EFFECT OF GROWTH REGULATORS ON GROWTH AND YIELD OF SOYBEAN (*Glycine max* (L.) Merrill)

BY

SUNIL KUMAR
B.Sc. (Agri.) Honours

MASTER OF SCIENCE
(Agriculture)
IN
AGRONOMY

AGRONOMY SECTION
COLLEGE OF AGRICULTURE LATUR,
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DISSERTATION

Submitted to the

Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani

in partial fulfilment of the requirement for the degree of

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2016

Dedicated To....

My Beloved Parents, Research Guide,

and Friends

For Building Up My Educational Career

And Excellent Wishes throughout

My life

....Sunil Kumar

CANDIDATE'S DECLARATION

I hereby declare that the dissertation

Or part thereof has not been

Previously submitted by me

For a degree of any

University or

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CERTIFICATE - I

This is to certify that the dissertation entitled **"Effect of growth regulators on growth and yield of soybean (*Glycine max* (L.) Merrill)"** submitted by Mr. **SUNIL KUMAR** to the **Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani** in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE** in the subject of **AGRONOMY** is record of original and bonafide research work carried out by him under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree. I also certify that the dissertation or part thereof has not been previously submitted for a degree of any university. The assistance and help rendered during the course of investigation and sources of literature have been duly acknowledged.

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Date: 23 /05 /2016

CERTIFICATE – II

This is to certify that the dissertation entitled **"Effect of growth regulators on growth and yield of soybean (*Glycine max* (L.) Merrill)"** submitted by Mr. **SUNIL KUMAR** to the **Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani** in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRONOMY** has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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LIST OF ABBREVIATIONS

ABA	-	Absissic acid
a.i.	-	Active ingredient
@	-	At the rate of
B	-	Boron
BC	-	Before Christ
B:C	-	Benefit to cost ratio
Ca	-	Calcium
$CaCO_3$		Calcium Carbonate
$Ca(NO_3)$		Calcium Nitrate
CC	-	Cost of cultivation
CCC	-	2- chloroethyl- trimethyl ammonium chloride
cm	-	Centimeter
C.D.	-	Critical difference
C.V.	-	Coefficent of variation
Cu	-	Copper
$Cu\ SO_4$	-	Copper sulphate
°C	-	Degree Celsius
DAS	-	Days after sowing
DAP	-	Diammonium phosphate
dm^2	-	Decimeter square
$dS\ m^{-1}$	-	Decisiemens per meter
E		East
EC	-	Electrical conductivity
EC	-	Emulsifiable concentrate
et al.	-	*et alli i.e* and others
Expt.	-	Experiment
Fig.	-	Figure

FYM	-	Farmyard manure
G	-	gram(s)
GMR	-	Gross monetary return
GA	-	Gibberellic acid
ha	-	Hectare (s)
IAA	-	Indole-3-acetic acid
IBA	-	Indole-3-butyric acid
kg	-	Kilogram(s)
L	-	Liter(s)
Lat.	-	Latitude
Long.	-	Longitude
M	-	Meter (s)
Max.	-	Maximum
Met.	-	Meteorological
$MgSO_4$		Magnesium Sulphate
Ml	-	Milliliter
mm	-	Millimeter
Mo	-	Molybdenum
MT	-	Million tone (s)
Min	-	Minimum
Mn	-	Manganese
$MnSO_4$	-	Manganese Sulphate
MW	-	Meteorological week
N	-	Nitrogen, North
NAA	-	Naphthalene acetic acid
NH_4OH	-	Ammonium hydroxide
NMR	-	Net monetary return
NS	-	Non- significant
OC	-	Organic Carbon

No./no.	-	Number(s)
%	-	Per cent
PAR	-	Plant growth regulators
P/P_2O_5	-	Phosphorus
ppm	-	Parts per million
PSB	-	Phosphorus Solubilising bacteria
KCl	-	Potassium Chloride
KNO_3	-	Potassium Nitrate
K or K_2O	-	Potassium
Q	-	Quintal(s)
RDF	-	Recommended dose of fertilizer(s)
RH	-	Relative humidity
₹/Rs	-	Rupee(s)
S	-	Sulphur
Sr.	-	Serial
SSP	-	Single super phosphate
pH	-	Puissance de hydrogen
cm^2	-	Square centimeter(s)
m^2	-	Square meter(s)
S.E m.	-	Standard error of mean
SSP	-	Single super phosphate
Temp.	-	Temperature
i.e.	-	id est *i.e* that is
T	-	Tonne(s)
viz.,	-	Videlicet (Namely, as follows)
Zn	-	Zinc

INTRODUCTION

CHAPTER- I

INTRODUCTION

Soybean (*Glycine max* (L.) Merill) is a leguminous crop and belongs to family Leguminoaceae with sub family Papilionaceae. It is popularly known as 'Wonder crop'. It is originated in China. It is self pollinated and short day plant. In India it was introduced in recent years. It is basically a pulse crop and gained an importance as an oilseed crop.

Soybean is 'miracle golden bean' of 21st century which possesses potential to revolutionized Indian economy by correcting the health of human being and soil. Soybean holds a very important position in the Indian agriculture and economy and it has a worth of over Rs. 5000 crores. It is an important crop in human and animal nutrition, because it is a major source of edible vegetable oil and high protein feed as well as food in the world.

Soybean is an excellent health food and contains about 40 per cent quality protein, 23 per cent carbohydrates and 20 per cent cholesterol free oil. Soybean protein is rich in valuable amino acid, lysine (5 %) which is deficient in most of the cereals. It also contains 60 per cent polyunsaturated fatty acids (52.8 % linolenic acid + 7.2 % linoleic acid). It has high calorific value releasing 432 calories from 100 gm edible protein as compared to 350 calories from cereals of same quantity (Dixit *et al*, 2011). Soybean is the cheapest source of proteins and hence it is called "Poor man's meat".

Soybean can also be easily processed into a number of processed food products like soya milk, soya cheese etc. Likewise, the rate of production of soy meal in India is on an increasing level with a production figure of 5 million tonnes. Soy oil is considered as one of the most important edible oil in the country. Indian production of soy oil is around 1 million tonnes annually and it accounts for about 18 % of total consumption of oils in the country. It can give a boost to the food-processing industry in rural areas. Soybean being a high protein and energy crop has high nutrient requirements. Its productivity is often limited by the low availability of essential nutrients or imbalanced nutrition.

India stands at the 5th position in area and production in the world after USA, Brazil, Argentina and China. The soybean producing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Uttar Pradesh, Andhra Pradesh, and Gujarat. Madhya Pradesh being the leading producing state of India contributes to more than 50 % of the total Indian production (Anonymous, 2015). It is also called the "soybean bowl" in India.

In India area sown under soybean was 110.65 lakh ha, productivity 785 kg/ha and production was 86.42 lakh MT. In Maharashtra area was 35.85 lakh ha, productivity 776 kg/ha and production was 27.83 lakh MT (Anonymous, 2015). District wise area under soybean also varied due to the effect of monsoon. Recently the area under soybean crop has increased more in Latur division. In this region area was 9.97 lakh ha, productivity 565 kg/ha and production was 5.63 lakh MT (Anonymous, 2015).

Not only water, light, carbohydrate, minerals and vitamins are required for plant but also other substances like hormones being involved in reaction and metabolism, which are indispensable for normal and better growth of plants. Hormones are organic compound other than nutrients which in small amount promote, inhibit or otherwise, modify the physiological process in plant. Growth regulators are known to improve the source-sink relationship, translocation of photoassimilates. Yield potential of pulses are greatly affected by non leaf synchronous habit, flower drop, nodule disintegration at the time of flowering, heavy senescence at the time of pod development (Sinha, 1974 and Chaturvedi *et al,* 1980). Photosynthetic ability of plant plays a singnificant role in high productivity and higher crop yields. An exogenous application of plant growth regulators affects the the endogenous hormonal pattern of the plant (Arshad and Frankenberger, 1993) .

The invention of plant growth regulator is an outstanding achievement which has contributed good deal in the process of agriculture. The use of plant growth regulator is the most important tool in hands of Agriculturist. The growth behaviour of many crop plants can be modified and often controlled by applying small amount of growth substance to seed, roots and leaves. It is well established fact that growth regulators exerts effect on cell elongation .The precise action depending on the concentration of the substance used and sensitivity of the organ concerned. The flower and pod drop may be reduced to some extent by spraying various growth regulators on foliage (Ramesh and Thirumuguran, 2001).

Auxins are organic substances which promote the apical dominance. Cell division and root formation are some of the functions of auxins. Auxins stimulate elongation of cells of stems and coleoptiles. IAA is the only naturally occurring hormone in the plant but NAA is synthetic chemical which is similar to IAA in its biological activity. NAA induces flowering in plants. All these chemical activities are similar to auxins. Auxins promote growth along the longitudinal axis when applied in low concentration to shoot of the plant. NAA is a potential antifugal agent some investigation indicated (Nakamura *et al.,* 1978). The yield of soybean can be enhanced through physiological growth manipulation by way of foliar application of growth regulators like NAA and nutrients like KNO_3, $ZnSO_4$ (Basole *et al,* 2003). NAA also significantly improve growth, yield attributes and quality of soybean (Thakare *et. al,* 2006).

Gibberellins are first isolated from *Gibberella fuzikuroi* fungus. Subsequently gibberellins were also found in plant tissue. There are 50 different forms of gibberellins designated as GA_1, GA_2, GA_3, GA_7, etc. Gibberellin generally increases cell division and cell elongation. The gibberellins commonly available GA_3 and is known as gibberellic acid. They promote cell elongation and increase in size of leaf, flower and fruit. Dormancy is broken by gibberellic acid. Gibberellins play an essential role in many aspects of plant growth and development such as seed germination (Haba *et al* 1985, Kumar and Neelakandan, 1992). The morphological and yield contributing characteristics of soybean could be modified by GA_3 at all development stages (Kalyankar *et al,* 2008).

Cycocel (Chlormequat Chloride) is a plant growth regulant, which generally retarded the stem elongation by preventing cell division in the sub apical meristem, usually without similarly affecting the apical meristem. This growth retardant are known to reduce the internodal length, reduce plant height. Cycocel growth retardant was reported to shorten and stregthen stems of the plant and thereby reduce losses caused by lodging.

Cycocel increases the maximum chlorophyll content and carotenoids (Konthoujm 2008). Cycocel significantly affects on yield contributing character

(Kothule *et al* 2003). Cycocel has been used to check the abscission of flower and modify the crop canopy for improving the yield in soybean (Singh *et al* 1987). Effect of growth retardant on growth and productivity of soybean was proved that the seed yield found higher over control due to increased symbiotic and photosynthetic phenomena (Singh and Sarkar 1976).

The foliar application of hormones increases the optimum growth and yield under adverse condition of soil. The pulse and oil seed crop yields are very poor and this discourages the wide cultivation for it. The plant normally produces large number of flower but most of them abscise and have no fruit setting. So the use of growth regulators proved better fruit setting to increase the yield. Plant growth regulators have great potential , their application and accurate assessment, etc. have to be jucidiously planned in terms of optimal concentrations.

Considering above point, the investigation was undertaken to study the **"Effect of growth regulators on growth and yield of soybean *(Glycine max* (L.) Merill)"**. The main objectives are as follows

1. To study the effect of different growth regulators on growth, yield and quality of soybean.
2. To study the economics of growth regulators in soybean

REVIEW OF LITERATURE

CHAPTER- II

REVIEW OF LITERATURE

The effect of various growth regulators and growth retardant on soybean crop plants studied by number of scientists is reviewed under following headings.

Influence of growth regulator on growth attributes

Govinadan *et al.* (2000) conducted a field experiment at Tamilnadu to study the effect of growth regulators cycocel, NAA and Gibberellic acid @ 40 ppm on the soybean cultivar cv. CO-1, CO-2, JS 335 and PK-472. The growth regulators were sprayed on the 35^{th} days after sowing. The result showed that NAA and GA increased the plant height and cycocel reduced the plant height.

Sarkar *et al.* (2002) conducted a field laboratory experiment on soybean in Bangladesh to study the effect of plant growth regulators on growth of soybean. Plants of soybean cv BS-3 were sprayed at 3 different times with two concentrations (100 and 200 ppm) of GA_3 and IAA. The result revealed that spraying with GA_3 @100 ppm produced tallest plant.

Leite *et al.* (2003) conducted a pot experiment on soybean in Brazil to study the effects of GA_3 and cytokinin on the vegetative growth of soybean. GA_3 (50 mg L^{-1}) was applied as seed treatment, leaving plants with water application as control. . GA_3 (100 mg L^{-1}) and cytokinin (30 mg L^{-1}) were sprayed on leaves at the physiological stage v_3, v_4 and 15 days after as foliar spray. It was observed that foliar application of GA_3 increased the plant height of soybean whereas seed treatment with GA_3 decreased the plant emergence and initial soybean root growth.

Rahman *et al.* (2004) conducted an experiment at the field laboratory of the department of Crop Botany Bangladesh during the *rabi* season. In these plants of soybean Cv. PB-1 were sprayed 3 times (spray at 15 DAS, spray at 30 DAS, and spray at 45 DAS) with two concentrations (100 and 200 ppm) of GA_3 and maleic hydrazide . It showed that spray at 30 DAS with concentration 100 ppm GA_3 produced tallest plant.

Naeem *et al.* (2004) carried out a field experiment at Government college Jaranwala, Pakistan to study the effect of growth hormones on the morphology of shoot of lentil was examined. The hormones viz., GA (500 mg L^{-1}), IAA (500 mg L^{-1}) and Kinetin (30 mg L^{-1}) were applied individually as well as in combination i.e. GA_3+IAA, . GA_3+kinetin, IAA+kinetin and GA_3+ IAA+kinetin. The result expressed that combined dose of GA_3+IAA, . GA_3+kinetin and GA_3+ IAA+kinetin significantly increased the number of internodes as well as the number of compound leaves.

Bora and Sarma (2006) conducted an experiment at Gauhati University Assam to study the effect of gibberellic acid and cycocel on growth, yield and protein content of pea (cv. Aparna and Azad-P-1). Growth regulators concentration is 10, 100, 250, 500, and 1000 μg mL^{-1} with a control set. The result revealed that GA_3 concentration was most effective in promoting shoot growth and cycocel all concentration reduced shoot growth.

Kalyankar *et al.* (2007) conducted a field experiment at M.A.U. Parbhani during *kharif* season of 2005. In this experiment, three different phytoharmones viz, GA (100, 150 ppm), NAA (50, 100 ppm) and CCC (200, 250 ppm) at various concentrations were tried as foliar spray on three soybean varieties (MAUS-61, MAUS-61-2 and MAUS-71). MAUS-61 sprayed of GA 150 ppm shows maximum plant height.

Dixit *et al.* (2008) conducted a field experiment at Allahabad U.P. to study the effect of foliar application of nutrients and NAA in mungbean during *kharif* season of 2005 in sandy-loam soil. In this experiment 12 treatments comprised of RDF, DAP 2%, NAA 40ppm, B 0.2%, Mo 0.05%, DAP 2%+NAA 40 ppm, DAP 2%+ B 0.2%, DAP 2%+Mo 0.05%, NAA 40 ppm+ B 0.2%, NAA 40 ppm + Mo 0.05%, B 0.2% +Mo 0.05%, DAP 2%+NAA 40 ppm+B 0.2%+Mo 0.05%.The experiment indicated highest plant height by DAP 2%+NAA 40 ppm+B 0.2%+Mo 0.05% followed by NAA 40 ppm.

A study was conducted by Konthoujam. (2008) at Manipur to study the response of soybean variety JS-335 to salicylic acid @ 50 ppm, ethrel @ 200 ppm, cycocel @ 500 ppm and control (water spray) applied as foliar spray. The foliar spray applied at different stages *viz.* flower initiation (40 DAS), pod- initiation (60DAS) and flower initiation + pod initiation. The study revealed that the application of ethrel @ 200 ppm at both flower initiation (40DAS) + pod initiation (60DAS) gave higher growth and yield.

Aucharmal *et al.* (2008) conducted an experiment at college of agriculture latur Maharastara to study the effect of plant growth regulators on urdbean during *kharif* season 2003-04. The experiment was laid out in randomized block design with 3 replications and seven treatment as 3 levels each of NAA (planofix) @ 20, 40 and 60 ppm and ethylene (ethrel) @ 50, 100 and 150 ppm along with control. The result indicated the highest height of plant by ethrel @ 50 ppm.

Hamayun *et al.* (2010) conducted an experiment at University of Peshawar Pakistan. The experiment was laid out to observe the role of exogenous gibberellic acid in salinity alleviation of soybean. The adverse effect of salt stress was mitigated by GA_3 and plant length and plant fresh biomass attributes significantly promoted when GA_3 was added to salt stressed soybean plants. GA_3 treatments increased daidzein and genistein contents (commonly known as phytoestrogen) of soybean leaves under control and salt stress conditions.

Aslam *et al.* (2010) carried out a field experiment at Arid Zone Research Institute Bhakkar , Gomal University Pakistan during *rabi* season of 2004-05 and 2005-06 on sandy loam soil. In this experiment they observed the response of chickpea to phytofix –plant growth regulator (GR- naphthalene acetic acid 4.5% a.i) and four available soil moisture depletion levels, i.e. $ASMDL_1$ (50%), $ASMDL_2$ (65%), $ASMDL_3$ (80%) and $ASMDL_4$ (95%) were in split plot arrangements. The result concluded that crop growth rate was maximum with PGR (NAA) and 80% avalible soil moisture depletion level.

Islam *et al.* (2010) conducted a field experiment at Agricultural University, Mymensingh, Bangladesh during 2005 to investigate the effect of GABA (a mixture of GA_3 and ABA) on morphological character, yield and yield attributes of blackgram. In this experiment 4 levels of GABA (0.25, 0.50,1.0 and 2.0 mg/l) along a control (Fresh water) were studied. The result revealed that GABA @ 1.0 mg/l significantly increased the plant height, number of branches per plant and number of leaves per plant.

Sapkal *et al.* (2011) conducted an experiment at Dr. PDKV, Akola during *kharif* season 2011. The experiment was laid out in a randomized block design with 3 replications of 7 different plant growth regulators viz., TIBA 100 ppm, NAA 50 ppm, GA_3 50 ppm, CCC 50ppm, CCC 1000ppm, water spray and control. Three foliar applications were given at on interval of 15 days starting from 21 DAS. The result exhibited that, foliar application of GA_3 (50 ppm) recorded significantly more plant height at 50% flowering stage.

Rahdari and Sharifzadeh (2012) studied an experiment at Islamic Azad University Iran to study the effect of auxin and cytokinins on morphological factor in soybean. In experiment 3 different concentration (0.5 mg/l, 1.5 mg/l and 2.5 mg/l) of auxin (NAA), cytokinin (BA) and combination of (NAA+BA) applied. The result revealed that highest stem length was recorded by NAA 0.5 mg/l and least by (NAA+BA) 2.5 mg/l.

Bairva *et al.* (2012) conducted a field experiment during the *rabi* season of 2010-11 at the research farm of National Research Centre on Seed Spices, Rajasthan to study the effect of bio-fertilizers and plant growth regulators on growth and yield of fenugreek. The experiment comprising of four levels of bio-fertilizers (no inoculation, Rhizobium, PSB and Rhizobium+PSB) and five levels of plant growth regulators (GA_3, 50 and 100 ppm and NAA 10 and 20 ppm and water). The result expressed that higher plant height and number of branches/plant with Rhizobium+PSB and in growth regulators 20 ppm NAA.

Shasikumar *et al.* (2013) carried out a field experiment at UAS, Dharwad during *kharif* season of 2011 to evaluate the effect of growth regulator, organic and inorganic foliar nutrition on yield and yield attributes of blackgram. The result indicated that application of RDF as a basal dose and foliar spray of 40 ppm NAA + 0.5% chelated micronutrient + 2% DAP given at 35 and 50 DAS recorded significantly higher growth components like plant height, number of branches, leaf area index and total dry matter production.

Khaswa *et al.* (2014) conducted an experiment at M.P.U.A.T. Udaipur on medium clay loam soil during rainy season of 2009 and 2010. The experiment had twenty seven treatments (three doses: 20, 30 and 40 kg P_2O_5 ha^{-1}); three sources SSP, PROM, and DAP and three plant growth regulators (water spray, benzyl adenine 50 ppm and NAA 100 ppm) were evaluated. Results conclude that 40 kg P_2O_5 ha^{-1}, SSP and NAA recorded significantly higher plant height.

A study was conducted by Rajesh *et al.* (2014) at Hyderabad to study the different growth regulating compounds on morphological quality and yield parameters in greengram during 2009-10. The basic material for the present investigation consist of greengram cv WGG-37 and two growth promoting (NAA and brassinosteroid each 20 ppm) and growth retarding substances (chlormequat chloride 187.5 g a.i ha^{-1} and mepiquat chloride 5% AS). These growth regulators sprayed at flower initiation stage. The result showed that highest plant hight increased with NAA 20 ppm.

A study was conducted by Ramesh and Ramprasad (2014) at Acharya N. G. Ranga Agricultural University, Hyderabad to study the effect of growth promiting (NAA 20 ppm and Brassinosteriod 25 ppm) and growth retarding substances (chlormequat chloride 5% AS and mepiquat chloride 50 %). These growth regulators were sprayed at flower initiation stage on soybean cv. JS-335. The result showed that highest plant height increased by NAA 20 ppm.

Upadhyay and Ranjan (2015) conducted an experiment at Uttarkhand University of horticulture during kharif 2012-13. The experiment had 10 treatments which have application of NAA, GA_3 and kinetin @ (10, 20 and 30 ppm) and the pot soil ratio of 20:40:40 N:P:K. The significantly highest plant height (cm) and leaf area (cm^2/plant) were recorded in NAA-20 ppm.

Influence of growth regulator on yield and yield attributes

Phanophat *et al.* (1986) conducted a field experiment at Thailand to study the effects of the application of NAA solutions of 0, 10, 25, 50 and 100 ppm to soybean SJ.2 and SJ.4 variety. NAA 3 foliar application applied at vegetative stage, flowering stage and pod-setting stage. The result indicated that the spraying of 10 ppm NAA resulted in 15 percent increase of pod number of the plant and gave 26 percent increase of seed yield. Soybean variety SJ.4 showed higher response to the application of NAA than SJ.2.

Mishra *et al.* (1994) studied a field experiment at JNKVV Indore to study the influence of fertility levels, cycocel, Rhizobium culture and farm yard manure on growth and yield of soybean grown on black clay soils. The result revealed that maximum seed yield of soybean (2286 kg/ha) was recorded due to the application of fertilizer NPK in combination with farm yard manure+ Rhizobium culture+ cycocel.

A pot experiment was carried out by Kamal *et al.* (1995) to evaluate the effect of PGR application at flowering stage on soybean for better result for grain yield and the yield components . Soybean Tachinagaha and Tidar cultivar the application of 1 ppm ABA, 1 ppm GA_3, 0.01 ppm epi-brassinolidae and 5 ppm kinetin at flowering stage increased the grain yield by 12.1, 5.8, 5.9 and 9.3% over the control respectively.

Govinadan *et al.* (2000) conducted a field experiment at Tamilnadu to study the effect of growth regulators cycocel, NAA and Gibberellic acid @ 40 ppm on the soybean cultivar cv. CO-1, CO-2, JS 335 and PK-472. The growth regulators were sprayed on the 35^{th} days after sowing. The result indicated that highest grain yield obtained with cycocel application and in cv. CO-1.

Sarkar *et al.* (2002) conducted a field laboratory experiment on soybean in Bangladesh to study the effect of plant growth regulators on yield of soybean. Plants of soybean cv BS-3 were sprayed at 3 different times with two concentrations (100 and 200 ppm) of GA_3 and IAA. Sprayed GA_3 @100 ppm produced tallest plant followed by 100 ppm IAA and 200 ppm IAA lowest seed yield/plant.

Kalpana *et al.* (2003) conducted a field experiment during south west monsoon season of 1999 and 2000 to study the effect of different irrigation layouts viz., flat beds, flat ridges, furrow and ridges and foliar nutrition on yield , quality and nutrient uptake of soybean. The foliar nutrition consisted of combined application of nutrients (DAP,KCl and boron) and growth hormone (NAA). Highest grain yield produced by ridges and furrow method of irrigation and foliar spraying combination of DAP 2%, KCl 1%, boron 0.2% and NAA 40 mg L^{-1}.

Basole *et al.* (2003) conducted an experiment at College of Agriculture Nagpur on deep vertisol soil during *kharif* season of 2001-2002 to study the response of soybean cv. JS-335 to hormone and nutrients. The experiment comprised of foliar application of growth regulator NAA (50 ppm) and nutrients viz., $FeSo_4$, $ZnSo_4$ and $MgSo_4$ (0.5%). A dose of 30:75:30 kg NPK ha^{-1} was used as a RDF. The data revealed that application of hormone and nutrients increased highest yield per plant significantly in treatments ½ RDF + NAA + $ZnSo_4$.

Kothule *et al.* (2003) conducted an experiment at M.A.U., Parbhani during *kharif*, 2001-2002 to study the effect yield and yield components by foliar spray of growth regulators and urea at 35 DAS. The foliar spray of growth regulators, i.e. GA, NAA, AA, CCC and SA each @100 and 200 ppm and urea @ 1% and 2% at 35 DAS was taken. All the growth regulators found to be significant in increasing yield and yield components. Among all the treatments SA @ 200 ppm was found to be most significant in increasing number of pods per plant, number of grains per pod, weight of grains per pod, 100 seed weight, grain yield/plant, and harvest index.

Rahman *et al.* (2004) conducted an experiment at the department of crop Botany Bangladesh during the *rabi* season. In these plants of soybean Cv. PB-1 were sprayed 3 times (spray at 15 DAS, spray at 30 DAS, and spray at 45 DAS) with two concentrations (100 and 200 ppm) of GA_3 and maleic hydrazide . Spray at 30 DAS with concentration 100 ppm GA_3 produced highest number of flower/ plant, number of pods/plant, number of seeds/pod, seed yield/plant, hundred seed weight, seed yield (t ha^{-1}).

Thakre *et al.* (2006) conducted an experiment at farm of Botany section, College of Agriculture, Nagpur, during *kharif* 2004-2005 to study the influence of two foliar sprays of 2% DAP, 2-10% cow urine and 50 ppm IAA and NAA on yield contributing character of soybean. Treatment ½ RDF + 2% DAP + 50 ppm IAA recorded the highest number and dry weight of per plant, 100 seed weight and seed yield per plant.

Bora and Sarma *et al.* (2006) conducted an experiment at Gauhati University Assam to study the effect of gibberellic acid and cycocel on growth, yield and protein content of pea (cv. Aparna and Azad-P-1). Growth regulators concentration was 10, 100, 250, 500, and 1000 µg mL^{-1} with a control set. The result revealed that GA_3 @ 250 µg mL^{-1} produced highest seed yield in both the varieties and Cycocel @ 100 and 250 µg mL^{-1} produced highest seed yield in cv. Azad-p-1 concentration

Gulluoglu *et al.* (2006) carried out an experiment to determine the effects of four plant growth regulators (GA_3 25ppm, Atonic 1.5 L/ha, Megahix 1 L/ha, Cytozyme 1 L/ha), two nutrient complex (Biomaster 1.25 L/ha, Kinetic 2 L/ha) and sea weed extract (Maxicrop 1 kg) . The effect of growth regulator response on pod-shattering rate and yield loss of both main and double croped soybean grown in prolonged hot and dry condition. The results showed that seed yield losses of main-cropped soybean could be alleviated by the application of atonik, Megahix and cytozyme and application of PGRs was not suggested for double- cropped soybean because yield reduction by pod shattering.

Kalyankar *et al.* (2008) conducted a field experiment at M.A.U. Parbhani during *kharif* season of 2005 to study the three different phytoharmones viz, GA (100, 150 ppm), NAA (50, 100 ppm) and CCC (200, 250 ppm at various concentrations were tried as foliar spray on three soybean varieties (MAUS-61, MAUS-61-2 and MAUS-71). MAUS-61-2 sprayed of CCC @ 250 ppm shows maximum grain yield per plant.

Konthoujam (2008) conducted an experiment during 2006-2008 at Manipur to study the response of soybean variety JS-335 to salicylic acid @ 50 ppm, ethrel @ 200 ppm, cycocel @ 500 ppm and control (water spray) applied as foliar spray. The foliar spray applied at different stages *viz*. flower initiation (40 DAS), pod-initiation (60DAS) and flower initiation + pod initiation. The study revealed that the application of ethrel @ 200 ppm at both flower initiation (40DAS) + pod initiation (60DAS) gave significantly highest yield.

Aucharmal *et al.* (2008) conducted an experiment at college of agriculture latur Maharastara to study the effect of plant growth regulators on urdbean during *kharif* season 2003-04. The experiment was laid out in randomized block design with 3 replications and seven treatment as 3 levels each of NAA (planofix) @ 20, 40 and 60 ppm and ethylene (ethrel) @ 50, 100 and 150 ppm along with control. The result indicated that highest grain yield produced by NAA @ 40 ppm.

Salunke *et al.* (2008) conducted a field experiment at MPKV Rahuri to study the effect of plant growth regulators. The experiment was laid out in factorial randomized block design (FRBD) with 3 replications involving 2 factors (A) variety viz JS -335, Phule Kalyani and the plant growth regulators viz TIBA (100 ppm), (NAA 50 ppm), GA_3 (50 ppm), CCC (500 ppm), CCC (1000 ppm), water spray and absolute control. The foliar spray of plant growth regulators were given at four times from 21 DAS at an interval of 15 DAS. The result showed that NAA 50 ppm recorded highest grain yield. The variety JS-335 recorded highest grain yield the Phule Kalyani and were at par with each other.

Dixit *et al.* (2008) conducted a field experiment at Allahabad U.P. to study the effect of foliar application of nutrients and NAA in mungbean during *kharif* season of 2005 in sandy-loam soil. In this experiment 12 treatments comprised of RDF, DAP 2%, NAA 40ppm, B 0.2%, Mo 0.05%, DAP 2%+NAA 40 ppm, DAP 2%+ B 0.2%, DAP 2%+Mo 0.05%, NAA 40 ppm+ B 0.2%, NAA 40 ppm + Mo 0.05%, B 0.2% +Mo 0.05%, DAP 2%+NAA 40 ppm+B 0.2%+Mo 0.05%. In experiment indicated that highest grain yield obtained by DAP 2%+NAA 40 ppm+B 0.2%+Mo 0.05% followed by NAA 40 ppm+ 0.5% and DAP 2%+NAA 40 ppm which were significantly superior to other treatments.

Kakad *et al.* (2008) conducted a field experiment at Dr. PDKV, Akola in *kharif* 2001-2002 to determine the effect of different pre sowing seed treatment on yield in soybean seed particularly those having germination marginally below the minimum seed certification standard (MSCS). The two seed lots i.e. L_1 (seed lots having germination percent above (MSCS) i.e. less than 75%) and L_2 (57%) were used with different pre sowing treatments. Growth regulators IAA, NAA (10 ppm) thiram and GA_3 50 ppm seed treated with different hydration timing. The results revealed that seed lots treated with IAA + NAA (10 ppm 6 hrs hydration) increases the number of pods/plant, number of seeds/pod, 100 seed weight (g) and yield. Significant influence of seed fortification treatments was observed on yield for lots as well as treatment. Among the seed lots seed lot (L_1) recorded higher seed yield per plant.

Kaya *et al.* (2010) carried out the present study in 2006 and 2007 crop season at Suleyman Demirel University, Turkey to investigate the effect of sowing times and different seed treatments (control, distilled water, 100, 200, 300 and 400 ppm GA_3) on 100 seed weight, harvest index and seed yield in 3 chickpea cultivar (Gokce,Akcin 91, and Ispanoyl). It was concluded that early sowing along with 100 ppm GA_3 and dH_2O treatments could be practiced to obtain higher seed yield in chickpea.

Aslam *et al.* (2010) carried out an experiment at Arid Zone Research Institute Bhakkar , Gomal University Pakistan during *rabi* season of 2004-05 and 2005-06 on sandy loam soil. In this experiment observed the response of chickpea to phytofix –plant growth regulator (GR- naphthalene acetic acid 4.5% a.i) and four available soil moisture depletion levels, i.e. $ASMDL_1$ (50%), $ASMDL_2$ (65%), $ASMDL_3$ (80%) and $ASMDL_4$ (95%) were in split plot arrangements. The result concluded that higher seed yield and yield components was maximum in chickpea with PGR (NAA) and 80% avalible soil moisture depletion level.

Islam *et al.* (2010) conducted a field experiment at Agricultural University, Mymensingh, Bangladesh during 2005 to investigate the effect of GABA (a mixture of GA_3 and ABA) on morphological character, yield and yield attributes of blackgram. In this experiment 4 levels of GABA (0.25, 0.50,1.0 and 2.0 mg/l) along a control (Fresh water) were studied. The result revealed that GABA @ 1.0 mg/l significantly increased yield and yield contributing character.

Sapkal *et al.* (2011) conducted an experiment at Dr. PDKV, Akola during *kharif* season 2011 to study the seven different plant growth regulators viz., TIBA 100 ppm, NAA 50 ppm, GA_3 50 ppm, CCC 500 ppm and 1000 ppm, water spray, control. Three foliar applications were given at on interval of 15 days starting from 21 DAS. The result exhibited that, foliar application of GA_3 (50 ppm) recorded significantly highest pods per plant, number of seeds per plant, seed yield per plot (kg), seed yield per ha (q.).

Azizi *et al.* (2012) carried out an experiment at Lorestan University Iran during summer of 2008 to study the effect of different levels of gibberelic acid as a hormone on the yield components of soybean . In experiment 4 levels of GA_3 concentration as (control, 125, 250 and 375 ppm) were sprayed over the plants and 2 levels of soybean genotypes (M_{11} and L_{17}) were used for the experiment. The results showed that the highest seed yield (4220 kg/ha) was achieved with 125 ppm of GA_3 and the M_{11} genotype.

A study was carried out by Kamil and Jobori (2012) at university of Baghdad to investigate localized effect of GA, Kinetin and mixture of both on sink site and filling in 2 cultivar of sunflower plant. The experiment was laid out in a completely randomized block design in a factorial experiment with 2 cultivar (Flame and Euroflore) and 4 plant growth regulators treatment control, GA 200 ppm, Kinetin 200 ppm, and (GA 200 ppm + Kinetin 200 ppm. The result revealed that the treatment of (GA 200 + Kinetin 200) ppm was most effective in increasing the number of total seeds, number of filled seeds, percentage of filled seeds and seed weight.

Bairva *et al.* (2012) conducted a field experiment during the *rabi* season of 2010-11 at the research farm of National Research Centre on Seed Spices, Rajasthan to study the effect of bio-fertilizers and plant growth regulators on growth and yield of fenugreek. The experiment comprising of four levels of bio-fertilizers (no inoculation, Rhizobium, PSB and Rhizobium+PSB) and five levels of plant growth regulators (GA_3, 50 and 100 ppm and NAA 10 and 20 ppm and water). The result expressed that higher seed and biological yield attributes were recorded with Rhizobium+PSB and application of growth regulators 20 ppm NAA.

Ramesh *et al.* (2013) studied an experiment at College of Agriculture, Rajendranagar, Hyderabad during *rabi* 2008-09 seasons. The application of two growth promoting (NAA and brassinosteroids) and growth retarding substances (chloromequat chloride and mepiquat chloride) on soybean variety Js-335 at flowering stage. The study revealed that higher yield and yield contributing character recorded with NAA (20 ppm) and brassinosteroids (25 ppm) .

Shasikumar *et al.* (2013) carried out a field experiment at UAS, Dharwad during *kharif* season of 2011 to evaluate the effect of growth regulator, organic and inorganic foliar nutrition on yield and yield attributes of blackgram. The result indicated that application of RDF as a basal dose and foliar spray of 40 ppm NAA + 0.5% chelated micronutrient + 2% DAP given at 35 and 50 DAS recorded significantly higher grain yield (1298 kg ha^{-1}).

Yakubu *et al.* (2013) conducted a field experiment during 2008 rainy season and 2009 dry season at Faculty of Agriculture Farm, Bayero University Nigeria. The experiment investigated the response of three varieties viz: SAMNUT 21, SAMNUT 22 and SAMNUT 23 and five levels of gibberellic acid viz: 0, 100, 200, 300 and 400 mg L^{-1}) foliar applied at 3 and 6 weeks after sowing on yield and yield traits of groundnut.The results showed that highest pod, kernel and haulm yields with 100 mg L^{-1} levels of gibberellic acid and variety SAMNUT 23 during wet and dry seasons.

Gupta *et al.* (2014) conducted an experiment at the College of Agriculture, Indore during *kharif* 2007 to study the basal application of nitrogen (20,30 and 40 kg/ha), two foliar spray of nitrogen (10 kg and 20 kg/ha) at 20 DAS in combination with basal application of 20 kg N/ha, foliar sprays of four growth regulators (methanol 20% @ 30 l/ha, triacontenol 0.1% EW @ 325 ml/ha, NAA 4.5% SL @ 13 gm CP/ha and cytokinin @ 975 ml CP/ha) in combination with foliar spray of 20 kg N/ha @ 20 and 35 DAS and absolute control. The result revealed that among the treatments application of triacontenol 0.1% EW along with basal application of nitrogen @ 20 kg/ha had recorded the maximum yield.

Khaswa *et al.* (2014) conducted an experiment at M.P.U.A.T. Udaipur on medium clay loam soil during rainy season of 2009 and 2010. The experiment had twenty seven treatments (three doses: 20, 30 and 40 kg P_2O_5 ha^{-1}); three sources SSP, PROM, and DAP and three plant growth regulators (water spray, benzyl adenine 50 ppm and NAA 100 ppm) were evaluated. Results conclude that 40 kg P_2O_5 ha^{-1}, SSP and NAA recorded significantly higher grain yield.

A study was conducted by Rajesh *et al.* (2014) at Hyderabad to study the different growth regulating compounds on morphological quality and yield parameters in greengram during 2009-10. The basic material for the present investigation consist of greengram cv WGG-37 and two growth promoting (NAA and brassinosteroid each 20 ppm) and growth retarding substances (chlormequat chloride 187.5 g a.i ha^{-1} and mepiquat chloride 5% AS). These growth regulators sprayed at flower initiation stage. The highest seed yield increased significantly with NAA 20 ppm followed by mepiquat chloride, brassinosteroid and chlormequat chloride.

Upadhyay and Ranjan (2015) conducted an experiment at Uttarkhand University of horticulture during kharif 2012-13. The experiment had 10 treatments which have application of NAA, GA_3 and kinetin @ (10, 20 and 30 ppm) and the pot soil ratio of 20:40:40 N:P:K. The significantly highest grain yield were recorded in NAA-20 ppm.

Influence of growth regulator on quality

Phanophat *et al.* (1986) conducted a field experiment at Thailand to study the effects of the application of NAA solutions of 0, 10, 25, 50 and 100 ppm to soybean SJ.2 and SJ.4 variety. NAA 3 foliar application applied at vegetative stage, flowering stage and pod-setting stage. Application of 100 ppm NAA to soybean plant would obtain higher protein content but lower oil content. Soybean variety SJ.4 showed higher response to the application of NAA than SJ.2 in producing seed protein.

Kalpana *et al.* (2003) conducted a field experiment during south west monsoon season of 1999 and 2000 to study the effect of different irrigation layouts viz., flat beds, flat ridges, furrow and ridges and foliar nutrition on yield , quality and nutrient uptake of soybean. The foliar nutrition consisted of combined application of nutrients (DAP,KCl and boron) and growth hormone (NAA). Highest oil (%) produced by ridges and furrow method of irrigation and foliar spraying combination of DAP 2%, KCl 1% and boron 0.2% rest of the treatment.

Basole *et al.* (2003) conducted an experiment at College of Agriculture Nagpur on deep vertisol soil during *kharif* season of 2001-2002 to study the response of soybean cv. JS-335 to hormone and nutrients. The experiment comprised of foliar application of growth regulator NAA (50 ppm) and nutrients viz., $FeSo_4$, $ZnSo_4$ and $MgSo_4$ (0.5%) a dose of 30:75:30 kg NPK ha^{-1} was used as a RDF. The data revealed that application of hormone and nutrients increased highest protein content in seed significantly in treatments ½RDF+ NAA+ $ZnSo_4$. The oil content in seed was found to be significantly increased in treatment 1/2RDF + NAA + KNO_3.

Thakre *et al.* (2006) studied an experiment at College of Agriculture, Nagpur, during *kharif* 2004-2005 to study the influence of two foliar sprays of 2% DAP, 2-10% cow urine and 50 ppm IAA and NAA on yield contributing character of soybean. Treatment ½ RDF + 2% DAP + 50 ppm IAA increased highest protein and oil content in seed.

Bora and Sarma (2006) conducted an experiment at Gauhati University Assam to study the effect of gibberellic acid and cycocel on growth, yield and protein content of pea (cv. Aparna and Azad-P-1). Growth regulators concentration was 10, 100, 250, 500, and 1000 μg mL^{-1} with a control set. The result revealed that highest protein content in seeds recorded with 500 μg mL^{-1} of cycocel.

Karim *et al.* (2006) carried out a field experiment during the *rabi* season in 2001-02 on silty loam soil at Sher-e- Bangla Agricultural University, Bangladesh. In this experiment foliar spray of 1500 ppm Knap and 10, 20 and 30 ppm NAA, either alone or in combination on chickpea. The result expressed that crude protein increased significantly with combination of 1500 Knap and 20 ppm NAA.

Kalyankar *et al.* (2008) conducted a field experiment at M.A.U. Parbhani during kharif season of 2005 to study the three different phytoharmones viz, GA (100, 150) ppm, NAA (50, 100) ppm and CCC (200, 250) ppm at various concentrations were tried as foliar spray on three soybean varieties (MAUS-61, MAUS-61-2 and MAUS-71). In this experiment MAUS-61-2 sprayed of GA @ 100 ppm shows maximum shoot length (cm) and CCC @ 200 ppm produces maximum root length (cm).

A study was conducted by Konthoujam. (2008) at Manipur to study the response of soybean variety JS-335 to salicylic acid @ 50 ppm, ethrel @ 200 ppm, cycocel @ 500 ppm and control (water spray) applied as foliar spray. The foliar spray applied at different stages *viz.* flower initiation (40 DAS), pod- initiation (60DAS) and flower initiation + pod initiation. The study revealed that the application of cycocel @ 500 ppm at both flower initiation (40DAS) + pod initiation (60DAS) gave higher growth yield.

Kakad *et al.* (2008) conducted a field experiment at Dr. PDKV, Akola in *kharif* 2001-2002 to determine the effect of different pre sowing seed treatment on yield in soybean seed particularly those having germination marginally below the minimum seed certification standard (MSCS). The two seed lots i.e. L_1 (seed lots having germination percent above (MSCS) i.e. less than 75%) and L_2 (57%) were used with different pre sowing treatments. Growth regulators IAA, NAA (10 ppm) thiram and GA_3 50 ppm seed treated with different hydration timing. The results revealed that seed lots treated with IAA + NAA (10 ppm 6 hrs hydration) increases the protein % and oil %.

Kaya *et al.* (2010) carried out the present study in 2006 and 2007 crop season at Suleyman Demirel University, Turkey to investigate the effect of sowing times and different seed treatments (control, distilled water, 100, 200, 300 and 400 ppm GA_3) on 100 seed weight, harvest index and seed yield in 3 chickpea cultivar (Gokce,Akcin 91, and Ispanoyl). It was concluded that late sowing along with GA_3 treatments could be practiced to obtain higher protein content in chickpea.

Rahdari and Sharifzadeh (2012) studied an experiment at Islamic Azad University Iran to study the effect of auxin and cytokinins on morphological factor in soybean. In experiment 3 different concentration (0.5 mg/l, 1.5 mg/l and 2.5 mg/l) of auxin (NAA), cytokinin (BA) and combination of (NAA+BA) applied. Highest protein increased by cytokinin 2.5 mg/l and least by control treatment.

A study was conducted by Rajesh *et al.* (2014) at Hyderabad to study the different growth regulating compounds on morphological quality and yield parameters in greengram during 2009-10. The basic material for the present investigation consist of greengram cv WGG-37 and two growth promoting (NAA and brassinosteroid each 20 ppm) and growth retarding substances (chlormequat chloride 187.5 g a.i ha^{-1} and mepiquat chloride 5% AS). These growth regulators sprayed at flower initiation stage. The highest seed protein increased with chlormequat chloride (187.5 g a.i ha^{-1}) in greengram.

A study was conducted by Ramesh and Ramprasad (2014) at Acharya N. G. Ranga Agricultural University, Hyderabad to study the effect of growth promiting (NAA 20 ppm and Brassinosteriod 25 ppm) and growth retarding substances (chlormequat chloride 5% AS and mepiquat chloride 50 %). These growth regulators were sprayed at flower initiation stage on soybean cv. JS-335. The result showed that highest seed protein content increased by NAA 20 ppm followed by brassinosteroid (25 ppm), Mepiquat chloride 5% As and chloromequat chloride compared to control and water spray.

Upadhyay and Ranjan (2015) conducted an experiment at Uttarkhand University of horticulture during kharif 2012-13. The experiment had 10 treatments which have application of NAA, GA_3 and kinetin @ (10, 20 and 30 ppm) and the pot soil ratio of 20:40:40 N:P:K. The significantly highest protein were recorded in NAA-20 ppm followed by GA_3 and kinetin.

Influence of growth regulator on economics

Thakre *et al.* (2006) studied an experiment College of Agriculture, Nagpur, during *kharif* 2004-2005 to study the influence of two foliar sprays of 2% DAP, 2-10% cow urine and 50 ppm IAA and NAA on yield contributing character of soybean. Treatment ½ RDF + 2% DAP + 50 ppm NAA produced higher yield and most beneficial considering the production cost.

Konthoujam (2008) conducted an experiment during 2006-2008 at Manipur to study the response of soybean variety JS-335 to salicylic acid @ 50 ppm, ethrel @ 200 ppm, cycocel @ 500 ppm and control (water spray) applied as foliar spray. The foliar spray applied at different stages *viz.* flower initiation (40 DAS), pod-initiation (60DAS) and flower initiation + pod initiation. The study revealed that the application of ethrel @ 200 ppm at both flower initiation (40DAS) + pod initiation (60DAS) gave significantly the highest net returns and B: C ratio.

Dixit *et al.* (2008) conducted a field experiment at Allahabad U.P. to study the effect of foliar application of nutrients and NAA in mungbean during *kharif* season of 2005 in sandy-loam soil. In this experiment 12 treatments comprised of RDF, DAP 2%, NAA 40ppm, B 0.2%, Mo 0.05%, DAP 2%+NAA 40 ppm, DAP 2%+ B 0.2%, DAP 2%+Mo 0.05%, NAA 40 ppm+ B 0.2%, NAA 40 ppm + Mo 0.05%, B 0.2% +Mo 0.05%, DAP 2%+NAA 40 ppm+B 0.2%+Mo 0.05%. In experiment highest benefit cost ratio was registered with DAP 2%+NAA 40 ppm+B 0.2%+Mo 0.05% (1.97) followed by DAP 2%+NAA 40 ppm (1.80).

Shasikumar *et al.* (2013) carried out a field experiment at UAS, Dharwad during *kharif* season of 2011 to evaluate the effect of growth regulator, organic and inorganic foliar nutrition on yield and yield attributes of blackgram. The result indicated that application of RDF as a basal dose and foliar spray of 40 ppm NAA + 0.5% chelated micronutrient + 2% DAP given at 35 and 50 DAS recorded significantly higher net returns and B:C ratio (₹ 52,900 ha^{-1} and 3.03) respectively.

MATERIAL AND METHODS

CHAPTER – III

MATERIAL AND METHODS

The details of the materials used and techniques adopted during the course of investigation on the soybean entitled **"Effect of growth regulators on growth and yield of soybean *(Glycine max* (L.) Merill)"**have been presented in this chapter.

3.1 General description

3.1.1 Location

The experiment was conducted during *kharif*, 2015-16 at Experimental Farm of Agronomy Section, College of Agriculture, Latur. The topography of experimental field was uniform and leveled.

3.1.2 Soil

The soil of the experimental site was deep, black in colour with good drainage. Representative soil samples were collected. Physico-chemical properties of soil were determined by taking soil samples from 0-30 cm strata at random all over the experimental area before laying out experimental plot field. A composite soil sample was prepared and analysed for estimation of its various physico-chemical properties. The relevant results are presented in Table 1.

The data presented in Table 1 on soil analysis showed that the soil of experimental plots was clayey in texture. The chemical composition of experimental plots indicated that the soil was low in available nitrogen (118.86 kg ha^{-1}), medium in available phosphorus (20.42 kg ha^{-1}), very high in available potassium (385.89 kg ha^{-1})and alkaline in reaction having pH of 7.45.

3.2 Climatic conditions

Geographically Latur is situated between 18°05' to 18°75' North latitude and between 76°25' to 77°25' East longitude. Its height from mean sea level is about 540.634 m and has sub tropical climate. The climate of Latur is characterized by a hot summer and general dryness throughout the year except during south west monsoon. The mean annual precipitation was about 734 mm. Most of the monsoon rains (72 per cent) received during June to September

Table 1: Physico-chemical properties of composite soil

Sr. No.	Particulars	Value (%)	Method used	Reference
I)	**Mechanical composition**			
a)	Fine sand (%)	26.32 %	International Pipette Method	Piper, 1966
b)	Silt (%)	23.51 %	International Pipette Method	Piper, 1966
c)	Clay (%)	49.30 %	International Pipette Method	Piper, 1966
d)	Textural class	Clayey	-	-
II)	**Chemical composition**			
a)	Soil pH	8.5	pH meter	Jackson, 1967
b)	Electrical conductivity (dSm^{-1} at 25^0 C)	0.20	Conductivity bridge	Jackson, 1967
c)	Organic carbon (%)	0.74	Walkley and Black method	Piper, 1966
d)	Available nitrogen (kg ha^{-1})	118.86	Alkaline Permanganate	Jackson, 1967
e)	Available phosphorus (kg ha^{-1})	20.42	Olsen method	Olsen *et al* 1954
f)	Available potassium (kg ha^{-1})	385.89	Flame photometer	Jackson, 1967

3.2.1 Weather conditions

The meteorological data recorded at meteorological observatory, Oilseeds Research Station, Latur during 2015-16 are presented in Table 3 and graphically depicted in Fig. 1 (a), 1(b) and 1(c).

The total rainfall received during crop growth season was 297.5mm and distributed over 25 rainy days during the course of experimentation.The crop was suffered with moisture stress at flowering and pod filling stage, due to less rainfall in 39^{th} MW and no rainfall from 42^{nd} MW onward. Growth and yield parameters of soybean crop were drastically reduced due to moisture stress. Water stress during crop duration resulted in forced maturity of crop followed by less leaf area, dry matter, pod and seed yields.

Table 2:Meteorological data during the course of investigation, 2015

M.W.	Date	Total rainfall (mm)	Rainy days (No.)	Temperature		Relative Humidity (%)	
				Min.	Max.	Max.	Min.
1	01-07 Jan.	305	1	13.6	25.5	82	60
2	08-14 Jan.	0.0	0	10.5	27.0	44	15
3	15-21 Jan.	0.0	0	10.9	28.0	48	20
4	22-28 Jan.	0.0	0	14.9	29.8	48	22
5	29 Jan.-04 Feb.	0.0	0	15.4	31.4	51	20
6	05- 11 Feb.	0.0	0	17.0	32.4	52	12
7	12-18 Feb.	0.0	0	15.4	35.1	44	09
8	19-25 Feb.	0.0	0	16.1	31.0	39	09
9	26 Feb.-04 Mar.	7.5	1	15.5	32.0	53	31
10	05- 11Mar.	0.0	0	16.3	34.7	45	21
11	12-18 Mar.	2.5	1	18.9	37.0	53	20
12	19-25 Mar.	0.0	0	21.2	37.2	35	14
13	26 Mar.-01 Apr.	0.0	0	22.3	32.7	33	14
14	02-08 Apr.	14.5	1	21.6	38.0	25	19
15	09-15 Apr.	26.5	2	19.3	32.7	61	40
16	16-22 Apr.	0.0	0	23.0	36.8	47	18
17	23-29 Apr.	0.0	0	24.7	38.7	39	20
18	30 Apr.-06 May	18.5	1	24.0	39.1	35	15
19	07-13 May	1.0	0	24.5	37.5	50	17
20	14-20 May	0.0	0	25.5	38.1	52	27
21	21-27 May	0.0	0	26.9	41.0	34	17
22	28 May-03 June	0.0	0	26.5	39.2	42	18
23	04-10 June	22.5	2	25.2	36.1	68	29
24	11-17 June	33.0	4	19.7	30.8	70	62
25	18-24 June	4.5	1	23.3	30.8	65	55
26	25 June-01 July	0.0	0	24.1	34.2	62	41
27	02-08 July	36.0	1	22.7	34.1	64	36
28	09-15 July	7.5	1	22.8	33.4	63	40
29	16-22 July	0.5	0	22.5	32.5	59	46
30	23-29 July	6.0	1	22.6	29.7	65	61
31	30 July- 5 Aug.	9.5	2	23.0	27.1	71	67
32	**6-12 Aug.**	**24.5**	**2**	**22.4**	**27.0**	**82**	**70**
33	**13-19 Aug.**	**26.5**	**5**	**22.1**	**28.1**	**72**	**72**
34	**20-26 Aug.**	**24.5**	**2**	**21.3**	**29.4**	**69**	**62**
35	**27Aug.-2 Sept.**	**14.0**	**1**	**22.3**	**30.8**	**72**	**52**
36	**03-09 Sept.**	**46.0**	**2**	**21.5**	**31.7**	**71**	**50**
37	**10-16 Sept.**	**104.0**	**4**	**21.1**	**28.1**	**88**	**67**
38	**17-23 Sept.**	**26.0**	**2**	**21.6**	**29.6**	**73**	**65**
39	**24-30 Sept.**	**0.0**	**0**	**21.5**	**30.7**	**67**	**55**
40	**01-07 Oct.**	**15.0**	**3**	**19.5**	**31.2**	**64**	**55**
41	**08-14 Oct.**	**17.0**	**3**	**18.3**	**31.8**	**65**	**46**
42	**15-21 Oct.**	**0.0**	**1**	**18.0**	**32.8**	**60**	**48**
43	**22-28 Oct.**	**0.0**	**0**	**18.6**	**33.5**	**60**	**41**
44	**29 Oct.- 04 Nov.**	**0.0**	**0**	**18.9**	**31.9**	**52**	**52**
45	05-11 Nov.	0.0	0	18.2	32.0	42	56
46	12-18 Nov.	0.0	0	16.3	30.7	66	61
47	19-25 Nov.	0.0	0	17.9	29.5	77	64
48	26 Nov.- 02 Dec.	0.0	0	17.2	30.8	65	56
49	03-09 Dec.	0.0	0	18.4	29.6	68	60
50	10-16 Dec.	0.0	0	17.8	30.4	70	49
51	17-23 Dec.	0.0	0	18.2	30.1	64	41
52	24-31 Dec.	0.0	0	18.0	30.0	63	46
	Total	**490.5**	**41**		-	-	-
	Total during crop Period	**297.5**	**25**				

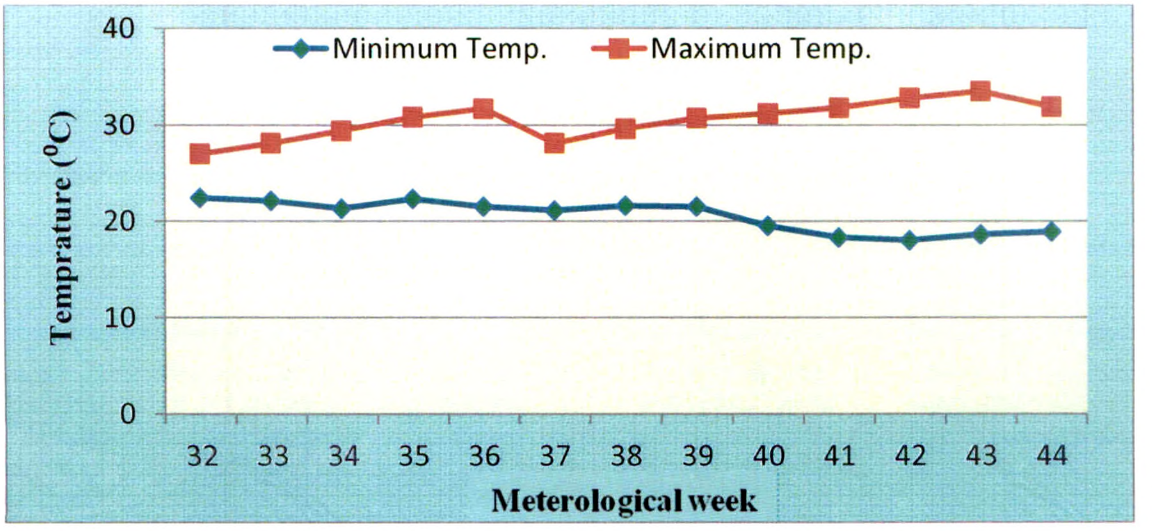

Fig:1 (a) Minimum and maximum temperature (^{0}C)

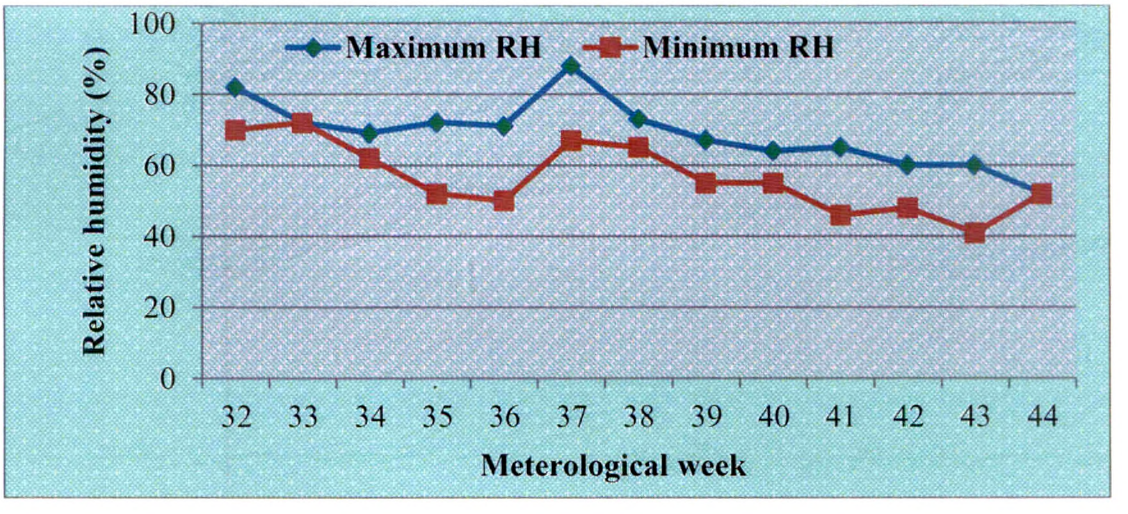

Fig:1 (b) Relative humidity (%)

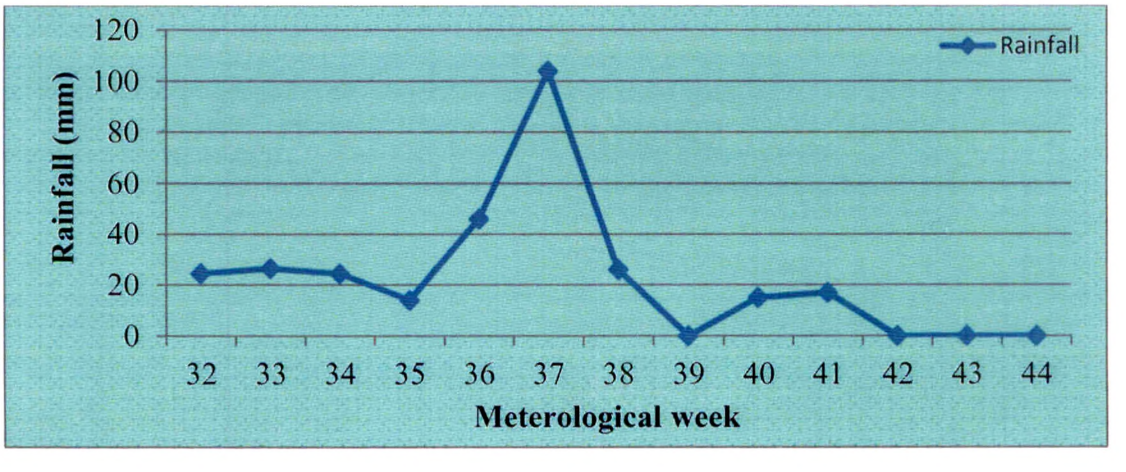

Fig: 1(c) Rainfall (mm)

The seed filling stage and the final stage began earlier in stressed plants and the duration of the maturation period was significantly reduced by stress, leading to accelerated senescence

3.2.2 Cropping history of the experimental plot for previous four years is presented in Table 2.

Table 3: Cropping history of the experimental plot

Year	*Kharif*	*Rabi*	*Summer*
2011-12	Soybean	Gram	Fallow
2012-13	Soybean	Gram	Fallow
2013-14	Soybean	Gram	Fallow
2014-15	Pigeonpea	Fallow	Fallow
2015-16	Present Experiment	-	Fallow

3.3 Experimental details

3.3.1 Experimental layout

The present experiment was laid out Randomized block design with three replications. The treatments consisting of foliar application of GA, NAA and CCC constituting eleven treatments as shown below.

3.2.2 TREATMENTS

T_1	:	RDF
T_2	:	RDF + GA 20ppm
T_3	:	RDF + GA 40ppm
T_4	:	RDF + GA 60ppm
T_5	:	RDF + NAA 20ppm
T_6	:	RDF + NAA 40ppm
T_7	:	RDF + NAA 60ppm
T_8	:	RDF + CCC 200ppm
T_9	:	RDF + CCC 250ppm
T_{10}	:	RDF + CCC 300ppm
T_{11}	:	RDF + water spray at moisture stress up to 45 DAS

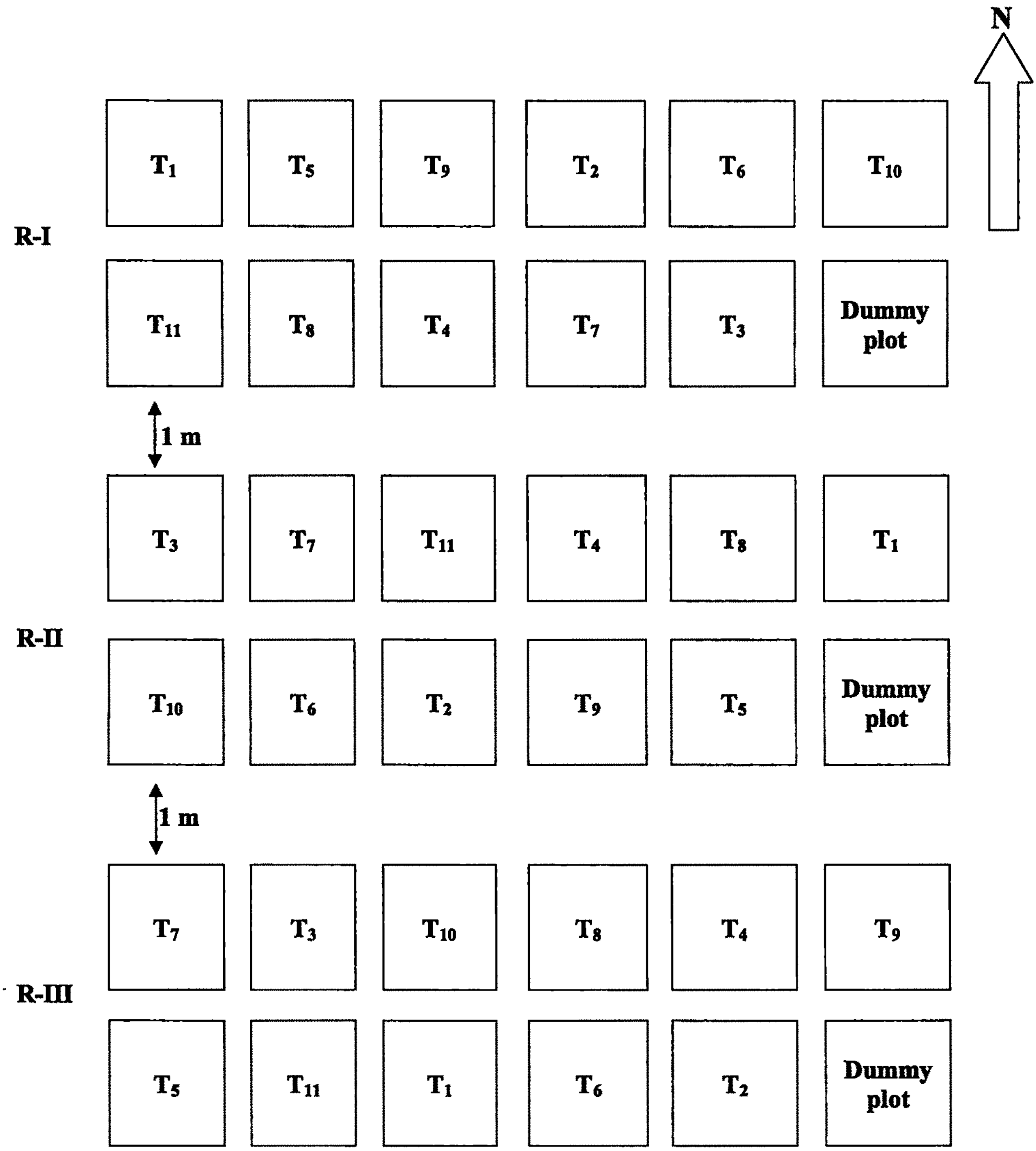

Fig. 2: PLAN OF LAYOUT

Plot size		:	$4.5 \times 4.8\ m^2$
Distance between :	Plot	:	0.5 m
:	Replication	:	1 m

3.3.3 EXPERIMENTAL DETAILS:

1)	Starting of programme	: *Kharif*, 2015-16
2)	Crop	: Soybean
3)	Variety	: MAUS-81
4)	Design of Experiment	: Randomised Block Design
5)	Treatments	: 11
6)	Replication	: 03
7)	Total No. of plots	: 33
8)	Plot size	
	Gross	: 4.8 x 4.5 m
	Net	: 4.5 x 3.6 m
9)	Distance between plots	: 0.5 m
10)	Distance between replications	: 1.0 m
11)	Row to row distance	: 45 cm
12)	Plant to plant distance	: 5 cm
13)	Method of sowing	: Dibbling
14)	RDF	: 30:60:30 NPK kg ha^{-1}
15)	Site	: Experimental Farm of Agronomy section, College of agriculture, Latur.

3.4 Cultural Operations

The schedule of various cultural operations carried out in the experimental field is presented in Table 4.

3.4.1 Preparatory cultivation

The land was ploughed about 20 cm deep. It was subsequently harrowed twice with common blade harrow to achieve loose and friable seed bed. After attaining of desired tilth the field was laid out as per plan and kept ready for sowing.

3.4.2 Fertilizer application

Fertilizer *viz.*, nitrogen, phosphorus and potassium were applied to respective plots as per the recommendation by using the urea (46% N), DAP (18% N and 46% P) and muriate of potash(60% K_2O).

Plate 1. General view of experimental field

Plate 2. General view of experimental field at flowering stage

Table 4: Schedule of cultural operations

Sr. No.	Particulars	Frequency	Date
1	Ploughing	1	27/04/2015
2	Harrowing	2	13/06/2015
			16/07/2015
3	Cleaning	1	14/06/2015
4	Soil sample taken		
	i) Initial	1	03/08/2015
	ii) Final	1	6/11/2015
5	Layout	1	4/08/2015
6	Fertilizer dose application	1	07/08/2015
7	Sowing by dibbling	1	08/08/2015
8	Gap filling	1	19/08/2015
9	Thinning	1	22/08/2015
10	Hand weedings	2	27/08/2015
			19/09/2015
11	Hand howing	2	24/08/2015
			18/09/2015
12	Spraying	2	10/09/2015
	[Trizophos, Chloropyriphos]		03/10/2015
13	Harvesting	1	03/11/2015
14	Threshing	1	05/11/2015

3.4.3 Seeds and sowing

The pure seed of soybean (MAUS-81) was obtained from Department of Agronomy, College of Agriculture, Latur. The variety is recommended for the Maharashtra under rainfed conditions. Sowing was done on 8^{th}Aug, 2015 by dibbling one seed at each hill at a recommended spacing of 45 cm x 5cm.

3.4.4 Emergence count and final plant stand

Emergence count was taken 10 days after sowing and final plant stand from each net plot was recorded at the harvest.

3.4.5 Intercultural operations

Two hand weeding and two hoeing were given during the growth period of soybean for control of weeds and better aeration in the soil.

3.4.6 Plant protection

The spraying of Trizophos @ 2 ml per litre, Chloropyriphos @ 20 ml per litre was undertaken for the control of aphids, leaf miners, girdle beetle and leaf eating catterpiller.

3.4.7 Spraying of growth regulators

In soybean foliar spray of growth regulators *viz.*,GA, NAA and CCC was carried out. Spraying of GA and NAA was done at 30 days after sowing and spraying of CCC was done at 45 days after sowing of soybean.

3.4.8 Harvesting and thresing

Harvesting was carried out at physiological maturity of crop with the help of manual labour by cutting plants close to the ground. Threshing was carried out as per treatments and seeds were separated by winnowing. The clean seeds were weighed as final yield.

3.5 Biometric observations

3.5.1 Sampling technique

Five plants from each net plot were randomly selected and labeled for taking biometric observations at different growth stages. The same plants were harvested separately for post harvest studies. The schedules of biometric observations on various parameters recorded during the present investigation are given in Table 5.

3.5.2 Plant height (cm)

The plant height was measured in cm from the base of plant up to base of top most fully opened leaf.

3.5.3 Number of functional leaves plant^{-1}

Total number of functional leaves born on sample plants were counted averaged one plant basis and recorded at different growth stages of crop up to harvest.

SCHEDULE OF BIOMETRIC OBSERVATIONS IN SOYBEAN

Table 5: Details of biometric and other observations recorded during present investigation

Sr. No.	Particulars	Frequency	Days after sowing	No. of Plants
A	**Pre Harvest Studies**			
1	Emergence count	1	10^{th} day	All plants per net plot
2	Final plant stand	1	At harvest	All plants per net plot
3	Height of the plant (cm)	5	30, 45, 60, 75 and at harvest	Five random plants from each net plot
4	Number of functional leaves plant^{-1}	5	30, 45, 60, 75 and at harvest	Five random plants from each net plot
5	Number of branches plant^{-1}	5	30, 45, 60, 75 and at harvest	Five random plants from each net plot
6	Number of pods plant^{-1}	4	60, 75 and at harvest	Five random plants from each net plot
7	Number of nodules plant^{-1}	5	30, 45, 60 and 75	One plants from each net plot
8	Leaf area plant^{-1} (cm^2)	5	30, 45, 60 and 75	Five random plants from each net plot
9	Total dry matter plant^{-1} (g)	5	30, 45, 60, 75 and at harvest	One plant from each net plot
B	**Post Harvest Studies**			
1	Pod yield per plant^{-1} (g)	1	At harvest	Five sample plants from each net plot
2	Seed yield plant^{-1} (g)	1	At harvest	Five sample plants from each net plot
3	Number of seeds plant^{-1}	1	At harvest	Five sample plants from each net plot
4	Test weight (g)	1	At harvest	1000 seeds weight from each net plot
5	Seed yield per net plot (kg)	1	At harvest	All plants from each net plot
6	Straw yield per net plot (kg)	1	At harvest	All plants from each net plot
7	Biological yield per net plot (kg)	1	At harvest	All plants from each net plot
C	**Chemical studies**			
1	Initial N,P and K status of soil	1	Before sowing	Soil sample from field
2	Oil & Protein content at harvest (%)	1	At harvest	Seed sample from each net plot

3.5.4 Leaf area plant^{-1} (dm^2)

Leaf area plant^{-1} (dm^2) was measured by taking length and width of each leaf multiply with the factor and number of leaves. Then averaging and converted on plant basis.

Leaf area plant^{-1} (cm^2) = L x B x K x N

Where is L = length of leaf in cm

B = Breadth of leaf in cm

K = leaf area constant (0.68869, Pawar, 1978)

N = number of leaves under that group

The summation of leaf area of all three groups in dm^2 calculated

3.5.5 Number of branches

Number of branches born on main shoot of a plant were counted and recorded at an interval of 15 days from 30 days onwards.

3.5.6 Number of pods plant^{-1}

The number of pods plant^{-1} were counted and recorded periodically on plant basis.

3.5.7 Dry matter accumulation

The weight of dry matter is an index of productive capacity of the plant. Hence, one representative plant from gross plot was randomly uprooted at each observation i.e. at 30, 45, 60, 75 days and finally at harvest. The roots of plant uprooted for dry matter study from each gross plot were removed. This separated plant was sun dried in the first instance and oven dried at 65 $\pm$ 2°C temperature till constant weight obtained. The constant weight was recorded as total dry matter weight (g) per plant for each treatment.

3.6 Post harvest studies

3.6.1 Grain yield plant^{-1} (g)

Weight of grain plant^{-1} was recorded after harvest. The samples constituted of five randomly selected plants from each net plot were cleaned and mean weight was recorded in gram.

3.6.2 Test weight (g)

One thousand representative seeds counted from the produce of net plot and their weight was recorded in grams as test weight.

3.6.3 Pod yield plant^{-1} (g)

The pods obtained from each plant were dried and weighed in gram.

3.6.4 Number of grains plant^{-1}

The total number of grains plant^{-1} from observational plant was counted.

3.7 Yield

3.7.1 Grain yield per plot

The plants from each net plot were threshed and grains were cleaned. The cleaned grains obtained from each net plot were weighted in kg which was then converted in to grain yield (kg ha^{-1}) by multiplying with hectare factor.

3.7.2 Straw yield plot^{-1}

After separation of grains from biological yield, remaining material (straw+ husk) was considered as straw yield and its final weights were recorded in kg per net plot, which was then converted in to straw yield (kg ha^{-1}) by multiplying with hectare factor.

3.7.3 Biological yield per net plot

The biological yield was recorded by the following formula.

Biological yield= Seed yield + Straw yield

3.7.4 Harvest index

Harvest index indicates the efficiency of plant material to convert the photosynthate in to the economic yield and it is worked out as

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Total biological yield (kg ha}^{-1})} \text{ X } 100$$

Biological yield = Seed yield + Straw weight + pod husk

Where, straw yield = Stalks + leaves

3.8 CHEMICAL ANALYSIS

3.8.1 Oil percentage in seed

Oil percentage in seed was estimated by Soxhlet ether extraction method.

3.8.2 Crude protein content

Nitrogen percentage was estimated by micro kjeldahal method (A.O.A.C., 1975). Crude protein percentage of grain was estimated by multiplying the nitrogen percentage by 6.25.

3.8.3 Available nitrogen

It was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956).

3.8.4 Available phosphorus

Phosphorus was extracted from the soil with 0.5M sodium bicarbonate by Olsen's method as described by Jackson (1967).

3.8.5 Available potassium

It was determined with neutral normal NH_4OH and potassium in extract was determined on Flame photometer (Piper, 1966).

3.9 Plant Growth analysis

Data on growth character were further used for working out following growth characters.

3.9.1 Absolute growth rate (AGR)

The rate of increase in growth variable (W) at the time (t) is called as absolute growth rate (AGR). AGR of two growth variables *viz.,*plant height and total dry matter weight were worked out by using following formula given by Richards (1969).

1. For height

$$AGR = \frac{H_2 - H_1}{t_2 - t_1} cm\ day^{-1}$$

2. For dry matter

$$AGR = \frac{W_2 - W_1}{t_2 - t_1} gm\ day^{-1}$$

Where,

H_2 and H_1 as well as W_2 and W_1 refer to the plant height and total dry matter weight of plant at time t_2 and t_1, respectively.

3.9.2 Relative growth rate (RGR)

Blackman (1919) pointed out that increase in dry matter of plant is a process of continuous compound interest, when the increments produced in any time interval are added to the capital for the growth in subsequent period. The rate of increment is called as relative growth rate (RGR). This is calculated by formula as given below and expressed in g g^{-1} day^{-1}.

$$RGR = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

Where,

Log_e – Natural Logarithms (2.3026)

W_1 and W_2 are the weight of total dry matter at time t_1 and t_2 respectively.

3.9.3 Leaf area index (LAI)

Since, the crop yield is to be assessed per unit of ground area instead of per plant, the leaf area existing on unit ground area was proposed by Watson (1952). The measure is known as leaf area index.

$$LAI = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Ground area per plant (cm}^2\text{)}}$$

3.10 Statistical analysis and interpretation of data

Data obtained on various variables were analyzed by "analysis of variance method" (Panse and Sukhatme, 1967).The total variance (S^2) and d.f. (n-1) divided into different possible sources. The variance due to replication and treatment effects were calculated and compared with error variance for finding out "F" values and ultimately for testing the significance at $P = 0.05$ wherever the results were found significant. Critical difference was calculated for comparison of treatment mean at 5 per cent level of significance where results are significant.

3.10.1 Simple correlation

Correlation studies were taken up between seed yield $plant^{-1}$ in relation to various important growths and yield attributes.

3.10.1.1 Simple correlation studies

Simple correlation co-efficient ('r' values) were computed between weight of seed $plant^{-1}$ (y) and the morphological characters (Xn) *viz.,*

X_1 - Plant height (cm) at harvest.

X_2 - Leaf area in cm^2 $plant^{-1}$ at harvest.

X_3 - Number of branches $plant^{-1}$ at harvest.

X_4 - Total dry matter $plant^{-1}$ at harvest.

X_5 - Test weight

X_6 - pod yield $plant^{-1}$(g)

X_7 - Seed yield $plant^{-1}$ (g)

The procedure and formula described by Snedecor and Cochran (1968) were adopted and significance was tested.

$$r = \frac{\Sigma\, xy}{\sqrt{(\Sigma x)(\Sigma y)}}$$

Where,

r = Correlation coefficient

x = Independent variable (attributes)

y = Dependent variable (yield)

3.11 Economics

3.11.1 Gross monetary returns

The gross monetary returns (₹ ha^{-1}) occurred due to different treatments in the present study were worked out by considering market prices of economic product, by product and crop residues during the experimental year.

3.11.2 Cost of cultivation

The cost of cultivation (₹ ha^{-1}) of each treatment was worked out by considering the price of inputs, charges for cultivation, labour, land and other charges.

3.11.3 Net monetary returns

The net monetary returns (₹ ha^{-1}) of each treatment were worked out by deducting the mean cost of cultivation (₹ ha^{-1}) of each treatment from the gross monetary returns (₹ ha^{-1}) gained from the respective treatments.

3.11.4 Benefit : cost ratio

The benefit: cost ratio of each treatment was calculated by dividing the gross monetary returns by the mean cost of cultivation.

EXPERIMENTAL FINDINGS

CHAPTER - IV

EXPERIMENTAL FINDINGS

The field experiment on soybean (*Glycine max* (L.) Merill) entitled **"Effect of growth regulators on growth and yield of soybean *(Glycine max* (L.) Merill)"** was conducted during *kharif* 2015-16 at Experimental Farm of Agronomy section, College of Agriculture, Latur. The summarized data on growth and yield parameters, statistical parameters and results are presented in this chapter.

4.1 Pre harvest studies

4.1.1 Emergence count and final plant stand

Data on mean emergence count and final plant stand as influenced by different treatments in arcsine values is presented in Table 6.

Data presented in Table 6 revealed that the mean emergence and mean final plant stand at harvest were 76.65 and 70.23 respectively, and were not influenced statistically by different treatments. This indicated that the crop stand was uniform and differences in the treatments on various parameters under study were due to treatment effects.

4.2 Biometric observation

4.2.1 Plant height

Data pertaining to the effect of various treatments on plant height are presented in Table 7 and depicted in Fig.(3). The mean plant height of soybean at 30, 45, 60, 75 and 90 DAS was 15.99, 21.66, 26.10, 30.19 and 30.37 cm respectively.

The perusal of data in Table 7 revealed that mean plant height plant^{-1} was increased continuously at each successive crop growth stages and reached maximum at harvest.The rate of increase in plant height was very fast upto 30 DAS, fast between 30-45 days and slow thereafter. Mean height plant^{-1} was influenced significantly by various treatments under study.

The plant height of soybean was influenced significantly at all growth stages of the crop except 30 DAS. At 45 DAS, maximum plant height (25.33 cm) was recorded with the foliar application of GA 60 ppm (T_4) which was at par with foliar application of GA 40 ppm (T_3), GA 20 ppm (T_2) and NAA 60 ppm (T_7) and found significantly superior over rest of the treatments.

Table 6: Emergence count and final plant stand (Arcsine values) of soybean as influenced by different treatmens

Treatments	Emergence count	Final plant stand
T_1- RDF	76.41	70.15
T_2- RDF + GA 20 ppm	76.97	70.42
T_3- RDF + GA 40 ppm	77.71	69.97
T_4- RDF + GA 60 ppm	77.71	70.88
T_5- RDF + NAA 20 ppm	75.93	69.68
T_6- RDF + NAA 40 ppm	75.71	69.63
T_7- RDF + NAA 60 ppm	77.31	70.82
T_8- RDF + CCC 200 ppm	75.32	69.30
T_9- RDF + CCC 250 ppm	76.37	69.79
T_{10}- RDF + CCC 300 ppm	76.44	70.05
T_{11}- RDF + water spray at moisture stress up to 45 DAS	78.28	71.89
SE $\pm$	1.63	1.31
C.D. at 5%	NS	NS
General Mean	**76.65**	**70.23**

At 60 DAS, maximum plant height (30.59 cm) was recorded when crop was sprayed with the foliar application of GA 60 ppm (T_4) which was at par with foliar application of GA 40 ppm (T_3) and GA 20 ppm (T_2) and found significantly superior over rest of the treatments.

At 75 DAS and at harvest maximum plant height was found with the foliar application of GA 60 ppm (T_4) which was at par with foliar application of GA 40 ppm (T_3), GA 20 ppm (T_2) and NAA 60 ppm (T_7) and found significantly superior over rest of the treatments.

Minimum height of soybean plants was observed with the application of CCC 300 ppm.

Table 7. Mean plant height (cm) of soybean as influenced by different treatments at various crop growth stages

Treatments	Days after sowing				At harvest
	30	45	60	75	
T_1- RDF	15.65	19.93	24.84	28.86	29.01
T_2- RDF + GA 20 ppm	16.35	23.13	28.12	32.22	32.40
T_3- RDF + GA 40 ppm	16.61	23.50	28.33	33.30	33.45
T_4- RDF + GA 60 ppm	16.69	25.33	30.59	35.25	35.47
T_5- RDF + NAA 20 ppm	15.99	21.57	26.09	29.50	29.65
T_6- RDF + NAA 40 ppm	16.06	22.17	26.33	30.06	30.25
T_7- RDF + NAA 60 ppm	16.13	22.47	26.73	30.99	31.14
T_8- RDF + CCC 200 ppm	15.57	20.51	23.92	28.83	28.98
T_9- RDF + CCC 250 ppm.	15.54	20.14	23.50	27.07	27.30
T_{10}- RDF + CCC 300 ppm	15.47	19.09	23.19	27.00	27.18
T_{11}- RDF + water spray at moisture stress up to 45 DAS	15.80	20.47	25.40	29.03	29.18
SE ±	0.75	0.99	1.3	1.52	1.52
C.D. at 5%	NS	2.93	3.83	4.49	4.49
General Mean	**15.99**	**21.66**	**26.10**	**30.19**	**30.37**

4.2.2 Number of functional leaves plant^{-1}

Data pertaining to the effect of various treatments on number of functional leaves plant^{-1} are presented in Table 8. The mean number of functional leaves of soybean at 30, 45, 60 and 75 DAS was 3.75, 8.68, 10.54 and 8.52 respectively.

Data presented in Table 8 revealed that the number of functional leaves plant^{-1} was increased continuously up to 60 days and then decreased thereafter at maturity due to leaf senescence.

At 30 DAS mean number of functional leaves plant^{-1} remained statistically uninfluenced due to different treatments.

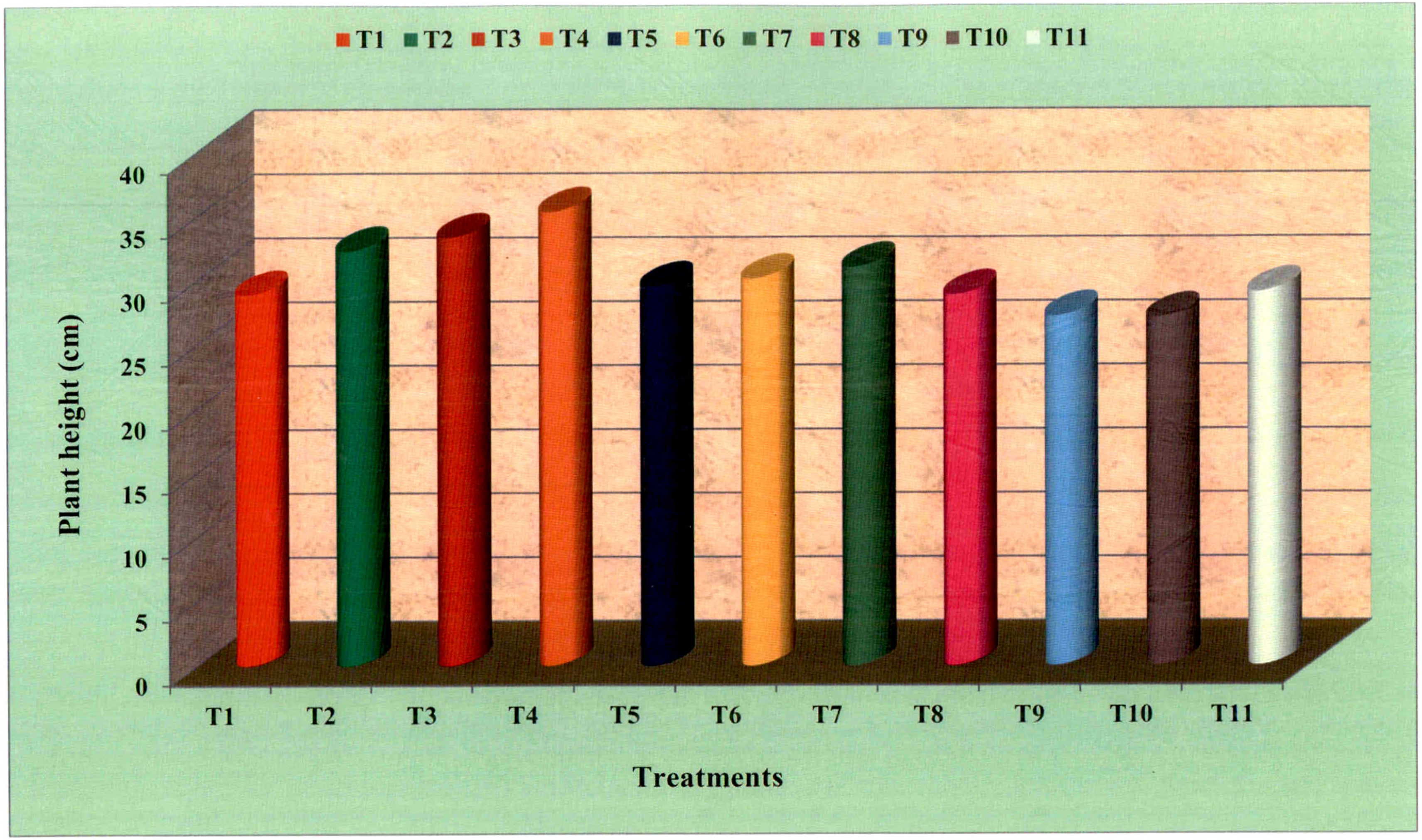

Fig:3 Mean plant height (cm) of soybean as influenced by different treatments at harvest

Table 8: Mean number of functional leaves as influenced by various treatments at different crop growth stages

Treatments	Days after sowing			
	30	45	60	75
T_1- RDF	3.67	7.47	9.13	7.13
T_2- RDF + GA 20 ppm	3.67	9.27	11.66	9.59
T_3- RDF + GA 40 ppm	3.60	9.73	11.83	9.70
T_4- RDF + GA 60 ppm	3.80	10.33	12.97	10.90
T_5- RDF + NAA 20 ppm	3.73	8.50	10.40	8.40
T_6- RDF + NAA 40 ppm	3.40	8.77	10.83	8.83
T_7- RDF + NAA 60 ppm	3.87	9.00	11.28	9.28
T_8- RDF + CCC 200 ppm	4.00	8.13	9.33	7.33
T_9- RDF + CCC 250 ppm	3.87	8.27	9.43	7.43
T_{10}- RDF + CCC 300 ppm	3.80	8.20	9.80	7.83
T_{11}- RDF + water spray at moisture stress up to 45 DAS	3.87	7.80	9.23	7.23
SE $\pm$	0.21	0.48	0.63	0.48
C.D. at 5%	NS	1.42	1.85	1.43
General Mean	**3.75**	**8.68**	**10.54**	**8.52**

At 45 and 60 DAS maximum number of functional leaves plant^{-1} were observed with the foliar application of of GA 60 ppm (T_4) which was at par with foliar application of GA 40 ppm (T_3), GA 20 ppm (T_2) and NAA 60 ppm (T_7) and found significantly superior over rest of the treatments.

At 75 DAS the foliar application of GA 60 ppm (T_4) recorded significantly higher number of functional leaves plant^{-1} which was at par with foliar application of GA 40 ppm (T_3), GA 20 ppm (T_2) and found significantly superior over rest of the treatments.

4.2.3 Leaf area plant^{-1} (dm^2)

Data pertaining to leaf area plant^{-1} influenced by various treatments are presented in Table 9 and depicted in Fig.(4). The mean leaf area per plant of soybean at 30, 45, 60 and 75 DAS was 2.75, 5.66, 8.99 and 7.35 dm^2 respectively.

Table 9. Mean leaf area plant^{-1} (dm^2) as influenced by various treatments at different crop growth stages

Treatments	Days after sowing			
	30	45	60	75
T_1- RDF	2.60	4.83	7.53	6.07
T_2- RDF + GA 20 ppm	2.67	6.45	10.69	8.36
T_3- RDF + GA 40 ppm	2.60	7.03	10.80	8.97
T_4- RDF + GA 60 ppm	2.80	6.13	10.20	8.20
T_5- RDF + NAA 20 ppm	2.73	5.93	8.27	7.07
T_6- RDF + NAA 40 ppm	2.40	5.71	8.08	6.96
T_7- RDF + NAA 60 ppm	2.87	5.59	8.01	6.79
T_8- RDF + CCC 200 ppm	3.00	5.30	8.40	7.13
T_9- RDF + CCC 250 ppm	2.87	5.03	8.81	7.18
T_{10}- RDF + CCC 300 ppm	2.80	5.23	9.11	7.63
T_{11}- RDF + water spray at moisture stress up to 45 DAS	2.87	5.07	7.90	6.50
SE $\pm$	0.18	0.31	0.45	0.32
C.D. at 5%	NS	0.92	1.34	0.96
General Mean	**2.75**	**5.66**	**8.89**	**7.35**

Data presented in Table 9 showed that the mean leaf area plant^{-1} was increased continuously at faster rate up to 60 days and decreased thereafter.

Mean leaf area plant^{-1} of soybean was influenced significantly at all growth stages except, 30 DAS.

At 45, 60 and 75 DAS maximum mean leaf area of plant^{-1} was observed with the foliar application of of GA 40 ppm (T_3) which was at par with

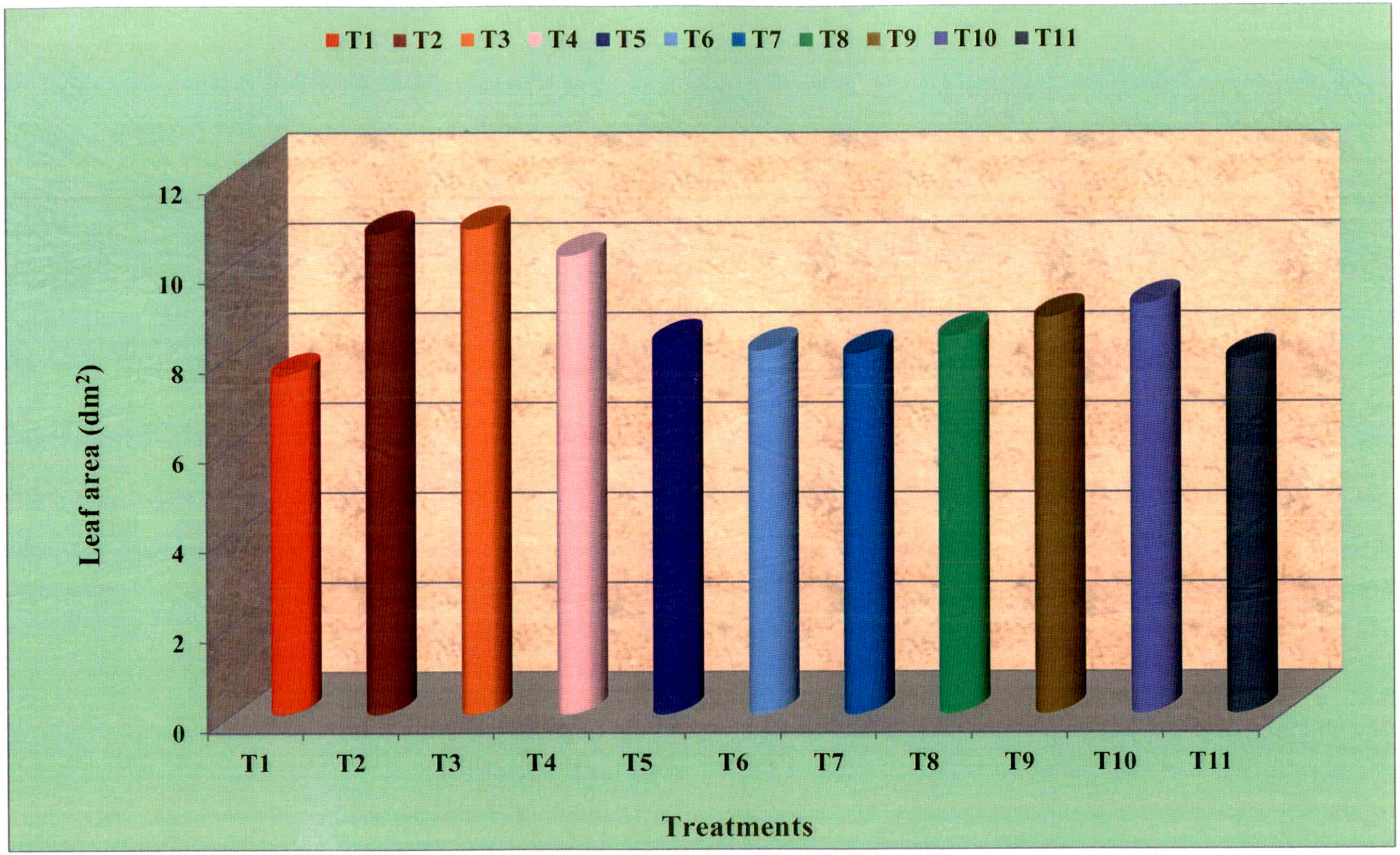

Fig : 4 Mean leaf area per plant (dm^2) as influenced by various treatments at 60 DAS foliar application of GA 20 ppm (T_2), GA 60 ppm (T_4) and was significantly superior over rest of the treatments.

4.2.4 Number of branches plant^{-1}

Data pertaining to the effect of various treatments on number of branches plant^{-1} are presented in Table 10. The mean number of branches of soybean at 45, 60 75 and at harvest DAS was 4.69, 8.38, 9.35 and 9.35 respectively.

Data revealed that the mean number of branches plant^{-1} were gradual up to 75 DAS and remained static at maturity. The rate of increase was faster during early stages. The maximum mean number of branches recorded at 75 DAS (9.35).

Table 10. Number of branches plant^{-1} as influenced by various treatments at different crop growth stages

Treatments	Days after sowing			At harvest
	45	60	75	
T_1- RDF	3.93	7.33	8.27	8.27
T_2- RDF + GA 20 ppm	5.53	9.47	10.53	10.53
T_3- RDF + GA 40 ppm	5.60	9.60	10.80	10.80
T_4- RDF + GA 60 ppm	5.20	9.03	9.93	9.93
T_5- RDF + NAA 20 ppm	4.97	8.07	9.03	9.03
T_6- RDF + NAA 40 ppm	4.73	8.00	8.87	8.87
T_7- RDF + NAA 60 ppm	4.63	7.87	8.77	8.77
T_8- RDF + CCC 200 ppm	4.10	8.13	9.13	9.13
T_9- RDF + CCC 250 ppm	4.52	8.30	9.37	9.37
T_{10}- RDF + CCC 300 ppm	4.27	8.87	9.80	9.80
T_{11}- RDF + water spray at moisture stress up to 45 DAS	4.07	7.57	8.30	8.30
SE ±	0.24	0.42	0.43	0.43
C.D. at 5%	0.73	1.24	1.29	1.29
General Mean	**4.69**	**8.38**	**9.35**	**9.35**

The mean number of branches plant^{-1} were influenced significantly at all growth stages. At 45 DAS application of GA 40 ppm recorded significantly higher number of branches $plant^{-1}$ which was at par with the application of GA 20 ppm (T_2), GA 60 ppm (T_4) and NAA 20 ppm (T_5) and significantly superior over rest of the treatments.

At 60, 75 and at harvest maximum number of branches were recorded with the foliar application of of GA 40 ppm (T_3) which was at par with application of GA 20 ppm (T_2), GA 60 ppm (T_4) and CCC 300 ppm ppm (T_{10}) and found significantly superior over rest of the treatments.

4.2.5 Total dry matter accumulation

The data pertaining to mean total dry matter accumulation $plant^{-1}$ (g) at various growth stages as influenced by different treatments are presented in Table 11 and depicted in Fg (5). The mean dry matter of soybean at 30, 45, 60 75 and 90 DAS was 2.73, 5.92, 12.65, 14.08 and 14.75 g respectively.

The process of dry matter accumulation $plant^{-1}$ was continuous from emergence to at harvest . The rate of increase in drymatter $plant^{-1}$ was slow between 0-30 days, fast between between 30-45 days, very fast between 45-60 days and again slow thereafter till maturity.

Mean total dry matter accumulation $plant^{-1}$ was influenced significantly at all growth stages except 30 DAS. At 45 DAS, maximum total dry matter (6.90 g) per plant was recorded with the foliar application of of GA 60 ppm (T_4) which was at par with foliar application of GA 40 ppm (T_3), GA 20 ppm (T_2) and NAA 60 ppm (T_7) and found significantly superior over rest of the treatments.

At 60, 75 and at harvest application of GA 40 ppm (T_3) recorded maximum total dry matter $plant^{-1}$ which was at par with foliar application of GA 20 ppm (T_2) and GA 60 ppm (T_4) and found significantly superior over rest of the treatments.

Table 11. Dry matter plant^{-1} (g) as influenced by different treatments at various crop growth stages

Treatments	Days after sowing				At harvest
	30	45	60	75	
T_1- RDF	2.57	5.13	10.53	12.00	12.57
T_2- RDF + GA 20 ppm	2.63	6.40	13.83	15.20	15.93
T_3- RDF + GA 40 ppm	2.83	6.63	15.10	16.50	17.27
T_4- RDF + GA 60 ppm	2.67	6.90	13.60	15.00	15.70
T_5- RDF + NAA 20 ppm	2.67	5.97	12.50	14.03	14.50
T_6- RDF + NAA 40 ppm	2.62	6.03	11.77	13.17	14.37
T_7- RDF + NAA 60 ppm	2.90	6.23	11.60	13.00	13.60
T_8- RDF + CCC 200 ppm	2.77	5.33	12.90	14.40	14.90
T_9- RDF + CCC 250 ppm	2.73	5.67	13.17	14.57	15.13
T_{10}- RDF + CCC 300 ppm	3.00	5.60	13.43	14.73	15.40
T_{11}- RDF + water spray at moisture stress up to 45 DAS	2.60	5.23	10.77	12.27	12.83
SE $\pm$	0.18	0.27	0.54	0.57	0.58
C.D. at 5%	NS	0.81	1.60	1.68	1.70
General Mean	**2.73**	**5.92**	**12.65**	**14.08**	**14.75**

4.2.6 Number of nodules plant^{-1}

Data on mean number of nodules plant^{-1} as influenced periodically by various treatments are shown in Table 12. The mean number of nodules of soybean at 30, 45, 60 and 75 DAS was 10.56, 22.09, 37.23 and 25.33 respectively.

Data presented in Table 12 showed that the mean number of nodules plant^{-1} was increased at faster rate up to 60 days and thereafter decreased gradually due to drying of nodules.

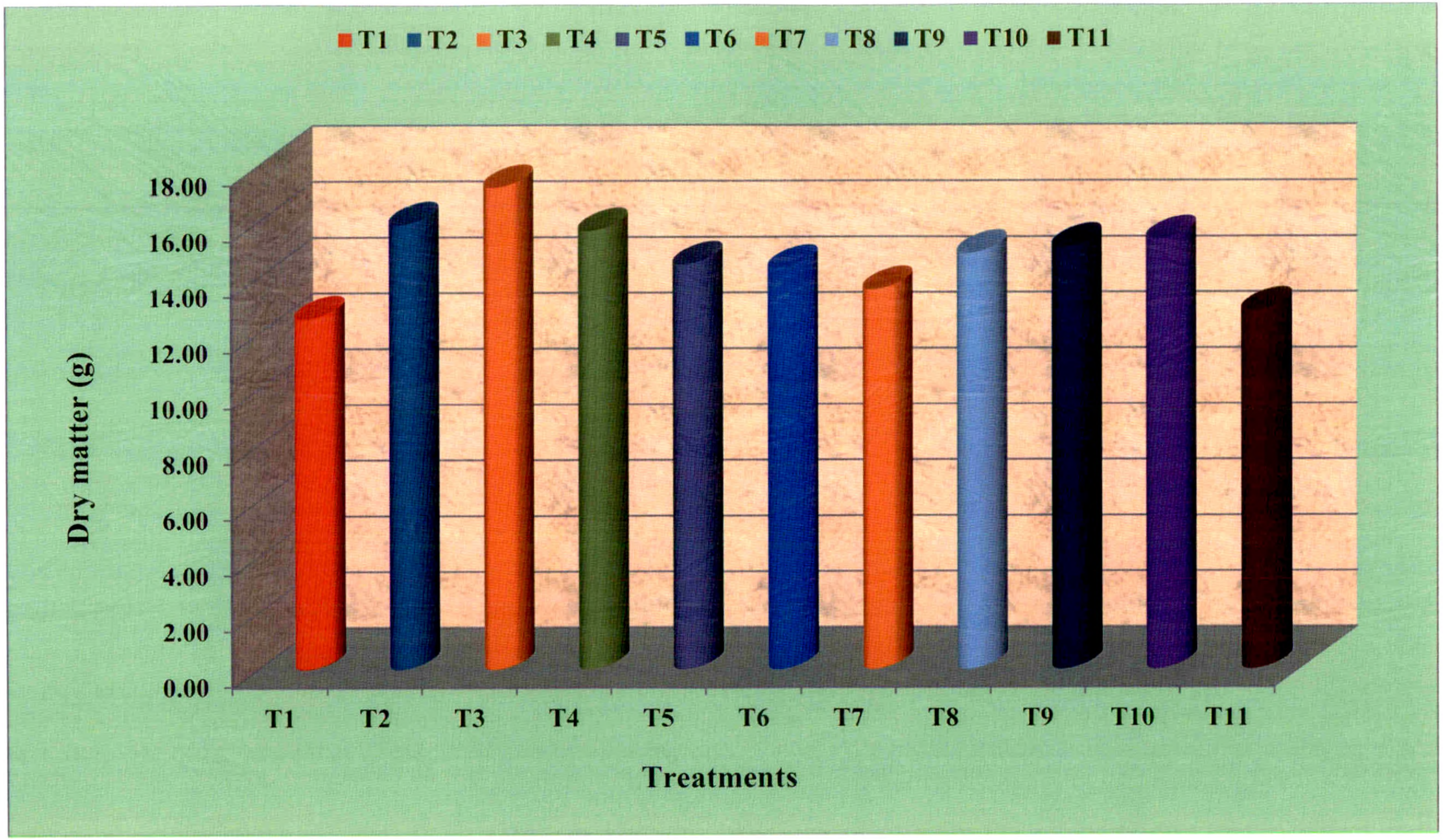

Fig:5 Mean total dry matter per plant (g) as influenced by different treatments at harvest

Table 12. Number of nodules plant^{-1} as influenced periodically by different treatments at various crop crop growth stages

Treatments	Days after sowing			
	30	45	60	75
T_1- RDF	10.03	19.00	34.00	22.67
T_2- RDF + GA 20 ppm	9.10	24.33	39.67	27.00
T_3- RDF + GA 40 ppm	10.50	25.33	40.17	28.33
T_4- RDF + GA 60 ppm	10.20	25.67	42.67	29.00
T_5- RDF + NAA 20 ppm	11.27	21.67	36.67	25.00
T_6- RDF + NAA 40 ppm	11.50	22.33	37.00	25.33
T_7- RDF + NAA 60 ppm	10.13	23.67	38.33	26.00
T_8- RDF + CCC 200 ppm	9.50	20.00	35.00	23.67
T_9- RDF + CCC 250 ppm	11.00	21.33	35.33	24.00
T_{10}- RDF + CCC 300 ppm	11.80	20.33	36.00	24.33
T_{11}- RDF + water spray at moisture stress up to 45 DAS	10.33	19.33	34.67	23.33
SE $\pm$	0.56	1.04	1.53	1.14
C.D. at 5%	NS	3.07	4.51	3.38
General Mean	**10.56**	**22.09**	**37.23**	**25.33**

At 30 DAS, mean number of nodules plant^{-1} was not influenced significantly due to different treatments. At 45, 60 and 75 DAS, the higher number of nodules plant^{-1} were recorded with the foliar application of of GA 60 ppm (T_4) which was at par with foliar application of GA 40 ppm (T_3), GA 20 ppm (T_2) and NAA 60 ppm (T_7) and found significantly superior over rest of the treatments.

4.2.7 Number of pods plant^{-1}

Data on mean number of pods plant^{-1} as influenced periodically by various treatments are presented in Table 13 and decipited in Fig (6) . It was observed from data that the number of pods plant^{-1} was progressively increased from 60 days onwards to till maturity. The mean number of pods plant^{-1} at 60, 75 and at harvest were 16.80, 19.90 and 20.85 respectively.

Table 13. Mean number of pods plant^{-1} as influenced by various treatments at different growth stages

Treatments	Days after sowing		At harvest
	60	75	
T_1- RDF	14.73	17.67	18.73
T_2- RDF + GA 20 ppm	19.07	21.63	22.53
T_3- RDF + GA 40 ppm	21.20	23.03	23.97
T_4- RDF + GA 60 ppm	18.13	21.13	22.03
T_5- RDF + NAA 20 ppm	16.07	19.23	20.13
T_6- RDF + NAA 40 ppm	15.90	18.80	19.80
T_7- RDF + NAA 60 ppm	15.80	18.70	19.80
T_8- RDF + CCC 200 ppm	16.23	19.90	20.80
T_9- RDF + CCC 250 ppm	16.33	20.20	21.13
T_{10}- RDF + CCC 300 ppm	16.47	20.63	21.53
T_{11}- RDF + water spray at moisture stress up to 45 DAS	14.90	17.93	18.83
SE ±	0.78	0.80	0.81
C.D. at 5%	2.31	2.35	2.40
General Mean	**16.80**	**19.90**	**20.85**

At 60 DAS, application of GA 40 ppm (T_3) recorded maximum number of pods plant^{-1} (21.20) which was at par with foliar application of GA 20 ppm (T_2) and was significantly superior over rest of the treatments.

At 75 and 90 DAS, maximum number of pods plant^{-1} were produced with the foliar application GA 40 ppm (T_3) which was at par with foliar application of GA 20 ppm (T_2) and GA 60 ppm (T_4) and found significantly superior over rest of the treatments.

Least number of pods were recorded under control plots where growth regulator was not applied.

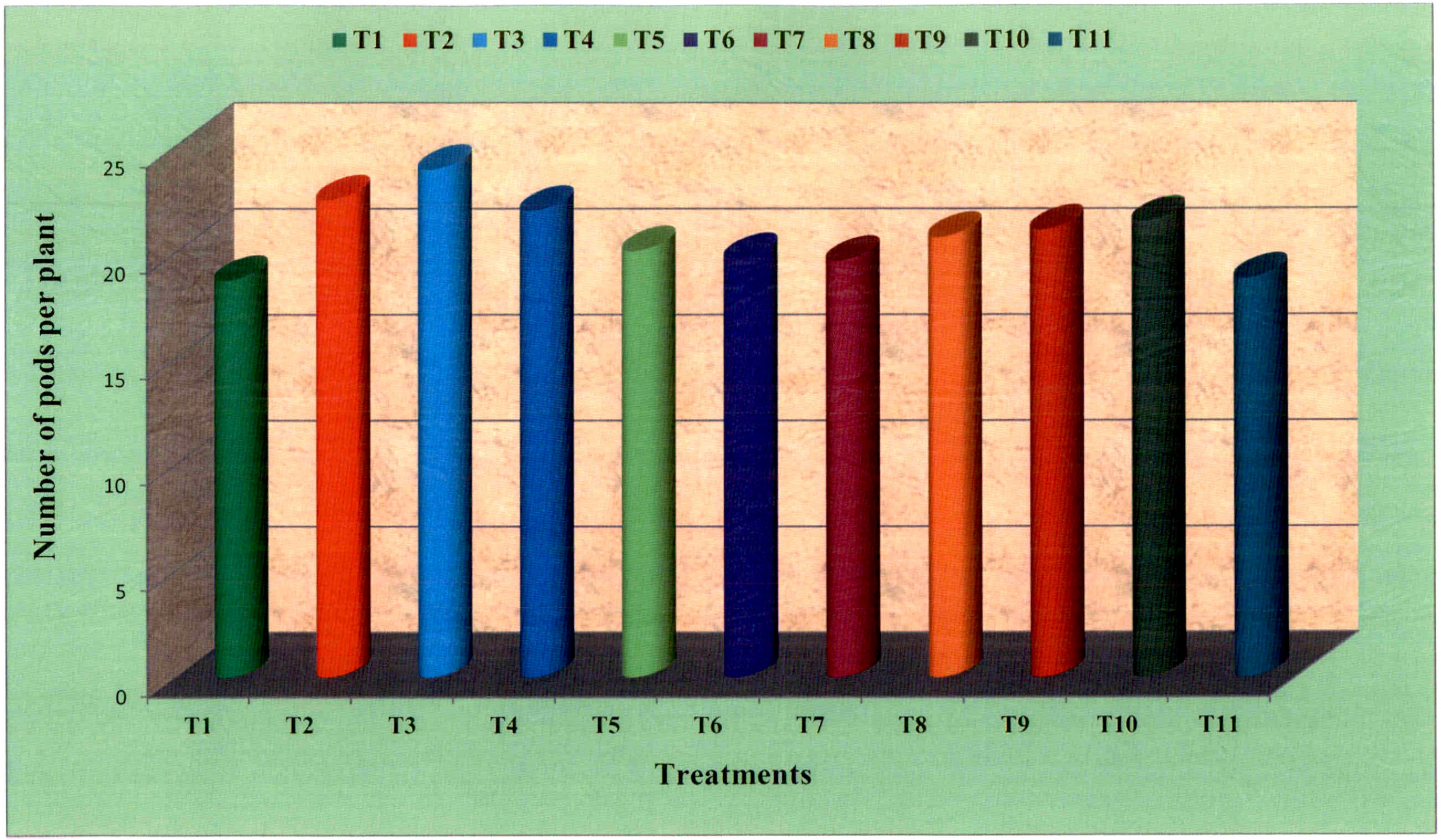

Fig:6 Mean number of pods per plant as influenced by various treatments at harvest

4.3 Growth Analysis

Data on growth characters *viz.,* plant height, dry matter and leaf area per plant were further subjected for the computation of different growth function, *viz.,* AGR, RGR and LAI. The inferences were drawn on mean value basis.

4.3.1 Absolute Growth Rate (AGR) for height (cm day^{-1} plant^{-1})

Data on AGR for height in (cm day^{-1} plant^{-1}) at various crop growth stages are presented in Table 14. The mean of AGR rate during 0-30, 31-45, 46-60, 61-75, 76-at harvest was 0.533, 0.379, 0.295, 0.273, 0.017 cm respectively.

The absolute growth rate for height was very- very fast between 0-30 days, very fast between 31-45 days, fast between 46-60 days and slow thereafter. The maximum value of AGR for plant height was observed with the application of GA 60 ppm (T_4) between 31-45 and 46-60 days.

Table 14: Mean Absolute Growth Rate (AGR) for plant height (cm day^{-1} plant^{-1}) as influenced by various treatments at different growth stages

Treatments	Between days after sowing				76-At harvest
	0-30	31-45	46-60	61-75	
T_1- RDF	0.522	0.285	0.327	0.268	0.015
T_2- RDF + GA 20 ppm	0.545	0.452	0.333	0.273	0.019
T_3- RDF + GA 40 ppm	0.554	0.460	0.322	0.331	0.015
T_4- RDF + GA 60 ppm	0.556	0.576	0.351	0.311	0.021
T_5- RDF + NAA 20 ppm	0.533	0.372	0.302	0.227	0.015
T_6- RDF + NAA 40 ppm	0.535	0.408	0.277	0.248	0.019
T_7- RDF + NAA 60 ppm	0.538	0.422	0.284	0.284	0.015
T_8- RDF + CCC 200 ppm	0.519	0.329	0.228	0.328	0.015
T_9- RDF + CCC 250 ppm	0.518	0.307	0.224	0.238	0.023
T_{10}- RDF + CCC 300 ppm	0.516	0.242	0.273	0.254	0.018
T_{11}- RDF + water spray at moisture stress up to 45 DAS	0.527	0.311	0.329	0.242	0.015
General Mean	**0.533**	**0.379**	**0.295**	**0.273**	**0.017**

The differences in AGR for plant height due to different treatments were not consistent 60 days onwards. The maximum value of AGR was (0.576 cm day^{-1} plant-1) observed due to foliar application of GA 60 ppm during 31-45 days.

4.3.2 Absolute Growth Rate (AGR) for dry matter (g day^{-1} $plant^{-1}$)

The data on AGR for dry matter (g day^{-1} $plant^{-1}$) are presented in Table 15.

The mean AGR for dry matter during 0-30, 31-45, 46-60, 61-75, 76-at harvest was 0.091, 0.213, 0.449, 0.095 and 0.067 g/day/plant respectively.

The absolute growth rate for dry matter was slow between 0-30 days, fast between 31-45 days, very fast between 46-60 and thereafter decreased towards maturity. The difference in AGR for dry matter due to differement treatments were not consistant. However, AGR attained its maximum mean value (0.449 g day^{-1} $plant^{-1}$) during 46-60 DAS of crop.

Table 15: Mean Absolute Growth Rate (AGR) for dry matter (g day^{-1} $plant^{-1}$) as influenced by various treatments at different growth stages

Treatments	Between days after sowing				76-At harvest
	0-30	31-45	46-60	61-75	
T_1- RDF	0.086	0.171	0.360	0.098	0.057
T_2- RDF + GA 20 ppm	0.088	0.240	0.507	0.091	0.073
T_3- RDF + GA 40 ppm	0.094	0.256	0.562	0.093	0.077
T_4- RDF + GA 60 ppm	0.089	0.282	0.447	0.093	0.070
T_5- RDF + NAA 20 ppm	0.089	0.220	0.436	0.102	0.047
T_6- RDF + NAA 40 ppm	0.087	0.227	0.382	0.093	0.120
T_7- RDF + NAA 60 ppm	0.097	0.233	0.347	0.093	0.060
T_8- RDF + CCC 200 ppm	0.092	0.171	0.504	0.100	0.050
T_9- RDF + CCC 250 ppm	0.091	0.196	0.500	0.093	0.057
T_{10}- RDF + CCC 300 ppm	0.100	0.173	0.522	0.087	0.067
T_{11}- RDF + water spray at moisture stress up to 45 DAS	0.087	0.176	0.369	0.100	0.057
General Mean	**0.091**	**0.213**	**0.449**	**0.095**	**0.067**

4.3.3 Relative Growth Rate (RGR) for dry matter (g g^{-1} day^{-1})

The data on RGR for dry matter (g $plant^{-1}$ day^{-1}) is presented in Table 16. The mean AGR at 0-30, 31-45, 46-60, 61-75, 76-at harvest was 0.033, 0.052, 0.051, 0.007 and 0.005 (g g^{-1} day^{-1}).

The maximum mean value of RGR for dry matter was observed during 31-45 DAS (0.052 g g^{-1} day^{-1}). The differences in RGR values due to different treatments were not consistant. The highest value of RGR (0.063 g g^{-1} day^{-1}) was recorded when crop was supplied GA 60 ppm at 31-45 days.

Table 16: Mean Relative Growth Rate (RGR) for dry matter (g g^{-1} day^{-1}) as influenced by different treatments at various crop growt stages

Treatments	Between days after sowing				76-At harvest
	0-30	31-45	46-60	61-75	
T_1- RDF	0.031	0.046	0.048	0.009	0.005
T_2- RDF + GA 20 ppm	0.032	0.057	0.053	0.006	0.005
T_3- RDF + GA 40 ppm	0.035	0.057	0.055	0.006	0.005
T_4- RDF + GA 60 ppm	0.033	0.063	0.045	0.007	0.005
T_5- RDF + NAA 20 ppm	0.033	0.054	0.049	0.008	0.003
T_6- RDF + NAA 40 ppm	0.032	0.056	0.045	0.007	0.009
T_7- RDF + NAA 60 ppm	0.035	0.053	0.040	0.008	0.005
T_8- RDF + CCC 200 ppm	0.034	0.044	0.059	0.007	0.003
T_9- RDF + CCC 250 ppm	0.034	0.049	0.056	0.007	0.004
T_{10}- RDF + CCC 300 ppm	0.037	0.042	0.058	0.006	0.004
T_{11}- RDF + water spray at moisture stress up to 45 DAS	0.032	0.047	0.048	0.009	0.005
General Mean	**0.033**	**0.052**	**0.051**	**0.007**	0.005

4.3.4 Leaf area index (LAI)

The data on leaf area index (LAI) is presented in Table 17. The mean LAI value at 30, 45, 60 and 75 DAS was 1.22, 2.52, 3.95 and 3.27. The leaf area index was low at initial stages of crop growth, gradually increased up to 60 days after sowing and thereafter it decreased toward the maturity of the crop. The highest mean LAI (3.95) was recorded at 60 days after the sowing.

Maximum LAI was observed when soybean crop was sprayed with GA 40 ppm (T_3) almost at all growth stages. It was followed by application of GA 20 ppm (T_2).

Table 17: Mean leaf area index (LAI) of soybean as influenced by different treatments at various crop growth stages

Treatments	Days after sowing			
	30	45	60	75
T_1- RDF	1.16	2.15	3.35	2.70
T_2- RDF + GA 20 ppm	1.19	2.87	4.75	3.71
T_3- RDF + GA 40 ppm	1.16	3.13	4.80	3.99
T_4- RDF + GA 60 ppm	1.24	2.72	4.53	3.64
T_5- RDF + NAA 20 ppm	1.21	2.63	3.67	3.14
T_6- RDF + NAA 40 ppm	1.07	2.54	3.59	3.09
T_7- RDF + NAA 60 ppm	1.27	2.48	3.56	3.02
T_8- RDF + CCC 200 ppm	1.33	2.36	3.73	3.17
T_9- RDF + CCC 250 ppm	1.27	2.24	3.92	3.19
T_{10}- RDF + CCC 300 ppm	1.24	2.32	4.05	3.39
T_{11}- RDF + water spray at moisture stress up to 45 DAS	1.27	2.25	3.51	2.89
General Mean	**1.22**	**2.52**	**3.95**	**3.27**

4.4 Post harvest studies

4.4.1 Number of pods plant^{-1}

Data on number of pods plant^{-1} as influenced by various treatments is presented in Table 18. The mean number of pods plant^{-1} of soybean was 20.85 at harvest.

The mean number of pods plant^{-1} was influenced significantly due to different treatments. The highest number of pods plant^{-1} (23.97) was observed with the application of GA 40 ppm (T_3) which was at par with GA 20 ppm (T_2) and GA 60 ppm (T_4) and found significantly superior over rest of the treatment.

4.4.2 Pod yield (g plant^{-1})

Data on mean pod yield (g plant^{-1}) as influenced by various treatments is presented in Table 18. The mean pods yield (g plant^{-1}) of soybean was 3.99 g.

The mean pods yield (g plant^{-1}) was influenced significantly due to different treatments. Foliar application of GA 40 ppm (T_3) gave the highest pod yield per plant (5.06 g) which was at par with GA 20 (T_2) and GA 60 ppm (T_4) ppm and found significantly higher over rest of the treatments.

Table 18: Number of pods, Pod weight, number of seeds, seed yield (g) and test weight (g) as influenced by various treatments

Treatments	No. of pods Plant^{-1}	Pod weight Plant^{-1} (g)	No. of seeds plant^{-1}	Seed yield Plant^{-1} (g)	Test weight (g)
T_1- RDF	18.73	3.03	25.00	2.33	98.10
T_2- RDF + GA 20 ppm	22.53	4.79	32.17	3.30	107.81
T_3- RDF + GA 40 ppm	23.97	5.06	34.00	3.59	109.95
T_4- RDF + GA 60 ppm	22.03	4.37	31.00	3.13	107.10
T_5- RDF + NAA 20 ppm	20.13	3.80	27.80	2.60	101.03
T_6- RDF + NAA 40 ppm	19.80	3.62	27.33	2.46	100.45
T_7- RDF + NAA 60 ppm	19.80	3.47	27.00	2.40	99.37
T_8- RDF + CCC 200 ppm	20.80	4.07	28.33	2.82	102.00
T_9- RDF + CCC 250 ppm	21.13	4.30	29.67	2.92	102.33
T_{10}- RDF + CCC 300 ppm	21.53	4.30	30.33	3.08	105.59
T_{11}- RDF + water spray at moisture stress up to 45 DAS	18.83	3.08	26.00	2.36	99.67
SE $\pm$	0.81	0.25	1.17	0.13	4.14
C.D. at 5%	2.40	0.76	3.46	0.41	NS
General Mean	**20.85**	**3.99**	**28.97**	**2.82**	**103.4**

4.4.3 Number of seeds plant^{-1}

Data on number of seeds plant^{-1} as influenced by various treatments is presented in Table 18. The mean number of seeds per plant was 28.97.

The mean number of seeds plant^{-1} was influenced significantly due to different treatments. Foliar application of GA 40 ppm (T_3) produced higher number of seeds (34.0) per plant which was at par with the foliar application of GA 20 ppm (T_2) and GA 60 ppm (T_4) and found significantly superior over rest of the treatments.

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

Data on seed yield (g plant^{-1}) as influenced by various treatments is presented in Table 18. The mean seed yield 2.82 (g plant^{-1}).

The mean seed yield (g plant^{-1}) was influenced significantly due to different treatments. The highest seed yield (g) plant^{-1} (3.59) was recorded with foliar application of GA 40 ppm (T_3) which was at par with GA 20 ppm (T_2) and GA 60 ppm (T_4) and found significantly superior over rest of the treatments.

4.4.5 Test weight (g)

Data on test weight (g) as influenced by various treatments is presented in Table 18. The mean test weight (g) was not influenced significantly due to different treatments.

The mean test was 103.4 g. Numerically higher test weight (109.95 g) was observed with the application of GA 40 ppm (T_3) closely followed by GA 20 ppm (T_2) and GA 60 ppm (T_4).

4.4.6 Seed yield (kg ha^{-1})

Data on seed yield (kg ha^{-1}) as influenced by various treatments is presented in Table 19 and decipited in Fig (7). The mean seed yield was 920 kg ha^{-1}.

The mean seed yield (kg ha^{-1}) was influenced significantly due to different treatments. Data revealed that the application of GA 40 ppm (T_3) recorded in higher seed yield (1072 kg ha^{-1}) which was at par with the application of GA 20 ppm (T_2) and GA 60 ppm (T_4) and found significantly superior over rest of the treatments.

4.4.7 Straw yield (kg ha^{-1})

Data on straw yield (kg ha^{-1}) as influenced by various treatments is presented in Table 19 .The mean straw yield was 1331 kg ha^{-1}.

The mean straw yield was influenced significantly due to different treatments. Data showed that the foliar application of GA 40 ppm (T_3) resulted in higher straw yield (1529 kg ha^{-1}) and it was at par with the foliar application of GA 20 ppm (T_2) and GA 60 (T_4) found significantly superior over rest of the treatments.

Table 19: Mean seed, straw, biological yield and harvest index as influenced by various treatments

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1- RDF	785	1165	1950	40.26
T_2- RDF + GA 20 ppm	1000	1430	2430	41.16
T_3- RDF + GA 40 ppm	1072	1529	2601	41.20
T_4- RDF + GA 60 ppm	987	1413	2400	41.11
T_5- RDF + NAA 20 ppm	906	1309	2214	40.90
T_6- RDF + NAA 40 ppm	899	1307	2205	40.75
T_7- RDF + NAA 60 ppm	892	1305	2197	40.59
T_8- RDF + CCC 200 ppm	909	1312	2221	40.92
T_9- RDF + CCC 250 ppm	913	1316	2228	40.96
T_{10}- RDF + CCC 300 ppm	922	1328	2250	40.98
T_{11}- RDF + water spray at moisture stress up to 45 DAS	834	1228	2063	40.45
SE $\pm$	40	61	104	-
C.D. at 5%	118	180	307	-
General Mean	**920**	**1331**	**2251**	**40.84**

4.4.8 Biological yield (Kg ha^{-1})

Data on biological yield (kg ha^{-1}) as influenced by various treatments is presented in Table 19 and decipited in Fig (7).The mean biological yield was 2251 kg ha^{-1}.

The mean biological yield was influenced significantly due to different treatments. The perusal of data in 19 indicated maximum biological yield (2601 kg ha^{-1}) with the foliar application of GA 40 ppm (T_3) which was at par with the foliar application of GA 20 ppm (T_2) and GA 60 (T_4) and found significantly superior over rest of the treatments.

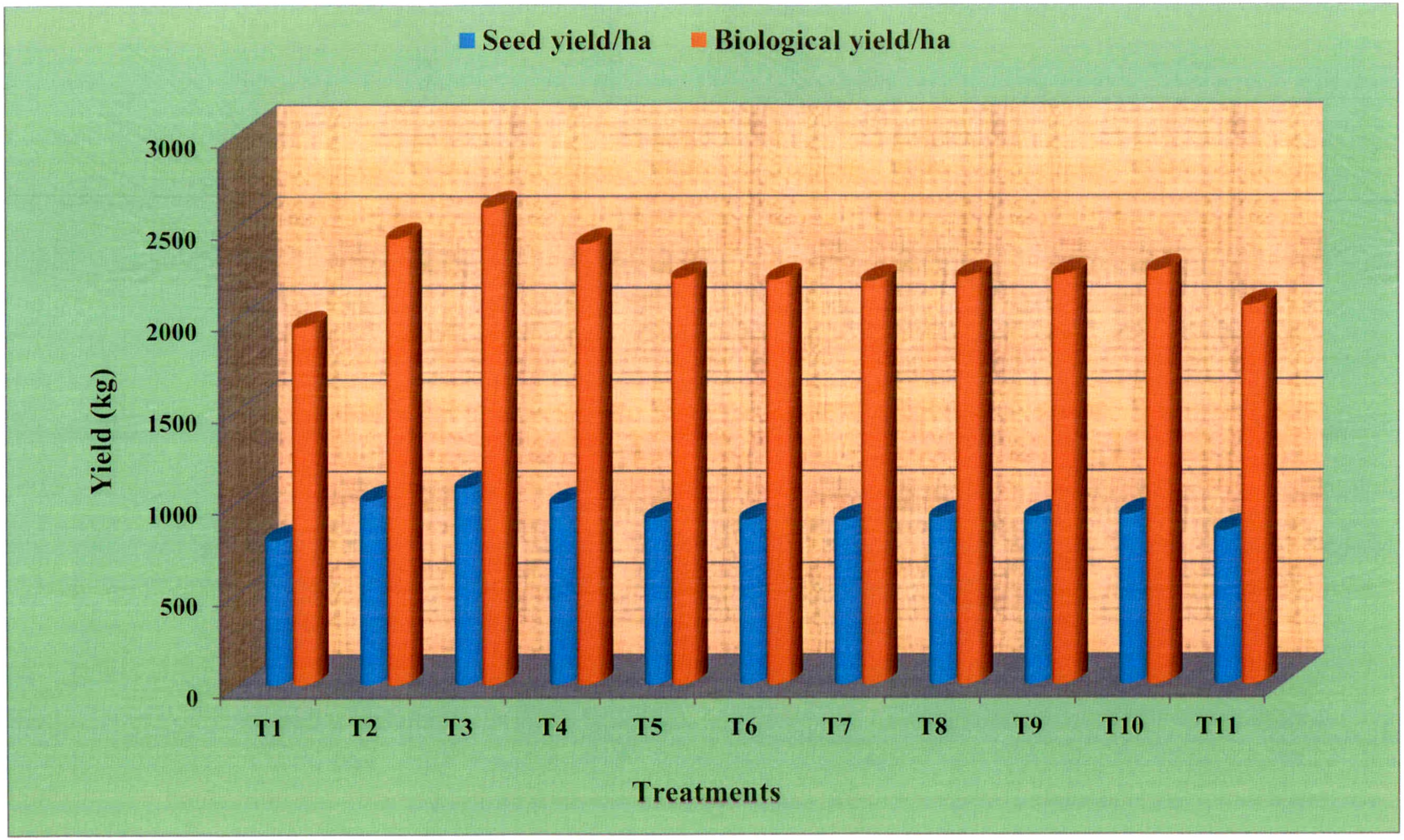

Fig:7 Seed and biological yield ha^{-1} as influenced by various treatments

4.4.9 Harvest index (HI)

Data of harvest index are presented in Table 19. The mean harvest index was 40.84. The highest harvest index (41.20) was recorded with the foliar application of GA 40 ppm (T_3) which closely followed by 20 ppm (T_2).

4.4.10 Protein content (%) and protein yield (kg ha^{-1})

Data on protein content and protein yield are presented in Table 20.

4.4.10.1 Protein content (%)

Data on protein content (%) as influenced by various treatments is presented in Table 20. The mean protein content was 39.31 %.

The mean protein content was not influenced significantly due to different treatments. Highest protein content recorded with foliar application of GA 40 ppm (T_3) which closely followed by GA 20 ppm (T_2).

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

Data on protein yield (kg ha^{-1}) as influenced by various treatments are presented in Table 20. The mean protein yield was 361.96 kg ha^{-1}.

The mean protein yield was influenced significantly due to different treatments. The highest protein yield (426.28 kg ha^{-1}) was recorded with foliar application of GA 40 ppm (T_3) which was at par with the application GA 20 ppm (T_2) and GA 60 ppm (T_4) and found significantly superior over rest of the treatments.

4.4.11 Oil content (%) and oil yield (kg ha^{-1})

Data on oil content and oil yield are presented in Table 20.

4.4.11.1 Oil content (%)

Data on oil content (%) as affected by various treatments is presented in Table 20. The mean oil content was 19.63.

The mean oil content was not influenced significantly due to different treatments. Highest oil content recorded with foliar application of GA 40 ppm (T_3) which closely followed by GA 20 ppm.

Table 20: Protein content , protein yield, oil content and oil yield as influenced by different treatments

Treatments	Protein content (%)	Protein yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
T_1- RDF	38.47	303.65	18.69	147.18
T_2- RDF + GA 20 ppm	39.70	396.42	20.21	202.03
T_3- RDF + GA 40 ppm	39.79	426.28	20.36	218.72
T_4- RDF + GA 60 ppm	39.68	391.99	19.95	196.96
T_5- RDF + NAA 20 ppm	39.23	354.04	19.63	176.60
T_6- RDF + NAA 40 ppm	39.11	351.21	19.26	172.33
T_7- RDF + NAA 60 ppm	39.00	347.52	19.43	172.02
T_8- RDF + CCC 200 ppm	39.57	359.78	19.74	179.73
T_9- RDF + CCC 250 ppm	39.59	361.63	19.70	180.55
T_{10}- RDF + CCC 300 ppm	39.65	365.88	19.85	182.66
T_{11}- RDF + water spray at moisture stress up to 45 DAS	38.61	323.19	19.10	157.94
S.E.	1.63	21.21	1.19	12.54
C.D. at 5%	NS	62.56	NS	36.99
General Mean	**39.31**	**361.96**	**19.63**	**180.61**

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

Data on oil yield (kg ha^{-1}) as influenced by various treatments are presented in Table 20. The mean oil yield was 180.61 kg ha^{-1}.

The mean oil yield was influenced significantly due to different treatments. The highest oil yield (218.72 kg ha^{-1}) was recorded with foliar application of GA 40 ppm (T_3) which was at par with GA 20 ppm (T_2), GA 60 ppm (T_4) and CCC 300 ppm (T_{10}) and found significantly superior over rest of the treatments.

4.5 Economics

4.5.1 Gross monetary returns (₹ ha^{-1})

Data pertaining to the gross monetary returns as influenced by different treatments is presented in Table 21. The mean gross monetary returns recorded was ₹ 36790 ha^{-1}.

Table 21. Mean seed yield, Gross monetary returns, Cost of cultivation, Net monetary returns, and B:C ratio as influenced by different treatments

Treatments	Gross return (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C Ratio
T_1- RDF	31400	25070	6330	1.25
T_2- RDF + GA 20 ppm	40000	25750	14250	1.55
T_3- RDF + GA 40 ppm	42867	26130	16737	1.64
T_4- RDF + GA 60 ppm	39467	26510	12957	1.49
T_5- RDF + NAA 20 ppm	36227	25379	10848	1.43
T_6- RDF + NAA 40 ppm	35947	25388	10559	1.42
T_7- RDF + NAA 60 ppm	35667	25397	10270	1.40
T_8- RDF + CCC 200 ppm	36360	25418	10942	1.43
T_9- RDF + CCC 250 ppm	36507	25430	11077	1.44
T_{10}- RDF + CCC 300 ppm	36880	25442	11438	1.45
T_{11}- RDF + water spray at moisture stress up to 45 DAS	33373	25370	8003	1.44
SE $\pm$	1596	-	1596	-
C.D. at 5%	4707	-	4707	-
General Mean	**36790**	**25571**	**11219**	-

The mean Gross monetary returns was influenced significantly due to different treatments. Highest gross monetary returns (₹ 42867 ha^{-1}) was recorded with the foliar application of GA 40 ppm (T_3) which was at par with the foliar application of GA 20 ppm (T_2) and GA 60 (T_4) and found significantly superior over rest of the treatments.

4.5.2 Net monetary returns (₹ ha^{-1})

Data pertaining to net monetary returns (₹ ha^{-1}) as influenced by the various treatments is presented in Table 21. The mean net monetary returns were recorded as 11219 ₹ ha^{-1}.

The mean net monetary returns was influenced significantly due to different treatments. The foliar application of GA 40 ppm recorded higher net monetary returns (₹ 16737 ha^{-1}) which was at par with the foliar application of GA 20 ppm (T_2) and GA 60 (T_4) was found significantly superior over rest of the treatments.

4.5.3 Benefit: Cost ratio

Data pertaining to the B:C ratio as influenced by various treatments is presented in Table 21. The mean benefit: cost ratio recorded was 1.46.

The B: C ratio was influenced significantly due to different treatments. The highest benefit : cost ratio (1.64) was recorded with foliar application of GA 40 ppm (T_3) which was at par with foliar application of GA 20 ppm (T_2), GA 60 (T_4) and found significantly superior over rest of the treatments .

4.6 Simple correlation studies

Data on simple correlation between seed yield per plant as dependent variable and plant height (cm), number of branches per plant, leaf area per plant, number of nodules per plant, total dry matter per plant (g), test weight (g) pod yield per plant independent variable were established and resultant data presented in Table 22.

Data presented in Table 22 revealed that positive and highly significant correlation were observed between seed yield per plant and plant height, leaf area, number of branches per plant, total dry matter per plant (g), test weight (g) and pod yield per plant.

Table 22: Simple correlation of grain yield per plant with growth, yield attributing character

	Plant height (cm)	Leaf area plant^{-1} (dm^2)	Number of branches plant^{-1}	Total dry matter plant^{-1}(g)	Test weight (g)	Pods yield plant^{-1} (g)	Seed yield plant^{-1} (g)
Plant height (cm)	1.000	**0.640***	0.487	0.450	0.393	0.414	0.441
Leaf area plant^{-1} (dm^2)		1.000	**0.965***	**0.909***	**0.925***	**0.928***	**0.950***
Number of branches plant^{-1}			1.000	**0.953***	**0.948***	**0.975***	**0.982***
Total dry matter plant^{-1}(g)				1.000	**0.926***	**0.985***	**0.955***
Test weight (g)					1.000	**0.956***	**0.960***
Pods yield plant^{-1} (g)						1.000	**0.973***
Seed yield plant^{-1} (g)							1.000

r value = 0.754

*** Significance at 5 per cent**

DISCUSSION

CHAPTER - V

DISCUSSION

The results of the present investigation entitled **"Effect of growth regulators on growth and yield of soybean *(Glycine max* (L.) Merill)"** conducted during *kharif,* 2015-16 at Experimental farm of Agronomy section, College of Agriculture, Latur are discussed in this chapter. An attempt has been made to evaluate and to offer the experimentations with experimental evidence wherever possible for noted variation in growth and development, seed and oil yield in soybean with a view to establish the cause and effect relationship as far as possible.

5.1 Soil

A glance at the Table 1 of the soil properties revealed that the soil of experimental plot was low in available nitrogen (118.86 kg ha^{-1}), medium in available phosphorus (20.42 kg ha^{-1}), very high in available potassium (385.89 kg ha^{-1}) and slightly alkaline (pH 7.45) in reaction. The soil was clayey in texture with moderate moisture holding capacity.

5.2 Weather

The weekly means of the meteorological data during 2015 revealed that the total rainfall of 490.5 mm was received 490.5 mm in 41 rainy days as against normal rainfall of 734 mm. It clearly indicates that this year was suffered with moderate drought receiving only 67 % of average annual rainfall.

Total rainfall received during experimental period was 297.5 mm in 22 rainy days. The mean monthly rainfall received in the month of june (60 mm in 7 rainy days) and July (59.5 mm in 5 rainy days) was not sufficient for normal sowing of soybean crop. The rainfall received during month of August was 89.5 mm in 10 rainy days. The rainfall received during month of September was 176 mm in 8 rainy days whereas in the month of October was 32 mm in 6 rainy days. The less rainfall in the month of October coincided with pod development stage of soybean which resulted in lower yield. Water stress during pod formation stage resulted in forced maturity of crop. Overall the thermo-aero-hydro-dynamic properties during crop season was not favorable for physiological activities of crop and its phenophysic development.

5.3 Emergence count and final plant stand

The mean emergence count and final plant stand (Arcsine values) was 76.65 and 70.23 respectively (Table-6). The emergence and final plant stand were statistically non-significant which indicated that the variations obtained in the investigation in different characters are the difference due to treatments only.

5.4 Crop growth

Growth and development of soybean characterized by different growth habit of crop were studied periodically. The vegetative and reproductive development of the crop culminating into economic yield was the terminal outcomes of growth which was affected by continuously interaction acquiring between environment and plant physiological processes.

The critical scrutiny of data on different growth parameters and yield attributes recorded periodically showed that growth pattern of soybean can be divided into three growth phases as below:

1. Emergence to early vegetative growth up to 30 DAS.
2. Grand growth phase from 31 to 45 DAS
3. Reproductive phase from 46 DAS onwards.

In order to know the growth of crop, the data recorded at various growth stages are presented in Table 22.

5.4.1 Plant height (cm)

Plant height was increased continuously up to harvest. The rate of increase in plant height was maximum in between 30 to 45 DAS indicating grand growth period. Thereafter, increase the plant height was very slow till maturity. The plant height was 52.65 per cent of maximum at 30 DAS and it increased at fast rate up to 45 DAS attaining 71.32 per cent height of maximum. At 60 DAS it was 85.94 per cent height of it.

Table 23. An extract of growth and yield contributing characters in soybean recorded at different growth period

Character		Days after sowing				
		30	45	60	75	At harvest
Plant height (cm)	Absolute	15.99	21.66	26.10	30.19	30.37
	Percent of maximum	52.65	71.32	85.94	99.41	100
Number of functional leaves	Absolute	3.75	8.68	10.54	8.52	-
	Percent of maximum	35.57	82.35	100	80.83	-
Number of branches $plant^{-1}$	Absolute	-	4.69	8.38	9.35	9.35
	Percent of maximum	-	50.16	89.62	100	100
Leaf area $plant^{-1}$ (dm^2)	Absolute	2.75	5.66	8.89	7.35	-
	Percent of maximum	30.93	63.66	100	82.67	-
Number of nodules $plant^{-1}$	Absolute	10.56	22.09	37.23	25.33	-
	Percent of maximum	28.36	59.33	100	68.04	-
Total dry matter $plant^{-1}$ (g)	Absolute	2.73	5.92	12.65	14.08	14.75
	Percent of maximum	18.50	40.13	85.76	95.45	100
Number of pods $plant^{-1}$	Absolute	-	-	16.80	19.90	20.85
	Percent of maximum	-	-	80.57	95.44	100

Table 24: An extract of relevant information showing effect of different treatments on growth and yield attributes

Sr. No.	Particulars	Treatments										
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
1.	Mean plant height at harvest (cm)	29.01	32.40	33.45	35.47	29.65	30.25	31.14	28.98	27.30	27.18	29.18
2.	Number of functional leaves plant^{-1} at 75 DAS	7.13	9.59	9.70	10.90	8.40	8.83	9.28	7.33	7.43	7.83	7.23
3.	Leaf area plant^{-1} at 60 DAS (dm^2)	7.53	10.69	10.80	10.20	8.27	8.08	8.01	8.40	8.81	9.11	7.90
4.	Number of branches plant^{-1} at harvest	8.27	10.53	10.80	9.93	9.03	8.87	8.77	9.13	9.37	9.80	8.30
5.	Number of nodules at 60 DAS plant^{-1}	34.00	39.67	40.17	42.67	36.67	37.00	38.33	35.00	35.33	36.00	34.67
6.	Total dry matter plant^{-1} at harvest (g)	12.57	15.96	17.27	15.70	14.50	14.37	13.60	14.90	15.13	15.40	12.83
7.	Number of pods plant^{-1} at harvest	18.73	22.53	23.97	22.03	20.13	19.80	19.80	20.80	21.83	21.53	18.83
8.	Pod yield plant^{-1} (g)	3.03	4.79	5.06	4.37	3.80	3.62	3.47	4.07	4.30	4.30	3.08
9.	Seed yield plant^{-1} (g)	2.33	3.30	3.59	3.13	2.60	2.46	2.40	2.82	2.92	3.08	2.36
10.	Number of seeds plant^{-1}	25.00	32.17	34.00	31.00	27.80	27.33	27.00	28.33	29.67	30.33	26.00
11.	Test weight (g)	98.10	107.81	109.95	107.10	101.03	100.45	99.37	102.00	102.33	105.59	99.67
12.	Grain yield (q kg ha^{-1})	7.85	10.00	10.72	9.87	9.06	8.99	8.92	9.09	9.13	9.22	8.34
13.	Straw yield (q ha^{-1})	11.65	14.30	15.29	14.13	13.09	13.07	13.05	13.12	13.16	13.28	12.28
14.	Biological yield (q ha^{-1})	19.50	20.30	26.01	24.00	22.14	22.05	21.96	22.21	22.28	22.50	20.63
15.	Harvest index (%)	40.26	41.16	41.20	41.11	40.90	40.75	40.59	40.92	40.96	40.98	40.45
17.	Oil yield (kg ha^{-1})	147	202	219	197	177	172	172	180	181	183	158
18.	Protein yield (kg ha^{-1})	304	396	426	392	354	351	348	360	362	366	323

5.4.2 Number of functional leaves and leaf area plant^{-1}

Number of functional leaves and leaf area plant^{-1} were found to be increased up to 60 DAS and decreased thereafter due to leaf senescence. At 30 and 45 days after sowing number of functional leaves and leaf area per plant were 35.57, 30.93 and 82.35, 63.66 per cent of maximum respectively. At 60 days, number of functional leaves and leaf area per plant was 100.00 per cent, and the respective figures at 75 DAS were 80.83 and 82.67 per cent of maximum.

5.4.3 Number of branches plant^{-1}

The mean number of branches plant^{-1} was increased at faster rate up to 60 DAS and thereafter gradual increase up to 75 days and there after remained constant at harvest. At 45, 60, 75 DAS and at harvest the branches were 50.16, 89.62, 100 and 100 per cent of maximum, respectively. It was found maximum at 75 DAS.

5.4.4 Number of nodules plant^{-1}

The mean number of nodules plant^{-1} increased up to 60 DAS and decreased thereafter gradually due to drying of nodules. They were 28.36, 59.33, 100 and 68.03 per cent of maximum at 30, 45, 60 and 75 respectively. At 60 DAS they were maximum in number and at harvest total drying of nodules take place.

5.4.5 Total dry matter plant^{-1}

The total dry matter production plant^{-1} increased continuously up to harvest. It was 18.50 and 40.13 per cent of maximum at 30 and 45 DAS. At 60 DAS dry matter was 85.76 per cent of maximum value . It was found maximum at harvest.

5.4.6 Number of pods plant^{-1}

Number of pods per plant was increased progressively from 60 DAS to at harvest. At 60, 75 and at harvest they were 80.57, 95.44 and 100 per cent of maximum, respective. It was found maximum at harvest.

5.5 Treatment effect

5.5.1 Growth and development

The beneficial effect of different treatments on plant height, number of functional leaves, leaf area, number of branches, number of pods plant^{-1} and total dry matter of soybean were evident during active growth and maturity.

The application of GA 60 ppm produced more vegetative growth in early period of crop growth. It was observed from the data that the plant height was found to be increased progressively at every stage of crop growth. The increase in height was rapid during 30-45 DAS and thereafter it increased marginally till maturity. The effect of different treatments on plant height was found to be significant and the higher plant height was recorded by the foliar application of GA 60 ppm (T_4) which was par with the foliar application of GA 40 ppm (T_3), GA 20 ppm (T_2) and NAA 60 ppm (T_7) as compared to other treatments.

The increase in growth attributes may be due to GA effect on cell division and cell elongation of internodes. Similar kind of observations were also recorded by Deotale *et al.* (1998) Sarkar *et al* (2002) and Sapkal *et al* (2011). Cycocel is antiauxin, which reduce the stem length may be attributed to a reduction in cell enlargement, osmotic solute in cell , permeability to water, wall pressure and wall synthesis, hence it shown lower plant height than control (Singh and Sarkar 1976).

Data on mean number of trifoliate functional leaves per plant and leaf area (Table-8 and 9) per plant revealed that these increased rapidly up to 60 DAS and and decreased thereafter towards maturity due to senescence of leaves. The foliar application of GA 60 ppm (T_4) recorded higher mean number of functional leaves which was at par with the foliar application of GA 40 ppm (T_3), GA 20 ppm (T_2) and NAA 60 ppm (T_7) at 45 and 60 days. The application of GA 40 ppm (T_3) recorded higher mean leaf area per plant which was at par with the application of GA 20 ppm (T_2) and GA 60 ppm (T_4) at 45 and 60 days. The application of growth regulator GA increased growth rate of leaves and leaf area might be due to cell division and cell elongation. Sathseeshan and Mohan kumaran (1994) also reported the similar results.

From the data (Table-10) on mean number of branches per plant it was revealed that the number of branches plant^{-1} were increased up to 75 DAS and remained constant at harvest. The rate of increase was high up to 30-60 days, moderate from 60-75 days and remained same thereafter at harvest. Mean number of branches were influenced significantly by various treatments. At 60, 75 and at harvest foliar application of GA 40 ppm (T_3) recorded maximum number of branches which was mostly at par with the foliar application of GA 20 ppm (T_2), GA 60 ppm (T_4) and CCC 300 ppm (T_{10}). It might be due to GA increase the plant height and this takes place more branches· Results were in confirmedly with the findings of Deotale *et al* (2008), Lee (1990) and Rahman *et al* (2004).

The data with respect to dry matter yield recorded at all the critical growth stages were presented in table 11. Total dry matter accumulation per plant was found to be increased continuously with advancement in the age of the crop till harvest. The rate of increase in dry matter accumulation was faster between 30 to 60 DAS and thereafter it increased with decreasing rate at harvest stage. The foliar application of GA 40 ppm (T_3) recorded maximum dry matter accumulation plant^{-1} at harvest (17.27 g) which was par with the foliar application of GA 20 ppm (T_2) and GA 60 ppm (T_4). It may be due to increased in plant height, number of functional leaves, leaf area plant^{-1} by GA which are of vital part of the plant where the more photosynthate takes place which reflected ultimately on dry matter accumulation. Similar kind of results were also reported Tanimoto (1990) and Maske *et al* (1997).

Mean value of absolute growth rate for plant height (cm day^{-1} plant $^{-1}$) at various crop growth stages is presented in Table 14. It showed that absolute growth rate increased rapidly and reached at peak between 31-45 days (0.379 cm day^{-1} plant^{-1}) and then slowed down till maturity. The maximum absolute growth rate for plant height was observed with the GA 60 ppm (T_4) between 31-45 and 46-60 days. The differences in AGR for plant height due to different treatments were not consistent at 60 days onwards.

Absolute growth rate for dry matter accumulation presented in Table 15 showed that it was slow during early stage of crop growth between 0-30 days, fast between 31-45 days, very fast between 46- 60 and thereafter decreased towards maturity. The higher AGR recorded with foliar application of GA 40 ppm (T_4) between 46-60 days. The differences in AGR for dry matter due to different treatments were not consistent . The maximum AGR recorded between (0.449 g day^{-1} $plant^{-1}$) 46-60 days.

Data on relative growth rate for dry matter (g g^{-1} day^{-1}) at various stages of crop growth is presented in Table 16. The maximum mean value of RGR for dry matter was observed during 31-45 DAS (0.052 g g^{-1} day^{-1}). The differences in RGR values due to different treatments were not consistant. The highest value of RGR (0.063 g g^{-1} day^{-1}) was recorded when crop was supplied with GA 60 ppm at 31-45 days.

The mean leaf area index (Table-17) was low at initial stage of crop growth and the highest at 60 DAS (3.95) and thereafter it decreases towards maturity of crop due to senescence. The foliar application of GA 40 ppm (T_3) (4.80) recorded highest leaf area index at 60 days .

5.5.2 Yield and yield attributes

The mean number of pods $plant^{-1}$ was significantly influenced by the various treatments. The foliar application of GA 40 ppm (T_3) (23.97) recorded higher mean number of pods $plant^{-1}$ but it was at par with the application of GA 20 ppm (T_2) (22.53) and GA 60 ppm (T_4) (22.03) and found significantly superior rest of the treatments. The increase in number of pods $plant^{-1}$ might be due to application of GA which increased the flower percentage and size and number of fruit resulted into increase in pods per plant in soybean (Sarkar *et al.* 2002). Growth stimulator enter into plant system and improved the net photosynthetic rate by increasing CO_2 fixation and photo respiration couples with increased cell elongation (Sharma *et al.* 1989). Results are in confirmty with the finding of Rhman *et al* (2004) and Sapkal *et al* (2011).

The effect of different treatments on mean grain yield (g $plant^{-1}$) was found to be significant. The foliar application of GA 40 ppm (T_3) recorded significantly higher mean seed yield (3.59 g $plant^{-1}$) which was at par with the foliar application of

GA 20 ppm (T_2) (3.30 g plant^{-1}) and GA 60 ppm (T_4) (3.13 g plant^{-1}). The treatment might have provided delayed senescence and thus contributed to the efficient pod and seed filling plant^{-1}. It resulted in increased mean seed yield (g) plant^{-1} consequently favored yield contributing characters Deotale *et al* (1996) and Awan and Alizai (1989) also reported similar results.

The effect of different treatments on mean number of seeds plant^{-1} was found to be significant. The foliar application of GA 40 ppm (T_3) recorded significantly higher number of seeds plant^{-1} (34 plant^{-1}) but it was at par with the foliar application of GA 20 ppm (T_2) (32.17 plant^{-1}) and GA 60 ppm (T_4) (31 plant^{-1}) . More number of seeds plant^{-1} was due to better growth and pod bearing capacity of the plant sprayed with GA. Results are in confirming with Sarkar *et al.* (2002).

The effect of different treatments on mean test weight (1000 seeds) was found to be non significant.

Seed yield (kg ha^{-1}) as influenced by different treatments was found to be significant. The foliar application of GA 40 ppm (T_3) recorded higher mean seed yield (1072 kg ha^{-1}) which was at par with the foliar application of GA 20 ppm (T_2) (1000 kg ha^{-1}) and GA 60 ppm (T_4) (987 kg ha^{-1}). This might be due to the cumulative effect in favouring growth contributing characters which have been clearly exhibited on the final produce. Results were in confirmedly with Rahman *et al* (2004), Kanavjia *et al* (2002) and kalyankar *et al* (2008).

Straw yield (kg ha^{-1}) as influenced by different treatments was found to be significant (Table-19). The foliar application of GA 40 ppm (T_3) recorded significantly higher mean straw yield (1529 kg ha^{-1}) which was at par with the foliar application of GA 20 ppm (T_2) (1430 kg ha^{-1}) and GA 60 ppm (T_4) (1413 kg ha^{-1}).

Data on biological yield kg ha^{-1} (Table-19) as influenced by different treatments was found to be significant. The foliar application of GA 40 ppm (T_3) recorded significantly higher mean biological yield (2601 kg ha^{-1}) followed by the foliar application of GA 20 ppm (T_2) and GA 60 ppm (T_4). This might be due to the superior values of morphological character (viz, plant height, leaf area, number of leaves and branches plant^{-1}), yield contributing charters (viz, number of flowers and pods plant^{-1} and number of seeds pod^{-1}) and also effect on chlorophyll content, photosynthetic rate in plants treated with GA. Similar kind of results were reported by Kalyankar *et al* (2008) and Zaho and Lin (1993).

The effect of different treatments on mean harvest index was found to be non-significant, whereas, data on harvest index showed highest harvest index (41.20) by the foliar application of GA 40 ppm (T_3). Results were in conformity with Khandagale *et al* (2009).

5.5.3 Quality attributes

The effect of different treatments on mean protein content (%) was found to be non-significant, whereas, mean protein yield (kg ha^{-1}) was found to be significant. The foliar application of GA 40 ppm (T_3) recorded higher mean protein content and mean protein yield (39.82 %, 426.62 kg ha^{-1} respectively). Similar results were reported by Huizen *et al* (1996), Macmillan and Phinney (1987) and Zhang *et al* (2011).

The mean oil content (%) was not influenced significantly with the application of different treatments. While, mean oil yield (kg ha^{-1}) was found to be significant with the application of different treatments. Foliar application of GA 40 ppm (T_3) produced significantly higher mean oil yield (205.64 kg ha^{-1}). It might be due to increase in synthesis and activation of lipolytic enzyme. Khandagale *et al* (2009) and Basole *et al* (2003) also recorded similar kind of results.

5.5.4 Economics of the soybean crop

Effect of growth regulators on gross monetary return and net monetary return (Table-21) was found to be significant. Foliar application of GA 40 ppm (T_3) gave significantly higher gross monetary returns and net monetary return which was at par with the application of GA 20 ppm (T_2) and GA 60 ppm (T_4). Similar highest B: C ratio was also recorded with the application of GA 40 ppm (T_3). Results were in confirmity with the findings of Thakre *et al* (2006) and Dixit *et al* (2008).

5.5 Simple correlation

The simple correlation studies showed that positive and highly significant correlation were observed between seed yield per plant and the characters plant height, leaf area, number of branches per plant, total dry matter per plant (g), test weight (g) and pod yield per plant.

SUMMARY AND CONCLUSION

CHAPTER- VI

SUMMARY AND CONCLUSION

An agronomic investigation entitled **"Effect of growth regulators on growth and yield of soybean *(Glycine max* (L.) Merill)"** was conducted at Experimental farm of Agronomy section, College of Agriculture, Latur. The objective of present study was to assess the effect of growth regulators on growth, yield, quality and economics of soybean.

The soil of the experimental site was clayey in texture, slightly alkaline in reaction, low in organic carbon, available nitrogen and available phosphorus but very high in available potash. It was well drained with moderate moisture retention capacity which was favourable for optimum growth of crop. The environmental conditions were moderately congenial due to drought at pod filling stage for normal growth and maturity of soybean crop.

The experiment was laid out in a Randomized Block Design with 11 treatments replicated thrice. The treatments were T_1- RDF, T_2- RDF + GA 20 ppm,T_3- RDF + GA 40 ppm, T_4- RDF + GA 60 ppm, T_5- RDF + NAA 20 ppm, T_6- RDF + NAA 40 ppm, T_7- RDF + NAA 60 ppm, T_8- RDF + CCC 200 ppm, T_9- RDF + CCC 250 ppm T_{10}- RDF + CCC 300 ppm and T_{11} – RDF + water spray at moisture stress up to 45 DAS. The gross and net plot size of each experimental unit was 4.8 m x 4.5 m and 4.5 x 3.6 m respectively. Sowing was done by dibbling method on 08^{th} August 2015. The RDF was applied before sowing. The recommended cultural practices and plant protection measures were under taken as per recommendation.

The various ancillary observations on growth and yield contributing characters were recorded during the experiment at an interval of 15 days and post harvest studies were carried out to evaluate the treatment effects on soybean crop. The crop was harvested on 3^{th} November 2015.

Data on emergence count as well as final plant stand was uniform indicating the differences obtained were due to treatments.

Important findings emerged from the present investigation are summarized below.

6.1 Effect of treatments

The effect of different treatments was noticed on important growth parameters *viz.*,plant height,number of branches, number of functional leaves, leaf area, number of nodules, total dry matter and number of pods $plant^{-1}$.

6.1.1 Growth parameters

The plant height and total dry matter increased at every stage of crop growth till maturity. The number of branches increased at faster rate up to 60 and thereafter gradual increase up to 75 days and maintained constant till maturity. The number of functional leaves and leaf area increased up to 60 days and decreased thereafter towards maturity due to senescence of leaf. The number of nodules increased positively up to 60 days and thereafter it started decreasing till harvest. The development of pods started from 60 DAS and increased continuously up to harvest.

The above mentioned growth parameters as plant height and number of functional leaves were recorded higher values with the application of GA 60 ppm (T_4) during the entire crop growth period. The mean number of branches, total dry matter $plant^{-1}$ and number of pods were recorded significantly highest with the application of GA 40 ppm (T_3) over rest of the treatments.

No specific trend was observed in AGR and RGR due to application of growth regulators. The application of growth regulator GA 40 ppm (T_3) was found to be effective in increasing higher value of LAI as compared to rest of the application of growth regulators.

6.1.2 Yield and yield attributes

The effects of different treatments on yield and yield attributing characters *viz.*, pod yield $plant^{-1}$,seed yield $plant^{-1}$, number of seeds $plant^{-1}$, test weight (g), seed yield, straw and biological yield (kg ha^{-1}) and harvest index (%) were considerably higher with the foliar application of GA 40 ppm (T_3) which was at par with the application of GA 20 ppm (T_2) and GA 60 ppm (T_4).

6.1.3 Quality attributes

The foliar application of GA 40 ppm (T_3) recorded the higher protein content (39.79 %) and protein yield (426.28 kg ha^{-1}). The maximum oil content (20.36 %) and oil yield (218.72 kg ha^{-1}) was recorded with the application of GA 40 ppm (T_3).

6.1.4 Economics

The foliar application of GA 40 ppm (T_3) recorded the higher GMR (₹ 42867) and NMR (₹ 16737) which was at par with the application of GA 20 ppm (T_2) and GA 60 ppm (T_4). The higher benefit: cost ratio (1.64) was recorded by the application of GA 40 ppm (T_3).

CONCLUSIONS

On the basis of field experiment conducted during the *Kharif* season 2015, it could be concluded that

1. Considering growth, yield attributes, yield as well as protein yield and oil yield, it is concluded that the foliar application of growth regulators GA 40 ppm was most remunerative for getting higher yield. It was closely followed by foliar application of growth regulators GA 20 ppm and 60 ppm.

2. The foliar application of GA 40 ppm was found to be most remunerative for getting good returns.

Above conclusions are based on single season research finding and its needs further confirmation by repeating the trial for at least one more season.

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ABSTRACT

ABSTRACT

Effect of growth regulators on growth and yield of soybean *(Glycine max* (L.) Merill

By

SUNIL KUMAR

A candidate for the degree

Of

MASTER OF SCIENCE (AGRICULTURE)

In

AGRONOMY

2016

Research Guide	**:**	**Dr. V.P. Suryavanshi**
Department	**:**	**Agronomy**

The experiment was conducted during *kharif* season of the year 2015-16 at Experimental Farm of Agronomy section, College of Agriculture, Latur, to study the effect of growth regulators on growth and yield of soybean. The experimental field was levelled and well drained. The soil was clayey in texture, low in available nitrogen (118.86 kg ha^{-1}), low in available phosphorus (20.42 kg ha^{-1}), very high in available potassium (385.89 kg ha^{-1}) and slightly alkaline in reaction (7.45 pH).

The experiment was laid out in a Randomized Block Design with 11 treatments replicated thrice. The treatments were T_1- RDF, T_2- RDF + GA 20 ppm,T_3-RDF + GA 40 ppm, T_4- RDF + GA 60 ppm, T_5- RDF + NAA 20 ppm, T_6- RDF + NAA 40 ppm, T_7- RDF + NAA 60 ppm, T_8- RDF + CCC 200 ppm, T_9- RDF + CCC 250 ppm T_{10}- RDF + CCC 300 ppm and T_{11} – RDF + water spray at moisture stress up to 45 DAS. The gross and net plot size of each experimental unit was 4.8 m x 4.5 m and 4.5 x 3.6 m respectively. Sowing was done by dibbling method on 08^{th} August 2015. The RDF was applied before sowing. The recommended cultural practices and plant protection measures were under taken as per recommendation.

Application of GA 40 ppm recorded significantly higher growth & yield attributes, yield, GMR, NMR which was at par with application of GA 20 ppm and 60 ppm.

VITAE

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