Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]

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RAM LAL JAT

Thesis

Doctor of Philosophy

(Agronomy)

2018

DEPARTMENT OF AGRONOMY
RAJASTHAN COLLEGE OF AGRICULTURE
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, UDAIPUR – 313 001 (RAJ.)

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(AGRONOMY)

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RAM LAL JAT

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RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

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Dated: ….. /…../2017

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Dated: …. /…../2017

This is to certify that the thesis entitled **"Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]**"submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Agronomy**, embodies bonafide research work carried out by **Mr. Ram Lal Jat** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on **23/12/2017**

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This is to certify that **Mr. Ram Lal Jat** of the **Department of Agronomy,** Rajasthan College of Agriculture, Udaipur has made all the corrections / modifications in the thesis entitled **"Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]**" which were suggested by the external examiner and the advisory committee in the oral examination held on …/…./2018. The final copies of the thesis duly bound and corrected were submitted on…../…../2018 are enclosed herewith for approval.

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Place: Udaipur

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ACRONYMS AND ABBREVIATIONS

%	:	Per cent	m	:	Meter
A.D.	:	Anno domini	m^2	:	Square metre
ANOVA	:	Analysis of variance	m^3	:	Cubic metre
B-C	:	Benefit cost ratio	Max	:	Maximum
BI	:	Branch Initiation	Meq	:	Milli equivalent
C.D.	:	Critical difference	mg	:	Milligram
CGR	:	Crop Growth Rate	mg m^{-3}	:	Milligram per cubic meter
cm	:	Centimetre	Min	:	Minimum
CO_2	:	Carbon dioxide	ml	:	Millilitre
CU	:	Consumptive Use	mm	:	Millimetre
CV	:	Coefficient of variation	MSS	:	Mean sum of square
Cv.	:	Cultivar	N	:	Nitrogen
d.f.	:	Degree of freedom	NAR	:	Net Assimilation Rate
DAP	:	Di- ammonium phosphate	No.	:	Number
DAS	:	Days after sowing	NS	:	Non-significant
DMA	:	Dry matter accumulation	ºC	:	Degree Celsius
DNA		Dioxin ribose nucleic acid	ºE	:	Degree East
dSm^{-1}	:	Deci simon per meter	ºN	:	Degree North
EC	:	Electrical conductivity	P	:	Phosphorus
et al.	:	(*et alibi*) or elsewhere	P_2O_5	:	Phosphorus pentaoxide
F	:	Flowering	PD	:	Pod development
Fig.	:	Figure	pH	:	Negative log of H ions activity
Fr. Wt.	:	Fresh weight	ppm	:	Part per million
g	:	Gram	q	:	Quintal
GA	:	Gibbrelic Acid	r	:	Correlation coefficient
Ha	:	Hectare	RGR	:	Relative Growth Rate
ha^{-1}	:	Per hectare	RNA	:	Ribose nucleic acid
HI	:	Harvest Index	₹	:	Rupees
Hrs	:	Hours	RWC	:	Relative Water Content
i.e.	:	(id est) that is	S	:	Sulphur
K	:	Potassium	S.Em. ±	:	Standard error of mean
K_2O	:	Potassium oxide	SPD	:	Split plot design
Kg		Kilogram			
KCl	:	Potassium Chloride	t	:	Tones
L	:	Litre	var.	:	Variety
L.	:	Linious	Vs.	:	Versus
LAI	:	Leaf Area Index	*Viz.*;	:	That is
Lit^{-1}	:	Per Liter	WUE	:	Water Use Efficiency
Cu	:	Copper	Fe	:	Iron
Mn	:	Manganese	RP	:	Rock Phosphate
SSP	:	Single super phosphate	Ca	:	Calcium
Mg	:	Magnesium	BR	:	Brassinosteroirds
IAA	:	Indole Acetic Acid	HBR	:	Homobrassinolide

Nacl	:	Sodium Cloride	DAT	:	Date after transplanting
@	:	At the rate	mgl^{-1}	:	Milligram per litre
$g\ g^{-1}$	:	Gram per gram	B	:	Boron
Zn	:	Zinc	uM	:	Micromole
RDF	:	Recommended dose of fertilizers			
PSB	:	Phosphorus solubilizing bacteria			
RDP	:	Recommended dose of phosphorus			
VAM	:	Vesicullar Arbusculer Micorhizea			
DAM	:	Days after maturity			

1. INTRODUCTION

Contrary to great stride in cereals and millets production during last few decades, desired rise in production of oil seeds is yet to be achieved, although India has 19 and 9 per cent of global acreage and production, respectively. The oilseed production in India lags behind the domestic demand and we are regularly importing edible oil**.** To bring the nation self sufficient at oilseed front, the only option is to enhance the productivity, since increase in acreage under oilseeds has limited or no scope in the country. On other hand, shrinking soil fertility during post green revolution era is another grave problem in achieving the sustainable crop production. A cafeteria of factors including imbalanced fertilization, over exploitation of soil nutrients due to high intensity cropping using high yielding varieties, socio-economic status of tenants, poor transfer of technology, indiscriminate resource use and resource degradation etc; are working behind this scenario. Legume oilseeds supplement the sustainable agriculture by improving physical, chemical and biological soil properties on account of providing quickly mineralizing residues, nitrogen fixation, deep and proliferated root system etc.

Soybeans [*Glycine max* (L). Merr.] is an ancient leguminous crop originated from China and have many industrial uses and importance for human use. It has also been termed as miracle bean because it contain about 40 per cent protein well balanced in essential amino acids, 20 per cent oil rich in poly unsaturated fatty acids, specially omega 6 and omega 3 fatty acids, 6-7 per cent total minerals, 5-6 per cent crude fibre and 17-19 per cent carbohydrates. Beside it has good amount of iron, vitamin B-complex and isoflavones such as diadzein, genisten and glycitn (Chouhan and Joshi, 2005). It has also been used for preparation of soya milk, antibiotics, cattle and poultry feed and improves soil fertility.

Among the oil seeds, soybean is one of the important crop in India. About 70% of the world`s soybean is produced in USA and China being the second largest producer. In terms of production, consumption and trade, soybean is the world most important grain legume. In India, soybean is the third largest oilseed crop (area: 10.18 M ha and production: 12.28 M tons) after rapeseed-mustard and groundnut. In Rajasthan, soybean is cultivated on an area of 0.9 M ha with production of 1.39 M tonne (Directorate of Economics and Statistics, 2012). Soybean productivity in India (1064 kg ha^{-1}) is much lower against the global productivity (2374 kg ha^{-1}), thus revealing greater chances of productivity enhancement in the country (FAO 2012). Among various agronomical, physiological and genetic constraints behind the lower soybean productivity; inadequate and imbalanced fertilization, flower drop, poor dry matter partitioning etc. occupy important place. A little part of applied and inherent soil phosphorus is utilized by crop plants in different soil groups, agro-climatic zones and under varying agronomic situations (Kanwar, 1976). Inability of native phosphorus to cope up with the soybean crop demand declines productivity on account of phosphorus deficiency symptoms, reduction in leaf area for photosynthesis activity (Morison and Baten, 1986), decreased pods plant^{-1} (Lauer and Belvins, 1989), severe restrictions in the nodulation (Israel, 1987). Phosphorus application enhances root growth, nitrogen fixation, yield contributing characters and higher yield of soybean (Meena, 2005).

Phosphorus is one of the limiting plant nutrients that affects soybean productivity (Wadokar *et al.,* 1996) on account of its direct role in maintaining energy balance, being a constituent of genetic material, its involvement in plant biochemical processes, nitrogen metabolism, enzymatic functions, root growth, translocation of carbohydrate, fatty acid, glyceroids and other essential intermediate compounds (Tisdale *et al.,*1995). Adequate phosphorus supplies also improve oil content of soybean (Vara *et al*., 1994). Effective phosphorus nutrition depends on a variety of factors mainly the soil reaction, soil organic matter, C: N: P ratio of soil, composition and solubility of phosphoric fertilizers, method of application etc. Soybean with an extensive root system explores a large volume of soil and responds well to applied fertilizer phosphorus (from various sources) due to its high phosphorus demand for optimum productivity. Indian soils are beset with inadequate phosphorus supply i.e. low to medium in 98% cases (Ghos and Hassan, 1979). The situation is further aggravated by invariable precipitation of phosphorus under both acidic and alkali pH as well as on account of considerable microbial immobilization. These situations are hatching both low phosphoric fertilizer use efficiency (more use of fertilizer) and contributing to phosphatic fertilizer import.

Sulphur fertilization in legumes and oilseeds is of prime importance in exploiting genetic potential of these crops. It is fourth major plant nutrient among the seventeen essential element needed for normal growth and development of the plants. Continuous use of sulphur free fertilizers, intensification of agriculture with high yielding varieties and use of scarce amount of organics have resulted in sulphur deficiency all over the country. In Rajasthan, Jaipur, Jodhpur and Udaipur districts have been identified as having deficiency of sulphur (Tondon, 1991). Sulphur is essential for chlorophyll formation and plays an important role in the formation of sulphur containing essential amino acids (cysteine, methionine and cystine), biosynthesis of protein and oil, formation of nodulation in legumes and synthesis of several enzyme that regulate the growth in plants. Studies carried out on sulphur nutrition in oilseeds indicated a considerable increase in yield and quality of oilseeds (Chauhan *et al.,* 2002).

The importance of micro-organism in soil nutrients cycling and their role in plant nutrition has been realized for long time. Attempts have been made to identify spcialised group of soil micro-organism that efficiently solubilze phosphorus from less available phosphate rocks (Bhattacharyya and Jain, 2000). These micro-organisms have been reported to execrate organic acid that dissolve phosphate materials and/or chelate cationic partner of the phosphate ion (Sperber, 1958 and Gour, 1990). The *Bacillus megatherium* was found superior over the other bacterial species in releasing available phosphorus in calcareous soils (Yadav and Singh 1991).

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

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

The effect of the application of Banzyladenine indicated that it was antagonistic to moisture stress (Virk *et al*., 1985). Although low concentration of the Banzyladenine ($4x10^{-5}$ M) accelerated the senescence of the carnation flower, higher concentration ($1\text{-}2x10^{-4}$ M) retarded senescence, thus increasing flower longevity (Van Staden and Joughin, 1998).

In light of limited scope for horizontal expansion of oilseeds, vertical expansion is only option left to us to increase the production of soybean through integration of enhanced nutrient use efficiencies by use of bio-fertilizers and inorganic manures as well as activating plant physiology by the use of plant growth regulators so as to alleviate the wide gap between the potential and existing yield levels. In this background, a two years field experiment entitled **"Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]**" was carried out with the following objectives:

1. To assess the effect of different levels of phosphorus in combination with sulphur and PSB on growth, yield and quality of soybean
2. To study the effect of different plant growth regulators on yield and quality of soybean
3. To prepare the balance sheet of nutrients under different options of nutrient management and growth regulators, and
4. To work out economics of different treatments.

2. REVIEW OF LITERATURE

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

2.1 EFFECT OF PHOSPHORUS

2.1.1 Growth characters

At Pantnagar, Bisht and Chandel (1996) concluded in two years experiment that application of 80 kg P_2O_5 ha^{-1}, significantly increased the biomass of soybean at harvest by 44.83 and 70.07 per cent over no phosphorus fertilization (39.7 and 28.4 g $plant^{-1}$, respectively) during both the years. From Udaipur, Jat *et al.* (1996) in two years field trial reported that application of 40 kg P_2O_5 ha^{-1} to soybean significantly increased nodule count $plant^{-1}$ and nodule dry weight $plant^{-1}$ in both the years over control. Similarly, Srivastava *et al.* (1998) at IARI, New Delhi revealed that application of 60 kg P_2O_5 ha^{-1} in pea significantly increased nodule dry weight, CGR, NAR and LAI as compared to no phosphorus and 30 kg P_2O_5 ha^{-1}. In an another study at Hisar, Kumar *et al.* (1999) reported that application of 80 kg P_2O_5 ha^{-1}, significantly increased plant height (51.91cm) and total dry matter (10.71 q ha^{-1}) of soybean at 60 DAS over no phosphorus fertilization. Ramasamy *et al.* (2000) observed that all the growth parameters of soybean were explicitly increased with increasing level of phosphorus. In the entire set of experiments significantly higher plant height, root length and number of branches $plant^{-1}$ were observed at 80 kg P_2O_5 ha^{-1} over control, however, it was at par with 60 kg P_2O_5 ha^{-1}. Ramasamy and Sankaran (2001) at NPRC, TNAU, Vamban conducted a two years experiment and observed that there was an appreciable increase in physiological attributes of soybean with the increasing levels of phosphorus from 0 to 80 kg P_2O_5 ha^{-1}. Phosphorus application at 80 kg ha^{-1} being at par with 60 kg ha^{-1} produced significantly higher dry matter at harvest (3380 and 5900 kg ha^{-1}) and LAI (1.522 and 1.639) over control during both the years. Field experiment conducted at Pantnagar showed that higher dose of phosphorus (90 kg P_2O_5 ha^{-1}) significantly increased the plant growth and root characteristics of soybean *viz.,* number of branches (5.71), number of leaves (30.37), root length (18.75 cm), fresh weight of root (1.80 g) and number of nodules (20.51) $plant^{-1}$ at flowering stage as compared to control and its lower doses 30 & 60 kg P_2O_5 ha^{-1} (Singh *et al.,* 2001). Likewise, phosphorus application at 60 kg P_2O_5 ha^{-1}, significantly influenced number of branches $plant^{-1}$, LAI and root dry weight of groundnut over 20 kg P_2O_5 ha^{-1}. The increment was found to the tune of 9.30, 8.62 and 8.33 per cent over 20 kg P_2O_5 ha^{-1} (Rao and Shaktawat, 2001). Similarly, Sharma *et al.* (2002) at RCA, Udaipur carried out an experiment on soybean and reported that application of 60 kg P_2O_5 ha^{-1} significantly improved plant height, branches $plant^{-1}$, nodules $plant^{-1}$, nodule weight $plant^{-1}$ and dry matter accumulation at harvest over 30 kg P_2O_5 ha^{-1}. Further increase in phosphorus level did not show any significant increase in these parameters. Dadhich, 2004 in a field experiment observed that the application of 40 kg P_2O_5 ha^{-1} significantly increased the number of nodule $plant^{-1}$ and nodule weight $plant^{-1}$ of soybean over contol, 20 kg P_2O_5 ha^{-1} and 30 kg P_2O_5 ha^{-1}.

Results of field experiment conducted at IARI, New Delhi revealed that the growth parameters *viz.*, LAI, NAR and total dry matter accumulation of groundnut were favoured by the application of phosphorus upto 40 kg P_2O_5 ha^{-1}. The LAI was increased upto 28.94, 33.55 and 23.80 per cent at 30, 60 and 90 DAS, respectively as compared to control through this treatment (Maity *et al.*, 2003). Tomar *et al*. (2004) conducted a field experiment during 1999 *Kharif* season in Madhya Pradesh found that all the treatments of phosphorus increased plant height, leaf area index, number of root nodules $plant^{-1}$, main root length, dry matter accumulation of soybean. Meena *et al.* (2006) at IARI, New Delhi reported that on pooled basis 60 kg P_2O_5 ha^{-1} significantly increased dry matter accumulation of chickpea at harvest over 30 kg P_2O_5 ha^{-1} and control. At Akola, Chavan *et al*. (2008) observed that increasing levels of phosphorus up to 75 kg P_2O_5 ha^{-1} significantly improved the plant height, number of branches $plant^{-1}$, leaf area index and dry matter accumulation in soybean crop over lower levels of phosphorus. Imade *et al*. (2010) investigated that the application of 100 Kg P_2O_5 ha^{-1} recorded highest plant height (at harvest) and dry matter accumulation of soybean.

Nawange *et al*. (2011) conducted a field experiment during *Rabi* season 2009-10 to find out the optimum dose of P and S on growth, yield attributes and yield of chickpea. They observed that the application of P_2O_5 up to 60 kg ha^{-1} indicated linear increase in the growth parameter *viz.* plant height, dry matter accumulation and stalk yield of chickpea over its preceeding doses. Munda *et al*. (2013) reported that the application of 32.25 kg P ha^{-1} through RP significantly improved the growth parameter *viz.* LAI, dry matter accumulation, pod $plant^{-1}$, grain $pods^{-1}$ and seed index of soybean. A field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh recorded that application of 50 kg P_2O_5 significantly increased the plant height, number of primary branch $plant^{-1}$ and number of leaves $plant^{-1}$ over other lower levels (Akter *et al.* 2013). Higher doses of P application (P90) invariably improved all the growth parameter of soybean (plant height, number of leaves, number of nodules $plant^{-1}$ and weight of fresh nodules) relative to its lowest dose (P30 and 60P) (Bhattacharjee *et al*., 2013).

2.1.2. Yield attributes and yield

Jat and Nepalia (1995) reported that response of soybean to phosphorus in terms of yield attributes and yield was significant upto 60 kg P_2O_5 ha^{-1}. Further increase in phosphorus did not influence these characters and yield. The increase in pods $plant^{-1}$, grains pod^{-1}, test weight and seed and stover yield was 13.85, 6.56, 20.27 and 31.36 & 27.42 per cent, respectively over control. Tuteja *et al.* (1995) noticed that application of 60 kg P_2O_5 ha^{-1} significantly increased number of pods $plant^{-1}$, seeds pod^{-1} and test weight of soybean. In comparison to grain yield of 14.0 q ha^{-1} under control, application of 60 kg P_2O_5 ha^{-1}, increased it up to 20.7 per cent. Agrawal *et al.* (1996) noticed a significant increase in seed index of soybean at 60 kg P_2O_5 ha^{-1} over control, whereas grain weight $plant^{-1}$, harvest index and seed yield of soybean increased significantly at 80 kg P_2O_5 ha^{-1}. Bisht and Chandel (1996) conducted a two years experiment and observed that application of 80 kg P_2O_5 ha^{-1} to soybean registered significantly higher number of pods $plant^{-1}$ (103.5 & 91.9) and test weight (17.6 & 12.9 g) as compared to no fertilization (74.2 & 67.4 and 12.6 & 10.9 g, respectively) during both years of experimentation. Due to the increase in yield attributes, the seed yield was also increased by 34.54 & 12.23 per cent over control (22.0 & 18.8 q ha^{-1}, respectively) with the same dose of phosphorus during both the years. Similarly, the seed yield of soybean was significantly influenced over control when crop was fertilized with phosphorus at 60 kg P_2O_5 ha^{-1}. The increase in grain yield was found 20.52 per cent over control (19.0 q ha^{-1}) (Sarkar and Tripathi, 1996). Nimje and Potkile (1998) at Nagpur reported that seed yield of soybean was significantly increased from 9.8 per cent to 36.2 per cent over control with the application of 25 to 125 kg P_2O_5 ha^{-1}, respectively. Likewise, Srivastava *et al.* (1998) revealed that application of 60 kg P_2O_5 ha^{-1} in pea significantly increased seed yield by 15.64 per cent over control (14.7 q ha^{-1}). Similarly, Rani (1999) also noted 9.58 per cent increase in seed yield of soybean in response to 60 kg P_2O_5 ha^{-1} over control (13.15 q ha^{-1}).

Chafie *et al.* (1999) observed that 75 kg P_2O_5 ha^{-1} produced significantly higher seed (12.06 q ha^{-1}) and straw (23.60 q ha^{-1}) yield of soybean over control (7.23 & 16.60 q ha^{-1}, respectively). However, it was found at par with 50 kg P_2O_5 ha^{-1}. Likewise at Hisar, Kumar *et al.* (1999) found that application of 80 kg P_2O_5 ha^{-1} produced significantly higher seed yield (21.08 q ha^{-1}) of soybean over control. In an another study, Ramasamy *et al.* (2000) at Vamban, Tamil Nadu observed differential response due to various levels of phosphorus on seed yield. Phosphorus application at 60 kg P_2O_5 ha^{-1} recorded significantly higher seed yield of soybean over control and 40 kg P_2O_5 ha^{-1}. However, it was found at par with P_2O_5 at 80 kg ha^{-1}. Five year studies at GAU, Targhadia demonstrated that application of P_2O_5 at 60 kg ha^{-1} to the soybean significantly increased grain (8.16 q ha^{-1}) and stover yield (21.85 q ha^{-1}) over no fertilization of phosphorus (7.27 and 17.42 q ha^{-1}, respectively) on pooled basis. However, it was found at par with 40 kg P_2O_5 ha^{-1} (Akbari *et al.*, 2001). During two successive years of study at TNAU, Vamban, Ramasamy and Sankaran (2001) reported that being at par with 60 kg P_2O_5, higher level (80 kg P_2O_5 ha^{-1}) significantly influenced the grain yield of soybean by 10.57

and 10.66 per cent as compared to control (1050 & 1285 kg ha^{-1}, respectively). In an another field study of two consecutive years, Rao and Shaktawat (2001) observed a positive relationship in pod and biological yield with increased level of phosphorus. They found that 60 kg P_2O_5 ha^{-1} registered significantly higher pod & biological yield of groundnut (18.54 & 50.93 q ha^{-1}) over 20 kg P_2O_5 ha^{-1} (16.32 & 46.56q ha^{-1}, respectively).

Khandwe and Sharma (2002) studied the effect of phosphorus on growth and productivity of soybean. Application of increasing levels of P upto 80 kg P_2O_5 ha^{-1} significantly improved the seed yield (2812 kg ha^{-1}). Kumar and Singh (2005) find out that application of 60 kg P_2O_5 ha^{-1} produce the significantly higher seed yield (2740 kg ha^{-1}) of sunflower over the control and 30 kg P_2O_5 ha^{-1}. Kausadilkar *et al.* (2003) showed that application of P_2O_5 at 90 kg ha^{-1} showed the highest yield for pods $plant^{-1}$, 100 seed weight, crude protein, seed and stover yields. Dadhich, 2004 conducted a field experiment and observed that the application of 40 kg P_2O_5 ha^{-1} recorded significantly highest grain (23.71 q ha^{-1}), stover (38.41 q ha^{-1}) and biological yield (62.16 q ha^{-1}) of soybean over contol, 20 kg P_2O_5 ha^{-1} and 30 kg P_2O_5 ha^{-1}.

Tomar *et al.* (2004) conducted a field experiment during 1999 *Kharif* season in Madhya Pradesh found that all the treatments of phosphorus increased number of pods $plant^{-1}$, number of seeds per pod, test weight, seed yield, stover yield , protein and oil contents of soybean. Gandhi and Shakhela (2005) noted that the individual application of P (40 kg P_2O_5 ha^{-1}) increased 38.9 per cent in seed yield of cluster been over control. However, the combined application of P (40 kg P_2O_5 ha^{-1}) and S (40 kg S ha^{-1}) significantly recorded the maximum seed (15.54 q ha^{-1}) and stover (33.10 q ha^{-1}) yields, which was 55.5 and 55.6 per cent higher over control, respectively.

A field experiment was conducted during *summer* season of the year 2001 at College Farm, N.M. College of Agriculture, Navasari (Gujarat) by Thanki *et al.* (2005). They revealed that the significantly higher yield of grain (10.8 q ha^{-1}) and stover (14.6 q ha^{-1}) were recorded under higher level of 60 kg P_2O_5 ha^{-1} over 30 kg P_2O_5 ha^{-1} and control. The increase in seed yield was 31.7% and 54.3% over 30 kg P_2O_5 ha^{-1} and control, respectively. Panchal *et al.* (2006) at Anand (Gujrat) revealed that application of phosphorus @ 50 kg P_2O_5 ha^{-1} significantly increased seed yield (15.93 q ha^{-1} and 19.18 q ha^{-1}) of mustard in the 2005 and 2006, respectively.

Ijgude and Kadam (2008) carried out a field experiment to study the effect of sulphur and phosphorus on yield of soybean at MPKV, Rahuri. Result of experiment showed that the increasing levels of sulphur and phosphorus significantly increased the seed and stover yield of soybean. The combined application of 40 kg S and 75 kg P_2O_5 ha^{-1} proved to be the best combination resulting in significant increase in grain (26.65 q ha^{-1}) and stover yield (30.50 q ha^{-1}). Mhango *et al.* (2008) conducted a farm trial at Champhira and Nchenachena Extension Planning Areas (EPAs) in Northern

Malawi and recorded a positive response to fertilizer application rate (60 kg P ha^{-1}) in maize and soybean seed yield but no effect on seed yield of groundnut and Bambara groundnut. Application of fertilizer increased stover production in all crops ($P<0.01$) except Bambara groundnut.

A field experiment was conducted by Chavan *et al*. (2008) on clayey soils during *kharif* season of 2005-06 at Akola, Maharashtra, to study the effects of the source and level of phosphorus with and without phosphate solubilizing bacteria inoculation on the growth, yield and quality of soybean (cv. TAMS-38). The increase in phosphorus level from 25 to 50 kg ha^{-1} and from 50 to 75 kg ha^{-1} significantly enhanced the yield attributes and seed yield. Tanwar (2002) reported that application of 90 kg P_2O_5 ha^{-1} in soybean provided significantly higher number of pods $plant^{-1}$, seeds pod^{-1}, test weight, seed yield, stover yield and biological yield than the plots treated with 30 kg P_2O_5 ha^{-1}. However, it remained at par with 60 kg P_2O_5 ha^{-1}. Two year experiment findings registered significantly higher seed yield (15.06 & 13.79 q ha^{-1}) with 60 kg P_2O_5 ha^{-1} during both the years over 30 kg P_2O_5 ha^{-1}. However, higher dose (90 kg P_2O_5 ha^{-1}) did not improve the yield significantly over 60 kg P_2O_5 ha^{-1} (Sharma *et al.*, 2002).

Shivakumar *et al.* (2004) reported that application of phosphorus at 80 kg P_2O_5 ha^{-1} significantly increased pod weight $plant^{-1}$, pods $plant^{-1}$, grains pod^{-1} and grain weight $plant^{-1}$ of chickpea over 40 kg and 0 kg P_2O_5 ha^{-1}. This level also significantly increased the grain and stover yield of chickpea over 40 and 0 kg P_2O_5 ha^{-1}. Meena *et al*. (2006) observed that crop fertilized with 60 kg P_2O_5 ha^{-1} significantly increased number of pods $plant^{-1}$, test weight of seed and seed yield of chickpea over control and 30 kg P_2O_5 ha^{-1}. A field experiment conducted in Bangladesh, Jahangir *et al.* (2009) found that application of 30 kg P_2O_5 ha^{-1} resulted in significant increase in seed and straw yield of soybean as compared to 20 kg P_2O_5 ha^{-1}. In a field experiment conducted at RCA Udaipur, Kanojia and Sharma (2009) observed that application of 60 kg P_2O_5 ha^{-1} to soybean crop recorded significantly higher seed and straw yields (277.33 and 570.81kg ha^{-1}, respectively) over 40 kg P_2O_5 ha^{-1}. Brar *et al.* (2010) observed that increasing levels of phosphorus, applied to soybean crop during 2002-04, significantly increased the seed yield of soybean as compared to lower levels. *Field experiments were conducted during 2002-03 and 2003- 04 at the research farm, College of Agriculture, Indore, revealed a progressive increase in yield of soybean and chickpea by application of phosphorus up to 39.6 kg* ha^{-1} *as compared to recommended level of 13.2 kg P per ha. Application of phosphorus @ 39.6 kg* ha^{-1} *to both the crops enhanced the system productivity (SEY 5,202 kg/ha) to about 30 per cent with higher net profit (Rs 36, 683) and B: C ratio (3.62) (Thakur and Girothia 2010).*

Paliwal *et al.* (2009) studied the effect of sulphur and phosphorus application on yield and N, P and K content of soybean grown on alfisol soil during *kharif* 2004 and 2005 at Ambikapur, (Chhattisgarh) for two year and found that increased application of phosphorus significantly increased the seed yield and contents of N, P and K up to 60 kg P ha^{-1} level over control, while the interaction effect of sulphur (40 kg ha^{-1}) and phosphorus (60 kg ha^{-1}) increased the seed and stover yield 25.23 and 31.54 q ha^{-1}, respectively. Imade *et al,* (2010) investigated that the application of 100 kg P_2O_5 ha^{-1} recorded highest seed and stover yield of soybean. However, the combined application of 40 kg S ha^{-1} and 75 kg P_2O_5 ha^{-1} proved to be the best combination resulting in significant increase pods $plant^{-1}$, seed and stover yield.

Nawange *et al.* (2011) conducted a field experiment during *Rabi* season 2009-10 to find out the optimum dose of P and S on growth, yield attributes and yield of chickpea. They observed that the application of P_2O_5 up to 60 kg ha^{-1} indicated linear increase in the growth, yield attributes, seed and straw yield of chickpea. Devi *et al.* (2012) conducted a field experiment at Canada during 2007-08 observed that the yield attributing characters; pods $plant^{-1}$, seeds pod^{-1}, seed index and yields of soybean increasing with increasing P levels up to application of 80 kg P_2O_5 ha^{-1}. Numbers of pods $plant^{-1}$, seeds pod^{-1}, seed index, seed, stover and biological yield of soybean were significantly increased by 40 kg P_2O_5 ha^{-1} with phosphorus solubilizing bacterial inoculation over its lower levels (Shivran *et al.,* 2012).

Sentimenla *et al.* (2012) conducted a field experiment at school of Agriculture Science and rural development, Medziphema Campus, Nagaland during *kharif* season of 2009 noted that the combined application of 60 kg P_2O_5 ha^{-1} and 1.5 kg boron ha^{-1} to soybean produced significantly higher seed and straw yield over control. Results of the research show that effect of phosphorus application doses up to 60 kg P_2O_5 ha^{-1} on the first pod length, number of pod $plant^{-1}$, thousand grain weight and seed yield were significant. Sedd yield increased with increasing phosphorous doses up to 60 kg P_2O_5 ha^{-1} but showed a decreasing at higher phosphorous applications. Phosphorous applications of 60 and 30 kg P_2O_5 ha^{-1} to soybean produced the highest values for seed yield (2511.7 kg ha^{-1} and 2433.3 kg ha^{-1}), respectively (Cetin and Ozturk, 2012). Application of 100% P (32.25 kg p ha^{-1}) through RP significantly gave the higher mean seed yield and harvest index of soybean as compared to 50% P (16.12 kg P ha^{-1}) at IARI New Delhi (Munda *et al.* 2013).

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka, resulted that numbers of pods $plant^{-1}$, number of seeds $plant^{-1}$, thousand seed weight, grain yield, biological yield increased significantly up to 30 kg P ha^{-1} (Akter e*t al.* 2013). Bhattacharjee *et al.* (2013) reported that the application of 90 kg P_2O_5 ha^{-1}significantly increased the number of total pods and filled pods $plant^{-1}$and stover yield relative to its lowest dose. This resulted in significantly improved seed yield at higher doses of P fertilization (30.2 q ha^{-1} yield at 90 kg P_2O_5 ha^{-1} compared to 23.5 q ha-1 and 28.2 q ha^{-1} at 30 kg P_2O_5 and 60 kg P_2O_5 ha^{-1}, respectively).

2.1.3 Nutrient content and uptake

Increasing rates of P application from 0 to 60 kg P_2O_5 ha^{-1} significantly enhanced N and P content of seed and straw of soybean (Jat and Nepalia, 1994). Anokar *et al.* (1995) found that total uptake of phosphorus by soybean was significantly higher in plots receiving 75 kg P_2O_5 ha^{-1}, with the increase by 49.23 per cent as compared to no phosphorus (8.49 q ha^{-1}). Jat and Nepalia (1995) reported 35.36, 59.75 & 33.44 per cent higher total uptake of NPK in soybean with 60 kg P_2O_5 ha^{-1} over control (87.1, 8.2 & 57.4 kg ha^{-1}, respectively). During two years of study, Bisht and Chandel (1996) at Pantnagar reported that application of 80 kg P_2O_5 ha^{-1} significantly increased the NPK and Zn uptake by soybean over control. The increase in NPK and Zn uptake was 85.81 & 159.6, 184.78 & 165.62, 102.36 & 148.70 and 100 & 119.31 per cent, respectively over no phosphorus fertilization during both the years. Sarkar and Tripathi (1996) found significant increase in N content of leaf (2.09 %), stem (1.94%), pod wall (2.13%), nodule (2.10 %) and seed (7.61 %) with 60 kg P_2O_5 ha^{-1} to soybean over control (1.72, 1.51, 1.84, 1.75 and 7.34 per cent, respectively). Similarly, Patel and Chandravanshi (1996) recorded increase in N and P content of soybean upto application of 90 kg P_2O_5 ha^{-1} but the magnitude of response was higher on P content as compared to N content. Nimje and Potkile (1998) reported significant increase in total N, root nodule N, plant N, P and K content of soybean with applied P rates of 0 to 125 kg ha^{-1}. Likewise, Singh *et al.* (1997) conducted a pot experiment and found that application of 11 kg P_2O_5 ha^{-1} to soil registered maximum N, P and K content of grain and straw of soybean over control and other lower doses. The N, P and K content of grain and straw were increased by 6.10 & 22.29, 38.46 & 121.42 and 4.32 & 4.54 per cent, respectively over control. Singh and Nepalia (1997) reported that application of 80 kg P_2O_5 ha^{-1} to soybean registered significantly higher oil yield over control. In an experiment, application of 90 kg P_2O_5 ha^{-1} registered significantly higher protein and oil content of soybean with 34.07 and 19.56 per cent, respectively over control. However, it was found at par with 75kg P_2O_5 ha^{-1} and this level also registered significantly higher NPK uptake by soybean with 81.32, 70.60 and 50.41 per cent increment over control (Chafie *et al.*, 1999). On the basis of five year study pooled analysis, Targhadia, Akbari *et al.* (2001) reported significantly increased NPK uptake (106.4, 8.22 & 45.1kg ha^{-1}, respectively) when the soybean was fertilized with 60 kg P_2O_5 ha^{-1} over no phosphorus (88.9, 6.44 & 35.2 kg ha^{-1}, respectively). While, Singh *et al.* (2001) reported that N and P content of soybean seed was significantly increased with the application of 90 kg P_2O_5 ha^{-1}. The N and P content of seed was increased by 103.27 & 36.04 per cent, respectively over control.

Application of 60 kg P_2O_5 ha^{-1} significantly increased oil and protein content of groundnut by 5.18 and 5.19 per cent as compared to 20 kg P_2O_5 ha^{-1} (Rao and Shaktawat, 2001). Umale *et al.* (2002) found significant increase in protein and oil content of soybean with 50 kg P_2O_5 ha^{-1}. At Udaipur, an increment to the tune of 90.01 and 129.96 per cent in N and P uptake by soybean was registered by the application of 90 kg P_2O_5 ha^{-1}, respectively over control (Shaktawat *et al.,* 2002). Dadhich, 2004 reported that the N, P, K, Cu, Zn, Fe and Mn uptake by seed and straw of soybean significantly increased with 40 kg P_2O_5 ha^{-1} over over contol, 20 kg P_2O_5 ha^{-1} and 30 kg P_2O_5 ha^{-1}.

Shivakumar *et al.* (2004) conducted an experiment and reported that chickpea fertilized with 80 kg P_2O_5 ha^{-1} significantly increased P uptake by seed and stover over its lower levels (0 and 40 kg P_2O_5 ha^{-1}). In Bangladesh, Jahangir *et al.* (2009) found that N and P content in soybean seed significantly increased with 30 kg P_2O_5 ha^{-1}as compared to lower levels. Thakur and Girothia (2010) reported significant increase phosphorus uptake by soybean + maize intercropping system with increasing levels of phosphorus up to 39.6 kg P ha^{-1} as compared to lower levels.

Sharma and Vyas (2002) find out that the protein, oil content and seed yield of soybean significantly increased with increasing levels of phosphorus up to 60 kg P_2O_5 ha^{-1}. Tanwar and Shaktawat (2003) conducted a field experiment during 1999-2000 and find out that the application of 38.7 kg P ha^{-1} increased N and P uptake in soybean by 13.3 and 18.7 per cent, respectively, over 12.9 kg P ha^{-1}. Sharma *et al.* (2004) recorded that the protein content, nitrogen and phosphorus uptake by soybean crop significantly increased with increase in level of phosphorus. Meena *et al.* (2005) conducted a study at IARI, New Delhi during 1997-98 and 1998-99, reported that the increasing levels of P upto 60 kg P_2O_5 ha^{-1} resulted in significant increase in P content, uptake and grain yield of chickpea over control. Meena *et al.* (2006) reported that application of 60 kg P_2O_5 ha^{-1} significantly increased protein content of seed over 30 kg P_2O_5 ha^{-1} and control. The increase in protein content was 24.54 kg ha^{-1} over control. Bishnoi *et al.* (2007) reported that application of phosphorus at 90 kg ha^{-1} significantly increased the protein content and grain yield of soybean.

Kanojia and Sharma (2009) conducted a field experiment during *kharif* seasons of 2003 and 2004. They investigated that increasing phosphorus levels did not differ significantly with RWC and proline content of leaves. However, 60 kg P_2O_5 ha^{-1} recorded significantly higher oil and protein content (19.76 and 40.77 per cent, respectively) and their yields (277.33 and 570.81 kg $ha^{-1,}$ respectively) over 40 kg P_2O_5 ha^{-1}. Jahangir *et al.*, (2009) found significant influence on oil content of soybean with application of 30 kg P_2O_5 ha^{-1} as compared to lower levels. Increasing levels of phosphorus up to 39.6 kg P_2O_5 ha^{-1} significantly increased the protein content in soybean seed in soybean + maize cropping system as compared to lower levels (Thakur and Girothia, 2010).

Imade *et al.* (2010) suggested that the oil content, protein content and nutrient uptake by soybean significantly increased with increase in levels of phosphorus from 50% to 100% RDF (75 kg P_2O_5 ha^{-1}). An investigation was carried out at PAU research farm during *kharif* season of 2002-04 by Brar *et al.* (2010) to study the response of soybean to different levels of phosphorus and sulphur. Phosphorus application resulted in additional grain yield to the tune of 1.8 and 4.2 q ha^{-1} at research farm and farmers' field, respectively. Phosphorus and sulphur uptake and apparent recovery efficiency increased significantly with P application.

Sentimenla *et al.*, 2012 at Nagaland during *kharif* season of 2009 revealed that the application of different levels P significantly increased the N, P, K and B uptake by soybean over control. Munda *et al.* (2013) found that the crop fertilized with 100% P (32.25 kg p ha^{-1}) through RP reported that the highest protein content and oil content of soybean over 50% P (32.25 kg p ha^{-1}). Bhatacharjee *et al.* (2013) reported that application of 90 kg P_2O_5 ha^{-1} to soybean registered significantly higher protein content over 30 and 60 kg P_2O_5 ha^{1}.

2.2 EFFECT OF SULPHUR

2.2.1 Growth characters

Application of 45 kg S ha^{-1} as gypsum resulted in the greatest plant height (66.4 and 56.6 cm) leaf area index (3.96 and 3.95) and dry matter accumulation (5.99 and 5.84 t ha^{-1}), of groundnut in both years (Kalaiyarasan *et al.* 2003). Nagar and Meena (2004) in a study found that plant height, dry matter accumulation and chlorophyll content increased significantly with increasing levels of sulphur from 0 to 60 kg ha^{-1} in guar. Tomar *et al.* (2004) in a field experiment found that application of 40 kg S ha^{-1} significantly increased plant height and dry matter accumulation of soybean over rest of the lower levels. Dongarkar *et al.* (2005) conducted study on effect of sulphur on growth of mustard and concluded that application of sulphur significantly influenced the growth, plant height and dry matter production up to 45 kg S ha^{-1}. Nepalia (2005) noticed that application of sulphur up to 60 kg ha^{-1} significantly increased crop dry matter and leaf area index in mustard. Rana *et al.* (2005) conducted a study during winter season on influence of sulphur on growth of Indian mustard under rainfed condition with 3 levels of sulphur (0, 20, 40 kg S ha^{-1}). They found that S significantly increased the growth at 20 and 40 kg S ha^{-1} over control.

Degra *et al.* (2008) in a field experiment indicated that successive rates of sulphur nutrition up to 60 kg ha^{-1} markedly enhanced the dry matter in both the years. However, plant height showed a significant response up to 40 kg S ha^{-1} and remained at par with higher level of S nutrition. Khan *et al.* (2008) conducted an experiment on Indian mustard, grown with different sulphur levels (0, 25, 50 and 75 kg ha^{-1}) revealed that sulphur at 25 kg ha^{-1} increased the leaf area and dry weight of the plant. Khatkar *et al.* (2009) observed that increasing levels of sulphur significantly increased plant height in mustard up to 30 kg S ha^{-1} over its preceding level. Kumar *et al.* (2009) reported that the highest dry matter yield (19.3 g/pot) at 55 days after sowing and at the time of maturity (straw yield 25.2 g/pot and grain yield 7.3 g/pot) was recorded with B-0.44 S-13.4 treatment.

In a field experiment during 2008-09 it was reported that soybean fertizilised with application of 20 kg sulhpur significantly increased the plant height of soybean over control (Farhad *et al.* 2010).

A field experiment was conducted at Kota to evaluate the response of phosphorus with and without PSB inoculation and sulphur on yield and yield attributes of soybean during *kharif* season 2006 and 2007. The results showed that the application of 40 kg S ha^{-1} significantly influenced the plant height, test weight and seed yield over its preceding doses (Sharma, 2011). Application of 40 kg sulphur ha^{-1} gave highest shoot height, root length, number of leaves $plant^{-1}$ and dry matter accumulation of soybean over control (Trivedi *et al.* 2011). Chhonkar and Shroti, 2011 conducted a field experiment and found that the plant height, days of 50 % flowering and maturity of mustard increased significantly over control up to 80 kg S ha^{-1} during both of the years of study, however LAI improved consistently with increased rate of sulphur and maximum values were recorded with 60 kg S ha^{-1}.

Patra *et al.* 2012 in a field experiment at Sriniketan, India found that the application of sulphur @ 40 kg ha^{-1} to sunflower significantly improved plant height as compared to other levels of sulphur application. Sheoran *et al.* 2013 revealed that the sulphur application increased the plant height, stem girth as well as larger head diameter of sunflower over control but did not show significant effect with plant height and stem girth. A field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh recorded that application of 20 S ha^{-1} to soybean significantly increased the plant height, number of primary branch $plant^{-1}$ and number of leaves $plant^{-1}$ (Akter *at el.* 2013). A field experiment was conducted at Nagaland University, Medziphema found that the application of 30 kg S ha^{-1} significantly improved growth characters *viz.* plant height, number of leaves, number of nodules $plant^{-1}$ and weight of fresh nodules of soybean (Bhatacharjee *et al.* 2013).

2.2.2 Yield and yield attributes

Singh *et al.* (2001) in a field experiment found that application of sulphur 60 kg ha^{-1} in soybean significantly increased seed yield (19.06 q ha^{-1}), haulm yield (43.40 q ha^{-1}) over control. Sharma *et al.* (2001) noted that application of 75 kg S ha^{-1} in the form of SSP proved to be the best treatment for increasing and improving the quality and seed yield of the soybean. They concluded that SSP is the ideal sulphur source since it is easily available and requires no special management practice during application. Dayanand and Meena (2002) in a field experiment found that application of sulphur 40 kg ha^{-1} in groundnut significantly increased pods $plant^{-1}$ (28.68), kernel pod^{-1} (1.64) and test weight (398.2 g) and also significantly increased pod yield (17.34 q ha^{-1}), kernel yield (11.38 q ha^{-1}) and biological yield (57.30 q ha^{-1}) over control.

Wasmatkar *et al.* (2002) in a study found that application of 30 kg S ha^{-1} resulted the higher seed yield (1962 kg ha^{-1}) and straw yield (2642 kg ha^{-1}) of soybean compared to control. Application of 45 kg S ha^{-1} as gypsum resulted in the greatest number of pods $plant^{-1}$ (26.1), 100 kernel weight (50.7 and 50.1 g), shelling percentage (78 % and 77.6 %) pod yield (2.38 and 2.35 t ha^{-1}) and kernel yield (1.86 and 1.83 t ha^{-1}) of groundnut in both years (Kalaiyarasan *et al.* 2003). Maity and Giri

(2003) observed that application of sulphur 30 kg ha^{-1} in groundnut significantly increased pods plant^{-1} (42.7), pod weight plant^{-1} (24.4 g), 100 kernel weight (40.1 g), pod yield (29.1 q ha^{-1}) and oil content (54.3 per cent) over control. Sangale and Sonar (2004) in a study observed that application of sulphur in soybean at increasing level from 0 to 30 kg ha^{-1} significantly increased seed yield and nutrient uptake. Sharma *et al.* (2004) conducted an experiment during 2002-03 to know the effects of S rate (0, 10, 20 or 30 kg ha^{-1}) and source (50% through ammonium sulfate + 50% through elemental S or compound fertilizer 13-33-0-15 S) on the performance of soybean. Thus 30 kg S ha^{-1} supplied through 13-33-0-15 S recoeded maximum number of pods plant^{-1} (50.0), number of seeds pod^{-1} (2.08), 100-grain weight (11.94 g), seed yield (1747 kg ha^{-1}) and straw yield (2214 kg ha^{-1}) of soybean. At West Bengal, soil incorporation of 30 kg S ha^{-1} gave significant higher pod yield than other levels of sulphur. Amongst source of sulphur, gypsum and SSP were the best, followed by elemental sulphur and pyrites in respect of yield, yield attributes and oil content of groundnut (Dutta and Patra, 2005). Singh *et al.* (2006) at Jharkhand in an experiment on soybean found that application of S at 60 kg ha^{-1} significantly increased seed and straw yield compared to control. Nasreen and Farid (2006) reported that addition of sulphur fertilizer significantly increased yield and yield attributes (grains pod^{-1}, pods plant^{-1} and test weight) of soybean. Seed yield and sulphur uptake were increased with the application of 40 kg S ha^{-1}.

Shinde *et al.* (2007) in a field experiment conducted at Akola reported that application of sulphur at 60 kg ha^{-1} in soybean significantly increased seed by 4.78 q ha^{-1} and straw yield by 11.03 q ha^{-1} over control. Singh and Mann (2007) in a study on groundnut at Banasthali (Raj.) observed that application of sulphur up to 40 kg ha^{-1} significantly increased pod yield during both the years being at par with that of 60 kg S ha^{-1}. They further found that application of 20, 40 and 60 kg S ha^{-1} increased the pod yield by 16.5, 22.7 and 22.8 per cent, respectively during 2001 and by 19.1, 26.5 and 29.8 per cent during 2002 over control. Mahale *et al.* (2008) in a study at Dapoli found that application of sulphur 30 kg ha^{-1} in sesame and groundnut intercropping system significantly increased grain yield of sesame (4.49 q ha^{-1}) which was at par with 60 kg S ha^{-1} and significantly superior over control. Kumar *et al.* (2009) reported that the highest dry matter yield (19.3 g/pot) at 55 days after sowing and at the time of maturity (straw yield 25.2 g/pot and seed yield 7.3 g/pot) was recorded with B-0.44 S-13.4 treatment in soybean. The combined application of sulphur and boron yielded highest oil content with B-0.44 S-13.4 (21.7%) application. In a field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka during 2008-09 reported that soybean fertizilised with application 20 kg sulphur significantly increased the 1000 seed weight, grain yield and straw yield of soybean (Farhad *et al.* 2010). Deshbhratar *et al.* (2010) suggested that the significantly increases in seed and straw yield of pigeon pea with application of 20 kg S ha^{-1}. Maximum number of pods plant^{-1}, number of grains pod^{-1} and test weight were observed with application of 20 kg S ha^{-1} and 50 kg P_2O_5

ha^{-1}. Prakasha *et al.* (2010) investigated that the maximum grain yield of soybean (20.5 q ha^{-1}) was recorded in treatment with application of sulphur at the rate of 40 kg ha^{-1}.

At Pantnagar, Saxena and Nainwal (2010) conducted an experiment to evaluate the response of sulphur and boron nutrition on yield and yield attributes of soybean. They suggested that application of 30 kg S ha^{-1} produced maximum pods plant^{-1}, grains pod^{-1}, test weight, seed and straw yield of soybean. A field experiment conducted at TNAU, Coimbatore during *kharif* 2007-08 revealed that application of 30 kg S ha^{-1} significantly increased the branches plant^{-1}, pods plant^{-1}, seeds pod^{-1} and 1000 seed weight and higher seed yield of soybean then other treatments (Vaiyapuri *et al* 2010). Field experiment were conducted at ARS, Kota showed that application of sulphur (30 kg P_2O_5 ha^{-1}) significantly increased the number of branches plant^{-1}, pods plant^{-1} and seeds per pod by 29, 23.9 and 11.6 per cent respectively and produced 16.1 per cent higher seed yield (1588 kg /ha) over control (Meena *et al* 2011). Application of 40 kg sulphur ha^{-1} gave highest number of pods plant^{-1}, length of pods, 100 seed weight and seed yield soybean over control (Trivedi *et al.*, 2011). A field experiment conducted at Nidhauli Kalam (Etah) U.P. observed that the number of siliqua plant^{-1}increased significantly from 152.01-189.00 and 155.07-192.79 with enhancement of sulphur from 0-80 kg S ha^{-1}. All the levels of sulphur produced higher number of seed siliqua^{-1} (10.12-10.34 and 10.33-1056) compared to no sulphur treatments (8.38 and 8.55) in both years of the study. The maximum seed yield (15.56 and 15.90 q ha^{-1}) and stover yield (43.96 and 44.85 q ha^{-1}) was recorded with the 80 kg S ha^{-1}(Chhonkar and Shroti, 2011).

Kumar and Kumar, (2011) reported that the effect of sulphur was found to be highly significant on the production of number of siliquae (pods) plant^{-1} and more number of grains per pod of mustard up to the application of sulphur at the rate of 40 kg/ha. A Field experiment was conducted at Agricultural Research Farm, Institute of Agriculture, Visva-Bharati University, Sriniketan, India, revealed that application of 40 kg S ha^{-1} recorded significantly increased yield attributes, *viz.* thalamus diameter, weight of thalamus, filled seeds capitulum^{-1}, and 100 seed weight (g), as well as seed and biological yield of soybean over other treatments (Patra *et al.* 2012).

A three year experiment was conducted during 2007-09 at Manipur revealed that application of 30 kg S ha^{-1} increased the yield attributing characters like number of branches plant^{-1}, pods plant^{-1} and 1000 seed weight and seed and straw yield of soybean (Devi *et al.* 2012). The substantial soybean yield improvement was observed due to sulphur application at all the centres. The region-wise pooled results revealed that the highest soybean yield was recorded with 20 kg S per ha in north plain (1, 644 kg ha^{-1}), 35 kg S ha^{-1} in north eastern (1, 873 kg ha^{-1}) and 30 kg S ha^{-1} in central (2, 064 kg ha^{-1}) and southern zone (2, 500 kg ha^{-1}). The highest sustainability yield index was associated with 35 and 40 kg S ha^{-1} in north plain and north eastern zones while it was maximum with 30 kg S ha^{-1} in central and southern zones. (**Billore and Vyas 2012**). A three year field experiment at Sambalpur (odisha) showed that the application of 40 kg S ha^{-1} recorded the maximum mature pods plant^{-1}, shelling percentage and the mean maximum pod and haulm yield of groundnut as compared to other lower levels (Das *et al.* 2013).

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh recorded that application of 20 kg S ha^{-1} significantly increased the numbers of pods plant^{-1}, number of grains plant^{-1}, thousand seed weight, grain yield, biological yield (Akter *at el.* 2013). A field experiment was conducted at the Experimental Research Farm of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema found that the application of 30 kg S ha^{-1} significantly improved the number of total pods and filled pods plant^{-1}, seed and stover yield of soybean (Bhatacharjee *et al.* 2013). A field experiment was conducted on brown sarson (Brassica rapa var brown sarson) 'KOS 101' during *rabi* 2007-08 and 2008-09 at Regional Research Station Wadura, SKUAST-K in temperate Kashmir observed that the application of 40 kg S ha^{-1} increased seed yield by 20 and 7 % and straw yield by 28 and 10 % over control and 20 kg S/ha, respectively. However, the difference between 40 and 60 kg S ha^{-1} for yield and yield attributes were nonsignificant. Increase in siliquae plant^{-1}, seeds siliqua^{-1}, 1,000-seed weight, seed and stover yield with application of 40 kg S/ha was to the tune of 14.2, 22.4, 15.3, 27.6 and 37.63 %, respectively over control (Singh *et al.*, 2013).

Das *et al.* (2013) observed that the application of 40 kg S ha^{-1} recorded the maximum mature pod plant^{-1}, shelling percentage and haulm yield of groundnut. Sheoran *et al.* 2013 revealed that the significant improvement in seed yield of sunflower was observed with each incremental dose of sulphur up to 40 kg S ha^{-1} with 6.9-9.0 % yield superiority over control. Application of graded levels of sulphur at the rate of 20 and 40 kg S ha^{-1} through gypsum increased the seed yield over control by 8.6 and 10.7 per cent, respectively whereas the corresponding increases were 8.5 and 10.4 % for ammonium sulphate, 5.4 and 7.3 % for single super phosphate and 4.9 and 7.5 % for elemental sulphur at the respective levels of sulphur nutrition. Highest seed yield (2.66 t ha^{-1}), net retruns (₹ 46.3* 10^{3}/ha) and B:C ratio (4.08) was recorded with application of 40 kg S ha^{-1} applied through gypsum. A 3-year field experiment was conducted at the Punjab Agricultural University, Ludhiana, during the rainy season of (*kharif*) 2006 to 2008 revealed that the highest plant height, pods plant^{-1}, seeds pod^{-1}, seed yield, stover yield, gross and net returns of soybean were recorded with 40 kg S/ha, which were statistically at par with 30 kg S ha^{-1} but significantly higher than other levels of sulphur. The productivity in 40 kg S ha^{-1} was enhanced 61.9% over the absolute control (Hari Ram *et al.*, 2014)

2.2.3 Nutrient content and uptake

Sonune *et al.* (2001) in a field experiment at Akola observed that application of sulphur in soybean at increasing levels from 0 to 40 kg ha^{-1} significantly increased the protein and oil contents of soybean grain over control. Singh *et al.* (2001) in a field experiment at Udaipur found that application of sulphur 60 kg ha^{-1} in soybean significantly increased seed yield (19.06 q ha^{-1}), haulm yield (43.40 q ha^{-1}), oil yield (378.80 kg ha^{-1}) and protein yield (736.37 kg ha^{-1}) over control. Das *et al.* (2001) conducted a pot culture experiment at Assam (India) to study the effects of K and S on nutrient availability, nutrient uptake and yield of soybean (cv. JS-2). The S applications have no significant influence on the availability of N, P and K in the soil. The application of K and S tended to increase nutrient uptake as reflected in the yield and yield attributes. In an experiment at Akola, Maharashtra noted that the highest uptake of N (124.02 and 128.25 kg ha^{-1}) was recorded with S at 15 kg ha^{-1} and Zn at 5 kg ha^{-1}, respectively. The highest uptake of P (14.71 and 14.31 kg ha^{-1}), K (59.15 and 58.35 kg ha^{-1}), S (12.03 and 10.75 kg ha^{-1}) and Zn (108.23 and 101.43 g ha^{-1}) was recorded with S at 30 kg ha^{-1} and Zn at 5 kg ha^{-1}, respectively (Wasmatkar *et al.*, 2002).

Venkatesh *et al.* (2002) found that sulphur was applied as single super phosphate, gypsum and elemental sulphur compared to the initial level, the content of available sulphur in the soil increased after the harvesting of groundnut. Sulphur at 30 and 45 kg ha^{-1} resulted in the highest content of available sulphur in soil. Sexton *et al.* (2004) reported that the nutrient uptake and availability of nutrients were significantly influenced by the addition of S and Rhizobium compared to the control. Nagar and Meena (2004) in a study at Jobner found that chlorophyll content increased significantly with increasing levels of sulphur from 0 to 60 kg ha^{-1} in guar and also significant increased protein content and total uptake of N, P and S up to 60 kg ha^{-1}.

Singh and Meena (2004) observed that application of S to mustard at 20, 40 and 60 kg ha^{-1} increased its uptake by 30, 46 and 54 per cent over the control. Sangale and Sonar (2004) in a study at Maharashtra observed that application of sulphur in soybean at increasing level from 0 to 30 kg ha^{-1} significantly increased seed yield and nutrient uptake. Gokhale *et al.* **(**2005) at Maharashtra, suggested that the application of S at 40 kg ha^{-1}either through gypsum or single super phosphate resulted the highest seed yield, oil and protein contents and sulphur uptake in seed and straw of soybean. The uptake of N, P, K and S by soybean and their availability in soil increased with sulphur levels and the highest values were recorded at 30 kg S ha^{-1} (Vijayapriya *et al.*, 2005). At Tamil Nadu, sulphur was supplied with 0, 20, 40, 60 and 80 kg ha^{-1}, in combination with elemental sulphur (T1), T1 + Thiobacillus (T2), naturally oxidized elemental sulphur (T3) and elemental sulphur (T4). Nitrogen, phosphorus, potassium and sulphur uptake were highest with the application of 40 kg S ha^{-1} (Arunageetha *et al.*, 2006). Piri and Sharma (2006) postulated that increasing levels of sulphur upto 45 kg ha^{-1} in mustard resulted in significantly higher sulphur uptake by both seed and straw over other levels. At Jharkhand the crop yield increased more due to application of sulphur compared to B application. The S x B interation revealed that maximum seed yield was obtained with 60 kg S + 2.0 kg B ha^{-1}. The oil and protein contents in soybean seed increased with successive increase of S and B levels. Increasing levels of S significantly increased the protein content in soybean seed. The maximum protein content (37.79%) in seed was recorded at 40 kg S + 0.5 kg B ha^{-1} (Singh *et al.*, 2006)

Shinde *et al.* (2007) in a field experiment conducted at Akola reported that application of sulphur at 60 kg ha^{-1} in soybean significantly increased oil (22.34) and protein (41.54) per cent and also significantly increased seed (4.78 q ha^{-1}) and straw yield (11.03 q ha^{-1}) over control. Singh and Mann (2007) in a study on groundnut at Bansthali (Raj.) observed that application of sulphur at 60 kg ha^{-1} significantly increased the available sulphur status at harvest in the soil. On an average, the available sulphur increased from intial value of 9.3 to 10.3, 12.1 and 13.8 kg ha^{-1}, respectively with the application of 20, 40 and 60 kg ha^{-1}. Patel *et al.* (2009) observed that application of 40 kg ha^{-1} applied through gypsum in mustard was recorded significantly the highest uptake of sulphur by seed and straw. Raghuwanshi *et al.* (2009) conducted a field experiment during the *kharif* seasons of 2007 and 2008 at Shajapur, Madhya Pradesh. They investigated that grain and straw yields, protein content, oil content, net return and cost: benefit ratio of soybean increased with increasing sulphur rate. The highest oil content (20.54 kg ha^{-1}), protein content (38.03 kg ha^{-1}) and net return (25 560 ₹ ha^{-1}) and cost: benefit ratio (1:3.84) were obtained with 50 kg S ha^{-1}. At Madhya Pradesh the results showed that soybean responded significantly in terms of yield and quality up to 30 kg S ha^{-1}through single superphosphate. The treatment of 40 kg S ha^{-1} produced significantly higher uptake of N, P, K and S increased the available N, P_2O_5, K_2O and S in the soil (Chaurasia *et al*., 2009).

Prakasha *et al.* (2010) conducted a field experiment during the *kharif* season of 2006 to study the influence of graded levels of sulphur on seed yield, quality, available nutrients and uptake of soybean. Among the various treatments, maximum protein yield (871.25 kg ha^{-1}), oil yield (397.50 kg ha^{-1}), available phosphorus (50.4 kg ha^{-1}), available sulphur (26.5 kg ha^{-1}), uptake of nitrogen, phosphorus, potassium and sulphur (194.0, 21.8, 78.7 and 9.9 kg ha^{-1}, respectively) were recorded in treatment with application of sulphur at the rate of 40 kg ha^{-1}. In a field experiment was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka during 2008-09 reported that soybean fertizilised with application 20 kg sulhpur significantly increased the protein content and oil content of soybean (Farhad *et al.* 2010). Meena *et al.* (2011) conducted a field experiment during *kharif* 2007 and 2008 on Vertisols of Kota. They reported that soybean responded significantly to the application of sulphur (S) and boron (B). Among the sulphur levels, 30 kg S ha^{-1} increased protein and oil content of soybean. Results showed that application of 30 kg S ha^{-1} and 1 kg B ha^{-1} found suitable for obtaining higher productivity and quality of soybean. Varun *et al.* (2011) conducted a field experiment at Agronomy Farm, B.A. College of Agriculture, Anand Agricultural University, Anand revealed that sulphur showed the significant effect on quality and yield of soybean. Oil and protein content in soybean grain was significantly higher at application of 40 kg S ha^{-1} in form of gypsum. The grain and stover yield also significantly increased with same dose of sulphur, where oil and protein content were recorded as 22.7 and 35.9 per cent, respectively. A field experiment was conducted by Najar *et al.* (2011) to study the influence of sulphur levels on nutrient uptake and quality of soybean (*Glycine max* L. Merrill). The results showed that increasing levels of sulphur significantly increase the nutrient uptake and quality of soybean up to the application of 30 kg S ha^{-1} but maximum yield and quality of soybean was recorded under 40 kg S ha^{-1} which was at par with 30 kg S ha^{-1}. Application of 40 kg S ha^{-1} recorded highest total N, P, K, S, Ca and Mg nutrients uptake by soybean over the rest of the treatments. The available S at harvest in the soil increased significantly with S levels. Trivedi e*t al.* 2011 in a field experiment observed that the application of 40 kg sulphur ha^{-1} gave highest seed protein content and protein yield of soybean over control. Chhonkar and Shroti, 2011 reported that the N content and protein content in mustard crop seed significantly influenced by graded levels of sulphur and maximum values were recorded at 60 S ha-1 however, sulphur content in mustard seed increased significantly up to 80 kg S ha-1 and oil content and oil yield also significantly increased with same level of sulphur.

Devi *et al.* 2012 noticed that application of 30 kg sulphur ha^{-1} and 1.5 kg boron ha^{-1} were found to be the optimum levels of sulphur and boron for obtaining maximum oil and protein content, total uptake of sulphur and boron, net return, cost benefit ratio of soybean under upland condition as compare to other levels of sulphur and boron respectively. Patra *et al.* 2012 found that the application of sulphur @ 40 kg ha^{-1} significantly improved total chlorophyll content and oil content, as compared to other levels of sulphur application. Singh *et al.*, 2013 conducted a field experiment at Regional Research Station, Wadura, SKUAST-K in temperate Kashmir on brown sarson recorded that uptake of N, P and K increased significantly by the application of 40 kg S/ha which was statistically at par with 60 kg S/h however, oil content increased significantly from 38.7 per cent without S application to 42.0 per cent with 60 kg S/ha. Beneficial fatty acids such as oleic and linoleic acid contents increased whereas undesirable components such as erucic acid content decreased with increasing doses of sulphur. Sheoran *et al.* 2013 revealed that application of graded levels of sulphur showed significant enhancement in oil yield. The oil yield inceased by 8.0 per cent with S application at the rate of 20 kg S ha^{-1} and 10.4 per cent with 40 kg S ha^{-1} in comparison to without S application. Application of S up to 20 kg ha^{-1} also significantly increased the N, P, and S content by 0.12, 0.09 and 0.07 per cent in seed and 0.06, 0.01 and 0.04 % straw, respectively over without application of S. Further increase in S to 40 kg S ha^{-1} resulted non conspicuous increase in nutrient content. While application of 40 kg S ha^{-1}

resulted in 14.2 and 19.0 per cent higher N uptake, 26.2 and 17.1 per cent higher P uptake and 44.4 and 34.7 per cent higher S uptake in seed and straw, respectively in comparison to no S application.

Das *et al.* (2013) observed in three year experiment that the significantly higher oil content of groundnut recorded with the application of 60 kg S ha^{-1}. A 3-year field experiment was conducted at the Punjab Agricultural University, Ludhiana, during the rainy season of *(kharif)* 2006 to 2008. The quality of soybean was significantly influenced by sulphur treatments. The protein content of 2.8% and oil content of 1.8% were higher under S 40 treatments than S 10. The highest protein and oil content recorded under S 40 treatment was statistically at par with S 30 treatment but significantly higher than S 10 and S 20 treatments. (Hari Ram *et al.*, 2014).

2.3 EFFECT OF PSB

2.3.1 Growth characters

Sindhu *et al.* (2002) recorded maximum grains and nodulation, nitrogenase activity and plant growth at 40 DAS due to seed inoculation of bacillus strain MRS 12, MRS 18, MRS 22 and MRS 27. Inoculation of soybean with bacillus cereus strain UW 85 increased growth of roots, shoots, nodules and plant N accumulation. UW 85 increases nodulation in soybean indirectly by increasing root growth and not stimulating the nodulation process par-se (Vessey and Buss, 2002). Bullied *et al.* (2002) carried out field studies and reported that inoculation of soybean with bacillus cereus UW 85 resulted in stimulation of seed yield by 9 per cent, seed N content by 14 per cent over control. Dadhich, 2004 at Udaipur reported that the application of PSB inoculation of soybean seed significantly increased the number of nodule $plant^{-1}$ (46.30) at 45 DAS over control while the maximum number of nodule $plant^{-1}$ (50.18) recorded with PSB+VAM, which were significantly higher over other biofertilizer levels. Purbey (2004) reported that at Udaipur, the fenugreek seed inoculation with PSB increased the plant height, dry matter accumulation, number of branches $plant^{-1}$, number of nodules $plant^{-1}$ and their dry weight $plant^{-1}$ at 45 days after sowing as compare to uninoculated.

Rathore (2008) reported that the application of PSB inoculation of blackgram seed significantly increased the number of nodule $plant^{-1}$ (25.09) at 45 DAS over control while the maximum number of nodule $plant^{-1}$ (27.24) recorded with PSB+VAM which were significantly higher over other biofertilizer levels. The findings of Singh *et al.* (2010) reported that the effect of PSB has shown better results of plant growth promotion compare to non P solubilizing bacterial isolates in lentil. Influence of three phosphate solubilizing bacteria i.e. RMV1, RMV4 and RPB3 were evaluated on growth, seed yield and nodulation of soybean through seed inoculation under field conditions. Results of the study revealed that all these isolates had significant impact on plant growth in terms of field emergence, root length, plant height, nodule dry weight, number of branch and nodule $plant^{-1}$ and finally seed yield over control. Among these, RPB3 exhibited greatest influence by 24.31, 64.79, 26.89 and 32.69 % for germination, root length, plant height and number of branches plant^{-1} respectively (Singh *et al.* (2010).

Kushwaha and Zia-ul-hasan (2011) at Bhopal revealed that maximum root length (2.20 and 1.90 cm), shoot length (2.30 and 2.10 cm), the maximum plant height (92 and 96 cm), height of first branch (25.50 and 24.90 cm), maximum number of branches plant^{-1} (21) and maximum number of nodes on main branch (19) were observed under Azotobacter with PSB treatment in cultivar TKG-22 of sesame during both years. Banerjee et al. (2012) conducted a two years study at Burdwan, West Bengal and documented that application of Azotobactor and PSB recorded significantly higher leaf area index, crop growth rate and net assimilation rate, total biomass and harvest index in Indian mustard over control. A field experiment was conducted during *rabi* season of 2009-10 and 2010-11 on clay loam soils at Kota (Rajasthan) revealed that application of 100 % RDF(N80, P17.5, S60) + seed inoculation with Azotobacter+ PSB (AP) significantly increased plant height, number of primary and secondary branches/ plant of Indian mustard over control (Meena *et. al.* 2013). A field experiment was conducted in *kharif* 2008 and 2009 to assess the effect of phosphorus fertilization in conjunction with biofertilizers, viz. Phosphorus solubilizing bacteria (PSB) i.e. Pseudomonas striata and vesicular arbuscular mycorrhizae (VAM) on soybean. Results showed that the aplication of biofertilizers elicited significant response in terms of LAI and total dry matter accumulation. Maximum LAI (2.37) and total dry matter accumulation (10.68 g/plant) was recorded when full dose of P was supplied through RP along with biofertilizers (Munda *et. al.* 2013).

2.3.2 Yield and yield attributes

Dubey (1998) observed a significant increase in nodule numbers and seed yield of soybean due to inoculation with PSB. The per cent increase in seed yield due to PSB inoculation was 13.7 per cent over control (0.95 t ha^{-1} seed yield). Similar findings were reported by Kulkarni *et al.* (2000). The investigation conducted under the auspices of AICARP invariably revealed that out of 37 field trials, in 10 trials PSB inoculation significantly increased yield of rice, wheat,chickpea, pigeonpea, soybean, groundnut and berseem. The increase in yield ranged from 0 to 50 per cent over no inoculation. (Biswas *et al.* 2001). Dadhich, 2004 at Udaipur reported that the yield attributing characters, seed, stover and biological yield significantly higher with PSB inoculation of seed over without inoculation while the maximum seed (20.20 q ha^{-1}), stover (34.28 q ha^{-1}) and biological yield (55.48 q ha^{-1}) recorded with PSB+VAM which were significantly higher over other biofertilizer levels. Rathore (2008) reported that the yield attributing characters, seed, haulm and biological yield of blackgram significantly higher with PSB inoculation of seed over without inoculation while the maximum seed

(9.97 q ha^{-1}), straw (18.88 q ha^{-1}) and biological yield (28.86 q ha^{-1}) recorded with PSB+VAM which were significantly higher over other biofertilizer levels.

Pathak and Sharma (2010) conducted a two years experiment at Alwar, Rajasthan and found that use of Azotobactor or PSB independently recorded numerically higher seed yield of Indian mustard than untreated control. Experiments were carried out in pots and in the field during 2004 and 2005 under natural conditions at Quaid-I-Azam University, Islamabad and the results showed that co-inoculation of *Bradyrhizobium* and *Pseudomonas* strains with the P_2O_5 treatment in soybean resulted in increased seed yield of 38% in pot experiments and 12% in the field experiment, compared with the P_2O_5 treatment alone (Afzal *et al.*2010).

A field experiment was conducted in a typical lateritic soil, during the *rabi* season of 2009-2010 and 2010-2011 at Agricultural Research Farm, Institute of Agriculture, Visva-Bharati University, Sriniketan, India, reported that the combined inoculation of PSB+VAM+*Azotobacter* recorded higher values of yield attributes, *viz.* thalamus diameter, weight of thalamus, filled seeds $capitulum^{-1}$, and 100 seed weight (g), as well as seed and biological yield over other treatments (Patra *et al.* 2012). A field experiment was carried out at Raipur during 2005-2007 revealed that application of 30 kg P_2O_5/ha through rock phosphate + Phosphorus Solubilization Bacteria + Rhizobium Inoculation + Vasiculler Arbusculer Micorhizea registered significantly higher seed yield, net return and rupee invested in P compare to application of 60 kg P_2O_5 ha^{-1} through rock phosphate without Boifertilizers (Sarawgi *et al.* 2012). A field experiment was conducted during rabi season of 2009-10 and 2010-11 on clay loam soils at Kota (Rajasthan) revealed that thet application of 100 % RDF (N80, P17.5, S60) + seed inoculation with Azotobacter+ PSB (AP) significantly increased number of siliquae/plant, test weight, seed and stover yield, net returns (Rs. 37200/ha) and B: C ratio (2.64) of Indian mustard over control (Meena *et. al.* 2013). Munda *et. al.* 2013 obseved that the significant improvement in yield attributes of soybean was recorded with application of biofertilizers. Application of 100% P through RP along with biofertilizers recorded the highest number of pods $plant^{-1}$ (30.63), number of seeds pod^{-1} (2.57) and seed index (13.62) and seed yield (1.56 t ha^{-1}).

2.3.3 Nutrient content and uptake

Pal (1997) carried out a field experiment and reported that seed inoculation of indigenous PSB (PAS-2 strain of Bacillus spp.) significantly increased the soybean yield over control. Further study revealed that PSB inoculation significantly improved the available N and P status of soil after soybean harvest over control. Dubey (2001) observed enhanced available N and P in soil after soybean harvest when PSB (*Pseudomonas striata*) was inoculated. Favourable effect of phosphobactrium (*Bacillus megetherium* var. phosphaticum) inoculation on grain yield P content and P uptake by cowpea and available P status of soil after cowpea harvest were observed by Duraisami *et al.* (2001). Dadhich, 2004 at Udaipur reported that the N, P, K, Cu, Zn, Fe and Mn uptake by seed and straw significantly increased with PSB inoculation of seed over without inoculation while the maximum N, P, K, Cu, Zn, Fe and Mn uptake by seed and straw recorded with PSB+VAM which were significantly higher over other biofertilizer levels.

Purbey (2004) concluded that seed inoculation with PSB recorded significantly higher nitrogen, phosphorus content and uptake by seed over uninoculated. Rathore (2008) reported that the N, P, K, Cu, Zn, Fe and Mn uptake by seed and straw significantly increased with PSB inoculation of seed over without inoculation while the maximum N, P, K, Cu, Zn, Fe and Mn uptake by seed and straw recorded with PSB+VAM which were significantly higher over other biofertilizer levels.

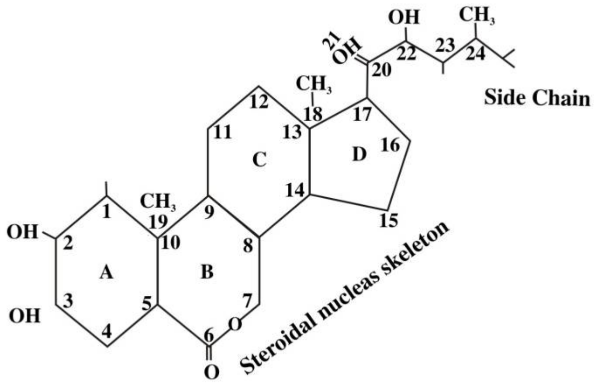
In a field experiment Patra *et al.* (2012) found that the combined inoculation of PSB+VAM+*Azotobacter* recorded significantly improved total chlorophyll content and oil content in soybean as compared to other treatment combinations. Meena *et. al.* 2013 obeseved that the application of 100 % RDF(N80, P17.5, S60) + seed inoculation with Azotobacter+ PSB (AP) significantly increased the oil content and oil yield (1,034 kg/ha) of Indian mustard over control. Munda *et. al.* 2013 reported that protein content and yield of soybean increased significantly with P application and biofertilizers. Protein content was maximum (38.89%) with the application of 100% P through RP along with biofertilizers. Treatments where biofertilizers were applied in combination with P fertilizer recorded higher protein content in soybean seed than when applied alone.

2.4 EFFECT OF PGR

2.4.1 Brassinolide

2.4.1.1 Growth characters

Brassinosteroids (BRs) are a group of naturally occurring polyhydroxy steroids with growth promoting activity, initially isolated from *Brassica napus* pollens (Grove *et al.*, 1979). Recent findings of BRs bio-synthetic mutant in *Arabidopsis thalamia* have provided sufficient evidence that BRs are essential for plant growth and development and thus regarded as a new class of plant hormones in addition to auxin, gibbrelines, cytokinins, abscic acid and ethylene (Choe *et al.,* 1997). Among naturally occurring BRs, brassinolide (BR_1) are considered to be the most important because their wide distribution as well as due to its potent biological activity.The ‘brassinolide’ was found to be a steroidal lactone with empirical formula of $C_{28}H_{48}O_6$. All brassinosteroid contains a steroidal nucleus with the oxygen function in ‘B’ ring and a side chain at D_{17}, similar to the side chain in plant sterol-Among naturally occurring BRs, brassinolide (BR_1) are considered to be the most important because their wide distribution as well as its potent biological activity.



Results of a two years experiment concluded by Chaplot (2000) at Udaipur (Rajasthan) revealed that foliar spray of 0.25 ppm BR at maximum tillering and ear emergence stages of wheat significantly enhanced seed, stover and biological yield to the tune of 7.11, 7.77 and 7.43% over water spray control, respectively. Hayat *et al.* (2001) while working at Aligarh, Uttar Pradesh reported that spraying 10−8 M of HBR (28 homobrassinolide) on 60 days old mustard plants generated significantly higher dry mass, chlorophyll content, photosynthetic rate, pods plant^{-1} and seed yield plant^{-1} than IAA.

Shivkumar *et al.* (2002) at Coimbatore observed that foliar spray of 0.1% brassinosteroid on pearl millet at 30 and 40 DAS significantly increased total chlorophyll content and protein content than control. Senthil *et al.* (2003) at Coimbatore observed that foliar application of brassinosteroid @ 0.1 ppm increased root and shoot length of rice than control. Mehta (2004) in a two years study at Udaipur concluded that foliar application of brassinosteroid (0.4 ppm) at anthesis and 15 days after anthesis in Indian mustard significantly improved the growth parameters (plant height, number of branches plant^{-1} and DMA at successive growth stages and chlorophyll content at 80 DAS) than water spray. He further reported that application of brassinosteroids significantly increased the dry matter partitioning towards pods and leaves at 50% pod development and physiological maturity which increased overall higher dry matter production plant^{-1} to the tune of 35.1% than control.

In an experiment at Udaipur, Kanojia (2006) reported that foliar spray of 0.25 PPM brassinolide in soybean at 30 and 60 DAS significantly improved the plant height, branches plant^{-1}, dry matter accumulation at successive growth stages and crop growth rate over water spray. At Udaipur, foliar application of brassinosteroid (0.4 ppm) recorded 35.1% higher dry matter plant^{-1} of mustard compared to control (Mehta *et.al*, 2006). Similarly, application of homobrassinolide (0.5 ppm) at 30, 45 and 60 DAS in sesame crop recorded significantly increased plant height (95.20 cm), number of leaves (87.56), CGR (11.11gm^{-2}day^{-1}) , RGR (0.629 gg^{-1}day^{-1}) and dry matter accumulation (29.67 g plant^{-1}), chlorophyll (1.496 mg g^{-1}fresh weight), soluble protein (11.98 mg g^{-1}), reducing sugar (6.456mg g^{-1}) and catalase (3.885 units g^{-1} tissue) over control (Prakash *et.al.*, 2007). Shahbaz and Ashraf (2007) in a pot experiment in Pakistan evaluated effect of foliar spray of BR (24-epibrassinolide) (0, 0.0125, 0.025 and 0.0375 mg litre^{-1} of water) on wheat and reported that exogenous application of BR increased plant biomass and growth under both saline and non-saline conditions. Prakash *et al.* (2008) in an experiment at Coimbatore (Tamil Nadu) in sesame found that out of various concentrations (0.25, 0.5 and 1.0 ppm) of BR (28-homobrassinolide) and control 30, 45 and 60 DAS; application of 1.0 ppm BR recorded maximum performance of plant height (61.2, 90.10, 95.20 cm), leaves plant^{-1} (63.00, 87.21, 87.56), branches plant^{-1} (3.9, 6.5, 8.5), LAI(1.231, 1.496, 1.532), CGR (9.92, 10.01, 11.11 g m^{-2} day^{-1}), RGR (0.612, 0.723, 0.629 g g^{-1} day^{-1}) and dry matter plant^{-1} (3.01, 4.72, 29.67 g). However, variations in plant height (30, 45 and 60 DAS), branches plant^{-1} (45 and 60 DAS), leaves plant^{-1} (45 and 60 DAS), LAI (30 and 60 DAS), dry matter plant^{-1} (30, 45 and 60 DAS), CGR (60 DAS), NAR (60 DAS) and RGR (45 and 60 DAS) were at par with foliar application of 0.5 ppm BR.

Sharma (2008) reported that foliar spray of brassinolide 0.5 ppm recorded significant improvement in plant height (97.26 cm), dry matter accumulation (11.57 t ha^{-1}), and chlorophyll content (2.58 mg g^{-1} fresh weight) over control. In a field experiment at Udaipur Ameta, (2009) found that the foliar application of brassinostroid recorded significantly higher plant height, dry matter accumulation, number of branches plant^{-1}, and higher CGR and RGR between 30-60, 60-90 and 90 DAS to at harvest over control. Meena (2011) conducted a two year experiment and found that foliar spray of brassinosteroid significantly increased plant height, number of primary, secondary and total branches plant^{-1} and dry matter accumulation plant^{-1} at successive growth stages and also recorded higher CGR and RGR between 30-60 DAS, 60-90 DAS and 90 DAS to harvest over control on pooled basis. Meena *et al.* (2013) at Udaipur (Rajasthan) found that BR (0.40 ppm) recorded significantly higher plant height, dry matter accumulation and CGR, RGR, NAR and leaf chlorophyll content of Indian mustard over control. Asha *et al.* (2014) evaluated BR (24-epibrassinolide) induced response on exogenous application of hormone in *Brassica juncea* and reported that application of BR (1 micro M and 1.5 micro M) significantly enhanced seed germination, inter node length (not root length), growth and biochemical parameters (soluble protein, glucose content and beta amylase activity). The hormone was proved to be physiologically and biochemically efficient in improving the vegetative growth of *Brassica*.

2.4.1.2 Yield and yield attributes

Krishnan *et al.* (1999) at Goa, reported that foliar application of brassinosteroid at vegetative stage, panicle initiation and anthesis stage resulted in increased number of fertile tillers, number of spikelets, fresh weight 100 grains and dry weight of 100 grains of rice by 68.7, 48.5, 64.2, 23.2 and 26.4 per cent, respectively over control. Similarly, brassinosteroid sprayed plants recorded the highest per cent of spikelet fertility (86.9 %) and number of spikelet penicle^{-1} (140). This resulted in a significant increase in grain yield of rice over control (Maibangsa *et al.* 2000). Two year experiment conducted by Chaplot (2000) at Udaipur revealed that foliar spray of 0.25 PPM brassinosteroids at maximum tillering and ear emergence stages of wheat significantly enhanced the grain, straw and biological yield of wheat by 7.11, 7.77 and 7.43 per cent over control, respectively. Studies at Coimbatore demonstrated that foliar application of brassinolide @ 0.1 ppm at 40 and 60 DAS to sunflower cultivar Co-4 recorded 0.79 per cent increase in yield over control (Velu, 2002). Shivakumar *et al.* (2002) noticed that brassinosteroid sprayed plants recorded maximum yield of pearl millet (3591 kg ha^{-1}), while control plots recorded yield only 3018 kg ha^{-1}. The yield in this treatment was found 18.98 per cent over control. Mehta (2004) in a two year study at Udaipur concluded that foliar application of brassinosteroid also significantly improved the yield attributes (siliquae plant $^{-1}$, seeds siliqua $^{-1}$ and test weight) which increased the mean seed and stover yield by 58.5 and 48.3% over control, respectively.

At RCA, Udaipur, purbey and Sen (2005) conducted a two year experiment and found that foliar spray of brassinosteroid at 0.5 ppm significant increased number of pods $plants^{-1}$ seeds pod^{-1}, pod length, test weight, seed and straw yield of fenugreek as compared to water spray. The increase in seed yield on pooled basis was found to the extent of 26.71 per cent over water spray. In an experiment at Udaipur, Kanojia (2006) reported that foliar spray of 0.25 ppm brassinolide in soybean at 30 and 60 DAS significantly improved yield attributes (pods $plant^{-1}$ seeds pod^{-1} and 1000 seed weight), grain yield, straw yield and harvest index over water spray. Prakash *et al.* (2007) also reported a significant improvement in yield, yield attributes and harvest index of sesame due to foliar spray of 0.5 ppm brassinolode at 30, 45 and 60 DAS. Prakash *et al.* (2008) in an experiment at Coimbatore (Tamil Nadu) in sesame found that out of various concentrations (0.25, 0.5 and 1.0 ppm) of BR (28-homobrassinolide) and control 30, 45 and 60 DAS; application of 1.0 ppm BR recorded maximum performance of capsules $plant^{-1}$ (98), seeds $capsule^{-1}$ (40.7), capsule weight (0.67 g $capsule^{-1}$), 1000 seed weight (2.17 g), seed yield $plant^{-1}$ (5.24 g), harvest index (36.58). However, variations in capsules $plant^{-1}$, seeds $capsule^{-1}$, capsule weight $plant^{-1}$, 1000 seed weight and harvest index were at par with foliar application of 0.5 ppm BR. Sharma (2008) at Udaipur found that foliar spray of brassinolide in wheat significantly increased yield attributes, seed yield (14.60 q ha^{-1}), stover yield (33.90 q ha^{-1}), biological yield (48.50 q ha^{-1}), net returns (Rs. 17174 ha^{-1}) and benefit cost ratio (1.74) over control. Ameta (2009) at udaipur reported that foliar application of bassinostroid recorded significantly higher siliqua $plant^{-1}$, seeds $siliqua^{-1}$, test weight, seed yield $plant^{-1}$, seed, stover and biological yield of mustard over control. Meena (2011) at Udaipur observed that the application of brassinolide produced significantly better yield attributes *viz.* siliqua $plant^{-1}$ seeds $siliqua^{-1}$ and 1000 seed weight as well as seed, stover, biological and oil yield compared to control. Sharma *et al.* (2012) in a field experiment on wheat at Udaipur (Rajasthan) found that application of BR (0.50 mg I^{-1}) recorded maximum increment in seed yield (14.10 per cent) over control. Among bio-regulators, BR provided the maximum net return (₹ 47,292 ha^{-1}) and benefit: cost ratio (3.37) which was significantly higher than control. Ananthi *et al.* (2013) in a field experiment at Coimbatore (Tamil Nadu) found that leaf chlorophyll content, total chlorophyll and seed yield of green gram were significantly improved on foliar spray of 0.1% humic acid + 0.1 ppm BR over water spray. Chaplot and Ameta (2014) at Udaipur (Rajasthan) compared effect of water spray and BR on growth, yield attributes and yield of two varieties of Indian mustard. They found that foliar application of BR (0.4 ppm) at branching and flowering proved to be the most effective and significant in increasing the seed yield that corresponded to 17.6% over water spray. Ameta *et al.* (2014) at Udaipur (Rajasthan) found that foliar application of BR recorded significantly higher seed, stover yield and biological yield over control. The per cent increase in seed, stover and biological yields over water spray were 17.63, 22.11 and 20.97, respectively.

2.4.1.3 Nutrient content and uptake

Kumawat (1996) reported that application of brassinosteroid @ 0.4 ppm in mustard significantly increased oil content (38.43%) and oil yield (5.82 g ha^{-1}) of mustard as compared to control. Chaplot (2000) observed that foliar application of 0.25 ppm brassinosteroid at maximum tillering and ear emergence stages in wheat significantly improved contents of N , Zn and S in grain, while in straw, it increased the contents of N, K and S over control (Water spray). Further, brassinosteroid application significantly enhanced uptake of N, P, K, S and Zn in grain as well as straw. In another experiment, Shivkumar *et al.* (2002) observed increased protein content (9.87 %) as compared to control (9.45 %), when brassinosteroid was sprayed on pear millet. Senthil *et al.* (2003) in a two years study at Coimbatore concluded that foliar application of 0.1 ppm brassinolide significantly increased root and shoot length and soluble protein content of rice. While conducting two year trial at Udaipur, Purbey and Sen (2005) reported that with foliar spray of brassinosteroid at 0.25 and 0.5 ppm N, P and protein content of fenugreek was found significantly superior over control. Further, they also found that brassinosteroid at 0.5 ppm increased N, P and protein content of fenugreek by 3.94, 5.34 and 3.66 per cent, respectively over control. At Udaipur, Kanojia (2006) reported that by application of 0.25 ppm brassinolide at 30 and 60 DAS enhanced protein content (19.32%) and oil yield (18.24 %) in soybean over control. Prakash *et al.* (2008) in an experiment at Coimbatore (Tamil Nadu) in sesame found that out of various concentrations (0.25, 0.5 and 1.0 ppm) of BR (28-homobrassinolide) and control 30, 45 and 60 DAS; application of 1.0 ppm BR recorded maximum performance of chlorophyll content (0.596, 0.892, 1.496 mg g^{-1}), soluble protein (9.81, 11.98, 11.01 mg g^{-1}) and oil content (52.86%). However, variations in chlorophyll content (60 DAS), soluble protein (45 and 60 DAS) were at par with foliar application of 0.5 ppm BR. Spraying 1.0 ppm BR thrice also increased sugar, soluble protein, catalase and peroxidase activities. Ameta (2009) conducted a two year experiment at Udaipur and observed that foliar application of brassinosteroid recorded significantly higher N and P concentration in seed and stover and N,P,K,S, and Zn accumulation by seed, stover and total uptake by crop over control. Further, oil content and its yield were recoerded higher with foliar application of brassinostroid over thiourea and control.

Hnilicka *et al.* (2009) studied the influence of 24-epibrassinolide on chemical structure and energy content in wheat grains (cv. Ebi, Estica, Samanta, AC Helena, Mollera and Lucia). The application of 24-epibrassinolide in stress conditions has positive effect on the monitored parameters (content of lipids, proteins, enzyme determination of total starch, energy content). Rajavel and Vincent (2009) reported that among different PGRs including IAA; foliar application of brassinosteroid 0.1 ppm significantly improving quality characters, total chlorophyll content (4.6%) and minimizing reduction in total chlorophyll at maturity of pearl millet than other treatments. Eleiwa and Ibrahim (2011) studied the effect of irrigating saline water at levels (0. 2000, 4000 and 6000 ppm NaCl solution and rates of BRs "28-homBL" (0, 50, 100 and 200 mg/L)) on chemical components and nutrients status in grains and straw of wheat plant (*Triticum aestivum* L). Salinity reduced sugar (reducing and non-reducing), total carbohydrate and protein percentage of wheat grains while foliar application with BRs significantly increase gradually all the chemical constituents under study as compared with control. BRs also significantly increased the concentration and total uptake of macro and micronutrients (N, P, K, Fe, Mn, Zn and Cu) in straw and grains of wheat plants at harvest. Meena (2011) at Udaipur found that foliar application of brassinolide increased leaf chlorophyll, relative water content and water use efficiency as compared to control. Sharma *et al.* (2012) in a field experiment on wheat at Udaipur (Rajasthan) found that application of BR (0.50 mg I^{-1}) significantly enhanced uptake of nutrients (N, P, K, S & Zn) over control. Vardhani *et al.* (2012) at Nizamabad (Andhra Pradesh) in a clay pot green house experiment (maintaining the natural conditions) confirmed certain physiological and metabolic roles of BRs in radish. They reported that use of 0.5, 1.0 and 3.0 u M BRs (24-epibrassinolide and 28-homobrassinolide) in radish 20th, 35th and 50th day stage elevated soluble proteins, nucleic acids (DNA and RNA) and carbohydrates (reducing sugars, non - reducing sugars and starch). Chaplot and Sumeriya (2013) at Udaipur (Rajasthan) found that foliar spray of BR (0.25 ppm) significantly enhanced leaf chlorophyll content which corresponded to 30.0, 31.6 and 30.0% 40, 55, and 70 DAS over water spray, respectively. Ameta *et al.* (2014) at Udaipur (Rajasthan) found that foliar application of BR recorded significantly higher total N, P, K, S and Zn uptake by 23.49, 23.73, 22.31, 20.06 and 21.00 per cent, respectively over water spray.

2.4.2 Benzyladenine

2.4.2.1 Growth characters

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

Vaid and Ranwah (2003) on mustard reported that the best growth was observed with 2.0 mg benzyladenine litre^{-1} 40 and 50 days after inoculation. The highest number of shoots were obtained with 5.0 mg benzyladenine liter^{-1}. While, at Udaipur, Menaria (2005) conducted a two year experiment and observed that foliar application of banzyladenine at 10 ppm significantly increased dry matter of fennel at 80, 120 DAT and at harvest over water spray during both years of study. Primary, secondary and tertiary branches were also increased significantly through benzyladenine spray as compared to control. Kanojia (2006) reported that foliar spray of benzyladenine in soybean recorded number of braches plant^{-1} and dry matter accumulation, CGR and RGR significantly superior over water spray and KCL. Meena (2011) at Udaipur, conducted a two year experiment and found that foliar spray of benzyladenine significantly increased plant height, number of primary, secondary and total branches plant^{-1} and dry matter accumulation plant^{-1} at successive growth stages and also recorded higher CGR and RGR between 30-60 DAS, 60-90 DAS and 90 DAS to harvest over control on pooled basis. Foliar spray of benzyladenine @ 50 ppm, significantly improved dry matter accumulation, leaf area index, number of green leaves, total chlorophyll content and CGR over water spray. (Kaswan 2013).

2.4.2.2 Yield and yield attributes

At Goa, Krishan *et al.* (1999) conducted an experiment on IR-50 Indica rice and found that application of benzylaminopurine significantly increased the yield attributes *viz.*, number of fertile tillers, total number of spikelets, number of filled spikelets, fresh and dry weight of 100 grains by 22.5, 15.4, 27.3, 16.9 and 20.9 per cent, respectively over control. Similarly, Patil *et al.* (2002) at Nagpur carried out an experiment and found that 6-benzyladenine had effectively improved all the yield parameters governing yield in soybean. Foliar application of 50 ppm 6-benzyladenine significantly increased pods plant^{-1} seeds pod^{-1} and seed yield plant^{-1} then water spray. Hence, a considerable improvement to the extent of 36.0 per cent incease in yield was achieved by 50 ppm concentration of 6- benzyladenine over control (10.69 q ha^{-1}). Likewise, Menaria (2005) conducted a two year investigation and reported that foliar application of benzyladenine 10 ppm significantly increased number of umbels plant^{-1}, seeds umbel-lets^{-1}, seed yield plant^{-1}, weight of 1000 seeds, seed, stover and biological yield of fennel over water spray during both the years of research. At Udaipur Kanojia (2006) conducted an experiment during *kharif* 2003-2004 and reported that benzyladenine significantly enhanced soybean yield characters *viz.* number of pods plant^{-1}, number of seed pod^{-1}, seed index and seed and straw yield respectively over control.

In an experiment at Udaipur, Kanojia and Sharma (2008) reported that foliar spray of 40 PPM benzyladenine in soybean at 30 and 60 DAS significantly improved yield attributes (pods plant^{-1}, seeds pod^{-1} and 1000 seed weight), grain yield, straw yield and harvest index over water spray. Meena (2011) at Udaipur observed that the application of benzyladenine produced significantly better yield attributes *viz.* siliqua plant^{-1}, seeds siliqua^{-1} and 1000 seed weight as well as seed, stover, biological and oil yield compared to control. Kaswan (2013) at Udaipur revealed that yield attributes *viz.*, pods plant^{-1}, seeds pod^{-1}, pod length and seed yield plant^{-1} were significantly improved by benzyladenine over water spray. These consequently results in increase of seed and biological yield by 10.87 and 10.69 per cent over water spray, respectively.

2.4.2.3 Nutrient content and uptake

In a pot experiment, Singh *et al.* (1994) reported that treatment of groundnut seeds with benzyladenine significantly increased nitrogen content in stover over control. At jobner, Yadav *et al.* (1997) conducted an experiment on two gram genotypes, ‘C-235’ (susceptible) and ‘RSG-143-1’ (moderately susceptible to water stress) grown in earthen pots and found that foliar application of benzyladenine @ 465 uM alleviated the adverse effect of water stress partly, in both the genotypes especially in ‘RSG 143-1’ by stimulating the accumulation of proline, amino acid content of leaves at 55 DAS was found significantly higher in both the genotype over untreated stressed plants, when plants were treated with benzyladenine @ 465 uM. Similarly, Patil *et al.* (2002) at Nagpur found that foliar application of benzyladenine at @ 50 ppm increased leaf chlorophyll by 10.1 and 13.8 per cent as compared to control (1.170 and 1.252 mg g^{-1}) at 45 and 60 DAS, respectively. Arun *et al.* (2003) failed to observe any significant effect on N, P and K content of rose leaves to application of benzyladenine increasing concentration of from 500 to 1500 ppm. Likewise, Menaria (2005) conducted a two year trial and concluded that foliar application of benzyladenine at 10 ppm significantly increased protein content and volatile oil content of fennel over water spray. Kanojia (2006) reported that foliar spray of benzyladenine in soybean significantly improvement of relative water content and proline content as compare to control. In another experiment at Udaipur, Meena (2011) reported that foliar spray of 40 ppm benzyladenine in soybean at 30 and 60 DAS significantly improved protein content and oil content over water spray.

Kaswan (2013) at Udaipur revealed that the foliar spray of benzyladenine @ 50 ppm significantly improved protein and oil content and their yield, nitrogen and phosphorus content and their uptake over water spray.

3. MATERIALS AND METHODS

The present investigation entitled **"Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]"** was carried out during *Kharif* seasons of 2013 and 2014 at the Instructional Farm, Department of Agronomy, Rajasthan College Agriculture, Udaipur. The details of the materials used, procedure followed and criteria adopted for evaluation of treatments during the course of investigation are described in this chapter.

3.1 LOCATION OF EXPERIMENTAL SITE

The experiment was conducted during the *kharif* 2013 and 2014 at Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, Udaipur (Maharana Pratap University of Agriculture and Technology, Udaipur) which is situated in the step foot of Aravali hills at $24^{0}35$ N latitude and $72^{0}42$ E longitude and at an elevation of 582.17 m above mean sea level. This region falls under agro-climatic zone IV a (Sub-Humid Southern Plains and Aravali Hills) of Rajasthan.

3.2 CLIMATE AND WEATHER CONDITIONS

This region has a typical semi- arid and sub-tropical climate characterized by mild winter and moderate summers, associated with high relative humidity especially during the months of July to September. The mean weekly meteorological observations recorded at the meteorological observatory of the Department of Agronomy, Rajasthan College Agriculture, Udaipur, during the season (*kharif* 2013 and *kharif* 2014) have been appended in Appendix I and the graphic presentation of the same has been given in (Fig. 3.1 & 3.2). A critical resume of meteorological data shows that a total rainfall received during the crop season of the *kharif* 2013 and *kharif* 2014 was 745 and 648 mm, respectively. Soybean crop experienced maximum and minimum temperature in the range of 27.1^{o} C to 34.6^{o} C and 14.9^{o} C to 25.8^{o} C, respectively during *kharif* season 2013 and 27.8^{o} C to 36.4^{o} C and 17.6^{o} C to 27.0^{o} C, respectively in the *kharif* season 2014.

3.3 PHYSICO-CHEMICAL PROPERTIES OF SOIL

The soil samples were drawn from different spots of the experimental site at a depth of 0-15 cm before experimentation and a composite soil sample was prepared, after proper drying, mixing and sieving. The composite soil samples for two years of experimentations were analysed for different physico-chemical characteristics of the soil. The soil of the experimental field was clay loam in texture, slightly alkaline in reaction, medium in organic carbon, available nitrogen, phosphorus and high in available potassium (Table 3.3).

Table 3.3 Physico-chemical properties of the soil of experimental site

Particulars	Values		Method of analysis	References
	2013	2014		
A. Mechanical analysis				
Sand (%)	38.26	37.32	Hydrometer method	Bouyoucos (1962)
Silt (%)	25.19	26.22		
Clay (%)	35.66	35.54		
Textural class	Clay loam	Clay loam	Triangular diagram	Brady (1983)
B. Physical analysis				
Bulk density (Mg m^{-3})	1.36	1.38	Core sampler method	Piper (1950)
Particle density (Mg m^{-3})	2.66	2.63	Core sampler method	Black (1965)
Porosity (%)	48.87	47.53	Core sampler method	Black (1965)
C. Chemical analysis				
pH (1: 2.5; soil: water)	7.67	7.54	Glass electrode pH meter	Piper (1950)
EC (dS/m^{-1} at 25^{o} C)	1.14	1.07	Conductivity bridge meter	Richards (1968)
Organic carbon (%)	0.71	0.73	Rapid titration method	Walkley and Black (1947)
Available nutrients (kg ha^{-1})				
Nitrogen (N kg ha^{-1})	296.14	301.27	Alkaline $KMnO_4$ method	Subbiah and Asija (1956)
Phosphorus (P_2O_5 kg ha^{-1})	21.52	22.79	Olsen's method	Olsen *et al*, (1954)
Potassium (K_2O kg ha^{-1})	344.33	346.61	Flame Photometer method	Richards (1968)
Sulphur (S kg ha^{-1})	8.6	8.8	Ammonium acetate-acetic acid extraction method	Black (1965)

3.4 CROPPING HISTORY

The experimental field was under continuous cropping during both the seasons for last 4-5 years. The commercial maize and wheat were grown on the experimental area in *kharif* and *rabi* seasons, respectively with recommended practices during 2011-12 and 2012-2013, followed by the present experiment during *kharif* seasons of 2013 and 2014.

3.5 EXPERIMENTAL DETAILS

3.5.1 Treatment details

The experiment consisted of 30 treatment combinations comprising 10 nutrient management (phosphorus, sulphur and PSB combinations) and three growth regulators *viz*., control (water spray), Brassinolide (0.4 ppm) and Benzyladenine (40 ppm). The details of treatments are:

A. Nutrient management

N_0 Absolute control

N_1 75 % RDP

N_2 100 % RDP

N_3 125 % RDP

N_4 75% RDP + 30 kg S ha^{-1}

N_5 100 % RDP + 30 kg S ha^{-1}

N_6 125 % RDP + 30 kg S ha^{-1}

N_7 75% RDP + 30 kg S ha^{-1} + PSB

N_8 100 % RDP + 30 kg S ha^{-1} + PSB

N_9 125 % RDP + 30 kg S ha^{-1} + PSB

B. Growth regulators

G_0 Water spray

G_1 Brassinolide (0.4 ppm) at 30 and 60 DAS

G_2 Benzyladenine (40 ppm) at 30 and 60 DAS

Plan of layout along with treatment allocation is depicted in Fig. 3.3.

3.5.2 Other experimental details

(i)	Total no. of treatment combinations	:	10 x 3 = 30
(ii)	No. of replications	:	3
(iii)	Experimental design	:	SPD (Split Plot Design)
	Main plot	:	Nutrient management
	Sub plot	:	Growth regulators
(iv)	Plot size		
	Gross	:	5.0 m X 3.0 m = 15 m^2

	Net	: $4.0 \text{ m} \times 2.4 \text{ m} = 9.6 \text{ m}^2$
(v)	Crop	: Soybean
(vi)	Variety	: JS 93-05
(vii)	Spacing	: $30 \times 10 \text{ cm}^2$
(viii)	Crop season	: Kharif 2013 and 2014
(ix)	Source of fertilizers	
	Nitrogen	: Urea (46% N)
	Phosphorus	: DAP (46% P_2O_5 & 18 N)
	Potassium	: MOP (60% K_2O)
	Sulphur	: Gypsum (18.6 % S & 23% Ca)

3.6 DETAILS OF CROP RAISING

The schedule of field operations performed for raising the crops is given below in Table 3.4.

3.6.1 Field preparation

After the harvesting of preceding commercial wheat crop, the experimental field was prepared by ploughing once with tractor drawn disc plough followed by cross harrowing and planking during the both years of experimentation. Then all the plots were demarcated and prepared according to layout (Fig 3.3).

Table 3.4 Schedule of field operations carried out during crop growth period

S. No.	Operations	Date	
		2013	2014
1.	Field preparation	29.06.2013	27.06.2014
2.	Layout and bunding	03.07.2013	29.06.2014
3.	Furrow opening	04.07.2013	30.06.2014
4.	Fertilizer application and sowing	05.07.2013	01.07.2014
5.	Pre-emergence application of Pendimethalin @ 1.50 kg a.i. ha^{-1}	06.07.2013	02.07.2014
6.	Post emergence application of Imezethapyr @ 75 g a.i. ha^{-1}	22.07 2013	16.07. 2014
7.	Thinning	28.07.2013	24.07.2014
8.	Hoeing and weeding	02.08.2013	29.07.2014
9.	First foliar spray of growth regulator	05.08.2013	01.08.2014
10.	First irrigation	03.09.2013	02.10.2014
11.	Second foliar spray of growth regulator	05.09.2013	01.09.2014
12.	Methyl parathion dusting	12.09.2013	09.09.2014
13.	Harvesting	16.10.2013	12.10.2014
14.	Threshing and winnowing	21.10.2013	18.10.2014

3.6.2 Fertilizer application

(i) Nitrogen

A uniform basal dose of 25 kg N ha^{-1} through urea was drilled at the time of sowing to all the plots after subtracting the nitrogen supplied through DAP as per treatment of phosphorus.

(ii) Phosphorus

Phosphorus application was made as per treatments through DAP in respective plots. They were applied just before sowing, in furrows at 2 to 3 cm below the seeds. However the recommended dose of phosphorus is 40 kg ha^{-1} in soybean for the zone.

(iii) Potassium

The crop was supplied with a uniform dose of 30 kg K_2O ha^{-1} at the time of sowing through Muriate of Potash.

(iv) Sulphur

Sulphur was applied through gypsum as per treatment before sowing and incorporated in soil.

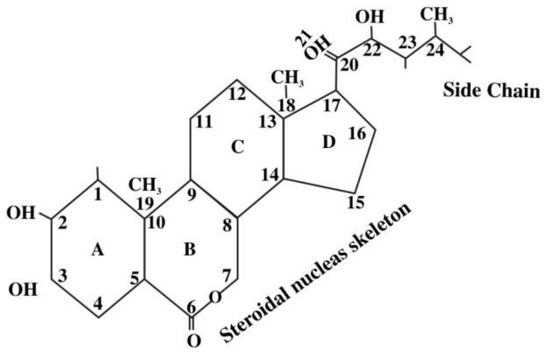
3.6.3 Agrochemicals

The foliar sprays of each agrochemical {Brassinolide (0.4 ppm), Benzyladenine (40 ppm) and water spray in control} were made at two growth stages *viz*., first at 30 DAS and second at 60 DAS as per treatment. Brassinolide was directly dissolve in water, however, Benzyladenine was first solubilised in alcohal then it was dissolved in water. All the agrochemicals were sprayed through knapsack sprayer fitted with flat fan nozzle using spray volume of 600 litres ha^{-1} during both the years of experimentation. In order to make sprays more effective, these were carried out either during morning or evening hours (avoiding noon hours). Teepol was mixed @ 0.5 ml $litre^{-1}$ with spray solution as a sticking agent. Details of these growth regulators are given as under:

(i) Brassinosteroid

Active ingredient - Brassinolide (BR_1)

Structural formula

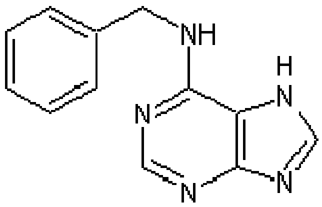


Mode of action - Stimulation of elongation and fission, effect on hormonal balance, effect on enzyme activity: H^+ pump activation and activation of protein and nucleic acid synthesis.

(ii) Benzyladenine (BA)

Chemical name: (E)-2-Methyl-4-(1*H*-Purin-6-Yl amino)-2-buten-1-01

Structural formula:



Mode of action: BA has cytokinins like activity. It stimulates cell division and delay senescence. It increases fruit set and improves their size and shapes.

3.6.4 Seed treatment and sowing

The seeds of soybean variety JS 93-05 were treated with Bavistin @ 2 g kg^{-1} seed in order to avoid fungal infection. *Rhizobium japonicum* culture inoculation was also done uniformly @ 5 g kg^{-1} seed just before the sowing. The bacterial inoculation through PSB (*Bacillus megetherium*) was done as per treatment just before sowing @ 5 g/kg seed. The sowing was done in furrows 30 cm apart and seeds were placed at a depth of 2 to 3 cm using seed rate of 80 kg ha^{-1}.

3.6.5 Weed management

Pre-emergence application of Pendimethalin @ 1.5 kg a.i. ha^{-1} and post emergence of Imazethapyr @ 75 g a.i. ha^{-1} was done in order to minimize weed infestation. One hoeing was also done at 30-35 DAS.

3.6.6 Plant protection

In order to minimize the infestation of crop pests, dusting of Methyl parathion 2 % @ 25 kg ha^{-1} was done at 60 DAS.

3.6.7 Irrigation

One irrigation was applied on 03.09.2013 during *kharif* 2013 and on 02.10.2014 during *kharif* 2014

3.6.8 Harvesting and threshing

The crop was harvested in the second fortnight of October when pods turned yellow and before shattering started. The crop was cut close to ground and the produce of net plot was tied in bundles and taken to the threshing floor. After proper drying, the bundles were weighed to record biological yield. Thereafter economical yield (seed yield) was obtained by threshing the crop and expressed in the term of qha^{-1}.

3.7 TREATMENT EVALUATION

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

3.7.1 Plant population:

Numbers of plants in one meter row length from five randomly selected points in each experimental unit were counted after thinning at 30 DAS and at crop maturity. These were averaged and expressed in lakh ha^{-1}.

3.7.2 Growth parameters

3.7.2.1 Plant height: Height of five randomly selected plants in each experimental plot was measured from base to the tip of main axis at 30, 60, 90 DAS and at harvest and averaged out and expressed in cm.

3.7.2.2 Dry matter accumulation: Five randomly selected plants from each plot at 30, 60, 90 DAS and at harvest were separated and taken in paper bags separately and thereafter dried in sunlight. Later on, these sun dried samples were chopped and kept in an oven at 70ºC temperature till achieved constant weight. The average dry matter was computed and expressed as g plant^{-1}.

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

3.7.2.4 Number and weight of nodules plant^{-1}: Five plants were dugout at 60 DAS and then roots were washed gently and thoroughly with water in sieve. The nodule were counted and expressed as number of nodules plant^{-1} and their corresponding weight after drying in oven to obtain constant weight was recorded on electric weighing machine precisely. The average was calculated and expressed as nodules dry weight plant^{-1} (mg/plant).

3.7.3 Growth indices

3.7.3.1 Leaf area index (LAI): At 30 60 and 90 DAS, leaves from five randomly selected plants from each experimental plot was detached. The leaves were directly measured in term of area on leaf area meter in order to work out total leaf area per plant. LAI was computed as suggested by Watson (1952) by using following formula.

$$Leaf\ area\ index\ (LAI) = \frac{Total\ leaf\ area\ per\ plant(cm2)}{Land\ area\ covered\ \ per\ plant(cm2)}$$

3.7.3.2 Crop growth rate (CGR)

The rate of increase in dry matter per unit ground area per unit time was computed and expressed in g m^{-2} day^{-1} suggested by Watson (1958) cm^{2}

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

Where,

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

3.7.3.3 Relative growth rate (RGR)

The relative growth rate is computed based on the size increase as function of time. Relative growth rate or efficiency index 'r' as suggested by (Gregory 1917, West *et al.* 1920). This efficiency index or RGR can be determine by measuring plant growth at two occasion (t_1 and t_2).

RGR was computed by using Dhopte and Manuel (1989) formula.

$$RGR\ (g\ g^{-1}\ day^{-1}) = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

Where,

W_1 = Total dry matter at time t_1

W_2 = Total dry matter at time t_2

t_1 = Time of first observation

t_2 = Time of second observation

3.7.3.4 Net assimilation rate (NAR)

It directly indicates the rate of net photosynthesis. It is expressed as g of dry matter production per dm^2 of leaf area in a day. For calculating NAR, leaf area of individual plant was used.

$$NAR\ (g\ dm^2\ day^{-1}) = \frac{(W_2 - W_1)\ (Log_e L_2 - Log_e L_1)}{(t_2 - t_1)\ (L_2 - L_1)}$$

Where,

W_1 = Total dry matter at time t_1

W_2 = Total dry matter at time t_2

t_1 = Time of first observation

t_2 = Time of second observation

L_1 = Leaf area at time t_1

L_2 = Leaf area at time t_2

3.7.3.5 Chlorophyll content: At 60 DAS total cholorophyll content was determined from a representative sample of fresh tissue taken from full expanded leaves. Chlorophyll was extracted by 80 per cent acetone and determined colorimetrically by Arnon (1949) method. The chlorophyll content was expressed in mg g^{-1} fresh weight.

Chlorophyll content was calculated by following formula:

$$\textit{Total cholorophyll content } (mg\ g^{-1}) = \frac{20.2\ A_{645} + 8.02\ A_{663}}{a \times 1000 \times W} \times V$$

Where; a = Length of light path in the cell (usually 1 cm)

A = Absorbance specific wave length

W = fresh weight of sample (g)

V = volume of extract (ml)

3.7.4 Yield attributes

3.7.4.1 Number and weight of pods plant^{-1}: Fully matured pods were counted from five representative plant samples of each plot. The average number of pods were worked out and expressed as pods plant^{-1}. The dry weight was also recorded and expressed as pods weight plant^{-1}(g).

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

3.7.4.3 Pod length: Twenty five pods were randomly taken from total pods of sampled plant and then length of each pod was measured. The average was worked out and expressed as length of pod in cm.

3.7.4.4 1000 – grain weight: For test weight, 1000 grain were taken from produce of each net plot and weighed on electric machine and expressed in g.

3.7.4.5 Grain yield plant^{-1}: All the dried pods of five randomly selected plants from each plot were threshed and their grains were weighed and the average weight plant^{-1} was worked out and expressed in grain yield plant^{-1} (g).

3.7.5 Yield

3.7.5.1 Seed yield: After threshing and winnowing, weight of dried seeds from each net plot was recorded and expressed in terms of kg ha^{-1}.

3.7.5.2 Haulm yield: Stover yield was obtained by subtracting the seed yield per net plot from the respective biological yield per net plot and finally expressed in terms of haulm yield in kg ha^{-1}.

3.7.5.3 Biological yield: The weight of thoroughly dried plants of net plot along with pods were recorded and expressed as biological yield in kg ha^{-1}.

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

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

3.7.6 Quality parameters

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

3.7.6.2 Oil yield: Oil yield was estimated by using the following formula:

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

3.7.6.3 Protein content: The protein content of seed was calculated by multiplying per cent nitrogen content in seed with constant factor 6.25 (Simson *et at*., 1965) and expressed as per cent protein content.

3.7.6.4 Protein yield: Protein yield was estimated by using the following formula:

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

3.7.7 Chemical analysis of plant

3.7.7.1 Nutrient content in seed and haulm: The plant seed and haulm samples, collected at harvest, were oven dried at 70ºC till constant weight was achieved. The dried samples were finely ground and passed through 40 mesh sieve and used for determination of nutrient content (N, P, K and S) as per method furnished in Table 3.5 and expressed in per cent in dry matter.

Table 3.5 Chemical methods for plant nutrient analysis

S. No.	Nutrient	Method	Reference
1.	Nitrogen	Nesseler's reagent colorimetric method	Lindner (1944)
2.	Phosphorus	Ammonium Vanadomolybdo-phosphoric acid yellow colour method	Richards (1968)
3	Potassium	Triple acid digestion method	(Jackson 1973)

4.	Sulphur	Turbiditimetric method	(Tabatabai and Bremner, 1970)

3.7.7.2 Nutrient uptake: For estimation of nutrient uptake (N, P, K and S) by seed and haulm at harvest, seed and haulm yields were multiplied by respective nutrient content and expressed as nutrient uptake in kg ha^{-1}.

$$Nutrient\ uptake\ by\ seed\ /haulm(kg\ ha^{-1})\ = \frac{Nutrient\ content\ in\ seed/haulm(\%) \times seed/haulm\ yield(kg\ ha^{-1})}{100}$$

The total uptake by the crop was computed by summing up the uptake by seed and haulm.

3.8 SOIL ANALYSIS

3.8.1 Available nitrogen, phosphorus, potassium and sulphur:

Soil samples were drawn from each experimental plot up to 15 cm depth with the help of screw type auger in zig-zag pattern from four different sites of each plot after harvesting of crop. Samples from each experimental plot were mixed thoroughly. These were dried, ground and passed through 2 mm sieve in order to analyze for available nitrogen, phosphorus, potassium and sulphur as per method given in Table 3.3.

3.9 NUTRIENT BALANCE SHEET

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

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

Where,

A = Initial nutrient status of the soil,

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

C = Nutrient taken by crop

Apparent gain / loss (F) = E – D

Where,

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

Actual gain / loss (G) = E – A

3.10 ECONOMICS / ECONOMIC VIABILITY

In order to evaluate the benefit accrued from the treatments applied, the economics of different treatments were worked out as follows in terms of net returns (₹ ha^{-1}) and benefit cost (B:C) ratio:

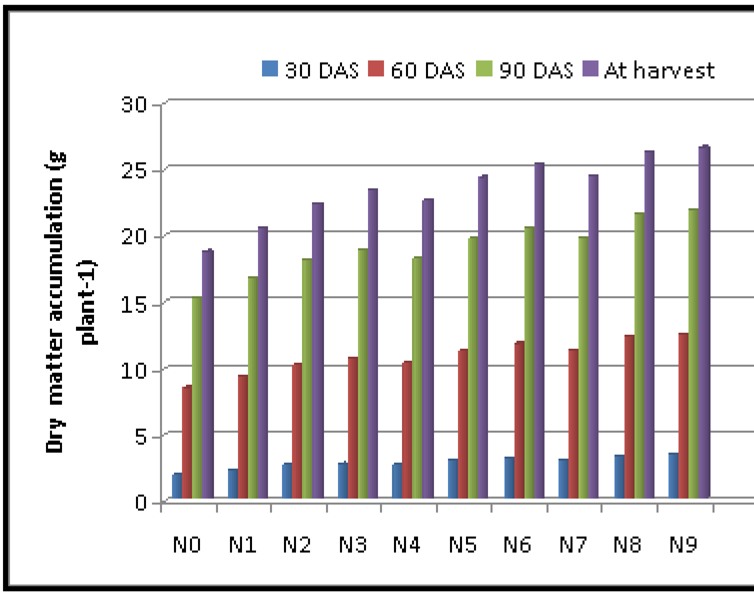
$$\text{Benefit Cost ratio} = \frac{\text{Net return (₹ ha}^{-1}\text{)}}{\text{Total cost (`₹ ha}^{-1}\text{) [Cost of cultivation + Treatment cost]}}$$

Cost of cultivation and gross income (`₹ ha^{-1}) of various treatments were calculated on the basis of the prevailing market rates for inputs and outputs during the year of experimentation. The rates of various items required to work out the cost of cultivation are given in appendices (Appendix XXV)

3.11 STATISTICAL ANALYSIS

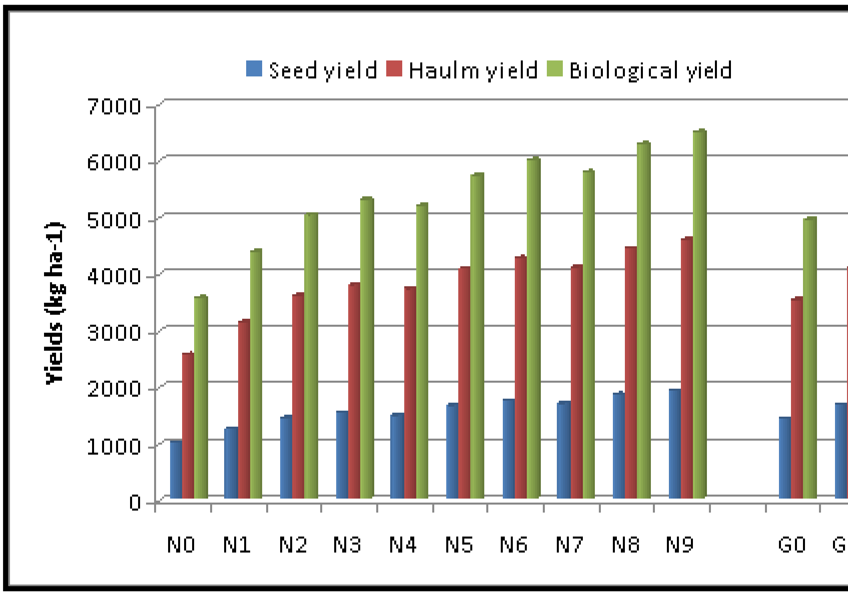
In order to test the significance of variation in experimental data obtained from various treatment effects, data were analyzed statistically. The critical differences were calculated to assess the significance of treatment mean, whenever the F test was found significant at 5 per cent level of significance. To estimate interrelation between various characters, correlation coefficient was computed. Further, in order to establish cause and effect relationship, regression equations were calculated. Regression analysis is one of the most important statistical techniques for practical applications. It's a statistical methodology that helps estimate the strength and direction of the relationship between two or more variables. The regression results show whether this relationship is valid. All these estimates were computed by standard statistical procedure described by Panse and Sukhatme (1989).

	30 DAS	60 DAS	90 DAS	At harvest
N0	1.78	8.38	15.1	18.63
N1	2.13	9.23	16.57	20.42
N2	2.52	10.09	18	22.2
N3	2.62	10.57	18.73	23.25
N4	2.58	10.23	18.11	22.45
N5	2.85	11.12	19.57	24.23
N6	2.98	11.7	20.36	25.21
N7	2.89	11.22	19.64	24.3
N8	3.15	12.24	21.39	26.16
N9	3.32	12.4	21.78	26.48

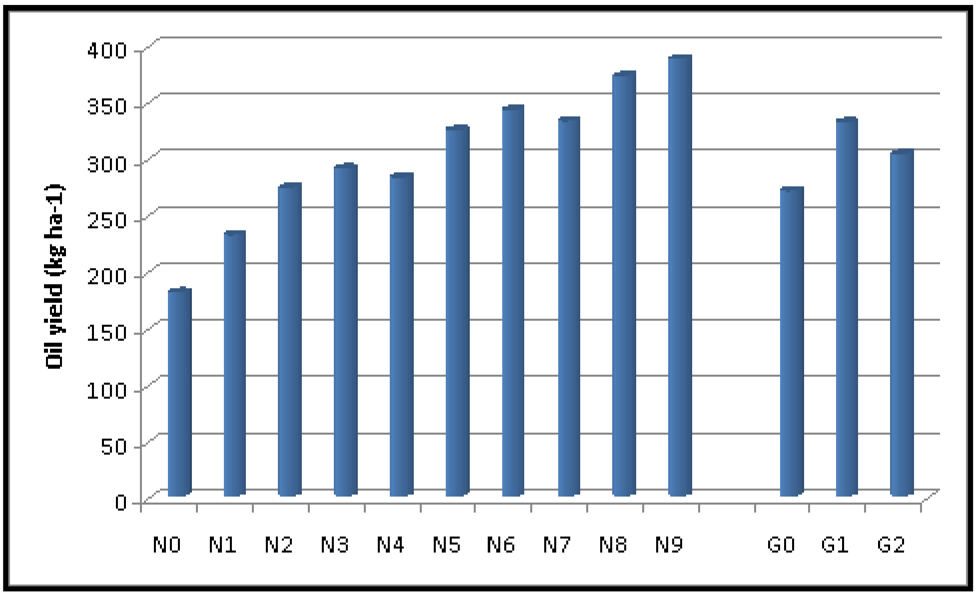


G0	2.66	10.23	18.26	22.67
G1	2.7	11.22	19.57	24.03
G2	2.68	10.7	18.94	23.29

	Seed yield	Haulm yield	Biological yield
N0	994	2553	3547
N1	1237	3125	4362
N2	1427	3585	5012
N3	1513	3774	5286
N4	1473	3702	5174
N5	1649	4063	5711
N6	1733	4251	5984
N7	1686	4084	5770
N8	1847	4420	6267
N9	1907	4573	6479
G0	1415	3517	4932
G1	1664	4069	5733
G2	1561	3853	5414

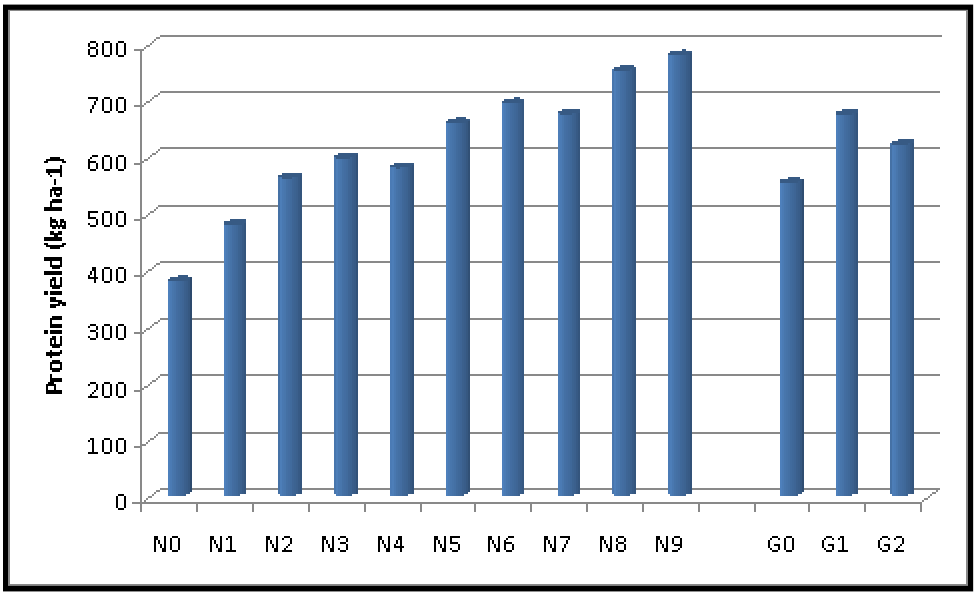


N0	180
N1	231
N2	273
N3	290
N4	282
N5	324

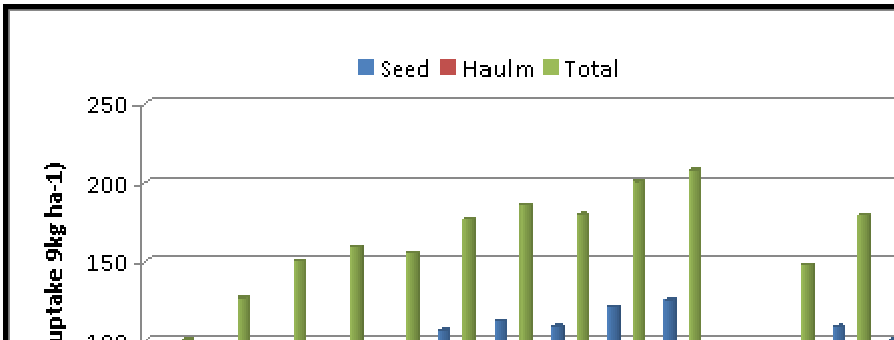


N6	342
N7	332
N8	372
N9	387
G0	270
G1	331
G2	303

N0	378
N1	478
N2	561
N3	596
N4	579
N5	658
N6	693
N7	674
N8	751
N9	778
G0	552
G1	673
G2	620

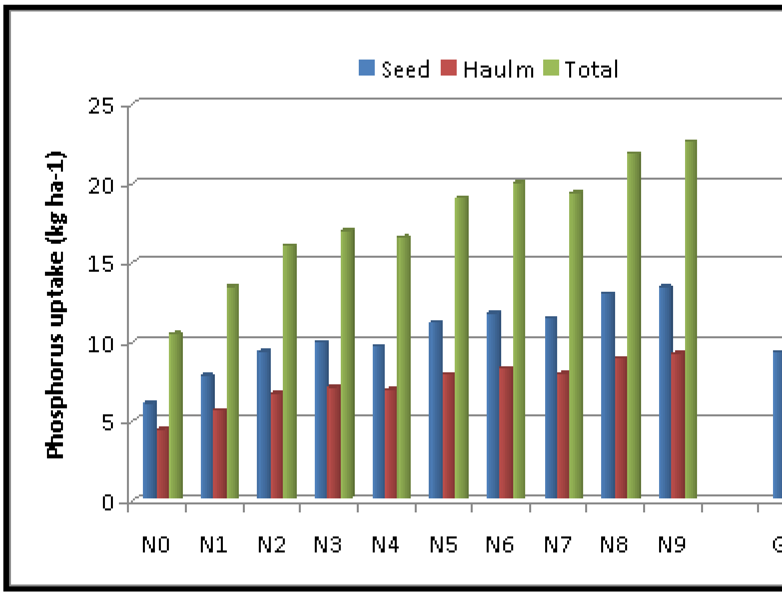


	Seed	Haulm	Total
N0	60.45	38.72	99.17



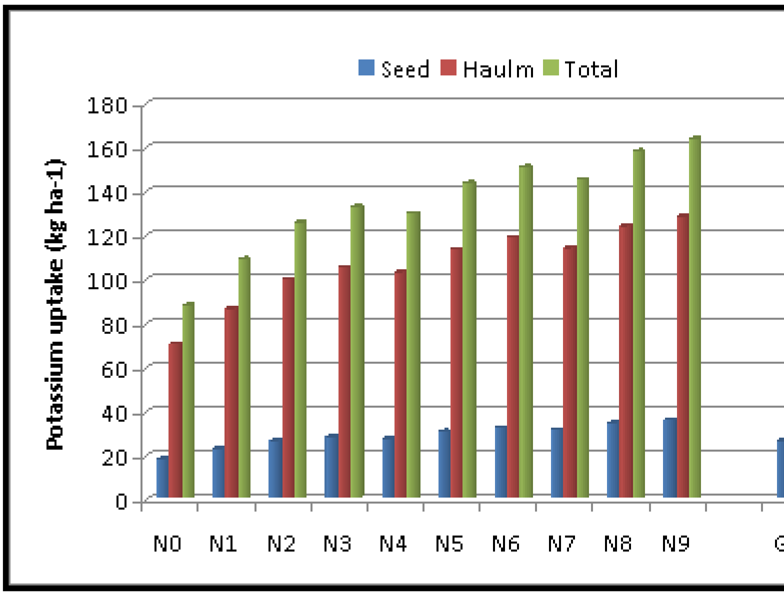
N1	76.56	49.35	125.91
N2	89.79	59.31	149.1
N3	95.31	62.75	158.06
N4	92.71	61.38	154.09
N5	105.32	70.05	175.36
N6	110.95	73.52	184.47
N7	107.91	70.59	178.5
N8	120.12	79.09	199.21
N9	124.43	82.17	206.6
G0	88.31	58.34	146.65
G1	107.61	70.38	177.98
G2	99.15	65.36	164.51

	Seed	Haulm	Total
N0	6.01	4.38	10.39
N1	7.77	5.57	13.35
N2	9.28	6.64	15.93
N3	9.85	7.03	16.88
N4	9.58	6.87	16.45
N5	11.11	7.82	18.93
N6	11.69	8.22	19.91
N7	11.38	7.88	19.26
N8	12.88	8.84	21.72
N9	13.33	9.16	22.5
G0	9.24	6.55	15.8

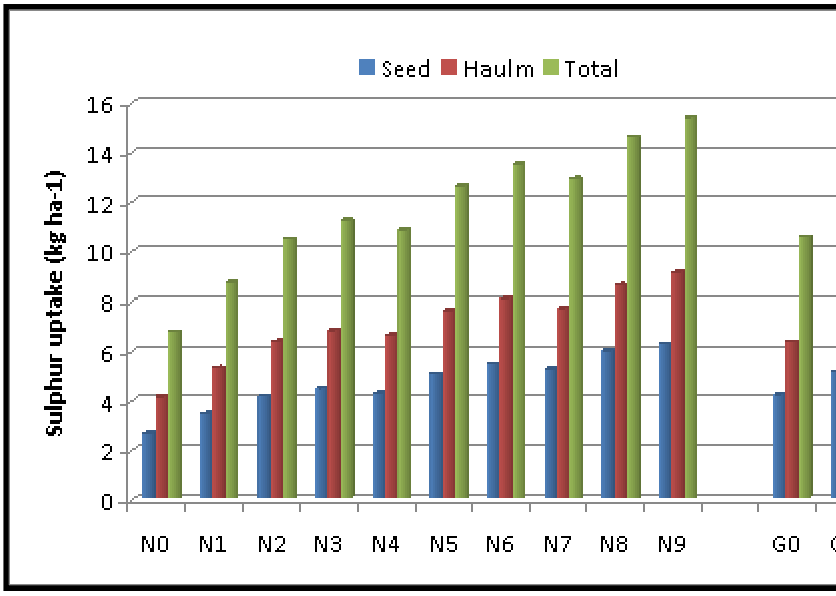


G1	11.26	7.86	19.12
G2	10.37	7.31	17.68

	Seed	Haulm	Total
N0	17.73	69.88	87.6
N1	22.34	86.04	108.39
N2	25.97	99.08	125.04
N3	27.67	104.51	132.18
N4	26.84	102.44	129.28
N5	30.25	112.8	143.05
N6	31.94	118.36	150.3
N7	31.06	113.44	144.49
N8	34.14	123.41	157.55
N9	35.3	127.78	163.08
G0	25.87	96.8	122.67
G1	30.51	113.31	143.82
G2	28.59	107.22	135.8

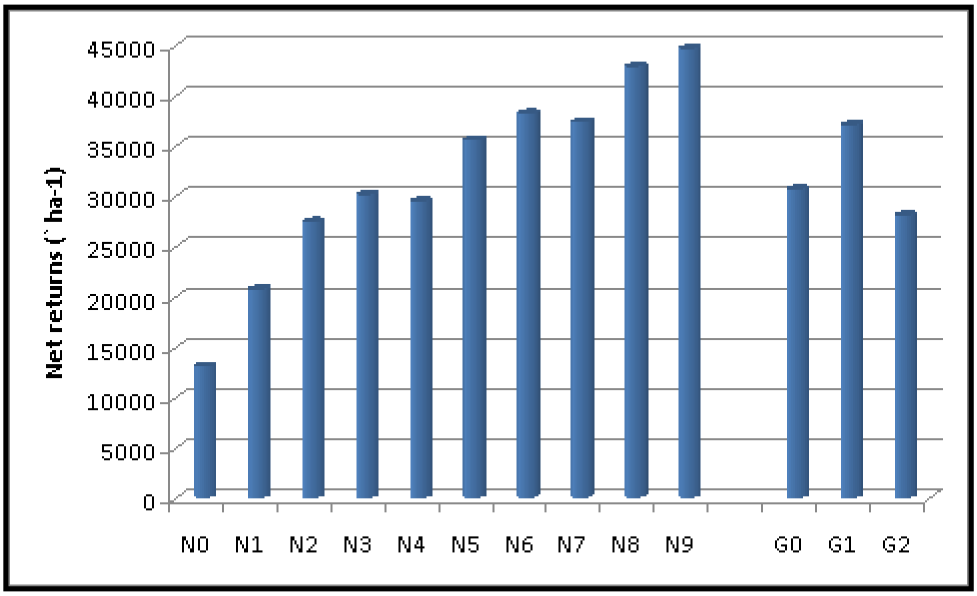


	Seed	Haulm	Total
N0	2.62	4.1	6.72
N1	3.42	5.27	8.69
N2	4.11	6.33	10.44
N3	4.43	6.77	11.2
N4	4.23	6.58	10.81
N5	5.02	7.56	12.58
N6	5.41	8.05	13.46

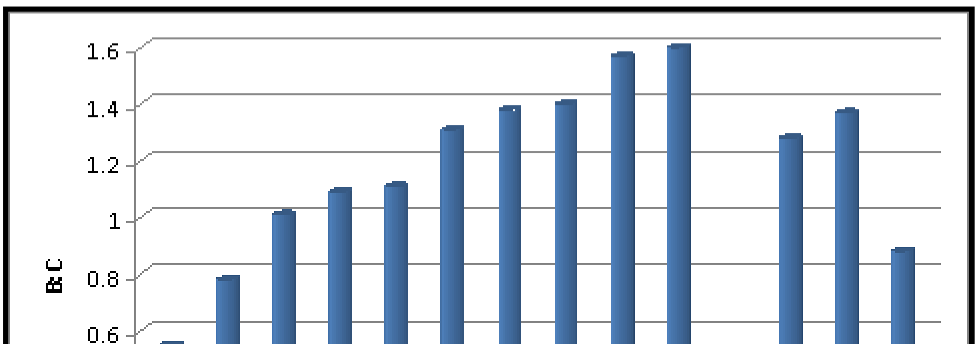


N7	5.21	7.66	12.88
N8	5.95	8.59	14.55
N9	6.23	9.1	15.34
G0	4.18	6.32	10.51
G1	5.11	7.6	12.71
G2	4.7	7.08	11.78

N0	13037
N1	20696
N2	27421
N3	30090
N4	29465
N5	35514
N6	38181
N7	37329
N8	42835
N9	44597
G0	30647
G1	37040
G2	28063

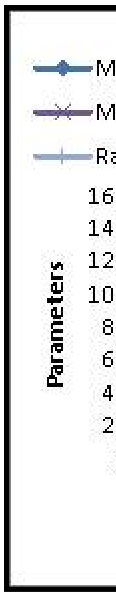


N0	0.54
N1	0.77



N2	1
N3	1.08
N4	1.1
N5	1.3
N6	1.37
N7	1.39
N8	1.56
N9	1.59
G0	1.27
G1	1.36
G2	0.87

	Max. Temp.(°C)	Min. Temp. (°C)	Max. R.H. (%)	Min. R.H. (%)	Wind velocity (km/hr)	Sunshine (hr/day)	Rainfall (mm)	Evaporation (mm)
26	33.2	25.8	5	54.1	8.4	4.1	9	7
27	32.9	24.8	80.6	62.6	5.8	2.1	12.8	4.6
28	30.7	24.1	81	70.1	5.5	1.8	73.4	3.8
29	29.7	24.2	83.6	73.4	4.5	1.5	83.8	3
30	30.6	23.6	88.1	77.3	3.4	1.6	134	2.3
31	29	23.2	89.4	80.3	4	1	63.6	1.9
32	28.8	23.2	88.3	76	3.7	1.1	85.2	2
33	29.2	23.3	88.3	75.3	4.8	2.9	25.6	3.2
34	30.2	23.5	80	71	5.7	2.8	16.8	3.5
35	30	22.7	82.1	60.1	4.6	5.9	0	4.9
36	31	22.4	76.9	50.1	4.4	8.1	0	5.1
37	34.6	22.2	79.6	51.4	2.4	6.5	51.2	5.2



38	32.9	22.8	81.9	58.7	3.5	6.4	17.2	4.3
39	27.1	21.4	90.6	84.4	5.3	1.1	95.6	1.5
40	30.7	21.9	86.3	60.7	3.4	6	6.2	3.6
41	30.5	21.4	89.4	62.1	2.7	6.4	70.6	2.7
42	33	18.5	82.6	35.4	1.8	8.5	0	3.5
43	30.5	14.9	79.7	31.1	2.9	9	0	3.7

	Max. Temp.(°C)	Min. Temp. (°C)	Max. R.H. (%)	Min. R.H. (%)	Wind velocity (km/hr)	Sunshine (hr/day)	Rainfall (mm)	Evaporation (mm)
26	36.2	25.9	5	36	11	9.3	0	11.7
27	36.4	27	64.1	34.3	9.3	6.3	0	10.3
28	35.4	25.5	74.7	50.1	6.2	5.3	12	6.9
29	31.9	24.3	80.7	63	6.2	2.9	95.6	5.3
30	30.1	24.2	86	76.6	5.1	0.6	51.6	2.9
31	30.3	23.7	89.9	77.3	4.2	2.4	109	3.3
32	27.8	23.9	86.6	76	4	0.4	47.2	2.8
33	29.6	23.5	80	65.4	5.8	3.4	0.2	3.5
34	32.9	23.4	86.1	66.6	2.8	6.6	40.8	4.7
35	31.8	23	87.4	67.3	3.6	6.4	31.6	4.2
36	29.1	22.8	89.3	76.1	4.5	3.1	165.2	3.5
37	28.7	21.4	92.4	82.9	1.6	3	94.8	2.4
38	32.5	19.8	84.1	52	2.8	8.8	0	4.5
39	31.8	19.4	80.1	48.4	2.5	8.9	0	4.1
40	33.9	20	80.7	38.4	1.9	8	0	3.7
41	34.4	18.1	79	34	2.6	8.3	0	4.7
42	32.5	17.6	75.6	32.4	2	8.4	0	3.7

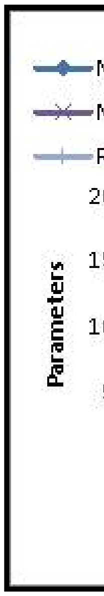


Table 3.1: Mean weekly meteorological data of *kharif* 2013

Date	Week No.	Temperature (°C)		RH (per cent)		Wind velocity (kmhr^{-1})	Sunshine (hrs day^{-1})	Rain fall (mm)	Evaporation (mm)
		Max.	Min.	Max.	Min.				
25 Jun -1 July	26	33.2	25.8	5.0	54.1	8.4	4.1	9.0	7.0
2 July - 8 July	27	32.9	24.8	80.6	62.6	5.8	2.1	12.8	4.6
9 July- 15 July	28	30.7	24.1	81.0	70.1	5.5	1.8	73.4	3.8
16 July - 22July	29	29.7	24.2	83.6	73.4	4.5	1.5	83.8	3.0
23 July- 29 July	30	30.6	23.6	88.1	77.3	3.4	1.6	134.0	2.3
30 July - 5Aug	31	29.0	23.2	89.4	80.3	4.0	1.0	63.6	1.9
6 Aug-12 Aug	32	28.8	23.2	88.3	76.0	3.7	1.1	85.2	2.0
13 Aug- 19 Aug	33	29.2	23.3	88.3	75.3	4.8	2.9	25.6	3.2
20 Aug- 26 Aug	34	30.2	23.5	80.0	71.0	5.7	2.8	16.8	3.5
27 Aug-2 Sept	35	30.0	22.7	82.1	60.1	4.6	5.9	0.0	4.9
3 Sept -9 Sept	36	31.0	22.4	76.9	50.1	4.4	8.1	0.0	5.1
10 Sept- 16 Sept	37	34.6	22.2	79.6	51.4	2.4	6.5	51.2	5.2
17 Sept - 23 Sept	38	32.9	22.8	81.9	58.7	3.5	6.4	17.2	4.3
24 Sept- 30 Sept	39	27.1	21.4	90.6	84.4	5.3	1.1	95.6	1.5
1 Oct – 7 Oct	40	30.7	21.9	86.3	60.7	3.4	6.0	6.2	3.6
8 Oct-14 Oct	41	30.5	21.4	89.4	62.1	2.7	6.4	70.6	2.7
15 Oct-21 Oct	42	33.0	18.5	82.6	35.4	1.8	8.5	0.0	3.5
22 Oct- 28 Oct	43	30.5	14.9	79.7	31.1	2.9	9.0	0.0	3.7

Table 3.2: Mean weekly meteorological data of *kharif* 2014

Date	Week No.	Temperature (°C)		RH (per cent)		Wind velocity (kmhr^{-1})	Sunshine (hrs day^{-1})	Rain fall (mm)	Evaporation (mm)
		Max.	Min.	Max.	Min.				
25 Jun -1 July	26	36.2	25.9	5.0	36.0	11.0	9.3	0.0	11.7
2 July - 8 July	27	36.4	27.0	64.1	34.3	9.3	6.3	0.0	10.3
9 July- 15 July	28	35.4	25.5	74.7	50.1	6.2	5.3	12.0	6.9
16 July - 22July	29	31.9	24.3	80.7	63.0	6.2	2.9	95.6	5.3
23 July- 29 July	30	30.1	24.2	86.0	76.6	5.1	0.6	51.6	2.9
30 July - 5Aug	31	30.3	23.7	89.9	77.3	4.2	2.4	109.0	3.3
6 Aug-12 Aug	32	27.8	23.9	86.6	76.0	4.0	0.4	47.2	2.8
13 Aug- 19 Aug	33	29.6	23.5	80.0	65.4	5.8	3.4	0.2	3.5
20 Aug- 26 Aug	34	32.9	23.4	86.1	66.6	2.8	6.6	40.8	4.7
27 Aug-2 Sept	35	31.8	23.0	87.4	67.3	3.6	6.4	31.6	4.2
3 Sept -9 Sept	36	29.1	22.8	89.3	76.1	4.5	3.1	165.2	3.5
10 Sept- 16 Sept	37	28.7	21.4	92.4	82.9	1.6	3.0	94.8	2.4
17 Sept - 23 Sept	38	32.5	19.8	84.1	52.0	2.8	8.8	0.0	4.5
24 Sept- 30 Sept	39	31.8	19.4	80.1	48.4	2.5	8.9	0.0	4.1
1 Oct – 7 Oct	40	33.9	20.0	80.7	38.4	1.9	8.0	0.0	3.7
8 Oct-14 Oct	41	34.4	18.1	79.0	34.0	2.6	8.3	0.0	4.7
15 Oct-21 Oct	42	32.5	17.6	75.6	32.4	2.0	8.4	0.0	3.7

4. EXPERIMENTAL RESULTS

Results of field experiment entitled **"Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]"** conducted during *kharif* seasons of 2013 and 2014 are presented in this chapter. Data were statistically analyzed deploying different criteria for evaluation of different treatments. The analysis of variance has been furnished in Appendices (I to XXV). Results of all main effects and only significant interactions are being presented in this chapter. Under the conditions when trend of data during 2013 and 2014 were similar, interpretations have only been made for pooled data in order to keep clarity intact in explanations or analysis and simultaneously to avoid lengthiness. An attempt has also been made to quite briefly present the reasons behind variability in different parameters induced by different sets of treatment in order to provide a basis for detailed discussion presented separately. Important data have also been presented graphically wherever felt necessary to depict important trends.

EFFECT OF TREATMENTS

4.1 Plant population

Nutrient management

A cursory look on data appended in Table 4.1 reveals that different nutrient management options failed to record significant variation in plant population of soybean at 30 DAS and at harvest during 2013, 2014 and on pooled basis.

Plant growth regulators

A perusal of data presented in Table 4.1 reveals that different PGRs failed to record any significant variation in plant population of soybean at 30 DAS and at harvest during both the years and on pooled basis.

4.2 Growth parameters

4.2.1 Plant height

4.2.1.1 Plant height at 30 DAS

Nutrient management

Table 4.2 shows that various treatments of nutrient management significantly increased the plant height of soybean at 30 DAS over control during both the years as well as pooled data basis. The maximum plant height at 30 DAS was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) which was statistically at par with N_9 during both years and pooled data basis. In pooled data basis, N_9 recorded significantly higher plant height over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 46.2, 32.3, 20.8, 15.2, 20.7, 11.8, 6.3 & 9.9 per cent, respectively.

Plant growth regulators

Data presented in Table 4.2 indicate that variations in soybean plant height under different PGRs during 2013, 2014 and on pooled basis were not significant at 30 days stage of soybean crop.

4.2.1.2 Plant height at 60 DAS

Nutrient management

It is evident from data (Table 4.2) that different nutrient management levels significantly affect the plant height at 60 DAS during both the years of experimentation as well as in pooled analysis. The maximum plant height was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and pooled data basis. In pooled data basis, N_9 recorded significantly higher plant height over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 48.85, 32.1, 20.7, 15.1, 20.5, 10.8, 6.3 & 10.8 per cent, respectively. However it was statistically at par with N_8.

Plant growth regulators

It is explicit from data (Table 4.2) that during both the year of experimentation, all the agrochemicals significantly increased plant height. Foliar spray of brassinolide and banzyladenine recorded significantly higher plant height by 15.2 & 5.2 per cent, respectively in 2013 and 8.5 & 4.1 per cent in 2014 over water spray. Further brassinolide recorded significantly higher plant height by 15.2 and 9.5 per cent in 2013 and 8.5 & 4.2 per cent in 2014 over water spray and benzyl adenine spray, respectively. However different PGRs failed to record any significant variation in plant height of soybean at 60 DAS on pooled basis.

4.2.1.3 Plant height at 90 DAS

Nutrient management

An examination of data presented in (Table 4.2) reveals that various treatments of nutrient management significantly increased the plant height of soybean over absolute control during both the years as well as pooled data basis. The maximum plant height was recorded with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both years and pooled data basis. In pooled data basis, N_9 recorded significantly higher plant height over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 47.0, 33.0, 21.1, 16.2, 20.6, 10.9, 6.6 & 10.6 per cent, respectively. However it was at par with N_8.

Data presented in Table 4.2 further reveal that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 10.8, 21.7 & 26.7 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) gave significantly higher plant height over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 20.2 and 9.0 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP and N_5 (100 % RDP + 30 kg Sulphur) by 18.2 and 8.3 percent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher plant height over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 16.2 and 6.6 per cent, respectively.

Plant growth regulators

Foliar spray of growth regulators significantly enhanced plant height of soybean than control during 2013, 2014 and on pooled basis (Table 4.2). In pooled data, foliar spray of brassinolide and banzyladenine recorded significantly higher plant height by 8.6 & 3.6 per cent, respectively over water spray. Further brassinolide recorded significantly higher plant height by 8.6 and 4.7 per cent over water spray and benzyladenine spray, respectively.

4.2.1.4 Plant height at harvest

Nutrient management

An analysis of data presented in Table 4.2 shows that different nutrient management options recorded significant variation in soybean plant height at harvest during 2013, 2014 and on pooled basis. The maximum plant height was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both years and pooled basis. In pooled basis, N_9 recorded significantly higher plant height over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 47.5, 33.6, 21.9, 16.6, 21.7, 12.1, 7.9 & 12.0 per cent, respectively.

Data furnished in Table 4.2 also indicate that among various nutrient management options, N_1 (75 % RD), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 10.3, 20.9 & 26.4 percent, respectively. Use of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recoeded significantly higher plant height over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 19.2 and 8.6 percent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 17.7 and 8.2 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher plant height over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 16.6 and 7.9 per cent, respectively.

Plant growth regulators

An interpretation of data in Table 4.2 reveals that different PGRs recorded significant variation in soybean plant height at harvest during both the individual years and on pooled basis. Application of brassinolide and benzyl adenine recorded significantly higher final plant height than water spray by 8.3 and 3.3 per cent, respectively on pooled basis. Further mean enhancement in final plant height by brassinolide was 4.8 and 8.3 per cent over benzyl adenine and water spray, respectively.

4.2.2 Dry matter accumulation

4.2.2.1 Dry matter accumulation at 30 DAS

Nutrient management

An analysis of data in Table 4.3 indicates that different nutrient management options recorded significant variations in dry matter accumulation (DMA) plant^{-1} 30 DAS during both the years of investigation and on pooled basis. Use of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded maximum dry matter accumulation which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both years and pooled data basis. On pooled data basis, N_9 recorded significantly higher dry matter accumulation over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 86.8, 55.8, 31.7, 26.7, 28.6, 16.4, 11.4 & 14.8 per cent, respectively.

Plant growth regulators

It is evident from data in Table 4.3 that variation in DMA plant^{-1} at 30 DAS among different growth regulators during 2013, 2014 and on pooled basis was not significantly affected by different plant growth regulators.

4.2.2.2 Dry matter accumulation at 60 DAS

Nutrient management

An interpretation of data in Table 4.3 indicates that different nutrient management options recorded significant variations in DMA plant^{-1} at 60 DAS during both the years of study and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded maximum dry matter accumulation which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both years and on pooled basis. On pooled basis, N_9 recorded significantly higher dry matter accumulation over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 49.7, 34.3, 22.8, 17.3, 21.2, 11.5, 5.9 & 10.5 per cent, respectively. However it was statistically at par with N_8.

Plant growth regulators

An analysis of data presented in Table 4.3 indicates that plant growth regulators recorded significant variation in DMA plant^{-1} at 60 DAS during both the individual years and on pooled basis. Foliar spray of brassinolide significantly enhanced the dry matter plant^{-1} than benzyladenine and water spray which was equivalent to 4.8 and 9.6 per cent, respectively. Further application of brassinolide and benzyladenine recorded 9.6 and 4.5 per cent higher mean dry matter plant^{-1} at 60 DAS than control.

4.2.2.3 Dry matter accumulation at 90 DAS

Nutrient management

An analysis of data in Table 4.3 indicates that different nutrient management options recorded significant variations in DMA plant^{-1} at 90 DAS during both the years of investigation and on pooled basis. The maximum dry matter accumulation was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both years and on pooled data basis. On pooled basis, N_9 recorded significantly higher dry matter accumulation over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 44.1, 31.4, 21.0, 16.2, 20.2, 11.2, 6.9 & 10.8 per cent, respectively. However it was statistically at par with N_8.

Data furnished in Table 4.3 further clearly indicate that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly higher over control by 9.7, 19.2 & 24.0 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) gave significantly higher dry matter accumulation over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 18.5 and 8.4 per cent, respectively. Use of N8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP and N_5 (100 % RDP + 30 kg Sulphur) by 18.8 and 9.2 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher dry matter accumulation over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 16.2 and 6.9 per cent, respectively.

Plant growth regulators

Foliar spray of brassinolide significantly enhanced dry matter plant^{-1} at 90 DAS than benzyladenine and water spray during 2013, 2014 and on pooled basis (Table 4.3). On pooled data basis, brassinolide spray recorded highest dry matter plant^{-1} at 90 DAS over benzyladenine and water spray which was equivalent to 3.32 and 7.17 per cent, respectively. Further benzyladenine also significantly increased mean dry matter plant^{-1} than water spray that was equivalent to 3.72 per cent.

4.2.2.4 Dry matter accumulation at harvest

Nutrient management

An examination of data in Table 4.3 indicates that different nutrient management options recorded significant variations in DMA plant^{-1} at harvest during both the years of study and on pooled basis. The treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded maximum dry matter accumulation which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. On pooled basis N_9 recorded significantly higher dry matter accumulation over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 42.1, 29.6, 19.2, 13.8, 17.9, 9.2, 5.0 & 8.9 per cent, respectively.

Data presented in Table 4.3 further indicate that N_1 (75 % RDP) N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 9.6, 19.1 & 24.7 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher dry matter accumulation over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 19.0 and 8.2 per cent, respectively. Use of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 17.8 and 7.9 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher dry matter accumulation over N_3 (125 % RDP and N_6 (125 % RDP + 30 kg Sulphur) by 26.04 and 10.04 per cent, respectively.

Plant growth regulators

It is explicit from data appended in Table 4.3 that different PGRs recorded significant variations in DMA plant^{-1} at harvest during the both years of experimentation and on pooled basis. Enhancement in mean dry matter plant^{-1} due to brassinolide was 3.1 and 5.9 per cent than benzyladenine and water spray, respectively. Further benzyladenine also recorded significantly higher dry matter plant^{-1} than water spray which was equivalent to 2.7 per cent.

4.2.3 Nodules per plant (60 DAS)

Nutrient management

An analysis of data reported in Table 4.4 indicates that different nutrient management recorded significant variation in nodule plant^{-1} at 60 DAS during both the individual years and on pooled basis. The maximum nodule plant^{-1} was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. On pooled basis, N_9 recorded significantly higher nodule plant^{-1} over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 99.6, 66.3, 42.9, 35.0, 39.3, 21.2, 15.5 & 16.3 per cent, respectively.

Data appended in Table 4.4 further show that among various nutrient management, N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 20.0, 39.7 & 47.9 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nodule plant^{-1} over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 42.9 and 19.7 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 36.3 and 15.7 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nodule plant^{-1} over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 35.0 and 15.5 per cent, respectively.

Plant growth regulators

It is apparent from data presented in Table 4.4 that different growth regulators recorded significant variation in nodule plant^{-1} at 60 DAS during either of the years of study and on pooled basis. Application of brassinolide and benzyladenine recorded significantly higher nodule plant^{-1} than water spray by 9.63 and 4.98 per cent on pooled basis. Further enhancement in nodule plant^{-1} by brassinolide was 4.43 and 9.63 per cent over benzyladenine and water spray, respectively.

4.2.4 Nodule weight plant^{-1}

Nutrient management

A critical examination of data reported in Table 4.4 reveals that different nutrient management options recorded significant variations in nodule weight plant^{-1} during both the years of research and on pooled basis. Use of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded maximum nodule weight plant^{-1} which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis.OIn pooled basis, N_9 recorded significantly higher nodule weight plant^{-1} over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 66.3, 44.7, 28.4, 25.1, 26.7, 15.0, 12.1 & 13.1 per cent, respectively. However it was at par with N_8.

Data presented in Table 4.4 further clearly reveal that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 14.8, 29.5 & 32.9 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher nodule weight plant^{-1} over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 28.0 and 12.0 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly higher over N_2 (100 % RDP and N_5 (100 % RDP + 30 kg Sulphur) by 24.6 and 11.6 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) gave significantly higher nodule weight plant^{-1} over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 25.1 and 12.1 per cent, respectively.

Plant growth regulators

Data furnished in Table 4.4 clearly reveal that different growth regulators recorded significant variations in nodule weight plant^{-1} during both the individual years and on pooled basis. Application of brassinolide and benzyladenine recorded significantly higher nodule weight plant^{-1} than water spray by 13.0 and 6.9 per cent on pooled basis. Further mean enhancement in nodule weight plant^{-1} by brassinolide was 5.6 and 13.0 per cent over benzyladenine and water spray, respectively.

4.2.5 Branches plant^{-1} at harvest

Nutrient management

A perusal of data presented in Table 4.4 shows that different nutrient management options recorded significant variations in branches plant^{-1} at harvest during both the years and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded maximum branches plant^{-1} which was significantly higher during both the years and on pooled basis. On pooled data basis, N_9 recorded significantly higher branches plant^{-1} over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 56.0, 37.2, 23.7, 20.0, 22.0, 11.6, 7.8 & 9.0 per cent, respectively. However, it was at par with N_8.

Data presented in Table 4.4 further reveal that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 13.6, 26.0 & 30.0 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher branches plant^{-1} over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 25.9 and 11.9 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 22.5 and 10.5 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) gave significantly higher branches plant^{-1} over N_3 (125 % RDP and N_6 (125 % RDP + 30 kg Sulphur) by 20.0 and 7.8 per cent, respectively.

Plant growth regulators

Data presented in Table 4.4 indicate that different PGRs recorded significant variations in branches plant^{-1} at harvest during both the years of experimentation and on pooled basis. Foliar spray of brassinolide recorded significantly higher branches plant^{-1} than benzyladenine and water spray. On pooled basis, Mean increase in branches plant^{-1} by brassinolide was 4.08 and 12.86 per cent over benzyladenine and water spray, respectively. Further benzyladenine also recorded significantly higher branches plant^{-1} than water spray which corresponded to 10.98, 6.50 and 8.43 per cent during 2013, 2014 and on pooled basis, respectively.

Interaction effects

An analysis of data in Table 4.4.1 reveals that among different combinations of nutrient management and growth regulators, interaction of G_1 (brassinolide) and N_8 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher branches plant^{-1} (6.41) which was also significantly higherover all other interactions under both the sets of dispositions (at same nutrient management option under varying growth regulator as well as at same growth regulator under varying nutrient management options)on pooled basis. However, branches plant^{-1} at harvest between the interactions brassinolide (G_1) with N_8 and brassinolide (G_1) with N_9 were at par during 2013, 2014 and on pooled basis.

4.2.6 Leaf area index

4.2.6.1 Leaf area index at 30 DAS

Nutrient management

A critical appraisal of data reported in Table 4.5 indicates that different nutrient management options recorded significant variation in LAI at 30 DAS during both the years of experimentation and on pooled basis. The maximum leaf area index was recorded with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. On pooled data basis, N_9 recorded significantly higher leaf area index over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 52.3, 36.9, 21.6, 16.4, 21.6, 10.1, 5.8 & 9.3 per cent, respectively. However, it was statistically at par with N_8.

Data appended in Table 4.5 further reveal that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 11.2, 25.2 & 30.8 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher leaf area index over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 25.2 and 11.1 percent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 20.1 and 8.7 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher leaf area index over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 16.4 and 5.8 per cent, respectively.

Plant growth regulators

Data presented in Table 4.5 reveal that different PGRs failed to record any significant variation in LAI 30 DAS during 2013, 2014 and on pooled basis.

4.2.6.2 Leaf area index at 60 DAS

Nutrient management

An examination of data furnished in Table 4.5 indicates that different nutrient management recorded significant variation in LAI at 60 DAS during 2013, 2014 and on pooled basis. Use of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded maximum leaf area index which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. On pooled basis, N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher leaf area index over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 52.5, 36.0, 23.3, 17.5, 22.2, 11.8, 7.4 & 10.6 per cent, respectively. However it was statistically at par with N_8.

Plant growth regulators

It is evident from data in Table 4.5 that different PGRs recorded significant variations in LAI at 60 DAS during both the years of experimentation and on pooled basis. Mean increase in leaf area index due to brassinolide and benzyladenine was 7.2 and 3.6 per cent at 60 DAS over water spray, respectively (on pooled basis). Further foliar spray of brassinolide significantly increased the leaf area index over benzyladenine and water spray by 7.2 and 3.4 per cent, respectively.

4.2.4.3 Leaf area index at 90 DAS

Nutrient management

An interpretation of data in Table 4.5 reveals that different nutrient management recorded significant variations in LAI at 90 DAS during both the years of research and on pooled basis. Supplementing nutrients to soybean crop on use of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment recorded maximum leaf area index which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both years and on pooled basis. On pooled basis, N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher leaf area index over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 56.0, 38.6, 24.7, 19.6, 24.2, 12.9, 9.1 & 12.5 per cent, respectively. However it was statistically at par with N_8.

Data presented in Table 4.5 further indicate that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly higher over control by 12.5, 25.1 &

30.4 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher leaf area index over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 23.1 and 10.3 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 21.6 and 10.1 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher leaf area index over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 19.6 and 9.1 per cent, respectively.

Plant growth regulators

Application of growth regulators significantly increased the leaf area index over the control at 90 DAS during 2013, 2014 and on pooled basis (Table 4.5). Mean enhancement in leaf area index due to brassinolide and benzyladenine was 7.9 and 4.1 per cent over water spray, respectively (on pooled basis). Further foliar spray of brassinolide significantly increased the leaf area index over benzyl adenine and water spray by 7.9 and 3.6 per cent, respectively.

4.3 Growth indices

4.3.1 Crop Growth Rate

4.3.1.1 Crop Growth Rate between 30-60 DAS

Nutrient management

An analysis of data in Table 4.6 indicates that different nutrient management recorded significant variations in CGR at 30-60 DAS during 2013, 2014 and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest CGR which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as pooled analysis. On pooled basis, N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher CGR over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 37.5, 28.0, 19.9, 14.2, 18.6, 9.7, 4.1 & 9.0 per cent, respectively. However it was statistically at par with N_8.

Data furnished in Table 4.6 further indicate that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 7.4, 14.6 & 20.4 percent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher CGR over N_1 (75 % RDP and N_4 (75 % RDP + 30 kg sulphur) by 17.9 and 8.8 percent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 20.0 and 9.9 percent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) gave significantly higher CGR over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 14.1 and 4.1 percent, respectively.

Plant growth regulators

A reference to data (Table 4.6) indicates that different PGRs recorded significant variations in CGR at 30-60 DAS during 2013, 2014 and on pooled basis. On pooled basis, mean enhancement in crop growth rate due to brassinolide and benzyladenine was 12.4 and 5.8 (30-60 DAS), respectively over water spray. Further foliar spray of brassinolide significantly enhanced the CGR at 30-60 DAS than benzyladenine and water spray which was to the tune of 6.2 and 12.4 per cent, respectively.

4.3.1.2 Crop Growth Rate between 60-90 DAS

Nutrient management

A perusal of data (Table 4.6) reveals that various treatments of nutrient management significantly influenced in CGR at 60-90 DAS during 2013, 2014 and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest CGR which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as in pooled analysis. On pooled basis, N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher CGR over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 39.5, 27.7, 18.5, 14.9, 19.1, 11.1, 8.3 & 11.4 per cent, respectively. However, it was statistically at par with N_8.

An interpretation of data presented in Table 4.6 further reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly higher over control by 22.4, 17.7 & 9.2 per cent, respectively. Application of 75 % RDP + 30 kg Sulphur + seed inoculated with PSB (N_7)recorded significantly higher CGR over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 14.7 and 6.9 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 15.8 and 8.5 percent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with

PSB) registered significantly higher CGR over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 14.9 and 8.3 percent, respectively.

Plant growth regulators

It is evident from data in Table 4.6 that different plant growth regulator recorded significant variations in CGR at 60-90 DAS than water spray during 2013 and on pooled basis but significant variations in CGR at 60-90 DAS was not found in 2014. On pooled basis, foliar spray of brassinolide recorded significantly higher CGR at 60-90 DAS than water spray which was equivalent to 3.98 per cent. However, pooled analysis between brassinolide and benzyladenine spray were not significant in CGR at 60-90 DAS.

4.3.2 Relative Growth Rate

4.3.2.1 Relative Growth Rate between 30-60 DAS

Nutrient management

A perusal of data (Table 4.6) reveals that various treatments of nutrient management significantly influenced RGR 30-60 DAS during both the years of experimentation as well as on pooled basis. Absolute control (N_0) recorded highest RGR which was significantly higher over rest of the treatments during both the years as well as in pooled analysis. In pooled data basis, N_0 recorded significantly higher RGR over N_1, N_2, N_3, N_4, N_5, N_6 N_7, N_8 and N_9 by 5.7, 11.4, 10.9, 12.4, 13.6, 13.4, 14.1, 13.9 & 17.5 per cent, respectively. Further different nutrient management options recorded a mixed trend in pooled RGR between 30-60 DAS in order of $N_0 > N_1 > N_3 > N_2 > N_4 > N_6 > N_5 > N_8 > N_7 > N_9$.

Plant growth regulators

A reference to data shown in Table 4.6 reveals that different PGRs recorded significantly higher RGR 30-60 DAS over water spray during both the years of experimentation and on pooled basis. Mean enhancement in relative growth rate due to brassinolide and benzy1adenine over water spray was 5.5 and 2.6 per cent, respectively. Further application of brassinolide also recorded 2.8 per cent higher RGR at 30-60 DAS in comparison to benzy1adenine spray.

4.3.2.2 Relative Growth Rate between 60-90 DAS

Nutrient management

Data appended in Table 4.6 clearly indicate that significant variations recorded in RGR at 60-90 DAS during both the years of research and on pooled basis under different nutrient management. Absolute control (N_0) recorded highest RGR which was significantly superior over rest of the treatments except N_1 (75 % RDP) and N_2 (100 % RDP) during both the years as well as in pooled analysis. On pooled basis, N_0 (Absolute control) recorded significantly higher RGR over N_3, N_4, N_5, N_6, N_7, N_8 and N_7 by 3.1, 3.6, 4.7, 6.4, 5.9, 5.9 & 5.3 per cent, respectively. However it was statistically at par with N_1 and N_2. Further different nutrient management recorded a mixed trend in pooled RGR between 60-90 DAS in order of N_0>N_1> N_2> N_3> N_4> N_5> N_9> N_8> N_7> N_6.

Plant growth regulators

Foliar application of growth regulators recorded significant variation in the relative growth rate between 60-90 DAS during 2013, 2014 and on pooled basis (Table 4.6). In pooled data, water spray recorded highest relative growth rate between 30-60 DAS over of brassinolide and benzyladenine spray, which was significantly higher by 4.8 per cent over brassinolide spray but remained at par with benzyladenine spray. Further mean enhancement in relative growth rate due to benzyladenine recorded significantly higher relative growth rate between 60-90 DAS by 3.2 per cent over brassinolide spray.

4.3.3 Net Assimilation Rate

4.3.3.1 Net Assimilation Rate between 30-60 DAS

Nutrient management

An analysis of data furnished in Table 4.7 indicates that different nutrient management options recorded significant variations in NAR 30-60 DAS during both the years of research and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest NAR which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as on pooled basis. Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher NAR over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 116.7 75.0, 46.4, 32.6, 43.4, 21.3, 10.8 & 19.2 per cent, respectively. However it was statistically at par with N_8.

An interpretation of data presented in Table 4.7 further reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 23.7, 48.0 & 63.4 percent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher NAR over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 46.7 and 20.2 percent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 44.6 and 19.8 percent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher NAR over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 32.6 and 10.8 percent, respectively.

Plant growth regulators

An analysis of data furnished in Table 4.7 reveals that different PGRs recorded significant variations in NAR 30-60 DAS during both the years of investigation and on pooled basis. Mean enhancement in NAR 30-60 DAS due to brassinolide and benzy1adenine than water spray was 20.5 and 9.7 per cent (30-60 DAS), respectively. Further brassinolide recorded significantly higher mean net assimilation rate by 9.9 and 20.5 per cent (30-60 DAS) over benzy1adenine and water spray, respectively.

4.3.3.2 Net Assimilation Rate between 60-90 DAS

Nutrient management

It is evident from data presented in Table 4.7 that different nutrient management options recorded significant variations in NAR 60-90 DAS during both the years of research and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest NAR which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as on pooled analysis. On pooled data basis, N_9 recorded significantly higher NAR over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 126.2, 77.1, 46.5, 35.9, 46.1, 23.6, 16.7 & 23.2 per cent, respectively. However it was statistically at par with N_8.

It is further inferred from data (Table 4.7) that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 27.7, 54.4 & 66.4 percent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher NAR over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 43.5 and 18.4 percent, respectively. N_8 (100 % RDP + 30 kg

Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP and N_5 (100 % RDP + 30 kg Sulphur) by 40.2 and 18.3 percent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher NAR over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 35.9 and 16.7 percent, respectively.

Plant growth regulators

Data presented in Table 4.7 reveal that different PGRs recorded significant variations in NAR 60-90 DAS during both the years of study and on pooled basis, Application of brassinolide and benzyladenine recorded significantly higher NAR 60-90 DAS than water spray by 13.2 and 7.7 per cent, respectively (on pooled basis). Further enhancement in NAR 60-90 DAS by brassinolide was 5.0 and 13.2 per cent over benzyladenine and water spray, respectively.

4.4 Yield Attributes and yields

4.4.1 Pods plant^{-1}

Nutrient management

An appraisal of data furnished in Table 4.8 reveals that different nutrient management recorded significant variations in pods plant^{-1} during both the years of study and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest pods plant^{-1} which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as on pooled basis. On pooled basis, N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher pods plant^{-1} over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 53.9, 36.2, 23.4, 20.6, 22.1, 11.5, 8.7 & 9.8 per cent, respectively. However it was statistically at par with N_8.

Data presented in Table 4.8 further reveal that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) recorded significantly higher pod plant^{-1}over control by 12.9, 24.7 & 27.6 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher pods plant^{-1} over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 24.0 and 11.1 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 22.0 and 10.3 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur

+ seed inoculated with PSB) registered significantly higher pods plant^{-1} over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 20.6 and 8.7 per cent, respectively.

Plant growth regulators

Data presented in Table 4.8 indicate that different growth regulators recorded significant variations in pods plant^{-1} during both the years of investigation and on pooled basis. Application of brassinolide and benzyladenine recorded significantly higher pods plant^{-1} than water spray by 12.2 and 5.6 per cent on pooled basis. Further brassinolide recorded maximum pods plant^{-1} which was 6.1 and 12.2 per cent higher than benzyladenine and water spray, respectively on pooled basis.

Interaction (Nutrient management X PGR)

An interpretation of data in Table 4.8.1 reveals that among the interaction of different nutrient management levels and growth regulators recorded significant variation in pods plant^{-1} (Table- 4.8.1). The interaction of brassinolide (G_1) with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded the maximum and significantly higher pods plant^{-1} under both the sets of dispositions (nutrient management within the growth regulator and growth regulator within the nutrient management) on pooled basis which corresponded to 60.28 Pods plant^{-1} which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.4.2 Seeds pod^{-1}

Nutrient management

The experimental results appended in Table 4.8 indicate that different nutrient management recorded significant variations in seeds pod^{-1} during both the years of research and on pooled basis. Use of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest seeds pod^{-1} which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as pooled analysis. On pooled data basis, N_9 recorded significantly higher seeds pod^{-1} over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 39.0, 27.8, 18.7, 16.3, 17.7, 9.6, 7.5 & 8.7 per cent, respectively. However it was statistically at par with N_8.

Data presented in Table 4.8 further reveal that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 8.7, 17.0 & 19.5 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher seeds pod^{-1} over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 17.4 and 8.2 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 16.6 and 7.6 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher seeds pod^{-1} over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 16.3 and 7.5 per cent, respectively.

Plant growth regulators

An interpretation of data presented in Table 4.8 reveals that different growth regulators recorded significant variations in mean seeds pod^{-1} during 2013, 2014 and on pooled basis. Foliar spray of brassinolide recorded significantly higher seeds pod^{-1} than benzyladenine and water spray which was equivalent to 3.5 and 8.7 per cent, respectively. Further benzyladenine also recorded significantly higher pods plant^{-1} which was 5.0 per cent higher than water spray.

4.4.3 Number of seeds plant^{-1}

Nutrient management

An appraisal of experimental results presented in Table 4.8 reveals that different nutrient management recorded significant variations in number of seed plant^{-1} during both the years of experimentation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest number of seed plant^{-1} which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as on pooled analysis. Data further reveal that, N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher number of seed plant^{-1} over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 55.6, 38.2, 24.3, 21.3, 22.8, 11.1, 9.5 & 10.2 per cent, respectively (on pooled basis). However, it was statistically at par with N_8.

Data presented in Table 4.8 further reveal that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly higher over control by 12.5, 25.1 & 28.2 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with

PSB) recorded significantly higher number of seed plant^{-1} over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 25.3 and 11.3 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP and N_5 (100 % RDP + 30 kg Sulphur) by 22.6 and 9.6 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher number of seed plant^{-1} over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 21.3 and 9.5 per cent, respectively.

Plant growth regulators

An analysis of data furnished in Table 4.8 reveals that different growth regulators recorded significant variations in number of seeds plant^{-1}during both the years of investigation and on pooled basis. Application of brassinolide and benzyladenine recorded significantly higher seeds pods^{-1} than water spray by 12.7 and 7.8 per cent on pooled basis. Further foliar spray of brassinolide recorded significantly higher seeds pod^{-1} than benzyladenine and water spray which was equivalent to 4.5 and 12.7 per cent, respectively.

Interaction (Nutrient management X PGR)

The interaction of different nutrient management levels and growth regulators recorded significant variation in number of seeds plant^{-1} (Table 4.8.1). The highest seeds pod^{-1} was recorded with foliar spray of G_1 (brassinolide) along with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB), under both the sets of dispositions (nutrient management within the growth regulator and growth regulator within the nutrient management) on pooled basis which corresponded to 138.0 seeds pod^{-1}, which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was statistically at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.4.4 Pod length

Nutrient management

An analysis of data in Table 4.9 indicates that different nutrient management recorded significant variations in pod length during 2013, 2014 and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest pod length which was significantly superior over rest of the treatments except

N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as in pooled analysis. Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher pod length over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 55.8, 37.6, 23.6, 17.2, 23.3, 11.9, 6.0 & 11.0 per cent, respectively (on pooled basis). However it was statistically at par with N_8.

An interpretation of data in Table 4.9 further reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 13.1, 25.9 & 32.9 per cent, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) reported significantly higher pod length over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 23.9 and 11.0 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was recorded significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 21.2 and 9.7 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher pod length over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 17.2 and 6.0 per cent, respectively.

Plant growth regulators

It is clear from data shown in Table 4.9 that different growth regulators recorded significant variations in mean pod length during 2013, 2014 and on pooled basis. Application of brassinolide recorded maximum mean pod length which was 3.1 and 8.1 per cent higher than benzyladenine and water spray, respectively. Further benzy adenine recorded significantly higher pods plant^{-1} by 4.8 per cent than water spray.

4.4.5 1000-seed weight

Nutrient management

A reference to data (Table 4.9) shows that different nutrient management recorded significant variations in 1000 seed weight during 2013, 2014 and on pooled basis. The treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest test weight which was significantly higher over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as in pooled analysis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher test weight over N_0, N_1, N_2,

N_3, N_4, N_5, N_6 and N_7 by 43.7, 30.7, 20.4, 17.2, 19.2, 11.2, 9.1 & 9.7 per cent, respectively (on pooled basis). However, it was statistically at par with N_8.

It is further apparent from data (Table 4.9) that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 9.9, 19.2 & 22.5 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher test weight over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 19.0 and 8.6 per cent, respectively. Application N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher 1000 seed weight over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 17.9 and 8.8 percent, respectively. Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher test weight over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 17.2 and 9.1 per cent, respectively.

Plant growth regulators

It is clear from data reported in Table 4.9 that different growth regulators recorded significant variations in test weight during both the years of investigation and on pooled basis. On pooled basis, brassinolide and benzyladenine recorded 9.9 and 5.7 per cent higher 1000 seed weight than water spray, respectively. Further foliar spray of brassinolide recorded significantly higher test weight than benzyladenine and water spray which was 4.0 and 9.9 per cent, respectively.

4.4.6 Seed yield plant^{-1}

Nutrient management

Data furnished in Table 4.9 reveal that different nutrient management recorded significant variations in seed yield plant^{-1} during both the years of experimentation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest seed yield plant^{-1} which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as pooled analysis. Treatment N_9 recorded significantly higher seed weight plant^{-1} over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and

N_7 by 68.5, 45.6, 27.9, 20.2, 25.7, 12.2, 10.5 & 11.3 per cent, respectively (on pooled basis). However, it was statistically at par with N_8.

It is further evident from data presented in Table 4.9 that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) recorded significantly highest seed yield plant^{-1} over control by 15.7, 31.7 & 40.1 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher seed yield plant^{-1} over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 30.7and 12.95 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) & recorded by 25.2 and 9.9 per cent, respectively higher seed yield plant^{-1} and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher seed weight plant^{-1} over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 20.27 and 10.58 per cent, respectively.

Plant growth regulators

It is explicit from data (Table 4.9) that different growth regulators recorded significant variations in seed yield plant^{-1} during 2013, 2014 and on pooled basis. Brassinolide recorded the maximum mean seed yield plant^{-1} which was 4.5 and 11.0 per cent higher than benzyladenine and water spray, respectively. Further brassinolide recorded maximum pods plant^{-1} which was 4.5 per cent higher seed yield plant^{-1} than benzyladenine spray.

Interaction (Nutrient management X PGR)

The interaction of different nutrient management levels and growth regulators recorded significant variation in seed yield plant^{-1} (Table 4.9.1). The highest seed yield plant^{-1} was recorded with foliar spray of G_1 (brassinolide) along with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB), under both the sets of dispositions (nutrient management within the growth regulator and growth regulator within the nutrient management) on pooled basis which corresponded to,10.05gm plant^{-1}, which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was statistically at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.4.6 Seed yield

Nutrient management

An examination of data furnished in Table 4.10 reveals that different nutrient management recorded significant variations in soybean seed yield during both the years of experimentation and on pooled basis. The maximum seed yield (1907 kg ha^{-1}) was resistered with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher seed yield (1907 kg ha^{-1}) over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 913, 670 480, 394, 434, 258, 174 & 221 kg ha^{-1}, respectively (on pooled basis). However, it was statistically at par with N_8.

A cursory look on data presented in Table 4.10 reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) registered significantly higher seed yield over control by 243, 433 & 519 kg ha^{-1}, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher seed yield over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 438 and 238 kg ha^{-1}, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 460 and 231 kg ha^{-1}, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher seed yield over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 394 and 174 kg ha^{-1}, respectively.

Plant growth regulators

Foliar application of growth regulators brought about significant improvement in seed yield during both the year as well as on pooled data basis (Table 4.10). Foliar spray of brassinolide (1664 kg ha^{-1}) and banzyladenine (1561 kg ha^{-1}) recorded significantly higher seed yield by 249 & 146 kg ha^{-1} over water spray (1415 kg ha^{-1}) (on pooled basis). Further brassinolide recorded significantly higher seed yield by 249 and 103 kg ha^{-1} over water spray and benzyladenine spray, respectively.

Interaction (Nutrient management X PGR)

An analysis of data furnished in Table 4.10.1 reveals that application of brassinolide 0.4 ppm (G_1) increased seed yield significantly over water spray (G_0), when no fertilizer applied as well as various RDP with or without sulphur and PSB. Similarly, benzyladenine 40 ppm (G_2) was also found significantly superior over water spray (G_0) at all levels of nutrient management, except Absolute control. Further, data show that N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) has produced maximum seed yield at all growth regulator treatments *viz.* water spray (G_0), brassinolide 0.4 ppm spray (G_1) and benzyladenine 40 ppm spray (G_2). This treatment was found significantly superior over rest of the nutrient management treatments, except N_5, N_6, N_7 and N_8, when water spray done. While at the brassinilide 0.4 ppm (G_1), this treatment was found at par with N_8 only. However, it was at par with N_8 and N_6 at benzyladenine 40 ppm spray (G_2).

An interpretation of data depicted in Table 4.10.1 further reveals that among different combinations of nutrient management and growth regulators, interaction of G_1 (brassinolide) along with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB), recorded the maximum and significantly higher seed yield under both the sets of dispositions (nutrient management within the growth regulator and growth regulator within the nutrient management) on pooled basis which corresponded to 2167 kg ha^{-1}, which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was statistically at par with foliar spray of brassinolide along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.4.7 Haulm yield

Nutrient management

An analysis of data reported in Table 4.10 reveals that different nutrient management recorded significant variations in haulm yield of soybean during both the years of research and on pooled basis. Application of N_9 (125 % RDP+ 30 Sulphur along with seed inoculations with PSB) significantly increased the haulm yield during both the years of experimentation. Maximum haulm yield recorded under the influence of N_9 (125 % RDP+ 30 Sulphur along with seed inoculations with PSB) which was significantly superior over rest of the treatments during both the years as well as on pooled basis, however, N_8 (100 % RDP+ 30 Sulphur along with seed inoculations with PSB) remained at par with each other across the year and on pooled basis. Treatment N_9 recorded significantly higher haulm yield over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 2020, 1448, 988, 799, 871, 510, 322, & 489 kg ha^{-1}, respectively (on pooled basis).

Data presented in Table 4.10 further show that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 572, 1032 & 1221 kg ha^{-1}, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher haulm yield over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 959 and 382 kg ha^{-1}, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher haulm yield over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 835 and

357 kg ha^{-1}, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher haulm yield over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 799 and 322 kg ha^{-1}, respectively

Plant growth regulators

Data presented in Table 4.10 clearly elucidate that different growth regulators recorded significant variations in haulm yield of soybean during both the years of experimentation and on pooled basis in order of brassinolide (G_1) > benzyladenine (G_2) > water spray (G_0). On pooled basis, foliar spray of brassinolide (G_1) and benzyladenine (G_2) significantly registered 552 and 336 kg ha^{-1} higher haulm yield (pooled) over water spray (G_0). Further foliar spray of brassinolide recorded significantly higher haulm yield than benzyladenine and water spray which was to the tune of 216 and 552 kg ha^{-1}, respectively.

Interaction (Nutrient management X PGR)

An examination of data reported in Table 4.10.2 indicates that among different combinations of nutrient management and growth regulators, interaction of G_1 (brassinolide) along with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded the maximum and significantly higher pooled haulm yield (5013 kg ha^{-1}) under both the sets of dispositions (at same nutrient management under varying growth regulator as well as at same growth regulator under varying nutrient management options). Pooled analysis show significant result over rest of treatment combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was statistically at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.4.8 Biological yield

Nutrient management

A cursory look on data reported in Table 4.10 reveals that different nutrient management recorded significant variations in biological yield of soybean during both the years of experimentation and on pooled basis. The maximum biological yield was recorded with N_9 (125 % RDP+ 30 sulphur along with seed inoculations with PSB) which prove significantly higher biological yield over rest of the treatment during both years as well as on pooled basis. It remained at par with N_8 (100 % RDP+ 30 sulphur along with seed inoculations with PSB). On pooled basis, N_9 recorded significantly higher biological yield over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 2932, 2117, 1467, 1193, 1305, 768, 495 & 709 kg ha^{-1}, respectively.

An interpretation of data in Table 4.10 further reveals that N_1 (75 % RDF), N_2 (100 % RDF) and N_3 (125 % RDF) recorded significantly higher biological yield over control by 815, 1465 & 1739 kg ha^{-1}, respectively. N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher biological yield over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 1408 and 596 kg ha^{-1}, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 1255 and 556 kg ha^{-1}, respectively, and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher biological yield over N_3 (125 % RDP and N_6 (125 % RDP + 30 kg Sulphur) by 1193 and 495 kg ha^{-1}, respectively.

Plant growth regulators

A critical examination of data appended in Table 4.10 clearly concludes that different growth regulators recorded significant variations in biological yield of soybean during both the year of investigation and on pooled basis. Foliar spray of brassinolide (5733 kg ha^{-1}) and banzyladenine (5414 kg ha^{-1}) recorded significantly higher biological yield by 801 & 482 kg ha^{-1}, over water spray (4932 kg ha^{-1}) (on pooled basis). Further foliar spray of brassinolide recorded significantly higher biological yield over benzyladenine and water spray by 319 and 801 kg ha^{-1}, respectively.

Interaction (Nutrient management X PGR)

An analysis of data reported in Table 4.10.3 shows that among different combinations of nutrient management and growth regulators, interaction between G_1 (brassinolide) along with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded the maximum and significantly higher biological yield (7180 kg ha^{-1}) under both the sets of conditions (at same nutrient management option under varying growth regulator as well as at same growth regulator under varying nutrient management) (pooled). On pooled basis, it was significantly superior over rest of the treatment combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.4.9 Harvest index

Nutrient management

Different nutrient management did not record significant variations in the harvest index of soybean during 2013 and 2014. However on pooled basis of the data it was recorded significant variation in harvest index (Table 4.10). Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher harvest index over N_0, N_1, N_2, N_3 and N_4. However, it was statistically at par with rest of the treatments.

Plant growth regulators

A perusal of data reported in Table 4.10 clearly reveal that different growth regulators failed to record any significant variation in harvest index during both the years of experimentation and on pooled comparison.

4.5 Quality parameters

4.5.1 Total chlorophyll content

Nutrient management

A perusal of data (Table 4.11) reveals that various treatments of nutrient management significantly influenced the total chlorophyll content of leaves at 60 DAS during both the years of experimentation as well as on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest total chlorophyll content in leaves, which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as on pooled basis. Treatment N_9 recorded significantly higher chlorophyll content over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 34.7, 25.6, 17.7, 14.3, 16.7, 9.4, 7.3 & 8.1 per cent, respectively (on pooled basis). However, it was at par with N_8.

Data presented in Table 4.11 further show that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 7.2, 14.4 & 17.8 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher chlorophyll content over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 16.2 and 7.9 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) found significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 15.6 and 7.4 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher chlorophyll content over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 14.3 and 7.3 per cent, respectively.

Plant growth regulators

Foliar spray of brassinolide and benzyladenine significantly increased total chlorophyll over water spray at 60 DAS during 2013, 2014 and on pooled basis

(Table 4.11). Increase in total chlorophyll due to brassinolide and benzyladenine was 5.8 and 3.7 per cent (60 DAS) over control, respectively. Further brassinolide recorded significantly higher total chlorophyll by 5.8 and 2.0 per cent over water spray and benzyladenine spray, respectively.

4.5.4 Protein content

Nutrient management

A perusal of data furnished in Table 4.11 reveals that different nutrient management recorded significant variations in seed protein content during both the years of investigation and on pooled basis. The highest protein content recorded with the application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) which was significantly superior over N_0, N_1, N_2, N_3 and N_4 but it was at par with N_5, N_6, N_7 and N_8 during both the years. However, on pooled basis, N_9(125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher seed protein content over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 7.0, 5.3, 3.5, 3.3, 3.4, 1.9, 1.7 & 1.7 per cent, respectively. However, it was statistically at par with N_8.

An analysis of data reported in Table 4.11 further indicate that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 1.6, 3.3 & 3.5 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher seed protein content over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 3.4 and 1.6 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 3.4 and 1.8 percent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher seed protein content over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 3.3 and 1.7 per cent, respectively.

Plant growth regulators

Data furnished in Table 4.11 illustrate that different plant growth regulators recorded significant variations in seed protein content during both the individual years as well as on pooled basis. On pooled basis, foliar spray of brassinolide and banzyladenine recorded significantly higher seed protein content by 3.5 & 1.7 per cent over water spray. Further brassinolide significantly increased the seed protein content over other growth regulators and registered an increase of 1.7 and 3.5 per cent over benzyladenine and water spray, respectively.

4.5.3 Protein yield

Nutrient management

An examination of data reported in Table 4.12 indicates that different nutrient management recorded significant variations in protein yield during both the years of study and on pooled basis. The treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded maximum protein yield which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher dry matter accumulation over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 105.8, 62.5, 38.5, 30.5, 34.2, 18.1, 12.1 & 15.3 per cent, respectively (on pooled basis).

Data presented in Table 4.12 further indicate that N_1 (75 % RDP) N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 26.6, 48.5 & 57.6 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher protein content over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 40.9 and 16.3 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 33.7 and 14.0 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher protein content over N_3 (125 % RDP and N_6 (125 % RDP + 30 kg Sulphur) by 30.5 and 12.4 per cent, respectively.

Plant growth regulators

It is explicit from data appended in Table 4.12 that different PGRs recorded significant variations in protein yield during both the years of experimentation and on pooled basis. Enhancement in mean protein yield due to brassinolide was 8.5 and 21.8 per cent than benzyladenine and water spray, respectively. Further benzyladenine also recorded significantly higher protein yield over water spray by 12.27 per cent.

Interaction (Nutrient management X PGR)

An analysis of data reported in Table 4.12.1 shows that among different combinations of nutrient management and growth regulators, interaction between G_1 (brassinolide) along with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded the maximum and significantly higher pooled protein yield (905 kg ha^{-1}) under both the sets of conditions (at same nutrient management under varying growth regulator as well as at same growth regulator under varying nutrient management). On pooled basis, it was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.5.4 Oil content

Nutrient management

It is evident from data presented in Table 4.11 that different nutrient management recorded significant variations in oil content during both the years of study and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered highest oil content in seed which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as pooled analysis. Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher oil content over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 11.8, 8.6, 6.0, 5.5, 5.7, 3.1, 2.5 & 2.8 per cent, respectively (on pooled basis). However, it was statistically at par with N_8.

It is further inferred from data (Table 4.11) that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 2.9, 5.5 & 5.9 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher oil content over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 5.6 and 2.8 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 5.5 and 2.6 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with

PSB) registered significantly higher oil content over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 5.5 and 2.5 per cent, respectively.

Plant growth regulators

A cursory look on data presented in Table 4.11 reveals that different growth regulators recorded significant variations in oil content during both the years of experimentation and on pooled basis. Foliar spray of brassinolide and banzyladenine recorded significantly higher oil content by 4.2 & 1.8 per cent over water spray (on pooled basis). Further brassinolide recorded the highest mean oil content in soybean and the magnitude of increase over benzyladenine and water spray was 2.3 and 4.2 per cent, respectively.

4.5.5 Oil yield

Nutrient management

An analysis of data reported in Table 4.12 indicates that different nutrient management recorded significant variation in oil yield during both the individual years and on pooled basis. The maximum oil yield was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both years and on pooled basis. Treatment N_9 recorded significantly higher oil yield over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 114.5, 67.3, 41.6, 33.1, 37.0, 19.3, 13.0 & 16.3 per cent, respectively (on pooled basis).

Data appended in Table 4.12 further show that among various nutrient management N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 28.2, 51.4 & 61.1 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher oil yield over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 43.8 and 17.7 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 36.4 and 14.9 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher oil yield over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 33.1 and 13.0 per cent, respectively.

Plant growth regulators

It is apparent from data furnished in Table 4.12 that different growth regulators recorded significant variation in oil yield during either of the years of study and on pooled basis. Application of brassinolide and benzyladenine recorded significantly higher oil yield than water spray by 22.3 and 12.2 per cent on pooled basis. Further enhancement in oil yield by brassinolide was 9.0 and 22.3 per cent over benzyl adenine and water spray, respectively.

Interaction (Nutrient management X PGR)

An examination of data reported in Table 4.12.2 shows that among different combinations of nutrient management and growth regulators, interaction of G_1 (brassinolide) along with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded the maximum and significantly higher pooled oil yield (447 kg ha^{-1}) under both the sets of dispositions (at same nutrient management option under varying growth regulator as well as at same growth regulator under varying nutrient management options). On pooled basis it was significantly superior over rest of the treatment combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was statistically at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6 Plant analysis

4.6.1 Nitrogen content in seed

Nutrient management

An examination of data in Table 4.13 reveals that different nutrient management recorded significant variations in nitrogen content in seed during both the years of experimentation and on pooled basis. The maximum nitrogen content was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nitrogen content over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 7.0, 5.3, 3.5, 3.3, 3.4, 1.9, 1.7 & 1.7 per cent, respectively (on pooled basis). However, it was statistically at par with N_8.

An analysis of results presented in Table 4.13 further reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 1.5, 3.3 & 3.5 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nitrogen content over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 3.5 and 1.6 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 3.4 and 1.8 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher nitrogen content over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 3.3 and 1.7 per cent, respectively.

Plant growth regulators

An examination of data presented in Table 4.13 elucidates that different growth regulators recorded significant variations in nitrogen content in seed of soybean during both the years of investigation and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_2) registered 3.5 and 1.7 per cent higher nitrogen content (pooled) in seed over water spray (G_0), respectively. Further brassinolide recorded the highest nitrogen content in seed by 1.7 and 3.5 per cent over benzyladenine and water spray, respectively.

4.6.2 Nitrogen content in haulm

Nutrient management

An appraisal of data furnished in Table 4.13 reveals that different nutrient management recorded significant variations in nitrogen content in haulm during 2013, 2014 and on pooled basis. The maximum nitrogen content in haulm was recorded with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nitrogen content in haulm over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 18.4, 13.9, 8.6, 8.0, 8.2, 4.1, 3.8 & 3.9 per cent, respectively. However, it was statistically at par with N_8.

Data presented in Table 4.13 further reveal that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly higher over control by 4.0, 9.0 & 9.7 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nitrogen content in haulm over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 9.5 and 4.1 per cent, respectively. treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 8.2 and 3.7 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nitrogen content in haulm over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 8.0 and 3.8 per cent, respectively.

Plant growth regulators

An evaluation of data reported in Table 4.13 illustrates that different growth regulators recorded significant variations in nitrogen content in haulm during both the years of study and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_2) registered 4.4 and 2.4 per cent higher pooled nitrogen content in haulm over water spray (G_0), respectively. Further brassinolide recorded the highest nitrogen content in haulm and showed an increase of 1.9 and 4.4 per cent over benzyl adenine and water spray, respectively.

4.6.3 Nitrogen uptake by seed

Nutrient management

A perusal of data presented in Table 4.13 reveals that different nutrient management recorded significant variations in nitrogen uptake by seed during both the years of experimentation and on pooled basis. The highest nitrogen uptake by seed was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher nitrogen uptake by seed over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 105.8, 62.5, 38.5, 30.5, 34.2, 18.1, 12.1 & 15.3 per cent, respectively. However, it was statistically at par with N_8.

An interpretation of data (Table 4.12) further reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 26.6, 48.5 & 57.6 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher nitrogen uptake by seed over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 40.9 and 16.3 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with

PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 33.7 and 14.0 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nitrogen uptake by seed over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 30.5 and 12.1 per cent, respectively.

Plant growth regulators

The experimental findings appended in Table 4.12 reveal that different plant growth regulators recorded significant variations in nitrogen uptake by seed during both the years of research and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar application of brassinolide (G_1) and benzyladenine (G_2) registered 21.8 and 12.2 per cent higher pooled nitrogen uptake by seed over water spray (G_0), respectively. Further brassinolide recorded highest nitrogen uptake by seed 8.5 and 21.8 per cent over benzyl adenine and water spray, respectively.

Interaction (Nutrient management X PGR)

An appraisal of data in Table 4.13.1 clearly indicates that interaction between G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher pooled nitrogen uptake by seed (144.87 kg ha^{-1}) over other interactions under both the sets of interaction (at same nutrient management under varying growth regulator as well as at same growth regulator under varying nutrient management o) on pooled basis which corresponded to 144.87 kg ha^{-1}, which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was statistically at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.4 Nitrogen uptake by haulm

Nutrient management

An analysis of data presented in Table 4.12 shows that different nutrient management recorded significant variations in nitrogen uptake by haulm during both the years of investigation and on pooled basis. The maximum nitrogen uptake by haulm was registered with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher nitrogen uptake by haulm over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 112.2, 66.5, 38.5, 30.9, 33.8, 17.3, 11.7 & 16.4 per cent, respectively. However, it was statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

An interpretation of data in Table 4.13 further reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 27.4, 53.1 & 62.0 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher nitrogen uptake by haulm over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 43.0 and 15.0 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 33.3 and 12.9 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher nitrogen uptake by haulm over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 30.9 and 11.7 per cent, respectively.

Plant growth regulators

An analysis of data presented in Table 4.13 reveals that different plant growth regulators recorded significant variations in nitrogen uptake by haulm during both the years of study and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_2) registered 20.6 and 12.0 per cent higher pooled nitrogen uptake by haulm over water spray (G_0), respectively. Further brassinolide recorded the highest nitrogen uptake in haulm and showed an increase of 7.6 and 20.6 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

A critical examination of data in Table 4.13.2 indicates that interaction of G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher pooled nitrogen uptake by haulm (92.25 kg ha^{-1}) over other interactions under study which corresponded to 92.25 kg ha^{-1}, which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was statistically at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.5 Total nitrogen uptake

Nutrient management options

A cursory look on data presented in Table 4.13 shows that different nutrient management recorded significant variations in total nitrogen uptake by soybean during 2013, 2014 and on pooled basis. The highest total nitrogen uptake was recorded with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher total nitrogen uptake over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 108.3, 64.0, 38.5, 30.7, 34.0, 17.8, 11.9 & 15.7 per cent, respectively (on pooled basis). Howeve,r it was statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

An examination of data reported in Table 4.13 further reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 26.9, 50.3 & 59.3 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher total nitrogen uptake over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 41.7 and 15.8 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 33.6 and 13.6 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher total nitrogen uptake over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 30.7 and 11.9 per cent, respectively.

Plant growth regulators

An appraisal of data reported in Table 4.13 reveals that different plant growth regulators recorded significant variations in total nitrogen uptake during both the years of experimentation and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar application of brassinolide (G_1) and benzyladenine (G_2) registered 21.3 and 12.1 kg ha^{-1} more total nitrogen uptake over water spray (G_0), respectively (pooled). Further brassinolide recorded the highest total nitrogen uptake by 8.1 and 21.3 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

An interpretation of data presented in Table 4.13.3 explicit that interaction of G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher pooled total nitrogen uptake by soybean (237 kg ha^{-1}) over other interactions which corresponded to 237 kg ha^{-1}, and was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.6 Phosphorus content in seed

Nutrient management

An interpretation of data presented in Table 4.14 reveals that different nutrient management recorded significant variations in phosphorus content in seed during both the years of study and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest phosphorus content in seed which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher phosphorus content in seed over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 15.5, 11.3, 7.4, 7.2, 7.3, 3.5, 3.4 & 3.5 per cent, respectively (on pooled basis). However, it was statistically at par with N_8 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB).

It is further explicit from data (Table 4.14) that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 3.8, 7.5 & 7.7 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher phosphorus content in seed over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 7.4 and 3.6 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 7.2 and 3.4 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher phosphorus content in seed over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 7.2 and 3.4 per cent, respectively.

Plant growth regulators

An appraisal of data (Table 4.14) reveals that different plant growth regulators recorded significant variations in phosphorus content in seed during 2013, 2014 and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar application of G_1 and G_2 registered 3.5 and 1.8 per cent higher phosphorus content in seed over water spray (G_0), respectively (pooled). Further brassinolide recorded the highest phosphorus content in seed and showed an increase of 1.7 and 3.5 per cent over benzyladenine and water spray, respectively

4.6.7 Phosphorus content in haulm

Nutrient management

A perusal of data (Table 4.14) reveals that different nutrient management recorded significant variations in phosphorus content in haulm during both the years of investigation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded maximum phosphorus content in haulm which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher phosphorus content in haulm over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 16.9, 12.4, 8.1, 7.6, 7.8, 4.0, 3.6 & 3.8 per cent, respectively (on pooled basis). However, it was statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

Data (Table 4.14) further elucidate that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 4.0, 8.1 & 8.6 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher phosphorus content in haulm over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 8.2 and 3.8 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 7.9 and 3.8 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher phosphorus content in haulm over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 7.6 and 3.6 per cent, respectively.

Plant growth regulators

Data presented in Table 4.14 illustrate that different plant growth regulators recorded significant variations in phosphorus content in haulm during both the years of research and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_2) registered 3.7 and 1.9 per cent higher phosphorus content in haulm over water spray (G_0), respectively (pooled). Further brassinolide recorded the highest phosphorus content in haulm which was 1.8 and 3.7 per cent over benzyladenine and water spray, respectively

4.6.8 Phosphorus uptake by seed

Nutrient management

An examination of data (Table 4.13) shows that different nutrient management recorded significant variations in phosphorus uptake by seed during both the years of research and on pooled basis. The maximum phosphorus uptake by seed obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher phosphorus uptake by seed over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 to the tune of 121.7, 71.5, 43.6, 35.5, 39.1, 19.9, 14.0 &

17.1 per cent, respectively (on pooled basis). However, it was statistically at par with N_8 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB).

It is further explicit from data (Table 4.14) that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 29.2, 54.4 & 63.8 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher phosphorus uptake by seed over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur), which was to the tune of 46.4 and 18.7 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher P uptake over N_2 (100 % RDP and N_5 (100 % RDP + 30 kg Sulphur) by 38.7and 15.93 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher phosphorus uptake by seed over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) to the tune of 35.5 and 14.0 per cent, respectively.

Plant growth regulators

Data appended in Table 4.1 clearly conclude that different plant growth regulators recorded significant variations in phosphorus uptake by seed during both the years of experimentation and on pooled basis. Foliar spray of brassinolide (G_1) and benzyl adenine (G_2) recorded 21.8 and 12.2 per cent higher phosphorus uptake (pooled) by seed over water spray (G_0), respectively. Further mean enhancement in phosphorus uptake by seed due to brassinolide was 8.5 and 21.8 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

An examination of data (Table 4.14.1) indicates that interaction of G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher pooled phosphorus uptake by seed (15.40 kg ha^{-1}) over other interactions, under both the sets of dispositions (nutrient management option within the growth regulator and growth regulator within the nutrient management options) on pooled basis which corresponded to 15.40 kg ha^{-1}, and was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.9 Phosphorus uptake by haulm

Nutrient management

A critical examination of data (Table 4.14) clearly reveals that different nutrient management recorded significant variations in phosphorus uptake by haulm during both the years of investigation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest phosphorus uptake by haulm which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. It was also obtained that N_9 recorded significantly higher phosphorus uptake by haulm over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 46.2, 32.3, 20.8, 15.2, 20.7, 11.8, 6.3 & 9.9 per cent, respectively. However, it was statistically at par with N_8.

It is clear from data presented in Table 4.14 that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 10.4, 20.9 & 26.8 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher phosphorus uptake by haulm over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 20.3 and 9.7 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher P uptake over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 18.6 and 8.8 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher phosphorus uptake by haulm over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 15.2 and 6.3 per cent, respectively.

Plant growth regulators

An interpretation of data presented in Table 4.14 indicates that different plant growth regulators recorded significant variations in phosphorus uptake by haulm during both the years of study and on pooled basis in order of brassinolide (G_1)> benzyl adenine (G_2)> water spray (G_0). Foliar spray of G_1 and G_2 registered 20.0 and 11.6 per cent higher phosphorus uptake (pooled) by haulm over water spray (G_0), respectively. Further mean enhancement in phosphorus uptake by haulm due to brassinolide was 7.5 and 20.0 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

An interpretation of data in Table 4.14.2 indicates that interaction of G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher pooled phosphorus uptake by haulm (10.24 kg ha^{-1}) over remaining interactions under consideration. On pooled basis which corresponded to 10.24 kg ha^{-1}, and was significantly superior over rest of the treatment combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was statistically at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.10 Total phosphorus uptake

Nutrient management

An analysis of data presented in Table 4.14 reveals that different nutrient management recorded significant variations in total phosphorus uptake by soybean crop during both the years of investigation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest total phosphorus uptake which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher total phosphorus uptake over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 116.5, 68.5, 41.2, 33.2, 36.7, 18.8, 13.0 & 16.8 per cent, respectively (pooled). However, it was statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

Data presented in Table 4.14 further explicit that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 28.4, 53.3 & 62.4 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher total phosphorus uptake over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 44.2 and 17.0 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) found significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 36.3 and 14.7 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher total phosphorus uptake over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 33.2 and 13.0 per cent, respectively.

Plant growth regulators

It is evident from data presented in Table 4.14 that different growth plant regulators recorded significant variations in total phosphorus uptake by soybean during both the years of research and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar application of G_1 and G_2 registered 21.0 and 11.8 per cent higher pooled total phosphorus uptake over water spray (G_0), respectively. Further brassinolide recorded the highest uptake by soybean crop and showed an increase of 8.1 and 21.0 per cent over benzyladenine and water spray, respectively.

Interaction (Nutrient management X PGR)

An analysis of data (Table 4.14.3) indicates that interaction of G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher total phosphorus uptake by soybean (25.64 kg ha^{-1}) over rest of interactions under test. On pooled basis it corresponded to 25.64 kg ha^{-1}, which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.11 Potassium content in seed

Nutrient management

An examination of data in Table 4.15 reveals that different nutrient management failed to record any significant variations in potassium content in seed during both the years of experimentation and on pooled basis.

Plant growth regulators

A perusal of data presented in Table 4.15 reveals that different plant growth regulators failed to record any significant variation in potassium content in seed during both the years of experimentation and on pooled basis.

4.6.12 Potassium content in haulm

Nutrient management

An appraisal of data reported in Table 4.15 reveals that variations registered in potassium content in haulm under different nutrient management during 2013, 2014 and on pooled basis were not significantly influenced.

Plant growth regulators

Data presented in Table 4.15 indicate that variations in potassium content in haulm among different plant growth regulators were not significant during 2013, 2014 and on pooled basis.

4.6.13 Potassium uptake by seed

Nutrient management

A perusal of data reported in Table 4.15 reveals that different nutrient management recorded significant variations in potassium uptake by seed during both the years of experimentation and on pooled basis. The maximum potassium uptake by seed was noticed with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Further data showed that treatment N_9 recorded significantly higher potassium uptake by seed over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 99.0, 58.0, 35.9, 27.5, 31.5, 16.6, 10.5 & 13.6 per cent, respectively. However, it was statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

An examination of data in Table 4.15 further shows that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly higher over control by 26.0, 46.4 & 58.0 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher potassium uptake by seed over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 39.0 and 15.7 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 31.4 and 12.8 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher potassium uptake by seed over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 27.5 and 10.5 per cent, respectively.

Plant growth regulators

The experimental findings appended in Table 4.15 reveals that different plant growth regulators recorded significant variations in potassium uptake by seed during both the years of research and on pooled basis in order of brassinolide (G_1)>

benzyladenine (G_2)> water spray (G_0). Foliar application of brassinolide (G_1) and benzyladenine (G_2) registered 17.9 and 10.5 per cent higher pooled potassium uptake by seed over water spray (G_0), respectively. Further mean enhancement in potassium uptake by seed due to brassinolide was 6.7 and 17.9 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

An appraisal of data reported in Table 4.15.1 clearly indicates that interaction between G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher pooled potassium uptake by seed (40.15 kg ha^{-1}) over other interactions under both the sets of interaction (at same nutrient management under varying growth regulator as well as at same growth regulator under varying nutrient management). On pooled basis it corresponded 40.15 kg ha^{-1} kg ha^{-1}, which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.14 Potassium uptake by haulm

Nutrient management

An analysis of data reported in Table 4.15 shows that different nutrient management recorded significant variations in potassium uptake by haulm during both the years of investigation and on pooled basis. The highest potassium uptake by haulm was recorded with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both years and pooled data basis. Treatment N_9 recorded significantly higher potassium uptake by haulm over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 84.3, 48.5, 28.9, 22.2, 24.7, 13.2, 7.9 & 12.6 per cent, respectively. However, it was statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

It is explicit from data presented in Table 4.15 that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 23.1, 41.7 &

49.5 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher potassium uptake by haulm over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 31.8 and 10.7 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) found significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 24.5 and 9.4 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher potassium uptake by haulm over N_3 (125 % RDP and N_6 (125 % RDP + 30 kg Sulphur) by 22.2 and 7.9 per cent, respectively.

Plant growth regulators

An analysis of data presented in Table 4.15 reveals that different plant growth regulators recorded significant variations in potassium uptake by haulm during both the years of study and on pooled basis in order of brassinolide > benzyladenine (G_2)> water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_2) registered 17.0 and 10.7 per cent higher potassium uptake (pooled) by haulm over water spray (G_0), respectively. Further brassinolide recorded significantly higher potassium uptake by haulm and showed an increase of 5.6 and 17.0 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

A critical examination of data presented in Table 4.15.2 indicates that interaction between G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher pooled potassium uptake by haulm (139.47 kg ha^{-1}) over other interactions under study, which corresponded to 139.47 kg ha^{-1}, and was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) (on pooled basis). However, it was statistically at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). .

4.6.15 Total Potassium uptake

Nutrient management

A cursory look on data reported in Table 4.15 shows that different nutrient management recorded significant variations in total potassium uptake by soybean during 2013, 2014 and on pooled basis. The maximum total potassium uptake was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher total potassium uptake over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 86.1, 50.4, 30.4, 23.3, 26.1, 14.0, 8.5 & 12.8 per cent, respectively (pooled). However, it was statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

It is further explicit from data (Table 4.15) that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly higher over control by 23.7, 42.7 & 50.8 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher total potassium uptake over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 33.3 and 11.7 per cent, respectively. N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 25.9 and 10.1 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher total potassium uptake over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 23.3 and 8.5 per cent, respectively.

Plant growth regulators

An appraisal of data in Table 4.15 reveals that different plant growth regulators recorded significant variations in total potassium uptake during both the years of experimentation and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar application of brassinolide (G_1) and benzyladenine (G_2) recorded 17.2 and 10.7 per cent more total potassium uptake over water spray (G_0), respectively (pooled). Further mean enhancement in total potassium uptake due to brassinolide was 5.9 and 17.2 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

An interpretation of data shown in Table 4.15.3 explicit that interaction of G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher total potassium uptake (pooled) by soybean (179.62 kg ha^{-1}) over other interactions. On pooled basis it corresponded to 179.62 kg ha^{-1}, which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.16 Sulphur content in seed

Nutrient management

An analysis of data depicted in Table 4.16 reveals that different nutrient management recorded significant variations in sulphur content in seed during both the years of experimentation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest sulphur content in seed which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Application of N_9 recorded significantly higher sulphur content in seed over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 23.9, 18.1, 13.1, 11.6, 13.5, 7.2, 4.4 & 5.5 per cent, respectively. However, it was statistically at par with N_8.

It is further evident from data furnished in Table 4.16 that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly higher over control by 4.9, 9.5 & 11.0 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher sulphur content in seed over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 11.95 and 7.66 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) found significantly higher over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 11.8 and 5.9 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher sulphur content in seed over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 11.6 and 4.4 per cent, respectively.

Plant growth regulators

The experimental results presented in Table 4.16 elucidate that different plant growth regulators recorded significant variations in sulphur content in seed during both the years of investigation and on pooled basis in order of brassinolide (G_1)>

benzyladenine (G_2)> water spray (G_0). Foliar spray of G_1 and G_2 registered 3.7 and 2.0 per cent higher sulphur content in seed over water spray (G_0), respectively (pooled). Further brassinolide recorded higher sulphur content in seed and showed an increase of 1.6 and 3.7 per cent over benzyladenine and water spray, respectively

4.5.17 Sulphur content in haulm

Nutrient management

A critical examination of data reported in Table 4.16 reveals that different nutrient management recorded significant variations in sulphur content in haulm during both the years of research and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest sulphur content in haulm which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher sulphur content in haulm over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 24.3, 18.4, 13.0, 11.1, 11.7, 6.9, 5.2 & 6.4 per cent, respectively (pooled). However, it was statistically at par with N_8.

An examination of data (Table 4.16) further reveals that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly higher over control by 5.0, 10.0 & 11.8 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher sulphur content in haulm over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 11.3 and 5.0 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 10.2 and 4.3 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher sulphur content in haulm over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 11.1 and 5.2 per cent, respectively.

Plant growth regulators

It is evident from data appended in Table 4.15 that different plant growth regulators recorded significant variations in sulphur content in haulm during both the years of experimentation and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar spray of G_1 and G_2 registered 3.9 and 2.2 per cent higher sulphur content in haulm (pooled) over water spray (G_0), respectively. Further mean enhancement in sulphur content in haulm by brassinolide was 1.6 and 3.9 per cent over benzyladenine and water spray, respectively

4.6.18 Sulphur uptake by seed

Nutrient management

It is explicit from data (Table 4.16) that different nutrient management recorded significant variations in sulphur uptake by seed during both the years of experimentation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest sulphur uptake by seed which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher sulphur uptake by seed (pooled) over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 137.7, 82.1, 51.5, 40.6, 47.2, 24.1, 15.1 & 19.5 per cent, respectively. However, it was statistically at par with N_8.

A critical examination of data presented in Table 4.16 further indicate that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 30.5, 56.8 & 69.0 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher sulphur uptake by seed over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 52.3 and 23.1 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 44.7 and 18.5 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher sulphur uptake by seed over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 40.6 and 15.1 per cent, respectively.

Plant growth regulators

It is evident from data (Table 4.16) that different plant growth regulators recorded significant variations in sulphur uptake by seed during 2013, 2014 and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_2) registered 22.2 and 12.4 per cent higher sulphur uptake by seed (pooled) over water spray (G_0), respectively. Further brassinolide recorded the sulphur uptake by seed and showed an increase of 8.7 and 22.2 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

An interpretation of data (Table 4.16.1) indicates that interaction of G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher sulphur uptake (pooled) by seed (7.21 kg ha^{-1}) over other interaction under evaluation, which corresponded to 7.21 kg ha^{-1}, and was significantly superior over rest of the treatment combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.5.19 Sulphur uptake by haulm

Nutrient management

An examination of data (Table 4.15) clearly reveals that different nutrient management recorded significant variations in sulphur uptake by haulm during both the years of experimentation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest sulphur uptake by haulm which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher sulphur uptake by haulm (pooled) over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 121.9, 72.6, 43.7, 34.4, 38.2, 20.3, 13.0 & 18.7 per cent, respectively. However, it was at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

It is further inferred from data (Table 4.15) that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly higher over control by 28.5, 54.3 & 65.1 per cent, respectively. Application of N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher sulphur uptake by haulm over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 45.3 and 16.4 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 35.7and 13.6 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher sulphur uptake by haulm over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 34.4 and 13.0 per cent, respectively.

Plant growth regulators

The experimental findings presented in Table 4.16 reveal that different plant growth regulators recorded significant variations in sulphur uptake by haulm during both the years of study and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar spray of G_1 and G_2 registered 20.2 and 12.0 per cent higher pooled sulphur uptake by haulm over water spray (G_0), respectively. Further mean enhancement in sulphur uptake by brassinolide was 7.3 and 20.2 per cent over benzyl adenine and water spray, respectively

Interaction (Nutrient management X PGR)

An examination of data (Table 4.16.1) reveals that interaction of G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher sulphur uptake (pooled) by haulm (10.12 kg ha^{-1}) over other interactions under comparison. This was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). However, it was at par with foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.6.20 Total sulphur uptake

Nutrient management

A critical examination of data (Table 4.16) shows that different nutrient management recorded significant variations in total sulphur uptake by soybean during both the years of investigation and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest total sulphur uptake which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher total sulphur uptake over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 128.2, 76.5, 46.9, 36.9, 41.9, 21.9, 13.9 & 19.0 per cent, respectively. However, it was statistically at par with N_8.

An examination of data (Table 4.16) clearly indicates that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) found significantly superior over control by 29.3, 55.3 & 66.6 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher total sulphur uptake over N_1 (75 %

RDP) and N_4 (75 % RDP + 30 kg sulphur) by 48.2 and 19.1 per cent, respectively. Application of N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 39.6 and 15.6 per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher total sulphur uptake over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 36.9 and 13.9 per cent, respectively.

Plant growth regulators

A cursory look on data (Table 4.15) elucidates that different growth regulators recorded significant variations in total sulphur uptake during both the years of research and on pooled basis in order of brassinolide (G_1)> benzyladenine (G_2)> water spray (G_0). Foliar application of brassinolide (G_1) and benzyladenine (G_2) registered 20.9 and 12.0 per cent higher total sulphur uptake over water spray (G_0), respectively. Further brassinolide recorded maximum total sulphur uptake and showed an increase of 7.8 and 20.9 per cent over benzyladenine and water spray, respectively

Interaction (Nutrient management X PGR)

An analysis of data (Table 4.16.3) reveals that interaction between G_1 (brassinolide) and N_9 (125 % RDP + 30 kg sulphur + PSB) recorded the maximum and significantly higher total sulphur uptake (pooled) by soybean (17.33 kg ha^{-1}) under both the sets of conditions (at same nutrient management under varying growth regulator as well as at same growth regulator under varying nutrient management), which was significantly superior over rest of the treatments combinations except foliar spray of G_1 (brassinolide) along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB). Howeve,r it was at par with foliar spray of brassinolide along with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

4.7 Soil studies

4.7.1 Available soil nitrogen

Nutrient management

An interpretation of data Table 4.17 reveals that different nutrient management recorded significant variations in available soil nitrogen after crop harvest during both the years of research and on pooled basis. The maximum available soil nitrogen was obtained with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. Treatment N_9 recorded significantly higher available soil nitrogen over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 18.2, 13.5, 9.6, 8.5, 9.1, 5.2, 4.2 & 4.6 per cent, respectively. However it was statistically at par with N_8.

Plant growth regulators

It is clearly evident from data furnished in Table 4.17 that variations in available soil nitrogen after crop harvest under different growth regulators were not significant during 2013, 2014 and on pooled basis.

4.7.2 Available soil phosphorus

Nutrient management

An analysis of data reported in Table 4.17 reveals that different nutrient management recorded significant variations in available soil phosphorus after crop harvest during both the years of experimentation and on pooled basis. The highest available soil phosphorus was recorded with N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) treatment which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled. It was also observed that treatment N_9 recorded significantly higher available soil phosphorus (pooled) over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 17.8, 13.3, 8.9, 8.0, 8.5, 4.8, 4.4 & 4.2 per cent, respectively. However, it was statistically at par with N_8.

Plant growth regulators

It is explicit from data in Table 4.17 that variations in available soil phosphorus after crop harvest under different plant growth regulators failed to record any significant difference during 2013, 2014 and on pooled basis.

4.7.3 Available soil potassium

Nutrient management

An interpretation of data (Table 4.16) reveals that different nutrient management recorded significant variations in available soil potassium after harvest of crop during both the years of research and on pooled basis. Application of N_9 (125

% RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest available soil potassium which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled basis. It was also observed that treatment N_9 recorded significantly higher available soil potassium over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 128.2, 76.5, 46.93, 36.9, 41.9, 21.9, 13.9 & 19.0 per cent, respectively. However it was statistically at par with N_8.

Plant growth regulators

It is clear from data furnished in Table 4.17 that variations in available soil potassium after crop harvest under different plant growth regulators were not significant during 2013, 2014 and on pooled basis.

4.7.4 Available soil sulphur

Nutrient management

An interpretation of data (Table 4.16) reveals that different nutrient management recorded significant variations in available soil sulphur after crop harvest during both the years of research and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest available soil sulphur which was significantly superior over rest of the treatment except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years and on pooled. Further data show that treatment N_9 recorded significantly higher available soil sulphur over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 17.9, 13.3, 9.3, 8.5, 11.5, 5.01, 4.2 & 4.4 per cent, respectively. However, it was statistically at par with N_8.

Plant growth regulators

A perusal of data (Table 4.16) clearly shows that variations in available soil sulphur after crop harvest under different plant growth regulators failed to record any significant difference during 2013, 2014 and on pooled basis.

4.7.5 Nutrient balance sheets

4.7.5.1 Nitrogen

4.7.5.1.1 Expected nitrogen balance (D values)

Nutrient management

An analysis of data presented (Table 4.17) reveals that expected nitrogen balance or D values recorded a considerable variation among different nutrient management during both the years of study and on mean basis. The mean D values ranged from 123.09 kg N ha^{-1} under N_9 (125 % RDF + 30 kg Sulphur + seed inoculated with PSB) to 230.52 kg N ha^{-1} under N_0 (control). Different nutrient management options recorded a mixed trend in mean D values in order of N_0> N_1> N_2> N_4> N_3> N_5> N_7> N_6> N_8> N_9.

Plant growth regulators

An interpretation of data (Table 4.18) reveals that water spray (G_0) recorded higher mean D value for soil nitrogen than brassinolide (G_1) and banzyladenine (G_2) that corresponded to a variation equal to 31.34 and 17.86 kg N ha^{-1}, respectively.

4.7.5.1.2 Apparent gain/ loss in soil nitrogen (F values)

Nutrient management

Data presented in Table 4.18 indicate that all nutrient management options recorded positive mean F values which ranged from 38.84 (N_0) to 195.46 kg N ha^{-1} (N_9). Application of 125% RDF (N_3) and its integration with 30 kg sulphur ha^{-1} (N_6), and 30 kg sulphur ha^{-1} + PSB (N_9) recorded higher mean F values over their respective counter parts involving 100% RDF i.e. N_2, N_5 and N_8 by 10.66, 8.10 and 5.44 per cent and 75% RDF i.e. N_1, N_4 and N_7 by 58.5, 37.8 and 27.6 per cent respectively. Mean F values recorded an order N_9> N_6> N_3 under treatments involving 125% RDF and N_8> N_5> N_2 under treatments involving 100% RDF and in case of treatments involving 75% RDF, the order was N_7> N_4> N_1.

Plant growth regulators

A reference to data (Table 4.17) elucidate that different plant growth regulators recorded higher mean F values for nitrogen than water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_3) recorded higher mean F value over water spray (G_0) by 32.0 and 17.9 kg N ha^{-1}, respectively.

4.7.5.1.3 Actual gain/ loss in soil nitrogen (G value)

Nutrient management

Data appended in Table 4.18 indicate that mean actual gain/ loss in soil nitrogen (G value) ranged from 18.85 kg ha^{-1} (N_9) to -30.33 kg ha^{-1} (N_0). However, 125% RDP (N_3) and its integration with 30 kg sulphur ha^{-1} (N_6) and 30 kg sulphur ha^{-1} + PSB (N_9) recorded less negative mean G values than their respective counter parts involving 100% RDP i.e. N_2, N_5 and N_8 which corresponded to 12.44, 13.13 and 12.92 kg N ha^{-1} and 75% RDP i.e. N_1, N_4 and N_7 which corresponded to 23.82, 25.22 and 25.16 kg N ha^{-1}, respectively.

Plant growth regulators

It is clearly inferred from data presented in Table 4.18 that different plant growth regulators recorded a negative mean G values (G=E-A) for soil nitrogen. Foliar spray of brassinolide (G_1) recorded less negative or higher mean G values over benzyladenine (G_3) and water spray (G_0) that corresponded to 0.59 and 0.72 kg N ha^{-1}, respectively.

4.7.5.2 Phosphorus

4.7.5.2.1 Expected phosphorus balance (D value)

Nutrient management

An examination of data reported in Table 4.19 reveals that expected phosphorus balance or D values ranged from 13.82 kg ha^{-1} under N_0 (control) to 51.71 kg P_2O_5 ha^{-1} under N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB). Use of 125% RDF (N_3) and its integration with 30 kg sulphur ha^{-1} (N_6) and 30 kg sulphur ha^{-1} + PSB (N_9) recorded higher mean D values over their respective counter parts involving 100% RDP i.e. N_2, N_5 and N_8 by registering an increase corresponding to 18.74, 19.92 and 21.72 per cent and 75% RDP i.e. N_1, N_4 and N_7 by registering an increase corresponding to 40.30, 43.81 and 47.95 per cent, respectively. This indicates that D value was in order of RDF + 30 kg sulphur ha^{-1} + PSB > RDP + 30 kg sulphur ha^{-1} > RDP. It is to note that mean D values followed an order N_3> N_6> N_9> N_2 N_5> N_8> N_1> N_4 N_7> N_0 for all treatments.

Plant growth regulators

An examination of data reported in Table 4.19 indicates that water spray (G_0) recorded higher mean D values for soil phosphorus over brassinolide (G_1) and benzyladenine (G_3) which corresponded to 3.75 and 2.49 kg ha^{-1}, respectively.

4.7.5.2.2 Apparent gain/ loss in soil phosphorus (F values)

Nutrient management

Apparent gain/ loss (F value) of soil phosphorus appended in Table 4.19 show that all nutrient management recorded negative mean F values except control (N_0) for soil phosphorus which ranged from -24.29 kg ha^{-1} (N_9) to 9.45 kg ha^{-1} (N_0). An interpretation of data on mean F values clearly reveals a mixed trend in order of N_0> N_7> N_4> N_1> N_8> N_5> N_2> N_9 N_6> N_3.

Plant growth regulators

A perusal of data presented in Table 4.19 shows that different growth regulators recorded higher mean F values for soil phosphorus than water spray (G_0). Foliar spray of brassinolide recorded 1.42 and 4.09 kg ha^{-1} higher mean F value over and benzyl adenine (G_3) and water spray (G_0), respectively.

4.7.5.2.3 Actual gain/ loss in soil phosphorus (G values)

Nutrient management

An interpretation of data presented in Table 4.19 indicates that mean actual gain/ loss in soil phosphorus (G value) under different nutrient management recorded a mixed trend which ranged from -0.94 kg ha^{-1} (N_0) to 3.21 kg ha^{-1} (N_9). However, 125% RDP (N_3) and its integration with 30 kg sulphur ha^{-1} (N_6) and 30 kg sulphur ha^{-1} + PSB (N_9) recorded higher mean F values over their respective counter parts involving 100% RDP i.e. N_2, N_5 and N_8 which corresponded to 0.21, 0.09 and 0.09 kg ha^{-1}, and 75% RDP i.e. N_1, N_4 and N_7 which corresponded to 1.17, 1.00 and 1.11 kg ha^{-1}, respectively.

Plant growth regulators

It is evident from data in Table 4.19 that different plant growth regulators recorded a positive mean G values (G = E-A) for soil phosphorus. Use of water spray

(G_0) recorded lower mean G values for soil phosphorus than brassinolide (G_1) and benzyl adenine (G_2) which corresponded to 0.34 and 0.18 kg ha^{-1}, respectively.

4.7.5.1 Potassium

4.7.5.3.1 Expected potassium balance (D values)

Nutrient management

An analysis of data presented in Table 4.20 reveals that expected potassium balance or D values recorded a considerable variation among different nutrient management during both the years of study and on mean basis. The mean D values ranged from 212.40 kg K_2O ha^{-1} under N_9 (125% RDF + 30 kg sulphur ha^{-1} + PSB) to 287.87 kg K_2O ha^{-1} under N_0 (control). Different nutrient management options recorded a mixed trend in mean D values in order of N_0> N_1> N_2> N_4> N_3> N_5> N_7> N_6> N_8> N_9.

Plant growth regulators

An interpretation of data depicted in Table 4.20 reveals that water spray (G_0) recorded higher mean D value for expected potassium balance than brassinolide (G_1) and benzyl adenine (G_2) that corresponded to a variation equal to (-) 21.14 and (-)13.13 kg K_2O ha^{-1}, respectively over water spray.

4.7.5.3.2 Apparent gain/ loss in soil potassium (F values)

Nutrient management

Data presented in Table 4.20 indicate that all nutrient management recorded positive mean F values which ranged from 21.47 kg K_2O ha^{-1} (N_0) to 117.15 kg K_2O ha^{-1} (N_9). Application of 125% RDF (N_3) and its integration with 30 kg sulphur ha^{-1} (N_6) and 30 kg sulphur ha^{-1} + PSB (N_9) recorded higher mean F values over their respective counter parts involving 100% RDF i.e. N_2, N_5 and N_8 by registering an increase to the extent of 15.0, 10.8 and 6.9 per cent and 75% RDF i.e. N_1, N_4 and N_7 by registering an increase to the extent of 63.4, 39.0 and 26.8 per cent, respectively. Mean F values recorded an order N_9> N_8> N_6> N_7> N_5> N_3> N_4> N_2> N_1> N_0 under all treatments.

Plant growth regulators

A reference to data (Table 4.20) elucidates that different plant growth regulators recorded higher mean F values for potassium than water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_2) recorded higher mean F value over water spray (G_0) by 24.03 and 14.72 kg ha^{-1}, respectively.

4.7.5.3.3 Actual gain/ loss in soil potassium

Nutrient management

Data appended in Table 4.20 indicate that mean actual gain/ loss in soil potassium (G value) ranged from -15.93 (N_9) to -36.14 kg ha^{-1} (N_0). However, 125% RDF (N_3) and its integration with 30 kg sulphur ha^{-1} (N_6) and 30 kg sulphur ha^{-1} + PSB (N_9) recorded less negative mean G values than their respective counter parts involving 100% RDF i.e. N_2, N_5 and N_8 which corresponded to 2.69, 2.48 and 2.05 kg ha^{-1} and 75% RDF i.e. N_1, N_4 and N_7 which corresponded to 5.41, 6.84 and 6.22 kg ha^{-1}, respectively.

Plant growth regulators

It is clearly inferred from data (Table 4.20) that different plant growth regulators recorded a negative mean G values (G=E-A) for soil potassium. Spray of brassinolide (G_1) recorded less negative or higher mean G values over benzyl adenine (G_2) and water spray (G_0) that corresponded to 1.29 and 2.88 kg ha^{-1}, respectively.

4.7.5.4 Sulphur

4.7.5.4.1 Expected sulphur balance (D value)

Nutrient management

An examination of data shown in Table 4.21 reveal that expected sulphur balance or D values ranged from 12.71 kg ha^{-1} under N_3 (125% RDF) to 43.10 kg ha^{-1} under N_4 (75% RDF + 30 kg sulphur ha^{-1}). Application of 75% RDF (N_1) and its integration with 30 kg sulphur ha^{-1} (N_4) and 30 kg sulphur ha^{-1} + PSB (N_7) recorded higher mean D values over their respective counter parts involving 125% RDF i.e. N_3, N_6 and N_9 by registering an increase corresponding to 19.5, 6.8 and 6.8 per cent and 100% RDF i.e. N_2, N_5 and N_8 by registering an increase corresponding to 13.3, 4.3 and 4.4 per cent, respectively. All treatments recorded a positive D value and the overall disposition was in a sequence of $N_4 > N_5 > N_7 > N_6 > N_8 > N_9 > N_0 > N_1 > N_2 > N_3$.

Plant growth regulators

A perusal of data reported in Table 4.21 reveals that water spray (G_0) recorded higher mean D values for expected sulphur balance than brassinolide (G_1) and benzyl adenine (G_2) which corresponded to 2.20 and 1.28 kg ha^{-1}, respectively.

4.7.5.4.2 Apparent gain/ loss in soil sulphur (F value)

Nutrient management

Data appended in Table 4.21 indicate that mean actual gain/ loss in soil sulphur (F value) ranged from -22.46 kg ha^{-1} (N_4) to 8.50 kg ha^{-1} (N_3). However, 125% RDF (N_3) and its integration with 30 kg sulphur ha^{-1} (N_6) and 30 kg sulphur ha^{-1} + PSB (N_9) recorded less negative and high positive mean F values than their respective counter parts involving 75% RDF i.e. N_1, N_4 and N_7 which corresponded to 2.96, 4.10 and 3.45 kg N ha^{-1}, 100% RDF i.e. N_2, N_5 and N_8 which corresponded to 0.91, 1.05 and 0.99 kg N ha^{-1}, respectively. An interpretation of data on mean F values clearly reveals a mixed trend in order of N_3> N_2> N_1> N_0> N_9> N_8> N_6> N_7 N_5> N_4.

Plant growth regulators

A perusal of data Table 4.21 shows that different plant growth regulators recorded a negative mean F values (F=E-D) for soil sulphur. Foliar spray of different growth regulators recorded higher and less negative mean F values for soil sulphur than water spray (G_0). Foliar spray of brassinolide (G_1) and benzyl adenine (G_2) recorded 2.48 and 1.44 kg ha^{-1} higher mean F value over water spray (G_0), respectively.

4.7.5.4.3 Actual gain/ loss in soil sulphur (G value)

Nutrient management

Data appended in Table 4.21 indicate that mean actual gain/ loss in soil sulphur (G value) ranged from -0.89 kg S ha^{-1} (N_9) to -4.40 kg S ha^{-1} (N_0). However, 125% RDF (N_3) and its integration with 30 kg sulphur ha^{-1} (N_6) and 30 kg sulphur ha^{-1} + PSB (N_9) recorded less negative mean G values than their respective counter parts involving 100% RDF i.e. N_2, N_5 and N_8 which corresponded to 0.15, 0.17 and 0.20 kg S ha^{-1}, 75% RDF i.e. N_1, N_4 and N_7 which corresponded to 0.90, 1.45 and 0.99 kg S ha^{-1}, respectively.

Plant growth regulators

It is evident from data reported in Table 4.21 that different plant growth regulators recorded a negative mean G values (G = E-A) for soil sulphur. Foliar spray of different growth regulators recorded higher and less negative mean G values for soil sulphur than water spray (G_0). Foliar spray of brassinolide (G_1) and benzyladenine (G_2) recorded 0.28 and 0.16 kg ha^{-1} higher mean F value over water spray (G_0), respectively.

4.8 Economics

4.8.1 Net return

Nutrient management

An analysis of data reported in Table 4.22 reveals that different nutrient management recorded significant variations in net return during 2013, 2014 and on pooled basis. Application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest net returns which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as on pooled basis. Treatment N_9 recorded significantly higher net returns over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by ₹ 30299, 23606, 17176, 14507, 15132, 9083, 6416 & 7268 ha^{-1}, respectively (pooled). However, it was statistically at par with N_8.

A reference to data in Table 4.22 further indicates that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly higher over control by ₹ 7659, 14384 & 17063 ha-^{1}, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher net returns over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by ₹ 16633 and 7864 ha-^{1} per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by ₹ 15414 and 7321 ha-^{1} per cent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher net returns over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by ₹ 14507 and 6416 ha-^{1} per cent, respectively.

Plant growth regulators

An analysis of data presented in Table 4.22 clearly shows that during either year of investigation as well as in pooled analysis, foliar application of brassinolide provided significantly higher net returns (₹ 37040 ha^{-1}) among all of the agrochemicals. Further water spray was also found significantly superior over benzyladenine. On pooled basis, brassinolide registered net returns of ₹ 37040 ha^{-1}, which was found higher by ₹ 6396 ha^{-1} and ₹ 8977 ha^{-1} over water spray and benzyladenine spray, respectively.

Interaction (Nutrient management X PGR)

An interpretation of data depicted in Table 4.10.1 reveals that foliar spray of brassinolide 0.4 ppm (G_1) increased net return significantly over water spray (G_0), when no fertilizer applied as well as various RDP with or without sulphur and PSB. Similarly, benzyladenine 40 ppm (G_2) was also found significantly superior over water spray (G_0) at all levels of nutrient management. Further, data show that N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) has recorded maximum net return at all growth regulator treatments *viz.* water spray (G_0), brassinolide 0.4 ppm spray (G_1) and benzyladenine 40 ppm spray (G_2). This treatment was found significantly superior over rest of the nutrient management treatments, except N_5, N_6, N_7 and N_8, when water spray done. While at the brassinilide 0.4 ppm (G_1) and benzyladenine 40 ppm (G_2), this treatment was found at par with N_8 only.

An analysis of data reported in Table 4.22.1 further reveals that among different combinations of nutrient management and growth regulators, interaction of G_1 (brassinolide) with N_9 (125% RDF + 30 kg Sulphur + seed inoculated with PSB) recorded the maximum and significantly higher pooled net return (₹ 54863 ha^{-1}) under both the ways of interactions (nutrient management within the growth regulator and growth regulator within the nutrient management). However, variations in net return were at par with interactions G_1 with N_8 on pooled basis. The interaction of G_1 and N_9 also recorded significantly higher net return over (₹ 54863 ha^{-1}) other combinations of nutrient management options and plant growth regulators except interactions G_1 (brassinolide) with N_8 (100% RDF + 30 kg Sulphur + seed inoculated with PSB) by registering values of ₹ 51455 ha^{-1}.

4.8.2 B-C ratio

Nutrient management

An examination of data reported in Table 4.21 elucidates that different nutrient management recorded significant variations in B-C ratio during both the years of investigation and on pooled basis. Supplementing nutrients to soybean crop using of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded highest B-C ratio which was significantly superior over rest of the treatments except N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) during both the years as well as o pooled basis. Treatment N_9 recorded significantly higher B-C ratio over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 43.7, 30.7, 20.4, 17.2, 19.2, 11.2, 9.1 & 9.7 per cent, respectively. However, it was statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

An evident of data (Table 4.22) further shows that N_1 (75 % RDP), N_2 (100 % RDP) and N_3 (125 % RDP) were significantly superior over control by 42.5, 85.1 & 100.0 per cent, respectively. Treatment N_7 (75 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered significantly higher B-C ratio over N_1 (75 % RDP) and N_4 (75 % RDP + 30 kg sulphur) by 80.5 and 26.3 per cent, respectively. Treatment N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) was found significantly superior over N_2 (100 % RDP) and N_5 (100 % RDP + 30 kg Sulphur) by 78.5and 20.0 percent, respectively and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) recorded significantly higher B-C ratio over N_3 (125 % RDP) and N_6 (125 % RDP + 30 kg Sulphur) by 47.2 and 16.0 per cent, respectively. .

Plant growth regulators

An interpretation of data (Table 4.22) indicates that brassinolide recorded significantly higher benefit cost ratio than water spray and benzyladenine during both the years and on pooled basis. Foliar spray of brassinolide (1.36) registered an increase in mean benefit cost ratio by 7.0 and 56.3 per cent over water spray (1.27) and benzyl adenine (0.87), respectively. Further water spray was found significantly superior as compared to benzyladenine spray.

Interaction (Nutrient management X PGR)

An analysis of data in Table (4.22.2) reveals that among different combinations of nutrient management and growth regulators, interaction of G_1

(brassinolide) with N_9 (125% RDF + 30 kg Sulphur + seed inoculated with PSB) recorded the maximum and significantly higher benefit cost ratio (1.97) (pooled) under both the ways of interactions (nutrient management within the growth regulator and growth regulator within the nutrient management). However, variations in cost benefit ratio were at par with interactions G_1 with N_8 on pooled basis. The interaction of G_1 and N_8 also recorded significantly higher benefit cost ratio over other combinations of nutrient management and plant growth regulators except interactions G_1 (brassinolide) with N_8 (100% RDF + 30 kg Sulphur + seed inoculated with PSB) by registering values of 1.88.

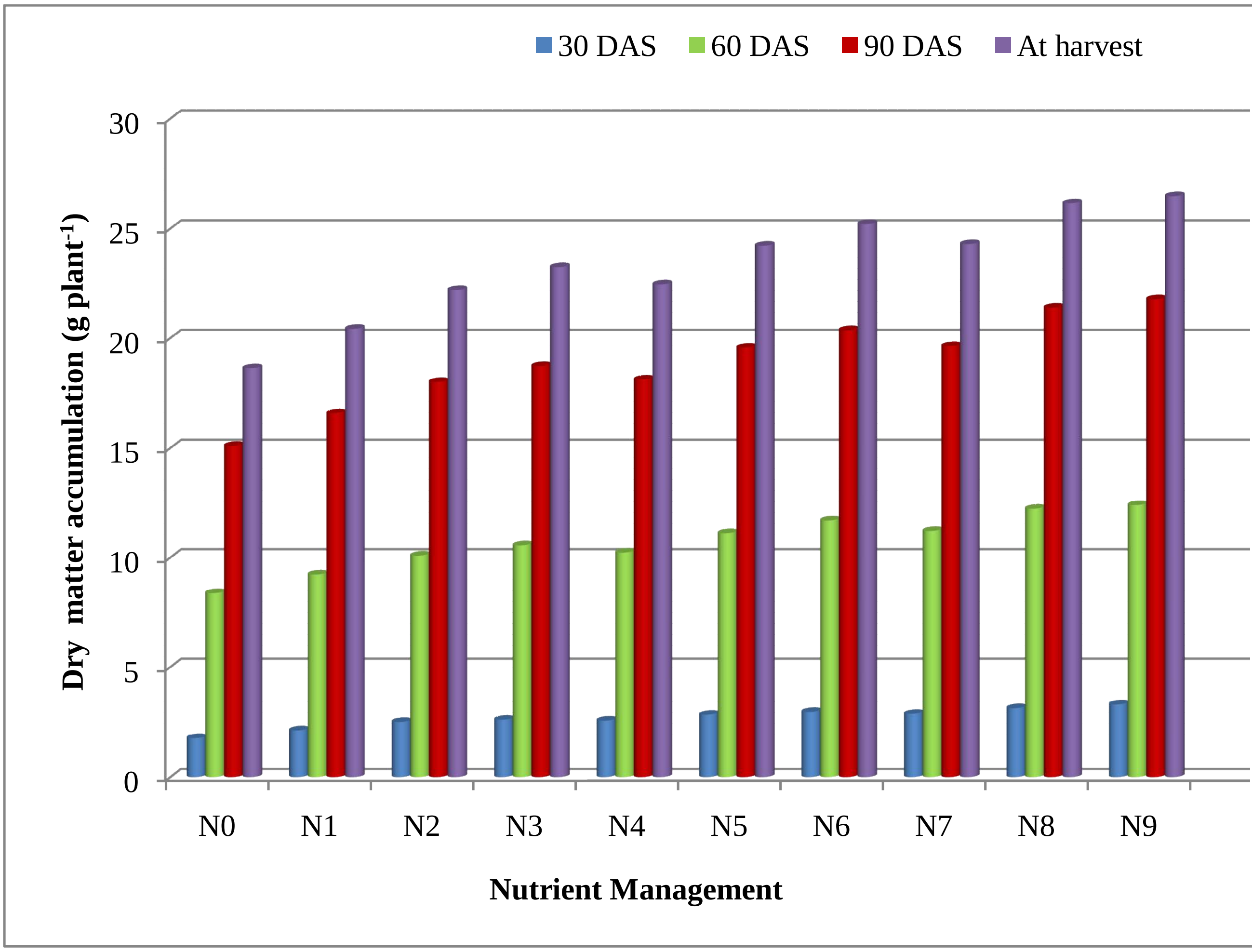


Fig.4.1: Effect of nutrient management and growth regulators on dry matter accumulation of soybean (Pooled)

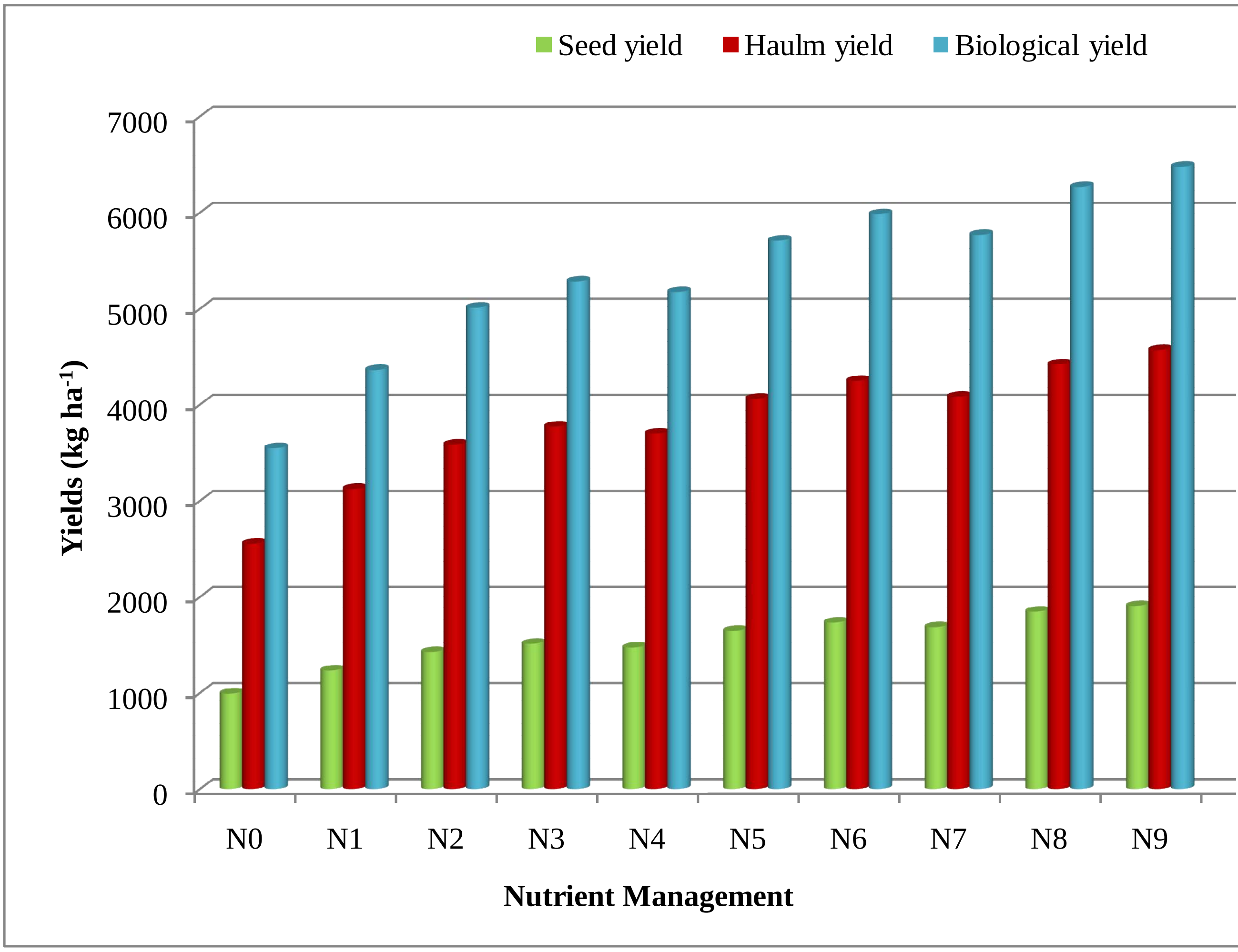


Fig.4.2: Effect of nutrient management and growth regulators on seed, haulm and biological yield of soybean (Pooled)

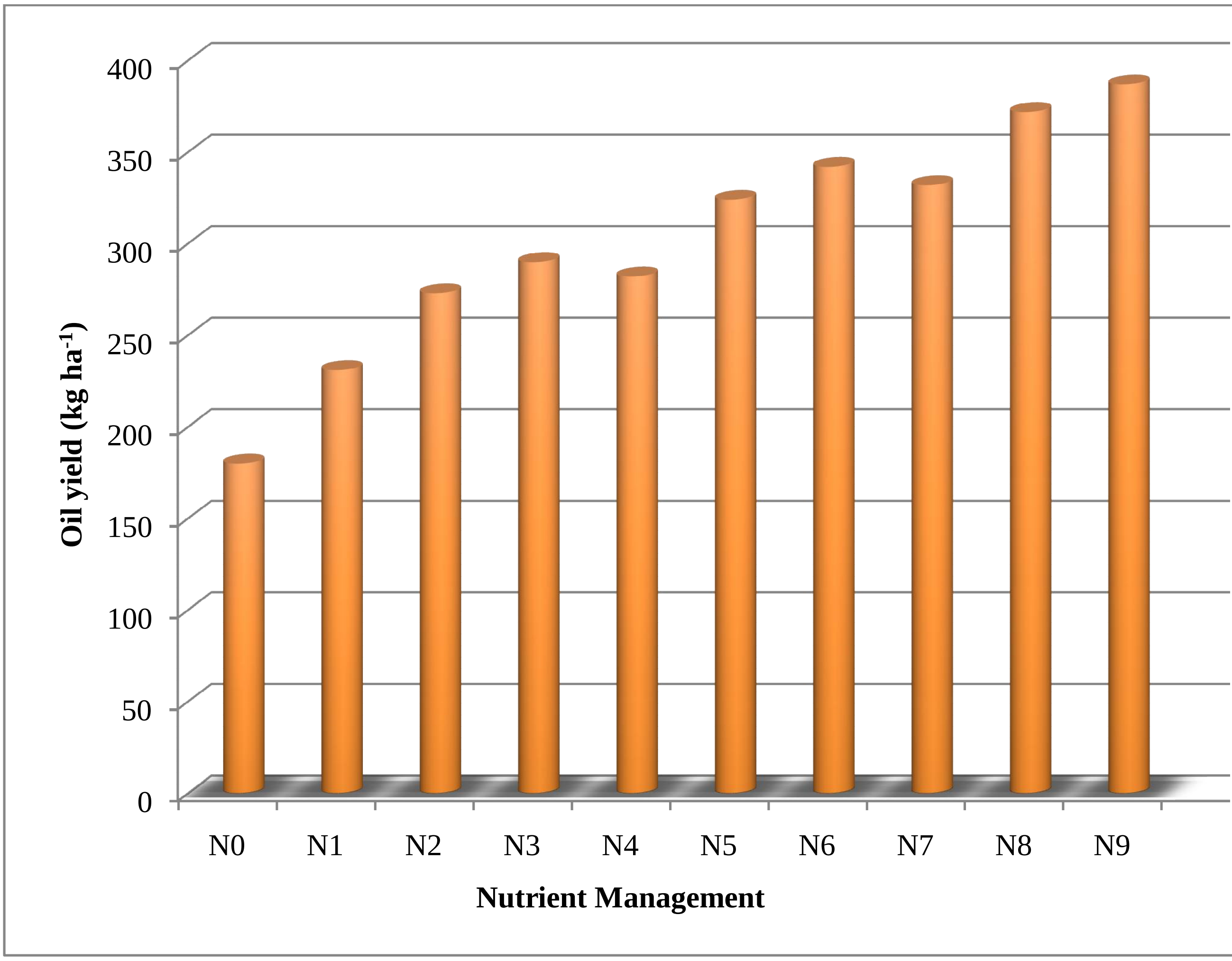


Fig.4.3: Effect of nutrient management and growth regulators on oil yield of soybean (Pooled)

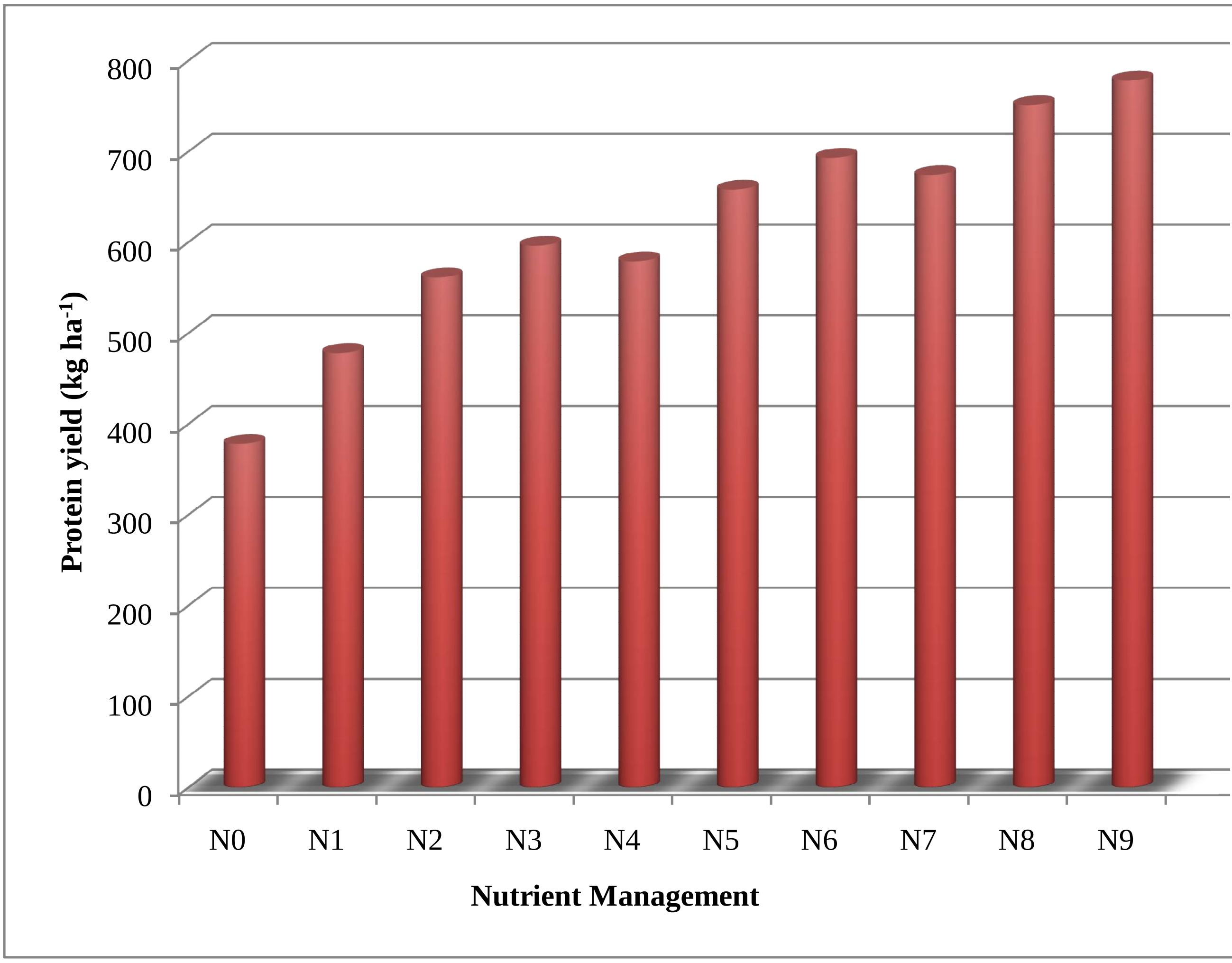


Fig.4.4: Effect of nutrient management and growth regulators on protein yield of soybean (Pooled)

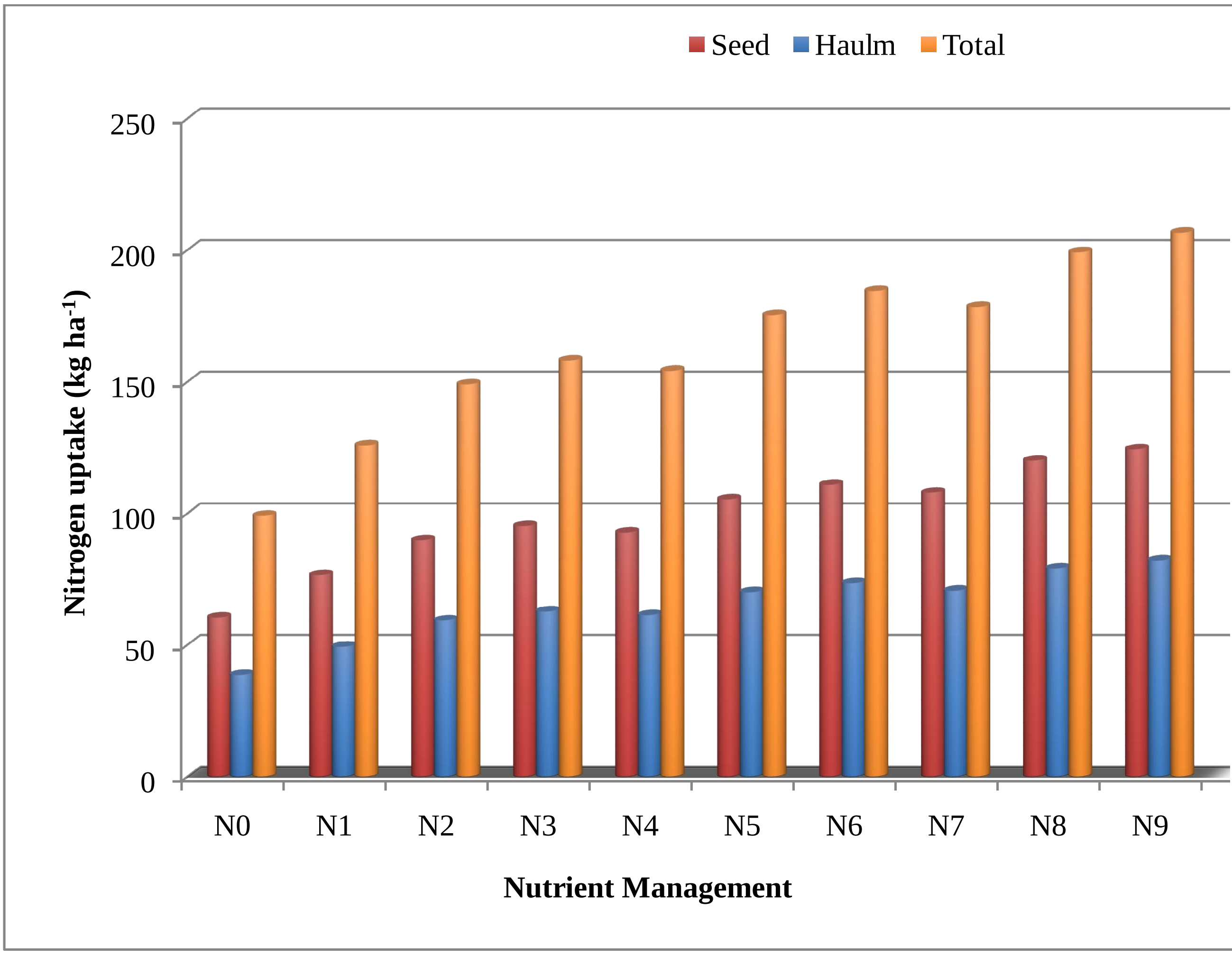


Fig.4.5: Effect of nutrient management and growth regulators on nitrogen uptake by soybean (Pooled)

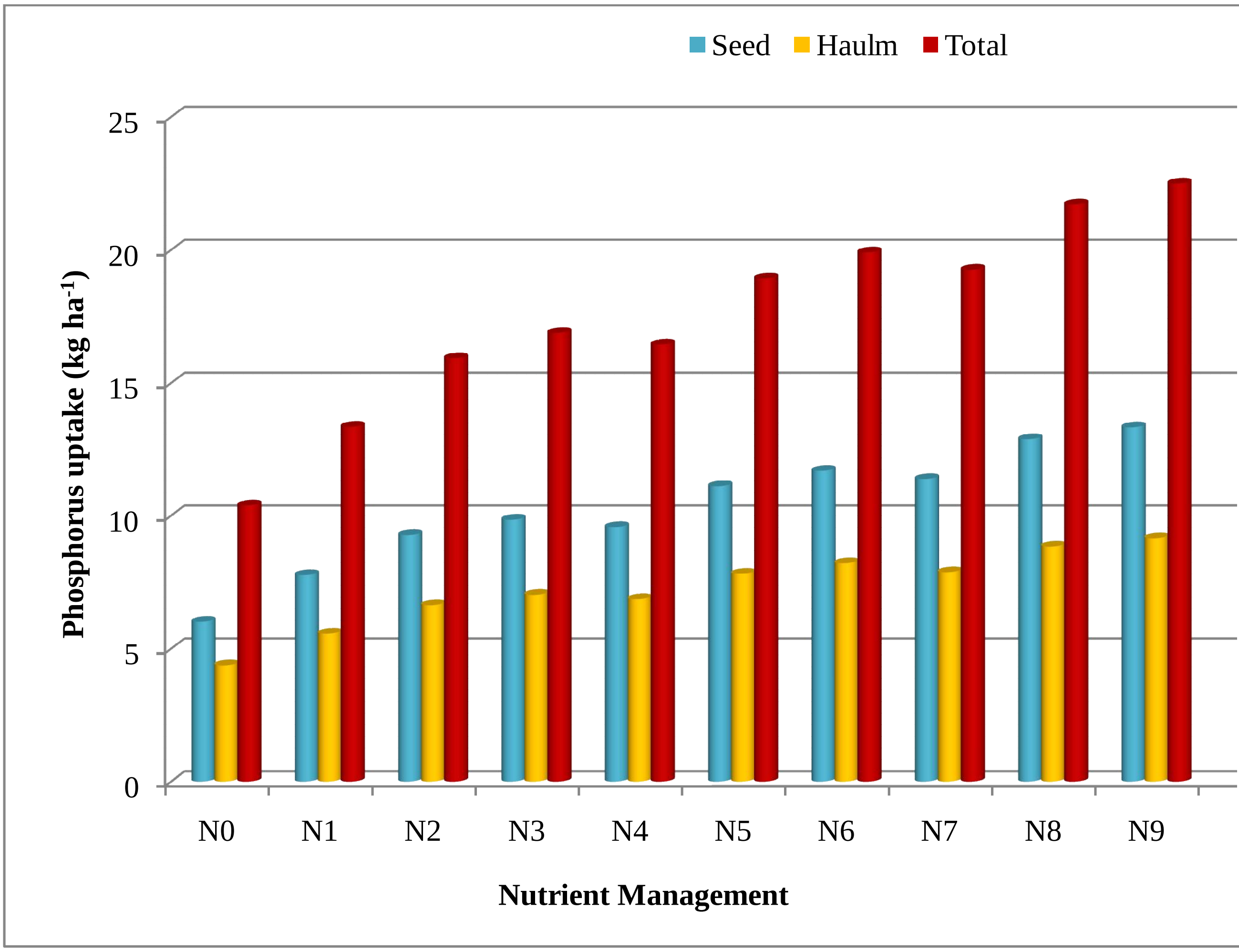


Fig.4.6: Effect of nutrient management and growth regulators on phosphorus uptake of soybean (Pooled)

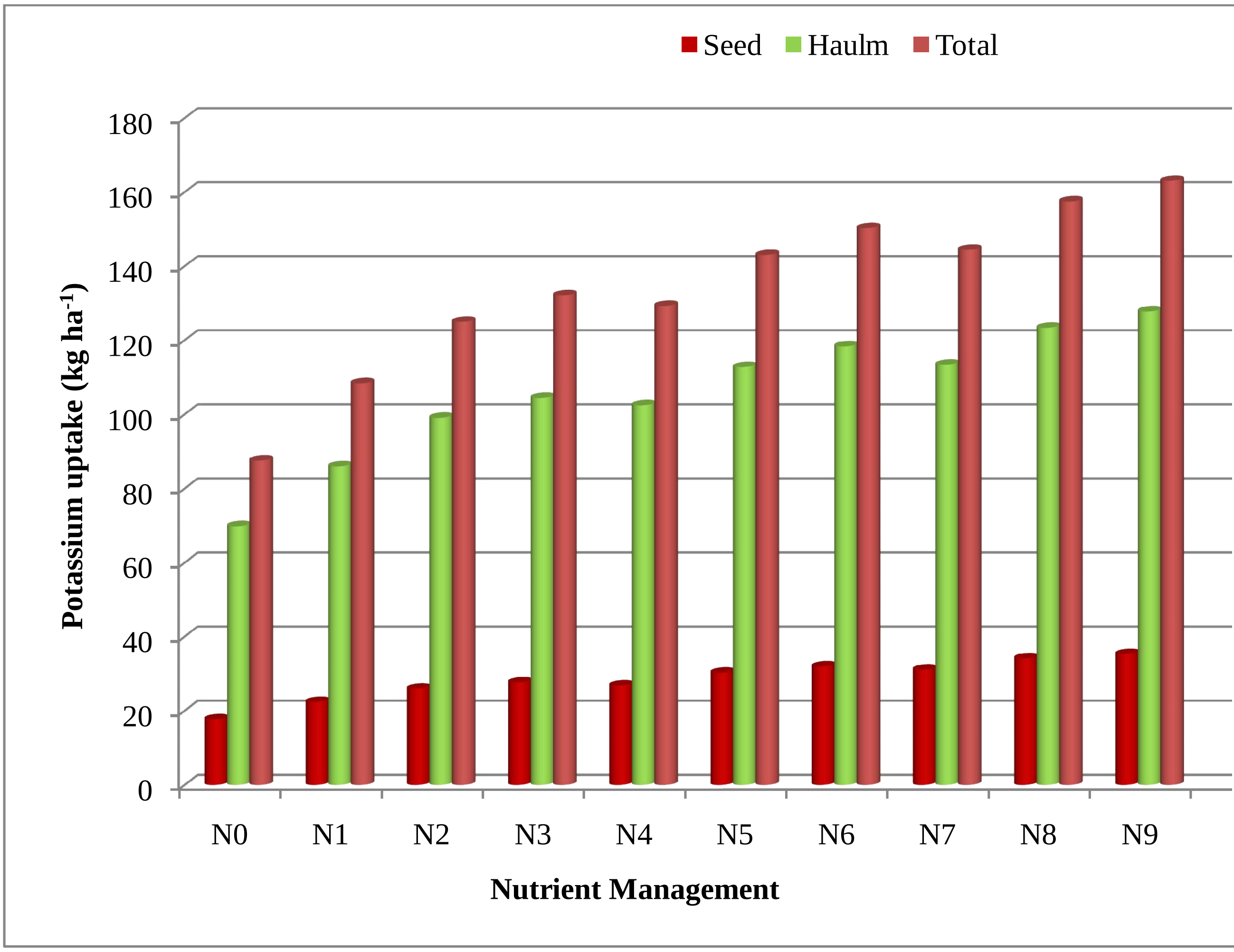


Fig.4.7: Effect of nutrient management and growth regulators on potassium uptake of soybean (Pooled)

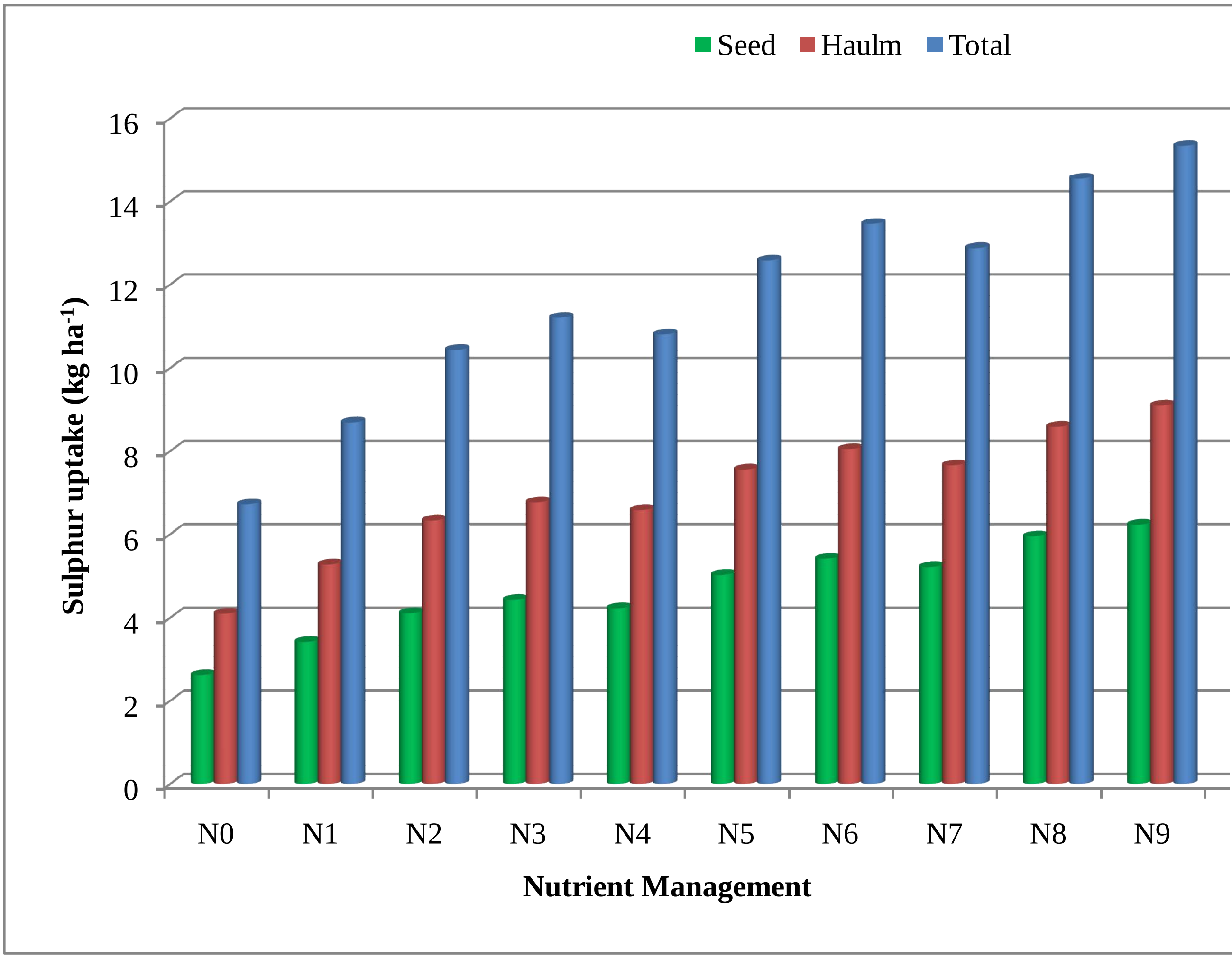


Fig.4.8: Effect of nutrient management and growth regulators on sulphur uptake of soybean (Pooled)

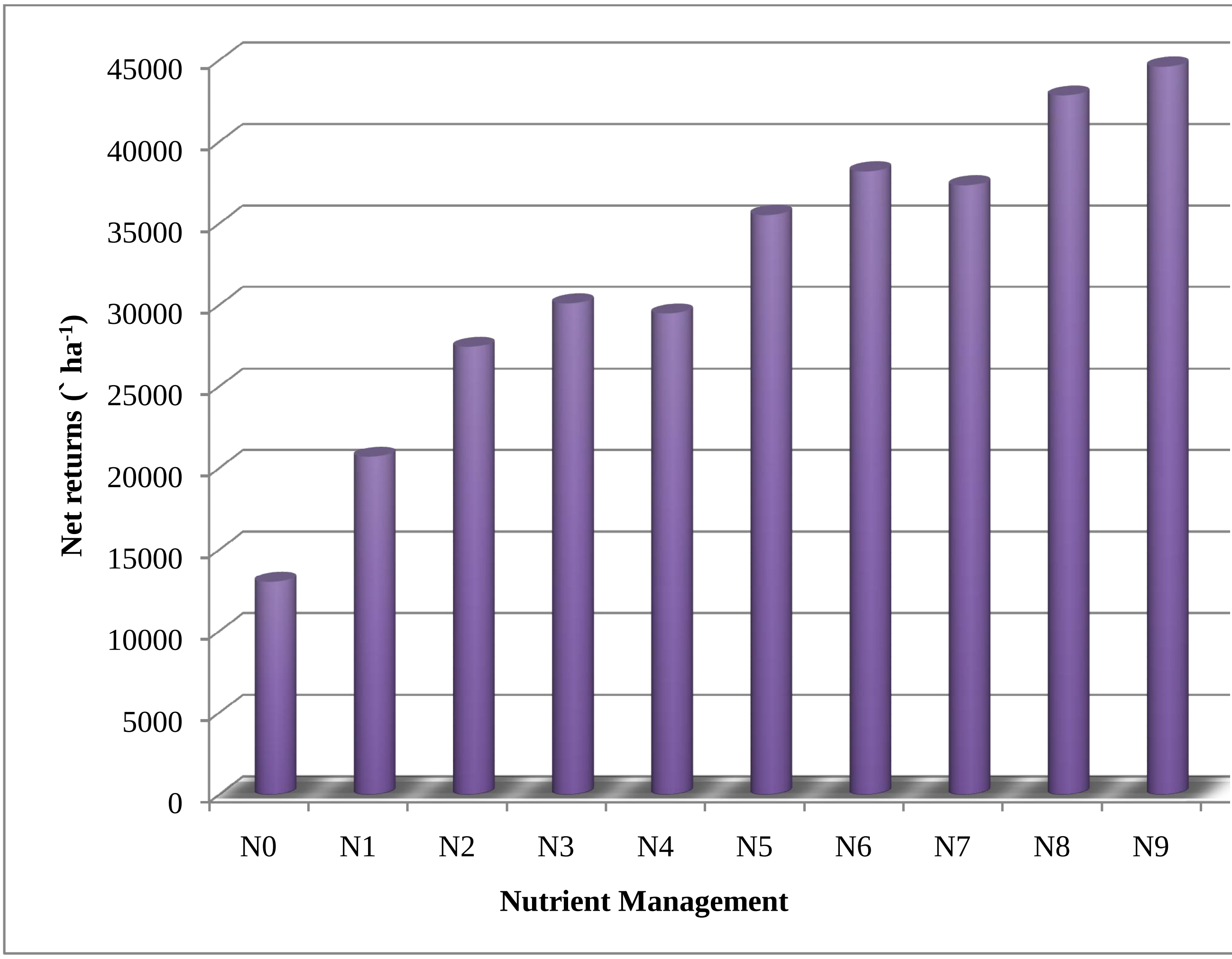


Fig.4.9: Effect of nutrient management and growth regulators on net return of soybean (Pooled)

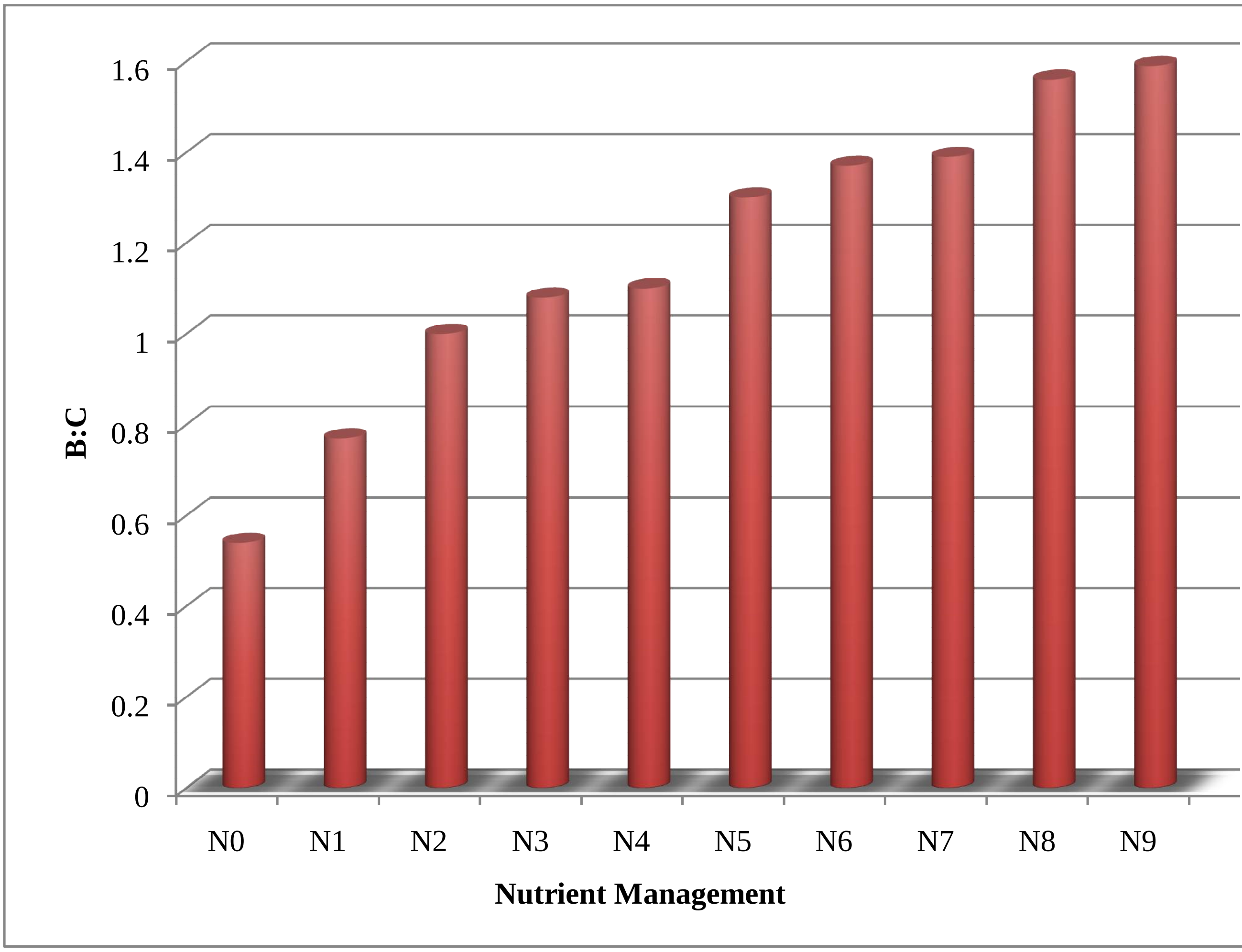


Fig.4.10: Effect of nutrient management and growth regulators on benefit cost ratio of soybean (Pooled)

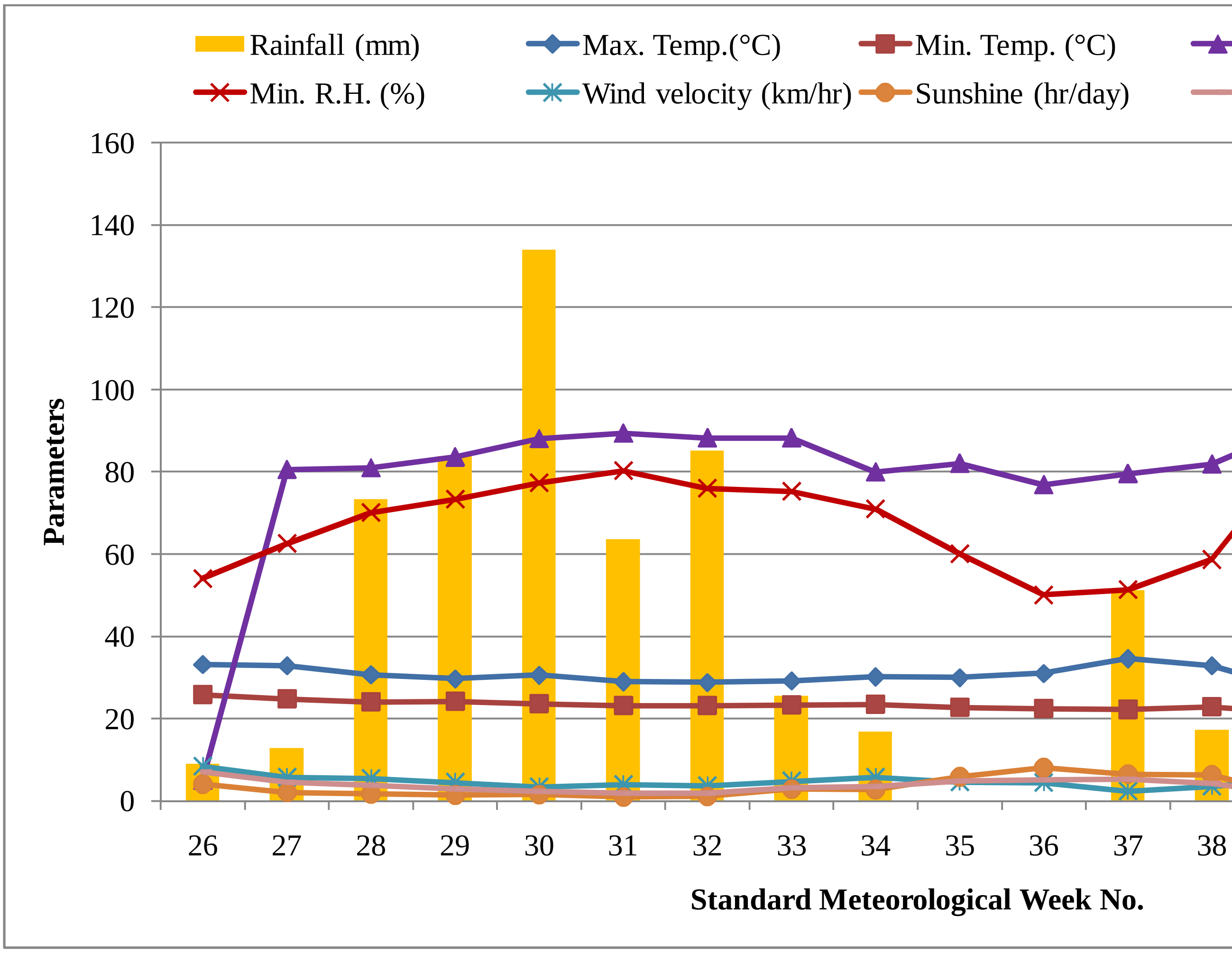


Fig.3.1: Mean weekly weather data recorded at Udaipur during *Kharif* 2013

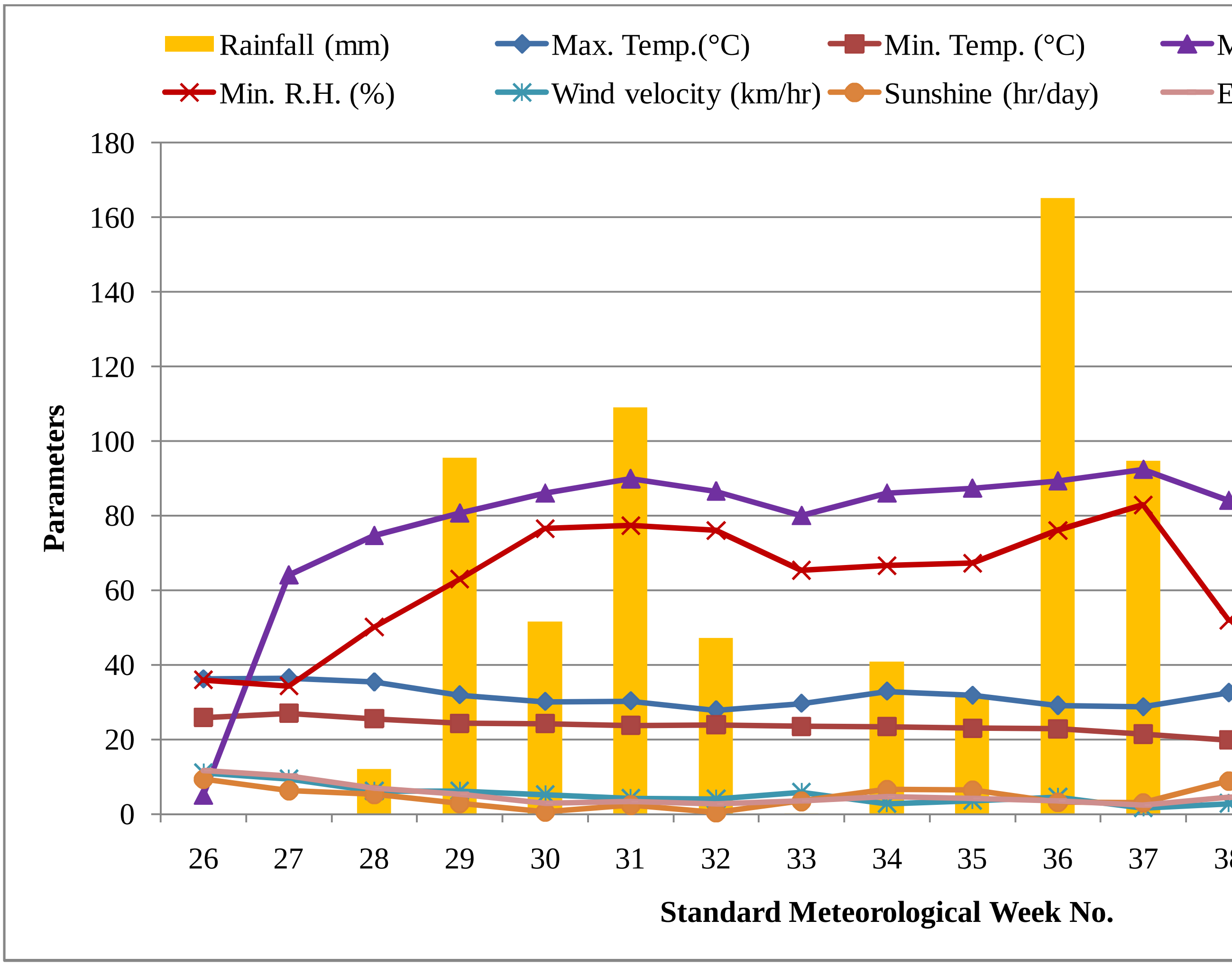


Fig.3.2: Mean weekly weather data recorded at Udaipur during *Kharif* 2014

Table 4.1 Effect of nutrient management and plant growth regulators on plant population of soybean

Treatments	**Plant population (Lakh ha^{-1})**					
	At 30 DAS			**At harvest**		
	2013	**2014**	**Pooled**	**2013**	**2014**	**Pooled**
Nutrient management						
N_0 (Absolute control)	3.11	3.20	3.16	2.86	2.92	2.89
N_1 (75 % RDP)	3.14	3.23	3.18	2.88	2.95	2.92
N_2 (100 % RDP)	3.16	3.24	3.20	2.91	3.00	2.96
N_3 (125 % RDP)	3.18	3.26	3.22	2.95	3.01	2.98
N_4 (N_1+30 kg Sulphur)	3.17	3.24	3.21	2.93	3.00	2.97
N_5 (N_2+30 kg Sulphur)	3.20	3.27	3.24	2.98	3.03	3.00
N_6 (N_3+30 kg Sulphur)	3.21	3.30	3.26	3.00	3.05	3.02
N_7 (N_4+ PSB)	3.20	3.29	3.25	2.99	3.04	3.02
N_8 (N_5+ PSB)	3.24	3.34	3.29	3.03	3.08	3.05
N_9 (N_6+ PSB)	3.25	3.35	3.30	3.05	3.11	3.08

SEm±	0.09	0.08	0.06	0.08	0.05	0.05
C.D. at 0.05	NS	NS	NS	NS	NS	NS
Growth regulators						
G_0 (Water spray)	3.18	3.26	3.22	2.94	2.99	2.97
G_1 (Brassinolide 0.4 ppm)	3.19	3.28	3.23	2.97	3.05	3.01
G_2 (Benzyladenine 40 ppm)	3.19	3.28	3.24	2.96	3.02	2.99
S.Em±	0.03	0.03	0.02	0.03	0.02	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS

NS=Non-significant

Table 4.2 Effect of nutrient management and plant growth regulators on plant height of soybean

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Nutrient management												
N_0 (Absolute control)	21.5	22.1	21.8	29.9	33.2	31.5	44.2	46.0	45.1	47.2	49.0	48.1
N_1 (75 % RDP)	23.8	24.3	24.1	34.1	37.0	35.5	49.2	50.8	50.0	52.0	54.1	53.1
N_2 (100 % RDP)	26.1	26.6	26.3	37.3	40.5	38.9	53.9	56.0	54.9	57.2	59.2	58.2
N_3 (125 % RDP)	27.4	27.8	27.6	38.8	42.7	40.8	56.1	58.4	57.2	59.9	61.8	60.8
N_4 (N_1+30 kg Sulphur)	26.1	26.6	26.4	37.3	40.6	39.0	54.1	56.2	55.1	57.3	59.3	58.3
N_5 (N_2+30 kg Sulphur)	28.5	28.9	28.7	40.6	44.1	42.4	58.8	61.1	60.0	62.2	64.3	63.3
N_6 (N_3+30 kg Sulphur)	29.8	30.1	29.9	42.1	46.2	44.2	60.9	63.8	62.4	64.6	66.9	65.7
N_7 (N_4+ PSB)	28.7	29.2	29.0	40.6	44.1	42.4	59.0	61.2	60.1	62.3	64.3	63.3
N_8 (N_5+ PSB)	31.0	31.5	31.3	44.4	47.8	46.1	63.9	66.1	65.0	67.2	69.8	68.5
N_9 (N_6+ PSB)	31.5	32.2	31.8	45.6	48.3	47.0	65.6	67.4	66.5	69.4	72.5	71.0

SEm±	0.8	0.8	0.5	1.0	1.1	0.8	1.5	1.6	1.1	1.6	1.7	1.2
C.D. at 0.05	2.2	2.3	1.5	3.0	3.3	2.2	4.6	4.7	3.2	4.9	4.9	3.3
Growth regulators												
G_0 (Water spray)	27.3	27.7	27.5	36.6	40.7	38.7	54.2	56.5	55.4	57.7	59.8	58.7
G_1 (Brassinolide 0.4 ppm)	27.6	28.1	27.8	42.1	44.2	43.2	58.9	61.4	60.1	62.5	64.8	63.6
G_2 (Benzyladenine 40 ppm)	27.4	28.0	27.7	38.5	42.4	40.5	56.6	58.2	57.4	59.6	61.8	60.7
S.Em±	0.3	0.3	0.2	0.4	0.4	0.6	0.6	0.6	0.4	0.6	0.6	0.4
CD (P=0.05)	NS	NS	NS	1.09	1.2	NS	1.6	1.6	1.1	1.7	1.7	1.2

NS=Non-significant

Table 4.3 Effect of nutrient management and plant growth regulators on dry matter accumulation of soybean

Treatments	Dry matter accumulation (g/							
	30 DAS			60 DAS			90	
	2013	2014	Pooled	2013	2014	Pooled	2013	2
Nutrient management								
N_0 (Absolute control)	1.74	1.81	1.78	8.28	8.47	8.38	14.98	1
N_1 (75 % RDP)	2.11	2.16	2.13	9.14	9.32	9.23	16.44	1
N_2 (100 % RDP)	2.47	2.56	2.52	10.00	10.18	10.09	17.85	1
N_3 (125 % RDP)	2.58	2.65	2.62	10.46	10.67	10.57	18.58	1
N_4 (N_1+30 kg Sulphur)	2.56	2.61	2.58	10.13	10.34	10.23	17.92	1
N_5 (N_2+30 kg Sulphur)	2.81	2.88	2.85	11.00	11.24	11.12	19.36	1
N_6 (N_3+30 kg Sulphur)	2.95	3.01	2.98	11.53	11.87	11.70	20.15	2
N_7 (N_4+ PSB)	2.87	2.91	2.89	11.12	11.33	11.22	19.47	1
N_8 (N_5+ PSB)	3.14	3.17	3.15	12.09	12.39	12.24	20.93	2
N_9 (N_6+ PSB)	3.28	3.36	3.32	12.28	12.52	12.40	21.12	2
SEm±	0.08	0.08	0.06	0.31	0.30	0.22	0.4715	0
C.D. at 0.05	0.24	0.24	0.16	0.93	0.88	0.62	1.4010	1
Growth regulators								
G_0 (Water spray)	2.63	2.69	2.66	10.17	10.30	10.23	18.06	1

G_1 (Brassinolide 0.4 ppm)	2.67	2.73	2.70	11.09	11.35	11.22	19.36	1
G_2 (Benzyladenine 40 ppm)	2.65	2.71	2.68	10.54	10.85	10.70	18.62	1
S.Em±	0.03	0.03	0.02	0.11	0.11	0.08	0.176	0
CD (P=0.05)	NS	NS	NS	0.33	0.30	0.22	0.5037	0

NS=Non-significant

Table 4.4 Effect of nutrient management and plant growth regulators on nodules plant^{-1} and nodules weight plant^{-1}, branches plant^{-1} of soybean

Treatments	Nodules plant^{-1} (60 DAS)			Nodules weight plant^{-1}(g) (60DAS)			Branches plant^{-1} (At harvest)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Nutrient management									
N_0 (Absolute control)	14.12	18.74	16.43	0.393	0.427	0.410	3.71	3.89	3.80
N_1 (75 % RDP)	17.45	21.99	19.72	0.452	0.490	0.471	4.21	4.43	4.32
N_2 (100 % RDP)	20.64	25.27	22.96	0.508	0.553	0.531	4.68	4.91	4.79
N_3 (125 % RDP)	21.81	26.80	24.30	0.523	0.567	0.545	4.80	5.09	4.94
N_4 (N_1+30 kg Sulphur)	20.74	26.35	23.55	0.513	0.563	0.538	4.72	5.00	4.86
N_5 (N_2+30 kg Sulphur)	24.31	29.80	27.05	0.565	0.620	0.593	5.12	5.50	5.31
N_6 (N_3+30 kg Sulphur)	25.66	31.15	28.41	0.577	0.639	0.608	5.38	5.62	5.50
N_7 (N_4+ PSB)	25.43	30.96	28.19	0.570	0.637	0.603	5.32	5.56	5.44
N_8 (N_5+ PSB)	28.55	34.04	31.30	0.627	0.697	0.662	5.76	5.99	5.87
N_9 (N_6+ PSB)	30.07	35.56	32.81	0.647	0.717	0.682	5.84	6.03	5.93
SEm±	0.92	0.89	0.64	0.016	0.016	0.011	0.14	0.14	0.07
C.D. at 0.05	2.72	2.64	1.83	0.047	0.049	0.033	0.41	0.40	0.20
Growth regulators									
G_0 (Water spray)	21.73	26.85	24.29	0.511	0.548	0.529	4.55	4.92	4.74
G_1	23.9	29.2	26.63	0.562	0.63	0.598	5.26	5.44	5.35

(Brassinolide 0.4 ppm)	9	7			3				
G_2 (Benzyladenine 40 ppm)	22.92	28.08	25.50	0.539	0.592	0.566	5.05	5.24	5.14
S.Em±	0.36	0.36	0.25	0.006	0.009	0.005	0.07	0.06	0.04
CD (P=0.05)	1.01	1.02	0.71	0.016	0.025	0.015	0.19	0.16	0.12

Table 4.4.1 Interaction effect of nutrient management and growth regulators on branches plant^{-1} (Pooled data of 2 years)

Nutrient management	Branches plant^{-1}		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	2.83	4.35	4.21
N_1 (75 % RDP)	4.12	4.51	4.32
N_2 (100 % RDP)	4.67	4.93	4.79
N_3 (125 % RDP)	4.83	5.09	4.91
N_4 (N_1+30 kg Sulphur)	4.76	5.01	4.83
N_5 (N_2+30 kg Sulphur)	5.22	5.42	5.28
N_6 (N_3+30 kg Sulphur)	5.09	5.73	5.68
N_7 (N_4+ PSB)	5.14	5.71	5.48
N_8 (N_5+ PSB)	5.39	6.41	5.83
N_9 (N_6+ PSB)	5.33	6.37	6.11
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.16	0.45
Growth regulators at same of Nutrient management		0.14	0.39

Table 4.5 Effect of nutrient management and plant growth regulators on leaf area index at successive growth stages of soybean

Treatments	LAI								
	30 DAS			60 DAS			90 DAS		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Nutrient management									
N_0 (Absolute control)	1.01	1.14	1.07	1.94	2.03	1.98	2.04	2.11	2.07
N_1 (75 % RDP)	1.14	1.25	1.19	2.17	2.26	2.22	2.27	2.39	2.33
N_2 (100 % RDP)	1.28	1.39	1.34	2.41	2.49	2.45	2.52	2.66	2.59
N_3 (125 % RDP)	1.36	1.45	1.40	2.52	2.63	2.57	2.61	2.79	2.70
N_4 (N_1+30 kg Sulphur)	1.28	1.40	1.34	2.43	2.51	2.47	2.53	2.67	2.60
N_5 (N_2+30 kg Sulphur)	1.43	1.52	1.48	2.66	2.75	2.70	2.77	2.94	2.86
N_6 (N_3+30 kg Sulphur)	1.50	1.57	1.54	2.76	2.87	2.81	2.87	3.05	2.96
N_7 (N_4+ PSB)	1.44	1.53	1.49	2.68	2.78	2.73	2.80	2.94	2.87
N_8 (N_5+ PSB)	1.58	1.64	1.61	2.92	3.02	2.97	3.06	3.23	3.15
N_9 (N_6+ PSB)	1.59	1.68	1.63	2.96	3.08	3.02	3.16	3.29	3.23
SEm±	0.04	0.04	0.03	0.08	0.07	0.05	0.08	0.09	0.06
C.D. at 0.05	0.12	0.11	0.08	0.22	0.22	0.15	0.24	0.26	0.17
Growth regulators									
G_0 (Water spray)	1.35	1.44	1.40	2.45	2.55	2.50	2.58	2.69	2.63
G_1 (Brassinolide 0.4 ppm)	1.37	1.47	1.42	2.63	2.74	2.68	2.75	2.92	2.84
G_2 (Benzyladenine 40 ppm)	1.36	1.46	1.41	2.55	2.64	2.59	2.67	2.81	2.74
S.Em±	0.01	0.02	0.01	0.03	0.03	0.02	0.02	0.03	0.02
CD (P=0.05)	NS	NS	NS	0.08	0.08	0.05	0.07	0.08	0.05

NS=Non-significant

Table 4.6 Effect of nutrient management and plant growth regulators on crop growth rate and relative growth rate at successive growth stages of soybean

Treatmen	Crop growth rate (g m^{-2} day^{-1})	Relative growth rate (g g^{-1} day^{-1})

ts	30-60 DAS			60-90 DAS			30-60 DAS			60-90 DAS		
	2013	**2014**	**Pooled**	**2013**	**2014**	**Pooled**	**2013**	**2014**	**Pooled**	**2013**	**2014**	**Pooled**
Nutrient management												
N_0 (Absolute control)	6.54	6.66	6.60	6.70	6.74	6.72	0.0519	0.0513	0.0516	0.0199	0.0196	0.0197
N_1 (75 % RDP)	7.03	7.16	7.09	7.29	7.39	7.34	0.0489	0.0487	0.0488	0.0196	0.0195	0.0195
N_2 (100 % RDP)	7.53	7.61	7.57	7.85	7.98	7.91	0.0466	0.0459	0.0463	0.0193	0.0193	0.0193
N_3 (125 % RDP)	7.88	8.02	7.95	8.11	8.22	8.16	0.0466	0.0464	0.0465	0.0192	0.0191	0.0191
N_4 (N_1+30 kg Sulphur)	7.57	7.73	7.65	7.79	7.95	7.87	0.0459	0.0459	0.0459	0.0190	0.0190	0.0190
N_5 (N_2+30 kg Sulphur)	8.19	8.36	8.27	8.36	8.53	8.44	0.0454	0.0453	0.0454	0.0188	0.0188	0.0188
N_6 (N_3+30 kg Sulphur)	8.58	8.86	8.72	8.62	8.69	8.66	0.0454	0.0457	0.0455	0.0187	0.0183	0.0185
N_7 (N_4+ PSB)	8.24	8.41	8.33	8.36	8.48	8.42	0.0451	0.0452	0.0452	0.0187	0.0186	0.0186
N_8 (N_5+ PSB)	8.95	9.22	9.09	8.85	9.47	9.16	0.0450	0.0455	0.0453	0.0183	0.0189	0.0186
N_9 (N_6+ PSB)	9.00	9.16	9.08	8.84	9.92	9.38	0.0440	0.0439	0.0439	0.0181	0.0194	0.0187
SEm±	0.23	0.22	0.16	0.17	0.21	0.14	0.0002	0.0001	0.0001	0.0002	0.0002	0.0001
C.D. at 0.05	0.70	0.64	0.46	0.52	0.62	0.39	0.0005	0.0004	0.0003	0.0006	0.0005	0.0004
Growth regulators												
G_0 (Water spray)	7.55	7.61	7.58	7.88	8.18	8.03	0.0454	0.0449	0.0452	0.0193	0.0196	0.0194
G_1 (Brassinolide 0.4 ppm)	8.42	8.61	8.52	8.27	8.43	8.35	0.0477	0.0477	0.0477	0.0185	0.0185	0.0185
G_2(Benzyladenine 40	7.89	8.14	8.02	8.08	8.41	8.24	0.0463	0.0465	0.0464	0.0190	0.0191	0.0191

ppm)												
S.Em±	0.09	0.07	0.06	0.09	0.15	0.09	0.0002	0.0001	0.0001	0.0002	0.0002	0.0001
CD (P=0.05)	0.25	0.21	0.16	0.25	NS	0.25	0.0005	0.0002	0.0003	0.0004	0.0006	0.0004

NS=Non-significant

Table 4.7 Effect of nutrient management and plant growth regulators on net assimilation rate at successive growth stages of soybean

Treatments	Net assimilation rate (g dm^2 day^{-1})					
	30-60 DAS			60-90 DAS		
	2013	2014	Pooled	2013	2014	Pooled
Nutrient management						
N_0 (Absolute control)	4.36	4.71	4.54	4.70	4.96	4.83
N_1 (75 % RDP)	5.44	5.80	5.62	5.93	6.42	6.17
N_2 (100 % RDP)	6.56	6.87	6.72	7.22	7.70	7.46
N_3 (125 % RDP)	7.20	7.65	7.42	7.72	8.37	8.04
N_4 (N_1+30 kg Sulphur)	6.68	7.04	6.86	7.19	7.77	7.48
N_5 (N_2+30 kg Sulphur)	7.90	8.32	8.11	8.51	9.16	8.84
N_6 (N_3+30 kg Sulphur)	8.58	9.18	8.88	9.07	9.64	9.36
N_7 (N_4+ PSB)	8.02	8.48	8.25	8.60	9.13	8.86
N_8 (N_5+ PSB)	9.43	10.01	9.72	9.89	11.03	10.46
N_9 (N_6+ PSB)	9.59	10.10	9.84	10.14	11.72	10.93
SEm±	0.45	0.43	0.31	0.29	0.37	0.23
C.D. at 0.05	1.32	1.28	0.89	0.86	1.10	0.67
Growth regulators						
G_0 (Water spray)	6.74	7.06	6.90	7.38	8.03	7.70
G_1 (Brassinolide 0.4 ppm)	8.07	8.56	8.32	8.39	9.05	8.72
G_2 (Benzyladenine 40 ppm)	7.32	7.82	7.57	7.92	8.69	8.30
S.Em±	0.16	0.16	0.11	0.13	0.19	0.11
CD (P=0.05)	0.45	0.44	0.31	0.36	0.54	0.32

Table 4.8 Effect of nutrient management and plant growth regulators on pods $plant^{-1}$, seeds pod^{-1} and seeds $plant^{-1}$ of soybean

Treatments	Pods $plant^{-1}$			Seeds pod^{-1}	
	2013	2014	Pooled	2013	2014
Nutrient management					
N_0 (Absolute control)	35.78	37.91	36.85	2.03	2.07

N_1 (75 % RDP)	39.89	43.35	41.62	2.21	2.25
N_2 (100 % RDP)	43.94	47.99	45.96	2.39	2.42
N_3 (125 % RDP)	45.31	48.76	47.03	2.44	2.46
N_4 (N_1+30 kg Sulphur)	44.48	48.39	46.44	2.40	2.44
N_5 (N_2+30 kg Sulphur)	48.62	53.06	50.84	2.59	2.61
N_6 (N_3+30 kg Sulphur)	50.11	54.26	52.18	2.63	2.66
N_7 (N_4+ PSB)	49.23	54.03	51.63	2.60	2.64
N_8 (N_5+ PSB)	53.32	58.90	56.11	2.78	2.82
N_9 (N_6+ PSB)	54.18	59.26	56.72	2.82	2.88
SEm±	1.26	1.50	0.63	0.05	0.05
C.D. at 0.05	3.75	4.44	1.81	0.16	0.16
Growth regulators					
G_0 (Water spray)	43.81	47.80	45.80	2.38	2.41
G_1 (Brassinolide 0.4 ppm)	49.50	53.30	51.40	2.59	2.62
G_2 (Benzyladenine 40 ppm)	46.15	50.68	48.41	2.49	2.54
S.Em±	0.49	0.57	0.38	0.03	0.02
CD (P=0.05)	1.42	1.62	1.06	0.09	0.07

Table 4.8.1 Interaction effect of nutrient management and growth regulators on pods plant^{-1} (Pooled data of 2 years)

Nutrient management	**Pods plant^{-1}**		
	Growth regulators		
	Water spray (G_0)	**Brassinolide 0.4 ppm (G_1)**	**Benzyladenine 40 ppm (G_2)**
N_0 (Absolute control)	25.88	43.82	40.84
N_1 (75 % RDP)	39.85	43.75	41.26
N_2 (100 % RDP)	44.73	47.61	45.56
N_3 (125 % RDP)	45.62	48.80	46.69
N_4 (N_1+30 kg Sulphur)	44.56	49.01	45.75
N_5 (N_2+30 kg Sulphur)	49.37	52.51	50.63
N_6 (N_3+30 kg Sulphur)	50.45	54.51	51.58
N_7 (N_4+ PSB)	50.03	53.64	51.22
N_8 (N_5+ PSB)	53.29	60.07	54.98
N_9 (N_6+ PSB)	54.24	60.28	55.64
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		1.42	3.98
Growth regulators at		1.19	3.36

same of Nutrient management		

Table 4.8.2 Interaction effect of nutrient management and growth regulators on seeds plant^{-1} (Pooled data of 2 years)

Nutrient management	Seeds plant^{-1}		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	64.08	95.52	88.33
N_1 (75 % RDP)	89.20	96.69	93.20
N_2 (100 % RDP)	99.09	108.12	103.08
N_3 (125 % RDP)	102.40	109.63	105.99
N_4 (N_1+30 kg Sulphur)	101.75	107.98	104.41
N_5 (N_2+30 kg Sulphur)	110.56	118.85	117.63
N_6 (N_3+30 kg Sulphur)	113.73	121.09	117.50
N_7 (N_4+ PSB)	107.49	122.03	120.37
N_8 (N_5+ PSB)	116.42	137.45	126.61
N_9 (N_6+ PSB)	119.83	138.06	127.93
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		2.86	8.00
Growth regulators at same of Nutrient management		2.28	6.41

Table 4.9 Effect of nutrient management and plant growth regulators on pods length, 1000-seed weight and seed yield plant^{-1} of soybean

Treatments	Pod length (cm)	1000-seed weight (g)

	2013	2014	Pooled	2013	2014
Nutrient management					
N_0 (Absolute control)	2.57	2.59	2.58	81.11	82.65
N_1 (75 % RDP)	2.89	2.96	2.92	89.21	90.86
N_2 (100 % RDP)	3.20	3.30	3.25	96.66	98.69
N_3 (125 % RDP)	3.36	3.50	3.43	99.29	101.46
N_4 (N_1+30 kg Sulphur)	3.22	3.31	3.26	97.51	99.89
N_5 (N_2+30 kg Sulphur)	3.55	3.64	3.59	104.02	107.52
N_6 (N_3+30 kg Sulphur)	3.67	3.91	3.79	106.32	109.45
N_7 (N_4+ PSB)	3.54	3.70	3.62	105.02	109.38
N_8 (N_5+ PSB)	3.84	4.04	3.94	113.14	117.21
N_9 (N_6+ PSB)	3.92	4.13	4.02	115.48	119.92
SEm±	0.10	0.10	0.07	2.36	2.44
C.D. at 0.05	0.29	0.31	0.21	7.00	7.25
Growth regulators					
G_0 (Water spray)	3.23	3.36	3.30	96.05	98.27
G_1 (Brassinolide 0.4 ppm)	3.51	3.64	3.57	105.01	108.68
G_2 (Benzyladenine 40 ppm)	3.40	3.52	3.46	101.27	104.15
S.Em±	0.04	0.03	0.02	1.22	1.12
CD (P=0.05)	0.10	0.10	0.07	3.48	3.20

Table 4.9.1 Interaction effect of nutrient management and growth regulators on seed yield plant^{-1} (Pooled data of 2 years)

Nutrient management	Seed yield plant^{-1} (g)		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	3.64	7.07	6.37
N_1 (75 % RDP)	6.26	6.91	6.62
N_2 (100 % RDP)	7.32	7.72	7.51
N_3 (125 % RDP)	7.66	8.27	8.05
N_4 (N_1+30 kg Sulphur)	7.46	7.83	7.63
N_5 (N_2+30 kg Sulphur)	8.37	8.74	8.57
N_6 (N_3+30 kg Sulphur)	8.52	8.89	8.67
N_7 (N_4+ PSB)	8.41	8.88	8.61
N_8 (N_5+ PSB)	8.99	10.00	9.23
N_9 (N_6+ PSB)	9.33	10.05	9.44

	S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators	0.21	0.59
Growth regulators at same of Nutrient management	0.16	0.47

Table 4.10 Effect of nutrient management and plant growth regulators on yield and harvest index of soybean

Treatments	Seed yield (kg ha^{-1})			Haulm yield (kg ha^{-1})			Biological yield (kg ha^{-1})			Harvest index (%)		
	2013	**2014**	**Pooled**	**2013**	**2014**	**Pooled**	**2013**	**2014**	**Pooled**	**2013**	**2014**	**Pooled**
Nutrient management												
N_0 (Absolute control)	984	1004	994	2552	2555	2553	3536	3559	3547	27.85	28.27	28.06
N_1 (75 % RDP)	1201	1273	1237	3035	3214	3125	4236	4488	4362	28.34	28.35	28.35
N_2 (100 % RDP)	1399	1455	1427	3496	3674	3585	4896	5129	5012	28.58	28.37	28.47
N_3 (125 % RDP)	1503	1523	1513	3715	3832	3774	5218	5355	5286	28.82	28.44	28.63
N_4 (N_1+30 kg Sulphur)	1473	1473	1473	3674	3729	3702	5147	5201	5174	28.62	28.32	28.47
N_5 (N_2+30 kg Sulphur)	1653	1644	1649	4024	4101	4063	5677	5746	5711	29.12	28.60	28.86
N_6 (N_3+30 kg Sulphur)	1713	1753	1733	4193	4309	4251	5906	6062	5984	28.98	28.91	28.95
N_7 (N_4+ PSB)	1661	1711	1686	4027	4142	4084	5688	5853	5770	29.21	29.23	29.22
N_8 (N_5+ PSB)	1818	1875	1847	4344	4496	4420	6163	6372	6267	29.45	29.39	29.42
N_9 (N_6+ PSB)	1874	1940	1907	4494	4652	4573	6367	6592	6479	29.36	29.38	29.37
SEm±	51	54	37	105	114	78	148	165	111	0.41	0.31	0.26
C.D. at 0.05	150	161	106	312	339	222	440	490	318	NS	NS	0.74
Growth regulators												
G_0 (Water spray)	1382	1448	1415	3416	3619	3517	4798	5066	4932	28.74	28.60	28.67
G_1 (Brassinolide 0.4 ppm)	1642	1686	1664	4013	4125	4069	5655	5810	5733	28.94	28.85	28.90

G_2 (Benzyladenine 40 ppm)	1559	1562	1561	3838	3868	3853	5397	5430	5414	28.82	28.72	28.77
S.Em±	15	17	12	28	32	43	39	43	29	0.21	0.23	0.16
CD (P=0.05)	44	50	33	81	92	61	111	124	82	NS	NS	NS

NS=Non-significant

Table 4.10.1 Interaction effect of nutrient management and growth regulators on seed yield (Pooled data of 2 years)

Nutrient management	**Seed yield (kg ha^{-1})**		
	Growth regulators		
	Water spray (G_0)	**Brassinolide 0.4 ppm (G_1)**	**Benzyladenine 40 ppm (G_2)**
N_0 (Absolute control)	946	1059	977
N_1 (75 % RDP)	1056	1363	1293
N_2 (100 % RDP)	1250	1517	1515
N_3 (125 % RDP)	1381	1580	1578
N_4 (N_1+30 kg Sulphur)	1378	1537	1503
N_5 (N_2+30 kg Sulphur)	1546	1761	1639
N_6 (N_3+30 kg Sulphur)	1633	1826	1739
N_7 (N_4+ PSB)	1629	1765	1664
N_8 (N_5+ PSB)	1656	2063	1821
N_9 (N_6+ PSB)	1676	2167	1876
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		58	163
Growth regulators at same of Nutrient management		37	103

Table 4.10.2 Interaction effect of nutrient management and growth regulators on haulm yield (Pooled data of 2 years)

Nutrient management	**Haulm yield (kg ha^{-1})**

	Growth regulators		
	Water spray (G_0)	**Brassinolide 0.4 ppm (G_1)**	**Benzyladenine 40 ppm (G_2)**
N_0 (Absolute control)	2339	2787	2534
N_1 (75 % RDP)	2688	3480	3206
N_2 (100 % RDP)	3159	3863	3734
N_3 (125 % RDP)	3397	4002	3922
N_4 (N_1+30 kg Sulphur)	3438	3907	3759
N_5 (N_2+30 kg Sulphur)	3807	4230	4152
N_6 (N_3+30 kg Sulphur)	4135	4422	4196
N_7 (N_4+ PSB)	3879	4204	4170
N_8 (N_5+ PSB)	4100	4781	4380
N_9 (N_6+ PSB)	4229	5013	4476
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		117	327
Growth regulators at same of Nutrient management		68	192

Table 4.10.3 Interaction effect of nutrient management and growth regulators on biological yield (Pooled data of 2 years)

Nutrient management	**Biological yield (kg ha^{-1})**		
	Growth regulators		
	Water spray (G_0)	**Brassinolide 0.4 ppm (G_1)**	**Benzyladenine 40 ppm (G_2)**
N_0 (Absolute control)	3285	3847	3511
N_1 (75 % RDP)	3744	4844	4499
N_2 (100 % RDP)	4409	5379	5249
N_3 (125 % RDP)	4778	5581	5500
N_4 (N_1+30 kg Sulphur)	4816	5444	5262
N_5 (N_2+30 kg Sulphur)	5352	5990	5791
N_6 (N_3+30 kg Sulphur)	5768	6249	5935
N_7 (N_4+ PSB)	5508	5968	5835

N_8 (N_5+ PSB)	5757	6844	6201
N_9 (N_6+ PSB)	5906	7180	6353
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		164	459
Growth regulators at same of Nutrient management		92	260

Table 4.11 Effect of nutrient management and plant growth regulators on quality parameter of soybean

Treatments	Quality parameters								
	Chlorophyll content (mg g^{-1}fresh wt)			Protein content (%)			Oil content (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Nutrient management									
N_0 (Absolute control)	2.05	2.09	2.07	37.82	38.20	38.01	18.08	18.13	18.10
N_1 (75 % RDP)	2.21	2.24	2.22	38.44	38.80	38.62	18.61	18.64	18.63
N_2 (100 % RDP)	2.36	2.38	2.37	39.04	39.51	39.28	19.06	19.13	19.10
N_3 (125 % RDP)	2.44	2.45	2.44	39.15	39.55	39.35	19.14	19.22	19.18
N_4 (N_1+30 kg Sulphur)	2.39	2.40	2.39	39.13	39.52	39.32	19.11	19.17	19.14
N_5 (N_2+30 kg Sulphur)	2.55	2.55	2.55	39.67	40.13	39.90	19.59	19.68	19.63
N_6 (N_3+30 kg Sulphur)	2.60	2.60	2.60	39.74	40.22	39.98	19.68	19.79	19.74
N_7 (N_4+ PSB)	2.57	2.58	2.58	39.72	40.22	39.97	19.64	19.74	19.69
N_8 (N_5+ PSB)	2.73	2.74	2.74	40.41	40.83	40.62	20.11	20.21	20.16
N_9 (N_6+ PSB)	2.78	2.79	2.79	40.46	40.90	40.68	20.18	20.32	20.25
SEm±	0.05	0.05	0.03	0.27	0.29	0.13	0.14	0.14	0.10
C.D. at 0.05	0.14	0.13	0.09	0.79	0.86	0.38	0.41	0.40	0.28
Growth regulators									
G_0 (Water spray)	2.39	2.40	2.40	38.70	39.06	38.88	18.95	19.00	18.97
G_1 (Brassinolide 0.4 ppm)	2.54	2.55	2.54	40.01	40.52	40.27	19.71	19.84	19.78
G_2 (Benzyladenine 40 ppm)	2.48	2.49	2.49	39.36	39.78	39.57	19.30	19.37	19.33
S.Em±	0.02	0.02	0.01	0.14	0.14	0.10	0.10	0.08	0.06

CD (P=0.05)	0.05	0.05	0.04	0.41	0.41	0.28	0.27	0.23	0.18

Table 4.12 Effect of nutrient management and plant growth regulators on protein and oil yield of soybean

Treatments	Protein yield (kg ha^{-1})			Oil yield (kg ha^{-1})		
	2013	**2014**	**Pooled**	**2013**	**2014**	**Pooled**
Nutrient management						
N_0 (Absolute control)	372	384	378	178	182	180
N_1 (75 % RDP)	462	494	478	224	238	231
N_2 (100 % RDP)	547	575	561	267	279	273
N_3 (125 % RDP)	589	603	596	288	293	290
N_4 (N_1+30 kg Sulphur)	577	582	579	282	283	282
N_5 (N_2+30 kg Sulphur)	656	660	658	324	324	324
N_6 (N_3+30 kg Sulphur)	682	705	693	337	347	342
N_7 (N_4+ PSB)	661	688	674	327	338	332
N_8 (N_5+ PSB)	735	766	751	366	379	372
N_9 (N_6+ PSB)	759	796	778	379	395	387
SEm±	22	21	11	11	10	6
C.D. at 0.05	65	63	31	33	30	16
Growth regulators						
G_0 (Water spray)	537	567	552	264	277	270
G_1 (Brassinolide 0.4 ppm)	659	686	673	325	336	331
G_2 (Benzyladenine 40 ppm)	616	623	620	303	304	303
S.Em±	7	7	5	3	3	2
CD (P=0.05)	19	19	13	10	10	7

NS=Non-significant

Table 4.12.1 Interaction effect of nutrient management and growth regulators on protein yield (Pooled data of 2 years)

Nutrient management	Protein yield (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	**Brassinolide 0.4 ppm (G_1)**	**Benzyladenine 40 ppm (G_2)**
N_0 (Absolute control)	353	409	371
N_1 (75 % RDP)	402	536	497
N_2 (100 % RDP)	483	605	596

N_3 (125 % RDP)	535	631	621
N_4 (N_1+30 kg Sulphur)	534	614	591
N_5 (N_2+30 kg Sulphur)	607	714	654
N_6 (N_3+30 kg Sulphur)	644	742	695
N_7 (N_4+ PSB)	641	717	665
N_8 (N_5+ PSB)	662	852	738
N_9 (N_6+ PSB)	658	905	770
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		20	56
Growth regulators at same of Nutrient management		15	42

Table 4.12.2 Interaction effect of nutrient management and growth regulators on oil yield (Pooled data of 2 years)

Nutrient management	Oil yield (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	167	197	177
N_1 (75 % RDP)	191	261	241
N_2 (100 % RDP)	232	299	288
N_3 (125 % RDP)	260	308	303
N_4 (N_1+30 kg Sulphur)	258	302	286
N_5 (N_2+30 kg Sulphur)	298	352	322
N_6 (N_3+30 kg Sulphur)	318	366	343
N_7 (N_4+ PSB)	315	354	328
N_8 (N_5+ PSB)	329	422	366
N_9 (N_6+ PSB)	335	447	379
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		10	28
Growth regulators at		8	21

same of Nutrient management

Table 4.13 Effect of nutrient management and plant growth regulators on nitrogen content and uptake in seed and haulm of soybean

Treatments	Nitrogen Content (%)						Nitrogen uptake (kg ha^{-1})								
	Seed			Haulm			Seed			Haulm			Total		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
Nutrient management															
N_0 (Absolute control)	6.051	6.113	6.082	1.502	1.527	1.514	59.53	61.38	60.45	38.39	39.04	38.72	97.92	100.42	99.17
N_1 (75 % RDP)	6.151	6.208	6.179	1.561	1.590	1.575	74.00	79.11	76.56	47.49	51.21	49.35	121.49	130.33	125.91
N_2 (100 % RDP)	6.247	6.321	6.284	1.625	1.677	1.651	87.52	92.06	89.79	56.92	61.70	59.31	144.44	153.76	149.10
N_3 (125 % RDP)	6.264	6.328	6.296	1.631	1.691	1.661	94.20	96.42	95.31	60.68	64.83	62.75	154.88	161.25	158.06
N_4 (N_1+30 kg Sulphur)	6.261	6.323	6.292	1.628	1.685	1.657	92.28	93.15	92.71	59.89	62.87	61.38	152.16	156.02	154.09
N_5 (N_2+30 kg Sulphur)	6.347	6.421	6.384	1.690	1.754	1.722	105.01	105.62	105.32	68.12	71.97	70.05	173.13	177.60	175.36
N_6 (N_3+30 kg Sulphur)	6.359	6.435	6.397	1.697	1.759	1.728	109.06	112.84	110.95	71.33	75.71	73.52	180.39	188.55	184.47
N_7 (N_4+ PSB)	6.356	6.435	6.396	1.695	1.758	1.726	105.70	110.13	107.91	68.34	72.83	70.59	174.04	182.96	178.50
N_8 (N_5+ PSB)	6.465	6.532	6.499	1.754	1.819	1.787	117.68	122.56	120.12	76.38	81.81	79.09	194.05	204.37	199.21
N_9 (N_6+ PSB)	6.474	6.545	6.509	1.762	1.827	1.794	121.46	127.40	124.43	79.31	85.03	82.17	200.77	212.43	206.60
SEm±	0.043	0.046	0.021	0.019	0.020	0.009	3.47	3.39	1.74	2.31	1.95	1.16	5.46	5.13	2.73
C.D. at	0.1	0.1	0.0	0.0	0.0	0.0	10.	10.	4.9	6.8	5.7	3.3	16.	15.	7.8

0.05	26	37	61	56	59	27	32	07	8	8	9	2	23	25	3
Growth regulators															
G_0 (Water spray)	6.192	6.250	6.221	1.615	1.673	1.644	85.90	90.71	88.31	55.58	61.10	58.34	141.48	151.82	146.65
G_1 (Brassinolide 0.4 ppm)	6.402	6.483	6.442	1.692	1.742	1.717	105.48	109.73	107.61	68.42	72.33	70.38	173.90	182.06	177.98
G_2 (Benzyladenine 40 ppm)	6.298	6.365	6.332	1.657	1.711	1.684	98.54	99.76	99.15	64.05	66.66	65.36	162.60	166.42	164.51
S.Em±	0.023	0.023	0.016	0.010	0.011	0.007	1.04	1.08	0.75	0.66	0.59	0.44	1.54	1.45	1.06
CD (P=0.05)	0.065	0.065	0.045	0.027	0.030	0.020	2.98	3.10	2.12	1.89	1.69	1.25	4.41	4.13	2.98

Table 4.13.1 Interaction effect of nutrient management and growth regulators on nitrogen uptake by seed (Pooled data of 2 years)

Nutrient management	Nitrogen uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	56.49	65.45	59.41
N_1 (75 % RDP)	64.30	85.82	79.55
N_2 (100 % RDP)	77.23	96.85	95.28
N_3 (125 % RDP)	85.57	101.00	99.34
N_4 (N_1+30 kg Sulphur)	85.41	98.22	94.51
N_5 (N_2+30 kg Sulphur)	97.19	114.20	104.56
N_6 (N_3+30 kg Sulphur)	103.06	118.66	111.13
N_7 (N_4+ PSB)	102.58	114.75	106.41
N_8 (N_5+ PSB)	105.97	136.24	118.15
N_9 (N_6+ PSB)	105.26	144.87	123.15
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		3.19	8.93
Growth regulators at same of Nutrient management		2.38	6.69

Table 4.13.2 Interaction effect of nutrient management and growth regulators on nitrogen uptake by haulm (Pooled data of 2 years)

Nutrient management	Nitrogen uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	34.57	43.15	38.43
N_1 (75 % RDP)	41.23	56.33	50.49
N_2 (100 % RDP)	50.93	65.21	61.78
N_3 (125 % RDP)	55.56	67.66	65.04
N_4 (N_1+30 kg Sulphur)	55.73	65.88	62.53
N_5 (N_2+30 kg Sulphur)	63.98	74.63	71.52
N_6 (N_3+30 kg Sulphur)	70.44	77.52	72.60
N_7 (N_4+ PSB)	65.87	73.66	72.23
N_8 (N_5+ PSB)	71.59	87.46	78.23
N_9 (N_6+ PSB)	73.52	92.25	80.74
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		1.99	5.58
Growth regulators at same of Nutrient management		1.40	3.94

Table 4.13.3 Interaction effect of nutrient management and growth regulators on total nitrogen uptake (Pooled data of 2 years)

Nutrient management	Nitrogen uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4	Benzyladenine

		ppm (G_1)	40 ppm (G_2)
N_0 (Absolute control)	91.06	108.60	97.85
N_1 (75 % RDP)	105.53	142.15	130.04
N_2 (100 % RDP)	128.16	162.07	157.06
N_3 (125 % RDP)	141.13	168.66	164.38
N_4 (N_1+30 kg Sulphur)	141.13	164.10	157.04
N_5 (N_2+30 kg Sulphur)	161.18	188.83	176.08
N_6 (N_3+30 kg Sulphur)	173.50	196.18	183.73
N_7 (N_4+ PSB)	168.44	188.42	178.64
N_8 (N_5+ PSB)	177.56	223.70	196.38
N_9 (N_6+ PSB)	178.78	237.12	203.89
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		4.73	13.24
Growth regulators at same of Nutrient management		3.34	9.41

Table 4.14 Effect of nutrient management and plant growth regulators on phosphorus content and uptake in seed and haulm of soybean

Treatments	Phosphorus Content (%)						Phosphorus uptake (kg ha^{-1})								
	Seed			Haulm			Seed			Haulm			Total		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2010	Pooled
Nutrient management															
N_0 (Absolute control)	0.5950	0.6126	0.6038	0.1710	0.1714	0.1712	5.87	6.15	6.01	4.37	4.38	4.38	10.24	10.53	10.39
N_1 (75 % RDP)	0.6189	0.6348	0.6268	0.1778	0.1785	0.1781	7.45	8.09	7.77	5.40	5.74	5.57	12.85	13.84	13.35
N_2 (100 % RDP)	0.6418	0.6574	0.6496	0.1847	0.1855	0.1851	8.99	9.57	9.28	6.47	6.82	6.64	15.46	16.40	15.93
N_3 (125 % RDP)	0.6427	0.6585	0.6506	0.1858	0.1861	0.1860	9.67	10.03	9.85	6.92	7.14	7.03	16.58	17.17	16.88
N_4 (N_1+30 kg Sulphur)	0.6422	0.6580	0.6501	0.1853	0.1858	0.1856	9.46	9.69	9.58	6.82	6.93	6.87	16.28	16.63	16.45
N_5 (N_2+30 kg Sulphur)	0.6666	0.6804	0.6735	0.1921	0.1927	0.1924	11.03	11.19	11.11	7.74	7.90	7.82	18.77	19.10	18.93
N_6 (N_3+30 kg Sulphur)	0.6676	0.6815	0.6745	0.1929	0.1935	0.1932	11.45	11.94	11.69	8.11	8.33	8.22	19.56	20.27	19.91
N_7 (N_4+ PSB)	0.6674	0.6809	0.6741	0.1925	0.1931	0.1928	11.10	11.65	11.38	7.76	8.00	7.88	18.86	19.65	19.26
N_8 (N_5+ PSB)	0.6909	0.7031	0.6970	0.1992	0.2003	0.1998	12.57	13.19	12.88	8.67	9.01	8.84	21.24	22.20	21.72
N_9 (N_6+ PSB)	0.6917	0.7037	0.6977	0.1995	0.2009	0.2002	12.99	13.68	13.33	8.98	9.35	9.16	21.96	23.03	22.50
SEm±	0.0066	0.0071	0.0033	0.0020	0.0020	0.0010	0.39	0.35	0.19	0.25	0.22	0.13	0.61	0.56	0.31
C.D. at 0.05	0.0195	0.0210	0.0094	0.0059	0.0061	0.0028	1.16	1.05	0.56	0.75	0.66	0.36	1.82	1.68	0.88
Growth regulators															
G_0 (Water spray)	0.6410	0.6554	0.6482	0.1842	0.1856	0.1849	8.93	9.56	9.24	6.34	6.77	6.55	15.27	16.33	15.80
G_1 (Brassinolide 0.4	0.6639	0.6786	0.6713	0.1918	0.1920	0.1919	10.99	11.52	11.26	7.76	7.96	7.86	18.75	19.48	19.12

ppm)															
G_2 (Benzyl adenine 40 ppm)	0.6525	0.6674	0.6599	0.1882	0.1888	0.1885	10.25	10.49	10.37	7.28	7.35	7.31	17.52	17.84	17.68
S.Em±	0.0035	0.0037	0.0026	0.0011	0.0010	0.0007	0.12	0.12	0.09	0.07	0.06	0.05	0.18	0.16	0.12
CD (P=0.05)	0.0101	0.0107	0.0072	0.0030	0.0028	0.0020	0.35	0.35	0.25	0.21	0.18	0.14	0.52	0.47	0.34

Table 4.14.1 Interaction effect of nutrient management and growth regulators on phosphorus uptake by seed (Pooled data of 2 years)

Nutrient management	Phosphorus uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	5.60	6.52	5.91
N_1 (75 % RDP)	6.47	8.73	8.11
N_2 (100 % RDP)	7.98	10.02	9.85
N_3 (125 % RDP)	8.80	10.49	10.26
N_4 (N_1+30 kg Sulphur)	8.89	10.12	9.72
N_5 (N_2+30 kg Sulphur)	10.22	12.06	11.05
N_6 (N_3+30 kg Sulphur)	10.85	12.52	11.71
N_7 (N_4+ PSB)	10.81	12.08	11.24
N_8 (N_5+ PSB)	11.33	14.61	12.70
N_9 (N_6+ PSB)	11.47	15.40	13.12
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.36	1.02
Growth regulators at same of Nutrient management		0.28	0.78

Table 4.14.2 Interaction effect of nutrient management and growth regulators on phosphorus uptake by haulm (Pooled data of 2 years)

Nutrient management	Phosphorus uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	**Brassinolide 0.4 ppm (G_1)**	**Benzyladenine 40 ppm (G_2)**
N_0 (Absolute control)	3.95	4.87	4.31
N_1 (75 % RDP)	4.72	6.34	5.65
N_2 (100 % RDP)	5.74	7.35	6.84
N_3 (125 % RDP)	6.16	7.72	7.20
N_4 (N_1+30 kg Sulphur)	6.09	7.14	7.39
N_5 (N_2+30 kg Sulphur)	7.24	8.28	7.95
N_6 (N_3+30 kg Sulphur)	7.90	8.67	8.09
N_7 (N_4+ PSB)	7.36	8.26	8.02
N_8 (N_5+ PSB)	8.07	9.74	8.72
N_9 (N_6+ PSB)	8.30	10.24	8.95
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.22	0.61
Growth regulators at same of Nutrient management		0.15	0.43

Table 4.14.3 Interaction effect of nutrient management and growth regulators on total phosphorus uptake (Pooled data of 2 years)

Nutrient management	Phosphorus uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	9.55	11.39	10.22
N_1 (75 % RDP)	11.20	15.07	13.77
N_2 (100 % RDP)	13.72	17.38	16.68
N_3 (125 % RDP)	14.96	18.21	17.47
N_4 (N_1+30 kg Sulphur)	14.99	17.26	17.11
N_5 (N_2+30 kg Sulphur)	17.46	20.34	19.00
N_6 (N_3+30 kg Sulphur)	18.75	21.19	19.81
N_7 (N_4+ PSB)	18.17	20.34	19.26
N_8 (N_5+ PSB)	19.40	24.34	21.42
N_9 (N_6+ PSB)	19.77	25.64	22.07
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.54	1.51
Growth regulators at same of Nutrient management		0.39	1.08

Table 4.15 Effect of nutrient management and plant growth regulators on potassium content and uptake in seed and haulm of soybean

Treatments	Potassium content (%)						Potassium uptake (kg ha^{-1})						Total		
	Seed			Haulm			Seed			Haulm					
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2010	Pooled
Nutrient management															
N_0 (Absolute control)	1.765	1.811	1.788	2.764	2.714	2.739	17.29	18.16	17.73	70.46	69.30	69.88	87.75	87.46	87.60
N_1 (75	1.7	1.8	1.8	2.7	2.7	2.7	21.	23.	22.	84.	87.	86.	105	111	108

% RDP)	86	19	03	75	31	53	48	21	34	29	80	04	.77	.00	.39
N_2 (100 % RDP)	1.810	1.826	1.818	2.784	2.741	2.762	25.35	26.59	25.97	97.40	100.76	99.08	122.74	127.34	125.04
N_3 (125 % RDP)	1.827	1.831	1.829	2.790	2.748	2.769	27.46	27.88	27.67	103.71	105.31	104.51	131.17	133.19	132.18
N_4 (N_1+30 kg Sulphur)	1.818	1.828	1.823	2.788	2.746	2.767	26.78	26.90	26.84	102.48	102.40	102.44	129.25	129.30	129.28
N_5 (N_2+30 kg Sulphur)	1.832	1.838	1.835	2.794	2.758	2.776	30.29	30.21	30.25	112.50	113.11	112.80	142.78	143.32	143.05
N_6 (N_3+30 kg Sulphur)	1.838	1.848	1.843	2.798	2.767	2.782	31.46	32.42	31.94	117.60	119.11	118.36	149.06	151.54	150.30
N_7 (N_4+ PSB)	1.836	1.846	1.841	2.786	2.765	2.775	30.51	31.61	31.06	112.31	114.56	113.44	142.82	146.17	144.49
N_8 (N_5+ PSB)	1.842	1.855	1.848	2.804	2.778	2.791	33.49	34.79	34.14	121.93	124.88	123.41	155.42	159.67	157.55
N_9 (N_6+ PSB)	1.844	1.858	1.851	2.809	2.784	2.796	34.54	36.06	35.30	126.25	129.32	127.78	160.78	165.37	163.08
SEm±	0.045	0.034	0.022	0.040	0.039	0.020	0.99	1.05	0.50	3.91	3.01	1.96	4.66	3.94	2.33
C.D. at 0.05	NS	NS	NS	NS	NS	NS	2.95	3.10	1.42	11.63	8.95	5.61	13.86	11.71	6.69
Growth regulators															
G_0 (Water spray)	1.817	1.835	1.826	2.770	2.730	2.750	25.15	26.59	25.87	94.70	98.90	96.80	119.85	125.49	122.67
G_1 (Brassinolide 0.4 ppm)	1.821	1.838	1.830	2.802	2.765	2.783	29.97	31.05	30.51	112.53	114.09	113.31	142.50	145.13	143.82
G_2 (Benzyl adenine 40 ppm)	1.822	1.835	1.828	2.796	2.764	2.780	28.47	28.70	28.59	107.45	106.98	107.22	135.92	135.68	135.80
S.Em±	0.010	0.010	0.007	0.018	0.018	0.013	0.28	0.36	0.23	1.10	0.96	0.73	1.27	1.13	0.85
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.81	1.01	0.64	3.16	2.74	2.06	3.64	3.22	2.39

Table 4.15.1 Interaction effect of nutrient management and growth regulators on potassium uptake by seed (Pooled data of 2 years)

Nutrient management	Potassium uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	16.81	18.94	17.43
N_1 (75 % RDP)	19.09	24.49	23.45
N_2 (100 % RDP)	22.54	27.71	27.65
N_3 (125 % RDP)	25.28	28.88	28.84
N_4 (N_1+30 kg Sulphur)	25.54	27.88	27.10
N_5 (N_2+30 kg Sulphur)	28.41	32.29	30.04
N_6 (N_3+30 kg Sulphur)	29.94	33.83	32.06
N_7 (N_4+ PSB)	29.97	32.56	30.64
N_8 (N_5+ PSB)	30.39	38.34	33.70
N_9 (N_6+ PSB)	30.78	40.15	34.96
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.94	2.64
Growth regulators at same of Nutrient management		0.72	2.03

Table 4.15.2 Interaction effect of nutrient management and growth regulators on potassium uptake by haulm (Pooled data of 2 years)

Nutrient management	Potassium uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	63.50	76.41	69.73
N_1 (75 % RDP)	73.37	96.22	88.54
N_2 (100 % RDP)	86.33	107.48	103.42
N_3 (125 % RDP)	93.35	111.36	108.82
N_4 (N_1+30 kg Sulphur)	94.30	108.74	104.28
N_5 (N_2+30 kg Sulphur)	104.85	118.05	115.51
N_6 (N_3+30 kg Sulphur)	114.36	123.56	117.16

N_7 (N_4+ PSB)	106.78	117.46	116.07
N_8 (N_5+ PSB)	113.36	134.34	122.52
N_9 (N_6+ PSB)	117.76	139.47	126.12
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		3.33	9.32
Growth regulators at same of Nutrient management		2.31	6.51

Table 4.15.3 Interaction effect of nutrient management and growth regulators on total potassium uptake (Pooled data of 2 years)

Nutrient management	Potassium uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	80.30	95.35	87.16
N_1 (75 % RDP)	92.46	120.71	111.99
N_2 (100 % RDP)	108.87	135.19	131.07
N_3 (125 % RDP)	118.63	140.25	137.66
N_4 (N_1+30 kg Sulphur)	119.84	136.61	131.38
N_5 (N_2+30 kg Sulphur)	133.26	150.34	145.55
N_6 (N_3+30 kg Sulphur)	144.30	157.39	149.22
N_7 (N_4+ PSB)	136.74	150.02	146.72
N_8 (N_5+ PSB)	143.75	172.68	156.21
N_9 (N_6+ PSB)	148.54	179.62	161.08
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		3.92	10.98
Growth regulators at same of Nutrient management		2.69	7.57

Table 4.16 Effect of nutrient management and plant growth regulators on sulphur content and uptake in seed and haulm (kg ha^{-1}) of soybean

Treatments	Sulphur content (%)						Sulphur uptake (kg ha^{-1})						Total		
	Seed			Haulm			Seed			Haulm					
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2010	Pooled
Nutrient management															
N_0 (Absolute control)	0.260	0.266	0.263	0.157	0.163	0.160	2.56	2.67	2.62	4.02	4.18	4.10	6.58	6.85	6.72
N_1 (75 % RDP)	0.272	0.280	0.276	0.165	0.172	0.168	3.27	3.56	3.42	5.01	5.53	5.27	8.29	9.09	8.69
N_2 (100 % RDP)	0.284	0.292	0.288	0.172	0.180	0.176	3.97	4.25	4.11	6.03	6.62	6.33	10.01	10.88	10.44
N_3 (125 % RDP)	0.286	0.299	0.292	0.175	0.183	0.179	4.30	4.55	4.43	6.52	7.02	6.77	10.83	11.57	11.20
N_4 (N_1+30 kg Sulphur)	0.278	0.296	0.287	0.174	0.181	0.178	4.10	4.36	4.23	6.40	6.75	6.58	10.50	11.12	10.81
N_5 (N_2+30 kg Sulphur)	0.298	0.310	0.304	0.181	0.190	0.186	4.94	5.11	5.02	7.31	7.81	7.56	12.24	12.92	12.58
N_6 (N_3+30 kg Sulphur)	0.306	0.318	0.312	0.185	0.193	0.189	5.26	5.56	5.41	7.76	8.33	8.05	13.02	13.89	13.46
N_7 (N_4+ PSB)	0.303	0.315	0.309	0.183	0.192	0.187	5.03	5.39	5.21	7.37	7.96	7.66	12.40	13.35	12.88
N_8 (N_5+ PSB)	0.316	0.328	0.322	0.190	0.199	0.194	5.76	6.15	5.95	8.25	8.93	8.59	14.01	15.08	14.55
N_9 (N_6+ PSB)	0.321	0.331	0.326	0.193	0.205	0.199	6.02	6.44	6.23	8.67	9.54	9.10	14.69	15.98	15.34
SEm±	0.003	0.004	0.002	0.002	0.002	0.001	0.18	0.16	0.09	0.25	0.21	0.12	0.41	0.36	0.21
C.D. at 0.05	0.010	0.011	0.005	0.006	0.007	0.003	0.54	0.48	0.26	0.74	0.63	0.35	1.23	1.09	0.59
Growth regulators															
G_0 (Water spray)	0.287	0.298	0.292	0.174	0.182	0.178	4.01	4.36	4.18	5.99	6.65	6.32	10.00	11.01	10.51
G_1 (Brassinolide 0.4 ppm)	0.298	0.309	0.303	0.181	0.189	0.185	4.94	5.27	5.11	7.32	7.87	7.60	12.27	13.15	12.71

G_2 (Benzyladenine 40 ppm)	0.293	0.304	0.298	0.178	0.186	0.182	4.62	4.79	4.70	6.89	7.27	7.08	11.51	12.06	11.78
S.Em±	0.002	0.002	0.001	0.001	0.001	0.001	0.06	0.06	0.04	0.07	0.06	0.05	0.12	0.11	0.08
CD (P=0.05)	0.005	0.005	0.004	0.003	0.003	0.002	0.16	0.16	0.12	0.21	0.19	0.14	0.36	0.31	0.23

Table 4.16.1 Interaction effect of nutrient management and growth regulators on sulphur uptake by seed (Pooled data of 2 years)

Nutrient management	**Sulphur uptake (kg ha^{-1})**		
	Growth regulators		
	Water spray (G_0)	**Brassinolide 0.4 ppm (G_1)**	**Benzyladenine 40 ppm (G_2)**
N_0 (Absolute control)	2.44	2.84	2.58
N_1 (75 % RDP)	2.86	3.82	3.58
N_2 (100 % RDP)	3.54	4.44	4.36
N_3 (125 % RDP)	3.95	4.71	4.62
N_4 (N_1+30 kg Sulphur)	3.89	4.48	4.33
N_5 (N_2+30 kg Sulphur)	4.61	5.48	4.98
N_6 (N_3+30 kg Sulphur)	5.02	5.79	5.43
N_7 (N_4+ PSB)	4.94	5.55	5.16
N_8 (N_5+ PSB)	5.22	6.78	5.86
N_9 (N_6+ PSB)	5.37	7.21	6.12
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.17	0.48
Growth regulators at same of Nutrient management		0.13	0.37

Table 4.16.2 Interaction effect of nutrient management and growth regulators on sulphur uptake by haulm (Pooled data of 2 years)

Nutrient management	Sulphur uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	3.68	4.55	4.07
N_1 (75 % RDP)	4.46	5.95	5.41
N_2 (100 % RDP)	5.48	6.92	6.57
N_3 (125 % RDP)	5.96	7.33	7.02
N_4 (N_1+30 kg Sulphur)	6.00	7.06	6.67
N_5 (N_2+30 kg Sulphur)	6.91	8.01	7.75
N_6 (N_3+30 kg Sulphur)	7.62	8.52	8.00
N_7 (N_4+ PSB)	7.09	8.06	7.84
N_8 (N_5+ PSB)	7.78	9.44	8.56
N_9 (N_6+ PSB)	8.25	10.12	8.95
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.22	0.61
Growth regulators at same of Nutrient management		0.16	0.44

Table 4.16.3 Interaction effect of nutrient management and growth regulators on total sulphur uptake (Pooled data of 2 years)

Nutrient management	Sulphur uptake (kg ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	6.12	7.39	6.64
N_1 (75 % RDP)	7.32	9.77	8.98
N_2 (100 % RDP)	9.03	11.36	10.93
N_3 (125 % RDP)	9.92	12.04	11.64
N_4 (N_1+30 kg Sulphur)	9.89	11.54	11.00
N_5 (N_2+30 kg Sulphur)	11.52	13.49	12.73
N_6 (N_3+30 kg Sulphur)	12.64	14.31	13.42
N_7 (N_4+ PSB)	12.03	13.60	12.99
N_8 (N_5+ PSB)	12.99	16.22	14.42
N_9 (N_6+ PSB)	13.61	17.33	15.07
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.36	1.02
Growth regulators at same of Nutrient management		0.26	0.74

Table 4.17 Effect of nutrient management and plant growth regulators on available nitrogen, phosphorus, potassium and sulphur after harvest of soybean

Treatments	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassi	
	2013	2014	Pooled	2013	2014	Pooled	2013	2
Nutrient management								
N_0 (Absolute control)	266.65	272.07	269.36	22.92	23.61	23.27	308.17	3
N_1 (75 % RDP)	277.35	283.75	280.55	23.99	24.41	24.20	311.39	3
N_2 (100 % RDP)	287.97	293.26	290.62	25.08	25.24	25.16	314.11	3
N_3 (125 % RDP)	290.01	296.77	293.39	25.36	25.38	25.37	316.30	3.
N_4 (N_1+30 kg Sulphur)	288.22	295.64	291.93	25.17	25.32	25.25	315.34	3
N_5 (N_2+30 kg Sulphur)	298.98	306.44	302.71	26.20	26.12	26.16	319.20	3.
N_6 (N_3+30 kg Sulphur)	302.11	309.15	305.63	26.31	26.20	26.25	322.68	3.
N_7 (N_4+ PSB)	301.24	307.49	304.36	26.25	26.36	26.31	321.64	3.
N_8 (N_5+ PSB)	312.71	318.95	315.83	27.28	27.37	27.33	325.81	3.
N_9 (N_6+ PSB)	315.98	321.11	318.54	27.39	27.45	27.42	327.86	3.
SEm±	3.57	3.48	1.78	0.35	0.25	0.17	10.27	1
C.D. at 0.05	10.60	10.35	5.12	1.03	0.75	0.50	NS	
Growth regulators								
G_0 (Water spray)	293.94	300.07	297.01	25.43	25.57	25.50	316.82	3.
G_1 (Brassinolide 0.4 ppm)	294.43	301.03	297.73	25.76	25.92	25.84	319.61	3.
G_2 (Benzyladenine 40 ppm)	293.99	300.29	297.14	25.59	25.76	25.68	318.32	3.
S.Em±	1.76	1.77	1.25	0.16	0.14	0.10	3.15	3
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	

Table 4.18 Nitrogen balance sheet of soil (kg ha^{-1}) under nutrient management and plant growth regulators in soybean

Treatments	Initial Status A			Nutrient added B	Crop uptake C			Expected nutrient balance D= (A+B-C)			Actual nutrient balance E			Apparent Gain/loss F=E-D	Actual gain/loss G=E-A
	2013	2014	Mean		2013	2014	Mean	2013	2014	Mean	2013	2014	Mean		
Nutrient management options															
N_0 (Absolute control)	297.12	302.25	299.69	30	97.92	100.42	99.17	229.20	231.83	230.52	266.65	272.07	269.36	38.84	-30.33
N_1 (75 % RDP)	297.12	302.25	299.69	30	121.49	130.33	125.91	205.63	201.92	203.78	277.35	283.75	280.55	76.78	-19.14

N_2 (100 % RDP)	297.12	302.25	299.69	30	144.44	153.76	149.10	182.68	178.49	180.59	287.97	293.26	290.62	110.03	-9.07
N_3 (125 % RDP)	297.12	302.25	299.69	30	154.88	161.25	158.06	172.24	171.00	171.62	290.01	296.77	293.39	121.76	-6.30
N_4 (N_1+30 kg Sulphur)	297.12	302.25	299.69	30	152.16	156.02	154.09	174.96	176.23	175.59	288.22	295.64	291.93	116.34	-7.76
N_5 (N_2+30 kg Sulphur)	297.12	302.25	299.69	30	173.13	177.60	175.36	153.99	154.65	154.32	298.98	306.44	302.71	148.39	3.02
N_6 (N_3+30 kg Sulphur)	297.12	302.25	299.69	30	180.39	188.55	184.47	146.73	143.70	145.21	302.11	309.15	305.63	160.42	5.94
N_7 (N_4+ PSB)	297.12	302.25	299.69	30	174.04	182.96	178.50	153.08	149.29	151.18	301.24	307.49	304.36	153.18	4.67
N_8 (N_5+ PSB)	297.12	302.25	299.69	30	194.05	204.37	199.21	133.07	127.88	130.47	312.71	318.95	315.83	185.36	16.14
N_9 (N_6+ PSB)	297.12	302.25	299.69	30	200.77	212.43	206.60	126.35	119.82	123.09	315.98	321.11	318.54	195.46	18.85
Growth regulators															
G_0 (Water spray)	297.12	302.25	299.69	30	141.48	151.82	146.65	185.64	180.43	183.04	293.94	300.07	297.01	113.97	-2.68
G_1 (Brassinolide 0.4 ppm)	297.12	302.25	299.69	30	173.90	182.06	177.98	153.22	150.19	151.70	294.43	301.03	297.73	146.03	-1.96
G_2 (Benzyladenine 40 ppm)	297.12	302.25	299.69	30	162.60	166.42	164.51	164.52	165.83	165.18	293.99	300.29	297.14	131.96	-2.55

Table 4.19 Phosphorus balance sheet of soil (kg ha^{-1}) under nutrient management and plant growth regulators in soybean

Treatments	Initial Status A	Nutrient	Crop uptake C	Expected nutrient balance	Actual nutrient balance E	Apparent	Actual

				added B	D= (A+B-C)									Gain/ loss	gain/ loss
	2013	2014	Mean		2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	F=E-D	G=E-A
Nutrient management options															
N_0 (Absolute control)	23.85	24.56	24.21	0.00	10.24	10.53	10.39	13.61	14.03	13.82	22.92	23.61	23.27	9.45	-0.94
N_1 (75 % RDP)	23.85	24.56	24.21	30.00	12.85	13.84	13.35	41.00	40.72	40.86	23.99	24.41	24.20	-16.66	-0.01
N_2 (100 % RDP)	23.85	24.56	24.21	40.00	15.46	16.40	15.93	48.39	48.16	48.28	25.08	25.24	25.16	-23.12	0.95
N_3 (125 % RDP)	23.85	24.56	24.21	50.00	16.58	17.17	16.88	57.27	57.39	57.33	25.36	25.38	25.37	-31.96	1.16
N_4 (N_1+30 kg Sulphur)	23.85	24.56	24.21	30.00	16.28	16.63	16.45	37.57	37.93	37.75	25.17	25.32	25.25	-12.51	1.04
N_5 (N_2+30 kg Sulphur)	23.85	24.56	24.21	40.00	18.77	19.10	18.93	45.08	45.46	45.27	26.20	26.12	26.16	-19.11	1.95
N_6 (N_3+30 kg Sulphur)	23.85	24.56	24.21	50.00	19.56	20.27	19.91	54.29	54.29	54.29	26.31	26.20	26.25	-28.04	2.04
N_7 (N_4+ PSB)	23.85	24.56	24.21	30.00	18.86	19.65	19.26	34.99	34.91	34.95	26.25	26.36	26.31	-8.64	2.10
N_8 (N_5+ PSB)	23.85	24.56	24.21	40.00	21.24	22.20	21.72	42.61	42.36	42.48	27.28	27.37	27.33	-15.16	3.12
N_9 (N_6+ PSB)	23.85	24.56	24.21	50.00	21.96	23.03	22.50	51.89	51.53	51.71	27.39	27.45	27.42	-24.29	3.21
Growth regulators															
G_0 (Water spray)	23.85	24.56	24.21	40.00	15.26	15.02	15.14	48.59	49.54	49.07	25.43	25.57	25.50	-23.57	1.29
G_1 (Brassinolide 0.4 ppm)	23.85	24.56	24.21	40.00	18.66	19.12	18.89	45.19	45.44	45.32	25.76	25.92	25.84	-19.48	1.63

G_2 (Benzyl adenine 40 ppm)	23.85	24.56	24.21	40.00	17.63	17.63	17.63	46.22	46.93	46.58	25.59	25.76	25.68	-20.90	1.47

Table 4.20 Potassium balance sheet of soil (kg ha^{-1}) under nutrient management and plant growth regulators in soybean

Treatments	Initial Status A			Nutrient added B	Crop uptake C			Expected nutrient balance D= (A+B-C)			Actual nutrient balance E			Apparent Gain/ loss F=E-D	Actual gain/ loss G= E-A
	2013	2014	Mean		2013	2014	Mean	2013	2014	Mean	2013	2014	Mean		
Nutrient management options															
N_0 (Absolute control)	344.33	346.61	345.47	30.00	87.75	87.46	87.60	286.58	289.15	287.87	308.17	310.48	309.33	21.47	-36.14
N_1 (75 % RDP)	344.33	346.61	345.47	30.00	105.77	111.00	108.39	268.56	265.61	267.09	311.39	314.75	313.07	45.99	-32.40
N_2 (100 % RDP)	344.33	346.61	345.47	30.00	122.74	127.34	125.04	251.59	249.27	250.43	314.11	317.47	315.79	65.36	-29.68
N_3 (125 % RDP)	344.33	346.61	345.47	30.00	131.17	133.19	132.18	243.16	243.42	243.29	316.30	320.66	318.48	75.19	-26.99
N_4 (N_1+30 kg Sulphur)	344.33	346.61	345.47	30.00	129.25	129.30	129.28	245.08	247.31	246.20	315.34	319.70	317.52	71.33	-27.95
N_5 (N_2+30 kg Sulphur)	344.33	346.61	345.47	30.00	142.78	143.32	143.05	231.55	233.29	232.42	319.20	324.56	321.88	89.46	-23.59
N_6 (N_3+30 kg	344.3	346.6	345.4	30.00	149.0	151.5	150.3	225.2	225.0	225.1	322.6	326.04	324.	99.19	-21.

Sulphur)	3	1	7		6	4	0	7	7	7	8		36		11
N_7 (N_4+ PSB)	344.33	346.61	345.47	30.00	142.82	146.17	144.49	231.51	230.44	230.98	321.64	325.00	323.32	92.35	-22.15
N_8 (N_5+ PSB)	344.33	346.61	345.47	30.00	155.42	159.67	157.55	218.91	216.94	217.93	325.81	329.17	327.49	109.57	-17.98
N_9 (N_6+ PSB)	344.33	346.61	345.47	30.00	160.78	165.37	163.08	213.55	211.24	212.40	327.86	331.22	329.54	117.15	-15.93
Growth regulators															
G_0 (Water spray)	344.33	346.61	345.47	30.00	119.85	125.49	122.67	254.48	251.12	252.80	316.82	320.35	318.59	65.79	-26.88
G_1 (Brassinolide 0.4 ppm)	344.33	346.61	345.47	30.00	142.50	145.13	143.82	231.83	231.48	231.66	319.61	323.33	321.47	89.82	-24.00
G_2 (Benzyladenine 40 ppm)	344.33	346.61	345.47	30.00	135.92	135.68	135.80	238.41	240.93	239.67	318.32	322.04	320.18	80.51	-25.29

Table 4.21 Sulphur balance sheet of soil (kg ha^{-1}) under nutrient management and plant growth regulators in soybean

Treatments	Initial Status A			Nutrient added B	Crop uptake C			Expected nutrient balance D= (A+B-C)			Actual nutrient balance E			Apparent Gain/ loss F=E-D	Actual gain/ loss G=E-A
	2013	2014	Mean		2013	2014	Mean	2013	2014	Mean	2013	2014	Mean		
Nutrient management options															
N_0 (Absolute control)	23.54	24.27	23.91	0.00	6.58	6.85	6.72	16.96	17.42	17.19	19.35	19.67	19.51	2.32	-4.40

N_1 (75 % RDP)	23.54	24.27	23.91	0.00	8.29	9.09	8.69	15.25	15.18	15.22	20.11	20.49	20.30	5.09	-3.61
N_2 (100 % RDP)	23.54	24.27	23.91	0.00	10.01	10.88	10.44	13.53	13.39	13.46	20.84	21.26	21.05	7.59	-2.86
N_3 (125 % RDP)	23.54	24.27	23.91	0.00	10.83	11.57	11.20	12.71	12.70	12.71	20.98	21.41	21.20	8.50	-2.71
N_4 (N_1+30 kg Sulphur)	23.54	24.27	23.91	30.00	10.50	11.12	10.81	43.04	43.15	43.10	20.92	20.35	20.64	-22.46	-3.27
N_5 (N_2+30 kg Sulphur)	23.54	24.27	23.91	30.00	12.24	12.92	12.58	41.30	41.35	41.33	21.69	22.16	21.92	-19.41	-1.99
N_6 (N_3+30 kg Sulphur)	23.54	24.27	23.91	30.00	13.02	13.89	13.46	40.52	40.38	40.45	21.88	22.31	22.09	-18.36	-1.82
N_7 (N_4+ PSB)	23.54	24.27	23.91	30.00	12.40	13.35	12.88	41.14	40.92	41.03	21.79	22.27	22.03	-19.00	-1.88
N_8 (N_5+ PSB)	23.54	24.27	23.91	30.00	14.01	15.08	14.55	39.53	39.19	39.36	22.58	23.05	22.82	-16.54	-1.09
N_9 (N_6+ PSB)	23.54	24.27	23.91	30.00	14.69	15.98	15.34	38.85	38.29	38.57	22.83	23.20	23.02	-15.55	-0.89
Growth regulators															
G_0 (Water spray)	23.54	24.27	23.91	30.00	10.00	11.01	10.51	43.54	43.26	43.40	21.15	21.47	21.31	-22.09	-2.60
G_1 (Brassinolide 0.4 ppm)	23.54	24.27	23.91	30.00	12.27	13.15	12.71	41.27	41.12	41.20	21.45	21.73	21.59	-19.61	-2.32
G_2 (Benzyladenine 40 ppm)	23.54	24.27	23.91	30.00	11.51	12.06	11.78	42.03	42.21	42.12	21.29	21.65	21.47	-20.65	-2.44

Table 4.22 Effect of nutrient management and plant growth regulators on net return and benefit cost ratio of soybean

Treatments	Net Returns (` ha^{-1})			Benefit cost ratio		
	2013	2014	Pooled	2013	2014	Pooled
Nutrient management						
N_0 (Absolute control)	11777	14298	13037	0.49	0.58	0.54
N_1 (75 % RDP)	18138	23254	20696	0.68	0.87	0.77
N_2 (100 % RDP)	24941	29900	27421	0.92	1.09	1.00
N_3 (125 % RDP)	28172	32008	30090	1.02	1.14	1.08
N_4 (N_1+30 kg Sulphur)	27996	30934	29465	1.05	1.15	1.10
N_5 (N_2+30 kg Sulphur)	33984	37045	35514	1.24	1.35	1.30
N_6 (N_3+30 kg Sulphur)	35704	40657	38181	1.28	1.45	1.37
N_7 (N_4+ PSB)	34751	39908	37329	1.30	1.49	1.39
N_8 (N_5+ PSB)	39933	45736	42835	1.46	1.65	1.56
N_9 (N_6+ PSB)	41477	47717	44597	1.48	1.69	1.59
SEm±	1815	2080	907	0.07	0.07	0.03
C.D. at 0.05	5391	6180	2602	0.20	0.22	0.09
Growth regulators						
G_0 (Water spray)	27992	33302	30647	1.17	1.37	1.27
G_1 (Brassinolide 0.4 ppm)	34583	39497	37040	1.28	1.45	1.36
G_2 (Benzyladenine 40 ppm)	26487	29638	28063	0.83	0.92	0.87
S.Em±	531	629	412	0.02	0.02	0.01
CD (P=0.05)	1519	1799	1159	0.06	0.07	0.04

Table 4.22.1 Interaction effect of nutrient management and growth regulators on net return (Pooled data of 2 years)

Nutrient management	Net return (` ha^{-1})		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	14709	16368	8036
N_1 (75 % RDP)	17451	26324	18313
N_2 (100 % RDP)	24310	31694	26258
N_3 (125 % RDP)	28599	33496	28176
N_4 (N_1+30 kg Sulphur)	29469	32721	26205

N_5 (N_2+30 kg Sulphur)	35305	40266	30972
N_6 (N_3+30 kg Sulphur)	38390	42322	33830
N_7 (N_4+ PSB)	38739	40891	32358
N_8 (N_5+ PSB)	39566	51455	37484
N_9 (N_6+ PSB)	39934	54863	38995
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		1712	4792
Growth regulators at same of Nutrient management		1302	3665

Table 4.22.2 Interaction effect of nutrient management and growth regulators on benefit cost ratio (Pooled data of 2 years)

Nutrient management	Benefit cost ratio		
	Growth regulators		
	Water spray (G_0)	Brassinolide 0.4 ppm (G_1)	Benzyladenine 40 ppm (G_2)
N_0 (Absolute control)	0.68	0.66	0.27
N_1 (75 % RDP)	0.74	0.99	0.58
N_2 (100 % RDP)	1.01	1.17	0.82
N_3 (125 % RDP)	1.17	1.21	0.86
N_4 (N_1+30 kg Sulphur)	1.25	1.23	0.82
N_5 (N_2+30 kg Sulphur)	1.46	1.48	0.96
N_6 (N_3+30 kg Sulphur)	1.55	1.52	1.03
N_7 (N_4+ PSB)	1.63	1.53	1.02
N_8 (N_5+ PSB)	1.63	1.88	1.16
N_9 (N_6+ PSB)	1.61	1.97	1.18
		S.Em±	CD (P=0.05)
Nutrient management at same level of growth regulators		0.06	0.17
Growth regulators at same of Nutrient		0.05	0.13

5. DISCUSSION

During course of presentation of the results of field experiment entitled **"Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]",** significant variations in performance of various parameters relating to growth, yield attributes, yield, nutrient content and uptake, soil nutrient status, quality and economics under different sets of treatments were cited. In this chapter, findings are briefly discussed in an analytical and rational manner furnishing suitable scientific reasoning and relevant work elsewhere to provide a comprehensive interpretation of results. All possible efforts have been made to precisely establish the cause and effect interrelationship that becomes mandatory in course of development of a technologically viable, economically feasible and sustainable module of integrated nutrient management and/ or plant growth regulator for higher productivity and benefits to growers of soybean in Sub Humid Southern Plains and Aravalli Hills and like regions.

5.1 NUTRIENT MANAGEMENT

5.1.1 Growth Parameters

Data furnished in Tables from 4.2 to 4.7 reveal that among different nutrient management, application of 125% RDP + 30 sulphur + PSB (N_9) significantly improved various growth parameters *viz.*, plant height at 30, 60, 90 and at harvest (Table 4.2), dry matter accumulation (DMA) plant^{-1} at 30,60, 90 and at harvest (Table 4.3), total number of branches plant^{-1}at harvest (Table 4.4) and nodules plant^{-1} and weight of nodule plant^{-1} at 60 DAS (Table 4.4). However it was statistically at par with 100% RDP + 30 sulphur + PSB (N_8). Since, DMA plant^{-1} represents a final outcome of aggregate of growing conditions including availability and utilization of different growth resources. Thus, it clearly reveals that N_9 maintained adequate soil nutrient supply to crop and soil microbes throughout crop period and this situation was substantively superior to remaining nutrient management options. Significantly higher performance of pooled DMA plant^{-1} and other growth parameters under N_9 followed by N_8 makes it pin pointedly clear that integration of 30 kg sulphur ha^{-1} +

PSB as bio-fertilizers was statistically superior over the independent effect of either 30 kg sulphur ha^{-1} or PSB bio-fertilizers on growth parameters under integration with 75% 100% or 125% RDP.

This in other way reveals the survival of microbial population of applied/ native microbes as well as P solubulization by PSB, enhanced substantially and maintained sustainably on application of 125% RDP ha^{-1} under N_9 which can be ascribed to relatively much long lasting and gradual nutrient release from inorganic phosphorus that maintained better energy/ nutrient supply to microbes than nutrient management options lacking bio-fertilizers. Significant enhancement in crop growth parameters under INM modules involving application of inorganic fertilizers with PSB well corroborate with findings of Nagdive *et al.* (2007a), Singh *et al.* (2008), Chand *et al.* (2010), Singh and Pal (2011), Singh *et al.*(2011), Banerjee *et al.* (2010) and Saberi and Hassan (2014).

Anyway, literature confirms to significant enhancement in crop growth parameters on integrated use of bio-fertilizers with inorganic fertilizers and all these dispositions support the results of this study. Implications conforming to lower response of bio-fertilizers on increasing rate of inorganic fertilization from 100% to 125% can be observed from all growth parameters and yield attributing characters data in Table 4.3 to 4.9. Lower response of bio-fertilizers on increasing RDP from 100 to 125% is also well illustrated, which can be ascribed to relative sufficiency or deficiency of soil available N, P and S for uptake by crop plants and for immobilization by microorganisms. Data also show that the order of per cent increase in pooled DMA $plant^{-1}$ followed a sequence of 30 kg sulphur + PSB > 30 kg sulphur at 75, 100% and 125% RDP. To understand the nutrient benefits from bio-fertilizers, it is also necessary to briefly understand the microbial dynamics in soil. In fact, soon after seeding there is more multiplication of microbes and during this phase usually peak soil microbial population is achieved due to more and readily available energy/ nutrients just after addition of inorganic fertilizers. The germinating seed and gradually growing plantlets derive benefits of such sufficiency of nutrients as made available by basal nutrient application but microorganisms at this stage immobilize energy/ carbon/ nutrients for enhancement in their population/ biomass. At later crop stages there exists a possibility that microbial population or benefits from bio-fertilizers can achieve a plateau for a variable period depending upon potential of soil to sustainably maintain requisite supply of carbon/ nutrients/ energy under a particular set of nutrient management or there can be decline in soil availability of energy/ nutrients/ carbon which can invariably reduce the microbial population/ biomass and resultant nutrient benefits from native/ applied microorganisms. However, for sustained maintenance of such microbial population/ biomass over the longer time periods, a sustained and continuous availability of carbon and nutrients are needed. A sustained increase in DMA plant^{-1} and associated growth parameters under N_9 thus, confirms to more and sufficient soil available nutrients for uptake by crop plants and immobilization by applied/ native microbes under N_9 which can further be ascribed to higher quantity of applied inorganic fertilizers and probable higher N fixation by *Rhizobium* and dissolution of fixed/ precipitated P by PSB. Thus, even pending no data on soil microbial population/ biomass, significant variations in performance of different growth parameters under treatments with and without bio-fertilizers, can be a good indicator to reveal enhanced or declined soil nutrient availability and for this purpose crop nutrient mining can be taken as a criteria (Table 4.18 to 4.21). However, data on growth parameters, nutrient content in seed and haulm and nutrient uptake by the crop (Table 4.13 to 4.16) comprehensively conclude that among different nutrient management options best soil nutrient supply to both crop as well as to applied/ native soil microbes was set in and maintained under N_9 throughout the entire crop growing season. Data reported in Table 4.4 further illustrate that N_9 registered a significantly higher pooled number of root nodules and nodule dry weight plant^{-1} that amounted to 99.6 and 66.3 per cent over control but remained at par with N_8. This confirm to higher nutrient mining potential of soybean plants under N_9 in comparison to other nutrient management options. Further, more root volume links with more root occupied soil volume that depicts the access of plant roots to more nutrients mining via established active/ passive ion uptake mechanisms (root interception, mass flow and diffusion). Results on significantly higher root biomass on integrated use of recommended inorganic fertilizers and bio-fertilizers well corroborate with findings of Panigrahi and Panda (2003), Mandal *et al*. (2006) and Mandal *et al.* (2010).

Alike DMA plant^{-1}, significant influence of nutrients under N_9 in case of CGR at 30-60 DAS & 60-90 DAS (Table 4.5), RGR at 30-60 DAS & 60-90 DAS (Table 4.5), NAR at 30-60 DAS & 60-90 DAS (Table 4.6), LAI at 30, 60 & 90 DAS (Table 4.7) and total chlorophyll contents 60 DAS (Table 4.11) were noticed. However, it was statistically at par with N_8 in context to all parameters. While attending growth parameters, variations in certain key estimates (LAI and chlorophyll content) under different nutrient management options having distinct variability in quantity and source of nutrients and possible variations in duration of supply/ mineralization of nutrients, need to be discussed in detail, since these estimates have potential to widely influence performance of interrelated growth/ yield/ quality parameters. Supplementing nutrients in an integrated manner under N_9 significantly enhanced the pooled LAI or size of photosynthetic apparatus that critically relates to more interception of radiant energy and conversion of solar energy into biomass. Significantly higher contents of total chlorophyll as well as dry weight plant^{-1} lasting up to very late stage of soybean crop under N_9 (Table 4.11 and Table 4.3) confirm not only enough physiological activeness of soybean plants up to such a late stage but it also endorses to higher rate of conversion of radiant energy into biomass for a considerable period of time. This can constitute a prominent cause behind significantly higher pooled performance of different growth parameters including NAR, DMA plant^{-1} and final plant height under N_9 treatment. Thus, the most distinguished and critical effects of nutrients applied in INM module, N_9 was noticed in the form of significantly higher pooled contents of total chlorophyll, size of photosynthetic apparatus or LAI, which can be finally ascribed to optimization of different physiological and metabolic processes of soybean plants on account of application of nutrients in higher quantities, long lasting and gradual nutrient release from residues recycled by previous crop, P solubulization by PSB. The nutrient effect under N_9 lasted up to physiological maturity and ultimately linked with wide variety of role of nutrients (N, P and S) in plants. Thus, nutrient supplemented through different sources in INM module N_9 brought orderliness in source to sink relationship of soybean plants which can again be ascribed to role of applied/ mineralized nutrients mainly N, P, S and certain other nutrients that can be enhanced favourably influenced variety of physiological and metabolic processes and structural set up of plants.

Therefore, overall improvement in crop growth under N_9 can finally be ascribed to optimum nutrition that brought synergy in keeping the orderliness in variety of physiological, bio-chemical, metabolic, cellular, structural and other plant functions due to sufficiency in availability of soil nutrients and consequent nutrient mining by crop plants/ immobilization by microbes.

P is involved in variety of bio-chemical processes *viz.* amino acid/ protein/ chlorophyll synthesis, N metabolism, carbohydrate utilization, enzyme functions, translocation of carbohydrates, fatty acids, glyceroids and several other essential intermediate metabolites. It is necessary for young and fast growing tissues and performs a variety of functions related to growth, development, photosynthesis and utilization of carbohydrates (Shah *et al*., 2004). Moreover, P dominantly regulates the fundamental processes of photosynthesis, root and shoot growth, partitioning of photosynthates, quality of plant products etc. (Brady and Weil, 2002, Meena, 2005). P significantly influences the plant growth and metabolism (Abel *et al*., 2002) owing to being a constituent of nucleic acid (DNA and RNA) which exerts a regulatory function on cell division potent to limit the expansion of leaves by a common regulatory process (Chiera *et al*., 2002, Brady and Weil, 2002). Besides, it is a constituent of plasma membrane, organic molecules (ATP, ADP and AMP) and several co-enzymes (Brady and Weil, 2002).

Sulphur on the other hand is a ubiquitous essential element that acts as a catalyst in plant metabolism, bio-chemical and physiological processes. It is required for synthesis of S containing amino acids (cystine and cysteine), iron-S clusters, polysaccharides, lipids, vitamins (thiamine and biotine), peptides (glutathione and phytochelatins), and secondary products (allyl Cys sulfoxides and glucocinolates). Cellular roles of S extend to regulation of enzymes (eg. proteolytic and nitrogensae), redox cycle, xenobiotic detoxifications etc. Sulfhydryl group (-SH) confers many thiols having ability to react with a broad spectrum of agents i.e. free radicals to heavy metals (Rabenstein, 1989). Main source of S for plants is sulphate ion and limitation of soil sulphate drastically influences plant growth and productivity. Deficiency of S in plants results in accumulation of N as non proteins (nitrates and ammonia) which impair the food quality. Besides, S is essential for formation of disulfide bonds (-S-S-) between polypeptide chain within protein molecule which enables the protein to fold and this ultimately decides the configuration and catalytic or structural properties of proteins. S is required for synthesis of co-enzyme A involved in oxidation and synthesis of fatty acids, synthesis of amino acids and oxidation of intermediates of citric acid cycle. S is not a constituent but it is required in synthesis of chlorophyll on account of fact that it is a vital part of ferredoxin, a Fe-S protein in the chloroplasts. Ferredoxin has a significant role in nitrate and sulphate reduction and assimilation of N by free living N fixing *Azotobacter* in soil. Plant S request suddenly enhances under both under abiotic and biotic stress. Thus, variations in fertilizer S and its mineralization from organic sources can be critical in governing bio-synthesis of chlorophyll, assimilation of photosynthates, dry matter production, oil content and finally the productivity of soybean plants under different nutrient management options.

It further necessitates here to attend the mechanisms involved in P solubulization by PSB in order to understand the possible enhancement in soil nutrient availability as distinguish by crop nutrient mining/ growth/ productivity under nutrient management options involving bio-fertilizers or those devoid of it.

PSB solubilise chemically bound soil P by release of organic acids (gluconic acid and 2-ketogluconic acid) or mineralize organic P through secretion of extra cellular phosphtases (Kim, 1998). Plant associated bacteria also produce phyto-hormones (auxins, cytokinins and gibberellins) (Tanimoto, 2005 and Taghavi, 2009). These phyto-hormones favourably influence root and shoot growth of plants (Asghar, 2002, Asghar, 2004, Sheng and Xia, 2006 and Taghavi, 2009). IAA, siderophores, HCN and ammonia are main plant growth promoting organic products released by PSB (*Bacillus spp*) (Zaidi *et al*., 2006, Wani *et al*., 2007c and Wani and Khan, 2010). Bacterial phyto-hormones (auxins, cytokinins and gibberellins) indirectly stimulate plant growth and development (Tanimoto, 2005 and Taghavi, 2009). Auxins (IAA) promote root length proliferation and elongation of root hairs and enhance branches and seed yield and oil content in plants (Asghar, 2002, Asghar, 2004, Shenng and Xia, 2006 and Taghavi, 2009). Cytokinins stimulate late cell division, cell enlargement and tissue expansion in certain plant parts (Salisbury, 1994). They also promote stomatal opening, stimulate shoot growth but decrease root growth (Hare, 1997). Gibberellins modify plant morphology by stem tissue expansion that contributes to normal root development (Salisbury, 1994 and Tanimoto, 2005). Bacteria balance plant ethylene production through production of auxins via ACC deaminitrogenase (1-aminocyclopropane-1-carboxylate deaminitrogenase) (Mastretta, 2006). ACC deaminitrogenase also increases under Cd and other heavy metal contamination in soil (Belimov 2005 and Dell Amico, 2005).

Thus, bio-fertilizers usage can improve plant uptake and utilization of N, P, Fe and certain other micro-nutrients, stimulate/ bring orderliness in root growth and thereby increase overall nutrient mining from soil and partly enhance crop growth/ productivity. Gradual dissolution of chemically precipitated soil P and resultant enhancement in soil available P on continuous usage of PSB can have still large favourable effect on crop growth/ productivity/ quality and soil fertility, besides these effects can last for longer period since most agricultural soils have large accumulated P reserves due to fixation which is sufficient to sustain maximum crop yields worldwide for about 100 years; however, approximately 95 to 99% part is insoluble phosphates, thus, P is utilized by plants in a very restricted manner (Pradhan and Sukla, 2005). Microbial population and nutrient benefits from bio-fertilizers can be greatly influenced by varying soil conditions owing to its direct link with potential survival, maintenance of optimum population/ biomass/ functioning which govern the overall benefits from these microorganisms/ bio-fertilizers. It is of high significance to mention here that well drained fine textured clay loam soils of Udaipur, are usually beset with higher biomass production potential mainly on account of improved soil water storage, less oxidation of OM, high CEC (20-50 meq/ 100 g soil) etc. or we can say that fine textured soils have a high potential to make more nutrients available to plants as well as to PSB/ soil microbes.

5.1.3 Yield attributes and yield

Data presented in Table 4.8 & 4.9 clearly reveal that among different nutrient management options, significantly maximum pooled performance of almost all the yield attributes (pods plant^{-1}, seeds pod^{-1}, seeds plant^{-1}, pod length, test weight, seed yield plant^{-1}) were recorded under N_9 but remained statistically at par with N_8. Significantly higher pooled performance of yield attributes can be ascribed to significantly higher pooled performance of different growth parameters (Table 4.2 to 4.7), contents of N, P and S in seed and haulm (Table 4.13 to 4.16) and N, P and S uptake (Table 4.13, 4.14 & 4.16) under N_9 in comparison to other nutrient management options. Significantly higher pooled yield attributes also fully support to significantly higher pooled yields (seed, haulm, biological, oil and protein) under N_9 in this study. This clearly shows higher physiological/ metabolic activeness and sufficient availability of secondary metabolites, proteins and soluble solids necessary for higher performance of yield attributes and finally the formation of seed yield under N_9. Significant increase in seed yield of soybean at 125% RDP + 30 sulphur + PSB (N_9) can be attributed due to fact that yield of a crop is a function of yield components which depends upon complementary interaction between vegetative and reproductive growth. The results on CGR and grain and biological yields are supported by Tanaka and Kawano (1966) and Nichiporovich (1967). This is very clearly evidenced in this study that higher dry matter production ultimately linked with improved source to sink relations at higher phosphorus levels with sulphur and PSB. In many legumes including soybean, poor sink capacity is attributed to poor retention of flowers capable of forming pods for which three possible explanations have been postulated, first being traditional favorite-hormones, the second assumes that other organs compete with flowers for want of metabolites and nutrients and last being limitation of vascular system for adequate and rapid supply of growth inputs from source to sink (Jeswani, 1986). The later assumption clearly suggests that plant can't be considered as a pool of carbon from which all sinks can draw it equally. This emphasizes need for higher production of metabolites during active reproductive phase. Hence, the increased number of pods plant^{-1} with more addition of phosphorus suggests greater formation of flowers and their retention due to adequate supply of nutrients / metabolites. Data (Table 4.13) also clearly revealed that phosphorus uptake was enhanced at 125% RDP + 30 sulphur + PSB (N_9) which shows active plant physiology and increased phosphorus uptake that is most possible under better crop root ramification since major mechanism for absorption of HPO_4 ions is mass flow and diffusion. Research findings clearly endorse that phosphorus leads to more root ramification and/ or higher root occupied soil volume of soybean (Ramasamy *et al.*, 2000 and Singh *et al.*, 2001) that critically also relates to more mining of other nutrients for longer duration as well as efficient translocation in the plant system apart from more root surface for *Rhizobium* infection (Dart, 1977). Higher phosphorus levels + sulphur +PSB did not only enhanced the phosphorus but nitrogen uptake (Table 4.13) was also significantly improved which again confirms the more physiological metabolic activeness of soybean plants which in integration with more root ramification that intercepted more HPO_4 ions that dominate in slightly alkali soil regime.

Significant variation in yield attributes and yield of soybean crop due to response of sulphur at slightly alkali soils of Udaipur was enhanced the phosphorus availability and uptake by soybean crop owing to localized lowering of soil pH, enhanced cation exchange etc. which in soil have favorably influenced variety of physiological and metabolic roles of sulfur. If we see sulfur, it is a structural component of amino acids (cystein and methionine), iron sulfur clusters, polyscharides, lipids, vitamins (thiamine and biotine), peptides (glutathione and phytochelatins), cofactors (Co factor A) and secondary products (allyl Cys sulfoxides and glucosinolates). Cellular roles of sulfur also extend to regulation of enzyme activity (eg. proteolytic and nitrogenase), redox cycle, xenobiotic detoxification etc. Sulfhydryl group (-SH) confers many thiols having ability to react with a broad spectrum of agent i.e. free radicals to heavy metals (Rebenstein, 1989). Thus, sulfur drastically influence plant growth and productivity also due to its influence on uptake of P and N and yield of S containing essential amino acids and proteins vital in enhanced productivity of crop plants. Though not a constituents, but S is vital in the biosynthesis of ferrodoxins. Fe- S protein occurring in the chloroplast has a significant role in NO_2 and So_4^{2-} reduction (Tisdale *et al.,* 1995). Thus, role of sulfur can not only be confined to enhanced availability and uptake of nitrogen, phosphorus but goes still beyond by virtue of its contribution in activating section plant physiology and metabolism that synchronized the growth and development of soybean plants that contributed to higher yields performance of sulphur in this study. Thus, overall analysis establishes that 125% RDP + 30 sulphur + PSB (N_9) was essential to economically enhance the soybean productivity in soils of Sub Humid Plains and Aravali Hills of Rajasthan state (Table 4.10 and 4.16).

A wide range of bacteria such as *Rhizobium, Azospirillum, Azotobacter, Pseudomonas, Bacillus,* and *Enterobacter* have been used as biofertilizer because of their positive effects on growth and productivity of plants *via* several mechanisms including plant hormones production, N**2** fixation, antagonism against phytopathogenic microorganisms and solubilization of nutrients (Kloepper and Schroth 1981, Rokhzadi and Toashih 2011). Several bacterial species, in association with plant rhizosphere, are capable of increasing availability of Phosphorus to plants, either by mineralization of organic phosphate, or by solubilization of inorganic phosphate by production of acids (Rodriguez and Fraga 1999). The PSB might have helped in releasing P from native as well as protecting fixation of added phosphate by excretion of organic acid and enzymes, some of hydroxyl acid may form chelates with cations as Ca++ and Fe++ which resulted in effective solubilisation of phosphates and rendered more available phosphorus for the plants leading to increased nutrient content of the plants which resulted in increased plan height as reported by Singh and Pareek (2003). The phosphate solubilizing bacteria is known produce vitamins and IAA and GA like growth substances (Sattar and Gaur 1987). Inoculation with PSB recorded higher chlorophyll content, which might be due to higher content of nitrogen and magnesium, which is core component of chlorophyll (Sattar and Gaur 1987). The high response of plant to the PSB inoculation might be due to mobilization of available P by the native soil microflora, or attributed due to increased PSB activity in the rhizosphere and consequently, by enhanced P solubilization. These reasons might have contributed towards its enhanced P uptake by the crops, an increase in plant height and total chlorophyll content and yield component (pods plant^{-1}, seed pod^{-1}, pod length, 1000- grain weight and seed yield plant^{-1}) as well as seed and haulm yield, oil and protein content and yield.

Seed yield is a complex trait that comprise of various components which together give rise to a highly complex yield structure (Diepenbrock, 2000). However, growth of pods and seeds occur when N absorption from soil is largely complete and N content of whole crop decreases during this phase which is likely to govern ontogenesis of fruits and seeds. Review of literature also supports significantly higher performance of yield attributes at higher levels of application of nutrients through inorganic fertilizers (Giri, 2001, Hatmode *et al.*, 2001, Kantwa and Meena, 2002, Singh *et al.*, 2004, Saxena *et al.*, 2005, Kumar *et al.*, 2006, Fathy and Ahmed, 2009, Mir *et al.*, 2010, Singh *et al.*, 2011, De and Sinha, 2012, Ram *et al.*, 2013 and Singh *et al.*, 2014), as well as in INM modules including inorganic + bio-fertilizers (Shrivastava *et al.*, 2000, Gudadhe *et al.*, 2005, Yasari and Patwardhan, 2007, Banerjee *et al.*, 2010, Pathak and Sharma, 2010, Banerjee *et al.*, 2012, Meena *et al.*, 2013, , Kumawat *et al.*, 2013 and Singh *et al.*, 2014).

It necessitate here to mention that INM module N_9 involved a higher level of nutrient application than already recommended inorganic fertilizer schedule (30 kg N, 40 kg P_2O_5 and 30 kg S ha^{-1}) in the region. Therefore, an account of response of soybean and different fertilizer recommendations is furnished here for clarity in the matter. Use of INM modules enhance the crop yields over and above the yields realized under recommended inorganic fertilizer schedules since it results in availability of nutrients in better synchrony with crop nutrients needs due to slower mineralization of organic nutrient sources, solubilisation of inorganic insoluble nutrient by microorganism and reduced nutrient losses and enhanced nutrient use efficiency/ recovery by crops and improvements in soil health and productivity hence, INM modules can sustain high crop yields in various cropping systems ensuring long-term sustainability of production systems (Aulakh, 2010).

Data in Table 5.1 reveals a strong correlation (further endorsed by regression equation) of seed yield with dry matter accumulation at 30, 60, 90 DAS and at harvest, plant height, 30, 60, 90 DAS and at harvest, branches plant^{-1}, nodule plant^{-1}, nodule weight plant^{-1}, pods plant^{-1}, seed pod^{-1}, pod length, seeds plant^{-1}, 1000 seed weight, seed yield plant^{-1}, N, P, K and S uptake by seed (r = 0.915 to 1.000). Similar, strong correlation of haulm and biological yield can also be observed with growth parameters nutrient contents/ uptake, seed yield and others in Table 5.1. Ilmulwar *et al.* (2003) has also reported significant and positive correlation between seed yield and biochemical (leaf chlorophyll content and seed oil content) and yield attributes (pods plant^{-1}, seeds pod^{-1}, 1000 seed weight and harvest index) in different cultivars of soybean.

5.1.2 N, P and S content and uptake

Data (Table 4.12 to 4.15) clearly reveal that among various nutrient management options the maximum and significantly higher pooled N, P and S contents in seed and in haulm was observed under N_9. However, it was statistically at par with N_8. This pin points on more soil availability of nutrients in nutrient management option under reference which resulted in significantly higher nutrient mining by soybean plants. Relative deficiency or imbalance of N, P and S can also involve a bit departure of certain key metabolic and physiological processes that can be finally related to role and functions of N, P and S that were critical in optimization of source to sink relationship in soybean plants. Since P is also a structural component of nucleic acid and somatic cell division almost ceases at stage close to crop maturity and there is also minimum energy requirement during this phase (less ATP synthesis), therefore, late mining of P by soybean plants might have not utilized on account of certain other reasons too. There can be potent environmental factors to influence cell division such as high temperature during maturity stage of deep rooted soybean crop can develop a high transpiration gradient and result in increased $H_2PO_4^-$ ion uptake but these ions could not have been assimilated/ metabolized due to minimum physiological/ metabolic activeness at maturity stage of crop.

If we cross talk on distinct variability in nutrient availability under different nutrient management options on clay loam soils of Udaipur *vis a vis* deep and ramified roots of dicot soybean plants often beset with high CEC (40-100 meq/ 100 g biomass) on account of presence of -COOH group which acts as exchange site similar to that of humus and account for 70-90% CEC. It clearly reveals the cause behind significantly higher response of soybean to applied/ native nutrients as revealed by significant higher pooled content and uptake of N, P and S by seed and stover on combining bio-fertilizers with inorganic fertilizers over corresponding inorganic fertilizer i.e. 75 100 and 125% RDP (Table 4.13, 4.14 & 4.16). Data appended from Table 4.13, 4.14 & 4.16 reveal that among different nutrient management options, significantly higher pooled uptake of N, P and S by seed and stover was noticed on application of 125% RDP + 30 sulphur + PSB (N_9). This depicts an outcome of a series of significantly variable interlinked factors/ plant processes under different nutrient management options mainly variations in soil availability of nutrients (N, P and S), nutrient mining by crop plants, growth/ biomass production, photo-morphogenesis, optimization of reproductive phase, source to sink strength, yield performance and quality parameters but the key focus remains the role/ functions of N, P and S.

It further necessitates here to briefly discuss passive ion uptake mechanisms so as to establish clarity in significant variations in pooled crop nutrient uptake/ crop growth/ yield attributes/ yield performance/ quality/ economics among different nutrient management options. Root interception enhances with increase in the quantity of absorbing roots in a given soil volume due to more root surface in contact with soil solution and mineral surface/ exchange complex. Normally roots occupy 1% or less soil volume but they can at maximum contact about 3% of available soil nutrients at a time but water movement within the soil redistributes/ moves nutrients further in soil solution as a continuous process. Another probability of higher nutrient uptake under N_9 can be through mass flow which is an important factor in plant nutrient mining, since this mechanism operates mainly through transpiration gradient. Significantly higher radiation intercepting and transpiring plant surface under N_9 as revealed by data on significantly higher pooled plant height (Table 4.2), DMA plant^{-1}

(Table 4.3), LAI (Table 4.5), CGR and NAR 30-60 (Table 4.6 and 4.7) etc. This is quite supportive to higher nutrient uptake through mass flow under N_9 in comparison to any other nutrient management option. Further, significantly higher contents of total chlorophyll under N_9 also confirms to higher rate of photosynthesis. Since process of photosynthesis involves proteolysis of water, therefore, higher photosynthesis rate can also invariably contribute to development of a steep transpiration gradient and higher nutrient uptake through mass flow under N_9 specifically during day time since all the nutrient management options have a uniform level of irrigation. Significantly higher pooled DMA plant^{-1} at different stages of soybean crop under N_8 further confirms to more photosynthesis and/ or an excellent poise between photosynthesis and respiration (plant biomass increment = photosynthesis – respiration). Under twin dispositions of more soil nutrient availability as confirmed by significantly higher pooled nutrient mining by soybean plants under N_9 (Table 4.13, 4.14 & 4.16), diffusion can also play an important role in nutrient mining by soybean plants under N_9. According to Fick's law, diffusion pertains to absorption of nutrients by plants under the influence of nutrient concentration gradient (high to low) that develops between absorbing roots and soil solution. More nutrient application + fairly high chances of more release/ mineralization of nutrients from organic/ mineral sources under N_9 (125% RDP + 30 sulphur + PSB), can be good possibility that more nutrient concentration in soil solution maintained under N_9 over other nutrient management options. Thus, variations in diffusion rates among different nutrient management options can constitute fairly a good reason behind significantly higher pooled nutrient uptake under N_9 since most of P move to roots through process of diffusion. Significantly higher pooled nutrient content and uptake under N_8 can also be partly due to energy (ATP) requiring active ion uptake. Aspects relating to gradual release of nutrients from soil OM/ previous crop residues, solubilization of native/ precipitated P by PSB, N fixation by *Rhizobium* and other linked probabilities of nutrient release in specific context to different nutrient management options have also been attended in this chapter for keeping the clarity intact in this context.

Significantly higher nutrient content in seed and/ or haulm and/ or higher crop nutrient uptake as well as significantly higher pooled performance of different growth parameters/ yield attributes/ yields/ quality/ economics in soybean crop on higher rate of nutrient usage have been reported in a diverse variety of nutrient scheduling works under different agro-climatic zones of the country has been reported in chapter 2. Increased levels of usage of inorganic fertilizers (Mishra and Kurchania, 2001, Shah, 2002, Rana and Rana, 2003, Shah *et al*., 2004, Singh and Meena, 2004, Singh *et al*., 2004, Reager *et al*., 2006, Kumar *et al*., 2011, Rajput, 2012, Kumawat *et al*., 2014, Saberi and Hassan, 2014 & Singh and Singh, 2014). Use of bio-fertilizers (*Azotobacter* and/ or PSB) over no bio-fertilizers inoculation (AICRP, 2000, Dubey, 2001, Duraisami *et al.* 2001, Dadheech, 2004, Purbey, 2004 and Rathore, 2008)[4]. Integrated use of inorganic fertilizers and/ or FYM and/ or bio-fertilizers (*Azotobacter* and/ or PSB) over independent use of inorganic fertilizers or FYM or bio-fertilizers (Bhat *et al*., 2005, Chand and Ram, 2008, Nagdive *et al*., 2007, Chand, 2007, Dadheech *et al*., 2009, Singh and Pal, 2011, Meena *et al*., 2013 and Singh and Singh, 2014). The works cited as above clearly conclude that nutrient content and uptake are distinctly governed by quantity of nutrient supplemented through organic and/ or inorganic nutrient sources. Nutrient content or concentration in plant tissues directly relates to optimum governance and continuance of diverse variety of cellular, structural, bio-chemical, metabolic and large variety of other physiological plant processes. This statement is well supported by significantly higher performance of different parameters in all the above referred research works. Talking about this study, data clearly endorse that maximum and significantly higher pooled concentration of N, P and S in seed and haulm under N_9 (Table 4.13,4.14 & 4.16) was clearly associated with significantly higher pooled performance of DMA plant^{-1} (Table 4.3), branches plant^{-1} (Table 4.4), LAI (Table 4.5), CGR 30-60 DAS (Table 4.6), NAR 30-60 DAS (Table 4.7), contents of total chlorophyll (Table 4.11), pod length (Table 4.8), pod plant^{-1} (Table 4.8), seed pod^{-1} (Table 4.8), number of seeds plant^{-1} (Table 4.9), test weight (Table 4.9), seed yield plant^{-1} (Table 4.9), seed, haulm, biological yields (Table 4.10 and 4.12), and status of available N, P and S after crop harvest (Table 4.17). Thus, nutrient content and uptake in this experiment distinctly governed the variability in growth, size of photosynthetic apparatus and related parameters, yield attributes, yield performance, soil fertility, residue recycling, quality parameters and economics which very well corroborate with finding of many research works furnished above.

5.1.4 Seed oil and protein content

Data (Table 4.11) clearly reveal that among different nutrient management options, significantly maximum pooled seed oil content was recorded under N_9 (125% RDP + 30 sulphur + PSB) but remained at par with N_8 which can be ascribed to more application and mining of nutrients (specifically S). Increase in oil content by sulphur application might be attributed to involvement of sulphur in the biosynthesis of oil. Sulphur is involved in the formation of glucosides and glucosinolates and sulphydril-linkage and activation of enzymes, which aid in biochemical reaction within the plant. The higher oil yield by sulphur application was obviously because of higher seed yield and oil content. Since S is being involved in fatty acid synthesis, it can potentially influence oil content particularly between nutrient management options involving 75%, 100% and 125% RDP (Table 4.11). Similarly, S can also influence amino acid/ protein/ biomass production in nutrient management options involving 75%, 100% and 125% RDP (Table 4.11). Other nutritional and physiological causes behind possible pooled variations in seed oil content have already been furnished in previous sections. This confirms to decline in availability/ mining of nutrients and synthesis of secondary metabolites with advancement of crop from flowering to maturity which can partly be ascribed to gradual decline in activeness of various metabolic/ physiological functions on progressive aging of crop plants including gradual decline in source to sink strength. However, exact reasons behind such decrease in seed oil content in soybean need to be precisely established by undertaking suitable physiological studies. Review of literature also confirms to increase in seed oil content on increasing rates of nutrient application through (1). Inorganic fertilizers: Joshi *et al.*, 2008, Singh and Sinsinwar, 2006, Bhalerao, 2001 and Ram *et al.*, 2013, Saxena *et al.*, 2005, Sumeria *et al.*, 2000 and Faujdar *et al.*, 2008, Saberi and Hassan, 2014, De and Sinha, 2012, Singh *et al.*, 2002 and Kumawat *et al.*, 2014 (80:40 kg N:P ha^{-1}) (2). Bio-fertilizers: Singh and Sinsinwar, 2006 and Pathak and Sharma, 2010 and Patra *et al.*, 2012 (3). INM modules: Mandal and Sinha, 2004, Singh *et al.*, 2011, Banerjee *et al.*, 2012 and Meena *et al.*, 2013.

Application of 125% RDP + 30 sulphur + PSB (N_9) significantly enhanced the soybean protein content and yield over other treatments but variations in protein content were statistically at par with 100% RDP + 30 sulphur + PSB (N_8). The improvement in protein content of grain with application of fertilizer (phosphorus) was expected of the nutrient especially N is considered to be an essential constituent and actively involved in synthesis of protein (Tisdale *et al.,* 2003). Similarly, phosphorus increased protein content due to its role in the improvement in nitrogen use efficiency, biological nitrogen fixation by supplying needed energy. Because nitrogen is a basic constituent of protein and with increase in the rate of phosphorus application, nitrogen availability increased which resulted in increased protein content in grain. Significant increase in protein content in grain with increasing P was also estimated by Prasad *et al.* (1993), Ameta (2002) and Meena (2005), Meena *et al.* (2004) and Kahlon *et al.* (2006).

The improvement in protein content in grain with the S fertilization seems to be on account of increased S and N content of soybean seed. It has also been empirically established that for every 15 part of N in proteins, there is 1 part of S which implies that N:S ratio is fixed within a narrow range of 15:1. Therefore, lack of S would reduce the amount of protein synthesized even if there were plenty of N available to plants (Dev and Sharma, 1988). Sulphur is known to increase the metabolic utilization of nitrogen by keeping N:S ratio within optimum range (*Dijkshoorn* and VanWijk, 1967). Therefore, sulphur application could be expected to have worked a favoruable N: S ratio for better synthesis of protein in plant system. The role of S can be viewed from its participation in the several biochemical processes for the metabolism of carbohydrates, fat and protein in plant system. Sulphur in the form of sulphate, is best known for its role in synthesis of S containing amino acids, namely methionine, cysteine and cystine (Lakkaneni and Abrol, 1994)

5.1.5 Soil fertility after crop harvest

Although both yearly and pooled data on N, P and S after crop harvest indicate that among different nutrient management options, N_9 registered significantly higher pooled available N, P and S in soil over other nutrient management options. However it was at par with N_8. It indicates a situation of nutrient surplus which is encountered when combined supply of applied/ mineralized nutrients exceeds the corresponding nutrient absorption by crop plants/ weeds and immobilization by native/ applied microbes. Significantly higher pooled availability of N, P and S under N_9 can be ascribed to variations in mineralization and subsequent accumulation of N, P and S during period close to harvest on account of fact that crop nutrient absorption rate sharply decline during this period. However, it noteworthy that different nutrient option recorded lower pooled values for available N and S after crop harvest than corresponding initial soil nutrient status which ranged from -19.84 kg ha^{-1} under N_8 to 29.34 kg ha^{-1} under N_1 for nitrogen and from 5.27 kg ha^{-1} under N_8 to 1.12 kg ha^{-1} under N_1 for Sulphur and from 10.81 kg ha^{-1} under N_8 to 15.32 kg ha^{-1} under N_1 for phosphorus. This clarifies that none of the nutrient management options improved the initial fertility status with respect to N and S and variations in pooled N, P and S status pin pointedly indicates on nutrient mineralization potential of various treatments in close context to terminal crop period together with the overall nutrient mining under different nutrient management options. However, significantly higher available N, P and S after harvest of soybean under higher levels of application of nutrients through inorganic and INM modules under this study well corroborate with findings of Rajput (2012), Mishra and Jain (2013) and Singh and Singh (2014).

There seems a synergistic effect of the P application on available N status of soil which may be due to positive influence of applied phosphorus on nodulation and symbiotic nitrogen fixation. Nodules after degradation may also release nitrogen in soil, possibly due to this fact increase in soil nitrogen was recorded. Israel (1985) also reported a specific role of phosphorus in the symbiotic nitrogen fixation and apart from its influence on overall growth. Significant build up of the soil available N could be attributed to increased activity of nitrogen fixing *Rhizobia* thereby resulting in higher accumulation of N in the soil (Parmar *et al.,* 1998). Kundu *et al.* (1998) and Sharma *et al.* (2000) also reported a positive N balance in soil is due to biological fixation of N_2 consequent to the inclusion of a legume in the crop sequence. Dubey (2000) also observed increased available N in soil after black gram harvest due to application of P which facilitates enhanced nodulation and N_2 fixing activity by *Rhizobium*. It is an accepted fact that 25 to 35 per cent of applied phosphorus is used by the crop and rest remain in soil in different form. Alike findings were also reported by Cahal *et al.* (1984) who estimated increase in available P content from 17.0 to 28.6 kg ha^{-1} (at harvest) with the application of 60 kg P_2O_5 ha^{-1}. Prasad (1983) also observed increased available phosphorus status in soil after harvest of the crop due to phosphorus application. The results are in close accordance with findings of Akbari *et al.* (2002) who also reported that phosphatic fertilizer was found beneficial for increasing available N and P content in medium black soil.

The increase in availability of nutrients with S might be due to higher rate of mineralization of nutrients, favourable environment for microbial activity as well as chemical activity, improved physico-chemical properties, ameliorative effect of S and better growth of roots resulting in high organic matter addition. Dose of sulphur fertilization seems to be the reason for relative enhancement in SO_4^{-2}-S content of soil (Tandon, 1991). Nguyen and Goh (1992) reported increase in carbon bonded sulphur fraction with increasing level of sulphur applied. Further similarly positive response of application of S fertilization to available S of soil was also reported by Ram and Dwivedi (1992), Kaprekar *et al.* (2003), Singh and Singh (2004), Deo and Khandelwal (2009) and Ruchi *et al.* (2012).

5.5 EFFECT OF AGROCHEMICALS

5.5.1 Brassinolide

5.5.1.1 Growth parameters

Data (Table 4.2 to 4.7) clearly illustrate that different PGRs recorded significant variations in pooled performance of various growth parameters of crop in order of brassinolide > benzyl adenine > water spray which can be ascribed to the fact that different PGRs vary in regulatory and stimulatory functions namely influence on different physiological processes, bio-chemical reactions and metabolic activities, harmonize and maintain optimum level of different enzymes and hormones in the plant, synthesis of bio-molecules and anti-oxidants, development of plant organs, maintenance of optimum plant water balance and stomatal conductance, carboxylation efficiency, flower initiation, length of reproductive and total crop duration etc.

Application of brassinolide [a polyhydroxy-steroidal lactone with remarkable plant growth promoting activity (Grove *et al*., 1979)] significantly enhanced various growth parameters of soybean like higher pooled plant height at 60, 90 DAS and at harvest, LAI 60 and 90 DAS, CGR 30-60 and 60-90 DAS, RGR 30-60 and 60-90 DAS, NAR 30-60 and 60-90 DAS, dry matter accumulation plant^{-1} at 60 & 90 DAS and at harvest, total chlorophyll contents at 60 DAS, number of branches plant^{-1} at 60 DAS and at harvest over benzyl adenine and water spray (Table 4.2 to 4.7). The favorable effect of brassinolide on overall growth of soybean could be ascribed to increased metabolic activities in the plant system as well as cell elongation, bending, division, reproductive & vascular development, membrane polarization, proton pumping in plants (Mandava & Thompson, 1983, Mandava, 1988, and Agarwal and Gehlot, 2000).

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

Foliar treatment of wheat plants with brassinosteroid has shown an almost 2-fold increase in rate of cytokinins accumulation maintained for a long period which confirms that growth stimulating activity of brassinosteroid is primarily due to its effects on cytokinin metabolism in plants. This suggests that brassinosteroid induced mobilization of rapid mechanisms of cytokinin metabolism and confirms to transformation of cytokinin phyto-hormones in seedling roots followed by their transport to sprouts (Avalbaev *et al.*, 2003). Brassinosteroid are important plant growth regulators in multiple plant developmental processes mainly due to stimulation of polar auxin transport capacities, modification in distribution of endogenous auxin and gravi-tropism of roots (Li *et al.*, 2005).

Brassinosteroid have photosynthesis regulations to enhance net photosynthetic rates, prevention of loss of photosynthetic pigments by activating enzymes of chlorophyll biosynthesis or initiation of chlorophyll synthesis via activation or biosynthesis of carbonic anhydrase that catalyses inter-conversion of CO_2 and HCO_3^- or activity of ribulose, 1-5-carboxylase/ oxygenase is enhanced and/ or enzymes involved in regeneration of ribulose, 1-5-biphosphate are protected which normally enhances the efficiency of photo-system II in some cases or there is improvement in efficiency of primary photosynthetic processes but it appears to be a rather secondary (Hola, 2011). In fact, nutrient concentration in plant tissues in the optimum range (neither toxic nor sub-optimal) critically relates to proper governance of different physiological, bio-chemical, metabolic, cellular and other key plant processes and this is important from point of view of overall growth and development of plants including orderliness in reproduction and source to sink strength that finally governs the seed yield. Increase in root biomass of rice on exogenous application of brassinosteroid has been reported by Senthil *et al*. (2003). Increase in dry matter accumulation under brassinosteroid has been ascribed to increase in leaf chlorophyll and soluble protein by Rani *et al.* (1989), increase in activity of nitrate reductase in roots and leaves by Singh *et al.*(1993) and chlorophyll content and photosynthesis under irrigated and stressed condition by Sairam (1994). Mandava and Thompson (1983) also reported significant increase in crop growth under brassinosteroid due to its positive influence on both cell division and elongation (swelling, curvature and splitting of the second inter node). As per Mandava (1988), primary effect of brassinosteroid is exerted on growth region of plant while increase in DMA plant^{-1} is clearly reported to arise out of increase in leaf chlorophyll, soluble protein (Sairam, 1994), photosynthesis (Shen *et al.*, 1990) and activity on nitrate reductase in roots and leaves (Singh *et al.*, 1993). Foliar usage of brassinosteroid promotes the crop growth due to enhanced chlorophyll content at various growth stages that increased the photosynthetic rate and dry matter accumulation plant^{-1} (Bhatia and Kaur, 1997). Besides it also induces membrane stability, helps in maintaining the plant water balance and has a direct effect on enzyme proteins (Agrawal and Gehlot, 2000).It improves plant growth in terms of increase in shoot length and leaves plant^{-1} (Arora *et al.*, 2010). Brassinosteroid also control regulatory processes that are more specific to plant growth including photomorphogenesis and skotomorphogenesis (Cevahir *et al.*, 2008, Li and Jin 2007 and Vert and Chory, 2006). Results on enhancement in contents of total chlorophyll on application of brassinosteroid over benyladenine and/ or water spray in this study well corroborate with findings of Hayat *et al*. (2001), Magda (2001a), Shivakumar *et al*. (2001 & 2002), Mehta (2004), Prakash *et al*. (2007), Sharma (2008), Rajavel and Vincent (2009), Ananthi *et al*. (2013), Meena *et al*. (2013) and Chaplot and Sumeria (2013).

A significant increase in dry matter could be observed from positive correlation exhibited between DMA at 30, 60, 90 and at harvest with plant height 30, 60, 90 and at harvest, CGR 30-60 RGR 30-60, NAR 30-60 and LAI 30 & 60 DAS (r = -0.590 to 0.998). The significant increase in crop growth as a result of brassinolide application under the present investigation is in close agreement with findings of Mitchell and Gregory (1972), Galstone (1983), Braun and Wild (1984), Ameta (1993), Fang *et al*. (1994), Kumawat (1996) and Mehta (2004).

5.5.1.2 Yield Attributes and Yield

Data appended from Table 4.8 to 4.10 conclude that different PGRs recorded significant variations in pooled performance of various yield attributes and different forms of yield in order of brassinolide > benzyladenine> water spray. Application of brassinolide registered significantly higher pooled values of different forms of yield and yield attributes over benzyladenine by registering a pooled enhancement corresponding to 103, 216, 399, 27.54 and 52.85 kg ha^{-1} in seed, haulm, biological, oil and seed protein yields; 3.17% in pod length, 3.57% in seeds pod^{-1}, 6.17% in number of pods $plant^{-1}$, 4.55 % number of seeds $plant^{-1}$,4.02% in test weight, 4.58% in seed yield $plant^{-1}$, respectively. Similarly, foliar usage of brassinolide registered significantly higher pooled values of different forms of yields and yield attributes over water spray by registering a pooled enhancement corresponded to 249, 552, 801, 60.52 and 120.62 kg ha^{-1} in seed, haulm, biological, oil and seed protein yields, 8.18% in pod length, 8.75%, in seeds pod^{-1}, 12.22% in number of pods $plant^{-1}$, 12.76% number of seeds $plant^{-1}$, 9.96% in test weight, 11.05% in seed yield $plant^{-1}$, respectively. Significant variations in pooled seed oil yield and protein yields among different PGRs (Table 4.12) can be ascribed to significant variations in pooled seed yield (Table 4.10) and oil and protein content (Table 4.11).

The marked improvement in various yield attributes of soybean with the application of brassinolide could be ascribed to overall improvement in growth of the crop, estimated in terms of DMA at various growth stages as well as attainment of higher growth efficiency between peak duration. Increase in productivity of soybean (seed yield) under the influence of this agrochemical was also found due to improvement in number of pods $plant^{-1}$, number of seeds pod^{-1} and seed index. It is also necessary to furnish an account of analysis to explain significantly higher pooled performance of different forms of yield and yield attributes under application of brassinolide over benzyladenine and water spray. Phyto-hormones (natural chemical messengers) or PGRs i.e. chemically synthesized phyto-hormones are translocated from site of production or application to other plant parts and play critical and vital roles in regulating plant responses at extremely low concentration (Javid *et al.*, 2011). Entire range of plant developmental processes are largely regulated by shift in hormonal balance and brassinosteroid are recognized regulators of transcription and translation and thereby they change pattern of total proteins, enzymes, rate of photosynthesis and finally seed yield. Brassinosteroid regulate the plant processes at enzyme level, enhance photosynthetic rate and other critical and interrelated processes, thus, these determine biological yield under natural conditions (Hayat *et al.*, 2010). Brassinosteroid have various kinds of regulatory activity on growth and development of plants that briefly comprise of growth promotion, increase in fertilizer use efficiency, shortening of vegetative growth period, increase in size and quantity of fruits, enhancement in nutritive component and quality, resistance to abiotic stress and diseases and increase in crop yield which is result of a cascade of bio-chemical reactions that intimately link with changes at cell level such as stimulation of elongation and fission as well as optimization of hormonal balance, enzyme activity, H^+ pump activation, protein and nucleic acid synthesis, amino acid and fatty acid composition and enhancement in photosynthetic capacity and translocation of products (Culter, 1991). Apart from growth, brassinosteroid are potent to influence the reproduction, maturation, senescence and crop yield. Specific stimulation of harvestable organs on account of PGRs is important in stage dependent crop nitrogen demand (Wiesler *et al*., 2001 and Rathke *et al*., 2006). It is significant to mention that brassinosteroid are obligatory plant constituents with highest concentration in reproductive organs and growing tissues like pollen, immature seed, shoot etc. (Sasse *et al.*, 1998, Fujioka *et al*., 1998 and Yokota *et al*., 1998) and can act as a potent cause behind higher pooled performance of different forms of yields and yield attributes under brassinosteroid over benzyladenine and water spray. Brassinosteroid characterized by bending, swelling and splitting of second inter node (Mandava, 1988), play an important role in plant growth and development (Mussing, 2005) through regulation of many cellular and physiological processes like cell division and elongation, synthesis of DNA, RNA and various proteins, enhancement in nucleic acid and protein synthesis, biosynthesis of cell wall components, micro-tubular organization pollen tube growth, differentiation of vascular system, distribution of assimilates to other plant parts, formation of adventitious roots, seed germination, flowering and reproduction, stress response, photo morphogenesis and senescence reported by Khripach *et al*. (2000), Castle *et al*. (2003), Hayat *et al*. (2003), Krishna (2003), Sasse (2003), Haubrick and Assmann (2006), Bajguz and Hayat (2009) and Divi and Krishna (2009).

Favourable influence of brassinosteroid on source to sink mechanism is another aspect of significant relevance and this can be a key reason behind significantly higher performance of pooled yield and yield attributes under brassinolide over benzyladenine and water spray in this experiment. Brassinosteroid increase source to sink strength that enhances translocation of food reserve to plant parts useful in yield formation that ultimately contribute to higher performance of yield attributes and seed yield (Petzold *et al.* 1992 and Kanojia, 2006). Brassinosteroid maintain optimum source-sink strength and proper partitioning of dry matter in plants (also well evident from data in Table 4.8). Findings of Luo *et al.* (1986) is in very much similar with Nakaseko and Yoshida (1989) and both the findings collectively confirm a significant enhancement in performance of different yield attributes and seed and stover yields due to substantial improvement in fruit set and seed filling on application of brassinosteroid at pre-anthesis stage over water spray. In this investigation, PGRs were also sprayed at pre-anthesis stage (30 DAS).

Use of brassinosteroid enhances activities of anti oxidative enzymes and increases contents of proteins and glutathione which clearly shows the stress-protective mechanism on uses of brassinosteroid (Arora *et al.*, 2010). Brassinosteroid treated radish plants confirmed to significant enhancement in both free and bound IAA, antioxidant levels (glutathione, proline, glycinebetaine, ascorbic acid and phyto-chelatins), free radical scavenging potential as indicated by higher cancelation of 1,1-diphenylpicrylhydrazyl and deoxyriboseand increased levels of phenols and soluble sugars while ABA, MDA and H_2O_2 contents significantly declined under metal stress conditions (Choudhary *et al.*, 2012). Foliar treatment of brassinosteroid in pea plants led to a change in structural organization of thylakoid membranes that in turn influences the kinetics of oxygen evolution, accelerates electron transport rate, increases effective quantum yield of photo-system II and photochemical quenching (all stress tolerance mechanism) (Dobrikova *et al.*, 2014).

Significantly higher seed and/ or stover and/ or biological yields is registered in a vast variety of crops (cereals, legumes, oilseed, tuber crops etc.) under use of brassinolide in foreign countries, at different research stations in India, widely support the results of this investigation. Results on significantly higher pooled performance of different forms of yields and yield attributes due to application of brassinolide over benzyladenine and water spray in this study well corroborate with findings of Hayat *et al.*(2001), Magda (2001a), Mehta (2004), Kanojia (2006), Prakash *et al.* (2007 & 2008), Meena *et al*. (2013), Chaplot and Ameta (2014) and Ameta *et al*. (2014).

Correlation studies carried out in the present investigation showed positive association between seed yield with pod plant^{-1} (r=0.922), seeds pod^{-1} (r=0.971), seeds plant^{-1} (r=0.951), seed yield plant^{-1} (r=0.917) and 1000 seed weight (r=0.971). The results of present study corroborate with the findings of Cerana *et al*. (1983), Meudt *et al*. (1984), Yokota and Takahashi (1986), Ameta (1993), Kumawat (1996) and Mehta (2004). At last, it may be concluded that application of brassinolide to soybean increased all the growth and developmental parameters, yield attributes and yields.

5.5.1.3 Quality parameters and nutrient uptake

Data appended in Table 4.11 illustrate that different PGRs registered significant variations in pooled oil content as well as in pooled seed protein content that was in order of brassinolide > benzyladenine> water spray. Foliar application of brassinolide registered a pooled enhancement in oil content in seed and protein content in seed over benzyladenine and water spray that corresponded to 2.32, 4.26 and 1.76, 3.57 per cent, respectively.

Significant increase in oil and protein yield due to foliar application of brassinolide over rest of the treatments could be ascribed due to increase in oil and protein content as well as seed yield. This was due to increased N uptake (Mai *et al*., 1989) and enhancement of various metabolic activities, water and mineral (nitrogen) uptake resulting in increased protein synthesis (Shen *et al*., 1990, Kulaeva *et al*., 1991, Schilling *et al*., 1991 and Sairam, 1994). The improvement in quality of soybean seed as a result of brassinolide spray could be attributed to their pivotal role in creating congenial nutritional environment, greater availability of essential nutrients and regular supply of metabolites for protein synthesis through improved translocation of metabolites from source to sink (seed). Significant improvement in oil and protein yield due to application of brassinolide is in close conformity with the work of Ameta (1993), Kumawat *et al*. (1997), Salvi (1997), Mehta (1998) and Mehta (2004). Seed protein content directly links with N concentration in seed (Table 4.13) which is directly associated with enhancement in various bio-chemical processes related to protein synthesis (Shen *et al.*, 1990, Kulaeva *et. al.*, 1991, Schilling *et al.*, 1991 and Kanojia, 2006). Significantly higher pooled seed protein content under PGRs over water spray can be ascribed to role of PGRs in promoting greater mining of essential nutrients from soil. Besides, PGRs increase in nitrate reductase activity and maintain regular supply of metabolites for protein synthesis on account of improved translocation of metabolites from source to real sink (seed). Results on significant improvement in seed oil content on foliar application of brassinolide is in close conformity with the findings of Ramraj (1997), Magda (2001), Mehta (2004), Shivkumar *et al*. (2002), Kanojia (2006) and Ameta (2009). Also, results on significantly higher seed oil content on owing to application of BRs well corroborates with findings of Shivkumar *et al*. (2002), Khaliq *et al.*(2006) and Prakash *et al*. (2008).

In the present investigation significant increase in the uptake of N, P, K and S as a result of foliar spray of brassinolide appears to be due to significant increase in seed, stover and total biomass production at harvest, as nutrient uptake to a greater extent is a function of dry matter production and to the lesser degree by per cent nutrient content. Significant variations in pooled content and uptake can be ascribed to variety of reasons mainly (1) variations in influence of various PGRs on vitality and optimum governance of different physiological, bio-chemical, metabolic and other important plant processes, (2) variations in root biomass and volume and resultant variations in net nutrient and moisture mining from a relatively larger soil volume under different PGRs and (3) variations in ability of PGRs to maintain optimum growth and better crop performance under biotic (disease and insects) and abiotic stresses (salt, heavy metal, high temperature etc.). The significance of nutrient concentration *vis a vis* growth and development of plants have also been attended in section 5.2.1. Aspect of more ion uptake via established active and passive mechanisms is although attended in section 5.1.1, however, more pooled nutrient uptake in PGR treatments over water spray as well as variations in nutrient uptake among brassinolide and benzylzdenine treatments due to development of variable steeper transpiration gradient on account of significant variations in pooled LAI, dry weight plant^{-1}, contents of chlorophyll and dry weight and volume of roots appears to be critical and decisive in this investigation so far variations in pooled nutrient content and uptake of N, P, K and S by soybean is concerned. Brassinosteroid have potential to regulate uptake of ions in the plant cells (reduced accumulation of heavy metals and radioactive elements), hence, they are quite important from food quality point of view (Khripach *et al.*, 1995 and 1996). Foliar application of brassinosteroid enables plants to fix greater amount of CO_2 in dark reaction of photosynthesis which can be a potent cause behind production of significantly higher pooled yield levels under brassinosteroid over benzyladenine and water spray while higher yield levels are usually directly linked with higher uptake of nutrients. Brassinosteroid treatment also reduces heavy metal content in crop produce and improves the quality of food stuff (Kroutil *et al.*, 2010). Results on significant enhancement in pooled uptake of N, P, K and S by soybean crop and other oilseeds on use of brassinosteroid and benzyladenine well corroborate with findings of Eleiwa and Ibrahim (2011), Sharma *et al.* (2012) and Ameta *et al.* (2014)

5.5.2 Benzyladenine

5.5.2.1 Growth parameters

At a non-significant plant population (Table 4.1) benzyl adenine significantly enhanced the growth parameters i.e. plant height (Table 4.2), dry matter accumulation (Table 4.3), branches plant^{-1}, number of nodule plant^{-1}, nodule weight plant^{-1} (Table 4.4), leaf area index (Table 4.5), crop growth rate and relative growth rate (Table 4.6), Net assimilation rate (Table 4.7) and total chlorophyll content (Table 4.11) over water spray which may be attributed due to their involvement in physiological and metabolic activities of plants which led to significant improvement in plant growth parameters on account of higher leaf photosynthetic rate and biomass productivity. The possibility of certain specific roles of benzyl adenine that favoured improved source to sink relations is obvious out of data on significantly higher dry matter partition in leaves and pods than the water spray.

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

5.5.2.2 Yield attributes and yield

A significant increase in yield attributes and seed and haulm yield of soybean was recorded as a result of foliar application of benzyladenine over water spray (Table 4.8 to 4.10). Application of benzyladenine increased the pooled seed yield, haulm yield and biological yield by 146, 336 and 482 kg ha^{-1}over water spray. Significant increase in seed yield of soybean could be ascribed to cumulative effect of yield components viz., pods $plant^{-1}$, seeds pod^{-1}, seeds $plant^{-1}$ and 1000 seed weight, which increased seed yield $plant^{-1}$ and ultimately led to greater seed production per unit area. As it is clear that pooled seed yield was found positively correlated with the yield attributes with correlation coefficient of 0.922, 0.971, 0.951 and 0.971, respectively in the order named above. These results are in cognizance with the findings of Williams and Cartwright (1980), Crosby *et al.* (1981), Krishnan *et al.* (1999), Samuel *et al.* (2000) and Pandey *et al.* (2001) who reported higher yield attributes and yield with the foliar application of benzyladenine in different crops.

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

5.3.2.3 Quality parameters and nutrient uptake

In the present investigation benzyladenine application significantly improved the quality of soybean seed assessed as protein and oil yield over water spray. Application of benzyladenine significantly improved N, P and S content in seed and haulm over control. N, P and S accumulation by seed and haulm along with their total uptake by soybean crop was significantly enhanced under benzyladenine application (Table-4.13, 4.14 and 4.16). Cytokinin (BA) may stimulate protein synthesis by stimulating the recruitment of previously untranslated mRNA into polysomes (Singh, 2004). This finding is in association with Pandey *et al*. (2001) and Patil *et al*. (2002), who recorded a remarkable improvement in protein content of seed. Further, significant improvement in oil content of seed might be due to increased transformation of stored translocated metabolites under the influence of favourable enzymatic activity created by BA application. While oil yield increased due to the increase in seed yield. These results are in close conformity with Samuel *et al*. (2000), Patil *et al*. (2002) and Vani *et al*. (2004). Patil *et al*. (2002) reported that foliar spray of benzyladenine increased nutrient uptake with concomitant increase in dry matter production. This is also clearly indicated by the positive correlation between nutrients uptake and yield of soybean.

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

S. Number	Dependent (Y)	Independent (X)	Correlation coefficient (r)		Regression equation r^2	(Y = a+ b X)			
1	Dry matter (g plant^{-1}) at 30 DAS	plant height at 30 DAS	0.989	**	0.978	-1.354	+	0.146	X
2	Dry matter (g plant^{-1}) at 60 DAS	plant height at 60 DAS	0.990	**	0.981	0.063	+	0.261	X
3	Dry matter (g plant^{-1}) at 90 DAS	plant height at 90 DAS	0.975	**	0.951	1.221	+	0.307	X
4	Dry matter (g plant^{-1}) at harvest	plant height at harvest	0.976	**	0.952	1.999	+	0.350	X
5	Dry matter (g plant^{-1}) at 60 DAS	CGR 30-60 DAS	0.987	**	0.975	-0.909	+	1.447	X
6	Dry matter (g plant^{-1}) at 60 DAS	RGR 30-60 DAS	-0.590	0.000	0.349	25.356	+	-315.277	X
7	Dry matter (g plant^{-1}) at 60 DAS	NAR 30-60 DAS	0.998	**	0.996	5.082	+	0.742	X
8	Dry matter (g plant^{-1}) at 60 DAS	LAI at 60 DAS	0.992	**	0.983	0.324	+	4.008	X
9	Dry matter (g plant^{-1}) at 60 DAS	LAI at 90 DAS	0.992	**	0.984	0.688	+	3.665	X
10	Seed yield (q ha^{-1})	Dry matter (g plant^{-1}) at 30 DAS	0.931	**	0.866	-0.887	+	6.096	X
11	Seed yield (q ha^{-1})	Dry matter (g plant^{-1}) at 60 DAS	0.965	**	0.932	-7.824	+	2.173	X
12	Seed yield (q ha^{-1})	Dry matter (g plant^{-1}) at 90 DAS	0.945	**	0.894	-9.333	+	1.310	X
13	Seed yield (q ha^{-1})	Dry matter (g plant^{-1}) at harvest	0.958	**	0.917	-10.714	+	1.122	X
14	Seed yield (q ha^{-1})	plant height at 30 DAS	0.915	**	0.837	-8.999	+	0.884	X
15	Seed yield (q ha^{-1})	plant height at 60 DAS	0.968	**	0.937	-7.978	+	0.575	X
16	Seed yield (q ha^{-1})	plant height at 90 DAS	0.977	**	0.955	-9.120	+	0.427	X
17	Seed yield (q ha^{-1})	plant height at harvest	0.970	**	0.940	-9.370	+	0.407	X
18	Seed yield (q ha^{-1})	Branches plant^{-1}	0.943	**	0.889	-3.905	+	3.815	X
19	Seed yield (q ha^{-1})	Nodules/plant	0.957	**	0.916	1.109	+	0.564	X
20	Seed yield (q ha^{-1})	Nodule wt	0.974	**	0.948	-3.552	+	33.706	X
21	Seed yield (q ha^{-1})	Pods plant^{-1}	0.922	**	0.850	-4.029	+	0.402	X
22	Seed yield (q ha^{-1})	Pod length	0.973	**	0.946	-6.354	+	6.337	X
23	Seed yield (q ha^{-1})	Seed yield (g/plant)	0.917	**	0.841	-1.350	+	2.093	X
24	Seed yield (q ha^{-1})	Seeds plant^{-1}	0.951	**	0.905	-4.467	+	0.182	X
25	Seed yield (q ha^{-1})	Seeds pod^{-1}	0.971	**	0.943	-12.557	+	11.179	X
26	Seed yield (q ha^{-1})	1000 grain weight (g)	0.971	**	0.943	-10.359	+	0.253	X
27	Seed yield (q ha^{-1})	N uptake by seed (kg ha^{-1})	0.999	**	0.997	1.673	+	0.140	X
28	Seed yield (q ha^{-1})	P uptake by seed (kg ha^{-1})	0.998	**	0.997	2.723	+	1.238	X

S. Number	Dependent (Y)	Independent (X)	Correlation coefficient (r)		Regression equation r^2	(Y = a+ b X)			
29	Seed yield (q ha^{-1})	K uptake by seed (kg ha^{-1})	1.000	**	0.999	0.737	+	0.520	X
30	Seed yield (q ha^{-1})	S uptake by seed (kg ha^{-1})	0.995	**	0.991	3.751	+	2.511	X
31	Haulm yield (q ha^{-1})	Dry matter (g $plant^{-1}$) at 90 DAS	0.937	**	0.878	-15.499	+	2.834	X
32	Haulm yield (q ha^{-1})	Dry matter (g $plant^{-1}$) at harvest	0.949	**	0.900	-18.461	+	2.425	X
33	Haulm yield (q ha^{-1})	plant height at 90 DAS	0.974	**	0.949	-15.344	+	0.928	X
34	Haulm yield (q ha^{-1})	plant height at harvest	0.968	**	0.936	-15.949	+	0.886	X
35	Haulm yield (q ha^{-1})	Chlorophyll content	0.974	**	0.949	-38.024	+	31.409	X
36	Haulm yield (q ha^{-1})	N uptake by haulm (kg ha^{-1})	0.997	**	0.994	8.395	+	0.460	X
37	Haulm yield (q ha^{-1})	P uptake by haulm (kg ha^{-1})	0.995	**	0.990	7.948	+	4.167	X
38	Haulm yield (q ha^{-1})	K uptake by haulm (kg ha^{-1})	1.000	**	0.999	1.439	+	0.347	X
39	Haulm yield (q ha^{-1})	S uptake by haulm (kg ha^{-1})	0.995	**	0.989	9.642	+	4.069	X
40	Biological yield (q ha^{-1})	Dry matter (g $plant^{-1}$) at harvest	0.954	**	0.909	-29.175	+	3.547	X
41	Biological yield (q ha^{-1})	plant height at harvest	0.970	**	0.941	-25.319	+	1.293	X
42	Biological yield (q ha^{-1})	Total N uptake (kg ha^{-1})	0.996	**	0.993	10.005	+	0.27	X
43	Biological yield (q ha^{-1})	Total P uptake (kg ha^{-1})	0.996	**	0.992	11.73	+	2.388	X
44	Biological yield (q ha^{-1})	Total K uptake (kg ha^{-1})	1.000	**	0.999	1.637	+	0.387	X
45	Biological yield (q ha^{-1})	Total S uptake (kg ha^{-1})	0.994	**	0.989	13.91	+	3.402	X
46	Protein yield (kg ha^{-1})	Seed yield (kg ha^{-1})	0.999	**	0.997	-72.609	+	44.444	X
47	Protein yield (kg ha^{-1})	Nitrogen content in seed (%)	0.960	**	0.921	-4336.784	+	782.013	X
48	Oil yield (kg ha^{-1})	Seed yield (kg ha^{-1})	0.999	**	0.997	-51.016	+	22.791	X
49	Oil yield (kg ha^{-1})	Oil content in seed (%)	0.970	**	0.940	-1427.857	+	89.313	X

6. SUMMARY

The results of field experiment entitled **“Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]**”, conducted during two consecutive kharif seasons of 2013 and 2014 presented and discussed in the preceding chapters are summarized below.

6.1 NUTRIENT MANAGEMENT

- No significant effect of different nutrient management was observed on plant population during both the years of study as well as on pooled comparison.
- The treatment N_9 (125% RDP + 30 kg sulphur + seed inoculated with PSB) registered significantly higher pooled plant height 30, 60, 90 DAS and at harvest over all other nutrient management during both the years as well as in pooled analysis. However, it was found statistically at par with N_8 (100% RDP + 30 kg sulphur + seed inoculated with PSB) in respect to plant height 30, 60, 90 DAS and at harvest.
- Application of nutrients in an integrated manner under N_9 recorded significant improvement in pooled leaf area index 30, 60 and 90 DAS (1.63, 3.02 and 3.23, respectively) on pooled basis over remaining nutrient management.
- Application of nutrients under N_9 (125% RDP + 30 kg sulphur + seed inoculated with PSB) recorded significantly higher CGR between 30-60 DAS (9.08 g m^{-2} day^{-1}) and 60-90 DAS (9.38 g m^{-2} day^{-1}) as well as significantly higher NAR between 30-60 and 60-90 DAS (9.84 and 10.93 g m^{-2} leaf area day^{-1}, respectively) on pooled basis over other nutrient management but N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) and N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) were statistically at par at all stages.
- Supplementing nutrients under N_9 (125% RDP + 30 kg sulphur + seed inoculated with PSB) recorded significant improvement in dry matter accumulation $plant^{-1}$ 30, 60 and 90 DAS and at harvest over other nutrient management during both the years of study and on pooled basis by registering a pooled value of 3.32, 12.40, 21.78 and 26.48 g, respectively. However, it remained at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

- Significantly higher content of total chlorophyll 60 DAS weas noticed under N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) in comparison to other nutrient management during both the years of experimentation and on pooled basis with values of this estimate corresponding to 2.79 mg g^{-1} fresh weight.
- Significant enhancement branches $plant^{-1}$, nodule $plant^{-1}$ and nodule weight $plant^{-1}$(g) were registered under N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) over rest of the nutrient management during 2013 and 2014 and on pooled basis with corresponding values of 5.93, 32.81 and 0.682 g, respectively.
- Significant improvement in the pooled performance of different yield attributes were registered on integration of 125 % RDP + 30 kg Sulphur + seed inoculated with PSB (N_9) over remaining nutrient management. This comprised of pod length (4.02 cm), pods $plant^{-1}$ (56.72); seed $plant^{-1}$ (128.61), seeds pod^{-1} (2.85) 1000 weight (117.70 g) and seed yield $plant^{-1}$ (9.61 g). However, N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) and N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) were statistically at par.
- Significant improvement in pooled yield performance (kg ha^{-1}) of soybean (seed: 1907, haulm: 4573, biological: 6479, oil: 386.73 and protein: 777.68) was recorded under N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) over other nutrient management during both the years of study and on pooled basis. However, both higher levels N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) and N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB) were found at par with each other. Although, N_8 recorded the significant maximum pooled harvest index (29.42) over N_0, N_1, N_2, N_3, and N_4 but remained at par with N_5, N_6, N_7 and N_9.
- Significant improvement in oil content (20.25%) in seed were recorded under 125% RDP + 30 kg Sulphur + PSB (N_9) over all other nutrient management during both the years of research and on pooled basis. Application of nutrients under N_9 recorded 11.87 and 7.02 per cent higher pooled oil content and protein content over control while it was at pat with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).
- The highest protein content recorded with the application of N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) which was significantly superior over N_0, N_1, N_2, N_3 and N_4 but it was at par with N_5, N_6, N_7 and N_8 during both the years. However, on pooled data basis,

N_9 recorded significantly higher seed protein content over N_0, N_1, N_2, N_3, N_4, N_5, N_6 and N_7 by 7.0, 5.3, 3.5, 3.3, 3.4, 1.9, 1.7 & 1.7 per cent, respectively, but statistically at par with N_8(100 % RDP + 30 kg Sulphur + seed inoculated with PSB).

- Significantly higher pooled nitrogen, phosphorus and sulphur content (6.509, 0.6977 and 0.326 %, respectively) in seed as well as significantly higher pooled nitrogen, phosphorus and sulphur content in haulm (1.794, 0.2002 and 0.199 %, respectively) was recorded on application of nutrients under N_9 in comparison to other nutrient management during both the years of investigation and on pooled basis. However, nitrogen, phosphorus and sulphur content in seed and were statistically at par with N_8 (100 % RDP + 30 kg Sulphur + seed inoculated with PSB).
- Nitrogen, phosphorus, potassium and sulphur uptake by seed, haulm and total uptake by soybean crop were significantly enhanced on application of 125% RDP + 30 kg sulphur + PSB (N_9) than other nutrient management during both the years of research and on pooled basis. Application of nutrients under N_9 registered 124.43, 13.33, 35.30, 6.23; 82.17, 9.16, 127.78, 9.10 and 206.60, 22.50, 163.08, 15.34 kg ha^{-1} pooled uptake of N, P, K and S by seed, haulm and total uptake by soybean crop which was 63.98, 7.32, 17.57, 3.61; 43.45, 4.78, 57.90, 5.00 and 107.43, 12.11, 75.48, 8.42 kg ha^{-1} higher than control, respectively.
- Nutrient status after harvest of soybean crop, significantly higher available nitrogen, phosphorus and sulphur were recorded under N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) in comparison to remaining nutrient management during 2013, 2014 and on pooled basis. Application of nutrients under N_9 registered 49.18, 4.15 and 3.51 kg ha^{-1} higher pooled available soil nitrogen, phosphorus and sulphur over the control, respectively.
- Application of nutrients under N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) registered the maximum mean E value for soil nitrogen, phosphorus, potassium and sulphur (318.54, 27.42, 329.54 and 23.02 kg ha^{-1}, respectively) among different nutrient management. Nutrient management under N_9 (125 % RDP + 30 kg Sulphur + seed inoculated with PSB) also registered maximum mean apparent gain/ loss or mean F values for soil nitrogen and potassium (195.46 and 117.15 kg ha^{-1}, respectively) which was 156.62 and 95.68 kg ha^{-1} higher irrespectively than the control (N_0), respectively. However, maximum mean apparent gain/ loss or mean F values for soil phosphorus and

sulphur was recorded under N_0 (9.45 kg ha^{-1}) and N_3 (8.50 kg ha^{-1}), respectively. Integrated nutrient management under N_8 also recorded least negative value for mean actual gain/ loss or mean G values for soil potassium and sulphur (-15.93 and -0.89 kg ha^{-1}, respectively) while this treatment also recorded the maximum mean G value for soil nitrogen and phosphorus (18.85 and 3.21 kg ha^{-1}) among different nutrient management.

- Among different nutrient management, application of 125% RDP + 30 kg Sulphur + PSB (N_9) registered maximum and significantly higher net returns (` 41477, 47717 and 44597 ha^{-1}, respectively) during 2013, 2014 and on pooled basis over other nutrient management except N_8 which was statistically at par with N_9. Integrated nutrient management under N_9 also recorded significantly higher pooled benefit cost ratio (1.59) over other nutrient management but variations were at par with N_8 which recorded a pooled benefit cost ratio of 1.56.

6.2 PLANT GROWTH REGULATORS

- Different PGRs failed to record any significant effect on plant population of soybean crop during both the years of investigation and on pooled basis.
- Foliar application of brassinolide (G_1), benzyladenine (G_2) recorded significantly higher plant height at harvest over water spray during both the years of research and on pooled basis and enhancement corresponded to 4.90 and 1.97 cm, respectively.
- Application of brassinolide (G_1) significantly improved LAI at 60 and 90 DAS over water spray (G_0) and benzyladenine (G_2) during both the years of study and on pooled basis by registering an increase equal to 0.18, 0.09, and 0.21, 0.11, respectively.

Significantly higher pooled values of CGR at 30-60 (8.52 g m^{-2} day^{-1}, respectively), RGR at 30-60 (0.0477 g g^{-1} day^{-1}) and NAR at 30-60 and 60-90 DAS (8.32 and 8.72 g m^{-2} leaf area day^{-1}, respectively) was registered under brassinolide (G_1) which corresponded to 6.23 and 12.40; 2.80, 5.53and 9.90 and 20.57 per cent over G_2 and G_0, respectively. While highest and significant pooled value of CGR at 60-90 DAS and NAR at 60-90 DAS recorded under brassinolide (G_1) which was 3.98 and 13.24 per cent higher over Control. However benzyl adenine gave significantly higher RGR at 61-90 DAS by 3.24 per cent over brassinolide spray.

- Dry matter accumulation plant^{-1} at 60 and 90 DAS and at harvest (11.22, 19.57 and 24.03 g, respectively) was significantly enhanced under brassinolide (G_1) over benzyladenine (G_2) and water spray (G_0) during 2013, 2014 and on pooled basis registering an increase corresponding to 4.8, 9.6; 3.3, 7.1 and 3.1, 5.9 per cent, respectively.
- Foliar application of G_1 simultaneously recorded significantly higher branches (5.35) than water spray (G_0) and benzyladenine (G_2) during both the years of research and on pooled basis and registering a pooled increase to the tune of 4.08 and 12.86 per cent over G_2 and G_0. Brassinolide (G_1) also recorded significantly higher nodules plant^{-1} and nodule weight plant^{-1} at 60 DAS over water spray (G_0) and benzyladenine (G_2) during 2013, 2014 and on pooled basis with pooled values corresponding to 26.63 and 0.598 g, respectively that amounted to an enhancement equal to 9.6, 13.0 and 4.4, 5.6 per cent over water spray (G_0) and benzyladenine (G_2), respectively
- Significantly higher total chlorophyll at 60 DAS (2.54 mg g^{-1} fw) was recorded under brassinolide (G_1) over water spray (G_0) and benzyladenine (G_2) during both the years and pooled basis and a pooled increase corresponding to 5.8 and 2.0, per cent, respectively were observed.
- Among different growth regulators, brassinolide (G_1) recorded significant pooled increase of different yield attributes which comprised of pods plant^{-1} (51.40), seed pod^{-1} (2.61), seeds plant^{-1} (115.54), pod length (3.57 cm), seed weight plant^{-1} (8.44 g), 1000 seed weight (106.84 g) over water spray (G_0) and benzyladenine (G_2). Above parameters also registered significantly higher values during both the years of study as well as pooled basis.
- Significant improvement in pooled yield performance of soybean with respect to seed, haulm, biological, oil and protein yield (1664, 4069, 5733, 331 and 673 kg ha^{-1}, respectively) was recorded under brassinolide (G_1) in comparison to water spray (G_0) and benzyladenine (G_2) which corresponded to an increase of 249, 103; 552, 216; 801, 319; 121, 53 and 61, 28 kg ha^{-1}, respectively. However, different growth regulators failed to record significant variation in harvest index during 2013, 2014 and on pooled basis.
- Significant improvement in pooled oil content in seed (19.78%) was registered under brassinolide (G_1) over water spray (G_0) and benzyladenine (G_2) and the corresponding pooled enhancement equal to 4.2 and 2.3 per cent, respectively, was noticed. Similarly, brassinolide (G_1) also

registered significant enhancement in seed protein content over water spray (G_0) and benzyladenine (G_2) during 2013, 2014 and on pooled basis and pooled values recorded under G_1 was found equal to 40.27%. The corresponding pooled increase under G_1 over water spray (G_0) and benzyladenine (G_2) was equal to 3.5 and 1.7 per cent, respectively.

- Significantly higher nitrogen, phosphorus and sulphur content in seed and haulm (6.442, 0.6713, 0.303 and 1.717, 0.1919, 0.185%, respectively) were recorded under brassinolide (G_1) over water spray (G_0) and benzyladenine (G_2) during both the years of experimentation and on pooled basis and pooled enhancement corresponded to 3.5, 1.7; 3.5, 1.7; 3.7, 1.6 in seed and 4.4, 1.9; 2.9, 0.5; 3.9, 1.6 in haulm per cent, respectively.
- Nitrogen, phosphorus, potassium and sulphur uptake by seed, and total uptake by soybean crop was significantly increased under brassinolide (G_1) over water spray (G_0) and benzyladenine (G_2) during both the years of investigation and pooled basis registering a pooled enhancement with 19.30, 8.46; 2.02, 0.89; 4.64, 1.92 and 0.93, 0.41 kg ha^{-1} for N, P, K and S uptake by seed; 12.04, 5.02; 1.31, 0.55; 16.51, 6.09 and 1.28, 0.52 kg ha^{-1} for N, P, K and S uptake by haulm and 31.33, 13.47; 3.32, 1.44; 21.15, 8.02 and 2.20, 0.93 kg ha^{-1} for N, P, K and S total uptake by soybean, respectively.
- Soil available nitrogen, phosphorus, potassium and sulphur after harvest of crop was not significantly influenced under different growth regulator during 2013, 2014 and on pooled basis.
- Maximum mean E value (297.73 kg ha^{-1}), mean F value (146.03 kg ha^{-1}) and least negative mean G value (-1.96 kg ha^{-1}) for soil nitrogen was recorded under brassinolide (G_1) and the corresponding increase in these values were 0.72, 0.59; 32.06, 14.07 and 0.72, 0.59 kg ha^{-1} over water spray (G_0) and benzyladenine (G_2), respectively. However, water spray (G_0) recorded higher mean D value for soil nitrogen (183.05 kg ha^{-1}) over G_1 and G_2 which corresponded to 31.34 and 17.86 kg ha^{-1} higher than G_1 and G_2, respectively.
- The highest mean D value (49.07 kg ha^{-1}) for soil phosphorus was registered under water spray (G_0) with an increase corresponding to 3.75 and 2.49 kg ha^{-1} over G_1 and G_2, respectively. The highest mean E value (25.84 kg ha^{-1}), least negative mean F value (-19.48 kg ha^{-1}) and mean G

value (1.63 kg ha^{-1}) for soil phosphorus was recorded under foliar spray of brassinolide (G_1) which were 0.34, 0.16; 4.09, 1.42 and 0.34, 0.16 kg ha^{-1} higher than water spray (G_0) and benzyladenine (G_2), respectively.

- Maximum mean D value (252.80 kg ha^{-1}) for soil potassium was recorded under water spray (G_0) and the corresponding increase over G_1 and G_2 was 21.14 and 13.13 kg ha^{-1}, respectively. Foliar spray of brassinolide (G_1) registered the highest mean E value (23.13 kg ha^{-1}) and mean F value (22.59 kg ha^{-1}) for soil potassium which was 2.88, 1.29 and 24.03, 9.31 kg ha^{-1} higher than G_1 and G_2, respectively. All the growth regulators recorded negative mean G values for soil potassium which ranged from -24.00 kg ha^{-1} under brassinolide (G_1) to -26.88 kg ha^{-1} under water spray (G_0).
- Maximum mean E value (297.14 kg ha^{-1}), least negative mean F value (-19.61 kg ha^{-1}) and least negative mean G value (-2.32 kg ha^{-1}) for soil sulphur was recorded under brassinolide (G_1) and the corresponding increase in these values were 0.28, 0.12; 2.48, 1.04 and 0.28, 0.12 kg ha^{-1} over water spray (G_0) and benzyladenine (G_2), respectively. However, water spray (G_0) recorded higher mean D value for soil sulphur (43.40 kg ha^{-1}) over G_1 and G_2 which corresponded to 2.20 and 0.92 kg ha^{-1} higher than G_1 and G_2, respectively.
- Among different growth regulators, significantly higher pooled net return of ` 37040 $ha^{-1}$ was recorded under brassinolide ($G_1$). Use of brassinolide ($G_1$) recorded significantly higher additional net return over water spray ($G_0$) and benzyladenine ($G_2$) and registered a pooled additional net profit equal to ` 6393 and 8977 ha^{-1}, respectively.
- Significantly higher B:C ratio was recorded under brassinolide (G_1) over water spray (G_0) and benzyladenine (G_2) during both the years of research and on pooled basis and the corresponding pooled enhancement was to the tune of 7.0 and 56.3 per cent, respectively.

6.3 INTERACTION (Nutrient management X PGR)

- The interaction of N_8 (100% RDP + 30 kg S ha^{-1} + PSB) with G_1 (brassinolide) at 30 and 60 DAS) registered significantly higher branches $plant^{-1}$ over remaining all the combinations during 2013, 2014 and on pooled basis under both the sets of conditions i.e. nutrient management within the growth regulator and growth regulators within the nutrient management. However, interaction of N_8 with G_1 resulted in statistically at par with N_9 (125% RDP + 30 kg S ha^{-1} + PSB) along with G_1 (brassinolide) during 2013, 2014 and on pooled basis.

- Significantly higher values of pods $plant^{-1}$, seed $plant^{-1}$ and seed weight $plant^{-1}$ were registered under interaction of N_9 (125% RDP + 30 kg S ha^{-1} + PSB) with G_1 (brassinolide) at 30 and 60 DAS) over all other combinations during 2013, 2014 and on pooled basis under both the sets of conditions. The interaction of N_9 with G_1 registered a pooled pods $plant^{-1}$, seed $plant^{-1}$ and seed weight $plant^{-1}$ equal to 60.28, 138.06 and 10.05 (g $plant^{-1}$), respectively However, interaction of N_9 with G_1 resulted in statistically at par with N_8 (100% RDP + 30 kg S ha^{-1} + PSB) along with G_1 (brassinolide) during 2013, 2014 as well as on pooled basis.
- Interaction of N_9 (125% RDP + 30 kg S ha^{-1} + PSB) with G_1 (brassinolide) at 30 and 60 DAS) recorded significantly higher values of seed, haulm, biological, oil and protein yield over remaining combinations of nutrient management and growth regulators during 2013, 2014 and on pooled basis under both the sets of conditions. The interaction of N_9 with G_1 registered a pooled seed, haulm, biological, oil and protein yield equal to 2167, 5013, 7180, 446.96 and 905.45 kg ha^{-1}, respectively. However, interaction of N_9 with G_1 resulted in statistically at par with N_8 (100% RDP + 30 kg S ha^{-1} + PSB) along with G_1 (brassinolide) during 2013, 2014 and on pooled basis.
- Significantly higher values for N, P, K and S uptake by seed, haulm and total uptake by soybean crop were registered under interaction of N_9 (125% RDP + 30 kg S ha^{-1} + PSB) with G_1 (brassinolide) at 30 and 60 DAS) over other combinations during 2013, 2014 and on pooled basis under both the sets of conditions i.e. nutrient management within the growth regulator and growth regulators within the nutrient management. Interaction of N_9 with G_1 registered a pooled N, P, K and S uptake by seed, haulm and total uptake by soybean equal to 144.87, 15.40, 40.15, 7.21; 92.25 10.24, 139.47, 10.12 and 237.12, 25.64, 179.62, 17.33 kg ha^{-1}, respectively. However, interaction of N_9 with G_1 resulted in statistically at par with N_8 (100% RDP + 30 kg S ha^{-1} + PSB) along with G_1 (brassinolide) during 2013, 2014 and on pooled basis.
- Interaction of N_9 (125% RDP + 30 kg S ha^{-1} + PSB) with G_1 (brassinolide) at 30 and 60 DAS) recorded significantly higher net return over all other combinations of nutrient management and growth regulators under both the sets of conditions i.e. nutrient management within the growth

regulator and growth regulators within the nutrient management during 2013, 2014 and on pooled basis and on pooled net return which was equal to ` 54863 ha^{-1}, respectively. However, it was remained statistically at par with N_8 (100% RDP + 30 kg S ha^{-1} + PSB) along with G_1 (brassinolide).

- The interaction of N_9 (125% RDP + 30 kg S ha^{-1} + PSB) with G_1 (brassinolide) at 30 and 60 DAS) registered the maximum and significantly higher pooled benefit cost ratio (1.97) over all other combinations of nutrient management and growth regulators under both the sets of conditions i.e. nutrient management option within the growth regulator and growth regulators within the nutrient management option on pooled basis but remained at par with N_8 (100% RDP + 30 kg S ha^{-1} + PSB) along with G_1 (brassinolide).

7. CONCLUSION

The results of the two years field experimentation revealed that soybean crop gave significantly higher seed yield by enhancing phosphorus application up to 100 % recommended dose of phosphorus (40 kg P_2O_5 ha^{-1}) in conjugation with 30 kg sulphur ha^{-1} along with seed treatment with phosphorus solubilising bacteria. Amongst growth regulators, foliar spray of brassinolide 0.4 ppm at 30 & 60 DAS resulted in significantly higher yield. The economic analysis of the nutrient management treatments in terms of net return revealed statistical significance of 40 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} along with seed treatment with PSB and amongst growth regulators brassinolide was superior over others.

Therefore, it is recommended that on the medium fertile clay loam alkaline soil of "Sub Humid Southern Plain and Aravalli Hills of Rajasthan" soybean should be fertilized with 100% RDP (40 kg P_2O_5 ha^{-1}) + 30 kg sulphur basal application along with seed treatment with PSB and crop should be sprayed with brassinolide 0.4 ppm at 30 & 60 DAS.

FUTURE THRUST

1. The initial soil nutrient status at 15-30 and 30-45 cm depth should be studied along with corresponding soil changes in soil nutrient status after crop harvest so as to work out the possible nutrient exploitation by soybean crop from 15-30 and 30-45 cm soil layers in order to prepare balance sheets of nutrients with ultimate aim to maintain soil fertility and reap sustainable higher yields of soybean in the zone.

2. Studies on residues recycled by immediately previous crops in the sequence along with nutrients contained in these residues so as to have an idea of possible mineralization of nutrients during soybean crop period which is of paramount significance from point of developing appropriate nutrient schedules in the region.

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Effect of Nutrient Management and Plant Growth Regulators on Productivity and Quality of Soybean [*Glycine max* (L.) Merrill]

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ABSTRACT

A field experiment entitled **''Effect of Nutrient Management and Plant Growth Regulators on Productivity and quality of Soybean [*Glycine max* (L.) Merrill]''** was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) for two consecutive *kharif* seasons of 2013 and 2014. The objectives of study were to assess effect of nutrient management and plant growth regulators on growth, yield attributes, yield and quality of soybean; changes in soil fertility by preparing nutrient balance sheets, significant interactions between nutrient management and plant growth regulators and economical feasibility of treatments. Soil of experimental site was clay loam in texture with medium status of available nitrogen and phosphorus, high in available potassium, low in available sulphur and slightly alkaline in reaction. The experiment consisted of 30 treatment combinations comprising of ten nutrient management (N_0: Absolute control N_1: 75% RDP, N_2: 100% RDP, N_3: 125% RDP, N_4: 75% RDP + 30 kg S ha^{-1}, N_5: 100% RDP+ 30 kg S ha^{-1}, N_6: 100% RDP + 30 kg S ha^{-1}, N_7: 75% RDP + 30 kg S ha^{-1} + PSB, N_8: 100% RDP + 30 kg S ha^{-1}+ PSB and N_9: 125% RDP + 30 kg S ha^{-1}+ PSB) in main plots and three growth regulators (G_0: Control, G_1: brassinolide, G_2: benzyladenine) in sub plots was conducted in split plot design replicated thrice.

Results revealed that application of 125% RDP + 30 kg S ha^{-1}+ PSB (N_9) recorded significantly higher (pooled) performance of various growth parameters viz. plant height 30, 60, 90 DAS and at harvest (31.83, 46.95, 66.51 and 70.95 cm, respectively), leaf area index (LAI) 30, 60 and 90 DAS (1.63, 3.02 and 3.23, respectively), crop growth rate (CGR) between 30-60 DAS and 60-90 DAS (9.08 and 9.38 g m^{-2} day^{-1}), net assimilation rate

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(NAR) between 30-60 DAS (9.84 g m^{-2} leaf area day^{-1}) and 60-90 DAS (10.93 g m^{-2} leaf area day^{-1}), dry matter accumulation (DMA) $plant^{-1}$ at 30, 60 and 90 DAS and at harvest (3.32, 12.40, 21.78 and 26.48 g, respectively), total chlorophyll at 60 DAS (2.79 mg g^{-1} fw), branches $plant^{-1}$ (5.93), nodule $plant^{-1}$(32.81) and nodule weight $plant^{-1}$(0.682 g). However, all the growth parameters were statistically at par with T_8 (100% RDP + 30 kg S ha^{-1}+ PSB).

Integrated nutrient management under N_9 (125% RDP + 30 kg S ha^{-1}+ PSB) also significantly enhanced the performance of different yield attributes of soybean over other nutrient management options which comprised pod length (4.02 cm); pods $plant^{-1}$ (56.72); seeds pod^{-1}(2.85), seeds $plant^{-1}$(128.61), seed weight $plant^{-1}$ (9.61 g) and 1000 seed weight (117.70 g) pooled basis. However, N_9 (125% RDP + 30 kg S ha^{-1}+ PSB) was found to be statistically at par with N_8 (100% RDP + 30 kg S ha^{-1}+ PSB) in respect to all yield attributing characters. Significant improvement in yield performance of soybean were noticed (seed yield: 1907, haulm yield: 4573, biological yield: 6479 oil yield: 387 and protein yield: 778 kg ha^{-1}) on pooled basis under N_9 (125% RDP + 30 kg S ha^{-1}+ PSB) over all other nutrient management options. Application of N_9 (125% RDP + 30 kg S ha^{-1}+ PSB) recorded a pooled increase of 933, 2020, 2932, 207 and 400 kg ha^{-1} in seed, haulm and biological, oil and protein yield over control, respectively. However, all the yield parameters were statistically at par with 100% RDP + 30 kg S ha^{-1}+ PSB (T_8).

Among nutrient management, N_9 also recorded the maximum and significantly higher pooled oil content (20.25 %), protein content (40.68 %); N, P and S content in seed (6.509, 0.6977 and 0.326 %, respectively), N, P and S content in haulm (1.794, 0.2002 and 0.199 %, respectively); N, P, K and S uptake by seed and haulm (124.43, 13.33, 35.30, 6.23 and 82.17, 9.16, 127.78, 9.10 kg ha^{-1}, respectively) and total N, P, K and S uptake by soybean crop (206.60, 22.50, 163.08 and 15.34 kg ha^{-1}, respectively), N, P, K and S status of soil after crop harvest (318.54, 27.42, 329.54 and 23.02 kg ha^{-1}, respectively), net return of ₹ 44597 ha^{-1} and B:C ratio (1.59).

The results revealed that among plant growth regulators, foliar application of brassinolide (G_1) at 30 and 60 DAS recorded significantly higher pooled performance of various growth parameters *viz.* plant height at 60, 90 and at harvest (43.19, 60.13 and 63.63 cm), LAI 60 and 90 DAS (2.59 and 2.74, respectively), CGR 30-60 and 60-90 DAS (8.52 and 8.35 g m^{-2} day^{-1}, respectively), NAR 30-60 and 60-90 DAS (8.32 and 8.72 gm^{-2} leaf area day^{-}

^{1}, respectively), DMA plant^{-1} 60 90 DAS and at harvest (11.22, 19.57 and 24.03 g, respectively), chlorophyll content at 60 DAS (2.54 mg g^{-1} fw) and branches plant^{-1} (5.35) over other rest of the treatment except T_8.

Alike growth parameters, use of brassinolide (G_1) also significantly enhanced the pooled performance of different yield attributes of soybean crop over other growth regulators evaluated in this study *viz.* pod length (3.57 cm); pods plant^{-1} (51.40); seeds pod^{-1}(2.61), seeds plant^{-1}(115.54), seed weight plant^{-1} (8.44 g) and 1000 seed weight (106.84 g). Significant improvement in the pooled yield performance (kg ha^{-1}) of soybean (seed yield: 1664, haulm yield: 4069, biological yield: 5733 oil yield: 331 and protein yield: 673 kg ha^{-1}) were recorded under brassinolide (G_1) which were 249, 552, 801, 60.52 and 120.62 kg ha^{-1} higher than the control (G_0), respectively.

Among different growth regulators, brassinolide (G_1) also recorded the maximum and significantly higher pooled oil content (19.78 %); protein content (40.27%) in seed; N, P and S content in seed and haulm (6.442, 0.6713, 0.303 and 1.717, 0.1919, 0.185%, respectively); N, P, K and S uptake by seed and haulm (107.61, 11.26, 30.51, 5.11 and 70.38, 7.86, 143.82, 7.60 kg ha^{-1}, respectively) and total N, P, K and S uptake by soybean (177.98, 19.12, 143.82 and 12.71 kg ha^{-1}, respectively. Brassinolide (G_1) also recorded significantly higher net return (₹ 37040) and benefit cost ratio (1.36) among different growth regulators evaluated in this study.

Among nutrient management and plant growth regulators, interaction of N_9 (125% RDP + 30 kg S ha^{-1}+ PSB) with brassinolide (G_1) statistically outperformed in pooled contents of pods plant^{-1}(60.28), seed plant^{-1}(138.06 gm), seed yield plant^{-1} (10.05 gm), seed, haulm and biological yields (2167, 5013 and 7180 kg ha^{-1}, respectively), oil and protein yields (447 and 905 kg ha^{-1}, respectively), N, P, K and S uptake by seed, haulm and total uptake by soybean (144.87, 15.40, 38.34, 6.78; 92.25 10.24, 134.34, 9.44 and 237.12, 25.64, 172.68, 16.22 kg ha^{-1}, respectively) net return (₹ 54863 ha^{-1}) and B:C ratio (1.97) under both the sets of evaluation i.e. nutrient management within the growth regulators as well as growth regulator within nutrient management. However, all the growth, yield and uptake parameters statistically were at par with interaction of 100% RDP + 30 kg S ha^{-1}+ PSB (T_8) with brassinolide (G_1).

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jktLFkku Ñf"k egkfo|ky; d mn;ij fLFkr if'k{k.kkRed i{k= ij yxkrkj nk o"k [kjhQ 2013 ,o 2014 d nkjku ,d {k= lijh{k.k **lk;kchu ¼Xykblhu eDl ¼,y-½ efjy½ dh mRikndrk ,o x.koÙkk ij ik"kd rRo ic/ku ,o of) fu;kedk dk iHkko**vk;kftr fd;k x;kA bl i;kx dk ie[k mí'; fofHkUu ik"kd rRo icU/ku fodYik ,o ikni of) fu;kedk dk lk;kchu dh of)] mit dk c<ku oky ?kVdk] mit ,o x.koÙkk d lkFk enk mojdrk e gku oky ifjoru dk ik"kd rRok dk lUrfyr ii= cukdj v/;;u djuk vkj fofHkUu mipkjk dk vkfFkd eY;kdu djuk lfEefyr FkkA ijh{k.k i{k= dh enk ljpuk e fpduh nkeV ,o vfHkfØ;k e {kkjh;rk d lkFk miyC/k u=tu ,o QkLQkjl dh ek=k e e/;e ,o miyC/k ikVk'k dh ek=k mPp Lrjh; FkhA bl i;kx e dy 30 mipkj le;Xek dk eY;kdu fodYi ¼,u$_0$ & i.k fu;=.k] ,u$_1$ & lLrr QkLQkjl dh 75 ifr'kr ek=k] ,u$_2$&lLrr QkLQkjl dh 100 ifr'kr ek=k] ,u$_3$ & lLrr QkLQkjl dh 125 ifr'kr ek=k] ,u$_4$ & lLrr QkLQkjl dh 75 ifr'kr ek=k ,o 30 fdykxke lYQj] ,u$_5$ & lLrr QkLQkjl dh 100 ifr'kr ,o 30 fdykxke lYQj] ,u$_6$ & lLrr QkLQkjl dh 125 ifr'kr ek=k ,o 30 fdykxke lYQj] ,u$_7$ & lLrr QkLQkjl dh 75 ifr'kr ek=k ,o 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k] ,u$_8$ & lLrr QkLQkjl dh 100 ifr'kr ek=k ,o 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k ,o ,u$_9$ & lLrr QkLQkjl dh 125 ifr'kr ek=k ,o 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k½ dk e[; Hkk&[k.Mk e rFkk rhu ikni of) fu;kedk dk ¼th$_0$& ty dk i.kh; fNMdko] th$_1$ & cflukykbM dk i.kh; fNMdko ,o th$_3$ & cfty,fMuhu dk i.kh; fNMdko½ dk Hk&[k.Mk e foHkkftr [k.M vfHkdYiuk e rhu iqjkofÙk d lkFk vk;kftr fd;k x;kA

∗ fo|kokpLifr Nk=] 'kL; foKku foHkkx] jktLFkku Ñf"k egkfo|ky;] mn;ij ¼jktLFkku½A

∗ vkpk;] 'kL; foKku foHkkx] jktLFkku Ñf"k egkfo|ky;] mn;ij ¼jktLFkku½A

ifj.kke Li"V :i l inf'kr djr g fd ,u9 ¼125 ifr'kr lLrr QkLQkjl dh ek=k $ 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k½ mipkj dk i;kx dju l lk;kchu d fofHkUu of) ekin.Mk tl fd ikni Åpkbl 30] 60] 90 ,o dVkbl mijkUr Øe'k% ¼31-83] 46-95] 66-51 ,o 70-95 lUVhehVj½ i.k {k= lpdkd 30] 60 ,o 90 fnu dh Qly voLFkk ij Øe'k% ¼1-63] 3-02] ,o 3-23½] 30 l 60 fnu d ,o 60 l 90 fnu dh Qly voLFkk ij Øe'k% 9-08 ,o 9-38 xke ifr oxehVj ifrfnu] 30 l 60 fnu ,o 60 l 90 fnu d e/; 'k) vkRe lkn nj Øe'k% 9-84 ,o 10-93 xke ifr ox ehVj i.k {k= ifrfnu] 'k"d inkFk lp;u ifr ik/kk 30] 60] 90 ,o dVkbl mijkDr Øe'k% 3-32] 12-40] 21-78 ,o 26-47 xke] dy i.k gfjr 60 fnu dh Qly voLFkk ij 2-79 feyhxke ifr xke rktk i.kHkkjkulkj] 'kk[kk, ifr ik/kk 5-93] tM xkB ifr ik/kk 32-81 ,o tM xkB Hkkj ifr ik/kk 0-682 xke nt fd; x; tcfd lHkh of) ekin.M ,u8 100 ifr'kr lLrr QkLQkjl dh ek=k $ 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k d lerY; ik; x;A ,u9 & 125 lLrr QkLQkjl ek=k dh ek=k $ 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k mipkj l lex ik"kd rRo icU/ku dju l mit c<ku oky ekin.Mk e vU; ik"kd rRo icU/k fodYik dh ryuk e lkf[;dh; vk/kkj ij nkuk o"kk d e/;kd d vk/kkj ij of) nt dh x;h tk bl idkj g & Qyh dh yEckbl ¼4-02 lUVhehVj] Qyh dh l[;k 56-72] cht ifrQyh 2-85] cht ifr ik/kk 128-61] chtk dk Hkkj ifr ik/kk 9-61 xke ,o 1000 chtk dk otu 117-70 xke nt fd;k x;kA gkykfd lHkh mit c<ku oky ekin.M ,u8 ,o ,u9 d e/; lkf[;dh; :i l lerY; ik; x;A

,u9 ¼125 ifr'kr lLrr QkLQkjl dh ek=k $ 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k½ mipkj e vU; ik"kd rRo icU/k fodYik dh ryuk e ifr gDVj cht mit ¼1907 fdykxke½] Hkl dh mit ¼4573 fdykxke½] tfod mit ¼6479 fdykxke½ ry mit ¼387 fdykxke½ ,o ikVhu mit ¼778 fdykxke½ nt dh x;hA ,u9 mipkj ,u0 ¼i.k fu;f=r½ dh ryuk e cht] Hkl] tfod] ry ,o ikVhu mit e Øe'k% 933] 2020] 2932] 206 ,o 400 fdykxke ifr gDVj lex of) nt dh x;hA gkykfd lHkh mit ekin.M ,u8 d lkf[;dh; :i l lerY; ik; x;A

fofHkUu ik"kd rRo fodYik e ,u9 mipkj u vf/kdre ,o lkFkd :i l vf/kd ry dh ek=k ¼20-25 ifr'kr½] ikVhu dh ek=k ¼40-68 ifr'kr½] cht e u=tu] QkLQkjl ,o lYQj dh ek=k Øe'k% 6-509] 0-6977 ,o 0-326 ifr'kr] Hkl e u=tu] QkLQkjl ,o lYQj dh ek=k Øe'k% 1-794] 0-2002] 0-199 ifr'kr½] cht ,o Hkl e u=tu] QkLQkjl] ikVf'k;e ,o lYQj dk mnxg.k Øe'k% 124-43] 13-33] 35-30] 6-23 vkj 82-17] 9-16] 127-78] 9-10 fdykxke ifr gDVj] lk;kchu }kjk dy u=tu] QkLQkjl] ikVf'k;e ,o lYQj dk mnxg.k

Øe'k% ¼206-60] 22-50] 163-08 vkj 15-34 fdykxke ifr gDVj Qly dh dVkbZ d mijkUr enk e u=tu] QkLQkjl iksVf'k;e ,o lYQj dh miyC/k ek=k Øe'k% 318-54] 27-42] 329-54 ,o 23-02 fdykxke ifr gDVj] 'k) ykHk ₹ 44]597 ,o ykHk ykxr vuikr ¼1-59½ ikl r g,A

ifj.kke Li"V :i l bfxr djr g fd fofHkUu ikni of) fu;kedk e 0-4 ih-ih-,e- cflukykbM dk 30 vkj 60 fnuk fd Qly voLFkk ij fNMdko dju l fofHkUu of)ekudu ekin.Mk e lex lkFkd of) nt dh xbZ tl 60] 90 vkj dVkbZ mijkUr ik/k dh Åpkb ¼43-19] 60-13 ,o 63-63 lVhehVj½ 60 ,o 90 fnu ij i.k {k= lpdkd ¼2-59 vkj 2-74½] Qly 30 l 60 ,o 60 l 90 fnu d e/; Qly of) nj ¼8-52 ,o 8-35 xke ifr ox ehVj ifrfnu½ 30 l 60 ,o 60 l 90 fnu d e/; 'k) vkReLkn nj ¼8-32 ,o 8-72 xke ifr ox ehVj i.k {k= ifrfnu½] ifr ik/kk 'k"d inkFk lp;u 60] 90 fnuk dh Qly voLFkk rFkk dVkbZ mijkUr Øe'k% 11-22] 19-57 vkj 24-03 xke] dy i.kgfjr 60 fnu dh Qly voLFkk ij 2-54 feyh xke çfrxke vkj 'kk[kk, ifr ik/kk 5-35 nt dh xbA

of) ekin.Mk dh rjg gh ¼th₁½ cflukykbM dk i;kx dju l lk;kchu e mit c<ku oky dkjdk e Hkh nlj of) fu;kedk dh ryuk e Qyh yEckbZ ¼3-57 lUVhehVj½] Qyh ifr ik/kk ¼51-40½] cht ifr Qyh ¼2-61½] cht ifr ik/kk ¼115-54½] cht Hkkj ifr ik/kk ¼8-44 xke½ vkj 1000 cht otu ¼106-84 xke½ e lkFkd lex of) nt dh xbA cflukykbM ¼th₁½ d i;kx dju l lex mit e lkFkd :i l l/kkj nt fd;k x;k ¼cht mit% 1664] Hkls mit% 4069] tfod mit% 5733] ry mit% 331 vkj iksVhu mit% 673 fdykxke ifr gDVj½ tk fd ty fNMdko ¼th₀½ l Øe'k% 249] 552] 801] 61 vkj 121 fdykxke ifr gDVj vf/kd FkhA

fofHkUu of) fu;kedk e th₁ dk mipkj dju l vf/kdre ,o lkFkd :i l vf/kd lexekdu cht e ry dh ek=k ¼19-78 ifr'kr½] iksVhu dh ek=k ¼40-27 ifr'kr½] cht ,o Hkls e u=tu] QkLQkjl ,o lYQj dh ek=k Øe'k% ¼6-442] 0-6713] 0-303 ,o 1-717] 0-1919] 0-185 ifr'kr½] cht ,o Hkls e u=tu] QkLQkjl] iksVf'k;e ,o lYQj dk mnxg.k Øe'k% ¼107-61] 11-26] 30-51] 5-11 vkj 70-38] 7-86] 143-82] 7-60 çfr'kr½ vkj lk;kchu dh Qly }kjk u=tu] QkLQkjl] iksVf'k;e ,o lYQj dk dy mnxg.k Øe'k% ¼177-98] 19-12] 143-82 ,o 12-71 fdykxke ifr gDVj½ nt fd;k x;kA vU; fofHkUu of) fu;edk dh ryuk e cflukykbM ¼th₁½ d mi;kx l 'k) ykHk :- 37040 ,o ykHk ykxr vuikr ¼1-36½ e Hkh lkFkd of) nt dh xbA fofHkUu ik"kd rRo icU/ku ,o ikni of) fu;kedk d l;ktuk e ,u$_9$ ¼125 ifr'kr lLrr QkLQkjl dh ek=k $ 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k½ ,o cflukykbM ¼th$_1$½ d l;ktu u fofHkUu ekin.M dk lkf[;dh; :i l c<k;k tl Qyh ifr ik/kk ¼60-28½] cht ifr ik/kk ¼138-06½] cht Hkkj ifr ik/kk ¼10-05 xke½ cht] Hkls ,o tfod mit ¼2167] 5013 vkj 7180 fdykxke ifr gDVj½ ry ,o ikVhu mit Øe'k% ¼447 vkj 905 fdykxke ifr gDVj½] cht] Hkls ,o lk;kchu dh Qly }kjk dy u=tu] QkLQkjl] ikVf'k;e ,o lYQj dk mnxg.k Øe'k% ¼144-87] 15-40] 38-34] 6-78(92-25] 10-24] 134-24] 9-44 vkj 237-12] 25-64] 172-68] 16-22 fdykxke ifr gDVj½ 'k) ykHk ¼:- 54863 ifr gDVj½ ,o ykHk&ykxr vuikr ¼1-97½ mHk; fLFkfr;k ¼,d ik"kd rRo icU/ku fodYi cnyr g, ikni of) fu;kedk ij rFkk ,d ikni of) fu;ked cnyr g, ik"kd rRo icU/ku ij½ dh fLFkfr e ikIr g,A gkykfd lHkh of)] mit ,o mnxg.k ekin.M l;ktd ,u$_8$ ¼100 ifr'kr lLrr QkLQkjl dh ek=k $ 30 fdykxke lYQj $ QkLQkjl ?kkyd thok.k½ ,o cflukykbM ¼th$_1$½ d lkFk lkf[;dh; lerY; ikIr g,A

Appendix I: Analysis of variance for plant population and plant height

Source of variation	d. f.	MSS											
		Plant population				Plant height							
		30 DAS		Harvest		30 DAS		60 DAS		90 DAS		Harvest	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	0.0213	0.0367	0.0230	0.0109	1.7008	2.2272	2.6177	5.6390	13.0886	7.4334	15.6252	8.3910
Fertility options (F)	9	0.0160	0.0205	0.0329	0.0285	90.2655**	88.5973**	199.9506**	206.1574**	384.4709**	406.5947**	414.8631**	450.6815**
Error (a)	14	0.0685	0.0577	0.0557	0.0260	5.1060	5.2516	9.0489	11.3565	23.2040	22.1611	29.1764	24.8796
Growth regulators (G)	3	0.0022	0.0027	0.0059	0.0275	0.5292	1.0304	241.5984**	91.2036**	161.1150**	186.5343**	179.5149**	185.4606**
F X G	21	0.0081	0.0062	0.0086	0.0033	0.3191	0.5124	0.1161	1.3790	5.9501	2.6121	1.9597	2.1240
Error (b)	48	0.0311	0.0271	0.0272	0.0177	2.4716	2.1439	4.3901	5.3810	11.0279	10.5329	10.9168	11.6692

*** Significant at 5% level, ** Significant at 1% level**

Appendix II: Analysis of variance for dry matter accumulation plant^{-1}, branches plant^{-1}, nodules plant^{-1} and nodules weight plant^{-1}(g)

Source of variation	d. f.	MSS													
		Dry matter accumulation plant^{-1}								Branches plant^{-1} at harvest		Nodules plant^{-1}(60 DAS)		Nodules weight plant^{-1}(g)	
		30 DAS		60 DAS		90 DAS		At harvest							
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	0.46	0.05	1.28	1.08	0.53	3.16	10.12	3.61	0.06	0.06	0.5881	0.3229	0.0046	0.0027
Fertility options (F)	7	4.54**	4.91**	43.13**	39.68**	67.65**	55.87**	219.18**	204.10**	7.88**	7.87**	216.9766**	248.9296**	0.0530**	0.0721**
Error (a)	14	0.42	0.48	0.99	0.70	1.05	4.09	13.13	7.18	0.10	0.14	7.1582	7.1270	0.0013	0.0024
Growth regulators (G)	3	0.35	0.20	27.17**	51.15**	100.02**	133.42**	345.22**	255.28**	0.16**	0.02**	38.1518**	44.2578**	0.0192**	0.0550**
F X G	21	0.04	0.05	0.85	0.67	0.45	1.86	5.23	1.76	0.01*	0.05*	0.3119	0.3949	0.0003	0.0001
Error (b)	48	0.35	0.22	0.85	0.68	1.03	3.41	5.78	3.70	0.07	0.10	3.7143	3.7849	0.0002	0.0024

*** Significant at 5% level, ** Significant at 1% level**

Appendix III: Analysis of variance for leaf area index (LAI) and crop growth rate (CGR)

Source of variation	d. f.	MSS									
		LAI						CGR			
		30 DAS		60 DAS		90 DAS		30-60 DAS		60-90 DAS	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	0.036	0.0011	0.031	0.004	0.057	0.032	1.92	0.44	4.50	0.35
Fertility options (F)	7	0.743**	0.7685**	0.727**	0.945**	0.685**	0.678**	20.56**	18.07**	3.04**	3.52**
Error (a)	14	0.013	0.0158	0.093	0.101	0.136	0.118	1.14	1.11	1.90	2.14
Growth regulators (G)	3	0.003	0.0058	1.832**	2.043**	1.327**	1.299**	23.40**	48.38**	23.20*	22.86
F X G	21	0.005	0.0005	0.010	0.008	0.010	0.010	0.98	0.79	1.12	2.31
Error (b)	48	0.009	0.0038	0.077	0.057	0.061	0.060	1.13	0.83	1.58	1.76

*** Significant at 5% level, ** Significant at 1% level**

Appendix-IV: Analysis of variance for relative growth rate (RGR) and net assimilation rate (NAR)

Source of variation	MSS

	d. f.	RGR				NAR			
		30-60 DAS		60-90 DAS		30-60 DAS		60-90 DAS	
		2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	0.000014	0.000005	0.0000083	0.000000	4.90	1.92	3.00	1.26
Fertility options (F)	7	0.000009**	0.000007**	0.0000006**	0.000004**	84.27**	81.10**	18.40**	24.02**
Error (a)	14	0.000011	0.000008	0.0000066	0.000007	4.75	3.47	1.12	5.69
Growth regulators (G)	3	0.000041**	0.000080**	0.0000120**	0.000007**	132.77**	207.82**	74.86**	81.98**
F X G	21	0.000004	0.000003	0.0000018	0.000003	2.64	1.29	1.82	5.43
Error (b)	48	0.000010	0.000006	0.0000046	0.000005	4.70	2.89	1.58	4.62

*** Significant at 5% level, ** Significant at 1% level**

Appendix V: Analysis of variance for yield attributes

Source of variation	d. f.	MSS											
		Yield attributes											
		Pods plant^{-1}		Seeds pod^{-1}		Seeds plant^{-1}		Pod length(cm)		1000 seed wt (g)		Seed yield plant^{-1}	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	0.0046	0.0036	0.0151	0.0408	0.004	0.0061	0.0405	0.0098	85.1903	17.4309	0.002	0.00165
Fertility options (F)	7	0.0630**	0.0574**	0.5511**	0.5558**	0.493**	0.4705**	1.6025**	2.1182**	978.6872**	1177.9377**	0.763**	0.77539**
Error (a)	14	0.0022	0.0033	0.0264	0.0259	0.005	0.0057	0.0866	0.0981	49.8950	43.5709	0.003	0.00248
Growth regulators (G)	3	0.5837**	0.5065**	0.3215**	0.3375**	3.064**	2.7879**	0.5800**	0.5826**	607.1381**	816.9587**	2.274**	2.25978**
F X G	21	0.0021*	0.0026**	0.0042	0.0068	0.006*	0.0085*	0.0007	0.0017	13.3552	2.8542	0.005*	0.00817**
Error (b)	48	0.0004	0.0013	0.0262	0.0172	0.001	0.0020	0.0378	0.0344	44.5448	31.1262	0.001	0.00014

*** Significant at 5% level, ** Significant at 1% level**

Appendix VI: Analysis of variance for seed, stover and biological yield and harvest index

Source of variation	d. f.	MSS			
		Seed	Haulm	Biological	Harvest index

		2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	16480	18946	313658	544824	465493	763752	0.093	0.101
Fertility options (F)	7	1187201**	1120765**	18413061**	17576402**	28931590**	27560680**	0.383	0.260
Error (a)	14	51256	47315	985589	900239	1478776	1352669	0.098	0.094
Growth regulators (G)	3	920261**	861976**	14453318**	13767758**	22662510**	21518831**	0.166	0.081
F X G	21	65471*	53372*	1241836*	963908*	1871060**	1470766*	0.059	0.004
Error (b)	48	16562	19259	355839	398660	519052	585980	0.092	0.092

*** Significant at 5% level, ** Significant at 1% level**

Appendix VII: Analysis of variance for oil, protein &chlorophyll content and oil & protein yield

Source of variation	d. f.	MSS									
		Oil content		Oil yield		Protein content		Protein yield		Chlorophyll content	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	0.5488	0.6102	697.37	785.90	0.4813	0.4258	1412.74	1783.10	0.0035	0.0302
Fertility options (F)	7	3.8381**	4.1859**	35245.60**	37668.35**	6.0888**	6.5096**	131372.15**	141003.64**	0.4683**	0.4165**
Error (a)	14	0.2964	0.2273	1097.78	887.97	0.6369	0.7509	4242.62	4034.97	0.0205	0.0182
Growth regulators (G)	3	4.3927**	5.3786**	29271.51**	26435.24**	12.8648**	15.9479**	115510.46**	106063.98**	0.1700**	0.1679**
F X G	21	0.0385	0.0518	664.30*	734.34*	0.0050	0.5642	2866.23*	4014.13**	0.0080	0.0019
Error (b)	48	0.2837	0.1867	344.43	354.29	0.6137	0.6055	1270.20	1378.68	0.0098	0.0096

*** Significant at 5% level, ** Significant at 1% level**

Appendix VIII: Analysis of variance for nitrogen and pphosphorus content in seed and haulm

Source of variation	d. f.	MSS			
		Nitrogen content		Phosphorus content	
		Seed	haulm	Seed	haulm

		2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	0.0123	0.0109	0.0017	0.0029	0.0005	0.0004	0.00003	0.00004
Fertility options (F)	7	0.1559**	0.1666**	0.0602**	0.0822**	0.0084**	0.0075**	0.00074**	0.00077**
Error (a)	14	0.0163	0.0192	0.0032	0.0035	0.0004	0.0004	0.00003	0.00004
Growth regulators (G)	3	0.3293**	0.4083**	0.0439**	0.0356**	0.0040**	0.0040**	0.00044**	0.00030**
F X G	21	0.0001	0.0144	0.0002	0.0003	0.0001	0.0000	0.00004	0.00004
Error (b)	48	0.0157	0.0155	0.0028	0.0033	0.0004	0.0004	0.00003	0.00003

*** Significant at 5% level, ** Significant at 1% level**

Appendix IX: Analysis of variance for potassium and sulphur content in seed and haulm

Source of variation	d. f.	MSS							
		Potassium content				Sulphur content			
		Seed		Haulm		Seed		Haulm	
		2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	0.0098	0.0183	0.0148	0.0110	0.0001	0.0001	0.00002	0.00003
Fertility options (F)	7	0.0060	0.0022	0.0016	0.0042	0.0035**	0.0039**	0.00107**	0.00142**
Error (a)	14	0.0179	0.0102	0.0142	0.0136	0.0001	0.0001	0.00004	0.00005
Growth regulators (G)	3	0.0002	0.0001	0.0084	0.0123	0.0009**	0.0010**	0.00033**	0.00042**
F X G	21	0.0003	0.0009	0.0001	0.0009	0.0000	0.0000	0.00000	0.00000
Error (b)	48	0.0032	0.0032	0.0094	0.0099	0.0001	0.0001	0.00004	0.00004

*** Significant at 5% level, ** Significant at 1% level**

Appendix X: Analysis of variance for nitrogen and phosphorus uptake by seed, haulm and total uptake

Source of variation	d. f.	MSS											
		Nitrogen uptake						Phosphorus uptake					
		Seed		Haulm		Total uptake		Seed		Haulm		Total uptake	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	36.17	45.65	8.31	14.38	45.31	108.17	0.48	0.59	0.18	0.17	0.76	1.39
Fertility options (F)	7	3363.13**	3609.69**	1466.34**	1758.82**	9269.72**	10398.38**	44.85**	47.6**	18.7**	20.3**	121.4**	130.1**

Error (a)	14	108.61	103.30	48.22	34.24	268.42	237.25	1.36	1.1	0.6	0.4	3.4	2.9
Growth regulators (G)	3	2957.07**	2715.24**	1278.65**	945.07**	8124.20**	6863.29**	32.74**	29.0**	15.7**	10.7**	93.7**	74.8**
F X G	21	73.38*	102.76**	18.77	22.85*	163.74*	179.18**	0.92*	0.91*	0.25	0.34**	1.98*	1.77*
Error (b)	48	32.52	35.29	13.12	10.43	71.49	62.76	0.45	0.46	0.16	0.12	0.99	0.80

*** Significant at 5% level, ** Significant at 1% l**

Appendix XI: Analysis of variance for potassium and sulphur uptake by seed, haulm and total uptake

Source of variation	d. f.	MSS											
		Potassium uptake						Sulphur uptake					
		Seed		Haulm		Total uptake		Seed		Haulm		Total uptake	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	6.56	2.28	35.45	41.55	43.03	59.32	0.15	0.14	0.14	0.15	0.29	0.58
Fertility options (F)	7	262.2**	265.4**	2694.3**	2911.1**	4635.9**	4927.2**	10.69**	12.14**	18.80**	23.16**	57.78**	68.74**
Error (a)	14	8.9	9.8	137.9	81.8	195.8	139.9	0.30	0.23	0.56	0.41	1.55	1.20
Growth regulators (G)	3	182.0**	149.0**	2532.8**	1733.0**	4072.3**	2895.8**	6.80**	6.29**	13.78**	11.11**	39.91**	34.09**
F X G	21	5.65*	6.85	38.30	51.31	71.10	71.18	0.19	0.22*	0.19	0.20	0.74	0.63
Error (b)	48	2.42	3.81	36.64	27.50	48.70	38.16	0.10	0.10	0.17	0.13	0.47	0.36

*** Significant at 5% level, ** Significant at 1% level**

Appendix XII: Analysis of variance for available nitrogen, phosphorus, potassium and sulphur after crop harvest

Source of variation	d. f.	MSS							
		Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Sulphur (kg ha^{-1})	
		2013	2014	2013	2014	2013	2014	2013	2014
Replication	2	95.90	62.47	0.43	0.45	26.22	7.98	0.19	0.31
Fertility options (F)	7	2086.78**	2102.81**	17.58**	13.21**	359.62	380.89	10.40**	12.58**
Error (a)	14	114.60	109.20	1.09	0.57	949.07	942.20	0.51	0.52
Growth regulators (G)	3	2.21	7.63	0.82	0.92	58.31	66.90	0.67	0.52
F X G	21	14.49	3.39	0.24	0.34	1.91	0.97	0.09	0.39

Error (b)	48	93.38	94.27	0.72	0.55	297.26	315.46	0.44	0.48

*** Significant at 5% level, ** Significant at 1% level**

Appendix XIII: Analysis of variance for net return and benefit cost ratio

Source of variation	d. f.	MSS			
		Net return		B-C ratio	
		2013	2014	2013	2014
Replication	2	27104643	31128768	0.03	0.05
Fertility options (F)	7	1320131794**	1237435301**	0.89**	0.79**
Error (a)	14	75405867	69707139	0.09	0.09
Growth regulators (G)	3	390334036**	368071106**	2.04**	2.42**
F X G	21	96333157**	78455837*	0.08**	0.07**
Error (b)	48	24521837	28413968	0.03	0.04

*** Significant at 5% level, ** Significant at 1% level**

Appendix XIV : Pooled analysis of variance for plant population, plant height and dry matter accumulation plant^{-1}

Source of variation	d. f.	MSS									
		Plant population		Plant height				Dry matter accumulation plant^{-1}			
		30 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
YEAR	1	0.33	0.16	11.23	523.22	205.90	214.49	0.17	2.37	10.77	38.73
Y X Rep	4	0.03	0.02	1.96	4.13	10.26	12.01	0.02	0.17	0.73	1.13
Fertility options (F)	7	0.04	0.06	178.86**	406.11**	791.07**	865.54**	3.90**	29.73**	78.44**	111.58**
F X Y	7	0.00	0.00	0.05	0.80	0.56	0.64	0.00	0.01	0.55	0.01
PE(a)	28	0.06	0.04	5.18	10.20	22.68	27.03	0.06	0.83	2.10	3.21
Growth regulators (G)	3	0.00	0.03	1.56	332.80**	347.65**	364.98**	0.03	14.72**	25.78**	28.08**
G x Y	3	0.00	0.00	0.06	19.92	3.08	0.02	0.00	0.14	0.24	0.06
F x G	21	0.01	0.01	0.54	0.74	7.36	4.01	0.01	0.11	1.96	2.34

F x G x Y	21	0.00	0.01	0.29	0.75	1.20	0.07	0.00	0.04	0.31	0.01
PE(b)	96	0.03	0.02	2.31	4.89	10.78	11.29	0.03	0.36	1.24	1.51

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XV : Pooled analysis of variance for crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and leaf area index (LAI)

Source of variation	d. f.	MSS								
		CGR		RGR		NAR		LAI		
		30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS	30 DAS	60 DAS	90 DAS
YEAR	1	1.28	3.03	0.0000003	0.0000005	8.65	21.60	0.423	0.415	0.922
Y X Rep	4	0.07	0.22	0.0000003	0.0000002	0.49	0.66	0.003	0.023	0.016
Fertility options (F)	7	12.25**	11.96**	0.0000873**	0.0000043**	53.05**	63.16**	0.577**	1.905**	2.264**
F X Y	7	0.02	0.49	0.0000006	0.0000011	0.04	0.66	0.002	0.001	0.004
PE(a)	28	0.46	0.33	0.0000002	0.0000003	1.73	1.00	0.013	0.050	0.028
Growth regulators (G)	3	13.44**	1.71*	0.0001001**	0.0000142**	30.25**	15.69**	0.008	0.508**	0.634**
G x Y	3	0.14	0.12	0.0000015	0.0000006	0.13	0.06	0.000	0.000	0.014
F x G	21	0.13	2.07	0.0000039	0.0000087	0.17	2.18	0.002	0.007	0.013
F x G x Y	21	0.04	0.28	0.0000005	0.0000009	0.05	0.45	0.001	0.001	0.004
PE(b)	96	0.20	0.47	0.0000005	0.0000010	0.74	0.77	0.006	0.023	0.021

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XVI : Pooled analysis of variance for branches plant^{-1}, nodule plant^{-1} and nodule weight plant^{-1}

Source of variation	d. f.	MSS		
		Branches plant^{-1} at harvest	Nodule plant^{-1} at 60 DAS	Nodule weight plant^{-1} 60 DAS
YEAR	1	2.7263	1210.3568	0.1285
Y X Rep	4	0.1119	0.4555	0.0037
Fertility options (F)	7	8.1776**	465.0266**	0.1243**
F X Y	7	0.0139	0.8796	0.0008
PE(a)	28	0.0868	3.5791	0.0007
Growth regulators (G)	3	5.8866**	82.2867**	0.0696**
G x Y	3	0.1730	0.1230	0.0046
F x G	21	0.3945**	0.6772	0.0003
F x G x Y	21	0.0659	0.0296	0.0001
PE(b)	96	0.1139	3.7496	0.0013

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XVII: Pooled analysis of variance for yield attributes

Source of variation	d. f.	MSS					
		Yield attributes					
		Pods plant^{-1}	Seeds Pod^{-1}	Seeds plant^{-1}	Pod lenth	1000 seed weight	Seed yield plant^{-1}
YEAR	1	758.35	0.0599	1308.82	0.8000	385.19	0.0878
Y X Rep	4	6.12	0.0280	26.81	0.0251	51.31	0.1209
Fertility options (F)	7	700.54**	1.1062**	3763.21**	3.6991**	2151.01**	26.7859**
F X Y	7	4.26	0.0007	11.94	0.0217	5.61	0.1165
PE(a)	28	7.18	0.0132	35.85	0.0433	24.95	0.2043
Growth regulators (G)	3	470.71**	0.6569**	2614.11**	1.1624**	1416.17**	10.6670**
G x Y	3	2.09	0.0020	7.26	0.0002	7.93	0.1212
F x G	21	40.50**	0.0078	122.63**	0.0021	10.03	1.5615**
F x G x Y	21	3.67	0.0032	6.47	0.0003	6.17	0.1729
PE(b)	96	8.54	0.0217	31.14	0.0361	37.84	0.1705

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XVIII : Pooled analysis of variance for seed, haulm and biological yield and harvest index

Source of variation	d. f.	MSS			
		Yield			
		Seed	Haulm	Biological	Harvest index
YEAR	1	6.2703	59.4641	104.3536	0.5177
Y X Rep	4	1.1787	2.4184	4.6759	1.7168
Fertility options (F)	7	141.5322**	681.5494**	1442.6989**	4.1295*
F X Y	7	0.3527	1.4537	2.9325	0.3093
PE(a)	28	2.4770	10.8229	22.1047	1.1820
Growth regulators (G)	3	95.1867**	474.7940**	994.6590**	0.8007
G x Y	3	1.5382	11.1797	20.8164	0.0094
F x G	21	3.0506**	8.5418**	19.2936**	1.8468
F x G x Y	21	0.3426	3.3968	4.5000	1.1822
PE(b)	96	0.8056	2.7798	5.1140	1.4455

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XIX : Pooled analysis of variance for oil, protein & chlorophyll content and oil & protein yield

Source of variation	d. f.	MSS				
		Oil content	Oil yield	Protein content	Protein yield	Chlorophyll content
YEAR	1	0.3129	3253.76	8.2563	20629.36	0.0076
Y X Rep	4	0.5795	741.64	0.4536	1597.92	0.0168
Fertility options (F)	7	8.0191**	12243.41**	6.3842**	48752.04**	0.8838**
F X Y	7	0.0049	152.07	0.0096	626.48	0.0010
PE(a)	28	0.1482	548.89	0.3185	2121.31	0.0194
Growth regulators (G)	3	9.7430**	327428.45**	56.6493**	1222871.92**	0.3379**
G x Y	3	0.0283	611.43	0.0840	2190.25	0.0000
F x G	21	0.0690	1278.01**	0.3116	6231.17**	0.0058
F x G x Y	21	0.0213	120.63	0.2575	649.20	0.0041
PE(b)	96	0.2352	349.36	0.6096	1324.44	0.0097

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XX: Pooled analysis of variance for nitrogen, phosphorus, potassium and sulphur content in seed and haulm

Source of variation	d. f.	MSS							
		Nitrogen content		Phosphorus content		Potassium content		Sulphur content	
		Seed	Haulm	Seed	Haulm	Seed	Haulm	Seed	Haulm
YEAR	1	0.211361	0.131444	0.009638	0.000021	0.011911	0.058709	0.005545	0.003159
Y X Rep	4	0.011611	0.002270	0.000413	0.000035	0.014044	0.012905	0.000063	0.000027
Fertility options (F)	7	0.322272**	0.141437**	0.015879**	0.001506**	0.007448	0.005315	0.000411**	0.000167**
F X Y	7	0.000246	0.001009	0.000015	0.000000	0.000764	0.000438	0.000048	0.000015
PE(a)	28	0.008153	0.001599	0.000195	0.000017	0.008943	0.007108	0.000051	0.000020
Growth regulators (G)	3	0.735457**	0.079291**	0.007989**	0.000733**	0.000224	0.020385	0.033195**	0.011158**
G x Y	3	0.002150	0.000223	0.000001	0.000007	0.000073	0.000330	0.000004	0.000003
F x G	21	0.007977	0.000488	0.000035	0.000074	0.000899	0.000465	0.000006	0.000004
F x G x Y	21	0.006593	0.000011	0.000025	0.000001	0.000381	0.000510	0.000003	0.000001
PE(b)	96	0.015606	0.003047	0.000397	0.000031	0.003172	0.009621	0.000100	0.000040

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XXI: Pooled analysis of variance for nitrogen and phosphorus uptake

Source of variation	d. f.	MSS	
		Nitrogen uptake	Phosphorus uptake

		Seed	Haulm	Total uptake	Seed	Haulm	Total uptake
YEAR	1	528.112	725.106	2490.856	9.597	2.575	22.114
Y X Rep	4	40.907	11.346	76.741	0.534	0.175	1.077
Fertility options (F)	7	1248.052**	487.060**	3293.973**	13.577**	5.739**	36.965**
F X Y	7	16.038	9.174	40.751	0.159	0.062	0.393
PE(a)	28	54.306	24.111	134.212	0.681	0.288	1.691
Growth regulators (G)	3	31305.521**	14471.915**	88323.105**	415.508**	175.349**	1130.052**
G x Y	3	56.070	31.954	164.610	0.606	0.499	2.108
F x G	21	159.518**	31.378**	308.905**	1.659**	0.459**	3.336**
F x G x Y	21	16.619	10.238	34.021	0.169	0.133	0.415
PE(b)	96	33.906	11.776	67.126	0.457	0.142	0.891

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XXII: Pooled analysis of variance for potassium and sulphur uptake

Source of variation	d. f.	MSS					
		Potassium uptake			Sulphur uptake		
		Seed	Haulm	Total uptake	Seed	Haulm	Total uptake
YEAR	1	37.846	139.794	323.114	3.626	12.743	29.965
Y X Rep	4	4.419	38.503	51.174	0.145	0.146	0.432
Fertility options (F)	7	72.257**	929.688**	1519.617**	2.875**	5.464**	16.258**
F X Y	7	1.586	11.148	18.816	0.040	0.162	0.340
PE(a)	28	4.438	68.961	97.915	0.149	0.280	0.774
Growth regulators (G)	3	2366.910**	25174.169**	42949.157**	102.570**	188.096**	567.819**
G x Y	3	5.839	82.221	129.802	0.147	0.297	0.845
F x G	21	11.420**	60.536*	109.216**	0.372**	0.269*	1.165**
F x G x Y	21	1.078	29.067	33.060	0.030	0.128	0.199
PE(b)	96	3.117	32.067	43.430	0.102	0.147	0.412

**** Significant at 1% level, PE (a) Pooled error a, PE (b) pooled error b**

Appendix XXIII: Pooled analysis of variance for available nitrogen, phosphorus, potassium and sulphur after crop harvest and net returns & B:C ratio

Source of variation	d. f.	MSS					
		Available Nitrogen	Available Phosphorus	Available Potassium	Available Sulphur	Net return	B:C ratio

YEAR	1	1808.9783	1.0474	601.4701	4.6595	894492942.78	1.0656
Y X Rep	4	79.1843	0.4397	17.1009	0.2533	13994907.19	0.0162
Fertility options (F)	7	4186.3227**	30.7874**	740.5057	22.9843**	284758296.13**	0.9209**
F X Y	7	3.2676	0.2560	3.1033	0.4533	7404908.40	0.0085
PE(a)	28	57.3009	0.5442	474.5367	0.2532	14817008.43	0.0205
Growth regulators (G)	3	8.9998	1.7439	125.2144	1.1988	7860264550.17**	9.2512**
G x Y	3	0.8425	0.0031	0.1846	0.0307	19813996.51	0.0516
F x G	21	14.9490	0.4590	2.6958	0.2985	39520020.58**	0.0667**
F x G x Y	21	2.9345	0.1166	0.1846	0.1876	4533912.76	0.0064
PE(b)	96	93.8269	0.6388	306.3584	0.4584	10176225.21	0.0132

**** Significant at 1% level, PE (a) Pooled error a, PE (b)**

Appendix- XXIV: Economic evaluation of treatment combinations evaluated in soybean crop

Treatments	Seed yield (kg ha^{-1})			Haulm yield (kg ha^{-1})			Gross return (` ha^{-1})			Net return (` ha^{-1})			Cost of cultivation(` ha^{-1})			B-C ratio		
	2013	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**	**2013**	**2014**	**Mean**
N_0G_0	915	978	946	2363	2314	2339	34448	38449	36449	12858	16559	14709	21590	21890	21740	0.60	0.76	0.68
N_0G_1	1071	1047	1059	2735	2840	2787	40288	41997	41142	15664	17073	16368	24624	24924	24774	0.64	0.69	0.66
N_0G_2	966	988	977	2558	2510	2534	36501	39251	37876	6811	9261	8036	29690	29990	29840	0.23	0.31	0.27
N_1G_0	999	1112	1056	2567	2810	2688	37612	44118	40865	14348	20554	17451	23264	23564	23414	0.62	0.87	0.74
N_1G_1	1326	1400	1363	3339	3622	3480	49783	55761	52772	23485	29163	26324	26298	26598	26448	0.89	1.10	0.99
N_1G_2	1278	1308	1293	3199	3212	3206	47945	51710	49827	16581	20046	18313	31364	31664	31514	0.53	0.63	0.58
N_2G0	1240	1260	1250	3121	3197	3159	46542	50023	48282	22720	25901	24310	23822	24122	23972	0.95	1.07	1.01
N_2G_1	1459	1574	1517	3660	4065	3863	54749	62651	58700	27893	35495	31694	26856	27156	27006	1.04	1.31	1.17
N_2G_2	1499	1531	1515	3707	3761	3734	56132	60527	58330	24210	28305	26258	31922	32222	32072	0.76	0.88	0.82
N_3G_0	1386	1375	1381	3339	3455	3397	51733	54525	53129	27353	29845	28599	24380	24680	24530	1.12	1.21	1.17
N_3G_1	1552	1607	1580	3904	4099	4002	58248	63873	61060	30834	36159	33496	27414	27714	27564	1.12	1.30	1.21
N_3G_2	1569	1586	1578	3903	3940	3922	58810	62801	60806	26330	30021	28176	32480	32780	32630	0.81	0.92	0.86
N_4G_0	1384	1373	1378	3422	3454	3438	51825	54442	53133	28311	30628	29469	23514	23814	23664	1.20	1.29	1.25
N_4G_1	1532	1542	1537	3849	3965	3907	57478	61360	59419	30930	34512	32721	26548	26848	26698	1.17	1.29	1.23
N_4G_2	1503	1503	1503	3752	3767	3759	56362	59577	57969	24748	27663	26205	31614	31914	31764	0.78	0.87	0.82
N_5G_0	1517	1575	1546	3672	3941	3807	56647	62406	59527	32575	38034	35305	24072	24372	24222	1.35	1.56	1.46
N_5G_1	1754	1767	1761	4288	4171	4230	65571	69473	67522	38465	42067	40266	27106	27406	27256	1.42	1.53	1.48
N_5G_2	1688	1590	1639	4112	4193	4152	63083	63505	63294	30911	31033	30972	32172	32472	32322	0.96	0.96	0.96
N_6G_0	1572	1695	1633	3920	4350	4135	58940	67400	63170	34310	42470	38390	24630	24930	24780	1.39	1.70	1.55
N_6G_1	1814	1838	1826	4373	4472	4422	67708	72564	70136	40044	44600	42322	27664	27964	27814	1.45	1.59	1.52
N_6G_2	1751	1726	1739	4287	4106	4196	65488	67932	66710	32758	34902	33830	32730	33030	32880	1.00	1.06	1.03
N_7G_0	1567	1691	1629	3763	3996	3879	58441	66485	62463	34867	42611	38739	23574	23874	23724	1.48	1.78	1.63
N_7G_1	1721	1809	1765	4204	4203	4204	64348	70949	67649	37740	44041	40891	26608	26908	26758	1.42	1.64	1.53
N_7G_2	1695	1633	1664	4112	4228	4170	63320	65045	64182	31646	33071	32358	31674	31974	31824	1.00	1.03	1.02
N_8G_0	1606	1707	1656	3938	4262	4100	60083	67614	63848	35951	43182	39566	24132	24432	24282	1.49	1.77	1.63
N_8G_1	2046	2080	2063	4782	4780	4781	76066	81476	78771	48900	54010	51455	27166	27466	27316	1.80	1.97	1.88
N_8G_2	1802	1840	1821	4313	4447	4380	67182	72549	69866	34950	40017	37484	32232	32532	32382	1.08	1.23	1.16
N_9G_0	1637	1715	1676	4052	4407	4229	61321	68226	64774	36631	43236	39934	24690	24990	24840	1.48	1.73	1.61
N_9G_1	2142	2193	2167	4996	5029	5013	79597	85877	82737	51873	57853	54863	27724	28024	27874	1.87	2.06	1.97
N_9G_2	1842	1911	1876	4433	4519	4476	68716	75153	71935	35926	42063	38995	32790	33090	32940	1.10	1.27	1.18

Appendix –XXV Cost of cultivation and prices used to compute economics of soybean

Particulars	Cost (`)/ unit		Total cost (`/ha)	
	2013	2014	2013	2014
A. Common cost of cultivation				
1. Land preparation (8 hrs)	645	650	5160	5200
2. Layout and seedbed preparation (8 man days)	169 man day^{-1}	169 man day^{-1}	1352	1352
3. Seed (80 kg)	50 kg^{-1}	52 kg^{-1}	4000	4160
4. Fertilizer N (30kg ha^{-1}) Through Urea	12.13	12.13	364	364
5. Fertilizer K_2O (30kg ha^{-1}) through MOP	27.76	27.76	833	833
6. Thinning, gap filling, hoeing and weeding (20 man days)	169 man day^{-1}	169 man day^{-1}	3380	3380
7. Insecticide application	--	--	700	800
8. Irrigation (2mandays/ irrigation)	200	200	400	400
9. Harvesting (15 man days)	169 man day^{-1}	169 man day^{-1}	2535	2535
10. Threshing and Winnowing (10 man days)	169 man day^{-1}	169 man day^{-1}	1690	1690
11. Miscellaneous	100	100	500	500
Total			**20914**	**21214**
B. Cost of treatments				
Nutrient management				
Absolute control	00.00	00.00	00.00	00.00
75 % RDP	55.81	55.81	1674	1674
100 % RDP	55.81	55.81	2232	2232
125 % RDP	55.81	55.81	2790	2790
75 % RDP + 30 Sulphur	55.81	55.81	1924	1924
100 % RDP + 30 Sulphur	55.81	55.81	2482	2482
125 % RDP + 30 Sulphur	55.81	55.81	3040	3040
75 % RDP + 30 Sulphur + PSB	55.81	55.81	1984	1984
100 % RDP + 30 Sulphur + PSB	55.81	55.81	2542	2542
125 % RDP + 30 Sulphur + PSB	55.81	55.81	3100	3100
Growth regulator				
water spray 2 Spray				
(Application charges 2 mandays/ spray)	169 / manday	169 / manday	676	676
Brassinolide 0.4 ppm 30 g / spray (2 Spray)	3300/litre	3300/litre	3034	3034
(Application charges 2 mandays/ spray)	169 / manday	169 / manday	676	676
Benzyladenine 40 ppm 30 g / spray (2 Spray)	135 / gm	135/gm	8100	8100
(Application charges 2 mandays/ spray)	169 / manday	169 / manday	676	676

Fertilizer cost : 1. Phosphorus (P_2O_5) : ₹ 55.81 kg^{-1} 2. Sulphur : ₹ 8.33 kg^{-1}
3. PSB : ₹ 30 pecket^{-1}(200 g)

Selling price:

Soybean seed in 2013 : ` 32.50 /kg
Soybean seed in 2014 : ` 34.00 /kg
Soybean stover in 2013 : ` 2.00 /kg
Soybean stover in 2014 : ` 2.25 /kg