Study of Nutrient Management on Productivity of Soybean

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By

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CERTIFICATE - I

This is to certify that the thesis entitled **"Study of nutrient management on productivity of soybean"** *submitted in partial fulfillment of the requirements for the degree of* **MASTER OF SCIENCE IN AGRICULTURE (Soil Science and Agricultural Chemistry)** *of Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur is a record of bonafide research work carried out by Mr.* **Ram Surendra Prajapati**, *I.D. No.AP/IN-218/2K, under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/ published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been acknowledged by him.

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RSPrajapati

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ABBREVIATION

S.N.	Legends	Description
1.	N_1	30 kg nitrogen
2.	N_2	46 kg nitrogen
3.	P_1	60 kg Phosphorus
4.	P_2	73kg Phosphorus
5.	K_1	20 potassium
6.	K_2	36 potassium
7.	^0C	Degree Celsius
8.	%	Percentage
9.	$Kgha^{-1}$	Kilogram per hectare
10.	@	At the rate of
11.	et al.	Alied (and other)
12.	G	Gram
13.	M	Meter
14.	cm	Centimeter
15.	min	Minimum
16.	max	Maximum
17.	RH	Relative humidity
18.	qha^{-1}	Quintal per hectare
19.	Rs.	Rupees
20.	i.e.	That is (in reference to)
21.	DAE	Days after emergence
22.	SMW	Standard mean week
23.	mm	Millimeter
24.	DAS	Days after sowing
25.	EC	Electrical conductivity
26.	$mgkg^{-1}$	Milligram per kilogram
27.	sq.m	Square meter

28.	D.F.	Degree of freedom
29.	Viz.	Wide list
30.	C.D.	Critical difference
31.	dSm^{-1}	Desi siements per meter
32.	$kmhr.^{-1}$	Kilometer per hour

CHAPTER – 1

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an important leguminous and oilseed crop of India. It is recognized as the efficient producer of the two scarce quality characters i.e. the protein and oil, which are not only the major components in the diet of mass vegetarians but also a boon to the developing countries. It contains about 40-42% protein and 20-22% oil (Barik and Chandel, 2001). Its major uses are as a source of edible oil and protein rich food, as well as cattle feed. Food value of 100 g edible soybean is as follows protein 43 g, carbohydrates 21 g, Fat 19 g, Minerals 5 g and Fiber 4 g (Ali, 2001). In India, soybean is grown in 7.2 million hectares with total annual production of 5.85 million tonnes. Soybean occupies the highest area and production amongst the oilseeds in Madhya Pradesh. In Madhya Pradesh it is grown in 4.44 million hectares with total production of 4.10 million tonnes, attaining the productivity level of 923 kg/ha (Anonymous, 2005). Thus soybean plays a vital role the agricultural economy of M.P. Soybean is extensively grown all over Madhya Pradesh because of its wide adoptability to agro-climatic conditions and high market value of the produce; hence Madhya Pradesh is designated as "Soya State" of India. Among the major soybean growing states, about 80% of the area and production is from Vertisols in the semi-arid regions of Central India.

The integrated nutrient management includes the efficient use of organics, inorganic and bio-sources of plant nutrients to harvest optimum yield over a period of time and also to maintain soil health. Among the secondary nutrients, sulphur is being recognized as the fourth major nutrient of practical importance. It helps in synthesis of sulphur containing amino acids and improving oil concentration. Therefore, to get maximum yield potential of soybean, sulphur application is recommended and this needs critical investigation.

Zinc is now being recorded as the third most important limiting nutrient in crop production after N and P. Zinc is an essential micronutrient and has several important roles in plant nutrition viz., enzyme activation (carbonic anhydrate), protection of bio-membranes, hormone metabolism (indol-3-acetic acid) and other functions (reduce toxicity of other element like Fe, altered metabolism of N, P, carbohydrates and nucleic acid). Deficiency of zinc causes marked decrease in number and size of pod and boldness of seed (Tisdale et al., 1985). Boron plays an essential role in the development and growth of new cells in the plant meristem. Manganese is also an essential compound of the major enzyme nitrate-reductase in plants. Now a days, the soils of the region are deficient in major and micronutrients this situation arises through the indiscriminate use of chemical fertilizers. That ultimately reduced the yield of cereals, leguminous crops. To overcome the problem, it is essential to use integrated nutrient management system in these areas. Looking to these facts, the study was conducted to evaluate the use of chemical fertilizer with organism and inoculants.

The present experiment entitled "Study of Nutrient management on productivity of soybean" was carried out in Kharif season of 2005.

The major objectives of the investigation are:

1. To study the effect of Nitrogen, Phosphorous, and Potassium along with Sulphur, Zinc, Manganese and Boron on plant growth, Yield attributes and seed yield of soybean.
2. To study the effect of these nutrients on chemical composition of plant and seed.
3. To study the residual effect of nutrient application on soil fertility and productivity.
4. To find out the economics of different treatments.

CHAPTER – 2

REVIEW OF LITERATURE

Soybean has a great importance in the state economic and lot of research work has been done to enhance the productivity of soybean but still per hectare yields are far below than the world average. There are so many factors responsible for low yield of soybean. The major once are erratic behavior of rain, dry spell and imbalance use of nutrient supply.

A brief resume of research work done in India on different aspects of use of N, P, K, sulphur, micronutrients i.e. Zn, Mn, B, farm yard manure and Biofertilizer and their effect on growth and yield of soybean has been presented here under the following heads:

1. Effect of different nutrients on growth of soybean
2. Effect of different nutrients on yield attributing characters of soybean
3. Effect of different nutrients on yield of soybean
4. Effect of different nutrients on chemical composition of soybean plant and seed
5. Residual effect of nutrients on soil fertility

1 Effect of different nutrients on growth of soybean

Sharma (1989) conducted a field trial under rainfed condition and reported that application of Sulphur @ 60-80 kg/ha increased the root growth and nodule growth of soybean.

Thakur and Mandloi (1990) reported that the application of 30 and 40 kg S/ha produced taller plants than control. Plant population at both the stages and mortality index remained unaffected. They also reported that application of 40-kg/ha Sulphur produced more root nodules in soybean crop and their dry weight. They further reported that Sulphur application gave maximum number of leaves per plant.

Prasad *et al.* (1991) reported that soybean plant height; branch number, leaf number and dry matter accumulation were increased over control with application of 75 kg S and 50 kg P_2O_5/ha. Dry matter accumulation was maximum at 60 DAS whereas rests of the characters were maximum between 30 DAS and 45 DAS.

Sharma (1992) observed that dry matter accumulation and number of root-nodules per plant were found to be significantly higher with application of NPK fertilizers and PSB in soybean.

Agarwal *et al.* (1996) laid out a field trial at Jabalpur (M.P.). Soybean cv. Gaurav, with 0-120 kg P_2O_5 and 0-10 kg Zn/ha. They reported that number of nodules per plant and plant height was increased up to 80 kg P_2O_5 + 5 kg Zn/ha.

Agarwal *et al.* (1996) reported that LAI of soybean crop increased up to 60 kg P_2O_5 and 5 kg Zn/ha. CGR was the highest with 120 kg P_2O_5 and 2.5 kg Zn/ha and RGR was highest with 120 kg P_2O_5 and was unaffected by Zn application.

Khamparia (1996) conducted an experiment on a clay-loam Vertisols. Results showed that various doses of phosphorus and zinc produced taller plants of soybean crop with profuse growth and root-nodulation and had more dry weight at 50 DAS as compared with control.

Amara (1999) stated that the effect of micronutrient and bio-fertilizers on soybean resulted in a high increase in total microbial count in rhizosphere. Spraying Fe^{2+} or Zn^{2+} singly or combined with Mn^{2+} increased nodule number. The weight of nodule increased appreciably after spraying Fe^{2+} and/or Zn^{2+} on the plants. Spraying Fe^{2+} and Zn^{2+} increased dry weight of plants.

Dwivedi et al. (1999) conducted a field experiment on soybean at JNKVV, Jabalpur (M.P.). They reported that application of 0-120 kg P_2O_5/ha along with 0-80 kg S/ha increased leaf area index, specific leaf weight, specific leaf area and dry matter accumulation.

Patel and Shastri (1999) conducted a field experiment in rainy season of 1987 and 1988 at Raipur (C.G.) on soybean cv. Gaurav was given 0, 15, 30 or 45 kg N/ha and 0, 30, 60 or 90 kg P/ha. The results showed that dry mater accumulation and growth rate was increased with recommended dose of N and P over control.

Gadallah (2000) in a pot experiment at Assint, Egypt found that zinc increased root growth at all water contents and increased shoot growth under high water stress.

Mandal *et al.* (2000) conducted experiment at Bhopal (M.P.) to study the growth and yield of soybean in relation to different nutrient management practices on Vertisols during the rainy season of 1998 under rainfed condition. Application of 100% NPK + 10 t FYM was superior to 100% NPK and control. They reported that dry matter accumulation and crop growth rate was increased.

Chorey et al. (2001) at Akola (Maharashtra) reported that the half recommended dose of N through enriched slurry of which at 4.5 q/ha and half recommended dose of fertilizer (N_{30}:P_{30} kg/ha) recorded comparatively higher dry mater, number and weight of root nodules in soybean.

Achakzai et al. (2002) at Quetta (Pakistan) found out that plant height, number of nodes and branches and petiole length of both non-ionic and ionic were significantly and positively increased by added fertilizer over their respective control treatment (T_1) but among various doses of fertilizer this increase was statistically non-significant.

Yadav (2003) conducted an experiment at College of Agriculture, Indore (M.P.) and reported that the application of 30 kg S/ha and 25 kg $ZnSO_4$/ha produced significant effect on plant height, dry matter of plant and leaf area index of soybean crop over control.

2 Effect of different nutrients on yield attributing characters of soybean

Deore and Kadam (1984) reported that groundnut varieties sprayed with 0.1 ppm B solution at 500 L per hectare at 35 and 50 days after sowing. B increased pod yields by 1.3-24.1 % (average 13.7 %) compared with untreated stand.

Khamparia (1996) reported in Vertisols that pods per plant, grain, straw and biological yield, grain to straw ratio and harvest index increased by P and Zn application in soybean. The highest grain yield was with 50 kg P_2O_5 and 6 kg Zn/ha.

Patel *et al.* (1996) reported that number of pods per plant and test weight significantly increased with increasing nitrogen and phosphorus level. They also found that increasing nitrogen and phosphorus levels significantly increased seed and straw yield of soybean.

Mandal and Sikdar (1999) concluded that the pod dry mater and seed yield of soybean was increased with increasing N rate, while number of pods per plant was greater than without N. Seed yield was greater with 30 than 60 kg S, while pod dry mater and number of pods per plant increased with increasing S rate. Yield was greatest with 100 kg N + 30 kg S/ha.

Gurkripal *et al.* (2001) reported that the growth attributes and grain yield of soybean significantly increased with the application of the fertilizers. The highest number of pods per plant (68.9) and seed yield (24.8 q/ha) was obtained at the fertilizer combination NPK Zn 90:80:60:25. The treatment NPK at 90:60:30 produced the highest 100-grain weight in soybean (16.6 g).

Patel and Puraji (2003) conducted a field experiment to study the effect of organic manures and fertilizers levels on growth parameters, yield attributes and yield of soybean. The dry matter production was significantly higher with the application of 150% RDF and 125% RDF over 100% RDF.

Yadav (2003) reported that the application of 30 kg S/ha and 25 kg $ZnSO_4$/ha produced significantly higher number of pods per plant, seed index, seed yield per plant of soybean per hectare over control.

3. Effect of different nutrients on yield of soybean

Savithri *et al.* (1984) conducted a field trial at Coimbatore (TamilNadu) and stipulated that the seed yield of soybean increased with the application of 25 kg $MnSO_4$ or zinc sulphate per hectare on red soil.

Sharma and Dixit (1987) at Indore (M.P.) observed marginal increase in seed yield of soybean with the application of 25 kg $ZnSO_4$ along with 20 kg nitrogen and 40 kg phosphorus.

Devrajan *et al.* (1988) have reported that sunflower given a basal NPK, growing on a red sandy loam soil were treated with Cu, Fe, Mn or Zn. Application 10 kg $CuSo_4$, 100 kg $FeSo_4$ or $MnSo_4$ or 3 sprays (foliar) of 0.5 % $ZnSo_4$30, 40 and 50 days after sowing gave seed yields of 2.80,2.78, 2.75 and 2.64 tonnes/ha respectively compared with 1.96 t/ha with NPK alone.

Sharma (1989) conducted a field trial at Indore (M.P.) in rainfed conditions and found that application of Sulphur @ 60-80 kg/ha gave 20-30 per pent increase in grain yield of soybean.

Vyas *et al.* (1989) noted at Indore (M.P.) that each tonne production of soybean seed, 12-15 kg Sulphur is essentially required.

Kacha *et al.* (1990) observed that the highest seed of soybean (14.3 q/ha) and straw (23.7 q/ha) yields were resultant of 30 kg N + 60 kg P/ha.

Sharma (1992) recorded soybean seed yield of 0.45, 1.36 and 1.59 t/ha with no fertilizer, 40 kg N + 26 kg P_2O_5 + 35 kg K/ha or NPK with 20 kg zinc sulphate/ha were respectively.

Gupta and Vyas (1994) at Kota showed that seed yield was not significantly affected by Mo application but was highest with 40 kg P_2O_5 and 15 kg $ZnSO_4$/ha.

Mansur *et al.* (1995) laid out a trial in Kharif season, 1989 and 1990 at Baihongal (Karnataka). Soybean cv. Hardee was given 2.5 or 5.0 kg Zn/ha as zinc sulphate, 2 or 4 kg B/ha as borax, 5 t farm yard manure (FYM)/ha or a combination of Zn + FYM. Average seed yield was highest with 5 kg Zn/ha in 1989 and was unaffected by treatment in 1990.

Singh and Singh (1995) concluded in a two year field experiment at Kanpur (U.P.) that K and S application increased seed yield of soybean in both years, while Zn application increased yield in 1989 only. Seed yield and net return were highest with 120 kg K_2O/ha in 1989.

Singh *et al.* (1995) conducted an experiment at Sikkim and concluded that application of lime 1 t/ha + FYM 15 t/ha + full dose of NPK gave significantly higher seed and straw yields of 15.9 and 45.9 q/ha of soybean, respectively over the control.

Agarwal et al. (1996) showed that the application of P_2O_5 and Zn increase harvest index significantly up to 80 kg and 5 kg/ha, respectively.

Balusamy *et al.* (1996) conducted a field trial at Coimbatore (TamilNadu) and concluded that Zn, B, FYM or a combination of FYM with each of the other treatments did not affect seed germination of soybean significantly. However, seed yield was highest with 10 kg Zn/ha + FYM.

Bisht and Chandel (1996) reported at Pant Nagar (U.P.) that at 30, 45 and 60 DAS biomass yield of soybean was highest with P + K + Zn + FYM, whereas, at harvest it was highest with Zn only in 1988 and N + K only in 1989.

Kadamdhad et al. (1996) observed in an experiment at Nagpur on soybean cv. JS 80-21 was given 30, 45 or 60 kg S and 15, 30 or 45 kg Zn/ha and concluded that seed yield was 1.12 t/ha without S or Zn and was highest 2.11 with 45 kg S and 30 kg Zn.

Carter and Gupta (1997) conducted an experiment to determine the effect of minimum tillage practices, in three long-term animal feed crop rotations, on micronutrient (B, Cu, Zn, Mn, Fe and Mo) content and grain quality of spring barley and soybean. They reported that grain micronutrient concentrations, however, for crop yield potential tended to be in the sufficient range and were not limiting for crop growth.

Raghuwanshi *et al.* (1997) reported that application of 25 and 50 kg S/ha increased soybean yield by 0.32 and 0.63 t/ha, respectively. Soybean responded more to zinc applied as $ZnSO_4$ than as $ZnCl_2$. Soybean yield was highest when both S and Zn were applied at the higher rates at each year.

Saxena and Chandel (1997) observed that seed yield of soybean were higher in treatment receiving Zn, B, Mo or FYM than control. In the control treatments, received recommended 20:80:40 kg NPK/ha, the application of 1 kg Zn produced the highest seed yield of 3.25 and 3.91 t/ha in 1991 and 1992, respectively. This treatment also had the highest value for symbiotic-N fixation and organic carbon in soil.

Tiwari *et al.* (1997) conducted a field experiment in 1990 at Jabalpur (M.P.) to study the effect of various manure and fertilizer treatment on growth of soybean and observed that maximum seed and straw yields were obtained with 10% NPK + FYM (2.18 t and 5.94 t/ha, respectively) and was lowest in control (0.91 t and 1.40 t/ha).

Patra (1998) observed that the application of 5 t FYM + NPK produced the highest mean seed yield (3.7 t/ha), which was 68% higher than the control yield (2.2 t). Application of 2.5 kg Zn and 5.0 kg Zn produced yields of 2.7 and 2.5 t, respectively, which were at par with control yield.

Rao *et al.* (1998) reported that the yield of soybean cv. Hardee grown at Hebbal, Bangalore was 1244 and 1362 kg/ha with 50 and 75 kg P_2O_5/ha, respectively and 1285, 1308 and 1316 kg/ha with 0, 5 and 10 kg S/ha, respectively.

Wankhade *et al.* (1998) reported that soybeans cv. Monatta and Sunflowers cv. Modern were given of B alone gave the highest Soybean seed yield, while Zn gave the greatest benefit to sunflowers. Combined application of Fe + B or Zn + Fe + B greatly increased soybean growth and yield.

Chafle *et al.* (1999) reported that seed yield of soybean cv. JS-335 grown at Nagpur (Maharashtra) in kharif, 1997-98 was 723 kg/ha without N or P fertilizers, 816 kg with 30 kg N/ha through urea and highest 1206 kg with 30 kg N + 90 kg P_2O_5 per hectare.

Dwivedi *et al.* (1999) conducted a field experiment on soybean cv. Gaurav at Jabalpur (M.P.) in kharif season of 1990-91 and 1991-92, which was given 0-120 kg P_2O_5 and 0-80 kg S/ha. They reported that seed yield was highest with 80 kg P_2O_5 and 60 kg S/ha.

Ravankar *et al.* (1999) reported that seed yield was 0.91 t/ha without fertilizers and the highest (2.69 t) with 150% of recommended NP + 20 kg S + 10 kg Zn/ha. When recommended NP + S + Zn were applied, some of the inorganic N could be replaced with organic sources without significant changes to crop yield.

Babhulkar *et al.* (2000) observed the highest yield of soybean with application of 7.5 t FYM/ha with half the recommended rates of N and P giving 26.81 and 20.10/% increases over the control and the full-recommended fertilizer rate, respectively. This treatment could save 50% of the N and P requirement and the total Zn requirement.

Mandal *et al.* (2000) reported that application of 100% recommended NPK + 10 t FYM/ha (F_2) was significantly superior to 100% recommended NPK (F_1) in respect of pods per plant, seed and stover yield and agronomic efficiency of fertilizer. Increase in seed yield of 95.48 and 83.38% were given by treatments F_2 and F_1 compared with control (F_0), respectively.

Madhavi *et al.* (2001) at Andhra Pradesh reported the highest seed yield of soybean was obtained in crops treated with NPK, 90:120:60 kg/ha.

Shelge *et al.* (2001) conducted a study at Parbhani (Maharashtra). The results on grain and biomass production revealed that the application of micronutrient under the recommended level of major nutrients with FYM significantly increased the yields. The application of zinc (T_2) without FYM increased the yields by 15% under the recommended levels of FYM the corresponding yield improvement due to zinc (T_6) was 45%.

Singh *et al.* (2001) showed that the application of 60 kg N/ha resulted in 22.1 and 21.2% increase in seed yield of soybean during the first and second year over 30 kg N/ha. The respective increase in straw and biological yields was 17.8 and 17.1 and 19.1 and 18.2%. Mean seed yield obtained under 60 kg S/ha was 18.97 q/ha being significantly higher over the control.

Thakur *et al.* (2001) conducted an experiment on Vertisols. The treatments were control (no S and Zn), 25 and 50 kg S through gypsum every year and alternative year in the kharif season only, and 5 and 10 kg Zn/ha in every year and alternate years. The results of four years study indicated 9-20% increase in yield of soybean.

Zada (2001) showed at Peshawar that application of Fe and Zn increased grain yield of soybean by means of increase in protein synthesis and N metabolism.

Dikshit and Khatik (2002) carried out a field experiment to study the effective combination of organic and inorganic nutrient sources on the availability, uptake, quality and yield of soybean (JS-335) in a typical Haplustert soil of Jabalpur. They reported that among all the nutrient sources 50% of recommended dose of NPK + 10 t FYM/ha recorded the highest grain (16.00 q/ha) and straw (30.75 q/ha) yield.

Singh *et al.* (2002) laid out an experiment at Bhopal on soybean and reported that S doses up to 60 mg/kg soil caused marked increase in seed yield (5.79 to 6.18 g/plant) and other biochemical yield.

Wasmatkar *et al.* (2002) conducted a field experiment to find out the effect to different levels of sulphur and zinc on quality and nutrient uptake of soybean. The results indicated that the application of 15 kg S/ha and 5 kg Zn/ha was recorded significantly higher grain yield. Application of 30 kg S/ha and 5 kg Zn/ha was recorded higher straw yield than control.

Singh (2003) reported that application of 30 kg S/ha through gypsum increase the seed yield of soybean seed from 19.4 to 27.1% over control (no S used).

Upadhyay (2003) reported that application of 100% NPK through fertilizers and $ZnSO_4$ + borax (25 kg + 3 kg/ha) to soybean crop and 100% NPK through fertilizers and PSB + Azotobacter (3 kg + 1 kg/ha) to wheat crop resulted in significantly higher grain yields over the farmer's practice and also considering the total productivity of the system.

Sharma *et al.* (2004) found that incorporation of N and P increased the soybean yield marginally (8%), but with incorporation of S, the yields increased by 45-49%, 68-69% and 80-87% with 10, 20 and 30 kg S/ha, respectively. Complex fertilizer (13-33-0-15 S) was significantly superior to mixed source i.e. ½ dose as ammonium sulphate + ½ as elemental Sulphur in increasing the root nodulation, yield attributes, uptake of P, K and DTPA zinc, oil and protein content in soybean.

Gokhale *et al.* (2005) conducted a field experiment to study the effect of sources and levels of Sulphur on seed yield, quality and Sulphur uptake by soybean. They found that increasing level of Sulphur from 0 to 40 kg/ha significantly increased the seed yield, content and Sulphur uptake by soybean. Further, they reported that the maximum seed yield (2970 kg/ha) was recorded with the application of S @ 40 kg/ha which was found significantly superior over no Sulphur application (2339 kg/ha).

4.Effect of different nutrients on chemical composition of soybean plant and seed

Sharma and Gupta (1992) conducted a field experiment to assess the N and S fertilizer required for soybean and safflower sequence on Vertisols and observed that the content of N, P and S in soybean seed increased considerably with N application. However, soybean seed containing 5.41% N, 0.49% P and 0.34% S by application of 40 kg N/ha.

Sharma and Misra (1997) conducted a field experiment on black clay soil with soybean cv. JS 71-05 given 0-40 kg N/ha, 6 t FYM alone, combined use of 6 t FYM + 20 kg N/ha through fertilizer, 40 kg N/ha + 25 kg $ZnSO_4$/ha and 120 kg N/ha + 5 t soybean crop residues/ha and observed that uptake of N, P, K, S, Ca and Mg were higher with application of 6 t FYM + 20 kg N/ha.

Dhillon and Dev (1978) conducted green house experiment on soybean and found that Sulphur application on soybean increased Sulphur uptake by the crop. The amount of Sulphur derived from fertilizer and the content of protein and sulphate Sulphur in plant increased significantly.

Bansal et al. (1983) observed that the critical limits of Sulphur concentration in soybean were 0.15 and 0.18 % for 36 and 60 days old plants, respectively.

Dwivedi *et al.* (1999) reported that application of "S and P alone as well as in combination increased the content and uptake of Ca, Mg and S at all physiological stage of growth. The S and P exhibits a synergistic effect on soybean and the highest nutrient content and uptake was observed in grain rather than straw at S_{50} and P_{50} level. The results showed that the response of S was higher than that of P.

Khamparia and Tomar (1999) conducted a field experiment at Sagar (M.P.) on soybean CV. JS 72-44, treated with 0-6 kg Zn/ha and 0-100 kg P_2O_5/ha. Observations showed that application of P increased plant P concentration but decreased Zn concentration while Zn application decreased plant P and increased plant Zn.

Panneerselvam *et al.* (1999) at Coimbatore showed that the application of bio-digested slurry at 5 t/ha + 30:120:40 kg NPK/ha gave the highest plant N uptake and soil available nitrogen.

Dikshit and Khatik (2002) observed in a field experiment at Jabalpur that 50 % of recommended dose of NPK + 10 t FYM ha^{-1}enhanced the availability of N, P, K and S in soil and uptake by soybean.

Wasmatkar *et al.* (2002) conducted a field experiment to find out the effect to different levels of Sulphur and Zinc on quality and nutrient uptake of soybean. The highest uptake of N was recorded with 15 kg S/ha and 5 kg Zn/ha, while maximum uptake of P, K, S and Zn were reported in treatment 30 kg S/ha and 5 kg Zn/ha.

5. Residual effect of nutrients on soil fertility

Bhatnagar *et al.* (1992) reported in soybean-wheat rotation receiving various combinations of NPK and FYM for 15 years at Almora (U.P.), that bulk density of the surface soil decreased significantly under NPK, NPK + FYM and N + FYM. Porosity was significantly greater in treatment with continuous application of FYM. FYM also increased infiltration rate.

Oswal (1993) studied the effect of FYM and compaction on sand and loamy sand soil. He showed that FYM increased EC, CEC and organic carbon, whereas it reduced K and S. compaction increased the bulk density.

Moharram et al. (1999) conducted a green house pot experiment and reported that soil biomass was increased by increasing compost rates, which was prepared by cow dung and poultry manure, while soil organic matter, total C and available-N content were increased over control. Inoculation helped in fixing atmospheric nitrogen in soil at the end of the growing season.

Sharma (1999) showed that the treatment involving FYM and crop residues applied either alone or in combination with reduce levels of fertilizer N were most effective in building up of soil fertility in the long term. Highest sustainable productivity of soybean and safflower, WUE and uptake of NPK and S were given by 5 t FYM/ha + application of 20 kg N and 13 kg P/ha (half of the recommended NP rates).

Babhulkar et al. (2000) observed significantly improvement in soil properties with the application of 7.5 t FYM/ha with half of the recommended rates of N and P.

Appavu et al. (2001) conducted a field study at Coimbatore to assess the effect of different organic manures; tillage methods and crop residue management practices. The results showed that incorporation of organic manures (coir pith, poultry manure, goat manure and FYM) increased the available Zn content.

Jat (2004) carried out experiment at the JNKVV, College of Agriculture, Indore (M.P.) and found that soil test crop response based $N_{27}P_{69}K_{40}$ + 5 t FYM/ha + S_{30} was found most effective in raising soybean productivity uptake of NPKS and Zn plant nutrients and residual balance of these nutrients in post-harvest soil except available nitrogen.

CHAPTER – 3

MATERIAL AND METHODS

The present chapter deals with a brief description of methods employed and materials used during the course of investigation.

3.1 Experimental site

The present experiment was laid out in the field No.4 of the Research Farm of J.N. Krishi Vishwa Vidhyalaya, College of Agriculture, Indore during Kharif, 2005. The topography of the field was uniform with an adequate drainage.

3.2 Location and climate

Indore is situated in Malwa plateau in the Western M.P. at an altitude of 555.5 meters above mean sea level (MSL). It is located at latitude 22.43°N and longitude of 75.66°E. It has subtropical climate having a temperature range of 21°C to 45°C and 6°C to 31°C in summer and winter season, respectively. The rainfall in the region is mostly inadequate and erratic. Late commencement, early withdrawal and two to three dry spells are the main features. The average rainfall is 846 mm. The meteorological data during crop season from month of June to October 2005 is been given in Table 3.2.1 The soil of the field was a typical medium black soil. Due to dominance of montmorillonitic clay it has high capacity to swell on wetting and to shrink on drying. These soils have high CEC.

Table 3.2.1 Meteorological data observed during crop growth period (June to October, 2005) recorded at Indore

SMW	Date		RH (%)	Temp (°C)		Rains (mm)	No. of rainy days	Soil Temp. (°c)	Wind velocity (Km/hr)	Evaporation (mm)
				Max	Min					
2005			Previous (up to 27th may)			6.8	1			
22			62.8	39.6	27.	0.0	0	34.6	5.1	9.2
(28th May to 3rd June)										
23	June	4-10	66.1	40.0	27.6	8.6	1	35.0	8.2	13.8
24		11-17	67.2	39.2	27.3	0.0	0	34.1	8.0	10.7
25		18-24	83.1	38.4	26.1	55.2	1	32.7	5.1	8.9
26		25-1	90.2	31.1	23.5	7.8	1	23.9	5.4	4.3
27	July	2-8	90.5	29.7	24.3	1.8	0	27.4	9.2	2.9
28		9-15	90.2	30.2	24.2	38.8	5	25.9	7.1	3.0
29		16-22	87.5	32.1	24.8	4.8	0	27.5	5.6	4.5
30		23-29	90.7	28.4	23.6	126.8	4	26.3	7.8	4.1
31		30-05	93.9	27.6	23.1	238.4	4	25.0	5.3	2.5
32	Aug	06-12	91.3	28.1	22.7	6.2	1	24.8	6.5	3.1
33		13-19	90.6	29.2	23.1	1.0	0	26.5	5.7	4.0
34		20-26	92.7	28.5	22.5	9.4	2	25.3	5.1	2.8
35		27-02	88.7	31.4	22.9	0	0	27.3	3.2	4.0
36	Sept	03-09	93.9	32.1	23.9	74.8	3	27.7	1.9	3.8
37		10-16	94.0	29.6	23.4	132.6	4	26.2	3.1	2.4
38		17-23	90.9	29.3	22.9	20.2	5	25.6	3.4	4.0
39		24-30	91.7	28.5	21.1	6.6	1	24.5	3.8	2.7
40	Oct	01-07	86.1	33.2	19.9	0	0	25.8	1.8	4.3
41		08-14	85.6	33.5	16.7	0	0	26.0	1.7	4.3
42		15-21	90.0	32.4	17.9	0	0	26.0	2.4	4.0

Source: AICRP on Dryland Agriculture; college of Agriculture, Indore (M.P.)

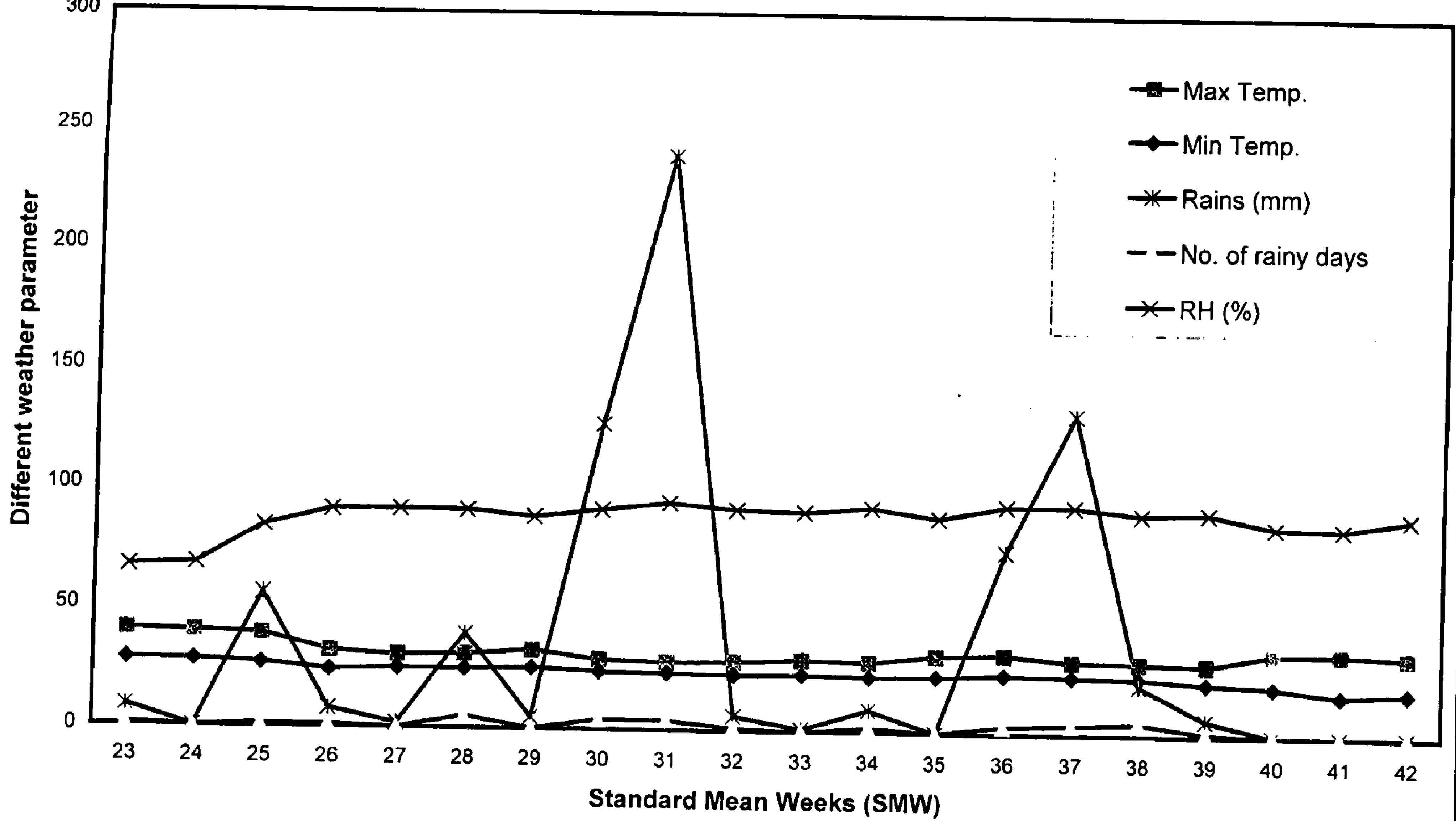


Fig. 3.2.1: Meteorological data observed during crop growth period (June to Octomber 2005) recorded at Indore

3.3 Physico-chemical condition of experimental field

Representative soil samples were collected from the experimental field. Soil samples were taken randomly with the help of auger up to a depth of 0-30 cm after the land preparation but prior to sowing soybean.

The samples were air dried, sieved through 2 mm sieve and used for mechanical and chemical analysis. The results are presented in Table 3.3.1

Table 3.3.1 Physico-chemical properties of experimental field

Constituents	Value	Method of analysis
Mechanical analysis		
Sand %	11.2	Bouyoucos hydrometer method.
Silt %	34.1	
Clay %	54.7	
Chemical analysis		
Soil pH (1:2)	8	Glass electrode method (pH meter Piper, 1950)
Electrical conductivity (dSm^{-1}) (1:2)	0.40	Solubridge method (Black, 1965)
Organic carbon %	0.31	Walkley and Black's rapid titration method (Walkley and Black, 1934)
Available nitrogen ($kgha^{-1}$)	180	Alkaline permanganate method (Subbiah and Asija, 1956)
Available phosphorus ($kgha^{-1}$)	12.8	Colorimetric method (Olsen et al., 1954)
Available potassium ($kgha^{-1}$)	394	Flame photometer method (Black, 1965)
Available sulphur ($kgha^{-1}$)	11.2	Colorimetric method (Tandon, 1993)
Available zinc ($mg\ kg^{-1}$)	1.17	Atomic absorption spectrophotometer (Lindsay and Norwell, 1978)
Available Mn ($mg\ kg^{-1}$)	55.75	Atomic absorption spectrophotometer (Lindsay and Norwell, 1978)
Available boron ($mg\ kg^{-1}$)	0.20	Hot water soluble boron (Gupta, 1967)

The different chemical constituents were determined in the composite soil sample. The initial fertility status of experimental field soil .The soil was slightly Saline in nature (PH 8 EC 0.4). The organic carbon and available nitrogen were low. The available phosphorus and sulphur were found in the medium range in the soil. The available potassium content in soil was in the medium range. The zinc, manganese and boron were found in the higher range.

3.4 Cropping history of the experimental field

The knowledge of previous crops on experimental field is essential to judge its productivity potential. The crops grown in the experimental field during the past four years are presented in Table 3.4.1

Table 3.4.1 History of the experimental field

Year	Kharif	Rabi
2001-2002	Soybean	Wheat
2002-2003	Soybean	Wheat
2003-2004	Soybean	Wheat
2004-2005	Soybean	Wheat
2005-2006	Soybean (experiment)	-

3.5 Experimental details

The present experiment consisting of 10 treatments combinations was carried out in a randomized block design. Details of experiment are given as below:

Experimental design	-	Randomized Block Design (RBD)
Number of treatments	-	10
Number of replications	-	4
Number of plots	-	40
Plot size (a) Gross	-	3.6 m x 7.5 m =27 m^2
(b) Net	-	2.4 m x 6.5 m =15.6 m^2
Row to row distance	-	30 cm
Plot to plot distance	-	1.0 m
Distance between replications	-	1.2 m
Total gross area	-	36.2 m x 39.5 m
Name of crop	-	Soybean [*Glycine max* (L.) Merrill]

Variety	-	JS-335
Seed rate	-	100 $kgha^{-1}$
Seed material source	-	Research Farm College of Agriculture, Indore
Date of sowing	-	12-07.2005
Date of harvesting	-	19.10.2005

3.6.Details of treatments: - The details of treatments presented below: -

Treatments	Combinations
T_1	N_2, P_2, K_2, S, Zn, Mn, B
T_2	N_2, P_1, K_2, S, Zn, Mn, B
T_3	N_2, P_2, K_1, S, Zn, Mn, B
T_4	N_2, P_2, K_2, S, Zn, B
T_5	N_2, P_2, K_2, S, Zn, Mn,
T_6	N_2, P_2, K_2, S, Mn, B
T_7	N_2, P_2, K_2, Zn, Mn, B
T_8	N_1, P_1, K_1 (Control)
T_9	N_1, P_1, K_1 + 10 t FYM / ha.
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.(Rhizobium)

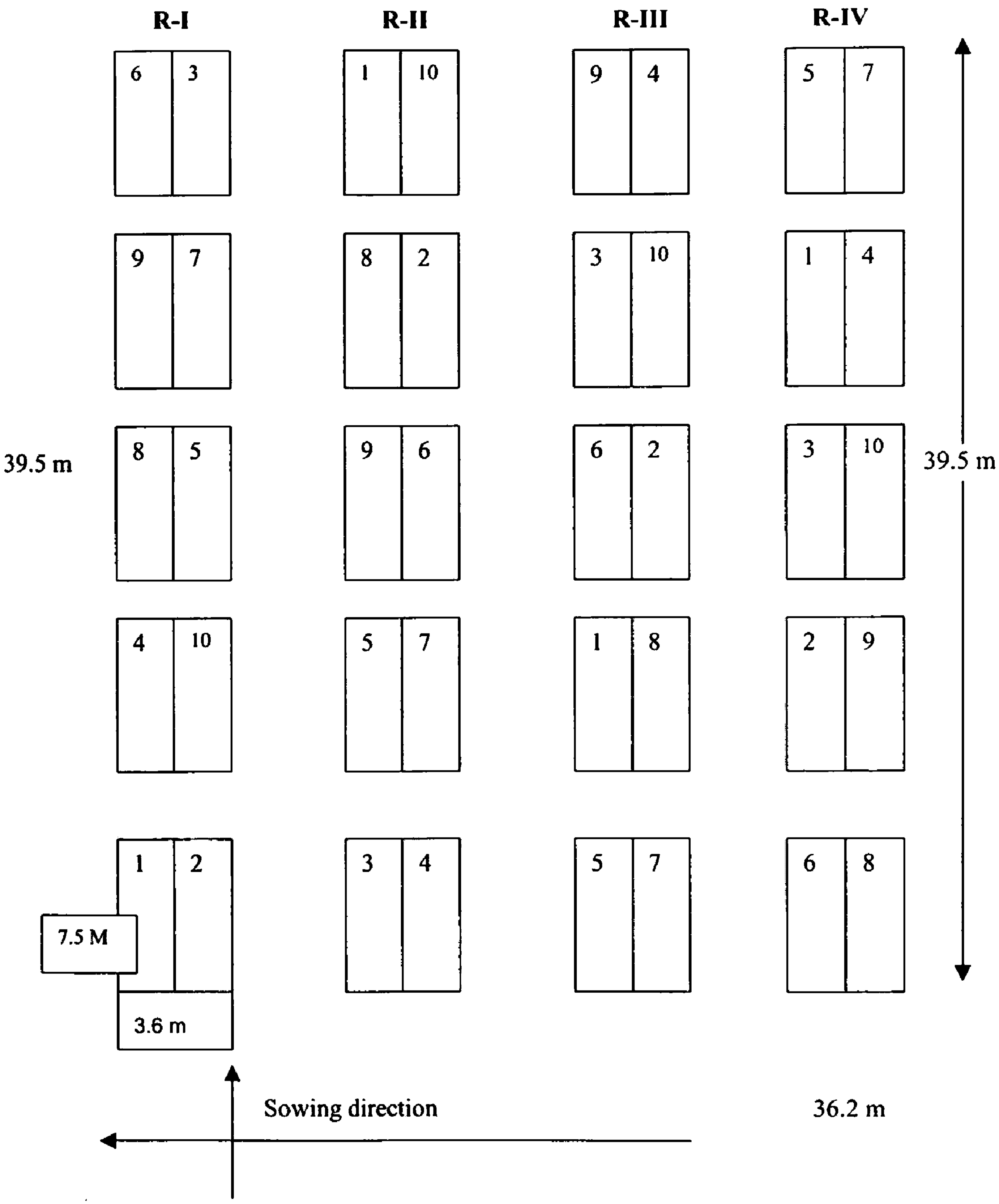
Note:

- N_2, P_2 & K_2 nutrient doses on the basis of soil test values
- N_1, P_1 & K_1 recommended doses of nutrients.

Source:

- N, P & K were applied through Urea, DAP & KCl respectively as basal dose.
- 46 kg N, 73 kg P_2O_5, 36 kg K_2O (applied on the basis of soil test values).
- 30 kg N, 60 kg P_2O_5, 20 kg K_2O (state recommendation).

Lay out: Study of nutrient management on productivity of soybean



- Sulphur (S) 6 kgha^{-1} through Gypsum as soil application.
- Zinc (Zn) two sprays 0.5 % solution of $ZnSO_4$ (8 kgha^{-1}.) as foliar application at 25 and 40 DAS.
- Manganese (Mn) two sprays of 0.5 % $MnSO_4$ (8 kgha^{-1}.) as foliar application at 25 and 40 DAS.
- Boron two sprays of 0.2 % Borax (3.2 kgha^{-1}.) as foliar application at 25 and 40 DAS.

3.7.Brief description of field operations: -

The brief descriptions of pre and post harvest field operations are given in Table 3.7.1

Table 3.7.1 Schedule for pre-harvest and post-harvest operations carried out during the course of investigation

SN	Operation	Date	Remarks
1	**Field preparation**		
	(a) Ploughing	05.04.2005	By tractor
	(b) Bakharing (two)	24.06.2005	By tractor
	(c) Planking after each bakharing	25.06.2005	By tractor
2	**Layout**	28.06.2005	By hand
3	**Soil sampling**	28.06.2005	Soil auger
4	**Application of fertilizer**	29.06.2005	By hand (manually before sowing & mixed
5	**Seed treatment and inoculation**	12.07.2005	By hand
6	**Sowing**	12.07.2005	By hand
7	**Intercultural (Hoeing)**	6.08.2005	By dora
9	**Weeding**	22.08.2005	By hand
10	**Plant protection**		
	(a) 1st spray of endosulphan	9.07.2005	By Knapsack sprayer
	(b) 2nd spray of endosulphan	12.09.2005	
11	**Harvesting**	19.10.2005	By hand
12	**Threshing and winnowing**	24.10.2005	By hand
13	**Collection of soil sample for analysis**	25.10.2005	Soil auger

3.8.Details of observations

The details of pre and post harvesting observations, which were recorded during the course of investigation, are presented in Table 3.8.1.

Table 3.8.1 Observations recorded for statistical analysis

SN	Observations	Size of sample net plot	Time of observation
1	Analysis of soil at initial and harvest stage for pH, EC, OC, N, P, K, S, Zn, Mn and B.		
2.	Plant observation		
	(A) Plant growth parameters		
	Plant population dynamics	One running metre length each at three random rows	20 DAS and before harvesting
	(a) Plant height (cm)	5 tagged plants	At 30, 60 and at harvesting
	(b) No. of branches/plant	5 tagged plants	At harvest
	(c) No. of root-nodules/plant	5 plants	At 40 DAS
	(d) Analysis of plant at 30,60 and harvest stage for N, P, K, S, Zn, Mn &B		
	(e) Analysis of seed at harvest for N, P &K		
	(B) Yield attributing characters		
	(a) Average No. of pods per plant	Average of 5 tagged plants	After harvest
	(b) Average No. of seeds per pod	Average of 20 pods	After harvest
	(c) Seed index	Weight of 100 seeds	After harvest
	(C) Yield of soybean		
	(b) Seed yield (kg ha^{-1})	On the basis of net plot	After harvest
	(c) Straw yield (kg ha^{-1})	On the basis of net plot	After harvest
	(d) Harvest index (%)	On the basis of net plot	After harvest
	(e) Economics of experimental treatments	By calculation	After harvest

3.8.1. Pre-harvest studies

(i) Plant population

The plant population was taken initially and finally at 20 DAS and before harvesting, respectively. Plant population was counted per meter row length at three random rows within each net plot and the mean thus obtained was used to estimate plant population for statistical analysis.

(ii) Height of the plant (cm)

In each net plot five plants were selected randomly and tagged for periodic observation. The height was recorded at 30, 60 and at harvest in all the plots. It was measured from the ground surface to the main stem apex.

(iii) Number of branches per plant

The primary branches were counted on five tagged plants at the harvesting of crop in all the plots.

(iv) Number of nodules per plant: -

The numbers of root nodules were counted by selecting 5 plants already tagged.

3.8.2. Post-harvest studies

(i) Number of pods per plant

The number of pods per plant was counted from five already tagged plants and mean per plant was calculated for analysis. The observations were recorded from all the plots.

(ii) Number of seeds per plant

The number of seeds per plant was counted from five already tagged plants and mean per plant was calculated for analysis. The observations were taken from all the plots.

(iii) Number of seeds per pod

The number of seeds per pod were counted from 20 randomly selected pods of 5-tagged plants for each plot.

(iv) Seed index

One hundred seeds were drawn from finally cleaned produce of each plot and weighed on balance.

(v) Seed yield (kg per hectare)

The seed yield per net plot was recorded after drying the seed. The plot yield was later on converted into kg per hectare by multiplying it by conversion factor.

(vi) Straw yield (kg per hectare)

The straw yield per plot was obtained by subtracting grain yield from bundle weight of each plot. This was later on converted into kg per hectare.

(vii) Harvest index%

The harvest index is calculated by the following equation:

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

3.9. Chemical analysis of soil and plant sample

3.9.1 Methods of soil analysis: -

Collection and preparation of soil sample

Composite soil samples were collected randomly with the help of soil sampling tube before sowing and after harvesting of crop from each plot. The samples were mixed thoroughly and dried in air, crushed, sieved through 2 mm sieve. The samples so prepared were analyzed for fertility status.

(i) Soil pH

Soil pH was determined by using Beckman glass electrode pH meter in 1:2, soil: water suspension (Piper, 1967).

(ii) Electrical conductivity

Electrical conductivity was also determined by electrical conductivity meter in 1:2 soil water suspensions at 25°C and it is expressed by dSm^{-1} (Desi seimens per meter).

(iii) Organic carbon

Organic carbon was determined by Walkley and Black (1934) wet digestion method. Organic carbon is expressed in percentage (%).

(iv) Available nitrogen (kg ha^{-1}.)

Determination of available nitrogen was done by alkaline permanganate method suggested by Subbiah and Asija (1956).

(v) Available phosphorus (kg ha^{-1}.)

The estimation of available P was done by using Olsen's extract (0.5 N sodium bicarbonates solution of pH 8.5) as referenced by Olsen et al. (1954). And determined as stannous chloride reduced blue colour

(vi) Available potassium (kg ha^{-1}.)

The available amount of potassium was determined by using N-neutral ammonium acetate as mentioned by Black (1965).

(vii) Available Sulphur (kg ha^{-1}.)

Available Sulphur was extracted by sodium acetate-acetic acid buffer solution pH 4.8 method and determined colloidal $BaSO_4$ in presence of gum acacia 0.51 percent solution turbidimetrically using Nephelometer.

(viii) Available zinc (mg kg^{-1}).

The soil was extracted by DTPA (Diethylene tetra amine penta acetic acid) solution and using Atomic Absorption Spectrophotometer, available Zn was estimated by the method suggested by (Lindsay and Norwell, 1978).

(ix) Available manganese (mg kg^{-1}).

The soil was extracted by DTPA (Diethylene tetra amine penta acetic acid) solution and using Atomic Absorption Spectrophotometer, available Mn was estimated (Lindsay and Norwell, 1978).

(x) Available boron (mg kg^{-1}).

Hot water soluble boron was determined calorimetrically by curcumine method as described by Black (1965).

3.9.2 Methods of Plant analysis: -

Collection and preparation of Plant Sample –

Plant sample from each plot were collected randomly at 30, 60 DAS and harvest of soybean crop. Roots were discarded and shoot with leaves were separated and used for further analysis.

Plant samples were dried in an oven at 60°C temperature for about 24 hours. Final grinding of these oven dried plant samples was done with the help of mechanical grinder.

The methods adopted for different factors involved in plant analysis are discussed briefly as under:

(i) Determination of nitrogen

Nitrogen was determined by micro Kjeldahl method, for which 1 g of plant sample was taken and digested in 100 ml Kjeldahl flask with concentrated H_2SO_4 in presence of triple salt mixture consisting of potassium sulphate, copper sulphate and selenium powder in the ratio of 100:20:05. The digested material was transferred to distillation unit and was distilled with 15 ml of 45% sodium hydroxide solution. The distilled ammonia was collected in 4% boric acid solution. After complete distillation the distillate was titrated against 0.01N standard sulphuric acid. The equivalent amount of nitrogen was calculated and results were expressed as content of nitrogen in percent. The process is described in detail by Piper (1967).

(ii) Determination of phosphorus

Extraction

One gram of oven dried plant sample was disgusted in diacid mixture consisting of concentrated nitric acid and 72% perchloric acid in the ratio of 2:1. The digested material was filtered through Whatman filter paper number

40 and diluted to 100 ml mark. Filtrate was used for determination of phosphorus, potassium and sulphur.

Development of colour

Ten ml of aliquot from the colourless filtrate was taken in 100 ml volumetric flask for determination and then 10 ml of vanadonolybdate reagent was added to it to develop yellow colour. The neck of the flask was washed with distilled water and diluted to 100 ml mark. After shaking thoroughly, it was kept for 30 minutes and there after transmittance percent of solution was read on spectrophotometer at 660 mμ. After setting the instrument to 100 reading of transmittance percent with blank prepared. The amount of phosphorus w ass expressed as percent.

(iii) Determination of potassium

Ten ml of the aliquot of the filtrate was taken in 100-ml volumetric flask and was diluted to the mark with distilled water. The potassium content extract was estimated by flame photometer as described by Black (1965). The results have been expressed as content of K in percent.

(iv) Determination of Sulphur

Development of turbidity

10 ml of aliquot of the filtrate was taken in a 25 ml volumetric flask; 1 ml of 6N HCl (seed solution) and 1 ml of 0.25 per cent gum acacia solution were added to it and shaken. Final volume was made up to mark with distilled water. Content of the flask were transferred to a beaker and 0.5 g of barium chloride crystals (30 mesh) were added and swirled gently for two minutes. Turbidity produced was measured as percent transmittance on spectrophotometer at 420 mμ. After setting the instrument to 100 reading of transmittance with blank prepared. The amount of Sulphur was expressed as S in percent (Tandon, 1993).

(v) Determination of Zinc and Manganese

Zn and Mn content were determined by atomic absorption spectrophotometer. Expressed in mg kg^{-1}.

(vi) Determination of Boron

Boron content in plant samples was determined colorimetrically by curcumin method as described by Black (1965) in the extract prepared by the following methods 0.5 g ground sample in quartz crucible and 0.5 g calcium hydroxide was added prior to dry ashing to prevent the volatilization loss of boron from the ash on a low flame (550 °C) to gray white ash. Cooled added distilled water with 5 ml of 1.0 N hydrochloric acid and evaporated to dryness on hot water bath and finally volume made up to 50 ml in volumetric flask (Gupta, 1967).

11 Economics of the treatments

It was calculated as per existing market prices by method described by Yang (1956) and Dhondyal (1971) for gross and net return and B: C ratio.

12.Statistical analysis

The data recorded were analyzed by the method of analysis of variance technique. The skeleton of ANOVA is given in Table 3.12.1. The SEm $\pm$ and CD at 5% were calculated as suggested by Panse and Sukhatme (1985).

Table 3.12.1 Skeleton of ANOVA table

Source of variance	DF	SS	MSS	Calculated F value	F table value
Replication	3				
Treatment	9				2.57
Error	27				
Total	39				

The standard error of mean was calculated by formula

$$SEm \pm = \sqrt{EMS/r}$$

Where,

EMS = Error Mean Sum of Square, r = Replication

CD was compared for judging the difference between two treatments. It was calculated from formulae:

$$CD\ (at\ 5\%) = SEm \times \sqrt{2} \times t_{(0.05)}\ edf$$

Where,

SEm = Standard Error of Mean

$t_{0.05}$ Edf = Table value of t at 5% level of significance and error degrees of freedom.

CHAPTER – 4

RESULTS

The results of experiment entitled "Study on nutrient management on productivity of soybean" conducted during Kharif, 2005 at the Students Research Farm (Field No.4), College of Agriculture, Indore (M.P.) are presented in this chapter. The observation data pertaining to various criteria used for treatment evaluation were statistically computed to test their significance. The analyses of variance for all these data have been given in appendices. The important parameters have been illustrated graphically.

4.1 Growth and development

4.1.1 Plant population

The data presented in Table 4.1.1.1 and depicted in Fig.4.1.1. revealed that the plant stand running per meter was not influenced significantly by any of the treatments at any growth stage. This indicates that the plant population was well maintained, being almost equal in different treatments i.e. 20.30to 21.70/m row length at harvest stage.

Table 4.1.1Plant population of soybean as influenced by different

Treatments		Plant population running per meter	
		20 DAS	At HARVEST
T_1	N_2, P_2, K_2, S, Zn, Mn, B	22.6	21.0
T_2	N_2, P_1, K_2, S, Zn, Mn, B	23.1	22.7
T_3	N_2, P_2, K_1, S, Zn, Mn, B	22.6	21.6
T_4	N_2, P_2, K_2, S, Zn, B	22.7	21.1
T_5	N_2, P_2, K_2, S, Zn, Mn,	23.1	22.6
T_6	N_2, P_2, K_2, S, Mn, B	23.4	22.4
T_7	N_2, P_2, K_2, Zn, Mn, B	22.6	21.3
T_8	N_1, P_1, K_1	22.7	21.5
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	22.3	21.2
T_{10}	N_1, P_1, K_1 + FYM 5 t + Biofertilizer 500 g ha^{-1}	22.4	21.7
	SEm $\pm$	0.17	0.3
	CD (5 %)	N.S	N.S.

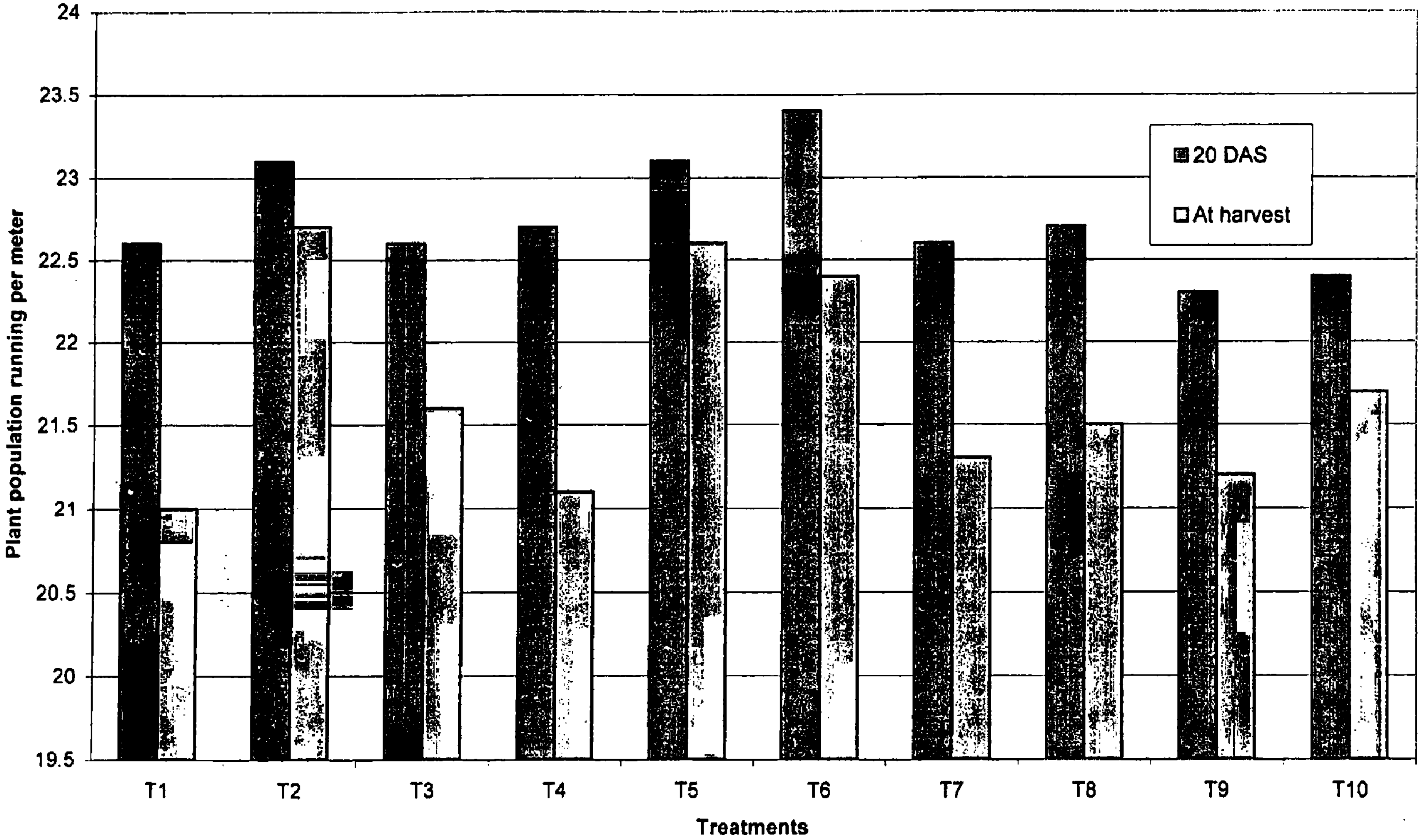


Fig. 4.1.1 Plant population of soybean as influenced by different treatments

4.1.2 Plant height (cm)

The plant height (cm) in general, increased 30 and 60 DAS period. Thereafter, a slight increase in height was noticed beyond 60 DAS up to harvest stage. Thus, the plant height was very fast between 30 and 60 DAS, and very slow beyond 60 DAS (Table 4.1.2 and Fig.4.1.2).

Table 4.1.2 Effect of different treatments on plant height (cm) of soybean at the successive stages of plant growth

Treatments	Combinations	Plant height (cm)		
		30 DAS	60 DAS	At harvest
T_1	N_2, P_2, K_2, S, Zn, Mn, B	27.8	57.82	58.3
T_2	N_2, P_1, K_2, S, Zn, Mn, B	27.5	57.75	58.9
T_3	N_2, P_2, K_1, S, Zn, Mn, B	27.3	56.2	57.6
T_4	N_2, P_2, K_2, S, Zn, B	26.7	55.3	56.3
T_5	N_2, P_2, K_2, S, Zn, Mn,	25.9	54.8	55.7
T_6	N_2, P_2, K_2, S, Mn, B	25.7	56.1	57.3
T_7	N_2, P_2, K_2, Zn, Mn, B	24.4	52.1	55.0
T_8	N_1, P_1, K_1	23.7	52.1	53.9
T_9	. N_1, P_1, K_1 + FYM 10 t ha^{-1}	27.4	57.3	60.8
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g /ha.	26.9	57.0	58.1
	SEm ±	0.040	0.57	0.17
	CD (5%)	0.083	1.12	0.49

The maximum plant height (60.8 cm) was recorded at maturity in case of T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}), and proved significantly superior to T_7 and T_8 treatments having no Sulphur and FYM (53.9 to 55.0 cm). The treatments T_4 without Mn T_5 without B tended to decrease this parameter. Application of NPK recounted (T_8) recorded the lowest plant height of 53.9 cm.

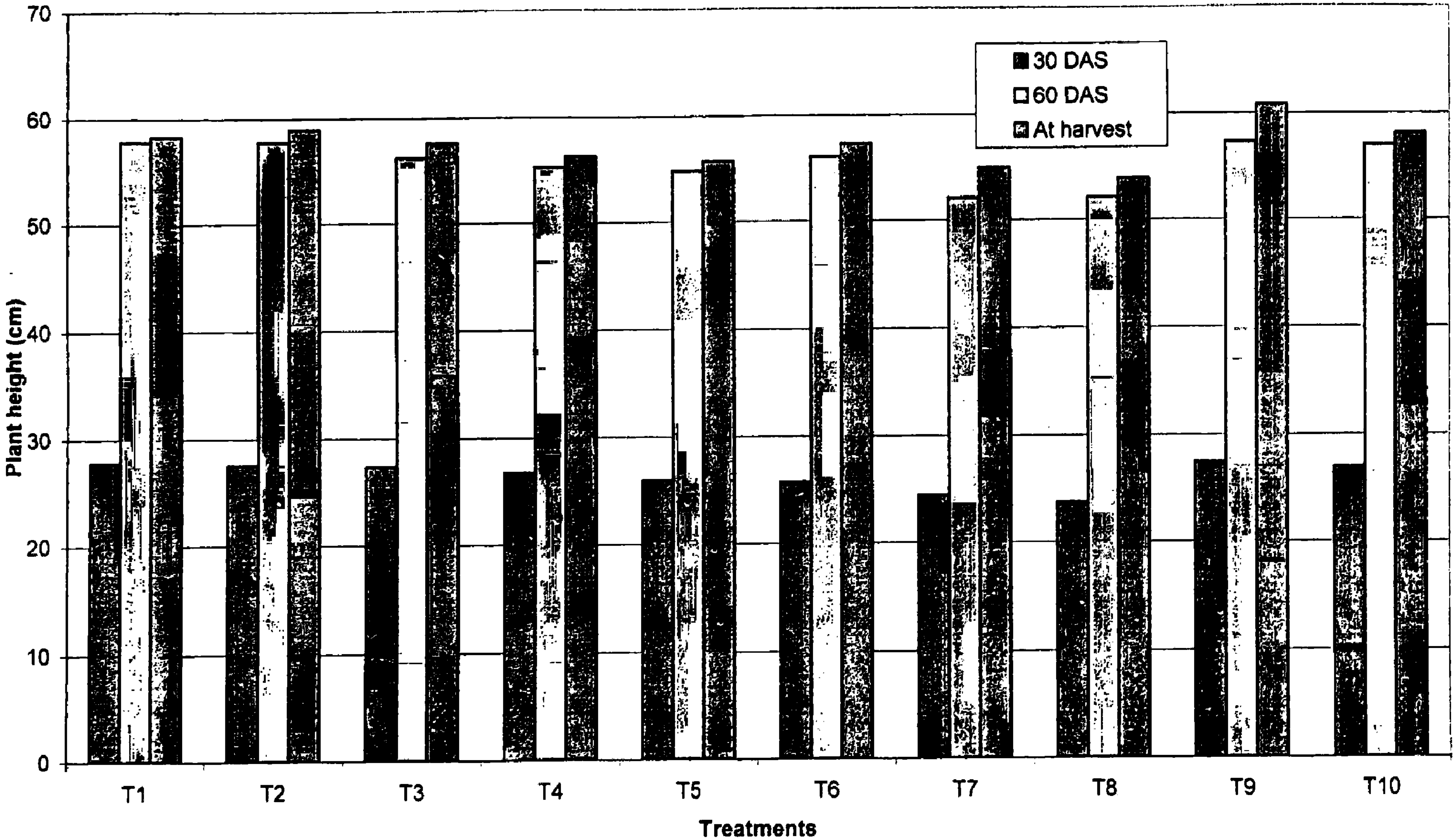


Fig.4.1.2 Effect of different treatments on plant height (cm) of soybean at the successive stages of plant growth

4.1.3 Number of branches per plant

It is apparent from the data (Table 4.1.3 and Fig.4.1.3) that the number of branches per plant was maximum (4 number) in T_1 (N_2, P_2, K_2, S, Zn, Mn, B) being significantly superior to all other treatments followed by T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}). This indicates that as application @ 10t ha^{-1} supplemented all those nutrients, which were available from T_1 treatment. However, theT_{10} (FYM10 t ha^{-1}) could not perform well in respect of branches per plant. The treatment T_8 having NPK alone produced significantly lowers number of branches (3) over most of the treatments.

Table 4.1.3 Number of branches per plant as affected by various treatments at harvest stage

Treatments.	Combinations	Number of branches per plant (at harvest)
T_1	N_2, P_2, K_2, S, Zn, Mn, B	4.0
T_2	N_2, P_1, K_2, S, Zn, Mn, B	3.7
T_3	N_2, P_2, K_1, S, Zn, Mn, B	3.5
T_4	N_2, P_2, K_2, S, Zn, B	3.6
T_5	N_2, P_2, K_2, S, Zn, Mn,	3.8
T_6	N_2, P_2, K_2, S, Mn, B	3.6
T_7	N_2, P_2, K_2, Zn, Mn, B	3.7
T_8	N_1, P_1, K_1	3.0
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	3.9
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	3.5
	SEm $\pm$	0.05
	CD (5%)	0.144

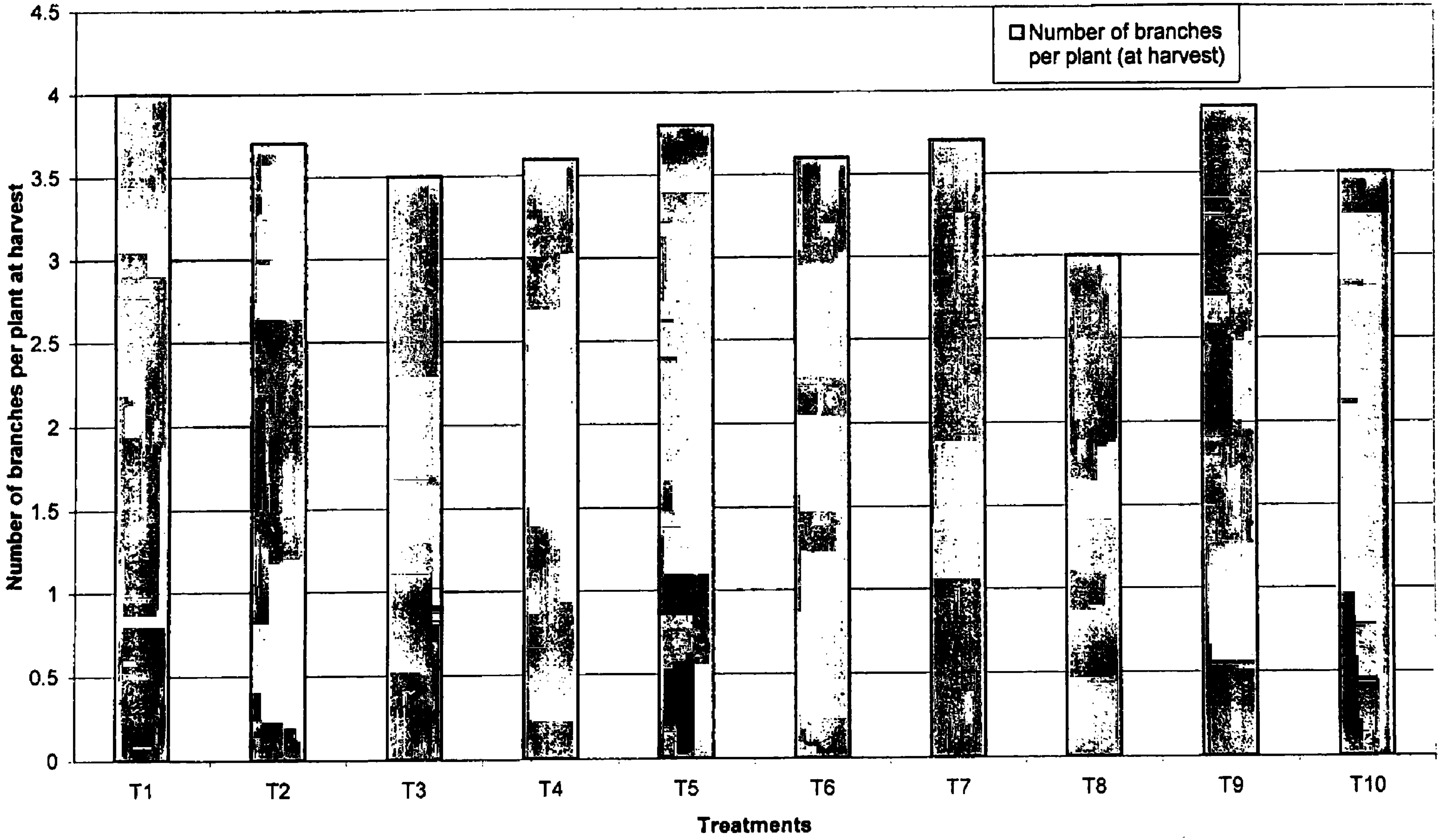


Fig. 4.1.3 Number of branches per plant as affected by various treatments at harvest stage

4.1.4 Number of root nodules per plant

The root nodules of soybean plant are responsible for the fixation of atmospheric nitrogen in the soil and their number may differ due to different nutrient management and other agronomic conditions.The data in Table 4.1.4 and Fig.4.1.4 revealed that the number of root nodules per plant was influenced significantly due to nutrient management treatments. Shows that the maximum number of root nodules (50.4 per plant) was recorded in T_{10} (N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.) treatment, which was significantly superior to the other treatments except T_1, T_2 and T_9 treatments. Thus, T_1, T_2 and T_9 treatments having the capacity to supply essential plant nutrient formed uniform number of root nodules (45.7 to 47.1$plant^{-1}$)

Table 4.1.4 Effect of different treatments on number of root nodules per plant at 40 DAS

Treatments	Combinations	Number of root nodules per plant
T_1	N_2, P_2, K_2, S, Zn, Mn, B	45.7
T_2	N_2, P_1, K_2, S, Zn, Mn, B	46.6
T_3	N_2, P_2, K_1, S, Zn, Mn, B	44.4
T_4	N_2, P_2, K_2, S, Zn, B	43.8
T_5	N_2, P_2, K_2, S, Zn, Mn,	45.1
T_6	N_2, P_2, K_2, S, Mn, B	44.7
T_7	N_2, P_2, K_2, Zn, Mn, B	43.7
T_8	N_1, P_1, K_1	42.1
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	47.1
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	50.4
	SEm $\pm$	0.086
	CD (5%)	0.248

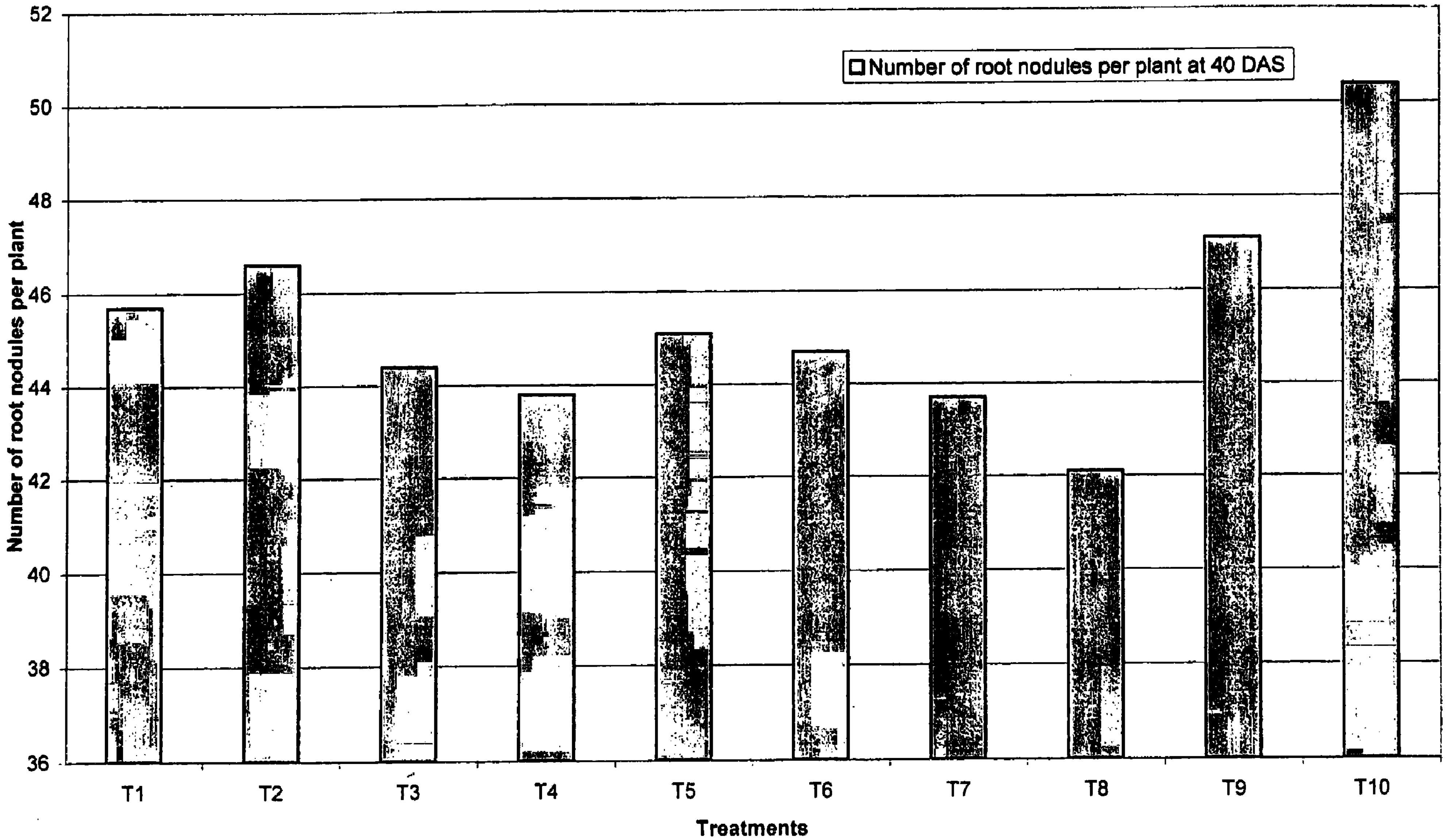


Fig. 4.1.4 Effect of different treatments on number of root nodules per plant at 40 DAS

4.2Yield-attributing characters

4.2.1 Number of pods per plant

The number of pods per plant is one of the important yield attributing characters, which determines the grain yield of soybean crop. The number of pods per plant directly affects the number of grains per plant and ultimately the final grain yield. The data in Table 4.2.1.1 and illustrated in Fig.4.2.1.1 revealed that T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}.) recorded the maximum number of pods (23.2 $plant^{-1}$), closely followed by T_2 and T_{10} (22.00 to 22.7 pods $plant^{-1}$). These treatments proved superiority over to T_4, T_5, T_6, T_7 and T_8 treatments. However, the control treatment (T_8) having only NPK resulted in the lowest number of pods (18.5 $plant^{-1}$). The quantity of applied nutrients also influenced this parameter. It is apparent when comparison is made between T_1, T_2 and T_3 treatments.

Table 4.2.1.1Number of pods per plant as affected by various treatments

Treatments	Combinations	Number of pods per plant
T_1	N_2, P_2, K_2, S, Zn, Mn, B	21.3
T_2	N_2, P_1, K_2, S, Zn, Mn, B	22.0
T_3	N_2, P_2, K_1, S, Zn, Mn, B	19.7
T_4	N_2, P_2, K_2, S, Zn, B	20.0
T_5	N_2, P_2, K_2, S, Zn, Mn,	20.2
T_6	N_2, P_2, K_2, S, Mn, B	19.4
T_7	N_2, P_2, K_2, Zn, Mn, B	19.1
T_8	N_1, P_1, K_1	18.0
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	23.0
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	22.7
	SEm ±	0.06
	CD (5%)	0.173

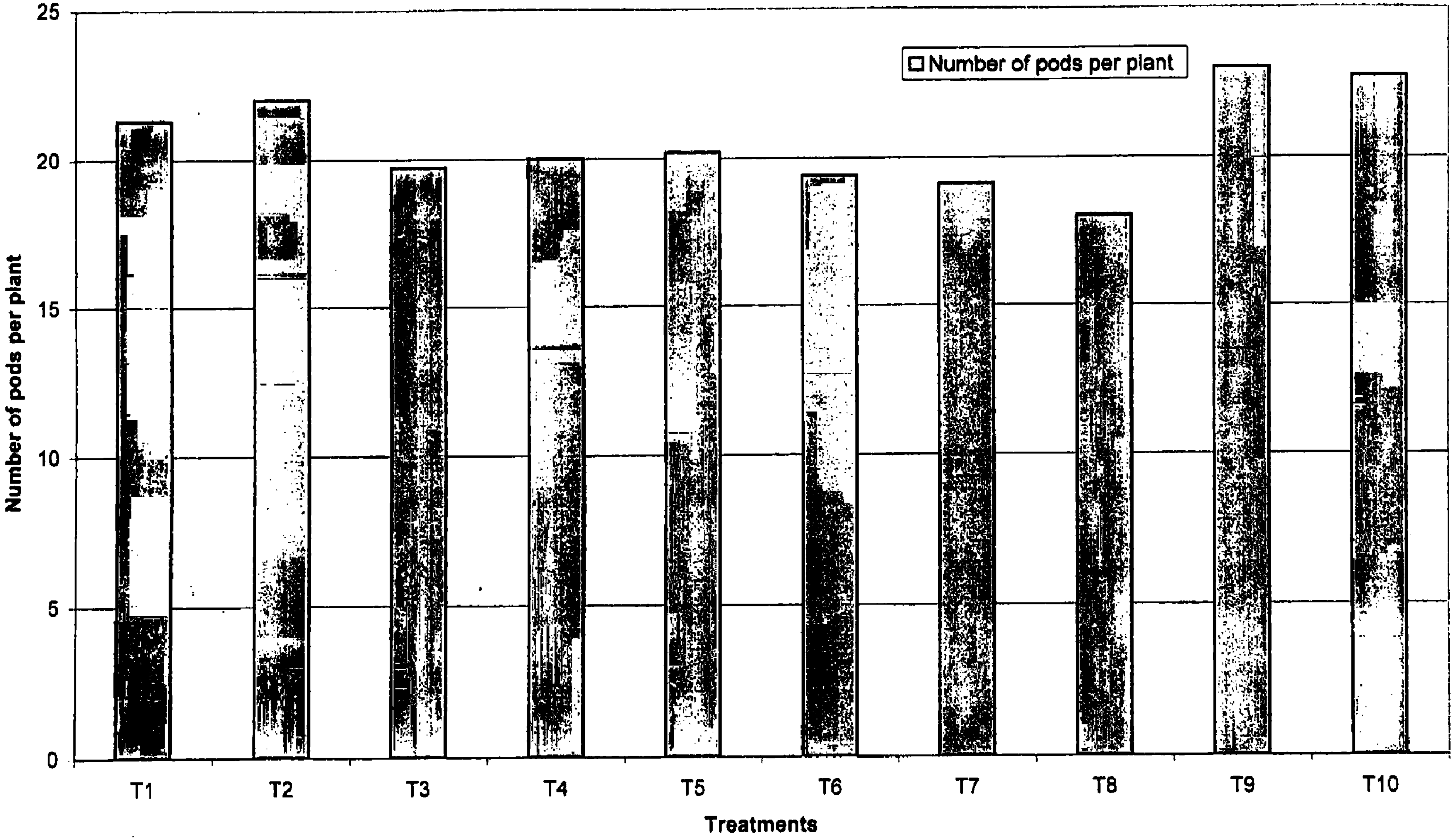


Fig. 4.2.1.1 Number of pods per plant as affected by various treatments

4.2.2 Number of seeds per plant

The number of seeds per pod and per plant is one of the important yield attributing characters, which determines the grain yield, and it directly affects the grain yield of the crop.

The data on average number of seeds/plant are presented in Table 4.2.2.1 and illustrated in Fig.4.2.2.1 These clearly indicate that application of N_1, P_1, K_1 + 10 t FYM / ha. (T_9) resulted in the highest number of seeds (54.27 plant^{-1}) and closely followed by T_{10} (N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g /ha.) i.e. 53.92 seeds plant^{-1}. The treatments comprising NPKS + Zn, B, Mn (T_1 and T_2) also produced the higher number seeds (47.9 and 48.1 plant^{-1}) respectively. The other treatments like T_3, T_4, T_5, T_6, T_7 and T_8 produced significantly lower number of seeds as compared to treatment T_8 (37.90 seeds plant^{-1}).

Table 4.2.2.1Number of seeds per plant as affected by various treatments

Treatments	Combinations	Number of seeds per plant
T_1	N_2, P_2, K_2, S, Zn, Mn, B	47.9
T_2	N_2, P_1, K_2, S, Zn, Mn, B	48.1
T_3	N_2, P_2, K_1, S, Zn, Mn, B	42.3
T_4	N_2, P_2, K_2, S, Zn, B	43.9
T_5	N_2, P_2, K_2, S, Zn, Mn,	44.4
T_6	N_2, P_2, K_2, S, Mn, B	41.2
T_7	N_2, P_2, K_2, Zn, Mn, B	39.8
T_8	N_1, P_1, K_1	37.9
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	54.2
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	53.9
	SEm ±	0.86
	CD (5%)	1.77

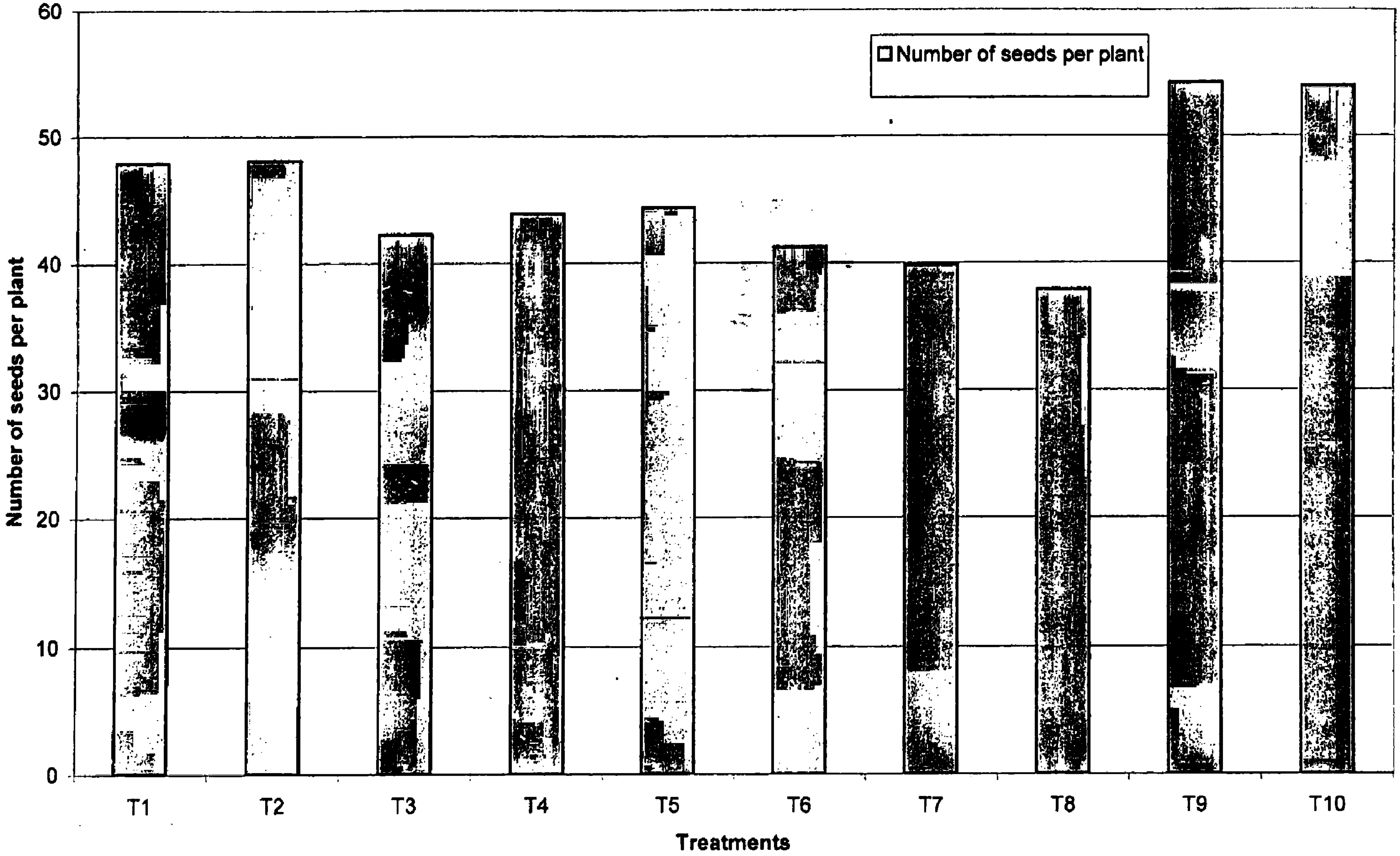


Fig.4.2.2 Number of seeds per plant as affected by various treatments

4.2.3 Number of seeds per pod

The data in Table 4.2.3.1 and in Fig.4.2.3.1 reveal that the maximum seeds (2.4/pod) were noted in T_9 (N_1, P_1, K_1 + 10 t FYM / ha.), which was non-significantly higher to other treatments. TreantmentT_{10} (N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g /ha.) produced 2.3 seeds/pod. On the other hand, the lower seeds/pod (2.05 to 2.3) was obtained in case of T_8 andT_7 treatments. The remaining T_1, T_3, T_4, T_5 and had the intermediate values (2.12 to 2.25 seeds / pod).

Table 4.2.3.1Number of seeds per pod of soybean as influenced by various treatments

Treatments	Combinations	No. of seeds per pod
T_1	N_2, P_2, K_2, S, Zn, Mn, B	2.2
T_2	N_2, P_1, K_2, S, Zn, Mn, B	2.3
T_3	N_2, P_2, K_1, S, Zn, Mn, B	2.1
T_4	N_2, P_2, K_2, S, Zn, B	2.1
T_5	N_2, P_2, K_2, S, Zn, Mn,	2.2
T_6	N_2, P_2, K_2, S, Mn, B	2.1
T_7	N_2, P_2, K_2, Zn, Mn, B	2.1
T_8	N_1, P_1, K_1	2.0
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	2.4
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	2.3
	SEm $\pm$	0.03
	CD (5%)	0.09

4.2.4Seed index

The data on seed index (100-seed weight) of soybean are presented in Table 4.2.4.1 and depicted in Fig.4.2.4.1 The perusal of data reveals that T_9 comprising N_1, P_1, K_1 + FYM 10 t ha^{-1}. recorded maximum seed index (18.00g) and closely followed by T_{10} (N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g /ha) i.e. 17.9 g. The treatment T_2 (N_2, P_1, K_2, S, Zn, Mn, B), gave seed index up to 17.5 g, whereas T_9 proved significantly superior to T_3, T_7 and T_8 (13.6 to 16.0 g seed index). All the nutrient management treatments resulted in significantly

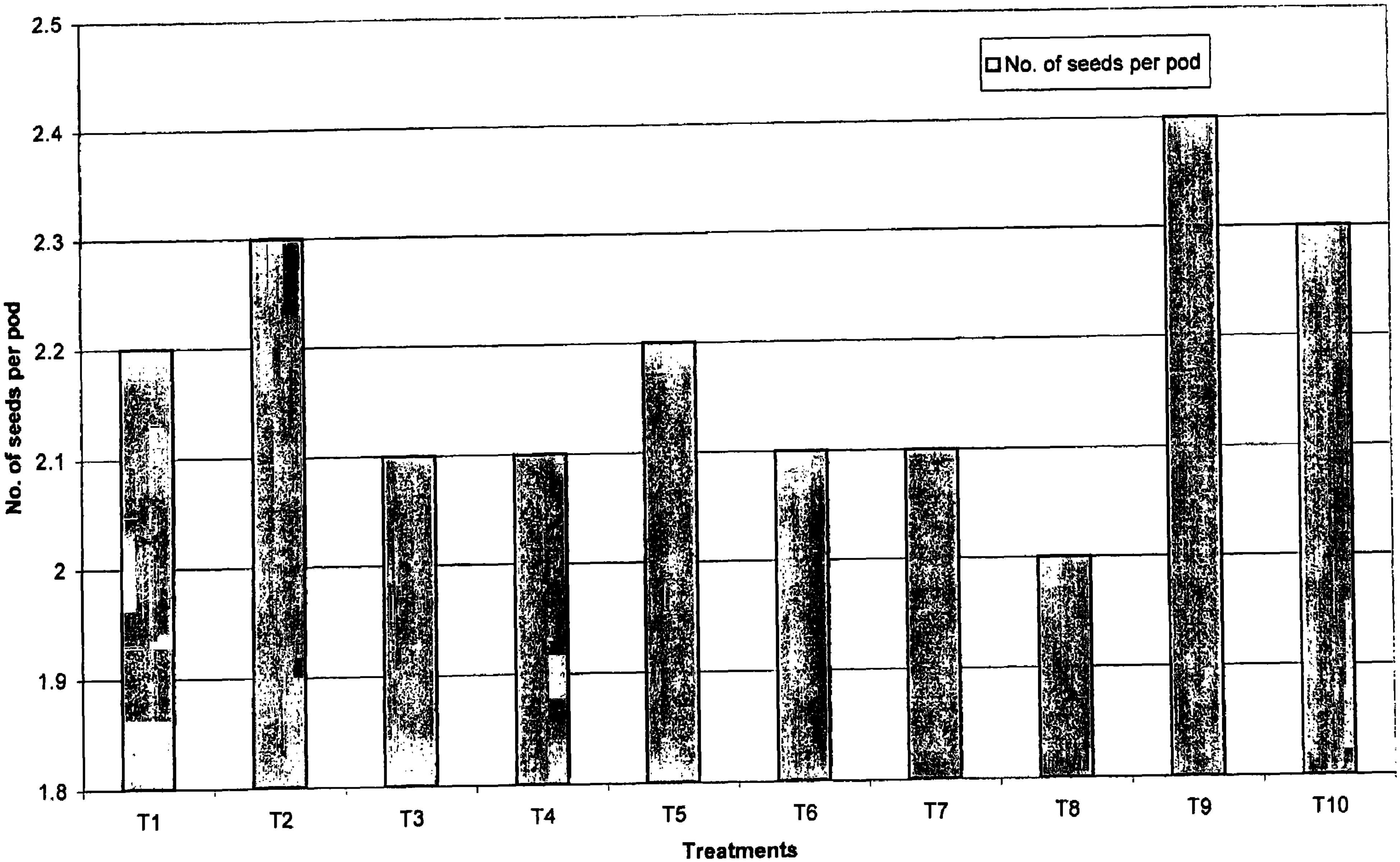


Fig.4.2.3 Number of seeds per pod of soybean as influenced by various treatments

higher seed index (14.5 to 18.00 g) over T_8 (N_1, P_1, K_1). The treatment T_8 recorded the lowest seed index (13.6 g).

Table 4.2.4.1Seed index

Treatments	Combinations	Seed index
T_1	N_2, P_2, K_2, S, Zn, Mn, B	17.3
T_2	N_2, P_1, K_2, S, Zn, Mn, B	17.5
T_3	N_2, P_2, K_1, S, Zn, Mn, B	16.0
T_4	N_2, P_2, K_2, S, Zn, B	17.3
T_5	N_2, P_2, K_2, S, Zn, Mn,	16.9
T_6	N_2, P_2, K_2, S, Mn, B	17.5
T_7	N_2, P_2, K_2, Zn, Mn, B	14.5
T_8	N_1, P_1, K_1	13.6
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	18.0
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	17.9
	SEm ±	0.02
	CD (5%)	0.06

4.3 Yield and harvest index

4.3.1 Seed yield per hectare

The perusal of data in Table 4.3.1.1 and Fig.4.3.1.1 revealed that the maximum seed yield of soybean of 2367kg/ha was recorded in T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}.) treatment, which showed its superiority over other treatments. However, this was followed by T_{10}, T_2 and T_1. There after the remaining treatments like T_3, T_4, T_5, T_6 and T_7 produced statistically equal yield. Application of $N_1P_1K_1$ alone (T_8) gave the significantly lowest yield (1774 kg ha^{-1}). Thus, the yield difference between the highest yielding treatment (T_9) and the lowest yielding treatment (T_8) was up to 553 kg ha^{-1}.

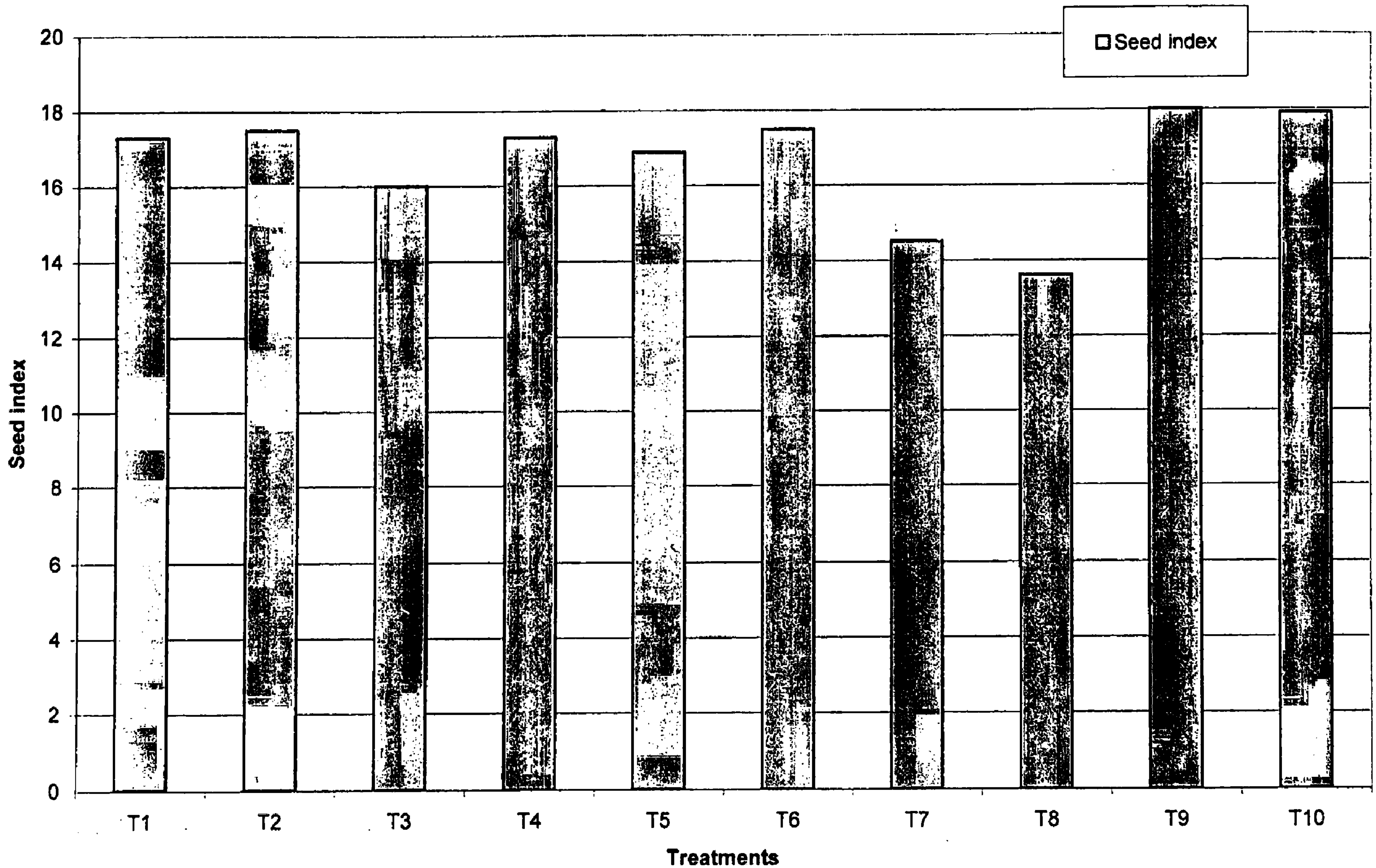


Fig.4.2.4 Seed index as influenced by different treatments combinations

Table 4.3.1.1Effect of different treatments on seed yield per hectare of soybean as influenced by different treatments

Treatments	Combinations	Seed yield (kg ha^{-1})
T_1	$N_2, P_2, K_2,$ S, Zn, Mn, B	2174
T_2	$N_2, P_1, K_2,$ S, Zn, Mn, B	2199
T_3	$N_2, P_2, K_1,$ S, Zn, Mn, B	2038
T_4	$N_2, P_2, K_2,$ S, Zn, B	2041
T_5	$N_2, P_2, K_2,$ S, Zn, Mn,	2059
T_6	$N_2, P_2, K_2,$ S, Mn, B	2014
T_7	$N_2, P_2, K_2,$ Zn, Mn, B	1953
T_8	N_1, P_1, K_1	1774
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	2367
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	2223
	SEm $\pm$	15.6
	CD (5%)	32.0

4.3.2 Straw yield per hectare

A critical examination of data (Table 4.3.2.1 and Fig.4.3.2.1) indicates that all nutrient management treatments increased the straw yield of soybean significantly over the control (T_8) having NPK alone. However, amongst all these treatments, the significantly higher straw yield (3030 kg ha^{-1}) was recorded in T_9 (N_1, P_1, K_1 + 10 t FYM / ha.) treatment, followed by T_2 (2838 kg ha^{-1}) and T_1 (2803 kg ha^{-1}). The treatments of T_{10}, T_4, T_3, T_6 produced significantly more yield than treatment T_5 and T_7.

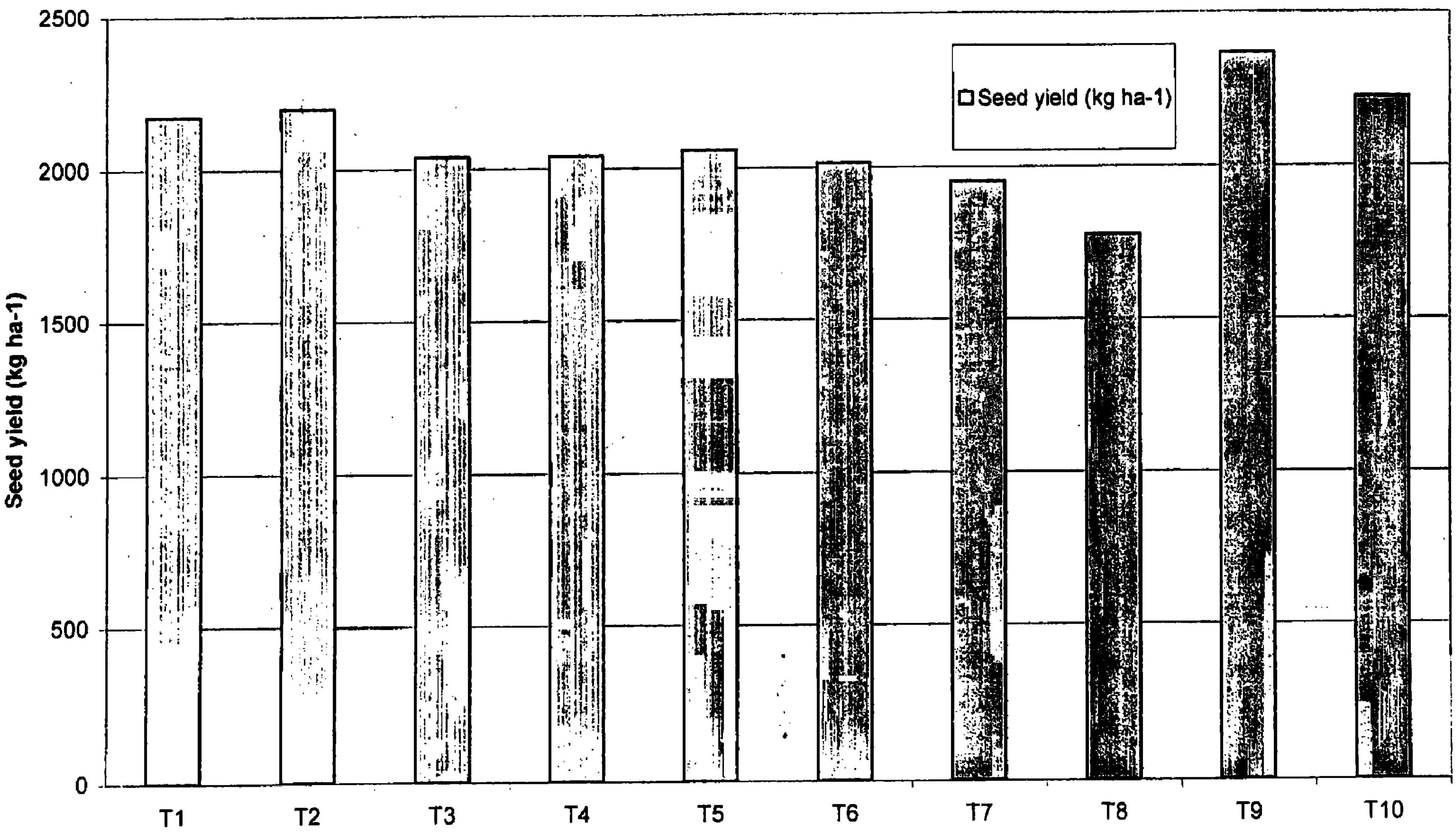


Fig.4.3.1 Effect of different treatments on seed yield per hectare of soybean as influenced by different treatments

Table 4.3.2.1 Effect of different treatments on straw yield per hectare of soybean as influenced by different treatments

Treatments	Combinations	Straw yield (kg/ha)
T_1	N_2, P_2, K_2, S, Zn, Mn, B	2803
T_2	N_2, P_1, K_2, S, Zn, Mn, B	2838
T_3	N_2, P_2, K_1, S, Zn, Mn, B	2521
T_4	N_2, P_2, K_2, S, Zn, B	2684
T_5	N_2, P_2, K_2, S, Zn, Mn,	2476
T_6	N_2, P_2, K_2, S, Mn, B	2509
T_7	N_2, P_2, K_2, Zn, Mn, B	2398
T_8	N_1, P_1, K_1	2059
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	3030
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	2785
	SEm $\pm$	79.
	CD (5%)	163

4.3.3 Harvest index (%)

Harvest index was calculated using the data given in Table 4.3.1 and 4.3.2 and the data on harvest index presented in Table 4.3.3.1 and Fig. 4.3.3.1. The data revealed that all the nutrient management treatments brought about lower harvest index as compared to the treatment having only N_1, P_1, K_1, fertility level, (T_8). The differences in harvest index among the treatments were non-significant. The maximum harvest index up to 46.3% and the minimum harvest index (43.2%) were recorded in T_8 (N_1, P_1, K_1) and in T_4 (N_2, P_2, K_2, S, Zn, B), respectively.

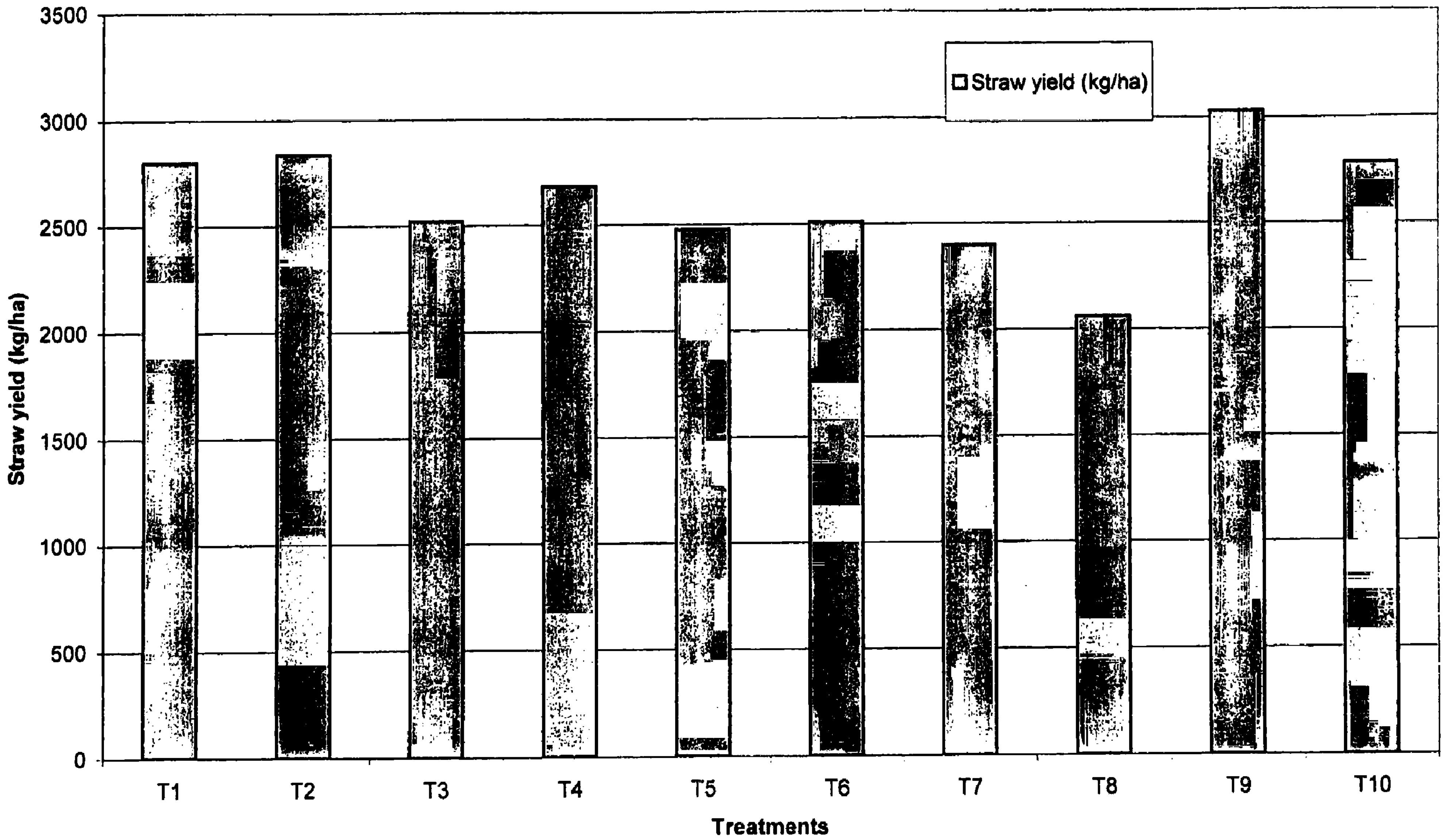


Fig. 4.3.2 Effect of different treatments on straw yield per hectare of soybean as influenced by different treatments

Table 4.3.3.1 Effect of different treatments on harvest index per hectare of soybean as influenced by different treatments

Treatments	Combinations	Harvest index (%)
T_1	N_2, P_2, K_2, S, Zn, Mn, B	43.7
T_2	N_2, P_1, K_2, S, Zn, Mn, B	43.7
T_3	N_2, P_2, K_1, S, Zn, Mn, B	44.7
T_4	N_2, P_2, K_2, S, Zn, B	43.2
T_5	N_2, P_2, K_2, S, Zn, Mn,	45.4
T_6	N_2, P_2, K_2, S, Mn, B	44.5
T_7	N_2, P_2, K_2, Zn, Mn, B	44.9
T_8	N_1, P_1, K_1	46.3
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	43.9
T_{10}	N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.	44.4
	SEm ±	0.43
	CD (5%)	NS

4.4. Economics of treatments under study

4.4.1 Expenditure

Total expenditure of each treatment is divided in to two parts, common expenditure and treatment wise extra expenditure. Common expenditure includes cost of Rhizobium culture, field preparation, seed, sowing operation, weeding, weedicide, insecticide, land revenue, spraying, watching, harvesting and threshing.

Extra expenditure includes cost of treatment. The prevailing rates of urea Rs.253/50 kg, DAP Rs.480/50 kg, MOP Rs.233/50 kg, FYM Rs.50/100 kg, gypsum Rs.80/50 kg, $ZnSO_4$ Rs.125/10 kg, $MnSO_4$ Rs.138/500 g, borax and Rs.150/500 g.

4.4.2 Gross income

The soybean grain and straw were sold in market @ Rs.1200/q. and Rs.50/q, respectively.

C = Market value of A + market value of B

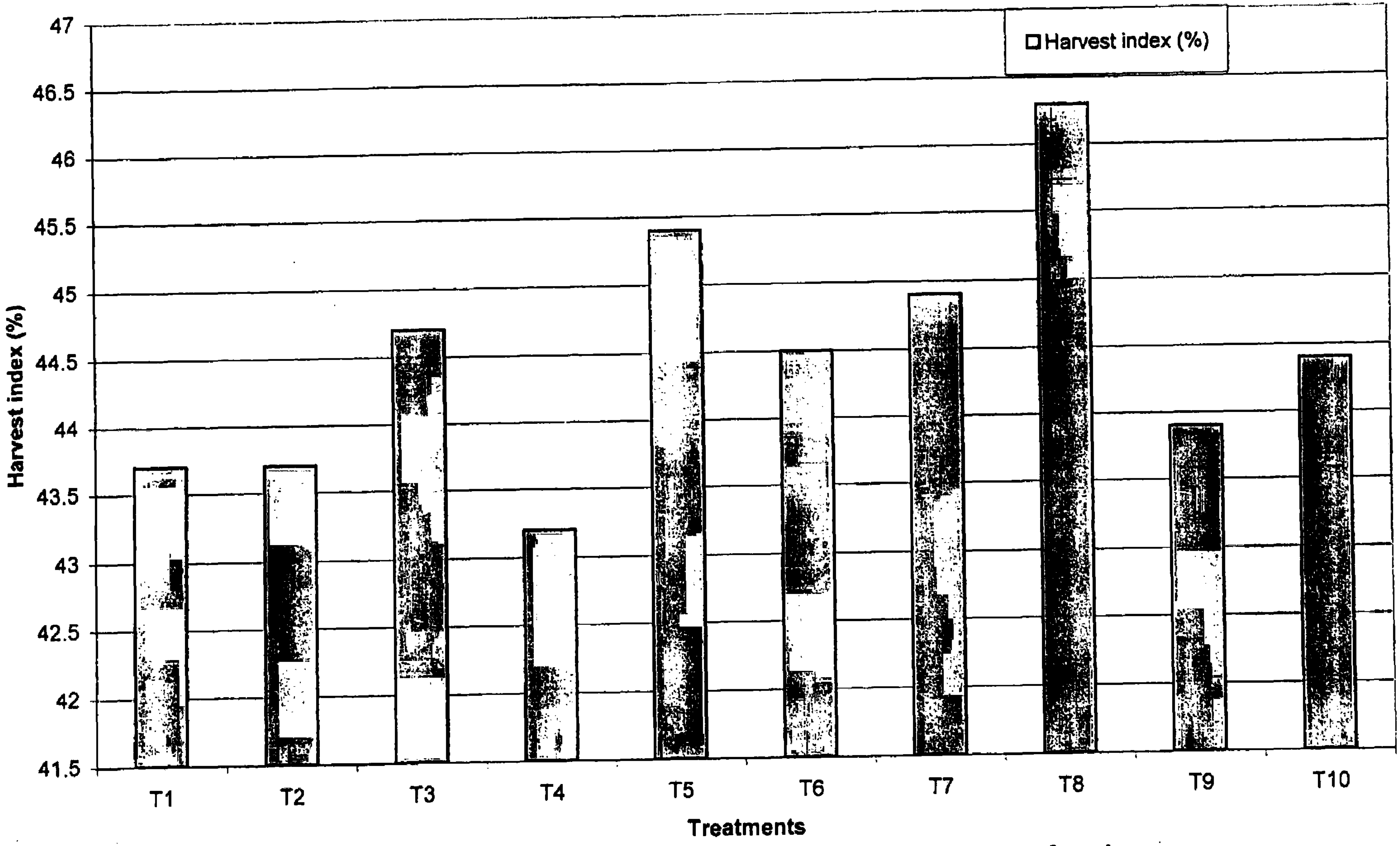


Fig.4.3.3 Effect of different treatments on harvest index per hectare of soybean as influenced by different treatments

The study of data in Table 4.4 revealed that maximum (Rs. 15348) input was used in T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}.) treatment followed by (Rs. 13969) in T_1 (N_2, P_2, K_2, S, Zn, Mn, B) treatment. The minimum (10348) expenditure was incurred under T_8 ($N_1P_1K_1$) treatment.

4.4.3 Net return and B: C ratio

The study of data on estimated net return (Table 4.3.4.1) revealed that the maximum net return up to Rs. 15190/ha was obtained from treatment T_{10} (N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g ha^{-1}.), followed by T_9 (N_1, P_1, K_1 + FYM10 t ha^{-1}.) i.e. Rs. 14571ha^{-1}. The treatment T_4 (N_2, P_2, K_2, S, Zn, B) attained the thin position, the net return being Rs. 14080 ha^{-1}. On the other hand, the minimum net return (Rs10726 ha^{-1}) was recorded in treatment T_7 having N_2, P_2, K_2, Zn, Mn, B. The benefit: cost ratio also followed the same trend. It was highest (2.18) case of T_{10} and minimum benefit: cost ratio (1.77) was noted in case of T_7.

Table 4.3.4.1 economic evaluation of different treatments

Treatment	Cost of prod-uction (Rs.)	Yield (kg/ha)		Income		B: C ratio
		Grain	Straw	Gross C=A+B (Rs.)	Net (Rs.)	
T_1	13969	2174	2803	27497	13528	1.97
T_2	13845	2199	2837	27811	13966	2.01
T_3	13842	2038	2521	25721	11879	1.86
T_4	11761	2041	2684	25841	14080	2.20
T_5	13009	2059	2476	25948.	12939	1.99
T_6	13869	2014	2509	25427.	11558	1.83
T_7	13915	1953	2398	24641	10726	1.77
T_8	10348	1774	2059	22317	11969	2.16
T_9	15348	2367	3030	29919	14571	1.95
T_{10}	12878	2223	2785	28068	15190	2.18

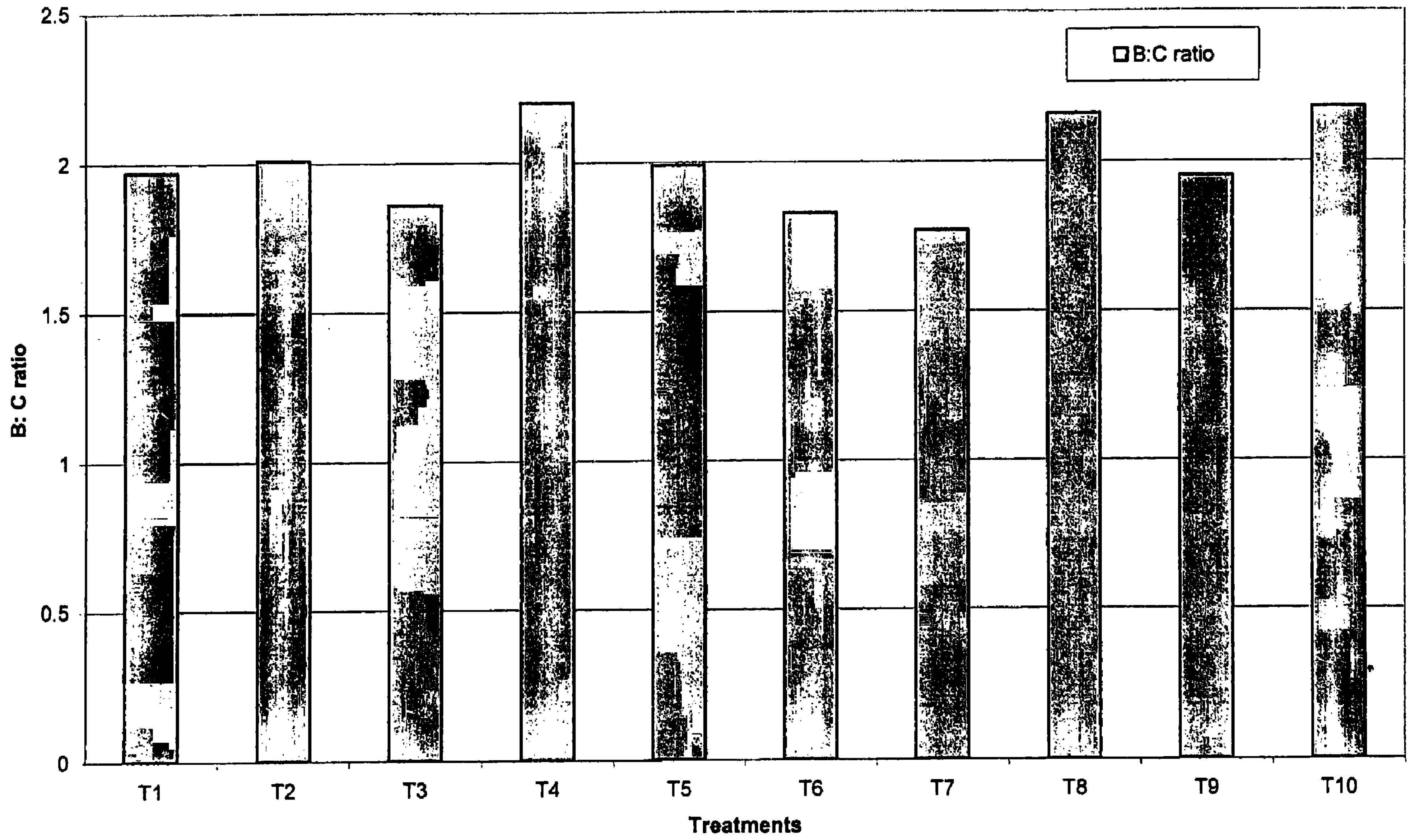


Fig. 4.3.4.1 economic evaluation of different treatments

4.5 Soil fertility status after harvest

The data in Table 4.5.2.1 shows the chemical properties of soil in different treatments at the harvest stage. pH and EC were decreased in treatments where FYM was applied, while organic carbon was increased due to the application of FYM. The available nitrogen was in general, increased after crop harvest in comparison to its initial value (180 kg ha^{-1}). However, the soil nitrogen was found higher (190 kg ha^{-1}) in T_9 treatment having 10 t FYM/ha in addition to $N_1P_1 K_1$ as well as in T_{10} having 5 t FYM and Biofertilizer in addition to N_1, P1, K_1, (190 kg ha^{-1}). The minimum increased nitrogen (185 kg ha^{-1}) was recorded in case of NPK alone treatment (T_8). The treatment without zinc (T_6) also recorded the lower nitrogen content (187 kg ha^{-1}). Due to application of FYM the infiltration rate of soil was increased.

The available phosphorus content in soil after crop harvest was, enhanced to some extent (13.1 to 17.5 kg ha^{-1}) over the initial level (12.8 kg ha^{-1}), in all the nutrient management treatments applied with P_2 to P_1. However, such enhancement was very slight in case of T_8 NPK alone treatment (13.1 kg ha^{-1}).

Similar, results were also observed in case of available potassium in soil. Initially, it was found to be 394 kg ha^{-1}. Applied potassium treatments @ 20 kg and 36 kg K_2O_5 ha^{-1} and its availability ranged from 428 to 495 kg ha^{-1}. The sulphur was applied to the soil in T_1 to T_6 treatments @ 6 kg ha^{-1} through gypsum. This small quantity of sulphur brought slightly increase in its level in soil after harvest of soybean crop as compared to rest of the treatments receiving no Sulphur.

As regard the micronutrients status in soil like zinc and manganese, which were foliar sprayed to soybean crop at 0.5% solution in all the treatments T_8 (N_1, P_1K_1) recorded higher content of zinc, whereas, Mn availability reduced as compared to its initial value.. In case of Borax 0.2 % solution sprayed as foliar and it increased in T_1, T_2, T_3, T_4, T_6 and T_7 while in the T_5, T_8, T_9 and T_{10} treatments slightly decreased in the post-harvest soil (Table 4.5.1).

Table 4.5.1 Changes in the nutrient status of after harvest soil as influenced by different nutrient management treatments applied to soybean crop

Treatments	Available nutrients									
	pH	EC	OC	N	P_2O_5	K_2O	S	Zn	Mn	B
		dSm^{-1}	%	$Kg\ ha^{-1}$.				$Mg\ kg^{-1}$		
$T_1 = N_2, P_2, K_2$, S, Zn, Mn, B	7.9	0.32	0.41	182	14.6	480	12.6	1.31	58.	0.21
$T_2 = N_2, P_1, K_2$, S, Zn, Mn, B	8.0	0.33	0.40	179	15.8	487	13.0	1.63	60.	0.23
$T_3 = N_2, P_2, K_1$, S, Zn, Mn, B	7.8	0.33	0.42	183	16.4	438	12.8	1.40	60.	0.22
$T_4 = N_2, P_2, K_2$, S, Zn, B	7.9	0.31	0.43	185	13.3	470	13.1	1.60	53.	0.23
$T_5 = N_2, P_2, K_2$, S, Zn, Mn,	8.0	0.32	0.42	183	14.2	463	12.3	1.53	59.	0.19
$T_6 = N_2, P_2, K_2$, S, Mn, B	8.0	0.32	0.44	187	16.8	457	11.8	1.288	59.	0.23
$T_7 = N_2, P_2, K_2$, Zn, Mn, B	8.0	0.33	0.45	189	13.5	440	10.5	1.30	60.	0.21
$T_8 = N_1, P_1, K_1$	7.9	0.29	0.43	185	13.1	428	9.7	1.27	52.	0.19
$T_9 = N_1, P_1, K_1$ + 10 t FYM / ha	7.8	0.33	0.46	190	17.5	495	10.5	1.50	52.	0.19
$T_{10} = N_1, P_1, K_1$ + 5 t FYM + Biofertilizer 500 g /ha.	7.9	0.33	0.45	190	16.3	490	11.2	1.43	52. 0	0.18
Initial status	8	0.31	0.40	180	12.8	394	11.2	1.17	55.	0.20

4.6 Nutrient content (%) in Plant and Seed

4.6.1 Nitrogen content

The data of with respect nitrogen content (%) at 30 DAS are presented in table 4.6.1. The data revealed that the treatment T_{10} showed higher nitrogen content (3.33 %) in soybean plant followed by T_9 (3.31 %) and T_2 (3.29 %).

The data of with respect nitrogen content (%) at 60 DAS are presented in table 4.6.1. The data revealed that the treatment T_{10} showed higher nitrogen content (2.94 %) in soybean plant followed by T_9 (2.93 %) and T_2 (2.92 %).

Nitrogen content in straw was found maximum (1.19 %) due to treatment T_{10} (N1, P1, K1 + 5 t FYM + Biofertilizer 500 g /ha) and minimum (1.08 %) in treatment T_8 (N_1, P_1, K_1 alone) as presented in table 4.6.1. indicated that the nitrogen content in straw of soybean was reduced as plant progressed to maturity.

The data of nitrogen content (%) in grain was also presented in Table 4.6.1, which showed that all the treatment increased the nitrogen content (%) in grain as compared to T_8. Maximum (5.8 %) nitrogen content in grain was found in T_{10} (N_1, P_1, K_1 + FYM 5 t + Biofertilizer 500 g /ha) and minimum (4.9 %) in T_8 (N_1, P_1, K_1 alone) also indicate, that the nitrogen content (%) in grain was higher as compared to straw.

Table 4.6.1 Nitrogen content (%) in plant and Grain as affected by various treatments

Treatments	Combinations	Nitrogen content (%)			
		30 DAS	60 DAS	At harvest	Grain
T1	N_2, P_2, K_2, S, Zn, Mn, B	3.27	2.90	1.16	5.5
T_2	N_2, P_1, K_2, S, Zn, Mn, B	3.29	2.92	1.17	5.6
T_3	N_2, P_2, K_1, S, Zn, Mn, B	3.17	2.86	1.13	5.2
T_4	N_2, P_2, K_2, S, Zn, B	3.22	2.87	1.14	5.3
T_5	N_2, P_2, K_2, S, Zn, Mn,	3.25	2.89	1.15	5.4
T_6	N_2, P_2, K_2, S, Mn, B	3.15	2.84	1.12	5.1
T_7	N_2, P_2, K_2, Zn, Mn, B	3.10	2.82	1.11	5.0
T_8	N_1, P_1, K_1	3.03	2.80	1.08	4.9
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	3.31	2.93	1.18	5.7
T_{10}	N_1, P_1, K_1 + FYM5 t + Biofertilizer 500 g ha^{-1}.	3.33	2.94	1.19	5.8
	SEm $\pm$	0.02	0.009	0.008	0.05
	CD (5%)	0.04	0.019	0.02	0.11

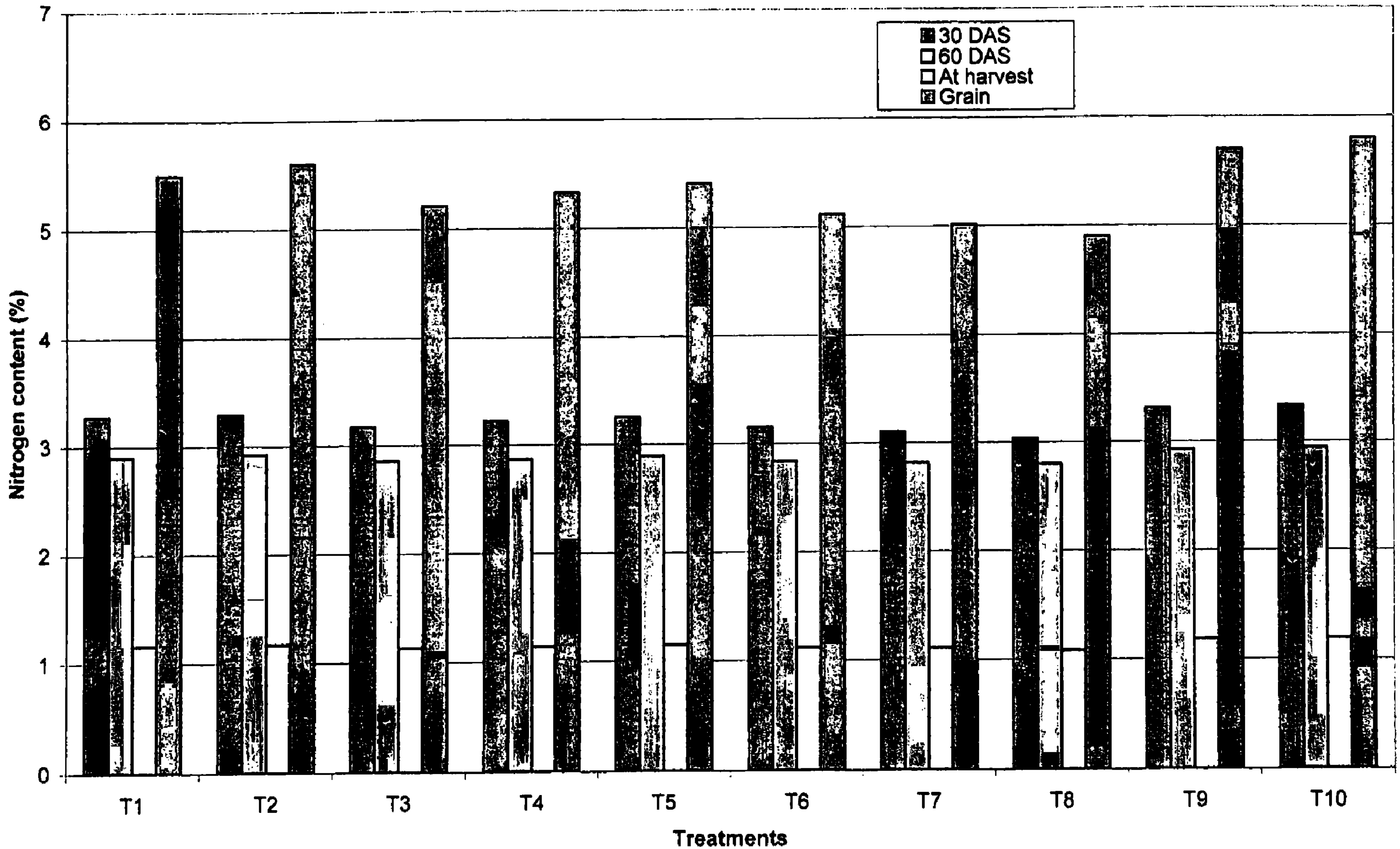


Fig. 4.6.1 Nitrogen content (%) in plant and Grain as affected by various treatments

4.6.2 Phosphorous content (%)in plant and Grain

The data of with respect phosphorous content (%) at 30 DAS are presented in table 4.6.2. The data revealed that the treatment T_9 showed higher phosphorous content (0.34 %) in soybean plant followed by T_{10} (0.33%) and T_2 (0.32 %).

The data of with respect phosphorous content (%) at 60 DAS are presented in table 4.6.2. The data revealed that the treatment T_9 showed higher phosphorous content (0.30 %) in soybean plant followed by T_{10} (0.29 %) and T_2 (0.28 %).

Phosphorous content in straw was found maximum (0.16 %) due to treatment T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}) and minimum (0.7 %) in treatment T_8 (N_1, P_1, K_1 alone) as presented in table 4.6.2. indicated that the phosphorous content in straw of soybean was reduced as plant progressed to maturity.

The data of phosphorous content (%) in grain was also presented in Table 4.6.2, which showed that all the treatment increased the phosphorous content (%) in grain as compared to T_8. Maximum (0.41 %) phosphorous content in grain was found in T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}) and minimum (0.32 %) in T_8 (N_1, P_1, K_1 alone) also indicate, that the phosphorous content (%) in grain was higher as compared to straw.

Table 4.6.2 Phosphorous content (%) in plant and grain as influenced by various treatments

Treatments	Combinations	Phosphorous content (%)			
		30 DAS	60 DAS	At harvest	Grain
T_1	N_2, P_2, K_2, S, Zn, Mn, B	0.31	0.27	0.13	0.38
T_2	N_2, P_1, K_2, S, Zn, Mn, B	0.32	0.28	0.14	0.39
T_3	N_2, P_2, K_1, S, Zn, Mn, B	0.27	0.24	0.10	0.35
T_4	N_2, P_2, K_2, S, Zn, B	0.28	0.25	0.11	0.36
T_5	N_2, P_2, K_2, S, Zn, Mn,	0.29	0.26	0.12	0.37
T_6	N_2, P_2, K_2, S, Mn, B	0.26	0.23	0.09	0.34
T_7	N_2, P_2, K_2, Zn, Mn, B	0.25	0.22	0.08	0.33
T_8	N_1, P_1, K_1	0.24	0.21	0.07	0.32
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	0.34	0.30	0.16	0.41
T_{10}	N_1, P_1, K_1 + FYM5 t + Biofertilizer 500 g ha^{-1}	0.33	0.29	0.15	0.40
	SEm ±	0.010	0.010	0.008	0.008
	CD (5%)	0.02	0.02	0.02	0.02

4.6.3 Potassium content in plant and Grain

The data of with respect potassium content (%) at 30 DAS are presented in table 4.6.3. The data revealed that the treatment T_9 showed higher potassium content (3.34 %) in soybean plant followed by T_{10} (3.33%) and T_2 (3.32 %).

The data of with respect potassium content (%) at 60 DAS are presented in table 4.6.3. The data revealed that the treatment T_9 showed higher potassium content (2.64 %) in soybean plant followed by T_{10} (2.63 %) and T_2 (2.62 %).

Potassium content in straw was found maximum (1.56 %) due to treatment T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}) and minimum (1.47 %) in treatment T_8

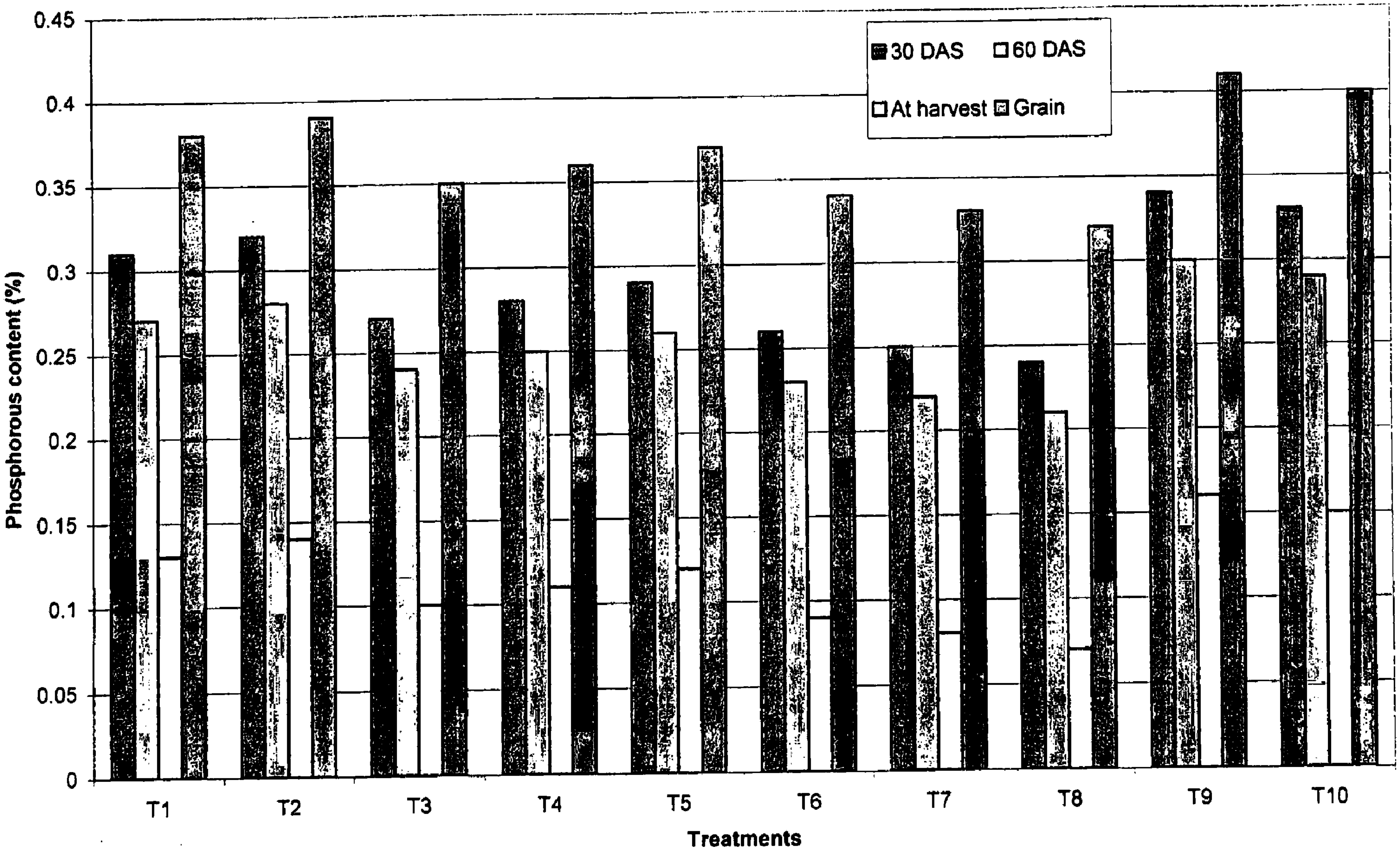


Fig.4.6.2 Phosphorous content (%) in plant and grain as influenced by various treatments

(N_1, P_1, K_1 alone) as presented in table 4.6.3. indicated that the potassium content in straw of soybean was reduced as plant progressed to maturity.

The data of potassium content (%) in grain was also presented in Table 4.6.3, which showed that all the treatment increased the potassium content (%) in grain as compared to T_8. Maximum (2.70 %) potassium content in grain was found in T_9 (N_1, P_1, K_1 + FYM 10 t ha^{-1}) and minimum (2.23 %) in T_8 (N_1, P_1, K_1 alone).

Table 4.6.3 Potassium content (%) in plant and Seed as influenced by various treatments

Treatments	Combinations	Potassium content (%)			
		30 DAS	60 DAS	At harvest	Grain
T_1	N_2, P_2, K_2, S, Zn, Mn, B	3.31	2.61	1.53	2.55
T_2	N_2, P_1, K_2, S, Zn, Mn, B	3.32	2.62	1.54	2.60
T_3	N_2, P_2, K_1, S, Zn, Mn, B	3.28	2.58	1.50	2.40
T_4	N_2, P_2, K_2, S, Zn, B	3.29	2.59	1.51	2.45
T_5	N_2, P_2, K_2, S, Zn, Mn,	3.30	2.60	1.52	2.50
T_6	N_2, P_2, K_2, S, Mn, B	3.27	2.57	1.49	2.35
T_7	N_2, P_2, K_2, Zn, Mn, B	3.26	2.56	1.49	2.30
T_8	N_1, P_1, K_1	3.25	2.55	1.47	2.23
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	3.34	2.64	1.56	2.70
T_{10}	N_1, P_1, K_1 + FYM5 t + Biofertilizer 500 g ha^{-1}.	3.33	2.63	1.55	2.65
	SEm ±	0.010719	0.012105	0.012336	0.035
	CD (5%)	0.021921	0.024754	0.025227	0.072

4.6.4 Sulphur content in plant

The data presented in table 4.6.4 revealed that Sulphur content in straw at 30 DAS was increased by various treatments as compared to T_8 (N_1, P_1, K_1 alone). The maximum (0.180 %) sulphur content in plant was

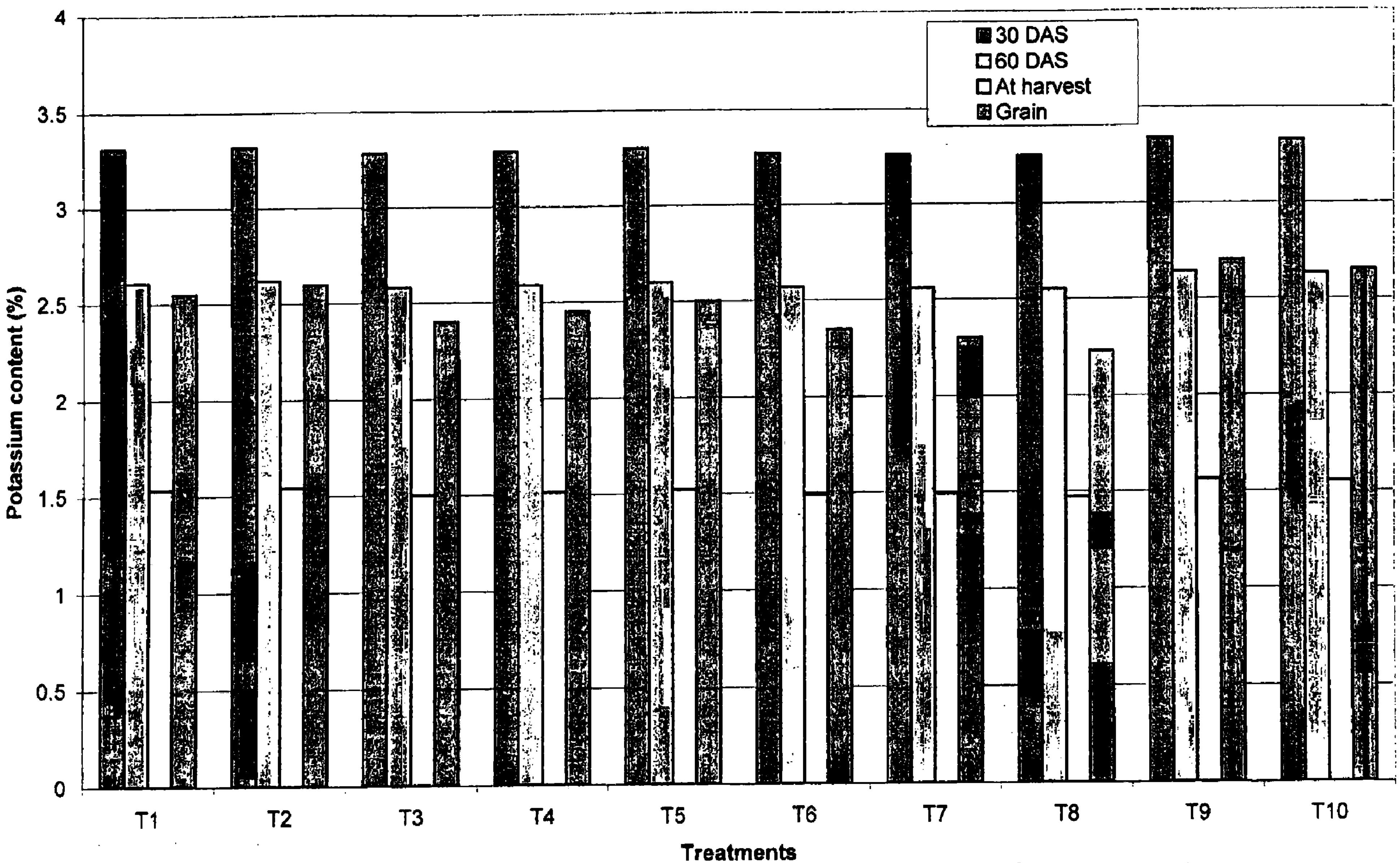


Fig.4.6.3 Potassium content (%) in plant and Seed as influenced by various treatments

recorded in T_9 (N_1, P_1, K_1 + 10t FYM /ha), while minimum (0.153 %) was recorded in T_8.

The data of 60 DAS are presented in Table 4.6.4 revealed that all treatments showed higher sulphur content in soybean straw as compared to T_8. The maximum (0.140 %) Sulphur content in straw was recorded in T_9 (N_1, P_1, K_1 + 10 t FYM /ha) and minimum (0.113 %) in T_8 (N_1, P_1, K_1 alone).

The data on sulphur content at harvesting presented in Table 4.6.4 revealed that the sulphur content (%) in straw was higher in all the treatments as compared to T_8 (N_1, P_1, K_1 alone)

The data in table 4.6.4 also indicated that the older plants contained less sulphur.

Table 4.6.4 Sulphur content (%) in plant as influenced by various treatments

Treatments	Combinations	Sulphur content (%)		
		30 DAS	60 DAS	At harvest
T_1	N_2, P_2, K_2, S, Zn, Mn, B	0.170	0.128	0.110
T_2	N_2, P_1, K_2, S, Zn, Mn, B	0.173	0.133	0.112
T_3	N_2, P_2, K_1, S, Zn, Mn, B	0.163	0.123	0.100
T_4	N_2, P_2, K_2, S, Zn, B	0.165	0.125	0.105
T_5	N_2, P_2, K_2, S, Zn, Mn,	0.168	0.128	0.108
T_6	N_2, P_2, K_2, S, Mn, B	0.160	0.120	0.097
T_7	N_2, P_2, K_2, Zn, Mn, B	0.158	0.118	0.095
T_8	N_1, P_1, K_1	0.153	0.113	0.085
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	0.180	0.140	0.115
T_{10}	N_1, P_1, K_1 + FYM5 t + Biofertilizer 500 g ha^{-1}.	0.178	0.135	0.113
	SEm $\pm$	0.003562	0.003645	0.004053
	CD (5%)	0.007284	0.007454	0.008269

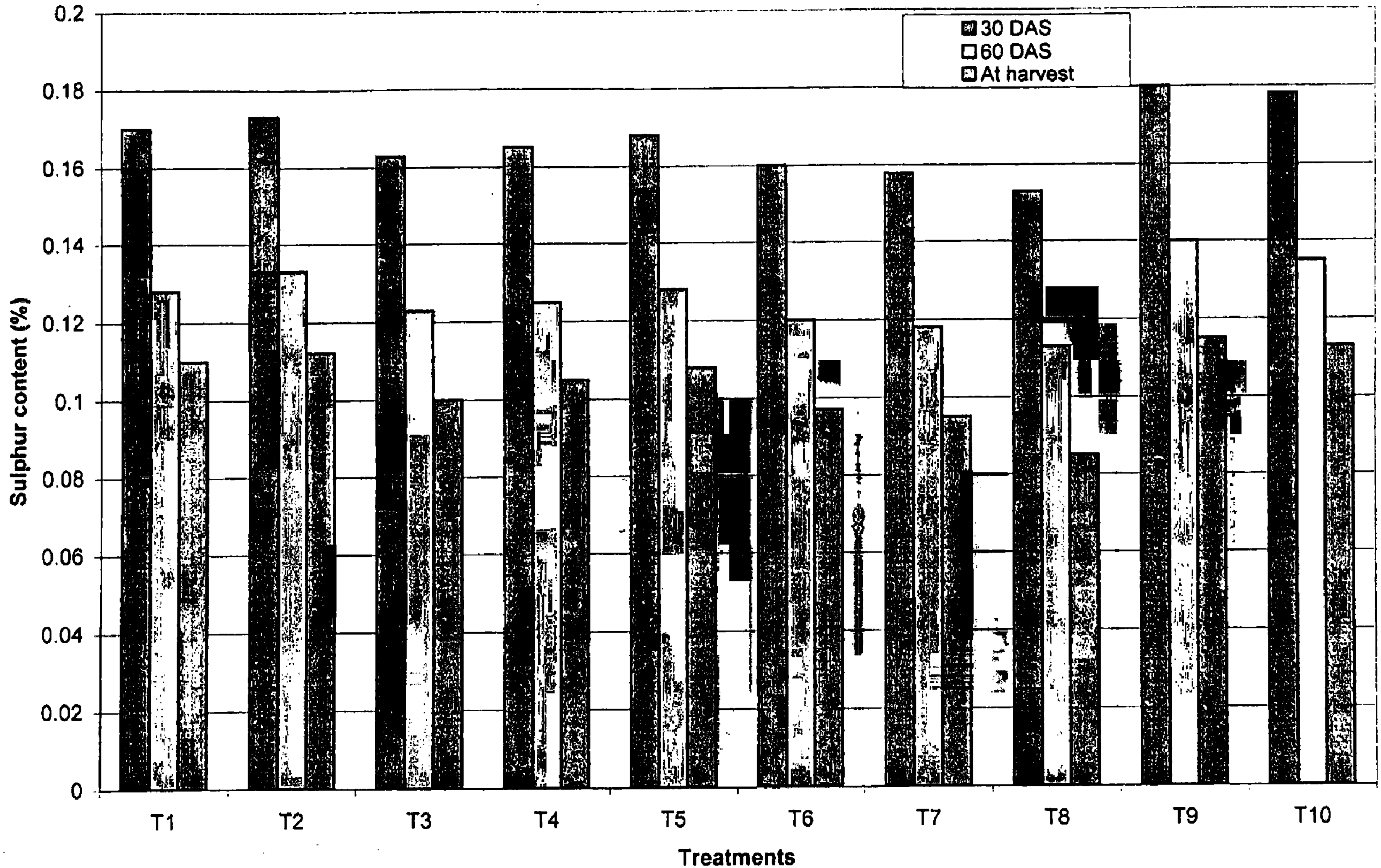


Fig.4.6.4 Sulphur content (%) in plant as influenced by various treatments

4.6.5 Zinc content (mg/kg) in Plant

The data presented in table 4.6.5 revealed that Zinc content in straw at 30 DAS was increased by various treatments as compared to T_8 (N_1, P_1, K_1 alone). The maximum (86.5 mg/kg) Zinc content in straw was recorded in T_9 (N1, P1, K1 + 10t FYM /ha), while minimum (73.0 mg/kg) was recorded in T_8.

The data of 60 DAS are presented in Table 4.6.5 revealed that all treatments showed higher Zinc content in soybean straw as compared to T_8. The maximum (71.5 mg/kg) Zinc content in straw was recorded in T_9 (N_1, P_1, K_1 + 10 t FYM /ha) and minimum (63.5 mg/kg) in T_8 (N_1, P_1, K_1 alone).

The data on Zinc content at harvesting presented in Table 4.6.5 revealed that the Zinc content (mg/kg) in straw was higher in all the treatments as compared to T_8 (N_1, P_1, K_1 alone)

Table 4.6.5 Zinc content (mg/kg) in plant as influenced by various treatments

Treatments	Combinations	Zinc content (mg/kg)		
		30 DAS	60 DAS	At harvest
T_1	N_2, P_2, K_2, S, Zn, Mn, B	83.0	69.8	50.5
T_2	N_2, P_1, K_2, S, Zn, Mn, B	84.8	70.3	51.8
T_3	N_2, P_2, K_1, S, Zn, Mn, B	78.5	66.0	47.3
T_4	N_2, P_2, K_2, S, Zn, B	79.0	67.3	48.0
T_5	N_2, P_2, K_2, S, Zn, Mn,	80.0	68.8	49.8
T_6	N_2, P_2, K_2, S, Mn, B	76.3	65.5	46.5
T_7	N_2, P_2, K_2, Zn, Mn, B	74.8	64.3	45.3
T_8	N_1, P_1, K_1	73.0	63.5	44.5
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	86.5	71.5	52.5
T_{10}	N_1, P_1, K_1 + FYM5 t + Biofertilizer 500 g ha^{-1}.	85.3	70.5	52.0
	SEm $\pm$	1.3222	1.2399	1.123
	CD (5 %)	2.7038	2.5356	2.297

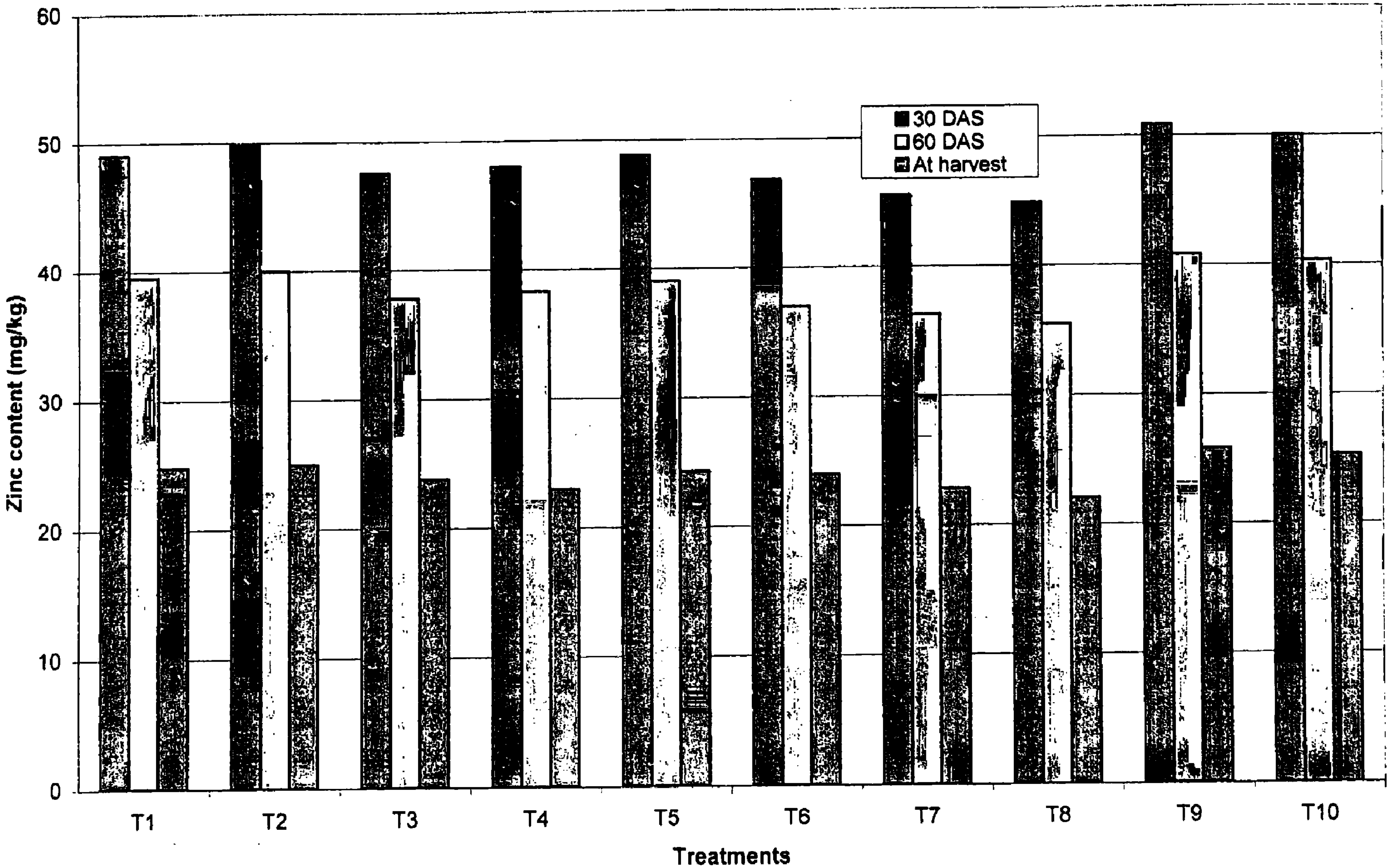


Fig. 4.6.5 Zinc content (mg/kg) in plant as influenced by various treatments

4.6.6 Manganese content in plant

The data presented in table 4.6.6 revealed that manganese content in straw at 30 DAS was increased by various treatments as compared to T_8 (N_1, P_1, K_1 alone). The maximum (50.8 mg/kg) manganese content in straw was recorded in T_9 (N1, P1, K1 + 10t FYM /ha) while minimum (44.8 mg/kg) was recorded in T_8.

The data of 60 DAS are presented in Table 4.6.6 revealed that all treatments showed higher manganese content in soybean straw as compared to T_8. The maximum (40.8 mg/kg) manganese content in straw was recorded in T_9 (N_1, P_1, K_1 + 10 t FYM /ha) and minimum (35.5 mg/kg) in T_8 (N_1, P_1, K_1).

The data on manganese content at harvesting presented in Table 4.6.6 revealed that the manganese content (mg/kg) in straw was higher in all the treatments as compared to T_8 (N_1, P_1, K_1)

Table 4.6.6 Manganese content (mg/kg) in plant as influenced by various treatments

Treatments	Combinations	Manganese content (mg/kg)		
		30 DAS	60 DAS	At harvest
T_1	N_2, P_2, K_2, S, Zn, Mn, B	49.0	39.5	24.8
T_2	N_2, P_1, K_2, S, Zn, Mn, B	49.8	40.0	25.0
T_3	N_2, P_2, K_1, S, Zn, Mn, B	47.5	37.8	23.8
T_4	N_2, P_2, K_2, S, Zn, B	48.0	38.3	23.0
T_5	N_2, P_2, K_2, S, Zn, Mn,	48.8	39.0	24.3
T_6	N_2, P_2, K_2, S, Mn, B	46.8	37.0	24.0
T_7	N_2, P_2, K_2, Zn, Mn, B	45.5	36.3	22.8
T_8	N_1, P_1, K_1	44.8	35.5	22.0
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	50.8	40.8	25.8
T_{10}	N_1, P_1, K_1 + FYM5 t + Biofertilizer 500 g ha^{-1}.	50.0	40.3	25.3
	SEm ±	0.725	0.702	0.435
	CD (5%)	1.487	1.436	0.884

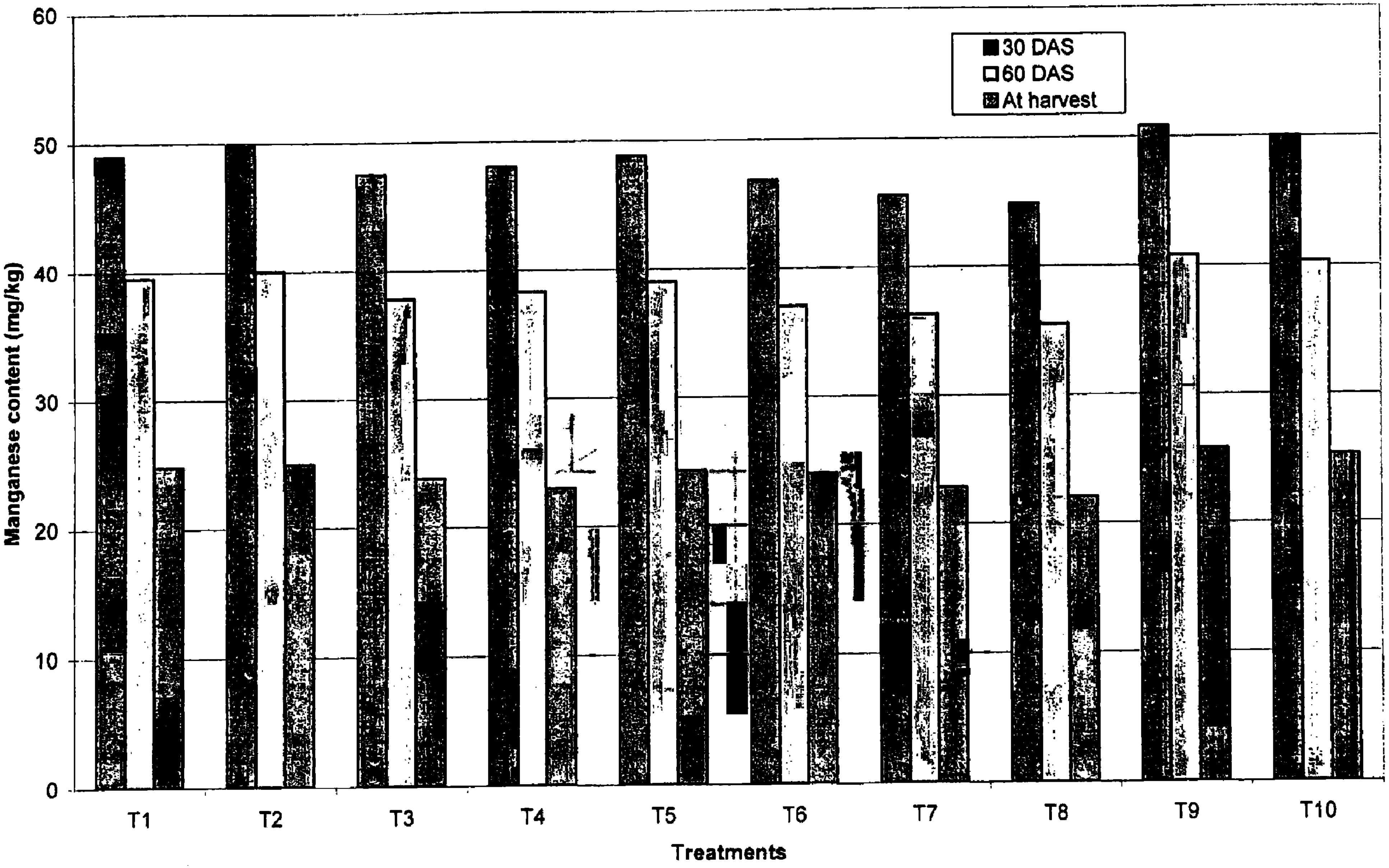


Fig.4.6.6 Manganese content (mg/kg) in plant as influenced by various treatments

4.6.7 Boron content in plant (mg/kg)

The data presented in table 4.6.7 revealed that Boron content in straw at 30 DAS was increased by various treatments as compared to T_8 (N_1, P_1, K_1 alone).The maximum (46.5 mg/kg) Boron content in straw was recorded in T_9 (N1, P1, K1 + 10t FYM /ha) while minimum (40.0 mg/kg) was recorded in T_8.

The data of 60 DAS are presented in Table 4.6.7 revealed that all treatments showed higher Boron content in soybean straw as compared to T_8. The maximum (47.5 mg/kg) Boron content in straw was recorded in T_9 (N_1, P_1, K_1 + 10 t FYM /ha) and minimum (32.0 mg/kg) in T_8 (N_1, P_1, K_1).

The data on Boron content at harvesting presented in Table 4.6.7 revealed that the Boron content (mg/kg) in straw was higher in all the treatments as compared to T_8 (N_1, P_1, K_1)

Table 4.6.7 Boron content (mg/kg) in plant as influenced by various treatments

Treatments	Combinations	Boron content (mg/kg)		
		30 DAS	60 DAS	At harvest
T_1	N_2, P_2, K_2, S, Zn, Mn, B	45.0	35.8	21.8
T_2	N_2, P_1, K_2, S, Zn, Mn, B	45.8	36.3	22.0
T_3	N_2, P_2, K_1, S, Zn, Mn, B	43.8	33.8	19.8
T_4	N_2, P_2, K_2, S, Zn, B	44.5	35.0	21.8
T_5	N_2, P_2, K_2, S, Zn, Mn,	43.0	34.3	19.0
T_6	N_2, P_2, K_2, S, Mn, B	44.0	34.5	20.8
T_7	N_2, P_2, K_2, Zn, Mn, B	42.0	33.0	18.5
T_8	N_1, P_1, K_1	22.0	32.0	18.0
T_9	N_1, P_1, K_1 + FYM 10 t ha^{-1}	46.5	37.5	23.8
T_{10}	N_1, P_1, K_1 + FYM5 t + Biofertilizer 500 g ha^{-1}.	46.0	37.0	23.0
	SEm ±	.822	0.616	0.702
	CD (5%)	1.68	1.26	1.43

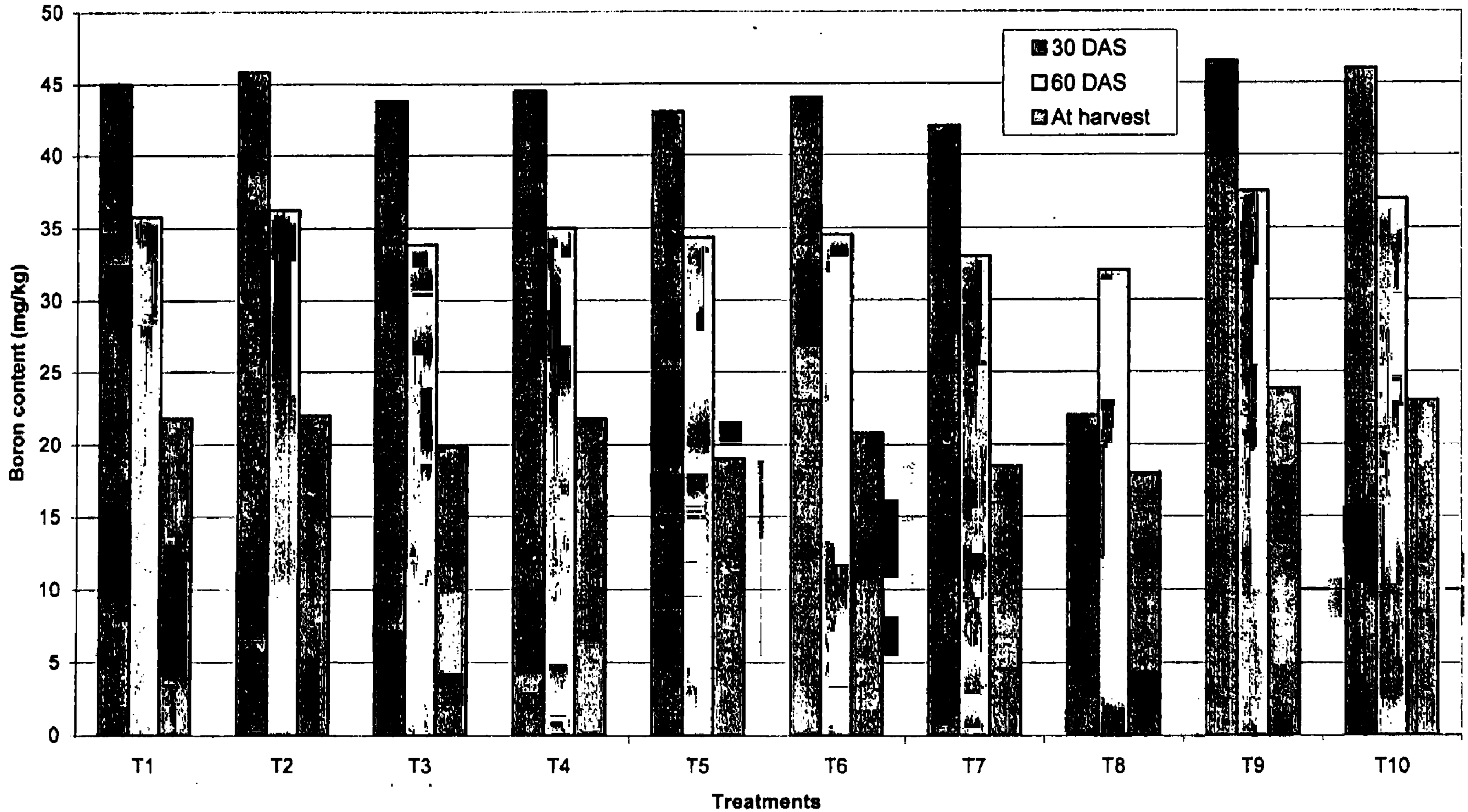


Fig. 4.6.7 Boron content (mg/kg) in plant as influenced by various treatments

CHAPTER – 5

DISCUSSION

In the preceding chapter, experimental findings were presented, which provided the detailed of the influence of various nutrient management treatments in soybean crop. In the present chapter, an attempt has been made to discuss the salient findings of the experiment (Summary Table 1, 2 and Table 4.2.2) and to offer explanation and experimental evidences for the observed variations in respect of the "Cause and effect" relationship as far as possible in the light of scientific reasoning and available evidences.

5.1 Pre-harvest studies

It is a well-known fact that the plant, by itself considered as a whole, reflects upon the grain yield obtained from it. The parameters that are used to represent the growth of the plant are directly concerned with the increase in the vegetative parts viz., plant height and number of branches per plant etc. Therefore, it was important to study the influence of various treatments on these characters and as to how these characters have influenced the economic yield.

5.1.1 Plant population

The different nutrient management treatments did not deviate the plant population (20 DAS and before harvest), significantly. This indicates that the uniform plant population was maintained in each treatment. Uniform plant population is the foremost prerequisite for testing the genuine difference between the treatments. The uniformity in crop stand also indicates that there was no adverse effect of full-recommended dose of chemical fertilizers on the germination and emergence of the soybean crop. The present findings are in close conformity with the findings of Thakur and Mandloi (1990), Balusamy et al. (1996) and Jat (2004).

5.1.2 Plant height

The periodical observations recorded on plant height showed that this growth parameter was increased with the advancement of plant growth till maturity stage. The most specific feature was that the rate of increase in plant height was highest (multi-fold) between 30 and 60 DAS in almost all the treatments, which may be due to active growth period of plants. The growth rate slowed down in magnitude beyond 60 DAS as the plant entered from the active vegetative phase to the reproductive phase.

The influence of different nutrient management treatments was up to the significant level. The maximum plant height was recorded, up to maturity stage, in case of T_9 ($N_1P_1K_1$ + 10 t FYM/ha), which was significantly higher to T_7 and T_8 treatments having incomplete plant nutrients i.e. no FYM and Sulphur. The second best treatment was T_2 having NPK with S, Zn, B and Mn. The treatments like T_4 having no Mn and also T_5 having no boron tended to decrease this parameter. Application of NPK alone (T_8) i.e. incomplete nutrition resulted in the lowest plant height.

These findings on plant height are in close agreement with those of Thakur and Mandloi (1990), Prasad et al. (1991), Agrawal et al. (1996), Khamparia (1996), Achakzai et al. (2002), Yadav (2003) and Jat (2004).

5.1.3 Number of branches per plant

The average numbers of branches per plant were increased up to maximum in T_1 applied with $N_2P_2K_2S$ + Zn, B, Mn, which were significantly superior over all other nutrient management treatments except T_9 ($N_1P_1K_1$ + 10 t FYM/ha). This highlights the fact FYM up to 10 t/ha supplemented all those nutrients, which were available from T_1 treatment having S, Zn, Mn in addition to NPK. However, the half dose of FYM (5t/ha) couldn't meet the nutritional requirement equivalent to that of treatment T_1. FYM up to 10 t/ha has definitely improved the Physico-chemical properties of the soil and enhanced the supply of multi-nutrients essential for better plant growth and development. The treatment having NPK only brought about the lowest number of branches/plant. The beneficial role of secondary and micronutrients along with NPK on the formation of branches has been reported by Prasad et al. (1991), Achakzai et al. (2002) and Jat (2004).

5.1.4 Root nodulation

The root nodules of soybean plant as a result of effective rhizobial population are responsible for the biological nitrogen fixation in the soil. The number of root nodules may differ due to different nutritional management and other agronomic conditions. The present results indicate that the number of root nodules was influenced significantly under different nutrient management conditions. The maximum root nodules/plant were observed in treatment T_{10} having seed inoculated with Rhizobium bacteria in addition to $N_1P_1K_1$ + 5 t FYM/ha. This treatment (T_{10}) was found significantly superior to most of the other treatments except T_1, T_2 and T_9 having almost all the essential plant nutrients. It is a well-known fact that S and Zn enhance the production and multiplication of root nodules. It may also due to favorable pH for growth of Rhizobium bacteria. FYM provided food for the bacteria. Application of NPK alone (T_8) resulted in the lowest root nodulation. The treatments deficient in Mn (T_4) and in S (T_7) also recorded the lower root nodulation. The results on dry weight of root nodules per plant followed the same trend because nodules dry weight is more or less directly related with the nodules number

The present findings reveal that Sulphur, zinc, boron and manganese and FYM with NPK increased the number of root nodules. Similar findings were also reported by Sarkar and Aery (1990), Thakur and Mandloi (1990), Sharma (1992), Khamparia (1996), Agrawal et al. (1996), Amara (1999), Chorey et al. (2001) and Jat (2004).

5.2 Post-harvest studies

The post harvest observations are recorded to find out the effectiveness of various treatments on the yield attributes, which are directly related with the grain yield. Different fertility levels (nutrient combinations) comprising major, secondary and micronutrients with and without FYM were used in the present experiment to evaluate the best nutrient combination.

The perusals of data evidently indicate that all the nutrient combinations (treatments) brought about remarkable improvement in the yield attributing characters viz., pods per plant, and seeds per plant and seed index.

5.2.1 Number of pods per plant

The pods per plant directly affect the number of seeds per plant and ultimately the final grain yield per hectare. The data indicated that T_9 ($N_1P_1K_1$ + 10 t FYM/ha) recorded the maximum number of pods per plant, closely followed by T_{10} ($N_1P_1K_1$ +5 t FYM/ha + Rhizobium) and T_2 ($N_2P_1K_2$ S_6 + Zn, B, Mn). These three treatments proved significantly superior to those treatments having incomplete plant nutrients (T_4 to T_8) for plant growth. Application of NPK only (T_8) produced the lowest number of pods per plant. The quantity of nutrients applied also influenced this parameter. In T_1 and T_3 treatments, the pod number was relatively less than that of T_2, which may be due to lower P dose in T_1, and lower K dose in T_3 over the T_2 treatment. These findings indicate that the balanced nutrient combinations increased the pod number per plant as compared to those of incomplete (imbalanced) nutrient combinations. In T_1 and T_5treatments, the number was relatively less (21.3 to 20.2) than in case of T_2. These findings are in agreement with those of Khamparia (1996), Mandal and Sikdar (1999), Mandal et al. (2000), Gurkripal et al. (2001), Yadav (2003) and Jat (2004).

5.2.2 Number of seeds per plant

The number of seeds per plant reflects the seed yield of soybean directly. The data evidently indicate that the various nutrient management treatments registered almost significantly higher number of seeds/plant over T_8 (NPK only). Application of $N_1P_1K_1$ with 10 t FYM/ha (T_9) resulted in the highest number of seeds/plant closely followed by T_{10} ($N_1P_1K_1$ + 5 t FYM/ha + Rhizobium). The treatments comprising micronutrients with NPK and Sulphur (T_1 and T_2) also produced the higher number of seeds/pod. These results indicate that NPK with secondary and micronutrients as well as with FYM had positive effect in the increased translocation of photosynthates from the vegetative parts to the reproductive organs of plants. This might have also resulted in the increased protein and oil contents resulted in the increased seed number per plant. Similar results have been reported by Jat

(2004). However, the results trends were different in case of seed number per pod.

5.2.3 Seed index

Seed index (100-seed weight) directly reflects the magnitude of grain yield of soybean. The data revealed that the seed index was significantly higher in all the treatments (except T_7) having secondary and micronutrients and FYM along with NPK as compared to the treatment having only NPK (T_8). The maximum seed index was recorded in T_9 having $N_1P_1K_1$ with 10 t FYM/ha, closely followed by T_{10} having $N_1P_1K_1$ + 5 t FYM + Rhizobium. The third best treatment was T_2 having $N_2P_1K_2S$, + B, Mn, Zn. The study of data have clearly indicated that Sulphur, zinc, boron and manganese either available to the plants from organic or inorganic sources registered higher seed index (bolder grains), because these nutrients improved the size of grain by improving transportation of manufactured food from source (vegetative parts) to the sink (reproductive organs) in plant and by increasing oil and protein content in seed. The result trend was almost the same in case of seed yield per plant. Similar findings were reported by Gurkripal et al. (2001), Singh et al. (2002), Yadav (2003) and Jat (2004).

5.2.4 Productivity (biological yield) per hectare

The grain yield of soybean depends upon the basic yield components i.e. plant population and yield per plant, depending upon the growth of the plant and the resultant grain productivity contributed by the number of pods per plant, grains per pod and seed index (100-seed weight). The results data exhibited that the grain and straw yield differed significantly by the different nutrient management treatments. The maximum grain yield (2367 kg/ha) was obtained under the influence of T_9 ($N_1P_1K_1$ + 10 t FYM/ha), which was significantly superior to all other treatments. The minimum grain yield (1774 kg/ha) was recorded in T_8 ($N_1P_1K_1$ only). The straw yield also showed the similar trend. The maximum (3030 kg/ha) and minimum (2059.2 kg/ha) straw yield was recorded in T_9 and T_8 treatments, respectively. Among the secondary nutrients, Sulphur and among the micronutrients, zinc, boron and manganese, and among the organic manures, FYM (the store-house of plant nutrients) brought about their unique functions in the better growth and development of plant, thereby increasing the productivity level of soybean by affecting positively in the entire yield-attributes. Thus, photosynthetic efficiency as well as physiological efficiencies of different nutrients increased with integrated nutrient management (NPK + FYM) in soybean. Similar kinds of findings were also observed by Agrawal et al. (1996), Kadamdhad et al. (1996), Raghuwanshi et al. (1997), Rao et al. (1998), Khare and Sharma (1998), Dwivedi et al. (1999), Mandal and Sikdar (1999), Sharma et al. (2000), Tomar et al. (2000), Shrivastava et al. (2000), Shelge et al. (2001), Thakur et al. (2001), Dikshit and Khatik et al. (2002), Singh et al. (2002), Yadav (2003) and Jat (2004).

5.2.5 Harvest index

The harvest index is the ratio of economic (grain) yield over the biological yield (grain plus straw), which is expressed in percentage. The study of data indicates that all the treatments registered higher harvest index as compared to T_8 ($N_1P_1K_1$ only) and the differences in harvest index among the various treatments were not significant. The maximum (46.3%) and minimum (43.2%) harvest index was recorded in T_8 ($N_1P_1K_1$) and in T_4 (N_2, P_2, K_2, S, Mn, and B) respectively. The next better treatments were T_5 and T_7, which recorded the harvest index up to the same range (44.9 to 45.4%). The other treatments possessed the intermediate values. It is evident from the data that Sulphur, zinc, boron, manganese and FYM along with NPK showed their beneficial influence upon this physiological parameter. Similar findings have been reported by Agrawal *et al.* (1996), Khamparia (1996) and Jat (2004).

5.2.6 Nutrient content in Plant

The data indicated that N content was increased in treatment T_{10} ($N_1P_1K_1$ + 5 t FYM/ha + Rhizobium), while minimum recorded in treatment T_8 ($N_1P_1K_1$ only). While P and K was recorded highest in treatment T_9 and lowest was recorded in T_8. The results were in agreement with results of Kacha *et al* (1990), Sharma and Gupta (1992), Sharma and Mishra (1997).

Study of data revealed Sulphur content was increased by application of Sulphur. Maximum Sulphur content was recorded in T $_9$, whereas minimum was recorded in T_8. Similar results were reported by Sharma and Gupta (1992), Sharma and Mishra (1997), Dillon and Dev (1998) and Dwivedi *et al* (1998). The study of data on Zinc content was increased by application of Zinc sulphate with. Maximum Zinc content was found in T $_9$, while minimum was recorded in T_8. Similar results were found by Khamparia and Tomar (1999) and Bisht and Chandel (1996).

The data also indicated that Mn content in plant was increased in T_9 and minimum was recorded in T_8. This may due to application of FYM because it has the entire essential nutrient. Similar results found in case of B content in plant. The maximum B content was recorded in T_9, whereas minimum was recorded in T_8. Such results were also found for Mn by Gettier *et al* (1985) and for B content in groundnut crop Kumar *et al* (1996).

5.2.7 Economics of the treatments

The study of data indicated that all the treatments gave higher gross and net return per hectare as compared to T_7 (N_2, P_2, K_2, Zn, Mn, B). The differences may be ascribed to the variation in yield levels and the expenditure incurred in the respective treatment. As for the yield is concerned, it was found maximum in T_{10} (N_1, P_1, K_1 + 5 t FYM + Biofertilizer 500 g /ha.) treatment, therefore the net return in this treatment was found highest. This was followed by T_9 (N_1, P_1, K_1 + 10 t FYM / ha.). The benefit: cost ratio of treatments T_{10} was highest (2.18) as compared to other treatments while T_7 having lowest (1.77). Similar findings were observed by Singh and Singh (1995), Bobde et al. (1998) and Jat (2004). Keeping the benefit: cost ratio into consideration, it may be advised to use 5 t FYM/ha + Rhizobium along with recommended NPK level to achieve maximum profit per unit area from soybean variety JS-335.

5.3 Soil fertility status

The summarized picture of the soil analysis results is presented in Table 4.5.2. The available nitrogen increased in all the treatments in the post-harvest soil as compared to the initial status. This may be due to insufficient utilization of applied nitrogen as well as biologically fixed nitrogen in root-nodules for pulse crop growth. It is a well-known phenomenon that quite a good amount of applied phosphorus, even up to one third, is fixed in the soil colloidal particles which is not available to the plants. Thus, only about 1/3 of applied phosphorus might have taken up by the plants and the remaining 2/3 was added in the reserve pool of soil phosphorus. In case of enhanced potassium in post-harvest soil, it may be said that some of the applied potassium remained in balance after crop absorption, because the soil reserve of potassium was already in the medium range and secondly, there was also no losses of potassium from the soil like nitrogen. The gain in available P and K in soil after harvest of soybean has also been reported by Ramesh and Reddy (2004) and in case of available NPKS by Dikshit and Khatik, (2002) and Jat (2004).

The unchanged status of Sulphur in post-harvest soil in all the treatments may be due to its addition in the smaller amount (6 kg/ha) through soil application. After crop growth and uptake of Sulphur by the crop there is no chance remains for its residual balance in the soil. In case of applied micronutrients (Zn, Mn and B), there was no any enhanced residual balance in all the treatments. This may be due to the fact that these micronutrients were applied in traces (2 to 5%) through plant foliage, and not through the soil. The crop had utilized these foliar-sprayed micronutrients for their growth and development and therefore no any chance left for their increased residual balance in the post-harvest soil. Whatever micronutrients available from FYM in T_9 and T_{10} were taken up by the vigorously growing plants hence, no addition in residual balance in the soil.

CHAPTER – 6

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

A field experiment was conducted during the Kharif season of 2005 at Student Research Farm (Field No.4), College of Agriculture, Indore (M.P.) on "Study of Nutrient management of productivity of soybean" The experiment consisted of 10 nutrient management treatments, replicated four times in a randomized block design. The soybean variety JS-335 was grown as per approved technical programme and recommended package of practices. The periodical observations were recorded, data tabulated and statistically computed. The salient findings as elucidate in the previous chapter are being summarized as below:

6.1 Summary

A. Growth parameters

1. In case of plant population, the differences due to different nutrient combinations were not significant.
2. Plant height (cm) at 30 and 60 DAS and at harvest was significantly higher in treatment (T_9) $N_1P_1K_1$ + FYM 10 t ha^{-1} and lower in treatment (T_8).$N_1P_1K_1$ alone. Plant height was found significant at all the growth stages up to harvest stage.
3. The maximum number of branches per plant was recorded under $N_1P_1K_1$ + FYM 10 t ha^{-1} (T_9) treatment and it were superior to others. The minimum branches were recorded under $N_1P_1K_1$ alone (T_8).
4. The number of root nodules at 40 DAS was statistically significant. Maximum number of root nodules per plant were recorded under $N_1P_1K_1$ + 5 t FYM + Rhizobium treated treatment (T_{10}) and minimum in $N_1P_1K_1$ alone treatment (T_8).

B Yield-attributing characters

1. The treatments T_9, T_{10}, T_2 and T_1 produced significantly more number of pods per plant as compared to $N_1P_1K_1$ alone (T_8). The application of $N_1P_1K_1$ + FYM 10 t ha^{-1} with the NPK fertility level produced higher number of pods per plant.

2. Seeds per pod was statistically non significant in all the treatments. Maximum seeds per pod were recorded in $N_1P_1K_1$ + FYM 10 t ha^{-1} (T_9) treatment and minimum in $N_1P_1K_1$ alone (T_8) treatment.

3. The maximum seed index (100-seed weight) was recorded under $N_1P_1K_1$ + FYM 10 t ha^{-1} (T_9) treatment that was significantly superior as compared to $N_1P_1K_1$ alone (T_8).

4. The highest seed yield per plant was obtained under the same T_9 treatment, equally followed by T_{10}, T_2 and T_1treatments. The minimum seed yield was recorded in $N_1P_1K_1$ alone (T_8) treatment. It was observed that there was significant difference in seed yield per plant due to application of various treatments.

5. All the treatments significantly increased the seed yield per hectare of soybean as compared to $N_1P_1K_1$ alone (T_8). Maximum yield was recorded under $N_1P_1K_1$ + 10 t FYM/ha (T_9) treatments and the minimum were recorded in $N_1P_1K_1$ alone (T_8). The application of FYM (10 t/ha) showed a synergic effect in increasing the seed yield of soybean per hectare.

6. All the treatments registered significantly higher straw yield per hectare over $N_1P_1K_1$ alone (T_8) treatment. Straw yield per hectare was maximum with $N_1P_1K_1$ + 10 t FYM/ha (T_9) treatment and minimum in $N_1P_1K_1$ alone (T_8) treatment.

7. The harvest index was maximum in treatment T_8 having $N_1P_1K_1$ and minimum in $N_2P_2K_2$ S, Mn, B alone (T_4) treatment.

8. The maximum net returns as well as and the benefit: cost ratio was obtained from (T_{10}). While minimum net return and benefit ratio T_8 and T_7 respectively.

9. The available N, P_2O_5 and K_2O in post harvest soil were higher in all the treatments as compared to their initial status. Sulphur and B were fluctuated in some soil samples that means these tends to decrease and increase while Mn and Zinc were significantly increased.

10. In after harvest soil pH and EC were decreased and organic matter was increased.

11. Nitrogen content in plant was higher in all the treatment as compared to T_8, whereas P, K, S, Zn, Mn and B were higher in T_9 and minimum were in T_8.

6.2 Conclusions

On the basis of above findings, some conclusions could be drawn, which are as follows:

Application of $N_1P_1K_1$ + FYM 10 t ha^{-1} showed promising effect on growth parameters and yield-attributing characters (i.e. plant height, number of branches per plant, number of root-nodules per plant, pods per plant, seeds per plant, seeds per pod, 100-seed weight and seed yield kg ha^{-1} over $N_1P_1K_1$ alone treatment (T_8) A higher net return was obtained in treatment (T_{10}).

The available N, P, K, Mn, zinc and organic carbon were significantly increased in post harvest soil as compared to their initial status. Sulphur and B were fluctuated in some soil samples that means these tend to decrease and increase. In post harvest soil pH and EC were decreased. Nitrogen content in plant was higher in all the treatment as compared to T_8, whereas P, K, S, Zn, Mn andB were higher in T_9 and minimum were in T_8.

6.3 Suggestions for further work

1. Further research should be conducted in order to supplement the NPK with micronutrients to increase the production.
2. To examine the validity of results the experiment should be repeated in the coming *Kharif* season as these results are based on one-year data.

3. Testing trials of different combinations of various nutrients such as Mo, Mg, Ca and B etc. with Sulphur, zinc and FYM for improving the crop yield economically should be conducted.
4. Micro nutrient mixtures like Zinc, Mn and B could be recommended to the farmers to supplement quantity of micronutrients to soybean crop to get economical yield.

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