Evaluation of Triacontanol at Varying Rates on Growth and Yield of Soybean

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2018

CERTIFICATE – I

*This is certify that the thesis entitled "**Evaluation of Triacontanol at Varying Rates on Growth and Yield of Soybean [Glycine max (L.) Merrill]**" submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)** of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by **Mr. Akash Sonkusale** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

All the assistance and helps received during the course of the investigation has been acknowledged by him.

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The matter embodied in the thesis has not been submitted for the award of any other degree/diploma. Due credit has been made to all the assistance and help.

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Place: Jabalpur
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LIST OF ABBREVIATIONS

Words		Abbreviations / Symbols
At the rate of	:	@
Centimetre	:	cm
Co-workers	:	*et al.*
Critical difference	:	CD
Day after sowing	:	DAS
Evapo - Transpiration	:	ET
Gram (s)	:	g
Gross monetary returns	:	GMR
Hectare	:	ha
Kilogram(S)	:	kg
Mean sum of square	:	M.S.S
Meter	:	m
Namely	:	*viz.,*
Net monetary returns	:	NMR
Nitrogen	:	N
Not significant	:	NS
Number	:	No.
per hectare	:	ha^{-1}
Per	:	/ or $^{-1}$
Percent	:	%
Phosphorus	:	P_2O_5
Potassium	:	K_2O
Logarithum of hydrogen ions	:	pH

concentration		
Quintal	:	q
Quintal per hectare	:	q ha^{-1}
Replication	:	r
Rupees	:	Rs.
Serial No.	:	S. No.
Standard meteorological weeks	:	SMW
Square meter	:	m^2
Square centimeter	:	cm^2
Standard error of means	:	S.Em$\pm$
Standard error of difference	:	S.Ed
Square	:	sq.
That is	:	*i.e.*

INTRODUCTION

The soybean [*Glycine max* (L.) Merrill] is a member of family leguminosae, sub-family papilionaceae. It is one of the most important protein and oilseed crops throughout the world. Its oil is the largest component of the world's edible oils. It has emerged as one of the important commercial crop in many countries. Soybean is also known as the "Golden bean" or "Miracle crop" because of its multiple uses. It is called as vegetarian meat and wonder crop because it is a rich and cheap source of protein (40-42%) and fat (18-20%). The oil contains about (0.5-1.0%) lecithin which is essential for building up of human nerve tissues. Due to high protein content, soybean is known as `poor man's meat'. Its oil is also used as raw material in manufacturing antibiotics, paints, varnishes, adhesives, lubricants etc. The bulk of the crop is solvent extracted for vegetable oil and then defatted soya meal which is used for animal feed. A very small proportion of the crop is consumed directly as food by humans. Soybean products, however, appear in large variety of processed foods.

Currently in India, it is grown in 10.50 million hectares with the production of 9.50 million tonnes (SOPA, 2017). Madhya Pradesh is a leading state in India for cultivation of soybean, where it is grown in 5.01 million hectares with the total production of 4.20 million tonnes. But the productivity is only 838 kg ha^{-1}, which is far below than its yield potential *i.e.* 2500 kg ha^{-1} (SOPA, 2017)

The role of plant growth regulators is well established in improvement of morpho-physiological attributes of the crop plants. The plant growth regulators stimulate the plant vegetative growth thereby enhancing the yield potential of the crop plants. Some of the growth regulators like salicylic acid, ethrel and cycocel may play a big role to increase the seed yield of soybean. Growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective pod formation, seed development and ultimately the productivity of soybean.

Salicylic acid is an endogenous growth regulator of phenol nature, which participates in the regulation of physiological processes in plant, such as stomata closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan and Balakrishnan, 2003).

Application of salicylic acid @ 125 ppm increased the dry matter production in black gram (Jaykumar *et al.,* 2008). Study of Abbas (1991) had shown that early development is related to higher ethylene levels, thus decreasing flowering and pod shedding and thereby reducing abscission and improving better pod set. Furthermore, it has been reported that salicylic acid applications increase carbon dioxide (CO_2) assimilation and photosynthetic rate and hence increased dry matter (Szepesi *et al*., 2005).

Triacontanol (TRIA), a saturated primary alcohol, is a natural component of plant epicuticular waxes (Crosby and Vlitos, 1959) and has plant growth enhancing properties. TRIA is used to increase crop yields on millions of hectares, particularly in Asia. Many researchers have reported enhancement in growth and yield of crop plants with the application of TRIA (Borowski *et al.,* 2000). When applied in field conditions, TRIA also caused an increase in vegetative growth, chlorophyll content and dry weight of various plants. There is little information pertaining to foliar application of triacontanol on growth and yield attributing characters in soybean. Keeping above facts in view, the present study entitled “Evaluation of triacontanol at varying rates on growth and yield of soybean” will be undertaken with the following objectives:

Objectives:-

1. To find out the suitable dose of triacontanol for higher yield of soybean
2. To see the effect of triacontanol on growth and yield attributes of soybean
3. To work out the economics of different treatments

REVIEW OF LITERATURE

The role of plant growth regulators is well established in improvement of morpho-physiological attributes of the crop plants. The plant growth regulators stimulate the plant vegetative growth thereby enhancing the yield potential of the crop plants. Some of the growth regulators like salicylic acid, ethrel and cycocel may play a big role to increase the seed yield of soybean.

Effect of triacontanol on growth

Muthuchelian *et al.* (1996) in the study of TRIA not only improves crop growth and yield under non-stress conditions, but it also can up-regulate crop growth under stressful environments. Exogenously applied TRIA has been reported to play a positive role in enhancing the plant growth in coral tree (*Erythrina variegate*).

Reddy *et al.* (2002) revealed that the foliar application of TRIA (50 μM and 100 μM) enhanced growth, measured higher shoot fresh and dry weight, in both sunflower cultivars (SMH-907 and SMH- 917) under both saline and non-saline conditions.

Vagner Maximino *et al.* (2003) reported that foliar application of GA_3 led to an increased in plant height, first node height, stem diameter, leaf area and dry matter production.

Bassiouny and Bekheta (2005) observed that salt stress increased proline level in both the cultivars in wheat *i.e.* Giza 168 and Gimeza 9; concentration increased in both cultivars Giza 168 and Gimeza 9. And also reported that ethylene level was increased in Gimeza 9, while it was decreased in Giza 168 with increasing salt level.

Ahmad *et al.* (2007) in the study, Salt stress caused a marked reduction in chlorophyll content, photosynthetic rate, transpiration rate, stomatal conductance and intrinsic CO_2 concentration of all four rice cultivars. Similarly, chlorophyll fluorescence attributes were also markedly altered due to imposition of NaCl stress. Pre sowing seed treatment with nitric oxide significantly improved chlorophyll content, and gas exchange and chlorophyll fluorescence attributes in salt-stressed and non-stressed plants of all four rice cultivars of rice cultivars, Shaheen basmatiand IRRI-6 performed better than cvs. Basmati PB-95 and KS-282 in terms of the parameters measured in this study.

Naheed *et al.* (2008) In the present study, saline stress significantly increased both leaf and root Na^+ contents in both mungbean lines. This increase in leaf or root Na^+ contents had also been observed in earlier studies on different crops such as rice.

Khan *et al.* (2009) reported that the effect of four concentration of TRIA (10^{-0},10^{-7},10^{-6} and 10^{-5} M) on the performance of mint *(Mentha arvensis* L.) regard to growth and other physiological attributes, crop yield and quality attributes and the yield and content of active constituents of the plant. The foliar application of TRIA at 10^{-6} M concentration significantly enhanced most of the growth and other physiological attributes, crop herbage yield and the yield and content of active constituents (menthol, l-methone, isomenthone and menthyl acetate) of mint at both the stages.

Naeem *et al.* (2009) reported that the application of five concentrations of TRIA (10^{-0} (Control), 10^{-8}, 10^{-7}, 10^{-6} and 10^{-5} M) at 15 day intervals. The plant fresh and dry weights, leaf-area, number and dry weight of nodules per plant, total chlorophyll and carotenoid content, nitrate reductase activity, carbonic anhydrase activity, nodule-nitrogen content, leghemoglobin content and leaf N, P, K and Ca contents were analyzed at 60, 90 and 120 days after sowing (DAS).

Verma *et al.* (2009) reported the increase in leaf area and net assimilation rate at a concentration of 0.10 ppm triacontanol. When compared with other growth regulator, triacontanol in very small amounts can effectively improve the process of growth and production on various types of plants, including on the plant of Groundnut (*Arachis hypogea* L.).

Shahbaz *et al.* (2011) observed that Salt stress markedly reduced growth, different gas exchange characteristics such as photosynthetic rate (*A*), water-use efficiency (WUE) calculated as *A/E* ,transpiration rate (*E*), internal

CO_2 concentration (C_i) and stomatal conductance (g_s) in all cultivars. The effect of 150 mM NaCl stress was non-significant on chlorophyll *a* and *b* contents, chlorophyll *a/b* ratio, RWC, RMP and leaf and root Cl^-, K^+ and P contents; however, salt stress markedly enhanced C_i/C_a ratio, free proline content and leaf and root Na^+ concentrations in all sunflower cultivars. Of all cultivars, cv. Hysun-38 was higher in gas exchange characteristics, RWC and proline contents as compared with the other cultivars.

Singh *et al.* (2012) study the foliar application of TRIA could enhance the growth, productivity and quality attributes of ginger. The plants were sprayed with five concentrations of TRIA *viz.,* 10^{-0}, 10^{-7}, 5×10^{-6}, 10^{-6} and 5×10^{-5} M at 25 day intervals. Among the applied treatments, foliar spray of TRIA at 10^{-6} M proved optimum and significantly enhanced plant height, leaf density, number of tillers per plant, fresh and dry weights of shoot and rhizome, total chlorophyll content, leaf and rhizome nitrogen, phosphorus and potassium concentrations as well as rhizome carbohydrate and protein contents at 120 and 180 days after planting (DAP).

Husain *et al.* (2017) revealed that the exogenous usage of salicylic acid and triacontanol had significant impact on different growth characters, fruiting and yield of strawberry as compared to control, although the interaction effect of these two growth regulators was non-significant for all the studied parameters. Among the salicylic acid and triacontanol treatments, the salicylic acid @ 2 mM and triacontanol @ 10 µM show maximum growth in vegetative characters of strawberry. Both the growth regulators significantly increased floral and fruiting characters.

Vijayakumar *et al.* (2017) study the growth regulators used were gibberellic acid (GA_3 @ 100,150 and 200 ppm), salicylic acid (SA @ 50, 100 and 150 ppm), brass inolide (BA @ 0.5, 1.0 and 1.5 ppm) and triacontanol (TR @ 1.0, 2.0 and 3.0 ppm). The growth regulators were applied as foliar sprays at two stages *viz.,* 45 days and 60 days after transplanting and water spray as control. Application of GA_3 at 150 ppm promoted the various growth and yield parameters. Spraying of GA_3 at 150 ppm showed increased plant height (69.03 cm), plant spread with 37.64 cm for NS direction at 90 days after planting, number of branches plant^{-1} (9.25). GA_3 at 150 ppm significantly increased the number of nodes plant^{-1} (11.47), followed by SA at 100 ppm (10.03) and number of branches plant^{-1} (9.25), followed by SA at 100 ppm (9.12). GA_3 at 150 ppm registered significantly more number of nodes (11.47). The lowest number of nodes recorded in control was 7.27. GA_3 at 150 ppm produced longer internodal length (5.57 cm) followed by SA at 100 ppm (5.25 cm).The shortest internodal length was recorded by control (1.76 cm).

Effect of triacontanol on physiological parameter

Birnberg and Brenner (1987) reported that GA_3 decrease the number of flowers and fruit set, probably by increasing vegetative mass which, in turn, shares the photoassimilates with the fruit.

Chen *et al.* (2002) observed the up-regulation of rbc gene by triacontanol (TRIA) application in rice seedlings which was ascribed to enhanced rate of photosynthesis.

Khan and Balakrishnan (2003) effects of foliar applied salicylic acid (SA), acetyl salicylic acid (ASA) and gentisic acid (GTA) on photosynthetic rates and growth of soybean (a C_3 plant) and corn (a C_4 plant) under greenhouse conditions. In general, the tested compounds enhanced photosynthetic rates in both soybean and corn. Stomatal conductance and transpiration were also increased. These compounds do not alter chlorophyll content. In some cases treatment with these compounds resulted in increased leaf areas and plant dry mass, however, plant height and root length were not affected.

Krishnan and Kumari (2008) reported that growth substance is effective to normalize metabolic processes on soybean plants treated with salt stress. The foliar application of triacontanol (TRIA) has been reported to enhance chlorophyll contents, total soluble sugars, protein, nucleic acids, photosynthetic rate and chlorophyll fluorescence in soybean.

Hassanein *et al.* (2009) reported that the growth and yield of sunflower (*Helianthus annuus* L.) is adversely affected by salt stress, gas exchange characteristics, proline contents and carbohydrates have been found to be reduced in sunflower under saline conditions.

Khan *et al.* (2009) observed that the effect of four concentration of TRIA (10^{-0},10^{-7},10^{-6} and 10^{-5} M) on the performance of mint (*Mentha arvensis* L.) regard to growth and other physiological attributes, crop yield and quality attributes and the yield and content of active constituents of the plant. The foliar application of TRIA at 10^{-6} M concentration significantly enhanced most of the growth and other physiological attributes, crop herbage yield and the yield and content of active constituents (menthol, methone, isomenthone and menthyl acetate) of mint at both the stages.

Verma *et al.* (2009) reported the increased in leaf area and net assimilation rate at a concentration of 0.10 ppm triacontanol. When compared with other growth regulator, triacontanol in very small amounts can effectively improve the process of growth and production on various types of plants, including on the plant of groundnut (*Arachis hypogea* L.).

Mehta *et al.* (2010) study the effects of high salt stress on PS II in detached wheat (*Triticum aestivum*) leaves, the seedlings were grown in knop solution and temperature was 20±2°C. Detached leaves were exposed to high salt stress (0.1–0.5 M NaCl) for 1 h in dark and chl a fluorescence induction kinetics was measured. Various parameters like Fv/Fm, ABS/RC, ETo/TRo, performance index and area over the florescence curve were measured and the energy pipeline model was deduced in response to salt stress.

Perveen *et al.* (2011) observed that the effect of pre-sowing application of TRIA was non-significant on all measured attributes except that it significantly increased the activity of pod under non-saline conditions. The cultivar difference with respect to the different attributes measured in the present investigation was non-significant.

Singh *et al.* (2012) study the foliar application of TRIA could enhance the growth, productivity and quality attributes of ginger. The plants were sprayed with five concentrations of TRIA *viz.,* 10^{-0}, 10^{-7}, 5×10^{-6}, 10^{-6} and 5×10^{-5} M at 25 day intervals. Among the applied treatments, foliar spray of TRIA at 10^{-6} M proved optimum and significantly enhanced plant height, leaf density, number of tillers per plant, fresh and dry weights of shoot and rhizome, total chlorophyll content, leaf and rhizome nitrogen, phosphorus and potassium concentrations as well as rhizome carbohydrate and protein contents at 120 and 180 days after planting (DAP).

Babu *et al.* (2012) reported that the Zn-EDTA (13%) treatments were 0 (control), 0.35 and 0.52 g pot^{-1} (0, 2 and 3 kg fed^{-1}). Irrigation of tomato plants by the lowest level of salinity (2000 ppm) increased plant height, fresh weight of aerial parts, leaf area, total chlorophyll content, NPK in tomato leaves, fruit setting, and total yield. On the contrary, saline water irrigation at 3000 and 4000 ppm decreased all the previous characters, but increased leaves dry matter percentage on the other hand, Zn – EDTA at the rate of 0.35 g pot^{-1} led to the highest plant height, fresh weight of aerial parts, leaf area, total chlorophyll content, NPK in leaves, fruit setting, and total yield, while the control treatment gave the lowest values for all the previous characters.

Perveen *et al.* (2013) application of triacontanol is a potential plant growth regulater reduce the negative effects of salinity stress, and improves the photosynthetic rate, the transpiration rate and the chlorophyll contents.

Robina *et al.* (2013) study the foliar application of TRIA markedly increased shoot and root fresh weight and length, A, E, stomatal conductance and WUE in both cultivars under both saline and non-saline regimes. TRIA did not show prominent effect on chlorophyll fluorescence attributes such as electron transport rate and photochemical quenching of sunflower plants. The TRIA level 100 µM was more effective as compared to the others and sunflower cultivar SMH-917 showed better performance than those of cv. SMH-907.

Asma *et al.* (2014) evaluate of the high biomass producing salt tolerant cultivars of a potential forage crop barley (*Hordeum vulgare* L.), 30 day old plants of 105 different accessions from different origin were subjected to saline and non-saline (control) conditions for 45 days. Salinity stress (150 mM NaCl) markedly suppressed plant growth (shoot and /or root fresh and dry weights), chlorophyll pigments (a and b), internal CO_2 concentration, stomatal conductance rate of transpiration and photosynthesis.

Mahajan GM (2014) plant growth is measured by height of the plant significantly improved. Application of NAA @ 40 ppm measured maximum plant height of soybean. The increased plant height may be due to the stimulating action of auxins which soften the cell wall by increasing its plasticity or may be the oxidative decarboxylation of synthetic auxins which could not be catalyzed by the enzyme peroxidise.

Effect of triacontanol on yield attributes and yield

Gutierrez-Coronado *et al.* (1998) reported that the salicylic acid application increased the number of flowers, pods plant^{-1}, shoot growth, root growth, plant height and seed yield of soybean, net return and B:C ratio.

Khan and Balakrishnan (2003) exogenous application of salicylic acid may influence a range of diverse process in plants including stomata closure, ion uptake and transport, ethylene synthesis, seed yield and B:C ratio.

kaur *et al.* (2015) four plant growth regulators application (salicylic acid @ 50 ppm, ethrel @ 200 ppm, cycocel @ ppm and water spray) in main plot and three stages of application time (at flower initiation, pod initiation and flower + pod initiation) in sub plot, was replicated thrice. Pods plant^{-1} in cycocel @ 500 ppm were significantly higher than ethrel, salicylic acid and water spray. Ethrel 200 ppm recorded seed yield statistically on par with salicylic acid 50 ppm but significantly higher than water spray and lower than cycocel 500 ppm. Pods per plant with plant regulators application at flower + pod initiation were significantly higher than flower and pod initiation.

Khatun *et al.* (2016) reported that the different plant growth regulator and their time of application showed significant effect on number of pods plant^{-1},100-seed weight, stover yield, biological yield, harvest index and gross and net return of soybean.

Shivran *et al.* (2016) study the response of fenugreek (*Trigonella foenum graecum* L.) to plant growth regulators and their time of application on growth, yield and economics such as triacontanol 1000 ppm and NAA 50 ppm. It observed that growth regulator treatments significantly influenced growth, yield attributes, yield and economics of fenugreek.

Zubair *et al.* (2017) study the soluble boron of solubor (0.1%) and bio-stimulants of Biozyme (1.5 ml l^{-1}) and triacontanol (10 ppm) and their combinations were sprayed at three timings: (i) At pink bud stage (ii) three weeks after fruit set of apple (iii) two months after second spray. Two months after second spray, solubor was replaced with 0.5% $CaCl_2$.The results revealed that combination of solubor + biozyme + triacontanol and solubor + biozyme was more effective to improve floral and yield characteristics with fruit set (74.71 and 69.50%) and yield (97.75 and 92.70 kg $trees^{-1}$).

Effect of triacontanol on economics

Khan and Balakrishnan (2003) exogenous application of salicylic acid may influence a range of diverse process in plants including stomata closure, ion uptake and transport, ethylene synthesis, seed yield and B:C ratio.

kaur *et al.* (2015) study the four plant growth regulators application (salicylic acid @ 50 ppm, ethrel @ 200 ppm, cycocel @ 500 ppm and water spray) in main plot and three stages of application time (at flower initiation, pod initiation and flower + pod initiation) in sub plot, was replicated thrice. Pods per plant in cycocel @ 500 ppm were significantly higher than ethrel, salicylic acid and water spray. Ethrel 200 ppm recorded seed yield statistically on par with salicylic acid 50 ppm but significantly higher than water spray and lower than cycocel 500 ppm. Pods per plant with plant regulators application at flower + pod initiation were significantly higher than flower and pod initiation.

Khatun *et al.* (2016) In this study, The different plant growth regulators [salicylic acid, gibberellic acid (GA_3), kinetin and distilled water (control)] and their time of application showed significant effect on number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, 100-seed weight, stover yield, biological yield, harvest index, seed grading (% by weight), protein and moisture content in seed of soybean. Salicylic acid gave the highest number of seeds pod^{-1}, harvest index, small size seed, protein and moisture content in seed (1.60, 39.06%, 19.47%, 44.56% and 12.9%, respectively). Kinetin spray produced the maximum 100-seed weight (11.58 g). Application of growth regulators at vegetative stage produced the highest stover yield (6.46 g $plant^{-1}$), flower initiation stage gave the larger size seed (59.09%), pod initiation stage showed the maximum pod length (2.43 cm), highest moisture content in seed (13.50%) and spray at flower + pod initiation stage produced the maximum 100-seed weight (12.00 g), harvest index (43.42%), medium size seed (32.53%), protein content in seed (44.31%). Among the treatment combinations the application of salicylic acid at flower and pod initiation stage showed the highest yield attributes and maximum protein content compared to those of other growth regulators.

MATERIALS AND METHODS

The present investigation was planned and taken up within the scope of the subject under study and the objectives framed out to realize the answers for the problem identified, as discussed in the chapter introduction. The experiment was conducted during the *kharif* season of 2017 under climatic and edaphic conditions of Jabalpur (M.P.). The material used and the methods employed during the course of investigation in the field and laboratory are briefly described in this chapter under the appropriate heads.

3.1 Experimental site

A field experiment was conducted at Product testing unit, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). The field was selected for experiment with uniform topography and all physical facilities *viz.,* labours, agrochemicals, equipments and irrigation water etc. were adequately available on the farm.

3.2 Climate

The climate of Jabalpur region is typically sub humid, featured by hot dry summer and cool dry winter. Jabalpur is situated at 23° 10' North latitude and 79° 59' East longitudes with an altitude of 411.78 meters above the mean sea level. It is classified under "Kymore Plateau and Satpura Hills" agro-climatic zone as per norms of National Agriculture Research Project (NARP), New Delhi. Recently, it has been identified as agro-ecological region number 10, named as Central Highlands (Malwa and Bundhelkhand), sub region number 10.1, named as hot sub-humid eco-region (Malwa Plateau, Vindhyanscarpland and Narmada Valley).

The mean annual rainfall of Jabalpur is 1350 mm, mostly received between mid-June to end of September with a little and occasional rains in remaining parts of the year. The mean monthly temperature goes down to the extent of 4ºC during winter, while the maximum temperature reaches as high as 45ºC during the summer. Generally, relative humidity remains very low during summer (15 to 30%), moderate during winter (60 to 75%) and attains higher values (80 to 95%) during rainy season.

Table 3.1. Weekly meteorological parameters during *kharif* season (July to October 2017)

Months	SMW (No.)	Temperature (^oC)		Relative Humidity (%)		Sun shine hrs.	Rainfall (mm)	Rainy days
		Max.	Min.	Mor.	Eve.			
July	26	35.8	24.9	87	55	6.6	66.6	03
	27	29.5	23.1	94	81	2.6	37.3	07
	28	31.1	24.5	93	79	3.0	83.6	05
	29	30.4	24.0	91	69	3.9	63.6	03
	30	31.7	22.9	90	74	1.4	86.3	06
Aug	31	31.0	23.9	87	68	3.5	23	01
	32	28.6	23.9	89	74	3.6	101.2	03
	33	27.0	23.7	87	67	3.6	7.8	01
	34	28.8	24.0	90	67	5.9	72.4	03
	35	32.2	23.7	90	65	3.9	22	03
Sept	36	30.6	24.0	88	65	7.1	1.5	00
	37	31.7	23.3	91	64	5.4	87.8	02
	38	33.0	22.4	90	73	3.0	98.3	03
	39	29.9	21.9	89	52	9.3	0	0
Oct	40	31.9	20.3	90	51	8.9	7.4	01
	41	31.5	21.7	92	56	8.4	9.2	01
	42	31.5	17.9	87	40	8.8	0	0
	43	31.7	15.9	81	26	8.9	0	0
Total							**768**	**42**

Source: Department of Physics and Agro-meteorology, College of Agricultural Engineering, JNKVV Jabalpur (M.P.)

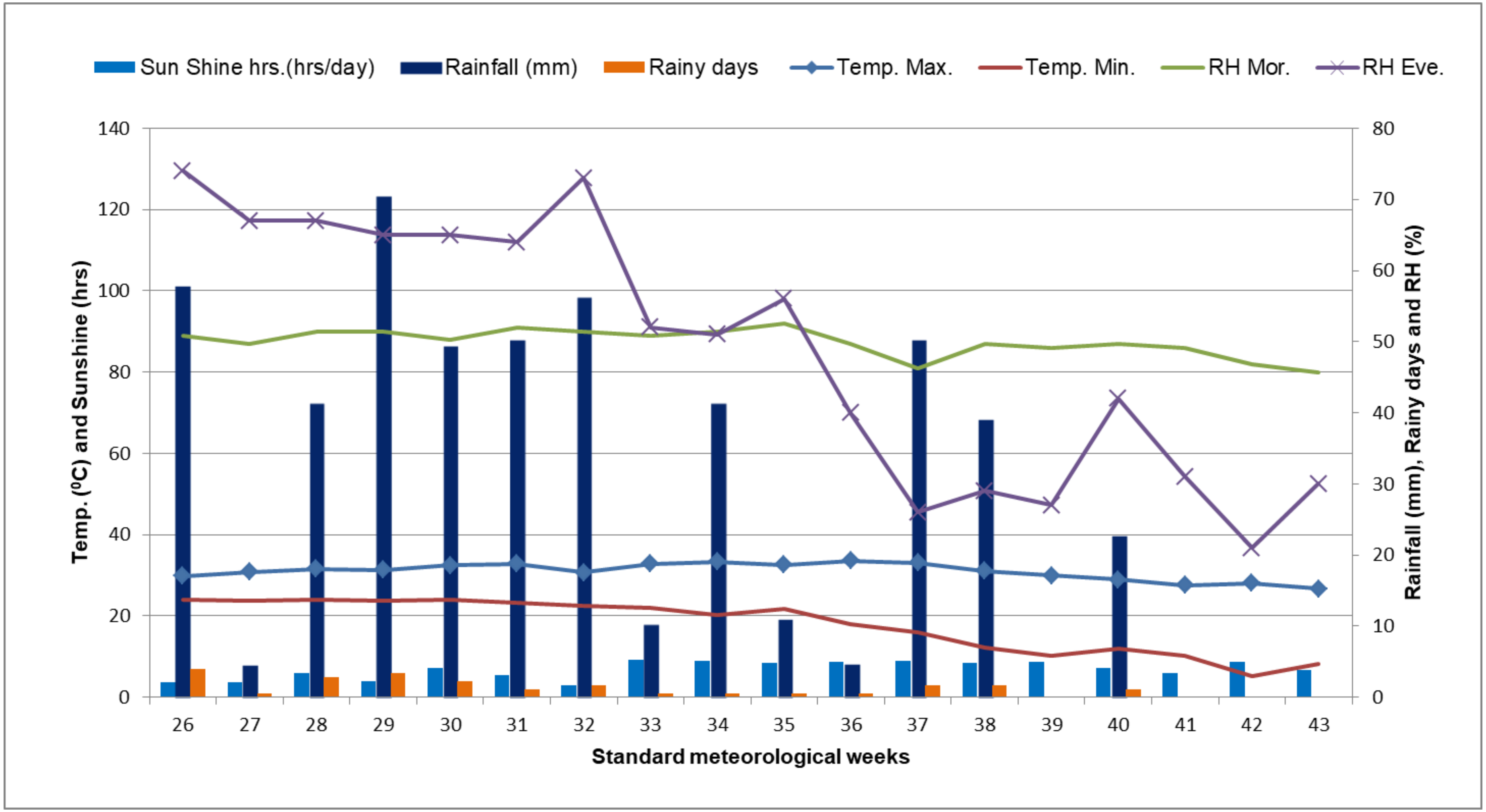

Fig. 1. Weekly meteorological parameters during *kharif* season (July to October 2017)

3.3 Weather conditions during crop season

Seasonal variations prevailing during the growth period play an important role not only in the growth and development of the crop, but also in the intensity of weeds which ultimately influence the final yield of crop. The weekly meteorological data recorded during crop season at Meteorological Observatory, College of Agriculture Engineering, Jabalpur are presented in Table 3.1 and graphically illustrated through the Figure 1.

It is evident from the data given in the Table 3.1 that weather conditions were almost favourable for the growth and development of soybean. The monsoon commenced in the first week of July and terminated in the 1st week of October. The total rainfall received during the crop season was 768 mm, which was equally distributed in 42 rainy days from July to 2nd week of October. Minimum and maximum mean temperature ranged from 15.9 ^{0}C to 24.9^{0}C and 27.0^{0}C to 35.8^{0}C, respectively. The relative humidity ranged between 81 to 94% in morning and 26 to 81% in evening. The sunshine hours varied between 1.4 to 9.3 hours per day.

3.4 Soil

The soil of the Jabalpur region is broadly classified as vertisol as per norms of US classification of soil. It is medium to deep in depth and black in colour. It swells by wetting and shrinks when dries. Thus, it develops wide cracks on the surface during summer season. The soil of the experimental field offers infestation of several weeds depending on the season and crops grown and management practices followed during the course of investigation.

In order to know the soil physico-chemical properties of the experimental field, ten soil samples were drawn randomly at the depth of 15 cm from different spots with the help of screw type soil auger. After this, all soil samples were thoroughly mixed together to make a composite sample. The composite sample after proper drying was grinded with the help of pistal and mortar and then subjected to various analysis in the laboratory, Department of Agronomy, JNKVV, Jabalpur.

The analytical values are given in the Table 3.2. It is clear from the data that the soil of the experimental field was sandy clay loam in texture. It was medium in organic carbon (0.60%), available nitrogen (367 kg ha^{-1}), phosphorus (16.23 kg ha^{-1}) and available potassium (317.10 kg ha^{-1}). The soil was nearly neutral in reaction (pH 7.1) and electrical conductivity (0.34 ds m^{-1}).

Table 3.2. Physio-chemical properties of soil of the experimental field

Constituents	Value	Class/ Group	Method used
Mechanical composition			
Sand (%) Silt (%) Clay (%)	29.52 33.78 36.70	Sandy Clay Loam	International Pipette method (Piper 1967)
Chemical analysis			
Organic carbon (%)	0.60	Medium	Walkley and Black rapid titration method (Walkey and Black 1934)
Available N (kg ha^{-1})	367.00	Medium	Alkaline permanganate method (Subbiah and Asija 1956)
Available P_2O_5 (kg ha^{-1})	16.23	Medium	Calorimeter method (Olsen et al. 1954)
Available K_2O (kg ha^{-1})	317.10	Medium	Flame Photometer method (Chapman and Pratt 1961)
Soil pH 1:2.5 (soil water ratio)	7.1	Neutral	Glass electric pH meter (Piper 1967)
Electrical conductivity (ds m^{-1})	0.34	Neutral	Solu-bridge method (Black 1965)

3.5 Cropping history

Table 3.3. Cropping history of the experimental field

Year	***Kharif***	Fertilizer dose NPK (kg ha^{-1})	***Rabi***	Fertilizer dose NPK (kg ha^{-1})
2013-2014	Soybean	(20:60:20)	Wheat	(120:60:40)
2014-2015	Soybean	(20:60:20)	Wheat	(120:60:40)
2015-2016	Soybean	(20:60:20)	Wheat	(120:60:40)
2016-2017	Soybean	(20:60:20)	Wheat	(120:60:40)
2017-18	Present experiment			

It is obvious from the information given in the above table that in the experimental field soybean-wheat cropping system was followed during last four year and the recommended dose of fertilizers was applied to both component crops. It indicates that the fertility status of the experimental field was uniform and the treatments have their own efforts.

3.6 Preparation of the field

For obtaining a good tilth for sowing of soybean in the experimental field, one summer ploughing followed by tractor driven cultivator (once) and disc harrow twice were performed and finally the field was leveled before seeding of the soybean.

3.6.1 Layout of the field experiment

A total ten plant growth promoter treatments were laid out in Randomized Block Design with three replications. These treatments were randomized in each replication using random table. The layout plan of the experiment has been graphically illustrated through the Figure 2. The details of the treatments are given as under.

Technical programme of work location:

Product testing unit, Department of Agronomy, JNKVV, Jabalpur.

Experimental details:-

Treatment: 10 (Plant Growth Promoter)

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})
T_1	Triacontanol	0.10
T_2	Triacontanol	0.15
T_3	Triacontanol	0.20
T_4	Triacontanol	0.25
T_5	Triacontanol	0.30
T_6	Triacontanol	0.35
T_7	Triacontanol	0.40
T_8	Triacontanol	0.50
T_9	Biovita (seaweed extract)	0.50
T_{10}	Control	-

Design : RCBD

Replication : 3

Other details

Gross plot size : 5.0 m x 3.6 m

Net plot size : 4.0 m x 3.0 m

Distance between replication : 1.5 m

Distance between plots : 1.0 m

Plant geometry : 30 cm x 5 cm

Variety : JS 20-29

Seed rate : 70 kg ha^{-1}

Recommended dose of fertilizer : 25:60:25 ($N:P_2O_5:K_2O$ kg ha^{-1})

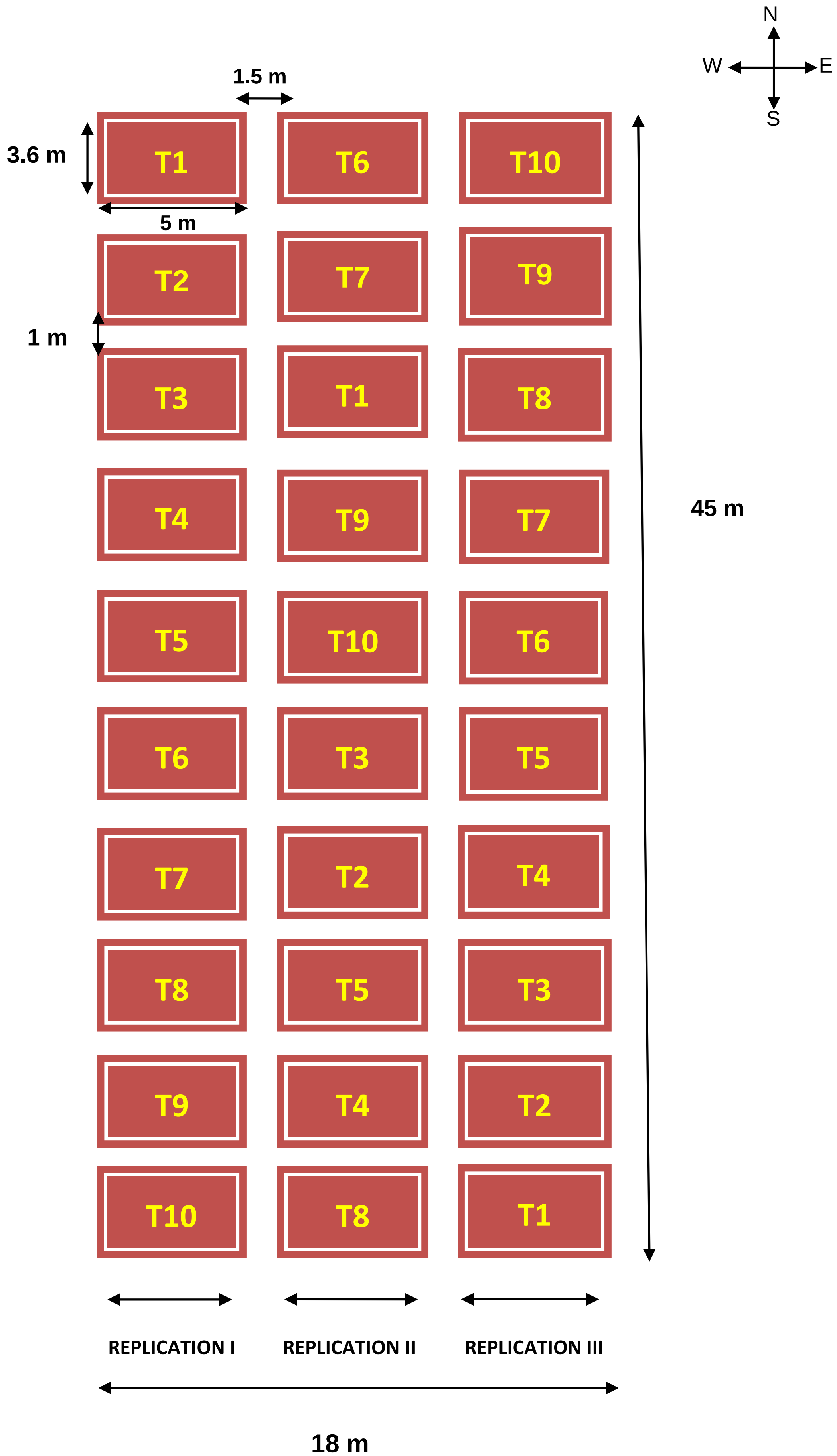

Fig. 2. Layout plan of field experimental

3.7 Agronomic characters of crop variety

The soybean variety JS 20-29 is an early maturing, high yielding variety with 3-4 seeds pod^{-1}. The plants are 60-80 cm tall with tawny color pubescence on the stem. It is a semi determinate variety having white flower which initiates in 45 DAS and ceases in about 75 days. It matures within 90-95 days. Seeds are greenish yellow, lustrous with blackish stover. The seed size is medium with 11-13 (g) seed index and 25-30 (q ha^{-}1) yield potential. It is a multiple resistant variety showing resistance to major diseases and insect pests. The variety has been found tolerant to excessive moisture, drought condition and adverse environments.

3.8 Schedule of agronomic operations

The agronomical operations performed during the course investigation done in the experimental field are given in Table 3.4.

Table 3.4. Details of different field operations done in soybean during *kharif* season, 2017

S.No	Field Operations	Date	Remarks
1.	Land preparation	25/06/2017	Mechanically
A	Layout of the experiment	27/06/2017	Manually
2.	Application of fertilizers	30/06/2017	Manually
3.	Seed treatment and sowing of seed	30/06/2017	Manually
4.	Gap filling	15/07/2017	Manually
5.	Hand weeding		
	a. At 20 DAS	20/07/2017	Manually by *khurpi*
	b. At 40 DAS	10/08/2017	Manually by *khurpi*
6.	Harvesting	13/10/2017	Manually by sickle
7.	Threshing and winnowing	18/10/2017	Manually by hand

3.9 Sowing management

3.9.1 Seed treatment

The seeds before sowing were treated with carboxin @ 2.5 g kg^{-1} of seed and also included with *Rhizobium* culture @ 5 g kg^{-1} of seed.

3.9.2 Sowing time and sowing method

Seeds were sown manually on 30 June 2017. The rows were opened with the help of pick axe and later sowing was done in each plot using a seed rate of 70 kg ha^{-1}. Seeds were sown manually in each experimental plot keeping a row to row distance of 30 cm at the depth of 3-4 cm. Then seeds were covered with fine and loose soil to save from birds and sunstroke. After sowing there was light rainfall which helped in proper germination of the sown seeds.

3.9.3 Gap-filling and thinning

Germination was almost completed after six days of sowing under each plot. Wherever the gaps were seen in the field, gap filling was done by reseeding of fresh treated seeds on seventh day after first seeding to maintain the uniform plant population in all plots. Likewise, where young germinated seedlings were overcrowded, thinning of extra seedlings was done at 15 DAS to maintain a uniform intra-row plant population nearly at 10 cm apart. Only thin and weak seedlings were uprooted for thinning of crowded plants without giving jerk to other neighboring plants.

3.10 Fertilizer application

Full dose of major plant nutrients (25 kg N + 60 kg P_2O_5 + 25 kg K_2O ha^{-1}) was applied as basal through urea, single super phosphate and muriate of potash. The whole quantity of all fertilizers were applied manually at the time of sowing as basal in the rows at about 2-3 cm below the seed.

3.11 Hand weeding

Hand weeding and hand hoeing were done manually with the help of *Khurpi* and hand hoe at 20 and 40 DAS as per treatment because there is no chemical application earlier for the weed control, so as to keep crop free from weeds during critical period of crop-weed competition.

3.12 Water management

Generally during *kharif* season no irrigation is required to soybean crop from sowing to harvesting. However, one irrigation was given in all the plots on 14th August, 2017 because of dry spell at the time of pre-flowering stage of the crop. Mean while, adequate drainage facility was also provided by making drainage channel between plots along the slope in the experimental field so as to drain excess water from the field which was more than the need of soybean crop.

3.13 Harvesting

The crop was harvested when the foliage of the soybean plants turned yellowish brown to brown in colour and leaf started shedding. One border row from each side and 50 cm at both ends of the rows were harvested and collected separately in order to eliminate the border effect thus leaving a net plot area of 12 m^2. The harvested produce from the border area of each plot was removed from the field. After this, harvesting of crop from net plot area was done plot wise separately with the help of sickles. The harvested produce of each plot was tied into bundles and tagged with luggage label for demarcation. The plot wise produce was transported to threshing floor and allowed for sun drying for 5 days.

3.14 Threshing and winnowing

After sun drying the produce was weighed plot wise by using spring balance. Then, threshing was done manually by beating up the produce with stick for each plot separately. The threshed produce of each plot was consisting of seeds and chaffy materials. The chaffy materials were removed and clean seed of each plot was separated by winnowing with hand fan *(supa)* manually. The yield of the sample plants taken for post-harvest studies was also included in the yield of each plot respectively. The weight of clean seed obtained from each plot was taken with the help of double pan balance.

3.15 Properties and mode of action of PGRs

3.15.1 Triacontanol

Triacontanol (TRIA) is a natural plant growth regulator found in epicuticular waxes. It is used to enhance the crop production in millions of hectares. TRIA-mediated improvement in growth, yield, photosynthesis, protein synthesis, uptake of water and nutrients, nitrogen-fixation, enzymes activities and contents of free amino acids, reducing sugars, soluble protein, and active constituents of essential oil in various crops (Naeem *et al*., 2009).

- Group : Saturated Primary Alcohol
- Empirical formula : $C_{30} H_{62} O$
- Molar mass : 338.81 g mol^{-1}
- Density : 0.77 g ml^{-1} at 95^{o} C

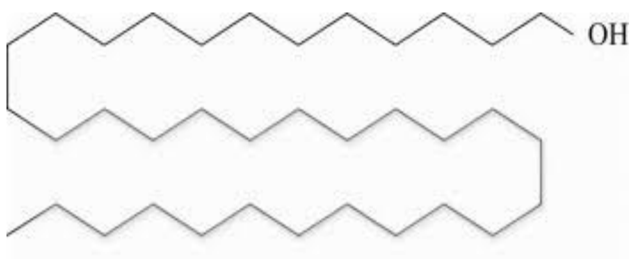

Fig. Structural formula of triacontanol (TRIA)

Mode of action

The present review covers the pivotal role of TRIA in plant growth and development, its mode of action and its significance in improving the crop productivity and quality of agricultural crops (Ries *et al.,* 1993).

3.16 Pre-harvest studies

3.16.1 Studies on crop

3.16.1.1 Plant population

The plant population of crop plants was taken at 30 DAS and just before harvest, from one meter square randomly in each plot and then averaged out. After this plant population (m^{-2}) was determined for each plot.

3.16.1.2 Plant height

The five plants were selected randomly in each plot and tagged for recording various observations. The height of marked plants was taken from the base (ground surface) up to the base of apical bud with the help of meter scale. This observation was recorded at 30 days interval in each plot starting from 30 DAS up to harvest of the crop.

3.16.1.3 Branches per plant

The number of branches per plant were counted on the 5 tagged plants in each plot at 30, 60, 90 DAS and harvest and then mean was determined for each treatment.

3.16.1.4 Leaf area and leaf area index

The leaf area was recorded with the help of leaf area meter in the Department of Crop and Herbal Physiology, College of Agriculture, Jabalpur at 30 and 60 DAS. The leaf area index expresses the total leaf area accumulated by the plants per unit of the ground area in which the crop is grown. LAI was computed as per following formula.

$$\text{Leaf area index} = \frac{\text{Total leaf area of crop}}{\text{Total ground area under the crop}}$$

3.16.1.5 Leaf chlorophyll content index

The leaf chlorophyll content index was recorded with the help of leaf chlorophyll meter in the Department of Crop and Herbal Physiology, College of Agriculture, Jabalpur at before and after 1^{st} and 2^{nd} spray.

3.16.1.6 Dry weight per plant

For taking dry weight per plant, 5 plants were uprooted from the second border row of each plot at 30, 60, 90 DAS and harvest stage. The weight of freshly uprooted plants of each plot after washing and dry their root was taken. After this the plants of each plot were tied together and marked with luggage label. These labeled plant samples were sun dried and then dried in oven at 60 ^{0}C for 48 hrs till constant weight. The weight of oven dried sample was recorded for each plot on electronic balance. Thereafter, the mean dry weight per plant was determined. Later on the data were converted into dry weight per plant in (g m^{-2}) by multiplying the plant population per meter square area.

3.16.1.7 Effective nodules per plant

From each plot five plants were uprooted at 45 and 60 DAS for nodulation study the plants from each treatment were uprooted with the help of a fork by removing the entire roots along with soil lump and then were kept as such in bucket, filled with water for half an hour. The roots of each plant were then gently cleaned carefully so that nodules are not separated from roots. After that, all the nodules were removed from the roots and pressed between two fingers for assessing the presence of leg-hemoglobin so as to know the effective nodules. Thereafter, the total number of effective nodules per plant was counted and mean was worked out.

3.17 Post-harvest observations

3.17.1 Number of pods per plant

Pods were removed from tagged five plants in each plot at harvest and then counting of these pods was made. Finally mean was computed by dividing the total values with five.

3.17.2 Number of seeds per pod

Random samples of 10 pods were drawn from the harvested produce of each plot to work out the mean number of seeds per pod.

3.17.3 Seed index (100-seed weight)

Seed sample for seed index were randomly taken from the finally cleaned produce of each plot for recording test weight. Then 100 seeds were counted treatment wise and weight of 100-seeds of each plot was recorded separately on an electrical balance in the laboratory of Agronomy Department, Jabalpur.

3.17.4 Biological yield

The total produce from each net plot was weighed with the help of dial balance in kg per plot. Seed yield and stover yield were all together regarded as biological yield. Biological yield was calculated with the following formula.

Biological yield = seed yield + stover yield.

3.17.5 Seed yield

The seed yield per net plot was recorded after winnowing the produce, with the help of double pan balance. Finally seed yield of each plot was converted into seed yield per hectare by multiplying with appropriate conversion factor.

3.17.6 Stover yield

The stover yield per plot was determined by subtracting seed yield (economical yield) of each plot from biological yield (bundle weight) of the same plot. This was later on converted in to stover yield per hectare by multiplying with the same conversion factor which was used in case of seed yield per hectare.

3.17.7 Harvest index

It is the ratio of economic yield to the biological yield. It was determined with the help of following formula and expressed in percentage as follows:

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

3.18 Economics of the treatments

The economic analysis of the treatments is very important to asses the practical utility of treatments for farmers point of view. Therefore, economics of different treatments were worked out in terms of cost of cultivation, gross monetary returns (GMR), net monetary returns (NMR) and benefit -cost ratio (B:C) on per hectare area basis to ascertain the economic viability of the treatments.

3.18.1 Cost of cultivation

The cost of cultivation for each treatment was determined on the basis of different inputs used for raising the crop under different treatments on one hectare area basis.

3.18.2 Gross monetary returns (GMR)

The values realized from the produce obtained under each treatment was computed on the basis of existing market price of the produce (both seed and stover) as the gross monetary returns (GMR) per hectare under different treatments as per the following formula.

Gross monetary returns = Value of seed + Value of stover

3.18.3 Net monetary returns (NMR)

The net monetary returns (NMR) per hectare under each treatment was determined by subtracting the cost of cultivation of a particular treatment from the GMR of the same treatment as per the following formula.

Net monetary returns = Gross monetary returns - Cost of cultivation

3.18.4 Benefit-cost ratio (B:C)

To estimate the benefits under different treatments for each rupee of expenditure incurred, B:C ratio of each treatment was calculated as below:-

$$\text{B:C} = \frac{\text{Gross monetary returns}}{\text{Cost of cultivation}}$$

3.19 Statistical analysis

The data pertaining to each character of the crop were tabulated and analyzed statistically by applying the standard technique. Analysis of Variance for randomized block design and the significance of treatments were tested to draw valid conclusions as described by Gomez and Gomez (1984). The differences of treatments mean were tested by 'F' test of significance on the basis of null hypothesis. If the variance ratios (F-test) were found significant at 5% level of significance, the standard error of mean (S.Em±) and critical differences (CD) were calculated accordingly and were interpreted for describing of the results.

Table 3.5. Skeleton of analysis of variance (ANOVA) is given below

Source of variation	d. f.	S. S.	M. S. S.	"F" cal.	
				5%	1%
Replication	2				
Treatment	9				
Error	18				
Total	29				

S.Em± = $\sqrt{SEM/r}$

S.Ed = S.Em x $\sqrt{2}$

CD = S.Ed x t (0. 05) (12 d.f.)

where,

S.Em = standard error of treatment means

S.Ed = standard error of difference between treatment means

CD = Critical difference

r = Number of replications

RESULTS

The data pertaining to the growth and yield of the soybean crop are presented here with the help of appropriate tables and illustrations. The treatment wise data of each character were statistically computed as presented by analysis of variance (ANOVA) tables in the *Appendix* section. An attempt has also been made to calculate the economics of the various treatment combinations based on the existing market rates of the experimental inputs and out puts.

4.1 Studies on crops

4.1.1 Plant population

Data on plant population of soybean recorded at 30 DAS and harvest stage under different doses of triacontanol are given in Table 4.1 and Figure 3.

The plant population of soybean was not affected due to different doses of triacontanol and it was practically different in all the foliar application including control plots where no foliar application were applied, suggesting that foliar application of triacontanol at different doses and biovita did not cause any adverse affect on crop plants. The plant population was non significantly under different treatments.

Table 4.1. Effect of different doses of triacontanol on plant population of soybean at different time intervals

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Plant population (m^{-2})	
			30 DAS	**At harvest**
T_1	Triacontanol	0.10	49.72	48.62
T_2	Triacontanol	0.15	49.95	49.18
T_3	Triacontanol	0.20	49.95	48.29
T_4	Triacontanol	0.25	50.18	48.95
T_5	Triacontanol	0.30	49.72	49.28
T_6	Triacontanol	0.35	49.05	48.38
T_7	Triacontanol	0.40	49.51	48.52
T_8	Triacontanol	0.50	50.18	49.52
T_9	Biovita (seaweed extract)	0.50	49.72	49.18
T_{10}	Control	**-**	49.95	48.38
	S.Em±		**0.07**	**0.13**
	CD (P=0.05)		**NS**	**NS**

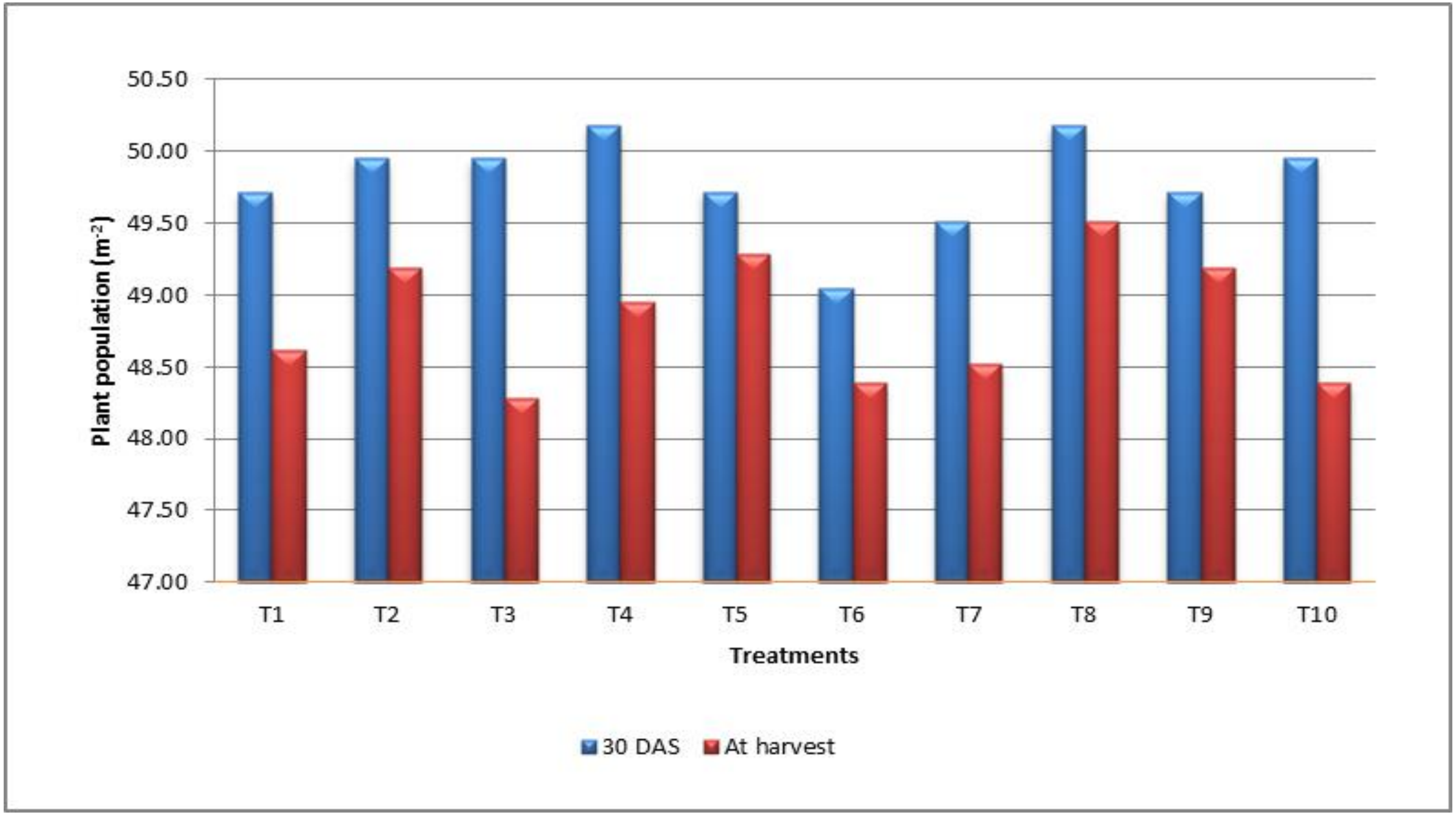

Fig. 3. Effect of different doses of triacontanol on plant population of soybean at different time intervals

4.1.2 Plant height

Data on plant height of soybean recorded at 30, 60, 90 DAS and harvest stage under different doses of triacontanol are presented in Table 4.2 and Figure 4.

The plant height, in general, was less under all the treatments during early period of crop growth, which was increased with age of crop being higher at 60 DAS and thereafter, it was slightly increased under all the treatments at 90 DAS but it was slightly decreased under all the treatments at harvest stage. However, the rate of increase in plant height was more between 30 and 60 DAS.

At 30 DAS, the plant height was affected significantly under different treatments. But at 60 DAS, significant variation in plant height was recorded under different treatments. Plant height was minimum (48.47 cm) under control plots, which was increased appreciably in plots receiving foliar application of triacontanol @ 0.10 g ha^{-1} (50.17 cm).

Maximum plant height was recorded plots receiving foliar application of triacontanol @ 0.50 g ha^{-1} (54.30 cm) at 60 DAS, followed by triacontanol @ 0.40 g ha^{-1} (54.25 cm). However, triacontanol @ 0.50 g ha^{-1} was significantly superior over control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments but it was statistically at par with triacontanol @ 0.25, 0.30, 0.35 and 0.40 g ha^{-1}. Similar trend was also observed at 90 DAS and harvest stage in relation to plant height of soybean.

Table 4.2. Effect of different doses of triacontanol on plant height of soybean at different time intervals

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Plant height (cm)			
			30 DAS	60 DAS	90 DAS	At harvest
T_1	Triacontanol	0.10	24.27	50.17	56.10	55.33
T_2	Triacontanol	0.15	24.47	51.30	57.07	56.03
T_3	Triacontanol	0.20	24.70	52.10	58.33	57.50
T_4	Triacontanol	0.25	25.53	54.00	59.97	59.73
T_5	Triacontanol	0.30	25.77	54.12	60.13	59.96
T_6	Triacontanol	0.35	25.93	54.20	60.25	60.09
T_7	Triacontanol	0.40	26.33	54.25	60.33	60.21
T_8	Triacontanol	0.50	27.17	54.30	60.47	60.33
T_9	Biovita (seaweed extract)	0.50	25.53	53.41	58.50	57.93
T_{10}	Control	-	23.30	48.47	53.70	53.37
	S.Em±		**0.14**	**0.14**	**0.25**	**0.30**
	CD (P=0.05)		**0.41**	**0.41**	**0.73**	**0.90**

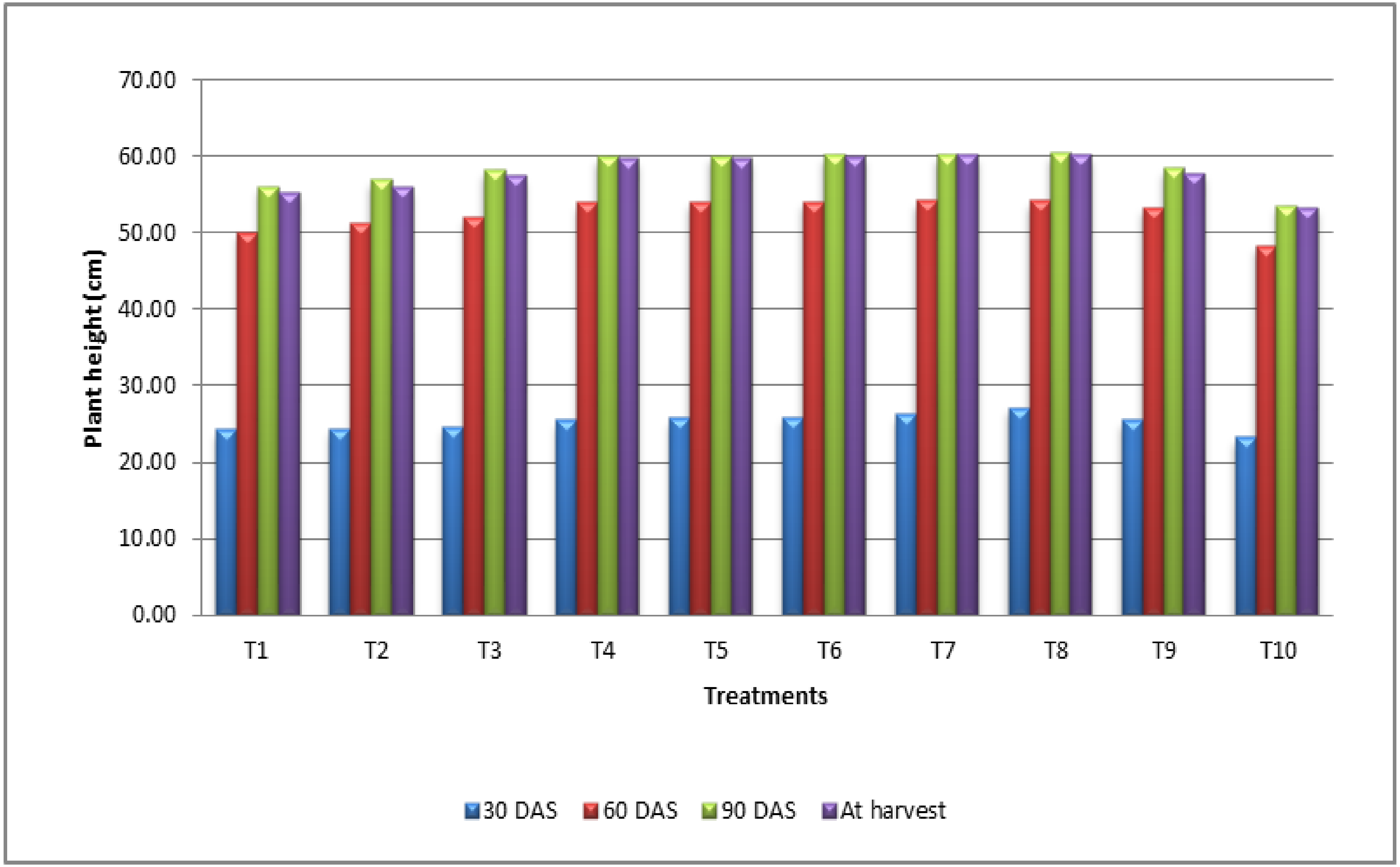

Fig. 4. Effect of different doses of triacontanol on plant height of soybean at different time intervals

4.1.3 Branches per plant

Data on branches per plant of soybean recorded at 30, 60, 90 DAS and harvest stage under different doses of triacontanol are presented in Table 4.3 and graphically illustrated through the Figure 5.

The branches per plant in soybean were less at 30 DAS, which were increased with time and attained the higher value at 60 DAS under all the treatments. However, the rate of increase in branches per plant was more between 30 and 60 DAS.

At 30 DAS, number of branches per plant was affected significantly under different treatments. But different dose of triacontanol caused significant variation on the number of branches per plant at 60 DAS. Control plots had the minimum number of branches per plant (3.81), which increased appreciably in plots receiving dose of triacontanol @ 0.10 g ha^{-1} (4.07). The dose of triacontanol @ 0.25 g ha^{-1} (4.57) cause marginal increase in branches per plant being the higher when these were applied at higher dose of triacontanol @ 0.50 g ha^{-1} (4.68) at 60 DAS, followed by triacontanol @ 0.40 g ha^{-1} (4.65). However, triacontanol @ 0.50 g ha^{-1} produced more branches as compared to control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments. Repeated results were observed at 90 DAS and harvest stage in relation to branches per plant in soybean.

Table 4.3. Effect of different doses of triacontanol on branches per plant of soybean at different time intervals

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Branches $plant^{-1}$			
			30 DAS	60 DAS	90 DAS	At harvest
T_1	Triacontanol	0.10	2.17	4.07	4.20	4.20
T_2	Triacontanol	0.15	2.30	4.23	4.33	4.33
T_3	Triacontanol	0.20	2.47	4.43	4.47	4.47
T_4	Triacontanol	0.25	2.60	4.57	4.63	4.63
T_5	Triacontanol	0.30	2.62	4.60	4.64	4.64
T_6	Triacontanol	0.35	2.65	4.63	4.66	4.66
T_7	Triacontanol	0.40	2.67	4.65	4.69	4.69
T_8	Triacontanol	0.50	2.69	4.68	4.73	4.73
T_9	Biovita (seaweed extract)	0.50	2.47	4.50	4.53	4.53
T_{10}	Control	-	2.00	3.81	3.93	3.93
	S.Em±		**0.03**	**0.04**	**0.05**	**0.05**
	CD (P=0.05)		**0.09**	**0.11**	**0.14**	**0.14**

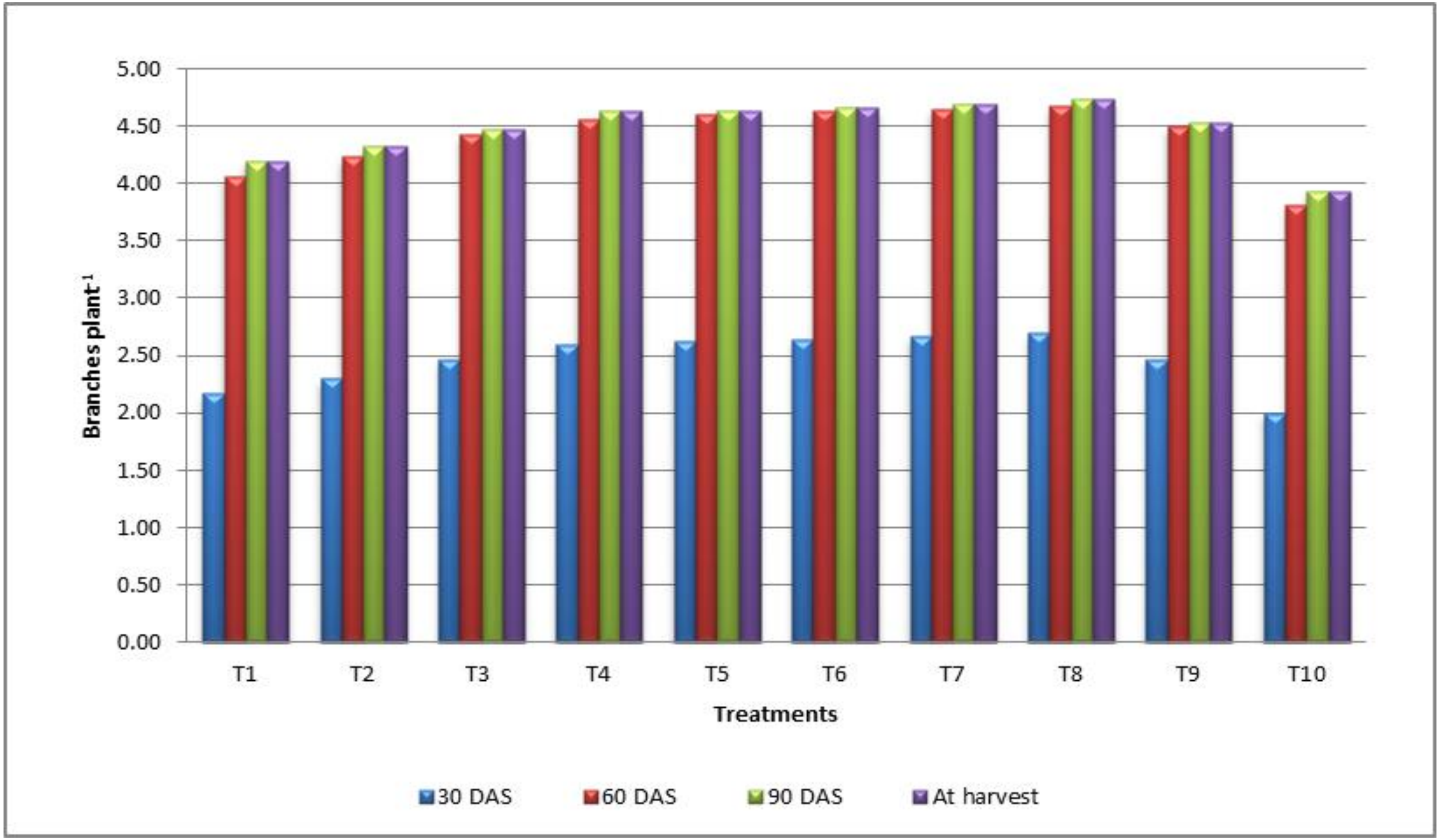

Fig. 5. Effect of different doses of triacontanol on branches per plant of soybean at different time intervals

4.1.4 Leaf area index

Leaf area index is the ultimate expression of photosynthetic activity of the plant, which may have a great bearing on growth and yield parameters during development phase of the crop. The data in relation to leaf area index of soybean as influenced by different treatments recorded at 30 and 60 DAS are presented in Table 4.4 and graphically illustrated through the Figure 6.

The leaf area index, in general, was less under all the treatments during early period of crop growth, which was increased with age of crop being higher at 60 DAS and thereafter, it was slightly decreased under all the treatments at harvest stage. However, the rate of increase in leaf area index was more between 30 and 60 DAS.

It is obvious from the data that leaf area index was affected significantly under different treatments at 30 DAS. But at 60 DAS, significant variation in leaf area index was recorded under different treatments. Among all the treatments, control plots had the minimum leaf area index (3.91), which was increased appreciably in plots receiving foliar spray of triacontanol @ 0.10 g ha^{-1} (4.11).

Maximum leaf area index was recorded plots receiving foliar spray of triacontanol @ 0.50 g ha^{-1} (5.11) at 60 DAS, followed by triacontanol @ 0.40 g ha^{-1} (5.08). However, triacontanol @ 0.50 g ha^{-1} was significantly superior over control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments but statistically at par with triacontanol @ 0.25, 0.30, 0.35 and 0.40 g ha^{-1} in relation to leaf area index of soybean.

Table 4.4. Effect of different doses of triacontanol on leaf area index of soybean at different time intervals

Treatment	**Plant Growth Promoter**	**Dose (g a.i. ha^{-1})**	**30 DAS**	**60 DAS**
T_1	Triacontanol	0.10	1.91	4.11
T_2	Triacontanol	0.15	2.04	4.45
T_3	Triacontanol	0.20	2.25	4.67
T_4	Triacontanol	0.25	2.68	5.00
T_5	Triacontanol	0.30	2.69	5.03
T_6	Triacontanol	0.35	2.71	5.05
T_7	Triacontanol	0.40	2.72	5.08
T_8	Triacontanol	0.50	2.74	5.11
T_9	Biovita (seaweed extract)	0.50	2.39	4.58
T_{10}	Control	-	1.69	3.91
	S.Em±		**0.03**	**0.04**
	CD (P=0.05)		**0.08**	**0.12**

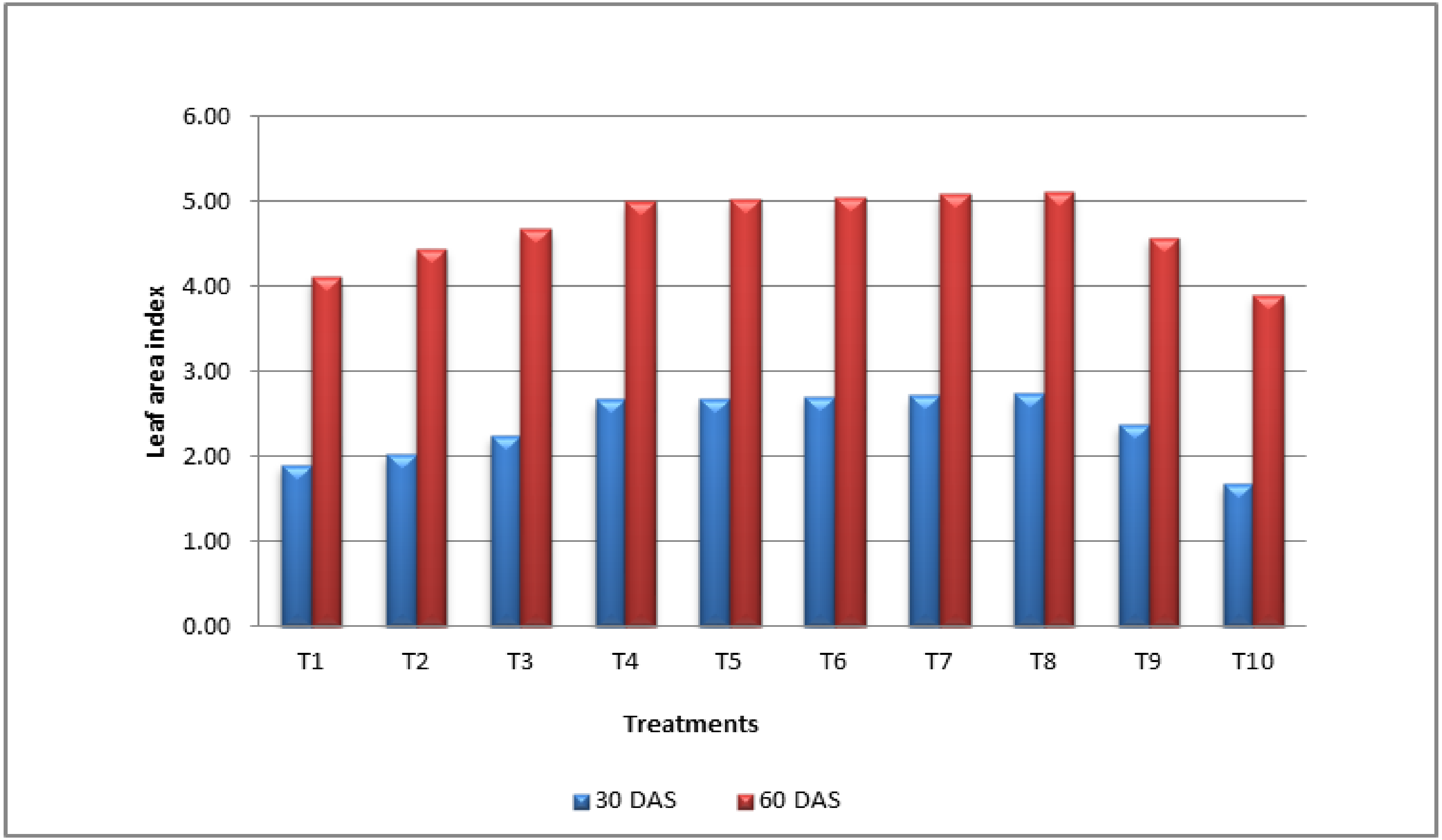

Fig. 6. Effect of different doses of triacontanol on leaf area index of soybean at different time intervals

4.1.5 Leaf chlorophyll content index

Data recorded on leaf chlorophyll content index of soybean plant at before and after 1st and 2nd spray under different doses of triacontanol are presented in Table 4.5 and Figure 7.

The leaf chlorophyll content was differed due to different treatments at various growth intervals of crop (before and after 1st and 2nd spray). It was affected significantly by various treatments. But before 1st spray, the leaf chlorophyll content was non significantly due to different doses of triacontanol including Biovita (seaweed extract) and control plots have no adverse effect on leaf chlorophyll content, which was increased with age of crop being higher after 1st spray of triacontanol and thereafter, it was increased under all the treatments at before 2nd spray and it was slightly increased under all the treatments at after 2nd spray. However, the rate of increase in leaf chlorophyll content was more between 30 and 60 DAS.

The leaf chlorophyll content was lower under control plots (32.88) at after 1st spray, when foliar application of triacontanol @ 0.50 g ha^{-1} was applied the higher leaf chlorophyll content (38.23) at after 1st spray, followed by triacontanol @ 0.40 g ha^{-1} (38.14). However, significantly triacontanol @ 0.50 g ha^{-1} produced more leaf chlorophyll content as compared to control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments but statistically at par with triacontanol @ 0.25, 0.30, 0.35 and 0.40 g ha^{-1}. Repeated results were observed at before and after 2nd spray in relation to leaf chlorophyll content of soybean.

Table 4.5. Effect of different doses of triacontanol on leaf chlorophyll content index of soybean at different time intervals

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Before 1st spray	After 1st spray	Before 2nd spray	After 2nd spray
T_1	Triacontanol	0.10	31.12	33.87	40.73	42.19
T_2	Triacontanol	0.15	31.18	34.52	41.45	42.95
T_3	Triacontanol	0.20	31.09	35.08	43.20	43.98
T_4	Triacontanol	0.25	31.60	37.99	44.25	46.35
T_5	Triacontanol	0.30	31.20	38.05	44.32	46.46
T_6	Triacontanol	0.35	30.85	38.09	44.40	46.49
T_7	Triacontanol	0.40	30.27	38.14	44.45	46.53
T_8	Triacontanol	0.50	31.00	38.23	44.48	46.67
T_9	Biovita (seaweed extract)	0.50	31.50	36.75	43.50	45.20
T_{10}	Control	-	30.78	32.88	39.94	40.83
	S.Em±		**0.25**	**0.15**	**0.16**	**0.20**
	CD (P=0.05)		**NS**	**0.44**	**0.47**	**0.59**

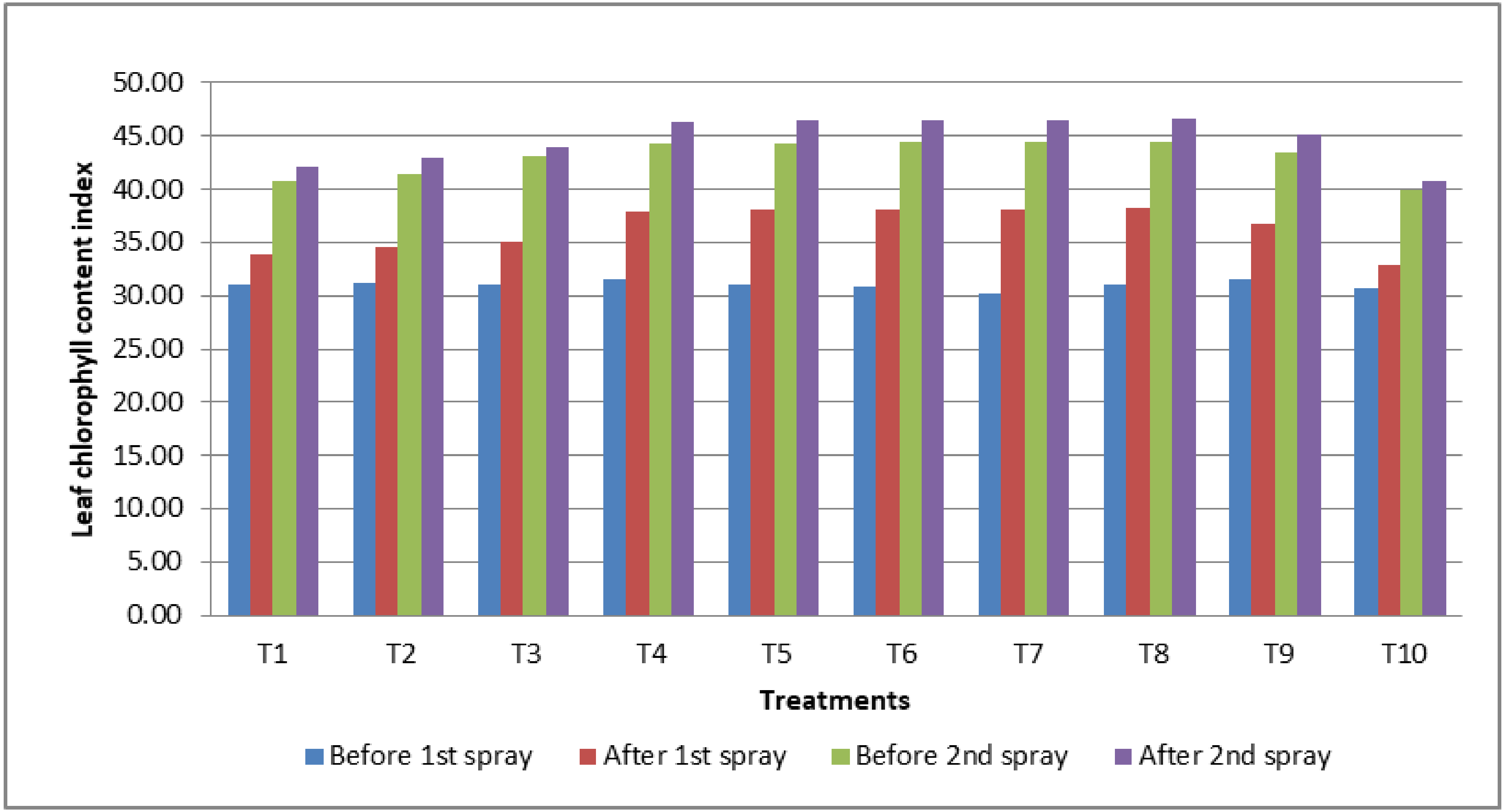

Fig. 7. Effect of different doses of triacontanol on leaf chlorophyll content index of soybean at different time intervals

4.1.6 Crop biomass

Data on average crop biomass of soybean plant as affected by various triacontanol treatments at 30, 60, 90 DAS and harvest stage are presented in Table 4.6 and graphically illustrated through the Figure 8.

It is evident from the data that average crop biomass (g m^{-2}) gradually increased with the advancement in the growth stages upto maturity under all the treatments. The rate of increase in crop biomass was most rapid during 30 to 60 DAS.

Different doses of triacontanol caused significant variations in the crop biomass at different time intervals. Control plots had the minimum quantity of crop biomass (353.14 g m^{-2}) at 60 DAS, which was increased appreciably at all the growth intervals as the plots receiving dose of triacontanol @ 0.10 g m^{-2} (374.43 g m^{-2}). The dose of triacontanol @ 0.25 g ha^{-1} (477.91 g m^{-2}) cause marginal increase in crop biomass in soybean being the higher when these were applied at higher dose of triacontanol @ 0.50 g ha^{-1} (483.66 g m^{-2}) at 60 DAS, followed by triacontanol @ 0.40 g ha^{-1} (482.33 g m^{-2}). However, the dose of triacontanol @ 0.50 g ha^{-1} produced more crop biomass as compared to control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments. Repeated results were observed at 90 DAS and harvest stage in relation to crop biomass in soybean.

Table 4.6. Effect of different doses of triacontanol on crop biomass of soybean plant at different time intervals

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Crop biomass (g m^{-2})			
			30 DAS	60 DAS	90 DAS	At harvest
T_1	Triacontanol	0.10	167.43	374.43	655.51	653.98
T_2	Triacontanol	0.15	172.58	394.96	663.17	661.61
T_3	Triacontanol	0.20	177.16	407.72	680.14	678.72
T_4	Triacontanol	0.25	230.78	477.91	761.61	759.94
T_5	Triacontanol	0.30	230.90	479.52	764.81	763.18
T_6	Triacontanol	0.35	231.12	481.22	766.56	765.05
T_7	Triacontanol	0.40	231.26	482.33	767.86	766.03
T_8	Triacontanol	0.50	231.60	483.66	769.28	768.27
T_9	Biovita (seaweed extract)	0.50	198.87	425.15	696.91	695.80
T_{10}	Control	-	163.01	353.14	603.90	602.71
	S.Em±		**1.00**	**4.03**	**4.97**	**4.95**
	CD (P=0.05)		**2.98**	**12.00**	**14.75**	**14.72**

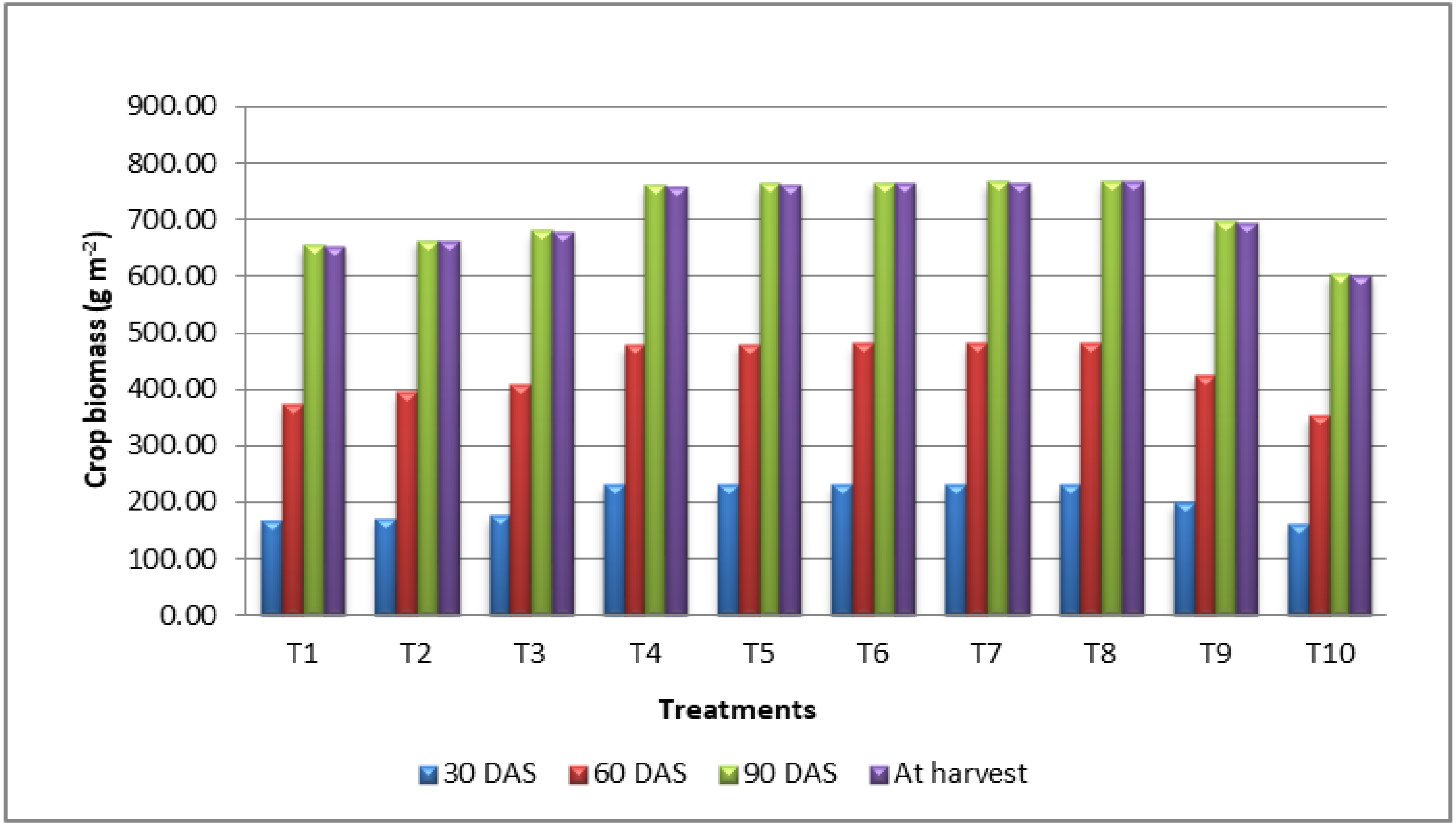

Fig. 8. Effect of different doses of triacontanol on crop biomass of soybean plant at different time intervals

4.1.7 Nodules per plant

Data recorded on nodules per plant of soybean plant at 45 and 60 DAS under different doses of triacontanol are presented in Table 4.7 and graphically illustrated through the Figure 9.

The nodules per plant, in general ,were less under all the treatments during early period of crop growth, which were increased with age of crop being higher at 60 DAS. However, the rate of increase in nodules per plant were more between 30 and 60 DAS.

At 45 DAS, the nodules per plant were affected significantly under different treatments. But at 60 DAS, significant variation in nodules per plant were recorded under different treatments. Nodules per plant were minimum (49.50) under control plots, which were increased appreciably in plots receiving foliar application of triacontanol @ 0.10 g ha^{-1} (51.33).

The maximum nodules per plant was recorded plots receiving foliar application of triacontanol @ 0.50 g ha^{-1} (55.58) at 60 DAS, followed by triacontanol @ 0.40 g ha^{-1} (55.48). However, triacontanol @ 0.50 g ha^{-1} was significantly superior over control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments but it was statistically at par with triacontanol @ 0.25, 0.30, 0.35 and 0.40 g ha^{-1} in relation to nodules per plant in soybean.

Table 4.7. Effect of different doses of triacontanol on nodules per plant of soybean at different time intervals

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Nodules $plant^{-1}$	
			45 DAS	60 DAS
T_1	Triacontanol	0.10	43.23	51.33
T_2	Triacontanol	0.15	43.93	51.77
T_3	Triacontanol	0.20	44.17	53.03
T_4	Triacontanol	0.25	47.30	55.17
T_5	Triacontanol	0.30	47.40	55.28
T_6	Triacontanol	0.35	47.48	55.37
T_7	Triacontanol	0.40	47.56	55.48
T_8	Triacontanol	0.50	47.65	55.58
T_9	Biovita (seaweed extract)	0.50	45.80	53.47
T_{10}	Control	-	42.27	49.50
	S.Em±		**0.23**	**0.14**
	CD (P=0.05)		**0.67**	**0.42**

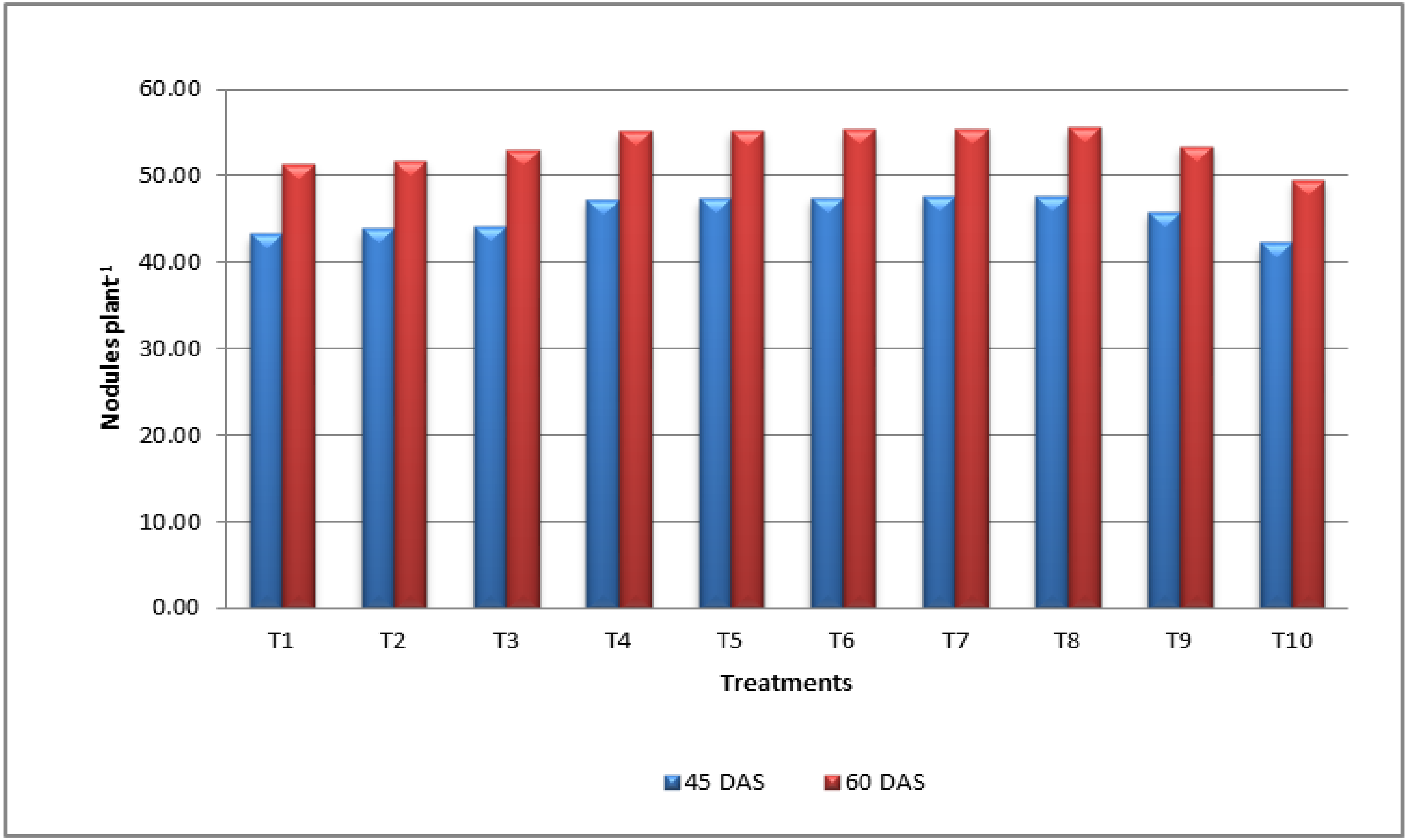

Fig. 9. Effect of different doses of triacontanol on nodules per plant of soybean at different time intervals

4.2 Yield attributing characters

4.2.1 Pods per plant

Data recorded on number of pods per plant as influenced by different doses of triacontanol in soybean are given in Table 4.8.

It is obvious from the data that number of pods per plant affected significantly under different treatments. Among all the treatments, the minimum number of pods per plant were recorded under control plots (27.70) which were increased appreciably in plots receiving foliar application of triacontanol @ 0.10 g ha^{-1} (28.63). The maximum number of pods per plant were recorded plots receiving foliar application of triacontanol @ 0.50 g ha^{-1} (35.03) followed by triacontanol @ 0.40 g ha^{-1} (35.00). However, triacontanol @ 0.50 g ha^{-1} was significantly superior over control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments but it was statistically at par with triacontanol @ 0.25, 0.30, 0.35 and 0.40 g ha^{-1} in relation to number of pods per plant of soybean.

Table 4.8. Effect of different doses of triacontanol on pods per plant in soybean

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Pods plant^{-1}
T_1	Triacontanol	0.10	28.63
T_2	Triacontanol	0.15	30.43
T_3	Triacontanol	0.20	32.42
T_4	Triacontanol	0.25	34.88
T_5	Triacontanol	0.30	34.94
T_6	Triacontanol	0.35	34.98
T_7	Triacontanol	0.40	35.00
T_8	Triacontanol	0.50	35.03
T_9	Biovita (seaweed extract)	0.50	33.75
T_{10}	Control	-	27.70
	S.Em±		**0.26**
	CD (P=0.05)		**0.76**

4.2.2 Seeds per pod

Data recorded on seeds per pod as influenced by different doses of triacontanol are given in Table 4.9.

It is evident from the data that number of seeds per pod affected significantly under different treatments. Among all the treatments, control plots had the minimum number of seeds per pod (2.13) which were significantly increased appreciably in plots receiving dose of triacontanol @ 0.10 g ha^{-1} (2.33). The dose of triacontanol @ 0.25 g ha^{-1} (2.79) cause marginal increase in number of seeds per pod in soybean being the higher when these were applied at higher dose of triacontanol @ 0.50 g ha^{-1} (2.87) followed by triacontanol @ 0.40 g ha^{-1} (2.86). However, the dose of triacontanol @ 0.50 g ha^{-1} produced more number of seeds per pod as compared to control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments in relation to number of seeds per pod in soybean.

Table 4.9. Effect of different doses of triacontanol on seeds per pod in soybean

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Seeds pod^{-1}
T_1	Triacontanol	0.10	2.33
T_2	Triacontanol	0.15	2.40
T_3	Triacontanol	0.20	2.60
T_4	Triacontanol	0.25	2.79
T_5	Triacontanol	0.30	2.81
T_6	Triacontanol	0.35	2.83
T_7	Triacontanol	0.40	2.86
T_8	Triacontanol	0.50	2.87
T_9	Biovita (seaweed extract)	0.50	2.67
T_{10}	Control	-	2.13
	S.Em±		**0.03**
	CD (P=0.05)		**0.10**

4.2.3 Seed index

Data presented in Table 4.10 showed that seed index of soybean was not affected due to different doses of triacontanol. Among treatments, the lower seed index (10.00 g) was recorded in control plots, which was non significantly increased appreciably in plots receiving foliar application of triacontanol @ 0.10 g ha^{-1} (10.33 g).

The higher seed index was recorded plots receiving foliar application of triacontanol @ 0.50 g ha^{-1} (11.77 g) followed by triacontanol @ 0.40 g ha^{-1} (11.50 g) produced higher seed index as compared to other foliar application treatments.

Table 4.10. Effect of different doses of triacontanol on seed index of soybean

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Seed index (g)
T_1	Triacontanol	0.10	10.33
T_2	Triacontanol	0.15	10.33
T_3	Triacontanol	0.20	10.67
T_4	Triacontanol	0.25	11.00
T_5	Triacontanol	0.30	11.00
T_6	Triacontanol	0.35	11.33
T_7	Triacontanol	0.40	11.50
T_8	Triacontanol	0.50	11.77
T_9	Biovita (seaweed extract)	0.50	11.00
T_{10}	Control	-	10.00
	S.Em±		**0.41**
	CD (P=0.05)		**NS**

4.3 Productive parameters

4.3.1 Seed yield

Data pertaining to seed yield of soybean (q ha^{-1}) under different doses of triacontanol are given in Table 4.11 and depicted graphically through Figure 10.

It is evident from the data that seed yield significantly affected due to different foliar application treatments. All the treated plots produced significantly more seed yield than control plots (19.85 q ha^{-1}). Seed yield was increased appreciably in plots receiving foliar application of triacontanol @ 0.10 g ha^{-1} (20.68)

Maximum seed yield was recorded plots receiving foliar application of triacontanol @ 0.50 g ha^{-1} (23.55 q ha^{-1}) followed by triacontanol @ 0.40 g ha^{-1} (23.51 q ha^{-1}). However, triacontanol @ 0.50 g ha^{-1} was significantly superior over control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments but it was statistically at par with triacontanol @ 0.25, 0.30, 0.35 and 0.40 g ha^{-1} in relation to seed yield of soybean.

4.3.2 Stover yield

Data pertaining to stover yield of soybean (q ha^{-1}) under different doses of triacontanol are given in Table 4.11 and depicted graphically in Figure 10.

It is evident from the data that stover yield significantly affected due to different foliar application treatments. All the treated plots produced significantly more stover yield than control plots (37.77 q ha^{-1}). Stover yield was increased appreciably in plots receiving foliar application of triacontanol @ 0.10 g ha^{-1} (38.35 q ha^{-1}).

Maximum stover yield was recorded plots receiving foliar application of triacontanol @ 0.50 g ha^{-1} (40.57 q ha^{-1}) followed by triacontanol @ 0.40 g ha^{-1} (40.54 q ha^{-1}). However, triacontanol @ 0.50 g ha^{-1} was significantly superior over control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments but it was statistically at par with triacontanol @ 0.25, 0.30, 0.35 and 0.40 g ha^{-1} in relation to stover yield of soybean.

Table 4.11. Effect of different doses of triacontanol on seed and stover yields

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})
T_1	Triacontanol	0.10	20.68	38.35
T_2	Triacontanol	0.15	21.10	38.81
T_3	Triacontanol	0.20	22.44	39.68
T_4	Triacontanol	0.25	23.41	40.43
T_5	Triacontanol	0.30	23.43	40.46
T_6	Triacontanol	0.35	23.48	40.49
T_7	Triacontanol	0.40	23.51	40.54
T_8	Triacontanol	0.50	23.55	40.57
T_9	Biovita (seaweed extract)	0.50	22.57	39.78
T_{10}	Control	-	19.85	37.77
	S.Em±		**0.09**	**0.13**
	CD (P=0.05)		**0.26**	**0.38**

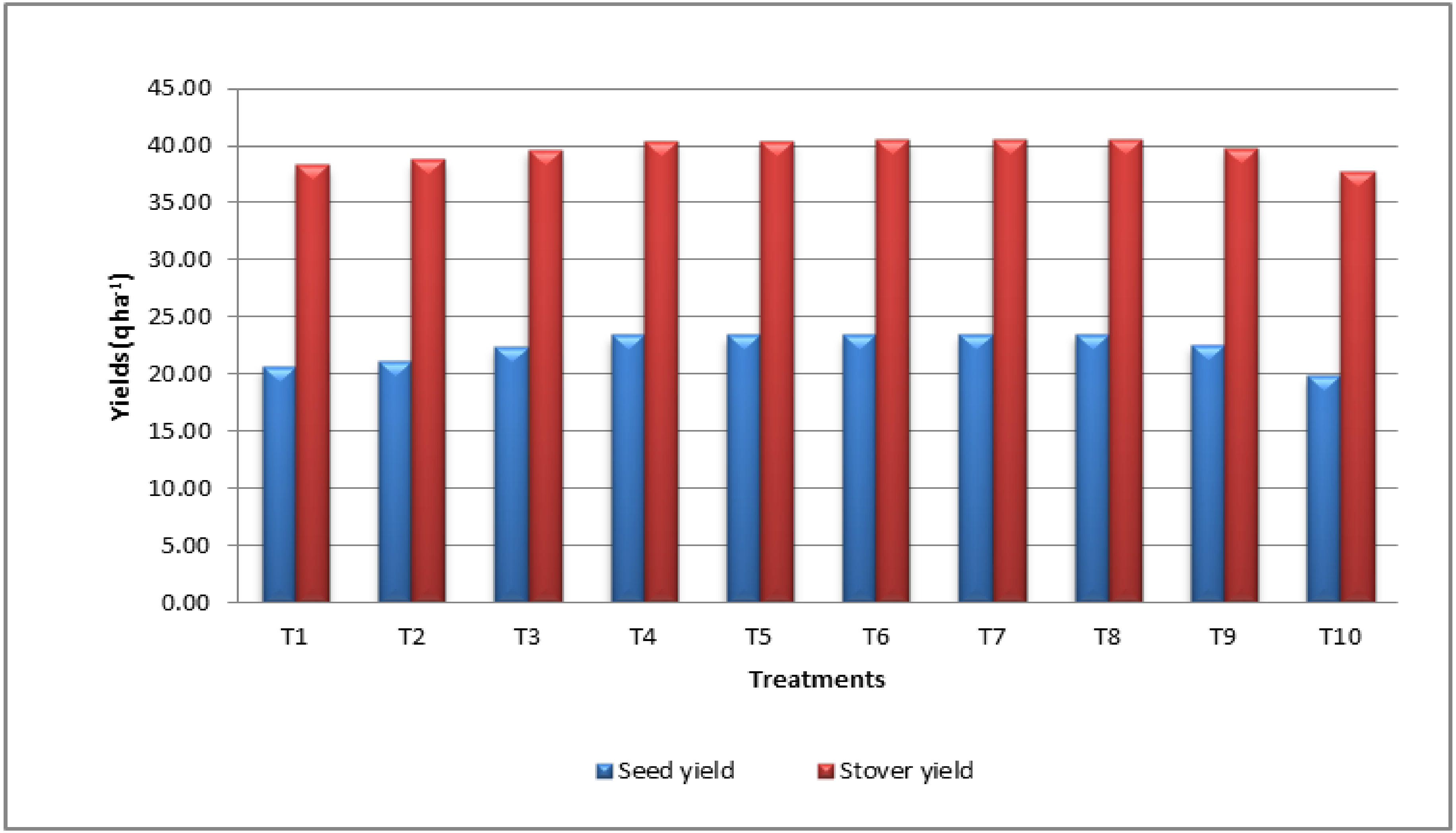

Fig. 10. Effect of different doses of triacontanol on seed and stover yields of soybean

4.3.3 Harvest index

The ratio of economic yield and biological yield (HI) expressed in percentage was affected by various treatments Table 4.12.

Among all the triacontanol treatments, control plots had the minimum harvest index (34.45%) which was increased appreciably in plots receiving the dose of triacontanol @ 0.10 g ha^{-1} (35.03). The dose of triacontanol @ 0.25 g ha^{-1} (36.67%) cause marginal increase in harvest index in soybean being the higher when these were applied at higher dose of triacontanol @ 0.50 g ha^{-1} (36.73%) followed by triacontanol @ 0.40 g ha^{-1} (36.71%). However, the dose of triacontanol @ 0.50 g ha^{-1} produced more harvest index as compared to control plots, biovita @ 0.50 g ha^{-1} and other triacontanol treatments.

Table 4.12. Effect of different doses of triacontanol on harvest index

Treatment	**Plant Growth Promoter**	**Dose (g a.i. ha^{-1})**	**Harvest index (%)**
T_1	Triacontanol	0.10	35.03
T_2	Triacontanol	0.15	35.22
T_3	Triacontanol	0.20	36.12
T_4	Triacontanol	0.25	36.67
T_5	Triacontanol	0.30	36.67
T_6	Triacontanol	0.35	36.70
T_7	Triacontanol	0.40	36.71
T_8	Triacontanol	0.50	36.73
T_9	Biovita (seaweed extract)	0.50	36.20
T_{10}	Control	-	34.45
	S.Em±		
	CD (P=0.05)		

4.4 Economic analysis of the treatments

The economic analysis of different doses of triacontanol was determined on per hectare area basis, which includes cost of cultivation, gross monetary returns, net monetary returns and benefit-cost ratio (profitability per rupee of investment) under different treatments.

4.4.1 Cost of cultivation (Rs ha^{-1})

Cost of cultivation was determined treatment wise on the basis of market price of various common and variable agro-inputs used [Appendix-I(D)]. The values thus obtained are presented in Table 4.13 and Figure 11.

Control plots had the minimum cost of cultivation (35601 Rs ha^{-1}), but it increased in foliar application of biovita @ 0.50 g ha^{-1} (Rs. 36276 ha^{-1}) and range of (Rs. 36101 to 36501 ha^{-1}) with the different doses of triacontanol. The maximum cost of cultivation was recorded plots receiving foliar application of triacontanol @ 0.50 g ha^{-1} (Rs. 36501 ha^{-1}) followed by triacontanol @ 0.40 g ha^{-1} (Rs. 36401 ha^{-1}).

4.4.2 Gross monetary returns (Rs ha^{-1})

The value of seed and stover yields, depending on the existing market rate of each produce was taken into consideration for determining gross monetary returns (GMR) under particular treatment Table 4.13 and Figure 11.

The GMR was minimum in control plots (Rs. 64319 ha^{-1}), which increased remarkably under all the plots receiving the dose of triacontanol and being maximum under the dose of triacontanol @ 0.50 g ha^{-1} (Rs. 75884 ha^{-1}) followed by triacontanol @ 0.40 g ha^{-1} (Rs. 75759 ha^{-1}).

4.4.3 Net monetary returns (Rs ha^{-1})

The net monetary returns (NMR) under each treatment was determined by subtracting the cost of cultivation from GMR of the particular treatment. The treatment wise values, thus obtained, are given in Table 4.14 and Figure 11.

It was obvious from the data that there was marginal profit of (Rs. 28718 ha^{-1}) when crop sown in control plots throughout the crop season while maximum NMR was gained from foliar application of triacontanol @ 0.50 g ha^{-1} (Rs. 39383 ha^{-1}) followed by triacontanol @ 0.40 (Rs. 39358 ha^{-1}).

4.4.4 Benefit - cost ratio

It refers to net monetary gain under a particular treatment with each rupee of investment. The benefit-cost indices as affected by different treatments are given in Table 4.14 and Figure 12.

It is evident from the data that minimum B:C ratio was recorded under control plots (1.81) which was increased appreciably in plots receiving foliar application of triacontanol @ 0.10 g ha^{-1} (1.85).

Maximum B:C ratio was recorded plots receiving foliar application of triacontanol @ 0.50 g ha^{-1} (2.08) followed by triacontanol @ 0.40 (2.08) and were same as triacontanol @ 0.25, 0.30, and 0.35 g ha^{-1}.

Table 4.13. Effect of different doses of triacontanol on cost of cultivation and GMR in soybean

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross monetary returns (Rs ha^{-1})
T_1	Triacontanol	0.10	36101	66909
T_2	Triacontanol	0.15	36151	68236
T_3	Triacontanol	0.20	36201	72410
T_4	Triacontanol	0.25	36251	75443
T_5	Triacontanol	0.30	36301	75507
T_6	Triacontanol	0.35	36351	75663
T_7	Triacontanol	0.40	36401	75759
T_8	Triacontanol	0.50	36501	75884
T_9	Biovita (seaweed extract)	0.50	36276	72816
T_{10}	Control	-	35601	64319

Table 4.14. Effect of different doses of triacontanol on NMR and B:C ratio in soybean

Treatment	Plant Growth Promoter	Dose (g a.i. ha^{-1})	Net monetary returns (Rs ha^{-1})	B:C Ratio
T_1	Triacontanol	0.10	30808	1.85
T_2	Triacontanol	0.15	32085	1.89
T_3	Triacontanol	0.20	36209	2.00
T_4	Triacontanol	0.25	39192	2.08
T_5	Triacontanol	0.30	39206	2.08
T_6	Triacontanol	0.35	39312	2.08
T_7	Triacontanol	0.40	39358	2.08
T_8	Triacontanol	0.50	39383	2.08
T_9	Biovita (seaweed extract)	0.50	36540	2.01
T_{10}	Control	-	28718	1.81

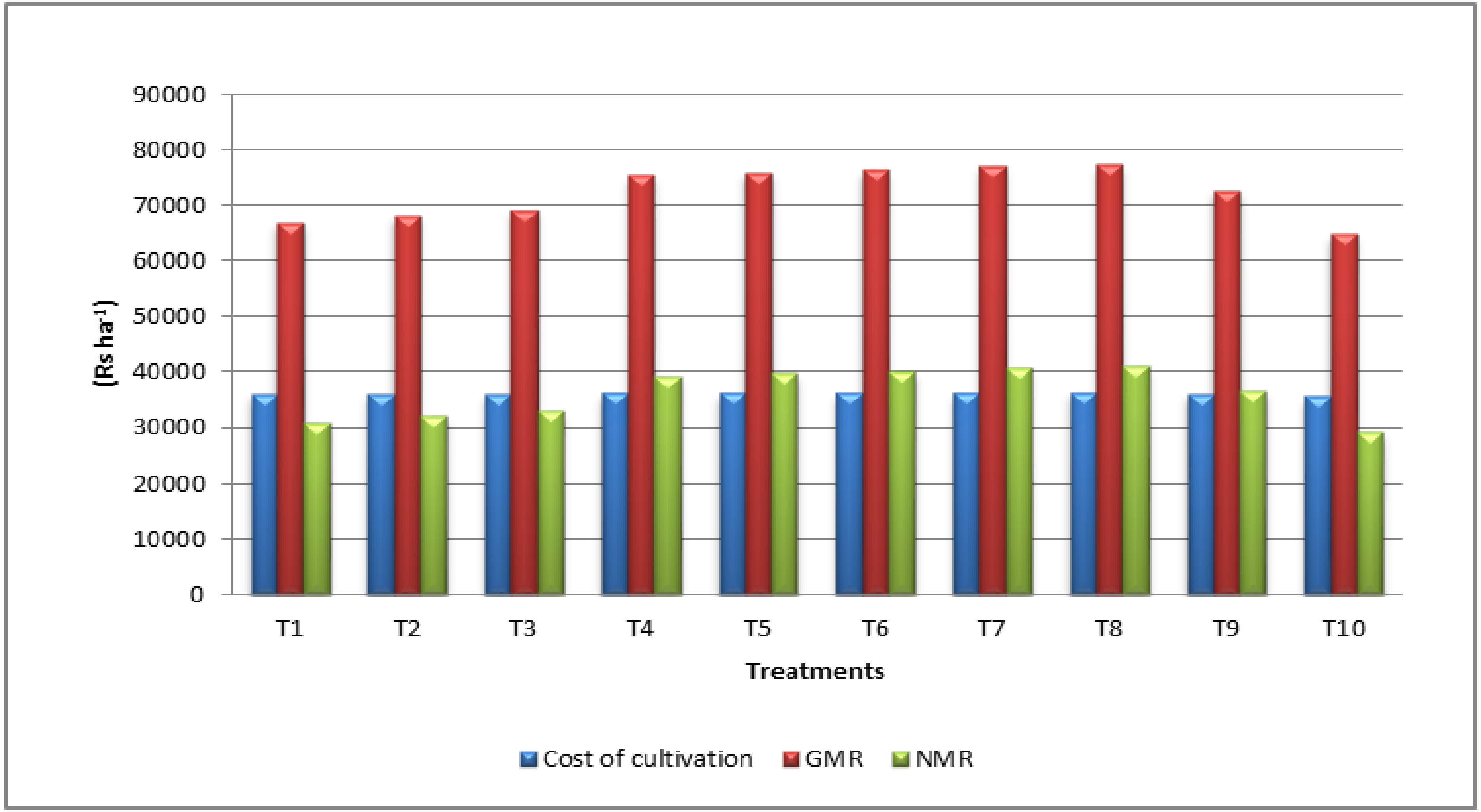

Fig. 11. Effect of different doses of triacontanol on cost of cultivation, GMR, NMR in soybean

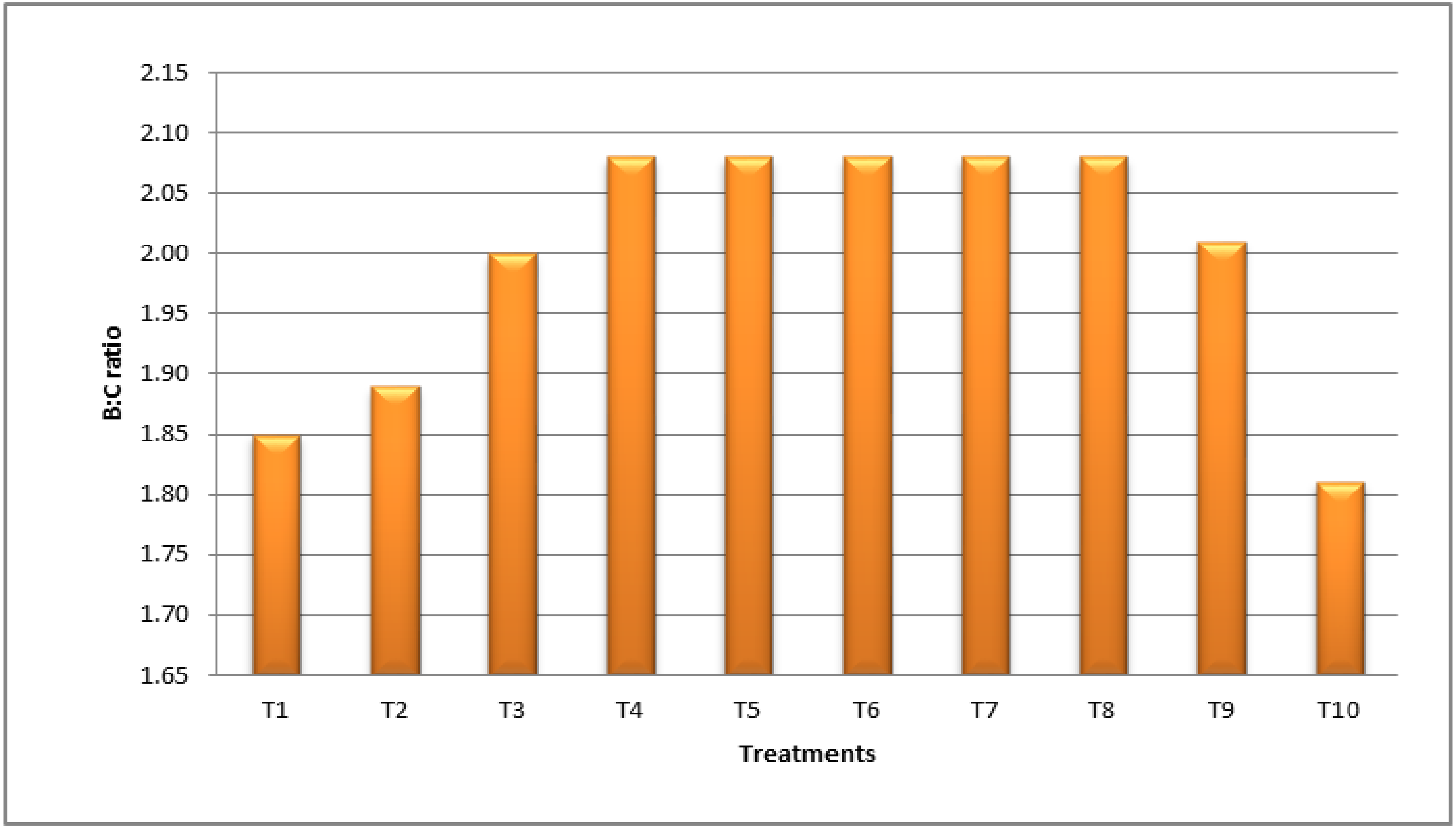

Fig. 12. Effect of different doses of triacontanol on B:C ratio in soybean

DISCUSSION

The efficacy of foliar application of triacontanol and biovita (seaweed extract) were assessed for their effect on crop growth parameters like plant population, plant height, branches per plant, leaf area index, leaf chlorophyll content index, crop biomass, nodules per plant and finally the seed yield has been presented in this chapter and efforts has been made to discuss the reason which may be responsible for some of the important results outlined in the previous chapter. As the yield is the final criteria for the evaluation of the efficiency of different treatments. The discussion therefore is necessarily centered on the effect of treatments on various characters as they finally decided the yield. The results obtained and outlined in the forthcoming pages to reach at a valid conclusion. The findings of this investigation have also been supported with the findings of other research workers and data recorded on various parameters during the course of investigation.

5.1 Edaphic and climatic variation

The cropped area mainly depends on the soil type and climatic conditions of the area, besides the impact of cultural practices followed under particular cropping system. In general fertility status of the soil was identical to the area as the same crop sequence (soybean - wheat) was followed since last four years with recommended dose of fertilizers to both the crops in sequence. The weather conditions which prevailed during the crop season were almost similar to that of average conditions of the locality. The average rainfall (1350.00 mm) and temperature (minimum and maximum mean temperature ranging from 15.4 $^{\circ}$C to 35.8 $^{\circ}$C) during the crop season was almost favourable for optimum growth and development of soybean. However, dry spell occurred during the start of first week of October which was nullified after one life saving irrigation to soybean and the variations that had been observed for various parameters under different treatments were mainly due to treatments effects rather than any other factors.

5.6 Study of plant growth parameters

Data given in Table (4.1) revealed that the plant population per meter square was non significantly due to different doses of triacontanol at 30 DAS and harvest stage, indicating that the different doses of triacontanol and biovita have no adverse effect on crop plants. The subsequent observation at harvest revealed slight declining trend under all the treatments but a greater drop was recorded in control plots which may be attributed to severe competitional stress by drought, light, moisture and nutrients, resulting in mortality of some of the crop plants.

Data given in Table (4.2) revealed that the plant height of soybean was differed due to different treatments at early growth stage (30 DAS) of crop. But, during advanced stages (at 60, 90 DAS and harvest stage), it was affected significantly by various treatments. The plant height of soybean was considerably more under foliar application of triacontanol @ 0.50 g ha^{-1} (54.30, 60.47 and 60.33 cm) at 60, 90 DAS and harvest stage, respectively as compared to control plots and biovita @ 0.50 g ha^{-1} and other triacontanol treatments, this may be due to foliar application and all the growth resources were optimally utilized by the crop plants. However, all the foliar application of treatments showed better plant height over control plots. The excellent growth under these treatments led to optimal utilization of growth resources; therefore, these treatments have long statured plants. These results are in close conformity with the finding of Naeem *et al.* (2009), Vagner Maximino *et al.* (2003) and Reddy *et al.* (2002).

Data given in Table (4.3) revealed that the branches per plant were remarkably differed due to different treatments at various growth intervals of crop (at 30, 60, 90 DAS and harvest stage). It was affected significantly by various treatments. The number of branches per plant were considerably more under the dose of triacontanol @ 0.50 g ha^{-1} (2.69, 4.68 and 4.73) at 30, 60 and 90 DAS, respectively, when the dose of triacontanol @ 0.50 g ha^{-1} was applied the higher branches of plant (4.73) at harvest stage, followed by triacontanol @ 0.40 g ha^{-1} (4.69) resulted in increased in the number of branches per plant at all the stages. This may be attributed to increased growth during critical period of crop growth as a result of effective crop growth on soybean seedlings. Because, both the treatments provided excellent growth which, led to optimum growth and development of crop plants and ultimately resulted in more number of branches per plant under these treatments. Almost similar results were obtained by kaur *et al.* (2015) and Khatun *et al.* (2016).

Data given in Table (4.4) revealed that the leaf area index was significantly differed due to different treatments at various growth intervals of crop (30 and 60 DAS). Control plots had the minimum leaf area index (1.69 and 3.91 at 30 and 60 DAS, respectively) and increased leaf area index of all treatments at stage of 60 DAS, when the dose of triacontanol @ 0.50 g ha^{-1} was applied the higher leaf area index (5.11) at 60 DAS, followed by triacontanol @ 0.40 g ha^{-1} (5.08) were obtained. Triacontanol @ 0.50 g ha^{-1} resulted in increased in leaf area index at all the stages. This may be attributed to increased leaves during critical period of crop growth as a result of effective number of leaves on soybean seedlings. The treatments provided excellent leaves growth which, led to optimum growth and development of crop plants and ultimately resulted in more leaf area index under these treatments Reddy et al. (2002). Almost similar results were obtained by Birnberg and Brenner (1987), Hassnein *et al.* (2009), Verma *et al.* (2009), Mehta *et al.* (2010).

Data given in Table (4.5) revealed that the leaf chlorophyll content was differed due to different treatments at various growth intervals of crop (before and after 1st and 2nd spray*).* It was affected significantly by various treatments. The leaf chlorophyll content was lower under control plots (30.78 and 32.88) at before and after 1st spray, when foliar application of triacontanol @ 0.50 g ha^{-1} was applied the higher leaf chlorophyll content (35.84 and 38.23) at before and after 1st spray, followed by triacontanol @ 0.40 g ha^{-1} (35.78 and 38.14) resulted in increased in the leaf chlorophyll content at all the stages. Similar trends were also observed at before and after 2nd spray. This may be attributed to increased growth during critical period of crop growth as a result of effective chlorophyll content on soybean seedlings. Because, both the treatments provided excellent growth which, due to optimum growth and development of crop plants and ultimately resulted in more leaf chlorophyll content under these treatments. Almost similar results were obtained by Chen *et al.* (2002), Hassanein *et al.* (2009), Verma *et al.* (2009), Krishnan and Kumari (2008) and Mehta *et al.* (2010).

Data given in Table (4.6) revealed that the crop biomass was significantly differed due to different treatments at various growth intervals of crop (30 60, 90 and at harvest). It was affected significantly by various treatments. The crop biomass were lower under control plots (163.01, 353.14 and 603.90 g m^{-2} at 30, 60 and 90 DAS, respectively) and increased crop biomass at 90 DAS of all treatments, when foliar application of triacontanol @ 0.50 g ha^{-1} was applied the higher crop biomass (769.28 g m^{-2}) at 90 DAS stage, followed by triacontanol @ 0.40 g ha^{-1} (767.86 g m^{-2}) were obtained. Triacontanol @ 0.50 g ha^{-1} resulted in increased in crop biomass at all the stages. This may be attributed to increased crop biomass during of crop growth as a result of effective crop biomass on soybean seedlings. The treatments provided excellent leaves growth which, led to optimum growth and development of crop plants and ultimately resulted in more crop biomass under these treatments. Almost similar results were obtained by Reddy *et al.* (2002).

Data given in Table (4.7) revealed that the nodules per plant were differed due to different treatments at various growth intervals of crop (45 and 60 DAS). It was affected significantly by various treatments. The nodules per plant were lower under control plots (42.27 and 49.50 at 45 and 60 DAS, respectively) and increased nodules per plant at stage of 60 DAS of all treatments, when foliar application of triacontanol @ 0.50 g ha^{-1} was applied the higher nodules per plant (55.58) followed by triacontanol @ 0.40 g ha^{-1} (55.48) at 60 DAS. Triacontanol @ 0.50 g ha^{-1} resulted in increased in nodules per plant at all the stages. This may be attributed to increased nodules during critical period of nodule growth as a result of effective nodules per plant on soybean seedlings. The treatments provided excellent nodules growth which, led to optimum growth and development of crop plants and ultimately resulted in more nodules per plant under these treatments. Almost similar results were obtained by Gutierrez-Coronado *et al.* (1998).

5.7 Effect on yield attributing characters of crop

The yield attributing traits *viz.,* pods per plant, seeds per pod and seed index (100 seed weight) were superior under foliar application of triacontanol @ 0.50 g ha^{-1} (35.03, 2.87 & 11.77, respectively). It was affected significantly by various treatments and seed index was non significant, followed by triacontanol @ 0.40 g ha^{-1} over control plots. Excellent growth and development of soybean plants under foliar application during yield character growth might have resulted in significantly superior yield attributes under foliar application of triacontanol @ 0.50 g ha^{-1} as compared to other foliar application treatments but statistically at par with triacontanol @ 0.25, 0.30, 0.35, 0.40 g ha^{-1}. Almost similar results were obtained by Birnberg & Brenner (1987), Kaur *et al.* (2015) and Khatun *et al.* (2016).

5.8 Productive parameters

Seed yield under a particular treatment is the result of complex phenomenon, which not only depends on the genetic constitution of the crop plants, but also on the production technology adopted. Control plots had the minimum seed yield (19.85 q ha^{-1}) due to foliar application of triacontanol at severe competition right from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally the seed yield (Table 4.11). All the treated plots receiving either manual foliar application of triacontanol produced higher yield as compared to control plots and biovita @ 0.50 g ha^{-1}. Foliar application of triacontanol @ 0.50 g ha^{-1} produced the highest seed yield (23.55 q ha^{-1}), followed by triacontanol @ 0.40 g ha^{-1} (23.51 q ha^{-1}) and proved its significantly superior over all the treatments but statistically at par with triacontanol @ 0.25, 0.30, 0.35, 0.40 g ha^{-1}. The crop under treated treatment attained lush growth due to elimination of problems from inter and intra row spaces besides better aeration due to manipulation of surface soil and thus, more space, water, light and nutrients were available for the better growth and development, which resulted into superior yield attributes and development, and consequently the highest yield. Bora and Bahra (1989), Kumar *et al.* (2001), Kaur *et al.* (2015) and Khatun *et al.* (2016).

Stover yield under a particular treatment is the result of complex phenomenon, which not only depends on the genetic constitution of the crop plants but also on the production technology adopted. The stover yield was lowest (37.77 q ha^{-1}) in the plots receiving contol plots due to severe competition right from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally the stover yield (Table 4.11). All the treated plots receiving either manual dose of triacontanol produced maximum yield over biovta @ 0.50 g ha^{-1} and control plots. The dose of triacontanol @ 0.50 g ha^{-1} produced the highest stover yield (40.57 q ha^{-1}) followed by triacontanol @ 0.40 g ha^{-1} (40.54 q ha^{-1}) and proved its superiority over all the treatments. The crop under treated treatment attained lush growth due to elimination of problems from inter and intra row spaces besides better aeration due to manipulation of surface soil and thus, more space, water, light and nutrients were available for the better growth and development, which resulted into superior yield attributes and development, and consequently the highest stover yield Kaur *et al.* (2015) and Khatun *et al.* (2016).

Harvest index (the ratio of economic yield to the biological yield) was higher under the dose of triacontanol @ 0.50 g ha^{-1} (36.73%) as compared to followed by triacontanol @ 0.40 g ha^{-1} (36.71%). Excellent growth and development of soybean plants under free environment during critical period of crop growth might have resulted in higher harvest index under these treatments (Table 4.12). While, control plots resulted in the lowest value of H.I. (34.45%). The control plots in resulted in stressful condition and ultimately suppress the growth and development of soybean plants Kaur *et al.* (2015) and Khatun *et al.* (2016).

5.11 Economic viability of treatments

Cost of cultivation play an important role in deciding the acceptability of any treatment by the farmers. It was obvious from the data that foliar application of triacontanol @ 0.50 g ha^{-1} (Rs. 36501 ha^{-1}), required maximum variable cost which was not affordable by the poor farmers and at the same time availability of labour during peak period is also not certain (Table 4.13). Thus, use of foliar spray triacontanol seems to be cheaper.

The gross monetary returns (GMR) was minimum (Rs. 64319 ha^{-1}) under control plots because of the lowest seed and stover yields (Table 4.13). But it was increased to a maximum level (Rs. 75884 ha^{-1}) under foliar application of triacontanol @ 0.50 g ha^{-1} followed by triacontanol @ 0.40 g ha^{-1} (Rs. 75759 ha^{-1}) also found superior and fetched the greater GMR over control plots because of increased seed and stover yields of the soybean crop.

Net monetary returns was found minimum under control plots (Rs. 28718 ha^{-1}), but increased to a maximum level under foliar application of triacontanol @ 0.50 g ha^{-1} (Rs. 39383 ha^{-1}) followed by triacontanol @ 0.40 g ha^{-1} (Rs. 39358 ha^{-1}) (Table 4.14). The low investment and better seed and stover yields coupled with good economic returns might be the reason for higher NMR over remaining treatments *viz*., triacontanol @ 0.10, 0.15, 0.20 and 0.25 g ha^{-1}. However, these foliar application of triacontanol were found superior over control plots treatment and fetched higher NMR of Rs. 30808 ha^{-1}, Rs. 32085 ha^{-1}, Rs. 36209 ha^{-1}, Rs. 39192 ha^{-1}, respectively.

The benefit-cost ratio represents the profitability of the treatments. The B:C ratio refers that total monetary gain under a particular treatment with each rupee of investment. The benefit per rupee of investment was lowest (1.81) in plots receiving control plots, which increased appreciably in plots receiving foliar application measures either through triacontanol (Table 4.14). Foliar application of triacontanol @ 0.10 g ha^{-1} caused slight improvement in the B:C ratio (1.85) and also increased dose of triacontanol @ 0.15 g ha^{-1} (1.89), which increased due to foliar application of triacontanol due to proportionate increase in profit per rupee of investment on foliar application. The foliar application of triacontanol @ 0.50 g ha^{-1} as recorded the maximum benefit (2.08) due to more gain each rupee of investment. However, GMR value was more under triacontanol @ 0.50 g ha^{-1}, it had more B:C ratio (2.08) followed by triacontanol @ 0.40 g ha^{-1} (2.08) and triacontanol @ 0.25, 0.30, 0.35 were same B:C ratio to soybean.

SUMMARY AND CONCLUSIONS

6.1 Summary

Soybean is an important oilseed crop and playing a vital role in sustaining the oilseed production in India over the past few years. In the different constraints, the weed management, nutrient management assumes the major importance for increasing the productivity of soybean. Intensive use of agro-chemicals coupled with congenial edaphic and weather conditions during *Kharif* season of 2017 further aggravate the weed manage, other factor resulting into low yields of soybean.

A field experiment was conducted during *kharif* season of 2017, Product Testing Unit, Department of Agronomy, JNKVV, Jabalpur (M.P.) to study the "Evaluation of Triacontanol at Varying Rates on Growth and Yield of Soybean" keeping above facts in view, present study has been taken with following objectives:-

1. To find out the suitable dose of triacontanol for higher yield of soybean
2. To see the effect of triacontanol on growth and yield attributes of soybean
3. To work out the economics of different treatments

The present experiment was carried out on clayey soil which was medium in organic carbon (0.60 %), available nitrogen (367 kg ha^{-1}) and phosphorus (16.23 kg ha^{-1}) but high in potassium (317.10 kg ha^{-1}) and neutral in reaction (7.1). The investigation was aimed to study the efficacy of drought effect through foliar application of triacontanol, biovita (seaweed extract) and control plots were laid out in Randomized Complete Block Design with three replications. All foliar application chemicals treatments were applied in 500 litre of water per hectare, using flat fan nozzle. Different observations on the crop parameters were carried out during the course of investigation. Plant population of soybean was recorded at 30 DAS and harvest stage. Growth parameters *viz.,* plant height (cm), number of branches per plant, leaf area index were recorded at different time intervals. pods per plant, seeds per pod and seed index (100 seed weight) were recorded at maturity. Finally, seed and stover yields were recorded treatment wise. Tabulation and statistical analysis of data were done for testing the significance among the different treatments which are summarized below.

6.1.1 Effect on crop

The plant population of soybean was not affected under all the treatments at 30 DAS and harvest stage, indicating that these treatments did not adversely affect the germination and further survival of crop plants. Consequently, plant population was almost similar under all the treatments. Growth parameters like plant height, branches per plant, leaf area, crop biomass, nodules per plant were significantly superior in treated plots than control plots. However, the dose of triacontanol @ 0.50 g ha^{-1} was better overall treatments followed by triacontanol @ 0.40 g ha^{-1}. Yield attributing traits *viz.,* pods per plant and seed index (100 seed weight) were also superior under treated plots as compared to control plots in which these parameters were inferior.

Both seed and stover yields were significantly higher under all the treatments receiving the dose of triacontanol @ 0.50 g ha^{-1} measure than control plots. Maximum seed yield of soybean was recorded under the dose of of triacontanol @ 0.50 g ha^{-1} followed by triacontanol @ 0.40 g ha^{-1} and proved superior over all the treatments.

6.1.2 Economic viability of treatments

Among all the treatments, the maximum cost of cultivation was recorded under foliar application of triacontanol @ 0.50 g ha^{-1} (Rs. 36501 ha^{-1}) followed by triacontanol @ 0.40 g ha^{-1}. Maximum gross monetary returns was obtained under foliar application of triacontanol @ 0.50 g ha^{-1} (Rs. 75884 ha^{-1}) followed by triacontanol @ 0.40 g ha^{-1} (Rs. 75759 ha^{-1}) though GMR was maximum in triacontanol treatments, but the net monetary returns and B:C ratio were also the highest under foliar application of triacontanol @ 0.50 g ha^{-1} (Rs. 39383 ha^{-1} and 2.08) followed by triacontanol @ 0.40 g ha^{-1} (Rs. 39358 ha^{-1} and 2.08) and were same B:C ratio in soybean.

6.2 Conclusions

Based on the results the following conclusions could be drawn.

1. The dose of triacontanol @ 0.25 g ha^{-1} was the suitable dose of triacontanol on higher yield of soybean. It was statistically at par with higher dose of triacontanol @ 0.50 g ha^{-1} and were same B:C ratio in soybean, that'swhy.
2. The dose of triacontanol @ 0.50 g ha^{-1} had higher growth parameter of soybean followed by triacontanol @ 0.40 g ha^{-1} and proved superior than other treatments.
3. The dose of triacontanol @ 0.50 g ha^{-1} were maximum net monetary returns and B:C ratio (Rs. 39383 ha^{-1} and 2.08) of soybean followed by triacontanol @ 0.40 g ha^{-1} (Rs. 39358 ha^{-1} and 2.08) and proved superior than other treatments.

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APPENDICES

Appendix I

[A] Common cost of cultivation per hectare area basis (Excluding cost of treatments)

Sr. No.	Particulars	Input (ha^{-1})	Cost Unit^{-1} (Rs)	Cost (Rs ha^{-1})
A	**Land preparation**			
I	Cultivator	1 pass	500 hr^{-1}	1000
II	Disc harrow	2 pass	500 hr^{-1}	2000
III	Levelling	1 pass	250 hr^{-1}	500
B	**Seed and sowing**			
I	Cost of seed	70 kg	52 kg^{-1}	3640
II	Seed treatment			
	Carboxin	160g	2000 kg^{-1}	320
III	Seed inoculation with *Rhizobium*	800g	20 200g^{-1}	80
IV	Seed treatment charges	1 man day	200 day^{-1}	200
		Seed drill	750 ha^{-1}	750
V	Sowing charges	2 man day	200 day^{-1}	400
VI	Gap filling	2 man	200 day^{-1}	400
C	**Fertilizers**			
I	Cost of fertilizers			
	N 25 kg through Urea	54 kg	295 50kg^{-1}	319
	P_2O_5 60 kg through SSP	375 kg	263 50kg^{-1}	1972
	K_2O 25 kg through MOP	42 kg	560 50kg^{-1}	470
II	Transportation charges			150
III	Application charges	2 man	200 day^{-1}	400
D	Harvesting, bundling and transportation	12 man days	200 day^{-1}	2400
E	Threshing and winnowing	8 man days	200 day^{-1}	1600
F	Land rent	6 month	18000 yr^{-1}	9000
	Total			**25601**

[B] Estimation of variable cost of cultivation due to various treatments (on per hectare area basis)

Treatment	Commercial Dose	Unit price (Rs litre^{-1} or kg^{-1})	Cost (Rs ha^{-1}) including application charges (400 Rs ha^{-1})
Tricontanol 0.10 g a.i. ha^{-1}	100	1000	500
Tricontanol 0.15 g a.i. ha^{-1}	150	1000	550
Tricontanol 0.20 g a.i. ha^{-1}	200	1000	600
Tricontanol 0.25 g a.i. ha^{-1}	250	1000	650
Tricontanol 0.30 g a.i. ha^{-1}	300	1000	700
Tricontanol 0.35 g a.i. ha^{-1}	350	1000	750
Tricontanol 0.40 g a.i. ha^{-1}	400	1000	800
Tricontanol 0.50 g a.i. ha^{-1}	500	1000	900
Biovita (seaweed extract) 0.50 g a.i. ha^{-1}	500	550	675
Control	-	-	

[C] Economic analysis of different doses of triacontanol treatments in soybean

Treatment	Cost of PGRs + Hand weeding (Rs ha^{-1})	Common cost of cultivation (Rs ha^{-1})	Cost of cultivation with treatments (Rs ha^{-1})
Tricontanol 0.10 g a.i. ha^{-1}	10500	25601	36101
Tricontanol 0.15 g a.i. ha^{-1}	10550	25601	36151
Tricontanol 0.20 g a.i. ha^{-1}	10600	25601	36201
Tricontanol 0.25 g a.i. ha^{-1}	10650	25601	36251
Tricontanol 0.30 g a.i. ha^{-1}	10700	25601	36301
Tricontanol 0.35 g a.i. ha^{-1}	10750	25601	36351
Tricontanol 0.40 g a.i. ha^{-1}	10800	25601	36401
Tricontanol 0.50 g a.i. ha^{-1}	10900	25601	36501
Biovita (seaweed extract) 0.50 g a.i. ha^{-1}	10675	25601	36276
Control	10000	25601	35601

[D] Economic analysis of different doses of triaconanol treatments in soybean

Treatment	Seed yield (q ha^{-1})	Value of seed (Rs ha^{-1})	Stover yield (q ha^{-1})	Value of Stover (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross monetary returns (Rs ha^{-1})	Net monetary returns (Rs ha^{-1})	B:C Ratio
Tricontanol 0.10 g a.i. ha^{-1}	20.68	63074	38.35	3835	36101	66909	30808	1.85
Tricontanol 0.15 g a.i. ha^{-1}	21.10	64355	38.81	3881	36151	68236	32085	1.89
Tricontanol 0.20 g a.i. ha^{-1}	22.44	68442	39.68	3968	36201	72410	36209	2.00
Tricontanol 0.25 g a.i. ha^{-1}	23.41	71400	40.43	4043	36251	75443	39192	2.08
Tricontanol 0.30 g a.i. ha^{-1}	23.43	71461	40.46	4046	36301	75507	39206	2.08
Tricontanol 0.35 g a.i. ha^{-1}	23.48	71614	40.49	4049	36351	75663	39312	2.08
Tricontanol 0.40 g a.i. ha^{-1}	23.51	71705	40.54	4054	36401	75759	39358	2.08
Tricontanol 0.50 g a.i. ha^{-1}	23.55	71827	40.57	4057	36501	75884	39383	2.08
Biovita (seaweed extract) 0.50 g a.i. ha^{-1}	22.57	68838	39.78	3978	36276	72816	36540	2.01
Control	19.85	60542	37.77	3777	35601	64319	28718	1.81

(Value of seed = Rs. 30.50 kg^{-1}, Value of stover = Rs. 1.00 kg^{-1})

[A] Mean sum of square for different growth parameter **Appendix II**

Source of variation	d.f.	Plant population (m^{-2})		Plant height (cm)			
		30 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Replication	2	0.01	0.02	0.06	0.03	0.09	0.00
Treatment	9	0.03	0.05	3.80	12.68	15.32	18.08
Error	18	0.02	0.05	0.06	0.06	0.18	0.28

[B] Mean sum of square for different growth parameter

Source of variation	d.f.	Leaf area index		Branches $plant^{-1}$			
		30 DAS	60 DAS	30 DAS	60 DAS	90 DAS	At Harvest
Replication	2	0.00	0.00	0.00	0.00	0.01	0.01
Treatment	9	0.46	0.57	0.17	0.25	0.20	0.20
Error	18	0.00	0.00	0.00	0.00	0.01	0.01

[C] Mean sum of square for different growth parameter

Source of variation	d.f.	Nodules plant^{-1}		Crop biomass (g m^{-2})			
		30 DAS	60 DAS	30 DAS	60 DAS	90 DAS	At Harvest
Replication	2	0.02	0.01	2.94	48.40	13.29	12.58
Treatment	9	13.83	13.07	2809.98	7790.26	11041.00	11011.60
Error	18	0.06	0.15	3.01	48.87	73.99	73.64

[D] Mean sum of square for different growth parameter

Source of variation	d.f.	Leaf chlorophyll content index			
		Before 1st spray	After 1st spray	Before 2nd spray	After 2nd spray
Replication	2	0.05	0.04	0.07	0.10
Treatment	9	0.43	12.88	8.89	13.77
Error	18	0.18	0.07	0.07	0.12

[E] Mean sum of square for different yield attributing characters

Source of variation	d.f.	Pods plant^{-1}	Seeds pod^{-1}	Seed index(g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Replication	2	0.18	0.00	0.19	0.01	0.01
Treatment	9	24.50	0.20	0.95	5.67	3.18
Error	18	0.20	0.00	0.50	0.02	0.02

CURRICULUM VITAE

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The author of this thesis Mr. Akash Sonkusale S/o Mr. Mahadev Sonkusale and Mrs. Kamal Sonkusale was born on 18th Feb 1993 in Bhopal (Madhya Pradesh). He has joined the following institutions and successfully completed the degree of M.Sc. (Ag.) during the year 2017-18 with 7.7 OGPA with 10 point scale.

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He has the following scientific interests-

Scientific interests

a. Agronomical crops research

b. Research work on Plant Growth Promoter

Awards

For the partial fulfillment of the master's degree programme, he was allotted a research problem on "Evaluation of Triacontanol at Varying Rates on Growth And Yield of Soybean" which was successfully conducted by him and being submitted in the form of the thesis.