0.18343	1.53181	5.43819
Treatment	23	0.19781*	0.20538*	0.55665	0.50656	3.41945*	4.68776*	7.47579*	9.62027*
S	1	0.08402	0.02802	0.28820	0.09127	0.00363	0.24908	3.60375	0.92042
L	2	2.05536*	2.29302*	2.15690*	3.30125*	18.61713*	20.81413*	29.52792*	59.97219*
A	3	0.00500	0.00272	2.53668*	1.60236*	13.29558*	21.10165*	34.44162*	32.92236*
S X L	2	0.01923	0.00134	0.01698	0.00292	0.46498	1.21930	0.06500	0.34198
S X A	3	0.02500	0.00411	0.02705	0.00472	0.02550	0.01968	0.15153	0.10958
L X A	6	0.00362	0.00120	0.01872	0.01819	0.07267	0.01915	0.86750	0.06080
S X L X A	6	0.03411	0.01322	0.06059	0.00347	0.01336	0.00395	0.02819	0.04281
Error	69	0.04794	0.09840	0.41788	0.57268	1.59930	1.45785	3.23702	4.69037
Total	95	2.63119	3.95367	14.08723	17.65862	63.21512	69.65346	133.29773	187.07208

* Significant at 5 % level of significance

APPENDIX – V

Pooled analysis of variance for dry matter accumulation at various stages

Source of variance	d.f.	MSS			
		Dry matter accumulation (g $plant^{-1}$)			
		30 DAS	**40 DAS**	**70 DAS**	**At harvest**
Year	1	2.5254187*	10.0558521*	87.0216021*	556.2408333*
Rep.	6	0.0639826	0.4059104	0.1994441	3.4850000
Treatment	23	0.3906988*	1.0220021*	7.9652779*	16.6770203*
S	1	0.1045333	0.3519187	0.0963021	4.0833333
L	2	4.3436521*	5.3898896*	39.2599630*	86.7041146*
A	3	0.0011118	4.0102521*	33.6914764*	67.1667389*
S X L	2	0.0126583	0.0098438	1.5408974	0.2547396
S X A	3	0.0190208	0.0154688	0.0037424	0.2293056
L X A	6	0.0027285	0.0203646	0.0662998	0.5507118
SXLXA	6	0.0153583	0.0258854	0.0033189	0.0130035
TXY	23	0.0124894	0.0412086	0.1419314	0.4190420
SXY	1	0.0075000	0.0275521	0.1564083	0.4408333
LXY	2	0.0047313	0.0682646	0.1713036	2.7959896
AXY	3	0.0066118	0.1287910	0.7057535	0.1972389
SXLXY	2	0.0079187	0.0100521	0.1433818	0.1522396
SXAXY	3	0.0100875	0.0163021	0.0414403	0.0318056
LXAXY	6	0.0020910	0.0165451	0.0255196	0.3775868
SXLXAXY	6	0.0319688	0.0381771	0.0139908	0.0580035
Error	138	0.0731692	0.4952771	1.5285745	3.9636957

* Significant at 5 % level of significance

APPENDIX – VI

Analysis of variance for crop growth rate and relative growth rate

Source of variance	d.f.	MSS							
		Crop growth rate (g m^{-2} day^{-1})				Relative growth rate (g g^{-1} day^{-1})			
		Between 40-70 DAS		Between 70 DAS – harvest		Between 40 -70 DAS		Between 70DAS – harvest	
		2003	2004	2003	2004	2003	2004	2003	2004
Rep.	3	0.47255	0.83573	2.90750	5.72847	0.00001580	0.0000297	0.0000116	0.0000124
Treatment	23	1.82361	2.83578	1.54500	1.61264	0.00000456	0.0000042	0.0000027	0.0000027
S	1	0.26138	0.40546	4.21243	2.99756	0.00002400	0.0000175	0.0000408	0.0000092
L	2	10.99605*	8.71241*	1.95864	12.39472*	0.00000456	0.0000019	0.0000080	0.0000034
A	3	5.78311*	14.36621*	6.49121	2.26252	0.00000628	0.0000146	0.0000057	0.0000110
S X L	2	0.65355	1.84225	0.26513	0.42810	0.00001210	0.0000119	0.0000014	0.0000054
S X A	3	0.02296	0.04276	0.15862	0.18194	0.00000020	0.0000007	0.00000073	0.00000080
L X A	6	0.11709	0.05239	1.12693	0.09770	0.00000161	0.0000060	0.00000465	0.00000036
S X L X A	6	0.04363	0.02782	0.02732	0.08800	0.00000310	0.0000003	0.00000021	0.00000013
Error	69	1.40560	1.80253	3.15737	3.89966	0.00002230	0.0000299	0.00004510	0.00001130
Total	95	46.78248	64.03501	87.37209	107.78416	0.00056000	0.0007500	0.00038000	0.00029000

* Significant at 5 % level of significance

APPENDIX – VII

Pooled analysis of variance for crop growth rate and relative growth rate

Source of variance	d.f.	MSS			
		Crop growth rate (g m^{-2} day^{-1})		Relative growth rate (g g^{-1} day^{-1})	
		Between 40-70 DAS	Between 70 DAS-harvest	Between 40-70 DAS	Between 70 DAS-harvest
Year	1	31.4436792*	205.1837999*	0.00000950	0.00024900*
Rep.	6	0.6541395	4.3179855	0.00002270	0.00001200
Treatment	23	4.4792909*	2.6846508	0.00000620	0.00000315
S	1	0.6589610	7.1584487	0.00004120	0.00001670
L	2	19.5995829*	12.0911626*	0.00000109	0.00006120
A	3	19.1450922*	8.0409846	0.00000963	0.00000330
S X L	2	2.2075005	0.6749458	0.00002260	0.00000612
S X A	3	0.0193987	0.2805776	0.00000058	0.00000087
L X A	6	0.1500100	0.6016045	0.00000170	0.00000293
SXLXA	6	0.0595051	0.0803316	0.00000201	0.00000020
TXY	23	0.1801035	0.4729885	0.00000259	0.00000226
SXY	1	0.0078754	0.0515442	0.00000025	0.00000032
LXY	2	0.1088822	2.2621978	0.00000536	0.00000521
AXY	3	1.0042244	0.7127390	0.00001130	0.00000826
SXLXY	2	0.2883085	0.0182806	0.00000144	0.00000066
SXAXY	3	0.0463187	0.0599871	0.00000027	0.00000065
LXAXY	6	0.0194667	0.6230191	0.00000051	0.00000208
SXLXAXY	6	0.0119491	0.0349902	0.00000133	0.00000014
Error	138	1.6040694	3:5285156	0.00002610	0.00001320

* Significant at 5 % level of significance

APPENDIX-VIII

Analysis of variance for yield attributes

Source of variance	d.f.	MSS							
		Yield attributes							
		Number of pods plant^{-1}		Number of seed pod^{-1}		Seed index (g)		Seed yield plant^{-1} (g)	
		2003	2004	2003	2004	2003	2004	2003	2004
Rep.	3	18.54250	12.40229	0.00642	0.01178	0.09843	0.31819	0.08152	0.42253
Treatment	23	31.87848*	14.23851	0.01945*	0.02153*	0.76028*	0.84664*	1.41223*	0.67639
S	1	18.72667	0.74378	0.01450	0.00004	0.22042	0.02190	0.75260	0.19350
L	2	181.40844*	103.32445*	0.06346*	0.08936*	1.92502*	5.83442*	10.48755*	3.25902*
A	3	106.85472*	36.73986	0.10066*	0.08456*	4.40415*	1.94901*	3.33586*	2.52486*
S X L	2	3.92698	0.49451	0.00003	0.00166	0.03082	0.15879	0.07415	0.15459
S X A	3	1.14028	0.85312	0.00015	0.00113	0.01099	0.16039	0.04020	0.02948
L X A	6	2.61858	0.29930	0.00022	0.00645	0.01562	0.09963	0.06064	0.10580
S X L X A	6	0.68517	0.75489	0.00034	0.00288	0.00253	0.08973	0.01889	0.03972
Error	69	11.62308	15.80750	0.01092	0.00698	0.28275	0.35750	0.29171	0.48118
Total	95	530.27500	485.13670	0.40659	0.33735	12.43046	15.03164	17.61790	16.67533

* Significant at 5 % level of significance

APPENDIX-IX

Pooled analysis of variance for yield attributes

Source of variance	d.f.	MSS			
		Yield attributes			
		Number of pods $plant^{-1}$	Number of seed pod^{-1}	Seed index (g)	Seed yield $plant^{-1}$ (g)
Year	1	668.8266797*	1.5123000*	10.6079005*	56.9525255*
Rep.	6	15.4723950	0.0091014	0.2083075	0.2520248
Treatment	23	43.2328493*	0.0384620*	1.4573487*	1.9155315*
S	1	13.4673047	0.0065333	0.1906380	0.8546672
L	2	279.1925203*	0.1516000*	7.2030766*	12.7192443*
A	3	132.2652936*	0.1823472*	5.9840866*	5.6319575*
S X L	2	2.6280328	0.0007583	0.0642724	0.0476203
S X A	3	1.7737686	0.0007722	0.0699714	0.0546561
L X A	6	1.4008717	0.0029389	0.0664085	0.0754679
SXLXA	6	1.1207842	0.0010639	0.0388432	0.0260300
TXY	23	2.8841427	0.0025130	0.1495657	0.1730907
SXY	1	6.0031380	0.0080083	0.0516797	0.0914380
LXY	2	5.5403641	0.0012250	0.5563599	1.0273318
AXY	3	11.3292936	0.0028722	0.3690727	0.2287672
SXLXY	2	1.7934599	0.0009333	0.1253391	0.1811286
SXAXY	3	0.2196297	0.0005028	0.1014130	0.0150325
LXAXY	6	1.5170071	0.0037306	0.0488363	0.0909776
SXLXAXY	6	0.3192807	0.0021611	0.0534099	0.0325773
Error	138	13.7152892	0.0089478	0.3201263	0.3864437

* Significant at 5 % level of significance

APPENDIX-X

Analysis of variance for yields and harvest index

Source of variance	d.f.	MSS							
		Yields (q ha^{-1})						Harvest index (%)	
		Seed yield		Stover yield		Biological yield			
		2003	2004	2003	2004	2003	2004	2003	2004
Rep.	3	2.33066	2.17919	6.49166	15.57593	16.13652	26.05975	1.65733	3.57968
Treatment	23	5.09939*	4.22843*	14.09508	13.73214	32.34936*	32.04750*	5.72713	1.42355
S	1	2.19010	0.18113	5.74282	0.45238	15.02584	1.20602	0.60992	0.17201
L	2	8.67932*	16.71942*	27.48355*	53.12722*	64.91965*	129.43467*	2.52844	2.37935
A	3	19.18130*	17.71323*	70.27851*	47.19989*	162.86467*	121.85127*	2.21991	3.68112
S X L	2	4.07578	0.36435	0.19552	5.32400	5.89680	3.06701	11.03344	4.81509
S X A	3	0.23635	0.27168	0.25396	0.92803	0.58605	2.12841	0.46317	0.10543
L X A	6	3.33525	1.15249	7.68496	3.84792	12.98155	9.14249	9.63418	0.14776
S X L X A	6	1.88687	0.33924	0.89643	5.16887	3.18917	7.34820	6.35601	0.98910
Error	69	1.70105	2.33081	8.65095	10.35265	10.81909	14.65141	8.76183	6.56986
Total	95	80.55019	88.20567	313.52570	358.96657	512.98739	608.73964	247.08742	165.60034

* Significant at 5 % level of significance

APPENDIX – XI

Pooled analysis of variance for yields and harvest index

Source of variance	d.f.	MSS			
		Yields (q ha^{-1})			Harvest index (%)
		Seed yield	Stover yield	Biological yield	
Year	1	327.5291297*	1199.4500630*	2780.5418521*	29.4715158
Rep.	6	2.2549255	11.0337929	21.0981340	2.6185081
Treatment	23	8.6176695*	25.7042759*	61.3842869*	4.4280718
S	1	1.8154630	4.7094005	12.3728521	0.7148740
L	2	24.0725646*	78.4404562*	188.5529646*	3.9196623
A	3	36.8061894*	114.6967089*	281.1597035*	5.1551314
S X L	2	3.4372271	1.7481396	0.4693083	15.0920061
S X A	3	0.3453394	0.2969394	1.2471590	0.3852457
L X A	6	3.4290826	9.9045646	20.6772597	4.9708466
SXLXA	6	1.5570451	3.6172368	8.3561757	2.7768715
TXY	23	0.7101482	2.1229445	3.0125738	2.7226130
SXY	1	0.5557755	1.4857922	3.8590021	0.0670632
LXY	2	1.3261750	2.1703146	5.8013521	0.9881253
AXY	3	0.0883394	2.7816852	3.5562368	0.7458898
SXLXY	2	1.0029083	3.7713812	8.4945021	0.7565214
SXAXY	3	0.1626936	0.8850589	1.4673035	0.1833599
LXAXY	6	1.0586597	1.6283160	1.4467806	4.8110909
SXLXAXY	6	0.6690681	2.4480687	2.1811972	4.5682411
Error	138	2.0159291	9.5017969	12.7352500	7.6658441

* Significant at 5 % level of significance

APPENDIX – XII

Analysis of variance for relative water content and proline content

Source of variance	d.f.	MSS							
		Relative water content (%)				Proline (µ mole g^{-1})			
		40 DAS		70 DAS		40 DAS		70 DAS	
		2003	2004	2003	2004	2003	2004	2003	2004
Rep.	3	6.60430	14.23175	6.27579	11.37461	0.00615	0.00255	0.00458	0.00192
Treatment	23	18.64540	7.86015	16.36876	10.98850	0.01409	0.00763	0.01486	0.00900
S	1	0.19984	0.66334	0.03450	0.82696	0.00202	0.00940	0.01788	0.00468
L	2	32.05499	2.09543	5.00466	8.13964	0.00499	0.01282	0.01563	0.00084
A	3	114.60755*	53.47913*	115.71170*	74.56292*	0.08201*	0.04020*	0.09135*	0.04431*
S X L	2	1.06240	1.29778	0.27106	0.90305	0.00959	0.00493	0.00388	0.01308
S X A	3	1.28996	0.90547	1.29883	0.53526	0.00249	0.00043	0.00037	0.00479
L X A	6	1.71437	1.48834	2.10289	1.12853	0.00169	0.00011	0.00110	0.00213
S X L X A	6	0.73848	0.20832	0.37444	0.29290	0.00489	0.00133	0.00052	0.00241
Error	69	19.96700	14.03022	24.38425	29.38588	0.00942	0.00593	0.01018	0.00646
Total	95	608.79346	397.18799	692.60730	771.49497	0.33093	0.19739	0.35266	0.21941

* Significant at 5 % level of significance

APPENDIX – XIII

Pooled analysis of variance for relative water content and proline content

Source of variance	d.f.	MSS			
		Relative water content (%)		Proline (μ mole g^{-1})	
		40 DAS	70 DAS	40 DAS	70 DAS
Year	1	253.9660021*	246.0469922*	0.4730255*	4.2245333*
Rep.	6	10.4180243	8.8252012	0.0043519	0.0032469
Treatment	23	23.9526716	26.2977772	0.0189400*	0.0209575*
S	1	0.7956750	0.5996505	0.0100630	0.0204187
L	2	25.2342146	12.8921036	0.0166797	0.0114646
A	3	161.0787090*	184.2287672*	0.1178297*	0.1309021*
S X L	2	0.0332688	0.7572661	0.0103849	0.0064000
S X A	3	1.1434764	1.5732936	0.0006700	0.0037854
L X A	6	1.7244090	2.8899203	0.0007089	0.0025500
SXLXA	6	0.4279660	0.3674634	0.0019460	0.0010854
TXY	23	2.5528847	1.0594813	0.0027810	0.0029040
SXY	1	0.0675000	0.2618130	0.0013547	0.0021333
LXY	2	8.9162021	0.2521984	0.0011255	0.0050021
AXY	3	7.0079729	6.0458464	0.0043769	0.0047611
SXLXY	2	2.3269187	0.4168443	0.0041391	0.0105583
SXAXY	3	1.0519542	0.2607977	0.0022561	0.0013722
LXAXY	6	1.4783021	0.3414943	0.0010852	0.0006778
SXLXAXY	6	0.5188354	0.2998790	0.0042780	0.0018451
Error	138	16.9986116	26.8850628	0.0076758	0.0083183

* Significant at 5 % level of significance

APPENDIX – XIV

Analysis of variance for quality parameters

Source of variance	d.f.	MSS							
		Quality parameters							
		Oil content (%)		Oil yield (kg ha^{-1})		Protein content (%)		Protein yield (kg ha^{-1})	
		2003	2004	2003	2004	2003	2004	2003	2004
Rep.	3	0.19731	0.04069	922.64421	807.46618	0.94459	3.41415	4185.07396	4473.87231
Treatment	23	2.50556*	3.69791*	3264.37981*	4211.98689*	2.94292	2.60054	11670.72217*	11409.28539*
S	1	0.28167	0.30263	993.84392	235.39173	0.09650	0.15844	3708.27997	377.32848
L	2	21.79652*	36.83951*	12469.97958*	28114.91570*	10.96133*	10.25916*	25724.35767*	44824.29266*
A	3	3.75736*	2.46804*	10692.84850*	11569.54927*	14.32034*	12.82419*	48248.49092*	50888.31763*
S X L	2	0.14372	1.00430	1543.88752	618.03323	0.81809	0.31852	7417.60351	1254.77180
S X A	3	0.17807	0.14100	160.53119	297.21286	0.08504	0.00089	350.70167	487.75663
L X A	6	0.15141	0.12143	1444.43000	495.49201	0.06484	0.00079	5958.08697	2077.63762
S X L X A	6	0.12518	0.08432	805.40642	100.19509	0.07112	0.00311	2814.71801	547.34302
Error	69	0.42896	0.82090	675.42639	1174.47551	2.05330	2.44591	3079.96399	3907.90344
Total	95	29.27271	47.27192	41484.36307	60112.30252	70.73297	79.60756	164499.78232	181826.83950

* Significant at 5 % level of significance

APPENDIX – XV

Pooled analysis of variance for quality parameters

Source of variance	d.f.	MSS			
		Quality parameters			
		Oil content (%)	Oil yield (kg ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})
Year	1	44.7663755*	191131.1054600*	64.8747658*	699230.9731932*
Rep.	6	0.1190005	865.0551946	2.1793687	4329.4731329
Treatment	23	5.9271516*	7057.7964197*	5.4652303*	21896.3712780*
S	1	0.5841047	1098.2939920	0.2511233	3225.6988320
L	2	57.6013896*	38840.2039291*	21.2073641*	68035.6971851*
A	3	5.8272658*	22233.7213758*	27.0117700*	98810.6207938*
S X L	2	0.9537062	2026.3132369	0.7159017	7248.2402558
S X A	3	0.2496783	353.6992681	0.0379114	628.2202970
L X A	6	0.0137965	1378.9797015	0.0320863	6149.1650333
SXLXA	6	0.0527632	576.9748647	0.0435135	2435.2420345
TXY	23	0.2763190	418.5702859	0.0782326	1183.6362870
SXY	1	0.0001880	130.9416558	0.0038186	859.9096185
LXY	2	1.0346396	1744.6913563	0.0131258	2512.9531438
AXY	3	0.3981269	28.6763949	0.1327563	326.1877546
SXLXY	2	0.1943146	135.6075131	0.4207064	1424.1350603
SXAXY	3	0.0693839	104.0447772	0.0480178	210.2380101
LXAXY	6	0.2590410	560.9423073	0.0335381	1886.5595526
SXLXAXY	6	0.1567437	328.6266367	0.0307194	926.8189939
Error	138	0.6249281	924.9509522	2.2496067	3493.9337151

* Significant at 5 % level of significance

APPENDIX – XVI

Analysis of variance for nitrogen content in plants at various stages

Source of variance	d.f.	MSS					
		Nitrogen content (%)					
		30 DAS		40 DAS		70 DAS	
		2003	2004	2003	2004	2003	2004
Rep.	3	0.014259	0.025679	0.006520	0.011348	0.005809	0.029462
Treatment	23	0.007570	0.011675	0.011568*	0.018990	0.008821	0.015796
S	1	0.007884	0.002709	0.002926	0.000551	0.015251	0.000683
L	2	0.051764*	0.127350*	0.053070*	0.140550*	0.049245*	0.070080*
A	3	0.002779	0.000059	0.037701*	0.048543*	0.025429*	0.071540*
S X L	2	0.003828	0.004763	0.008539	0.004529	0.006095	0.003045
S X A	3	0.003437	0.000087	0.000648	0.000040	0.000012	0.000053
L X A	6	0.003287	0.000054	0.000778	0.000033	0.000031	0.000164
S X L X A	6	0.002777	0.000136	0.003369	0.000018	0.000073	0.000102
Error	69	0.006240	0.014377	0.006099	0.012170	0.006448	0.012042
Total	95	0.215808	0.445847	0.235483	0.436847	0.221733	0.427536

* Significant at 5 % level of significance

APPENDIX – XVII

Pooled analysis of variance for nitrogen content in plants at various stages

Source of variance	d.f.	MSS		
		Nitrogen content (%)		
		30 DAS	40 DAS	70 DAS
Year	1	0.0936333*	0.2380083*	0.0202130
Rep.	6	0.0199691	0.0089344	0.0176359
Treatment	23	0.0172608*	0.0284336*	0.0229429*
S	1	0.0099187	0.0030083	0.0111935
L	2	0.1707443*	0.1831599*	0.1183990*
A	3	0.0017632	0.0824424*	0.0874866*
S X L	2	0.0085609	0.0121755	0.0080646
S X A	3	0.0014188	0.0002597	0.0000283
L X A	6	0.0017783	0.0003606	0.0000611
SXLXA	6	0.0013755	0.0016707	0.0001090
TXY	23	0.0019833	0.0021246	0.0016737
SXY	1	0.0006750	0.0004688	0.0047402
LXY	2	0.0083693	0.0104599	0.0009261
AXY	3	0.0010750	0.0038014	0.0094825
SXLXY	2	0.0000297	0.0008922	0.0010750
SXAXY	3	0.0021056	0.0004285	0.0000366
LXAXY	6	0.0015630	0.0004509	0.0001340
SXLXAXY	6	0.0015373	0.0017165	0.0000653
Error	138	0.0103082	0.0091344	0.0092450

* Significant at 5 % level of significance

APPENDIX – XVIII

Analysis of variance for nitrogen content in seed and stover

Source of variance	d.f.	MSS			
		Nitrogen content (%)			
		Seed		Stover	
		2003	2004	2003	2004
Rep.	3	0.024181	0.087402	0.012919	0.000615
Treatment	23	0.075339	0.066574	0.002247	0.003223
S	1	0.002471	0.004056	0.000600	0.007176
L	2	0.280610*	0.262634*	0.004639	0.016191*
A	3	0.366601*	0.328299*	0.013171*	0.011396*
S X L	2	0.020943	0.008154	0.000009	0.000107
S X A	3	0.002177	0.000023	0.000097	0.000012
L X A	6	0.001660	0.000020	0.000158	0.000006
S X L X A	6	0.001821	0.000080	0.000173	0.000014
Error	69	0.052565	0.062615	0.004040	0.002687
Total	95	1.810764	2.037953	0.123079	0.087131

* Significant at 5 % level of significance

APPENDIX – XIX

Pooled analysis of variance for nitrogen content in seed and stover

Source of variance	d.f.	MSS	
		Nitrogen content (%)	
		Seed	Stover
Year	1	1.6607940*	0.0354797*
Rep.	6	0.0557918	0.0067672
Treatment	23	0.1399099*	0.0049079
S	1	0.0064288	0.0018130
L	2	0.5429085*	0.0186488*
A	3	0.6915013*	0.0241554*
S X L	2	0.0183271	0.0000474
S X A	3	0.0009705	0.0000505
L X A	6	0.0008214	0.0000748
SXLXA	6	0.0011139	0.0001016
TXY	23	0.0020028	0.0005619
SXY	1	0.0000978	0.0059630
LXY	2	0.0003360	0.0021811
AXY	3	0.0033986	0.0004115
SXLXY	2	0.0107701	0.0000693
SXAXY	3	0.0012293	0.0000589
LXAXY	6	0.0008586	0.0000891
SXLXAXY	6	0.0007864	0.0000859
Error	138	0.0575899	0.0033639

* Significant at 5 % level of significance

APPENDIX – XX

Analysis of variance for phosphorus content in plants at various stages

Source of variance	d.f.	MSS					
		Phosphorus content (%)					
		30 DAS		40 DAS		70 DAS	
		2003	2004	2003	2004	2003	2004
Rep.	3	0.000097	0.000147	0.000156	0.000163	0.000030	0.000212
Treatment	23	0.000341*	0.000507*	0.000520*	0.000620*	0.000509*	0.000403*
S	1	0.000028	0.000273	0.000096	0.000165	0.000196	0.000131
L	2	0.003811*	0.005626*	0.004477*	0.006233*	0.004185*	0.001721*
A	3	0.000019	0.000005	0.000890	0.000295*	0.000896*	0.001153*
S X L	2	0.000027	0.000010	0.000070	0.000287	0.000127	0.000332
S X A	3	0.000006	0.000008	0.000013	0.000010	0.000003	0.000124
L X A	6	0.000005	0.000005	0.000010	0.000004	0.000024	0.000119
S X L X A	6	0.000007	0.000006	0.000001	0.000018	0.000009	0.000081
Error	69	0.000047	0.000149	0.000097	0.000141	0.000132	0.000139
Total	95	0.003789	0.007451	0.006368	0.008153	0.006965	0.006504

* Significant at 5 % level of significance

APPENDIX – XXI

Pooled analysis of variance for phosphorus content in plants at various stages

Source of variance	d.f.	MSS		
		Phosphorus content (%)		
		30 DAS	40 DAS	70 DAS
Year	1	0.0202130*	0.0145603*	0.0040425*
Rep.	6	0.0001221	0.0001595	0.0001211
Treatment	23	0.0008313*	0.0010782*	0.0008246*
S	1	0.0002385	0.0002567	0.0003229
L	2	0.0093433*	0.0106306*	0.0055817*
A	3	0.0000077	0.0009695*	0.0020162*
S X L	2	0.0000310	0.0000924	0.0004140
S X A	3	0.0000074	0.0000151	0.0000489
L X A	6	0.0000075	0.0000120	0.0000347
SXLXA	6	0.0000071	0.0000119	0.0000413
TXY	23	0.0000167	0.0000619	0.0000874
SXY	1	0.0000630	0.0000047	0.0000033
LXY	2	0.0000944	0.0000794	0.0003244
AXY	3	0.0000165	0.0002159	0.0000321
SXLXY	2	0.0000061	0.0002650	0.0000442
SXAXY	3	0.0000057	0.0000078	0.0000788
LXAXY	6	0.0000029	0.0000023	0.0001079
SXLXAXY	6	0.0000062	0.0000076	0.0000484
Error	138	0.0000977	0.0001187	0.0001355

* Significant at 5 % level of significance

APPENDIX – XXII

Analysis of variance for phosphorus content in seed and stover

Source of variance	d.f.	MSS			
		Phosphorus content (%)			
		Seed		Stover	
		2003	2004	2003	2004
Rep.	3	0.001209	0.000033	0.000060	0.000066
Treatment	23	0.001855*	0.001361*	0.000282*	0.000450*
S	1	0.000513	0.000473	0.000003	0.000100
L	2	0.016251*	0.011971*	0.002494*	0.004477*
A	3	0.003110*	0.002258*	0.000482*	0.000330*
S X L	2	0.000145	0.000051	0.000009	0.000120
S X A	3	0.000000	0.000001	0.000002	0.000004
L X A	6	0.000001	0.000002	0.000003	0.000004
S X L X A	6	0.000005	0.000001	0.000002	0.000004
Error	69	0.000536	0.000405	0.000042	0.000082
Total	95	0.027754	0.019795	0.003193	0.005393

* Significant at 5 % level of significance

APPENDIX – XXIII

Pooled analysis of variance for phosphorus content in seed and stover

Source of variance	d.f.	MSS	
		Phosphorus content (%)	
		Seed	Stover
Year	1	0.0026329*	0.0052188*
Rep.	6	0.0006210	0.0000633
Treatment	23	0.0031554*	0.0007040*
S	1	0.0009855	0.0000689
L	2	0.0278589*	0.0067959*
A	3	0.0051784*	0.0007642*
S X L	2	0.0001553	0.0000932
S X A	3	0.0000001	0.0000045
L X A	6	0.0000021	0.0000040
SXLXA	6	0.0000021	0.0000023
TXY	23	0.0000611	0.0000279
SXY	1	0.0000004	0.0000342
LXY	2	0.0003622	0.0001755
AXY	3	0.0001895	0.0000477
SXLXY	2	0.0000417	0.0000360
SXAXY	3	0.0000007	0.0000016
LXAXY	6	0.0000007	0.0000024
SXLXAXY	6	0.0000039	0.0000035
Error	138	0.0004706	0.0000619

* Significant at 5 % level of significance

APPENDIX – XXIV

Analysis of variance for nitrogen uptake by plants at various stages

Source of variance	d.f.	MSS					
		Nitrogen uptake (kg ha^{-1})					
		30 DAS		40 DAS		70 DAS	
		2003	2004	2003	2004	2003	2004
Rep.	3	0.318188	2.372120	2.951007	10.264426	1.291881	9.692084
Treatment	23	3.425687*	3.971981*	8.545573	9.315272	35.678295*	54.084534*
S	1	1.600556	0.501993	4.393934	1.014986	2.166184	0.911738
L	2	35.499823*	44.574708*	34.958861*	61.240367*	197.032722*	242.632851*
A	3	0.090815	0.050490	38.298875*	29.577628*	138.272463*	247.709154*
S X L	2	0.395453	0.035272	0.523057	0.002288	1.833316	6.387936
S X A	3	0.444007	0.052801	0.445882	0.008435	0.195395	0.094826
L X A	6	0.075332	0.016252	0.215361	0.274258	0.707750	0.231673
S X L X A	6	0.557205	0.204371	0.610660	0.057871	0.175408	0.031498
Error	69	0.714294	1.588023	5.136498	7.792495	13.564888	13.251168
Total	95	43.010550	69.348507	186.606528	260.908902	586.817896	729.117048

* Significant at 5 % level of significance

APPENDIX – XXV

Pooled analysis of variance for Nitrogen uptake by plants at various stages

Source of variance	d.f.	MSS		
		Nitrogen uptake (kg ha^{-1})		
		30 DAS	40 DAS	70 DAS
Year	1	47.2610660*	174.7542926*	583.9856*
Rep.	6	1.3451542	6.6077164	5.491982
Treatment	23	7.1786435*	17.1921992*	87.88128*
S	1	1.9476388	4.8162788	0.133617
L	2	79.8019211*	94.2776445*	437.735*
A	3	0.0263297	65.8957421*	375.5178*
S X L	2	0.3113081	0.2387378	6.848882
S X A	3	0.2954708	0.2108301	0.095042
L X A	6	0.0554778	0.2604947	0.772176
SXLXA	6	0.2727391	0.2814754	0.082762
TXY	23	0.2190241	0.6686454	1.881549
SXY	1	0.1549106	0.5926407	2.944306
LXY	2	0.2726102	1.9215828	1.930563
AXY	3	0.1149753	1.9807609	10.46386
SXLXY	2	0.1194163	0.2866072	1.37237
SXAXY	3	0.2013375	0.2434865	0.195179
LXAXY	6	0.0361054	0.2291245	0.167247
SXLXAXY	6	0.4888365	0.3870558	0.124144
Error	138	1.1511586	6.4644969	13.40803

* Significant at 5 % level of significance

APPENDIX – XXVI

Analysis of variance for nitrogen uptake by seed and stover

Source of variance	d.f.	MSS			
		Nitrogen uptake (kg ha^{-1})			
		Seed		Stover	
		2003	2004	2003	2004
Rep.	3	107.137893	114.531131	18.360451	32.514772
Treatment	23	298.770488*	292.077706*	42.112117*	48.815220*
S	1	94.931967	9.659609	14.038546	4.107478
L	2	658.543556*	1147.501892*	85.808774*	213.048643*
A	3	1235.161367*	1302.740931*	227.555244*	181.135060*
S X L	2	189.890650	32.122158	0.533545	12.121325
S X A	3	8.977963	12.486570	0.761384	2.313419
L X A	6	152.527026	53.187523	14.758564	8.979433
S X L X A	6	72.056781	14.011981	1.392372	10.680103
Error	69	78.847078	100.042328	19.741544	24.182662
Total	95	4211.194427	4654.767091	795.275529	962.966023

* Significant at 5 % level of significance

APPENDIX – XXVII

Pooled analysis of variance for nitrogen uptake by seed and stover

Source of variance	d.f.	MSS	
		Nitrogen uptake (kg ha^{-1})	
		Seed	Stover
Year	1	17900.3129137*	3080.3639252*
Rep.	6	110.8345122	25.4376113
Treatment	23	560.5471047*	84.9060206*
S	1	82.5778901	1.4793950
L	2	1741.7138479*	284.6374690*
A	3	2529.5518923*	403.3070207*
S X L	2	185.5549505	3.7845229
S X A	3	16.0824396	0.8955722
L X A	6	157.4186249	20.3475247
SXLXA	6	62.3421961	6.6370281
TXY	23	30.3010889	6.0213164
SXY	1	22.0136862	16.6666298
LXY	2	64.3316005	14.2199476
AXY	3	8.3504065	5.3832828
SXLXY	2	36.4578575	8.8703477
SXAXY	3	5.3820931	2.1792313
LXAXY	6	48.2959245	3.3904725
SXLXAXY	6	23.7265662	5.4354467
Error	138	89.4447031	21.9621032

* Significant at 5 % level of significance

APPENDIX – XXVIII

Analysis of variance for phosphorus uptake by plants at various stages

Source of variance	d.f.	MSS					
		Phosphorus uptake (kg ha^{-1})					
		30 DAS		40 DAS		70 DAS	
		2003	2004	2003	2004	2003	2004
Rep.	3	0.001677	0.028126	0.029606	0.064454	0.009285	0.075030
Treatment	23	0.043370*	0.054768*	0.121035*	0.131157	0.585762*	0.764968*
S	1	0.009843	0.000801	0.057383	0.025322	0.026510	0.001728
L	2	0.463865*	0.619738*	0.583341*	0.997015*	3.642017*	3.354880*
A	3	0.001119	0.000819	0.485196*	0.317125*	1.989904*	3.364249*
S X L	2	0.004121	0.000369	0.004053	0.005777	0.032195	0.207140
S X A	3	0.003670	0.000639	0.005771	0.001252	0.005453	0.026073
L X A	6	0.000638	0.000125	0.004852	0.003527	0.015057	0.033295
S X L X A	6	0.005584	0.002254	0.008271	0.001568	0.003532	0.016293
Error	69	0.007488	0.017543	0.060354	0.087090	0.146121	0.178448
Total	95	0.506419	0.851497	2.345684	3.073067	7.860920	10.044084

* Significant at 5 % level of significance

APPENDIX – XXIX

Pooled analysis of variance for phosphorus uptake by plants at various stages

Source of variance	d.f.	MSS		
		Phosphorus uptake (kg ha^{-1})		
		30 DAS	40 DAS	70 DAS
Year	1	0.9285871*	2.8390390*	12.8778271*
Rep.	6	0.0149014	0.0470300	0.0421572
Treatment	23	0.0954674*	0.2422467*	1.3143263*
S	1	0.0081292	0.0794716	0.0073506
L	2	1.0777969*	1.5513350*	6.9723207*
A	3	0.0003890	0.7733708*	5.2301270*
S X L	2	0.0032232	0.0008921	0.1994479
S X A	3	0.0027104	0.0036612	0.0067769
L X A	6	0.0004239	0.0058765	0.0220660
SXLXA	6	0.0022901	0.0035653	0.0059184
TXY	23	0.0026709	0.0099453	0.0364039
SXY	1	0.0025147	0.0032334	0.0208869
LXY	2	0.0058065	0.0290205	0.0245768
AXY	3	0.0015493	0.0289501	0.1240261
SXLXY	2	0.0012671	0.0089381	0.0398867
SXAXY	3	0.0015992	0.0033620	0.0247495
LXAXY	6	0.0003394	0.0025028	0.0262851
SXLXAXY	6	0.0055480	0.0062731	0.0139064
Error	138	0.0125156	0.0737222	0.1622846

* Significant at 5 % level of significance

APPENDIX – XXX

Analysis of variance for phosphorus uptake by seed and stover

Source of variance	d.f.	MSS			
		Phosphorus uptake (kg ha^{-1})			
		Seed		Stover	
		2003	2004	2003	2004
Rep.	3	0.997470	0.846185	0.405050	1.182648
Treatment	23	3.117561*	3.121926*	1.318871*	1.810446*
S	1	1.428888	0.348113	0.263827	0.274380
L	2	9.954412*	16.402129*	5.869027*	12.594805*
A	3	11.679791*	11.293428*	5.351360*	4.196042*
S X L	2	1.212925	0.152529	0.019357	0.497850
S X A	3	0.089960	0.113386	0.002411	0.067360
L X A	6	1.352574	0.544130	0.347444	0.220898
S X L X A	6	0.752608	0.143607	0.024578	0.177494
Error	69	0.672546	1.061213	0.381363	0.550631
Total	95	40.367322	49.188837	19.287739	27.727240

* Significant at 5 % level of significance

APPENDIX – XXXI

Pooled analysis of variance for phosphorus uptake by seed and stover

Source of variance	d.f.	MSS	
		Phosphorus uptake (kg ha^{-1})	
		Seed	Stover
Year	1	144.3022324*	85.3533212*
Rep.	6	0.9218276	0.7938488
Treatment	23	5.9346603*	2.9867549*
S	1	1.5937763	0.5381552
L	2	25.6224039*	17.8157431*
A	3	22.8648567*	9.3755504*
S X L	2	1.1002746	0.2500130
S X A	3	0.1414553	0.0291813
L X A	6	1.4462456	0.5160526
SXLXA	6	0.6269406	0.1191973
TXY	23	0.3048267	0.1425621
SXY	1	0.1832247	0.0000517
LXY	2	0.7341370	0.6480885
AXY	3	0.1083623	0.1718514
SXLXY	2	0.2651786	0.2671937
SXAXY	3	0.0618909	0.0405899
LXAXY	6	0.4504582	0.0522900
SXLXAXY	6	0.2692749	0.0828748
Error	138	0.8668791	0.4659968

* Significant at 5 % level of significance

APPENDIX – XXXII

Analysis of variance for available phosphorus in soil after harvest, net returns and B : C ratio

Source of variance	d.f.	MSS					
		Available P (kg ha^{-1}) in soil after harvest		Net returns (Rs ha^{-1})		B : C ratio	
		2003	2004	2003	2004	2003	2004
Rep.	3	0.094248	0.270570	6710453.548611	6836856.926215	0.065578	0.080665
Treatment	23	2.516921*	3.337166*	48957811.886739*	44496507.149126*	0.865026*	1.125371*
S	1	2.643384	0.853151	29756060.510416*	9631417.252602	0.569836*	0.380438*
L	2	26.334157*	36.819517*	16733345.887813*	33448815.954479*	0.092863	0.147828*
A	3	0.067270	0.095237	329510275.194445*	305456406.863715*	6.122671*	8.294968*
S X L	2	0.111566	0.445954	5305662.773230	2549.829479	0.050011	0.001859
S X A	3	0.160715	0.188320	659708.093750	783013.085939	0.016438	0.013896
L X A	6	0.139877	0.067053	7772232.264757	3372690.910590	0.082170	0.034541
S X L X A	6	0.138521	0.019624	2508708.684896	1321851.716145	0.021610	0.011647
Error	69	0.753261	0.920123	3598698.106582	5193347.632737	0.037315	0.047136
Total	95	36.715633	47.018333	464823734.465000	467423740.622466	7.555680	9.792626

* Significant at 5 % level of significance

APPENDIX – XXXIII

Pooled analysis of variance for available phosphorus in soil after harvest, net returns and B : C ratio

Source of variance	d.f.	MSS		
		Available P (kg ha^{-1}) in soil after harvest	Net returns (Rs ha^{-1})	B:C ratio
Year	1	55.7929687*	932104743.3450550*	7.5793214*
Rep.	6	0.1824094	6773655.2374131	0.0731215
Treatment	23	5.7026409*	91792196.6446173*	1.9633328*
S	1	3.2500021	36622797.7617187*	0.9407415*
L	2	62.6426099*	48095144.071458*	0.2323796*
A	3	0.0567722	634164164.2999130*	14.3164588*
S X L	2	0.5016349	2586308.8318749	0.0194154
S X A	3	0.2994632	441640.0776927	0.0191413
L X A	6	0.0178800	8698730.1579863	0.0915815
SXLXA	6	0.0743773	2870837.5295130	0.0260057
TXY	23	0.1514459	1662122.3912476	0.0270639
SXY	1	0.2465333	2764680.0013008	0.0095328
LXY	2	0.5110641	2087017.7708321	0.0083112
AXY	3	0.1057354	802517.7582474	0.1011799
SXLXY	2	0.0558849	2721903.7708340	0.0324551
SXAXY	3	0.0495722	1001081.1019936	0.0111933
LXAXY	6	0.1890495	2446193.0173607	0.0251296
SXLXAXY	6	0.0837675	959722.8715293	0.0072511
Error	138	0.8366916	4396022.8696596	0.0422251

* Significant at 5 % level of significance

Appendix : XXXIV

Cost of cultivation (Rs ha^{-1}) and prices used to compute economics

(A) Common cost of cultivation

S.No.	Particulars	Unit cost (Rs)		Cost (Rs ha^{-1})	
		2003	2004	2003	2004
1.	Land preparation (4 hrs)	150 hr^{-1}	150 hr^{-1}	600	600
2.	Layout, bunding and furrow opening (10 mandays)	60 $manday^{-1}$	60 $manday^{-1}$	600	600
3.	Fertilizer application and sowing (10 mandays)	60 $manday^{-1}$	60 $manday^{-1}$	600	600
4.	Seed (80 kg ha^{-1})	22 kg^{-1}	25 kg^{-1}	1760	2000
5.	Alachlor application + 2 mandays			780	800
6.	Thinning and gap filling (2 mandays)	60 $manday^{-1}$	60 $manday^{-1}$	120	120
7.	Hoeing and weeding (25 mandays)	60 $manday^{-1}$	60 $manday^{-1}$	1500	1500
8.	Endosulphan spray + 3 mandays	320 $litre^{-1}$	320 $litre^{-1}$	560	560
9.	Irrigation	200 $irrigation^{-1}$	200 $irrigation^{-1}$	400	200
10.	Harvesting (15 mandays)	60 $manday^{-1}$	60 $manday^{-1}$	900	900
11.	Threshing (by thresher)	25 hr^{-1}	25 hr^{-1}	150	150
12.	Winnowing (2 mandays)	60 $manday^{-1}$	60 $manday^{-1}$	120	120
	Total			**8090**	**8150**

(B) Treatment Cost

S.No.	Particulars	Unit cost (Rs)		Cost (Rs ha^{-1})	
		2003	2004	2003	2004
I	**Phosphorus (P_2O_5)**				
	(a) Through DAP (kg ha^{-1})				
	40	21.3 kg^{-1}	21.3 kg^{-1}	852	852
	60	21.3 kg^{-1}	21.3 kg^{-1}	1278	1278
	80	21.3 kg^{-1}	21.3 kg^{-1}	1704	1704
	(b) Through RP (34/74)				
	40	6.47 kg^{-1}	6.47 kg^{-1}	294	294
	60	6.47 kg^{-1}	6.47 kg^{-1}	441	441
	80	6.47 kg^{-1}	6.47 kg^{-1}	588	588
	(c) Solubilizer				
	Cow dung (1 : 3 ratio)				
	40 (353.33 kg ha^{-1})	15 q^{-1}	15 q^{-1}	52.5	52.5
	60 (529.99 kg ha^{-1})	15 q^{-1}	15 q^{-1}	78.75	78.75
	80 (706.66 kg ha^{-1})	15 q^{-1}	15 q^{-1}	105.0	105.0
	(d) PSB (2 kg ha^{-1})	10 PKT^{-1}	10 PKT^{-1}	60	60
	(e) Cost of inoculation (1 manday)	60 $manday^{-1}$	60 $manday^{-1}$	60	60
	(f) N through urea				
	(i) For DAP				
	40	10.43 kg^{-1}	10.43 kg^{-1}	185.65	185.65
	60	10.43 kg^{-1}	10.43 kg^{-1}	148.10	148.10
	80	10.43 kg^{-1}	10.43 kg^{-1}	-	-
	(ii) For RP (34/74)	10.43 kg^{-1}	10.43 kg^{-1}	260.75	260.75
	(g) Agrochemicals (2 spray)				
	Brassinolide	2000 lit^{-1}	2000 lit^{-1}	500	500
	Benzyladenine	1724/10 g	1724/10 g	7758	7758
	KCl	25 kg^{-1}	25 kg^{-1}	250	250
	Water spray	-	-	-	-
	2 mandays for spray	60 $manday^{-1}$	60 $manday^{-1}$	120	120

APPENDIX - XXXV

Economics of treatments in soybean

Treatment combination	Seed yield (q ha^{-1})			Stover yield (q ha^{-1})			Gross returns (Rs ha^{-1})			Cost of cultivation (Rs ha^{-1})			Net returns (Rs ha^{-1})			B : C ratio		
	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean	2003	2004	Mean
$S_1L_1A_1$	11.48	14.32	12.90	30.16	34.01	32.09	20953	27835	24394	9748	9808	9778	11205	18027	14616	1.15	1.84	1.49
$S_1L_1A_2$	11.66	14.12	12.89	27.83	34.54	31.18	20726	27696	24211	17006	17066	17036	3720	10631	7176	0.22	0.62	0.42
$S_1L_1A_3$	10.85	13.54	12.20	26.79	32.92	29.85	19466	26508	22987	9498	9558	9528	9968	16950	13459	1.05	1.77	1.41
$S_1L_1A_4$	10.31	13.23	11.77	27.79	32.17	29.98	18961	25902	22431	9248	9308	9278	9713	16595	13154	1.05	1.78	1.42
$S_1L_2A_1$	15.29	16.43	15.86	31.90	37.42	34.66	26258	31534	28896	10136	10196	10166	16122	21338	18730	1.59	2.09	1.84
$S_1L_2A_2$	12.16	15.49	13.83	30.72	35.52	33.12	21955	29792	25874	17394	17454	17424	4561	12338	8450	0.26	0.71	0.48
$S_1L_2A_3$	12.21	14.57	13.39	28.86	33.15	31.00	21638	27956	24797	9886	9946	9916	11752	18010	14881	1.19	1.81	1.50
$S_1L_2A_4$	11.42	14.67	13.04	28.22	33.65	30.93	20483	28216	24349	9636	9696	9666	10847	18520	14683	1.13	1.91	1.52
$S_1L_3A_1$	13.00	16.48	14.74	32.80	36.36	34.58	23453	31338	27396	10414	10474	10444	13039	20864	16952	1.25	1.99	1.62
$S_1L_3A_2$	12.73	15.37	14.05	30.75	35.26	33.00	22693	29564	26128	17672	17732	17702	5021	11832	8426	0.28	0.67	0.48
$S_1L_3A_3$	10.87	14.33	12.60	27.94	33.94	30.94	19719	27831	23775	10164	10224	10194	9555	17607	13581	0.94	1.72	1.33
$S_1L_3A_4$	12.50	14.55	13.52	27.70	34.61	31.16	21786	28296	25041	9914	9974	9944	11872	18322	15097	1.20	1.84	1.52
$S_2L_1A_1$	12.62	14.59	13.61	30.09	33.17	31.63	22424	27990	25207	9437	9497	9467	12987	18492	15740	1.38	1.95	1.66
$S_2L_1A_2$	12.44	14.29	13.36	27.82	32.67	30.24	21729	27459	24594	16695	16755	16725	5034	10704	7869	0.30	0.64	0.47
$S_2L_1A_3$	11.44	13.70	12.57	27.93	31.89	29.91	20452	26466	23459	9187	9247	9217	11265	17219	14242	1.23	1.86	1.54
$S_2L_1A_4$	12.29	13.96	13.13	29.30	33.02	31.16	21836	27102	24469	8937	8997	8967	12899	18105	15502	1.44	2.01	1.73
$S_2L_2A_1$	14.37	16.80	15.59	32.50	37.49	35.00	25184	32049	28617	9611	9671	9641	15574	22379	18977	1.62	2.31	1.97
$S_2L_2A_2$	13.19	15.68	14.43	31.66	37.18	34.42	23473	30462	26967	16869	16929	16899	6605	13534	10069	0.39	0.80	0.60
$S_2L_2A_3$	11.43	14.42	12.93	28.81	34.84	31.82	20623	28177	24400	9361	9421	9391	11263	18757	15010	1.20	1.99	1.60
$S_2L_2A_4$	11.29	14.05	12.67	28.05	33.84	30.94	20283	27427	23855	9111	9171	9141	11173	18257	14715	1.23	1.99	1.61
$S_2L_3A_1$	13.21	16.63	14.92	32.99	37.88	35.43	23768	31919	27844	9784	9844	9814	13984	22075	18030	1.43	2.24	1.84
$S_2L_3A_2$	12.70	15.74	14.22	31.37	37.16	34.26	22786	30532	26659	17042	17102	17072	5744	13431	9587	0.34	0.79	0.56
$S_2L_3A_3$	11.85	14.43	13.14	28.23	33.64	30.93	21054	27890	24472	9534	9594	9564	11520	18296	14908	1.21	1.91	1.56
$S_2L_3A_4$	11.27	13.86	12.56	28.58	32.42	30.50	20364	26815	23590	9284	9344	9314	11080	17472	14276	1.19	1.87	1.53

Selling price (Rs. q^{-1}): A) Seed i. Year 2003 – 1300
ii. Year 2004 – 1350
B) Stover i. Year 2003 – 200
ii. Year 2004 – 250