EFFECT OF LIQUID BIOFERTILIZERS ON MORPHO-PHYSIOLOGY AND YIELD ATTRIBUTES OF SOYBEAN (*Glycine Max*. (L.) Merrill)

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B.Sc.(Agri.)

MASTER OF SCIENCE

IN

AGRICULTURAL BOTANY

(Plant Physiology)

DEPARTMENT OF AGRICULTURAL BOTANY

COLLEGE OF AGRICULTURE, PARBHANI

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PARBHANI 431 402 (M.S.) INDIA

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BY

POTE CHITRA KAILAS

B.Sc.(Agri.)

DISSERTATION

Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani

in partial fulfillment of

requirement for the degree of

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(Agriculture)

IN

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(Plant Physiology)

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VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH

PARBHANI 431 402 (M.S.) INDIA

2020

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I HEREBY DECLARE THAT THIS DISSERTATION

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Assistant Professor
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VNMKV, Parbhani - 431 402 (M.S.)

<u>CERTIFICATE-I</u>

This is to certify that the dissertation entitled **"EFFECT OF LIQUID BIOFERTILIZERS ON MORPHO-PHYSIOLOGY AND YIELD ATTRIBUTES OF SOYBEAN (*Glycine max* (L.) Merrill)"** submitted by Miss. **POTE CHITRA KAILAS** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL BOTANY (PLANT PHYSIOLOGY)** is recorded of original and bonafide research work carried out by her under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree.

I also certify that the dissertation or part there of has not been previously submitted by her for a degree of any university.

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Date : 30/09 /**2020**

Dr. A. B. Jadhav
(Research Guide)

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This is to certify that the dissertation entitled **"EFFECT OF LIQUID BIOFERTILIZERS ON MORPHO-PHYSIOLOGY AND YIELD ATTRIBUTES OF SOYBEAN (*Glycine max* (L) Merrill)"** submitted by **Miss. POTE CHITRA KAILAS** to the Vasantrao Naik Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL BOTANY (PLANT PHYSIOLOGY)** has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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PLAGIARISM CLEARANCE CERTIFICATE

This is to certify that the dissertation entitled, **"EFFECT OF LIQUID BIOFERTILIZERS ON MORPHO-PHYSIOLOGY AND YIELD ATTRIBUTES OF SOYBEAN (*Glycine Max.* (L.) Merrill)",** submitted by **Miss. Pote Chitra Kailas Reg. No: 2018A/37M** has been properly examined by URKUND: Anti plagiarism software**.** The percentage of similarities found in the thesis is 08 %.

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Place: Parbhani

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Pote

(Pote Chitra Kailas)

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ABBRIVATIONS

Symbol		Reference
%	:	Per cent
/	:	Per
@	:	At the rate of
BSS	:	Bright sun shine
°C	:	Degree Centigrade
-1	:	Per
Cm	:	Centimeter
cm^2	:	Centimeter square
C.D.	:	Critical Difference
CGR	:	Crop growth rate
c.v.	:	Coefficient of variation
CGR	:	Crop growth rate
DAS	:	Days after Sowing
Dept.	:	Department
EC	:	Electrical conductivity
et al.	:	*et alia* (and others/and other co-workers)
etc.	:	et cetera (and other similar things)
Fig.	:	Figure
g	:	Gram (s)
G.M	:	General Mean
Ha	:	Hectare
hr	:	Hour
i.e.	:	That is
Kg	:	Kilogram
Km	:	Kilometer
LAI	:	Leaf Area index
M	:	Meter
Mg	:	Milligram
M.S.	:	Maharashtra State
Max.	:	Maximum
Met.	:	Meteorological

Min.	:	Minimum
mm	:	Millimeter
MW	:	Meteorological week
N.S.	:	Non Significant
No.	:	Number
NAR	:	Net assimilation rate
pp	:	Pages
PM	:	Post meridien *i.e.* after noon
qt	:	Quintal
RH	:	Relative humidity
S.E. ±	:	Standard Error of Mean
Sig.	:	Significant
Sr.	:	Serial
T (t)	:	Tone
Viz.	:	Videlict (Namely)
kg/ha	:	Kilogram per hectare
RDF	:	Recommended dose of fertilizes
RGR	:	Relative growth rate

Introduction

CHAPTER-I

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is an important oilseed crop. It belongs to leguminaceae sub family Fabaceae (Papilionaceae) and genus *Glycine*. Soybean is native of Eastern Asia and wild forms of soybean occurs in China and Korea. It has been cultivated in India for a long time. It is having a special significance in energy crisis, Agriculture industry and export trade of India. It is a self pollinated short durational crop and it can withstand in adverse condition. It is emerged as a cheapest source of high quality protein (40-45%) and edible oil (20-22%). It also contains carbohydrates 26%, minerals 4%, phospholipids 2% and vitamins (thiamine & riboflavin). Health professionals consider soy proteins as superior proteins. Due to its high protein content soybean is known as ‘poor man’s meat’. Soybean is often designated as ‘Golden bean’, ‘Yellow jewel’, ‘Greater treasure’, ‘Natures miracle’ and ‘Meat of the field’ etc.

Major soybean growing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Kernataka and Andhra Pradesh. India rank 5th in area and production of soybean. Maharashtra rank 2nd in production in soybean after Madhya Pradesh. In India area under soybean in *kharif* 2018-19 was 108.396 lakh hectares with production of 114.832 lakh tonne. In Maharashtra soybean production during *kharif* 2018-19 was 36.296 lakh metric tonnes from an area of 37.365 lakh hectares. (Source: SOPA 2019).

The liquid biofertilizers are suspentions having agriculturally useful microorganisms, which fix atmospheric nitrogen and solubilize insoluble phosphates and make it available for the plant. Liquid biofertilizer known to influence nodulation, symbiotic nitrogen fixation and growth, yield quality of pulses. They reduces the use of chemical fertilizer by 15-40%. They have long shelf life and easy to produce and apply, more temperature tolerant and contamination free. The application of biofertilizers results in increased water uptake, root development, vegetative growth and nitrogen fixation. They can add 20-200kg N/ha under optimum soil condition and there by increased crop yield 15-25% of total crop yield.

The prices of fertilizers are increasing day by day and therefore, it is necessary to reduce the cost of fertilizers by using *Bradyrhizobium* and PSB inoculation to increase yield of legume crops. Biofertilizers cannot replace chemical fertilizers, but certainly are capable of reducing their input. Seed inoculation with effective *Bradyrhizobium* inoculant is recommended to ensure adequate nodulation and N_2 fixation for maximum growth and yield of pulse crop. Biofertilizer do not supply nutrients directly to crop plants but have capacity to fix atmospheric nitrogen and convert insoluble phosphate into soluble form. Rhizobium is a gram negative bacteria which inhibit the root nodules of leguminous crops. Rhizobia is a soil bacteria which fix N_2 inside the root nodules of leguminous.

Phosphorous is the second major plant nutrient limiting factor for crop productivity. It plays important role in plant metabolism such as cell division, development and photosynthesis, nutrient transport, transfer of genetic information and regulation of metabolic pathways. (Meenu Rathi *et al*. 2016) Adequate phosphorus nutrition enhances many aspects of plant development including flowering, fruiting and root growth. (Lingaraju *et al*. 2016) Phosphate solubilizing or mobilizing biofertilizer convert the insoluble soil phosphate into soluble forms by secreting several organic acid and under optimum condition they can solubilise/mobilize about 30-50 kg / 2.5 ha due to which crop yield increased by 10 to 20%. They are cheaper, pollution free and renewable energy sources. Sulphur oxidizers are involved in oxidation of elemental sulphur to plant available sulphate. Sulphur is one of the essential plant nutrient and it contributes to yield and quality of crops. It plays an important role in formation of proteins, vitamins and enzymes. Sulphur is a constituent of the essential amino acids cystine, cysteine and methionine. (R. Vidyalakshmi 2009)

Zinc is one of the essential micro-nutrient required for the normal healthy growth and reproduction of crop plants. It plays a important role in plant metabolism. (Hughes and Poole 1989) Zinc is present in the enzyme system as a co-factor and it is metal activator of many enzymes (Parisi *et al* 1969). Zinc solubilizing bacteria exhibit other traits beneficial to plants such as phosphate solubilization. In view of above mentioned fact, the present investigation was carried out, "EFFECT OF LIQUID BIOFERTILIZERS ON MORPHO-PHYSIOLOGY AND YIELD ATTRIBUTES OF SOYBEAN (*Glycine Max*.(L.)Merrill) with following objectives:-

1. To quantify the impact of biofertilizers on morpho-physiological traits of soybean
2. To study the effect of biofertilizers on yield contributing characters
3. To assess the effect of biofertilizers on quality parameters of soybean

Review of Literature

CHAPTER – II

REVIEW OF LITERATURE

This chapter deals with the research work carried out on studies on "**Effect of liquid biofertilizers on morpho-physiology and yield attributes of soybean (*Glycine Max.* (L.) Merrill.)**" A brief summary of research work carried out by various research workers in India and abroad on this aspect has been highlighted and reviewed.

2.1 Effect of biofertilizers on morpho-physiological traits of soybean

Dubey (1997) revealed that the individual seed inoculation of *Rhizobium* and PSB recorded the significantly higher number of branches and number of leaves of soybean which might be due to greater nitrogen fixation P solubilization and availability of phosphorous.

Mekki *et al*. (2005) recorded that application of organic manure at a rate of 20 tone/acre as a sole treatment and also when it associated with biofertilizer as one treatment had more plant height and dry weight / plant in soybean.

Sharma *et al*. (2009) revealed that the combined application of FYM @ 5t ha^{-1} + Seed inoculation with *Rhizobium* + ZnSo4 @ 15 Kg ha^{-1} + crop residue @ 5t ha^{-1} recorded significantly higher plant height (184.09 cm) primary branches per plant (12.34) and secondary branches per plant (7.86) as compare to all other treatments in pigeonpea.

Amit *et al*. (2010) revealed that the dual inoculation of seed with *Rhizobium* + PSB recorded significantly higher plant height, number of branches/plants, root nodules/plant of green gram as compared to control and all other treatments.

Anwar *et al*. (2010) recorded that the *Bradyrhizobium* inoculation was beneficial in nodulation, plant fresh weight, dry matter production, plant height, seed yield and hay yield of soybean varieties PB-1 and G-2.

Koushal *et al*. (2011) conducted the field experiment at College of Agriculture, Amritsar and recorded that the maximum plant height of 16.89 cm, 65.78 cm and 73.37cm at 30, 60 and 90 days respectively in soybean crop.

Argaw (2012) studied the evaluation of co-inoculation of *Brady-rhizobium japonicum* and phosphate solubilizing *pseudomonas spp*. effect on Soybean (*Glycine max* L. (Merrill.)) in Assossa area and revealed that the dual inoculation with TAL-378 (*Bradyrhizobium japonicum*) and PSB significantly increased plant height at harvest, number of nodules per plant, nodule volume per plant, nodule fresh weight/plant and shoot height at late flowering and early pod setting compared to the other treatments.

Arnab Banerjee *et al.* (2012) carried out a field experiment at Burdwan, West Bengal (India) and revealed that the combined treatment of biofertilizer, chemical fertilizer and compost significantly increased the LAI, LAD, CGR and NAR and reduced LAR during crop maturity in Mustard (*Brassica campestris* cv. B_9).

Paritosh Patra *et al*. (2013) revealed that inoculation of biofertilizers significantly affected plant height and total chlorophyll content in sunflower.

Jaga *et al*. (2015) revealed that the application of 75% NPK + VAM + Rhizobium + PSB recorded the significantly higher nodules per plant (73.7), nodules weight (481 mg/nodule), plant height (76.2 cm), pods per plant (31.6), seed yield (26.8 q ha^{-1}), leaf area index (14.2) and harvest index (49.4%) as compared to control in soybean.

Tanushree Mondal *et al*. (2015) studied the impact of reduced dose of chemical fertilizer and its combination with biofertilizer and vermicompost on morpho-physiological and biochemical traits of mustard (*Brassica campestris cv*. B_9). He concluded that 25% reduced dose of chemical fertilizer and its combination with vermicompost was optimum for most of the parameters studied as compared to the control at both crop stages.

Uikey *et al.* (2015) studied the influence of organic, chemical and biofertilizer on growth and yield of pea and revealed that 10 t FYM $^{-ha}$ + 45:75:60 kg/ha NPK + Rz + PSB culture showed significantly maximum plant height (65.87 cm), number of leaves per plant (157.90), number of pods per plant (26.40), number of seed per pod (7.01) and yield (26.54 q^{-ha}).

Kumar *et al*. (2016) revealed that the application of combination of *rhizobium*, PSB and P levels had significantly increase the growth and yield attributes such as plant height, number of branches/plant, nodulation, dry matter accumulation/plant, number of pods/plant, test weight (g), grain yield, straw yield and biological yield qt^{-ha} of urdbean.

Sarawa *et al*. (2016) studied the effect of biological fertilizer on the growth and nodule formation of soybean (*Glycine max* (L.) Merrill) in ultisol under net house conditions and they revealed that treatments of M-bio (microbial) fertilizer at concentration of 12 ml per liter of water provide the highest growth such plant height as 44.65 cm, stem diameter as 0.86 cm and roots length as 24.49 cm.

Kaluram *et al.* (2017) studied that the all growth attributes of fenugreek such as plant height (cm), number of branches per plant, number of root nodules per plant and weight of fresh nodules per plant (mg) as well as seed and straw yield were recorded significantly higher by application of 75% RDF + *Rhizobium* + PSB liquid formulation.

Daravath *et al.* (2017) recorded that the growth parameters such as plant height, number of functional leaves, root length and dry matter yield were significantly increased due to dual inoculation with 10 ml of *Bradyrhizobium japonicum* kg^{-1} seed + 10 ml of PSB kg^{-1} seed and number of branches of soybean was significantly increased with individual seed inoculation of 10 ml *Bradyrhizobium japonicum* kg^{-1} seed of soybean.

Ade *et al*. (2018) revealed that the dual inoculation of *Rhizobium* + PSB recorded significantly the highest plant height, dry matter, LAI followed by the individual inoculation of *Rhizobium* and PSB in pigeon pea.

Dawarika *et al*. (2018) revealed that the treatment-8 (100% RDF + *Rhizobium* 20 g kg^{-1}) was recorded the best performance in plant height (cm), pod length (cm), number of pods per plant, weight of pod at 50 and 75 days of crop maturity in Cowpea (var. Pusa Barsati).

Nagar *et al.* (2018) conducted the field experiment at Instructional Farm of Rajasthan College of Agriculture, Udaipur during *kharif* 2015 to study the response of soybean [*Glycine max (*L.) Merrill] to microbial inoculation and sulphur and revealed that the microbial inoculation and sulphur significantly increased the growth attributes such as plant height, dry matter accumulation, LAI, primary branches plant^{-1}, number of pods plant^{-1} and yield attributes number seeds pod^{-1}, seed index, grain and straw yield over the control.

Neelam Singh *et al*. (2018) revealed that the application of 100% RDF with bioformulation as NPK liquid formulation + Zn solubilizing bacteria produced highest LAI, CGR, RGR values.

2.2 Effect of biofertilizers on yield and yield attributing characters of soybean

Govindan *et al* (2003) revealed that the *Rhizobium* and phosphate solubilizing bacteria was synergistic and their inoculation increase the significantly seed yield of soybean (30.9 and 33.6%) over control treatment.

Marlen Hernandez *et al.* (2003) studied response of soybean G7-R-315 cv to single and combined inoculations with *Bradyrhizobium japonicum* and *Glomus fasciculatum* strains and recorded that the positive influence of microorganisms on soybean plant height and yield.

Mekki B.B. *et al*. (2005) recorded that seed yield (g/plant), pods weight (g/plant), as well as, number of pod plant^{-1}, seeds pod^{-1} and 1000-seed weight were decreased by adding biofertilizer singly, but when it associated with organic manure showed the highest seeds and pods weights in soybean.

Gupta *et al.* (2006) revealed that the significantly higher pods/plants, 1000 seeds weight, seed yield as well as straw yield over other 2 varieties of urdbean (*vigna mungo).*

Tran Thi Ngoc Son *et al*. (2006) recorded that the application of bradyrhizobia (*Bradyrhizobium japonicum*) and phosphate solubilizing bacteria (*Pseudomonas spp*.) can enhance the number of nodules, dry weight of nodules, yield components, grain yield, soil nutrient availability and uptake of soybean crop.

Mahanta and Rai *et al.* (2008) conduct the field experiment at New Delhi and recorded that the application of 50% recommended dose of P as SP (single superphosphate) + PSB + VAM shows the highest yield during the first year in soybean (2.0 t/ha) and during both the years in wheat (4.4 and 4.6 t/ha in the first and second years respectively), but that of 50% recommended dose of phosphate as RP (rock phosphate) + PSB + VAM registered the highest grain yield (2.2 t/ha) during the second year in soybean.

Dhage Shubhangi *et al*. (2008) revealed that the 100% RDF with dual inoculation (*Rhizobium* + PSB) resulted in the highest grain (1363 kg ha^{-1}) and straw yields (1798 kg ha^{-1}) in soybean.

Qasim Shahid *et al.* (2009) recorded that the inoculation with *Rhizobium japonicum* improved soybean yield and yield components as compared to non-inoculated seed.

Selvakumar *et al*. (2009) revealed that addition the combination inoculation of *Rhizobium* + phosphobacteria significantly increased growth and yield of blackgram compared with control.

Arshad Javaid *et al*. (2010) studied the effect of a symbiotic nitrogen fixing bacterium *Bradyrhizobium japonicum* strain and a commercial biofertlizer EM (effective microorganisms) on growth, nodulation and yield of soybean [*Glycine max* (L.) Wilczek] and concludes that the soybean yield can be significantly enhanced by the application of *B. japonicum* and EM in farmyard manure amendment.

Mishra and Kedar (2010) revealed that the combined inoculation of field pea seeds with *Rhizobium* + PSB + PGPR, grain and straw yields were increased by 19.06 % and 30.62 % over *Rhizobium*, 19.06 % and 30.62 % over PSB and 19.06 % and 30.62 % over PGPR alone inoculations, respectively.

Akbari *et al*. (2011) studied the effect of biofertilizers, nitrogen fertilizer and farmyard manure on grain yield and seed quality of sunflower (*Helianthus annus* L.) and he revealed that biofertilizer improved plant productivity and quality in sunflower seed.

Koushal *et al*. (2011) recorded that the highest number of pods per plant (80.40) and highest test weight (17.02g) in the treatment where 50 per cent recommended N applied through urea + 50 per cent N through FYM + PSB and the lowest of these were found in the control treatment.

Argaw (2012) revealed that the co-inoculation with TAL-378 (*Bradyrhizobium japonicum*) and PSB, and dual fertilization of nitrogen (N) and phosphorus (P) fertilizers significantly increased number of pods per plant, number of seeds per pod per plant and seed yield $ha^{-1}$of soybean compared to the other treatments.

Sarawgi *et al.* (2012) studied the effect of phosphorous application along with PSB, *Rhizobium* and VAM on P fraction and productivity of soybean (*Glycine max*) and recorded that the application of 30 kg P_2O_5/ha through rock phosphate (RP) + PSB *Rhizobium* inoculation + VAM recorded significantly higher seed yield, net return and return/ rupee invested in P compared to application of 60 kg P_2O_5/ha through rock phosphate without biofertilizers.

Waghmare *et al*. (2012) revealed that the application of 75% NPK with FYM and biofertilizers *Rhizobium* and PSB showed superiority for pod yield plant^{-1}, seed yield plant^{-1}, 100 seed weight, seed yield, protein and oil yield in soybean seed over all other treatments.

Shivran *et al.* (2012) recorded the application of 40 kg P_2O_5/ha with PSB inoculation significantly increased the number of pods per plant (64.27), seeds per pod (2.63) seed yield (24.53q/ha), straw yield (37.57q/ha) and biological yield of soybean (JS-335).

Manochehr *et al.* (2013) revealed that the chlorophyll index, nodule dry weight, pod yield per plant and grain yield per unit area, except leaf area index (LAI) which is affected by bio-fertilizer, influenced by interaction of bio and chemical fertilizers and BJ and BJ + PSB produced higher LAI than NI (non-inoculated) and PSB.

Paritosh *et al*. (2013) recorded that the inoculation of PSB + VAM + Azotobacter showed significant effect on grain yield, stalk yield, biological yield, harvest index, and oil content, as compared to PSB + Azotobacter and VAM + Azotobacter inoculation in sunflower crop.

Bhavsar and Bhat (2015) studied the effect of *Rhizobium* liquid biofertilizer on soil and Cheak pea (*Cicer arientinum*) and recorded that the inoculation of seed with an effective strain of *Rhizobium* resulted in significant increase in nodulation, N_2 content in shoot, root and grain yield over uninoculated control.

Kumar *et al*. (2016) studied the effect of *Rhizobium*, PSB and P-levels on growth, yield attributes and yield of Urdbean (*Vigna mungo* L.) and revealed that the application of 75 kg/ ha P_2O_5 + PSB + *Rhizobium* significantly improve the plant growth, yield and its attributing traits.

Lingaraju *et al* (2016) conducted the field experiment at Main Agricultural Research Station Dharwad and revealed that higher seed yield of soybean (35.96 q ha^{-1}) was obtained with the treatment combination of dual inoculation of PSB + VAM with foliar spray of 0.1% humic acid at flower initiation and was higher to an extent 22.5 per cent compared to control (27.90 q ha^{-1}).

Islam *et al*. (2017) studied the response of soybean to *Rhizobium* biofertilizer under different levels of phosphorus and revealed that the inoculation of seeds with *Bradyrhizobium* and application of N and P fertilizer at recommended dose recorded the highest grain and straw yield of soybean.

Ade *et al*. (2018) revealed that the dual inoculation of *Rhizobium* + PSB recorded significantly higher number of pods/plants, highest seed yield kg/ ha and harvest index followed by the individual inoculation of PSB + *Rhizobium* in pigeonpea.

Nagar *et al.* (2018) studied the response of soybean [*Glycine max (*L.) Merrill] to microbial inoculation and sulphur and recorded that the microbial inoculation and sulphur significantly increased the growth attributes such as plant height, dry matter accumulation, LAI, primary branches $plant^{-1}$, number of pods $plant^{-1}$ and yield attributes number seeds pod^{-1}, seed index, grain and haulm yield over the control.

Desai *et al*. (2019) recorded that the highest seed yield (1760 kg ha^{-1}, 1809 kg ha^{-1} and 1843 kg ha^{-1}) of soybean (NRC-37) was found with the application of vermicompost @ 2.5 t ha^{-1}, 60 kg P_2O_5 and seed treatment of *Rhizobium* + PSB, respectively.

2.3 Effect of biofertilizers on quality parameters of soybean (oil content, protein content)

Mekki *et al*. (2005) recorded that the treatment of single biofertilizer was increased the oil % of seed and also increased the protein % by adding the organic manure + biofertilizer treatment due to the increase in N% at the same treatments in soybean.

Gupta *et al.* (2006) studied the effect of biofertilizer and phos-phorous levels on yield attributes, yield and quality of urdbean (*vigna mungo*) and revealed that the seed inoculation with phosphorous solubilizing bacteria showed the significant increase in seed yield and protein content and N and P uptake over uninoculated treatment.

Selvakumar *et al*. (2009) studied the effect of biofertilizers on growth and yield of blackgram and recorded that the highest chlorophyll content and protein content was showed in T_7 with combined effect of *Rhizobium* and phosphobacteria.

Dhage and Kachhave (2010) studied the effect of biofertilizers on yield, nutrient content and quality of soybean (*Glycine max*) under rainfed condition and revealed that the application of treatment T1S3 (100% RDF + *Rhizobium* + PSB) gave the significantly highest seed yield (15.5q/ha) which was 51.4% more over control.

Akbari *et al*. (2011) studied the effect of biofertilizers, nitrogen fertilizer and farmyard manure on grain yield and seed quality of sunflower (*Helianthus annus* L.) and he recorded that the application of biofertilizer decreased the saturated fatty acids (palmitic and stearic) and increased unsaturated fatty acids (linoleic acid and oleic acid) and oil content, compared with untreated plants.

Iraj *et al*. (2012) studied the effects of biofertilizers on grain yield and protein content of two soybean (*Glycine max* L.) cultivars (Williams and Line no. 17) and observed that fertilizer levels of b1(N + P), b3(N + *Bacillus* and *Pseudomonas* + 50% of P), and b5(*B. japonicum* + 50% of N + *Bacillus* and *Pseudomonas* + 50% of P) produced the highest protein percentage. It therefore seems that biofertilizers can be considered as a replacement for part of chemical fertilizers in soybean production.

Waghmare *et al*. (2012) conducted the field experiment at the Research Farm, Department of Agronomy, College of Agriculture, Latur to study the effect of integrated nutrient management in soybean (*Glycine max* (L.) Merrill) and revealed that the application of 75% NPK with FYM and biofertilizers *Rhizobium* and PSB showed superiority for pod yield plant^{-1}, seed yield plant^{-1}, 100 seed weight, seed yield, protein and oil yield in soybean seed over all other treatments.

Jaga *et al*. (2015) studied the effect of bio-fertilizers and fertilizers on yield and quality of soybean [*Glycine max* (L.) Merrill.] and revealed that the application of 75% NPK + VAM + *Rhizobium* + PSB recorded maximum total chlorophyll content (2.8 mg g^{-1}), carbohydrates (5.46 mg g^{-1}), reducing sugars (1.97 mg g^{-1}), protein (37.7 %) and oil content (19.5%) as compared to control in soybean.

Ade *et al*. (2018) conducted the field experiment at Experimental Farm, Agronomy Section, College of Agriculture, Latur to study the effect of phosphorus and biofertilizers on growth, yield and economics of pigeon pea (*Cajanus cajan* L. Millsp.) under rainfed condition and revealed that the dual inoculation of PSB+ *Rhizobium* recorded the highest protein content (19.15 %).

Neelam Singh *et al*. (2018) revealed that the application of 100% RDF with bioformulation as NPK liquid formulation + Zn solubilizing bacteria produced highest protein and oil yield of groundnut followed by 100% RDF with biogrow application.

Chaudhari *et al*. (2019) recorded that the application of 40 kg S/ha and bio-fertilizer seed treatment application showed the significantly highest seed yield, protein content, phosphorus and sulphur content and uptake by seed of green gram.

Material and Methods

CHAPTER III

MATERIAL AND METHODS

The details of the materials used and techniques adopted during the course of investigation on the soybean entitled "**Effect of liquid biofertilizers on morpho-physiology and yield attributes of soybean (*Glycine Max*. (L.) Merrill)"** have been presented in this chapter.

3.1 General description

3.1.1 Experimental site

The experiment was conducted during *kharif* season 2019-2020 at instructional farm of Department of Agril. Botany College of Agriculture, VNMKV Parbhani, in Maharashtra.

3.1.2 Soil

The soil was typical black cotton having medium fertility and fairly good drainage. The land having uniform topography was used to study the influence of morpho-physiology and yield attributing characteristic of soybean.

3.1.3 Climate and weather conditions

Geographically, Parbhani is situated at $19^{0}16^{'}$ north latitude and $76^{0}47$' east longitude and at 409 altitudes above sea level and has a sub-tropical climate. The average annual precipitation is 900 mm with 57 rainy days. The mean daily maximum temperature varies from 24.7^{0}C. The month of November, December, January and February were humid and moisture index was positive, winter was cool with moisture index oscillating to deficit side and rest of the period was dry. Parbhani district comes under assured rainfall zone.

Table 1. Weekly weather data 2019-20 (VNMKV, Parbhani Location)

WK	Period	Rainfall (mm)	Humidity (%)		Temperature (°C)		EVP (Hrs.)	BSS (Hrs.)	W. V. (K/mph)
			AM	PM	Max.	Min.			
27	02 July-08 July	10.6	33.2	23.1	76	58	5.1	2.7	8.3
28	09 July-15 July	34.2	33.5	22.6	83	49	5.5	6.7	7.0
29	16 July-22 July	11.2	34.2	22.9	79	46	6.6	7.7	5.8
30	23 July-29 July	64.3	30.6	22.6	81	62	4.5	4.1	6.3
31	30 July-05 Aug.	85.4	28.1	21.8	92	85	2.1	1.2	6.6
32	06 Aug.-12 Aug.	62.2	30.5	22.0	89	65	4.0	3.5	6.2
33	13 Aug.-19 Aug.	9.7	32.3	21.5	80	57	4.6	5.4	4.6
34	20 Aug.-26 Aug.	1.2	32.2	22.0	80	56	5.6	6.5	6.0
35	27 Aug.-02 Sept.	78.0	31.2	21.5	88	59	4.6	5.6	4.7
36	03 Sept.-09 Sept.	13.2	30.1	21.6	83	70	2.9	2.0	4.7
37	10 Sept.-16 Sept	86.4	30.0	21.2	88	68	2.8	4.7	5.4
38	17 Sept.-23 Sept	118.8	30.9	21.9	94	67	2.3	5.1	3.5
39	24 Sept.-30 Sept	35.6	31.3	21.1	92	62	3.7	6.5	3.3
40	01 Oct.-07 Oct.	21.2	31.4	20.5	88	60	3.8	7.3	2.8
41	08 Oct.-14 Oct.	5.1	31.5	20.1	87	53	4.1	7	2.7
	Total Mean	637.1	471	326.4	1280	917	62.2	76	77.9

3.4 Experimental design and treatments

The experiment was laid out in Randomized block design with four replications and six treatments given below

Experimental details

Season	:	*Kharif* 2019-20
Crop	:	Soybean
Variety	:	MAUS-612
Sowing date	:	4 July 2019
Design of experiment	:	Randomised block design
Gross plot size	:	4m x 3m
Net plot size	:	3.6m x 2.7m
Spacing	:	45cm x 5cm
Replication	:	Four
No. of treatments	:	Six
Fertilizer application	:	30: 60: 30 NPK kg/ha
Place of experiment	:	Instructional farm of Department of Agril. Botany College of Agriculture, Parbhani

Treatment details:

Biofertilizer treatment before sowing as per recommendation 50ml/10kg of seeds.

T_1	:	Absolute control
T_2	:	Recommended dose of fertilizer
T_3	:	RDF + Inoculation of Rhizobium
T_4	:	RDF + Inoculation of Rhizobium + PSB
T_5	:	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria.
T_6	:	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizer

Materials required:

I. Seed

Soybean seeds of variety MAUS-612 was used for conducting the experiment. Seed of soybean variety MAUS-612 was obtained from Breeder seed production Unit, VNMKV Parbhani. The recommended seed rate 65 kg ha^{-1} was used for sowing.

II. Liquid Biofertilizers

The four liquid biofertilizers were used for seed treatment of soybean seed before sowing for 12 hrs. The liquid biofertilizers was brought from Biological Nitrogen Fixation Laboratory, Department of Soil Science and Agricultural Chemistry, VNMKV, Parbhani.

3.5 Land preparation

The field was brought to good tilth with one deep ploughing by tractor and three harrowing. The weeds and residues of previous crop were removed from the experimental field. The land was levelled with the help of plank and furrows were made.

3.5.1 Layout

The field was laid out as per Randomised Block Design and replicated four times. Each experimental treatment had gross plot size of 4m x 3m and net plot size of 3.6m x 2.7m. The row to row spacing was 45 cm and plant to plant spacing was 5 cm. The layout of the field experiment was given in Fig.1

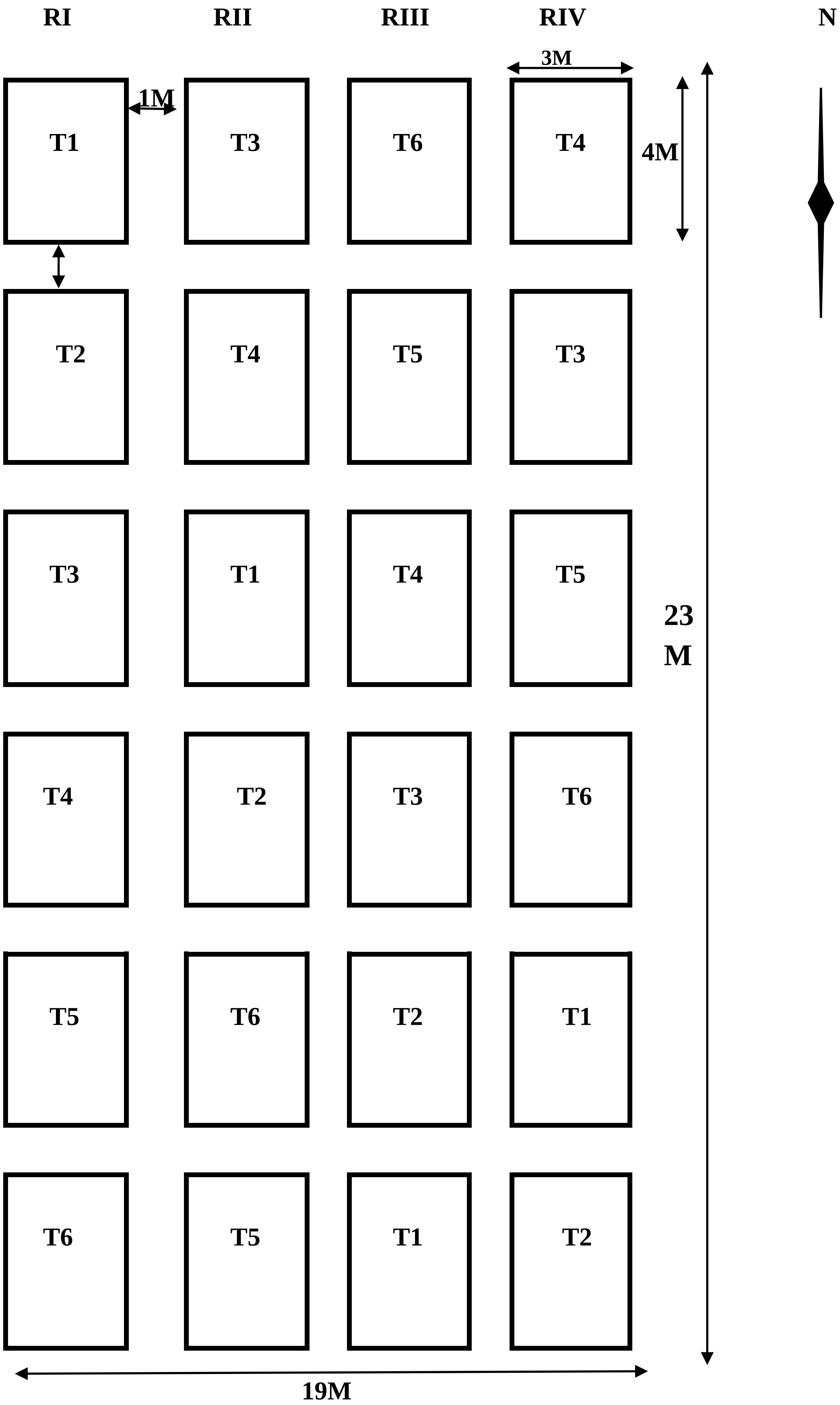

Fig.1. PLAN OF LAYOUT

Plate 1 : General view of field experiment

Plate 2 : Flowering stage of soybean crop

Plate 3 : Maturity stage of crop

3.6 Sowing and thinning

The sowing was done by dibbling method on 4 July 2019. Two seeds per hill were dibbled. Gap filling was done after 6 days. Thinning was done 15 days after sowing and finally one healthy plant was allowed to grow at each hill.

3.7 Fertilizer application

The fertilizers were applied @ 30:60:30 kg/ha and full dose of nitrogen, phosphorus and potash was given at the time of sowing.

3.8 Plant protection measures

One spray of Profenofos @ 2 ml/lit of water and second spray of Emamectin Benzoate @ 1 g/lit of water was sprayed as per the recommendation was undertaken to control leaf eating caterpillar and pod borer respectively.

3.9 Intercultural operations

With an object to keep the crop free from weeds two hand weeding and one hoeing were carried out. There was no weedicide applied.

3.10 Biometric observations

Five plants per treatment were randomly selected for recording all the periodical biometric observations during the growth and development of soybean crop as affected by given treatments. The various parameters/observations on which data were recorded are given below.

3.10.1. Height of plant

Plant height was recorded in centimeter from the base of stem to the last opened upper leaf.

3.10.2. Number of branches per plant

Total number of branches per plant was counted and recorded.

3.10.3. Leaf area

Leaves were graded into three categories *viz.*, small, medium and large. One of the representative samples from each class was sampled and leaf was measured by using leaf area meter. It is expressed in cm^2 per plant.

3.10.4. Leaf area index

The leaf area existing on unit ground area was proposed by Watson (1952) as an appropriate measure of crop growth. This measure is known as leaf area index. It is dimension less ratio and calculated by following formula.

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

3.10.5. Crop Growth Rate (CGR)

The daily increment in plant biomass is termed as crop growth rate (Watson, 1952) or productivity rate (Leith, 1965) or rate of dry matter production. It was determined as per the following formula suggested by Watson, in 1952.

$$CGR = \frac{W_2 - W_1}{P\ (T_2 - T_1)} \quad \text{(g/cm}^2\text{ of ground area/day)}$$

Where,

W_1 and W_2 are the dry weight of the plant at time T_1 and T_2 and P is land area.

3.10.6. Relative Growth Rate (RGR)

Relative growth rate is the increase in plant dry matter per unit of time in relation to initial weight. It was calculated as per formula which given by Fisher in 1921 and expressed in g/g/day.

$$RGR = \frac{\text{Loge } W_2 - \text{loge } W_1}{t_2 - t_1}$$

Where,

W_1 = weight of dry matter at time t_1

W_2 = weight of dry matter at time t_2

t_1 = initial time of observation

t_2 = final time of observation

3.10.7. Net Assimilation Rate (NAR)

Net assimilation rate is expressed as increase in dry matter per unit leaf area per unit time. It is expressed in g/dm^2/day.

$$NAR = \frac{W_2 - W_1}{T_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1}$$

Where,

W_1 = total dry weight of plant in g at time t_1

W_2 = total dry weight of plant in g at time t_2

A_1 = leaf area per plant at time t_1

A_2 = leaf area per plant at time t_2

t_1 = initial time of observation

t_2 = final time of observation

3.10.8. Total dry weight

The selected plants uprooted and washed it under running tap water and dry them with filter papers to remove the excess water and take the fresh weight of whole plant. The parts of the plant i.e. root, stem and leaves were separated. And keep it separately in paper bag and dry in oven at 80^0C for 48 hours. The dry weight calculated on 30, 60, 90 days after sowing. It is expressed in gram per plant.

3.10.9. Days to 50% flowering

Number of days required for 50 per cent of the plants to flower were counted and recorded.

3.11. Yield attributes

3.11.1 Number of pods

Number of pods of five randomly selected plants from each plot was recorded and averaged to get the number of pods per plant.

3.11.2 Test weight

Weight of the 100 seed was recorded from the produce of each treatment and expressed in grams.

3.11.3 Harvest index (HI)

Harvest index indicated the crop yield efficiency to produce grain yield per unit of total biological yield. Harvest index in different treatments was worked out by following formula given by Donald (1962).

$$HI (\%) = \frac{\text{Economic or grain yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

3.11.4. Yield /plot

The plants harvested from each net plot were threshed and weight of clean produce was recorded in kilograms per plot.

3.11.5. Yield /ha

The plants harvested from each net plot were threshed and weight of clean produce was recorded in kilograms per plot and converted into quintals per hectare.

3.12. Quality/Biochemical parameters

3.12.1 Chlorophyll content

The chlorophyll content of leaf was measured by using an instrument SPAD. The observations were recorded during day time between 11 a.m. to 13 p.m.

The chlorophyll values were recorded at 30, 45, 60, 75 and 90 days after sowing. For recording the observations three leaves were selected from each selected plant in plot. Then mean values of chlorophyll content were calculated.

3.12.2. Oil content

The seeds obtained from each treatment and replication wise were used individually for estimation of oil content of soybean by using NMR method. In this method an individual sample taken in glass tube and weight on electronic weighing balance and then this inserted in NMR machine and within 15-30 seconds, it analyses an oil content from the sample.

3.12.3. Protein content

The nitrogen content was estimated at STRU, Parbhani. Protein content in seed was estimated by using KEL PLUS Nitrogen Estimation System where a factor of 6.25 is multiplied with N% to get protein content % which contains digestion, distillation and titration units separately.

Reagents required

1) Potassium sulphate
2) Copper sulphate
3) Sulphuric acid
4) Sodium Hydroxide (NaOH)
5) Boric acid
6) Methyl red
7) Bromocresol green

8) Hydrochloride acid (HCl)

Chemical preparation

1. **Catalyst mixture**

   10:1 ratio of potassium sulphate and copper sulphate is used for catalyst mixture.

2. **40% NaOH**

   40 g NaOH is dissolved in 100 ml distilled water in a standard flask.

3. **4% Boric acid**

   4 g Boric acid is dissolved in 100 ml distilled water in a standard flask.

4. **0.1 N HCl**

   Make up 8.6 ml HCl as 1 lit. by using distilled water in a standard flask.

5. **Mixed indicator**

   Dissolve 0.3 g Bromocresol green + 0.2 g Methyl red in 400 ml of 90% Ethanol.

Procedure:

Digestion:

1. Add 3 g catalyst mixture + 0.2 g soybean seed powered sample and 10 ml conc. sulphuric acid to 250 ml Macro DTL Tube.
2. Load the sample in the digestion unit with manifold.
3. Start the Kelpus digestion unit after connecting inlets to the tap.
4. Allow the temperature to increase till 350^0C and kept for 10 min. followed by increasing the temperature till 420^0C for 1 and half hour.
5. End point of digestion is where the colour changes to **bluish green.**

Distillation:

1. Add 30 ml distilled water to each Macro DTL Tube, and load the sample tube in sample side.
2. Take 25 ml Boric acid add with mixed indicator (4-5 drops) in a 250 ml conical flask and place at the receiver end.
3. Allow the unit to run, which adds 40 ml alkali (NaOH) within 14 seconds and starts the process for 9 min.
4. During the process, liquid Ammonia will collect in the Boric acid and the Boric acids color will change to **green.**

Titration:

1. Take 0.1 N HCl in titration unit.
2. Adjust the flow and titration of the conical flask is done against HCl.
3. End of titration is where the color changes from green to pink.
4. Note the titer value (TV)
5. Titer value of a black sample which excludes the sample is recorded which is used as Blank value (BV).

$$\% \text{ Nitrogen} = \frac{14.01 \times 0.1 \times (TV - BV) \times 100}{\text{Wt of sample (gm)} \times 1000}$$

$$\text{Protein } \% = N\% \times 6.25$$

3.13. Statistical analysis

The field data were analyzed statistically as per randomized block design and laboratory data were analyzed. Data of all entries in the experiment was subject to analysis of variance (Panse and Sukhatme, 1985) for testing the significance of treatments.

Experimental Findings

CHAPTER-IV

EXPERIMENTAL FINDINGS

The important findings in the form of summarized data on different aspects biometric observations, growth analysis, yield and yield attributes and biochemical and quality of soybean as influenced by liquid biofertilizers during the course of investigation are critically interpreted and results are presented in this chapter along with tables under appropriate heads.

4.1 Morphological traits

4.1.1 Effect of liquid biofertilizers on plant height

The data regarding plant height plant^{-1} cm recorded at 30, 60 and 90 days after sowing were presented in Table 2 and graphically depicted in fig.2. It was evident from the results that the plant height was significantly affected due to seed treatment with combined liquid biofertilizers and recommended dose of fertilizers.

The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded significantly superior plant height at 30 DAS (28.70 cm), 60 DAS (54.75 cm) and 90 DAS (66.80 cm) over the other treatments at all the growth stages of soybean.

The treatments T_4 (RDF + Inoculation of Rhizobium + PSB) and T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) remained at par with each other. The lower plant height was observed with treatment T_1 (Absolute control).

Table 2. Effect of liquid biofertilizers on plant height

Tr. No.	Treatments	Days after sowing		
		30	60	90
T1	Absolute control	25.90	45.00	58.09
T2	Recommended dose of fertilizer	25.95	48.03	58.93
T3	RDF + Inoculation of Rhizobium	26.75	50.18	61.70
T4	RDF + Inoculation of Rhizobium + PSB	27.30	50.33	62.02
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	27.90	52.63	64.10
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	28.70	54.75	66.80
	S.Em.±	1.48	1.54	1.88
	C.D. at 5%	NS	4.64	5.68
	GM	27.08	50.15	61.94

4.1.2 Effect of liquid biofertilizers on number of branches per plant

The data regarding number of branches plant^{-1} recorded at 30, 60 and 90 days after sowing were presented in Table 3 and graphically depicted in fig.3. It was evident from the results that the number of branches plant^{-1} was significantly affected due to seed treatment with combined liquid biofertilizers and recommended dose of fertilizers.

The highest number of branches plant^{-1} was observed with treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) at all the growth stages of soybean. The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded significantly highest number of branches plant^{-1} at 30 DAS (3.70), 60 DAS (8.88) and 90 DAS (17.03) over the other treatments.

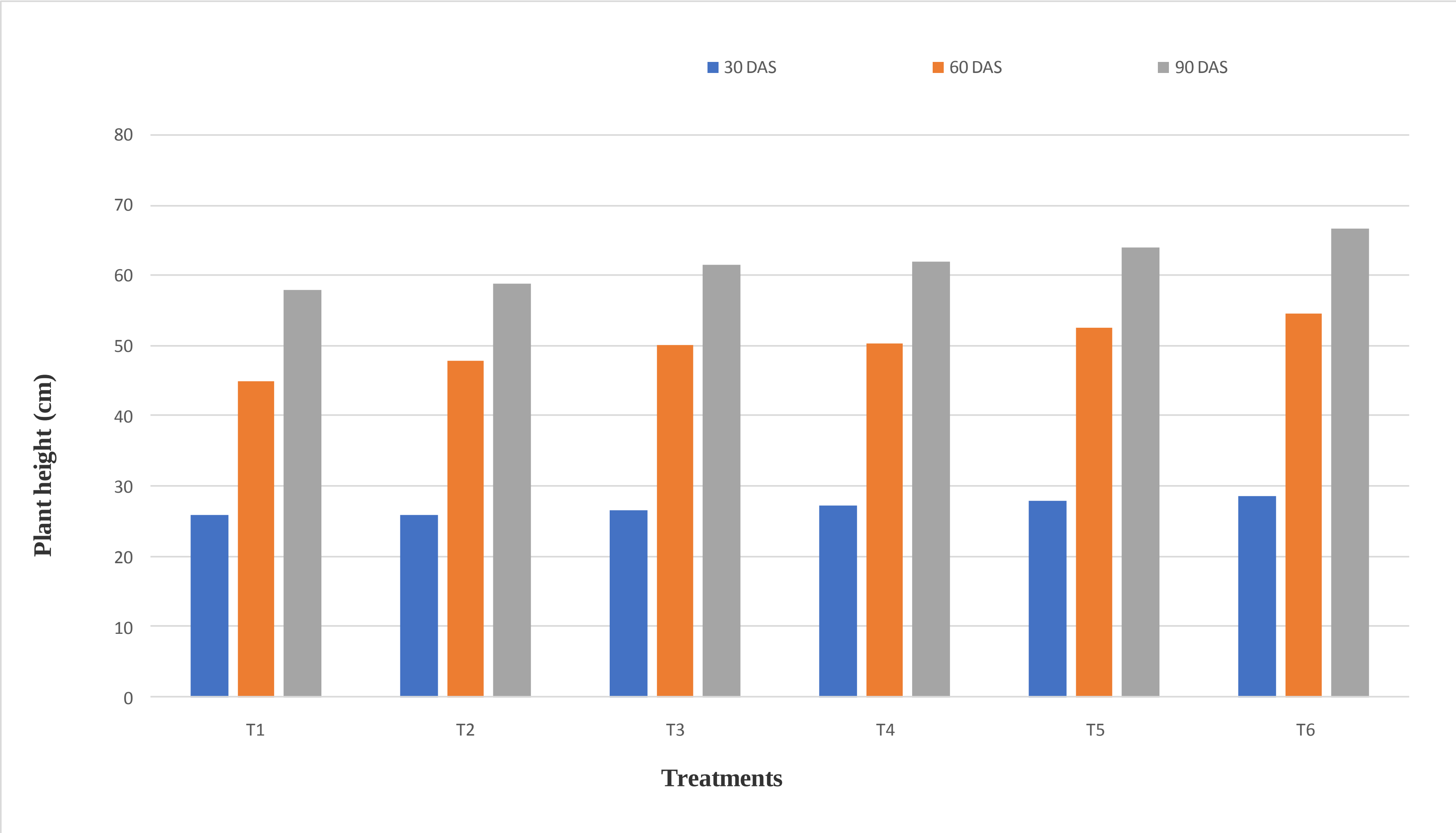

Fig.2. Effect of liquid biofertilizers on plant height

Table 3. Effect of liquid biofertilizers on number of branches per plant

Tr. No.	Treatments	Days after sowing		
		30	**60**	**90**
T1	Absolute control	3.05	7.38	13.10
T2	Recommended dose of fertilizer	3.30	7.58	14.10
T3	RDF + Inoculation of Rhizobium	3.40	7.60	14.65
T4	RDF + Inoculation of Rhizobium +PSB	3.53	8.15	15.25
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	3.55	8.35	15.95
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	3.70	8.88	17.03
	S.Em.±	0.28	0.26	0.59
	C.D. at 5%	NS	0.80	1.79
	GM	3.42	7.98	15.01

The treatments T_4 (RDF + Inoculation of Rhizobium + PSB) and T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) remained at par with each other. And at all growth stages significantly lower number of branches plant^{-1} was observed with treatment T_1 (Absolute control).

4.1.3 Effect of liquid biofertilizers on leaf area (cm^2) per plant

The data regarding mean leaf area (cm^2) plant^{-1} recorded at 30 and 60 days after sowing were presented in Table 4 and graphically depicted in Fig.4. The data summarized in Table 4 revealed that the mean leaf area (cm^2) plant^{-1} was increased continuously up to 60 DAS.

The effect of different treatments on leaf area was found to be significant at all growth stages except at 30 DAS. The highest leaf area (cm^2) plant^{-1} was observed with treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) at 30 and 60 DAS. The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded.

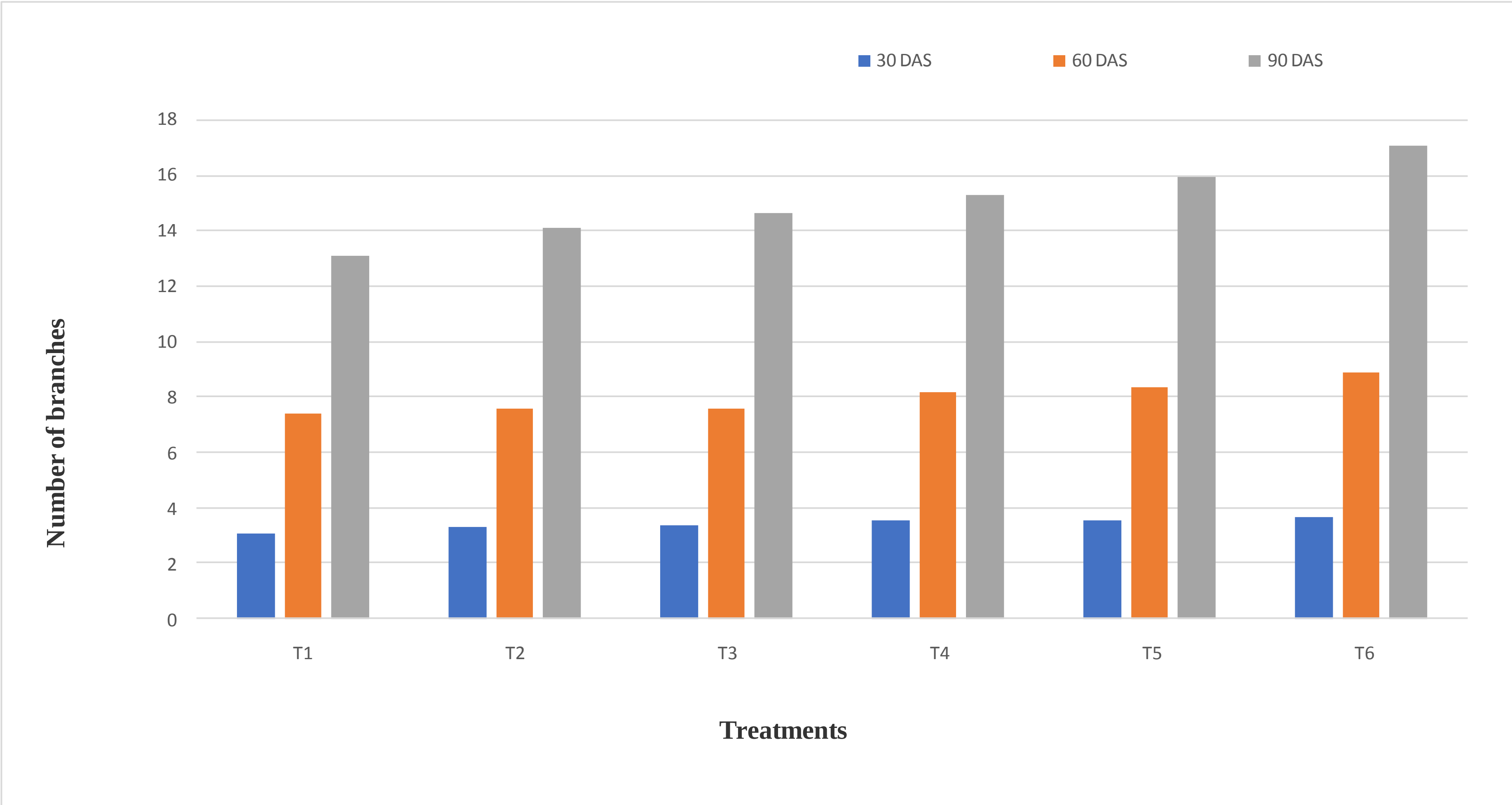

Fig.3. Effect of liquid biofertilizers on number of branches

Table 4. Effect of liquid biofertilizers on leaf area (cm^2) per plant

Tr. No.	Treatments	Days after sowing	
		30	**60**
T1	Absolute control	238.25	1970.50
T2	Recommended dose of fertilizer	255.75	1976.25
T3	RDF + Inoculation of Rhizobium	264.25	1982.50
T4	RDF + Inoculation of Rhizobium + PSB	270.00	2030.00
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	294.00	2054.50
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	311.25	2076.25
	S.Em.±	16.13	26.32
	C.D. at 5%	NS	79.33
	GM	272.25	2015.00

significantly highest leaf area cm^2 $plant^{-1}$ at 30 DAS (311.25 cm^2) and 60 DAS (2076.25cm^2) over the other treatments, followed by treatments T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) and T_4 (RDF + Inoculation of Rhizobium + PSB) after T_6. And at both 30 and 60 DAS significantly lower leaf area cm^2 $plant^{-1}$ was observed with treatment T_1 (Absolute control) (238.25 cm^2) and (1970.50 cm^2) respectively.

4.1.4 Effect of liquid biofertilizers on leaf area index

The data on leaf area index (LAI) is presented in Table 5 and graphically depicted in fig.5.

The leaf area index was low at initial stages of crop growth, gradually increased up to 60 days after sowing. The highest mean LAI was recorded at 60 DAS.

Treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded maximum LAI at 30 DAS (1.38) and 60 DAS (9.22) over rest of treatments. The lowest LAI was recorded by treatment T_1(Absolute control).

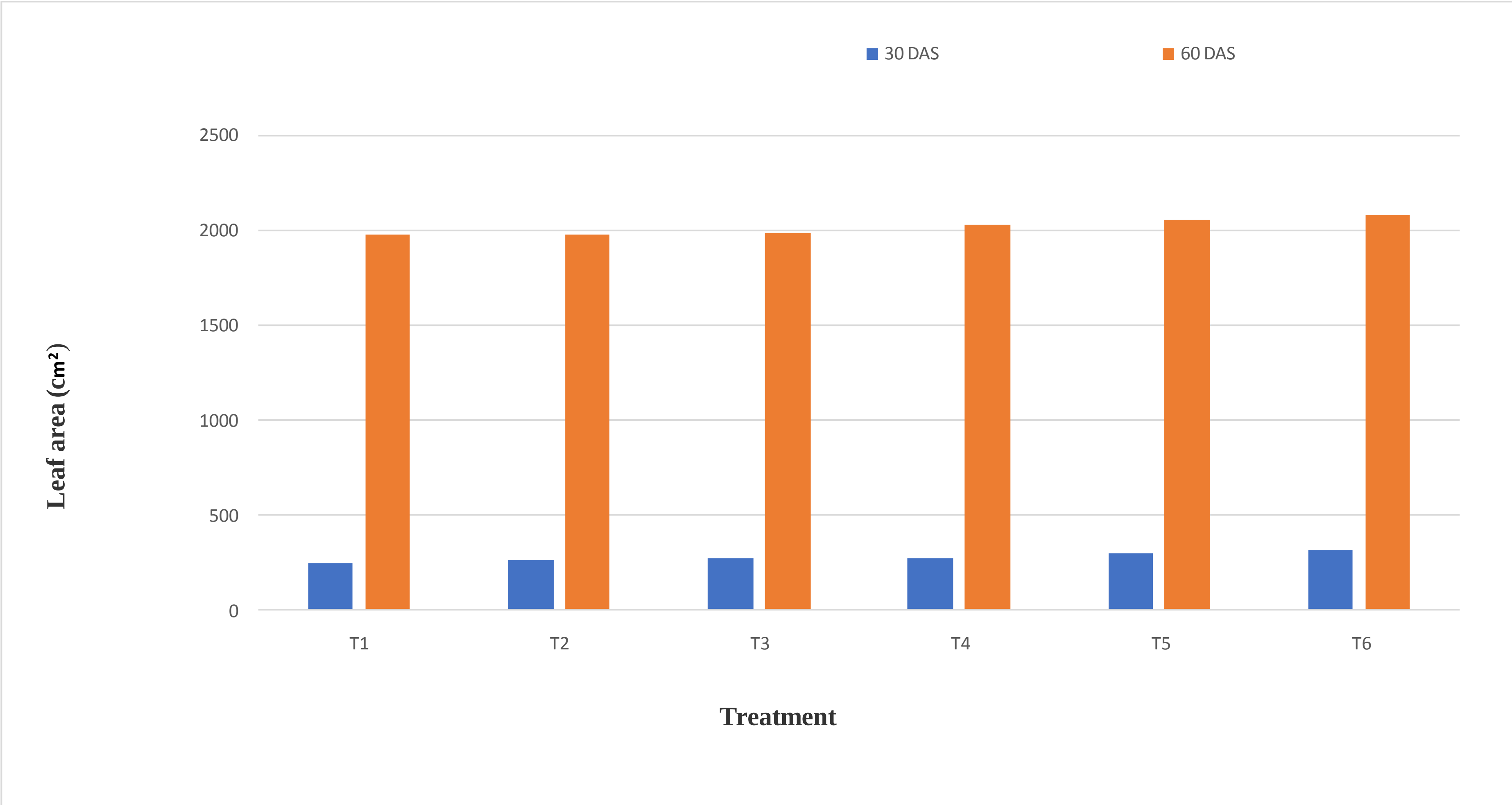

Fig. 4. Effect of liquid biofertilizers on leaf area

Table 5. Effect of liquid biofertilizers on leaf area index

Tr. No.	Treatments	Days after sowing	
		30	**60**
T1	Absolute control	1.05	8.75
T2	Recommended dose of fertilizer	1.13	8.78
T3	RDF + Inoculation of Rhizobium	1.17	8.81
T4	RDF + Inoculation of Rhizobium +PSB	1.2	9.02
T5	RDF + Inoculation of Rhizobium +PSB +Sulphur oxidizing bacteria	1.30	9.13
T6	RDF + Inoculation of Rhizobium +PSB +Sulphur oxidizing bacteria + Zinc solubilizers	1.38	9.22
	GM	1.21	8.95

4.1.5 Effect of liquid biofertilizers on crop growth rate (g/cm^2/day)

The data regarding crop growth rate (g/cm^2/day) was estimated at 0-30, 30-60 and 60-90 days after sowing were presented in Table 6 and graphically depicted in fig.6.

The crop growth rate almost doubled at 0-30 DAS and decreased thereafter. At 0-30 DAS among the liquid biofertilizers treatments, T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (0.486667 g/cm^2/day) recorded higher crop growth rate, which was higher as compared to other treatments. Lower crop growth rate was observed in T_1 (Absolute control) (0.32 g/cm^2/day) which was significantly lower as compared to other treatments.

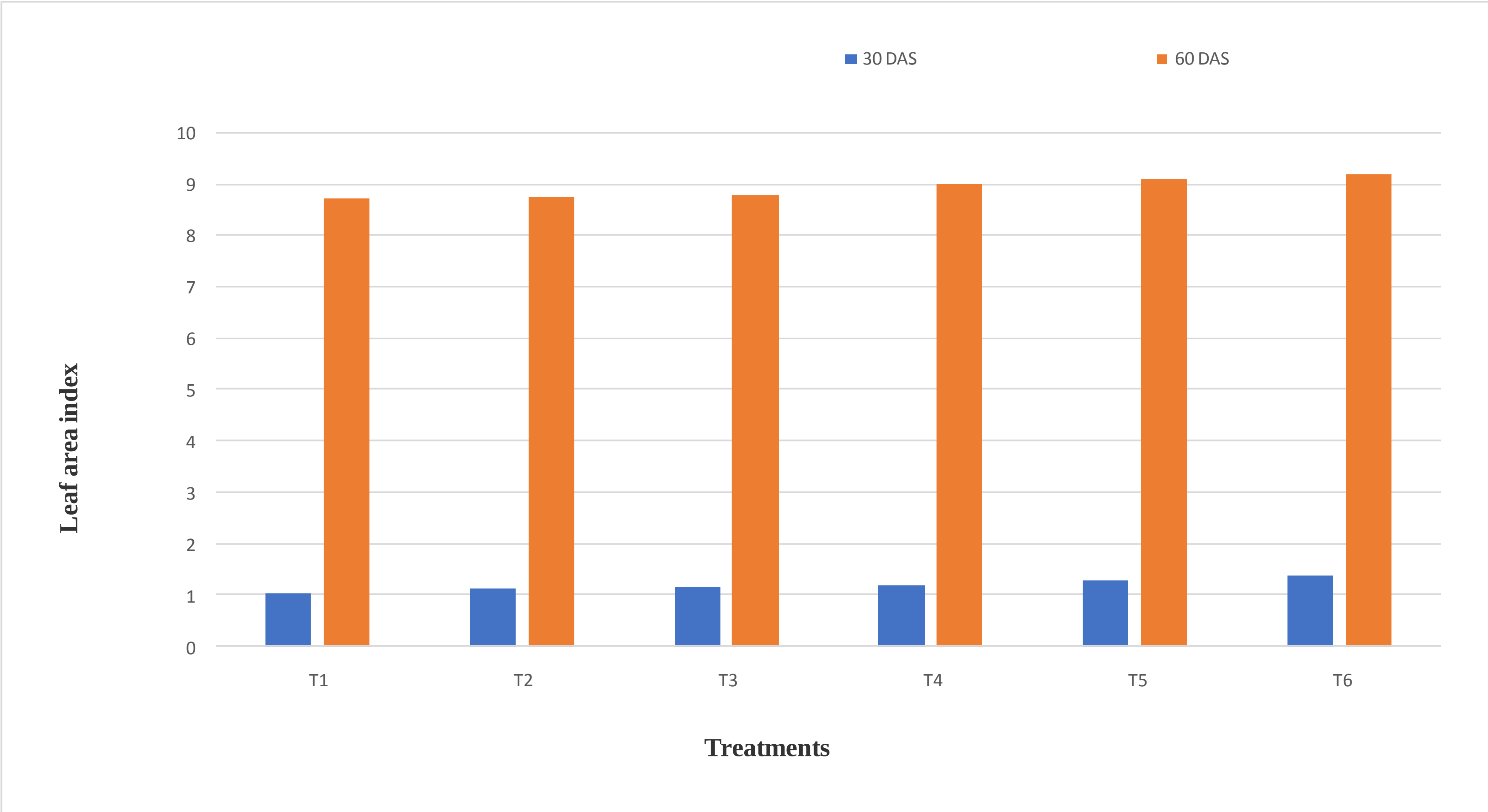

Fig.5. Effect of liquid biofertilizers on leaf area index

Table 6. Effect of liquid biofertilizers on crop growth rate (g/ cm^2/day)

Tr. No.	Treatments	Days after sowing		
		0-30	**30- 60**	**60- 90**
T_1	Absolute control	0.32	0.032467	0.024933
T_2	Recommended dose of fertilizer	0.328	0.033267	0.024444
T_3	RDF + Inoculation of Rhizobium	0.329333	0.034853	0.032
T_4	RDF + Inoculation of Rhizobium + PSB	0.372	0.034311	0.049333
T_5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	0.442667	0.036911	0.046044
T_6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	0.486667	0.037956	0.059911
	Grand mean	0.379778	0.034961	0.039444

At 30-60 DAS and 60-90 DAS among the liquid biofertilizers treatments, T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (0.037956g/cm^2/day), (0.059911 g/cm^2/day) recorded higher crop growth rate, which was higher as compared to other treatments. Lower crop growth rate was observed in T_1 (Absolute control) (0.032467 g/cm^2/day), (0.024933 g/cm^2/day) respectively which was significantly lower as compared to other treatments.

4.1.6 Effect of liquid biofertilizers on relative growth rate (g/g/day)

The data regarding relative growth rate (g/g/day) was estimated at 0-30, 30-60 and 60-90 days after sowing were presented in Table 7 and graphically depicted in fig. 7.

The value of relative growth rate for dry matter was higher from 0-30 DAS. The maximum mean value RGR for dry matter was observed in T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (0.28015 g/g/day) at 0-30 DAS and followed by T_5 (0.25482 g/g/day) and T_4 (0.21414 g/g/day) and lower value of RGR was recorded T_1 (Absolute control) (0.18421 g/g/day). At 30-60 DAS and 60-90 DAS also recorded the highest value in treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (0.0402 g/g/day), (0.024824 g/g/day) respectively. And the lowest value

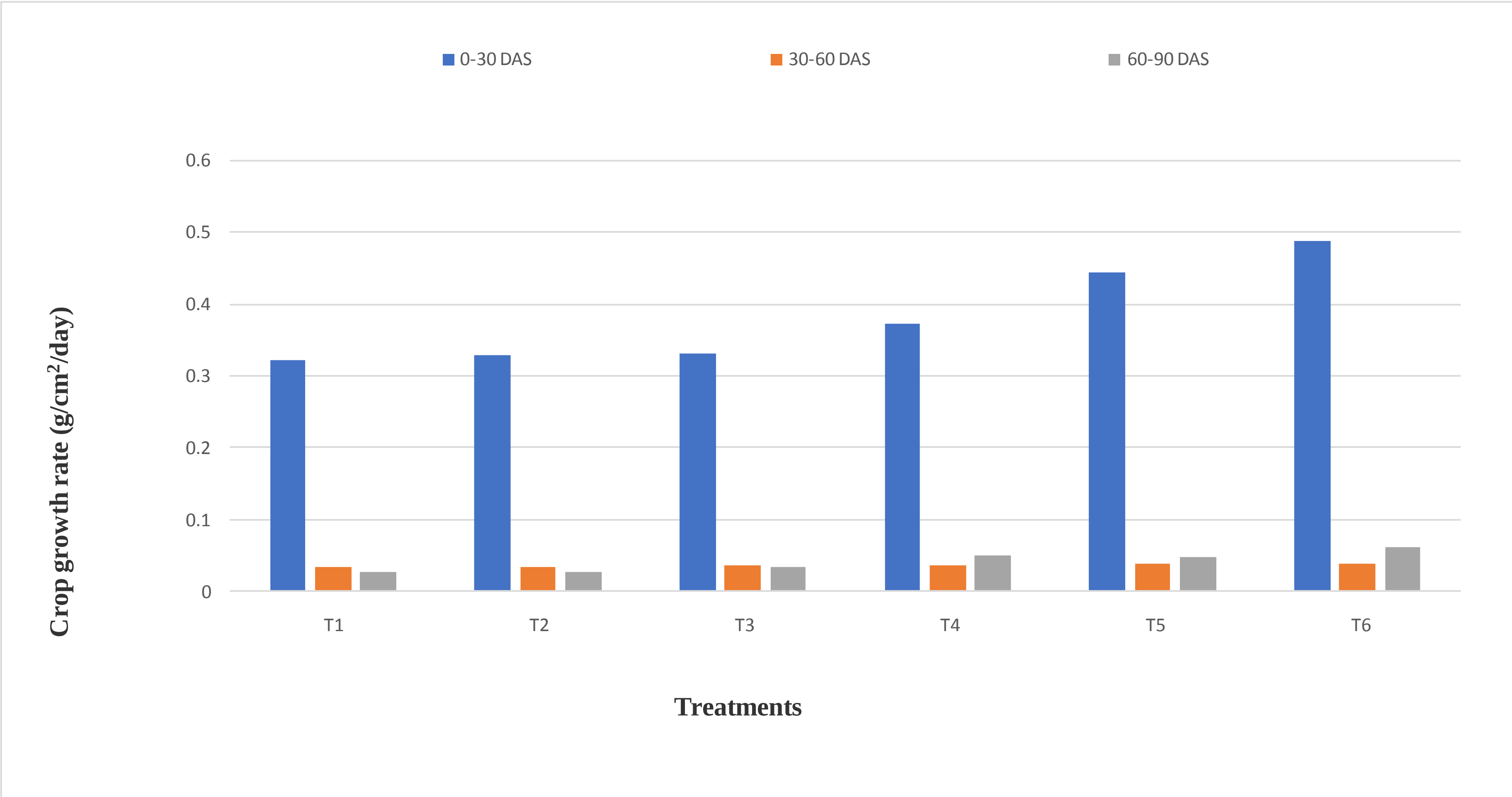

Fig.6. Effect of liquid biofertilizers on crop growth rate (g/cm^2/day)

recorded by the treatment T_1 (Absolute control) (0.04656 g/g/day), (0.015213 g/g/day) respectively.

Table 7. Effect of liquid biofertilizers on relative growth rate (g/g/day)

Tr. No.	Treatments	Days after sowing		
		0-30	30-60	60-90
T_1	Absolute control	0.18421	0.04656	0.015213
T_2	Recommended dose of fertilizer	0.18881	0.04658	0.014668
T_3	RDF + Inoculation of Rhizobium	0.18958	0.0476	0.017669
T_4	RDF + Inoculation of Rhizobium + PSB	0.21414	0.04421	0.024028
T_5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	0.25482	0.04176	0.021247
T_6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	0.28015	0.0402	0.024824
	Grand mean	0.21862	0.04448	0.019608

4.1.7 Effect of liquid biofertilizers on net assimilation rate (g/dm^2/day)

The data regarding net assimilation rate (g/dm^2/day) was estimated at 0-30 and 30-60 days after sowing were presented in Table 8 and graphically depicted in fig.8.

Table 8. Effect of liquid biofertilizers on net assimilation rate (g/dm^2/day)

Tr. No.	Treatments	Days after sowing	
		0-30	30- 60
T_1	Absolute control	0.184208	0.105678
T_2	Recommended dose of fertilizer	0.188813	0.108428
T_3	RDF + Inoculation of Rhizobium	0.189581	0.11335
T_4	RDF + Inoculation of Rhizobium + PSB	0.214142	0.111758
T_5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	0.254821	0.120154
T_6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	0.28015	0.123628
	Grand mean	0.218619	0.113833

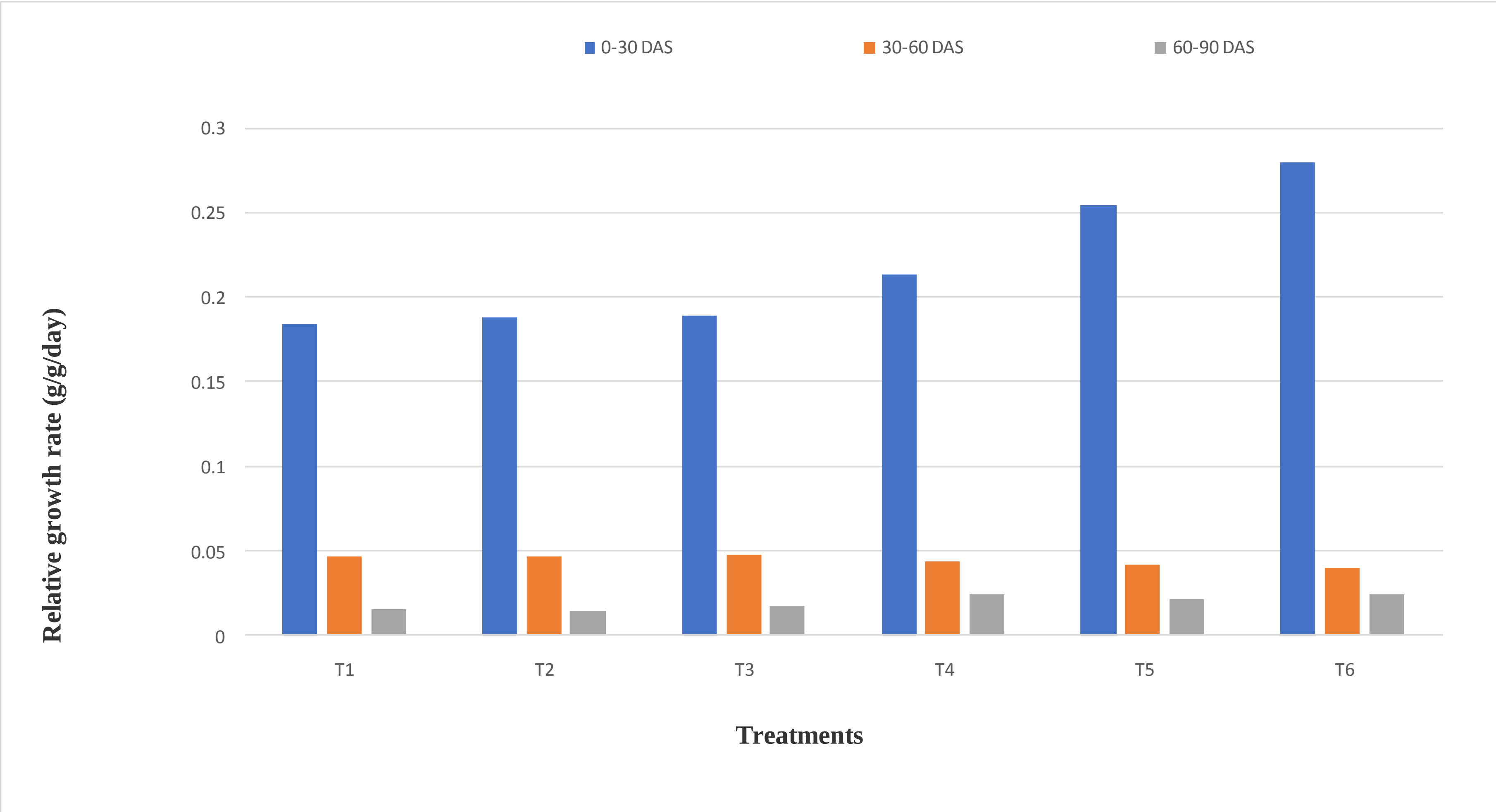

Fig.7. Effect of liquid biofertilizers on relative growth rate (g/g/day)

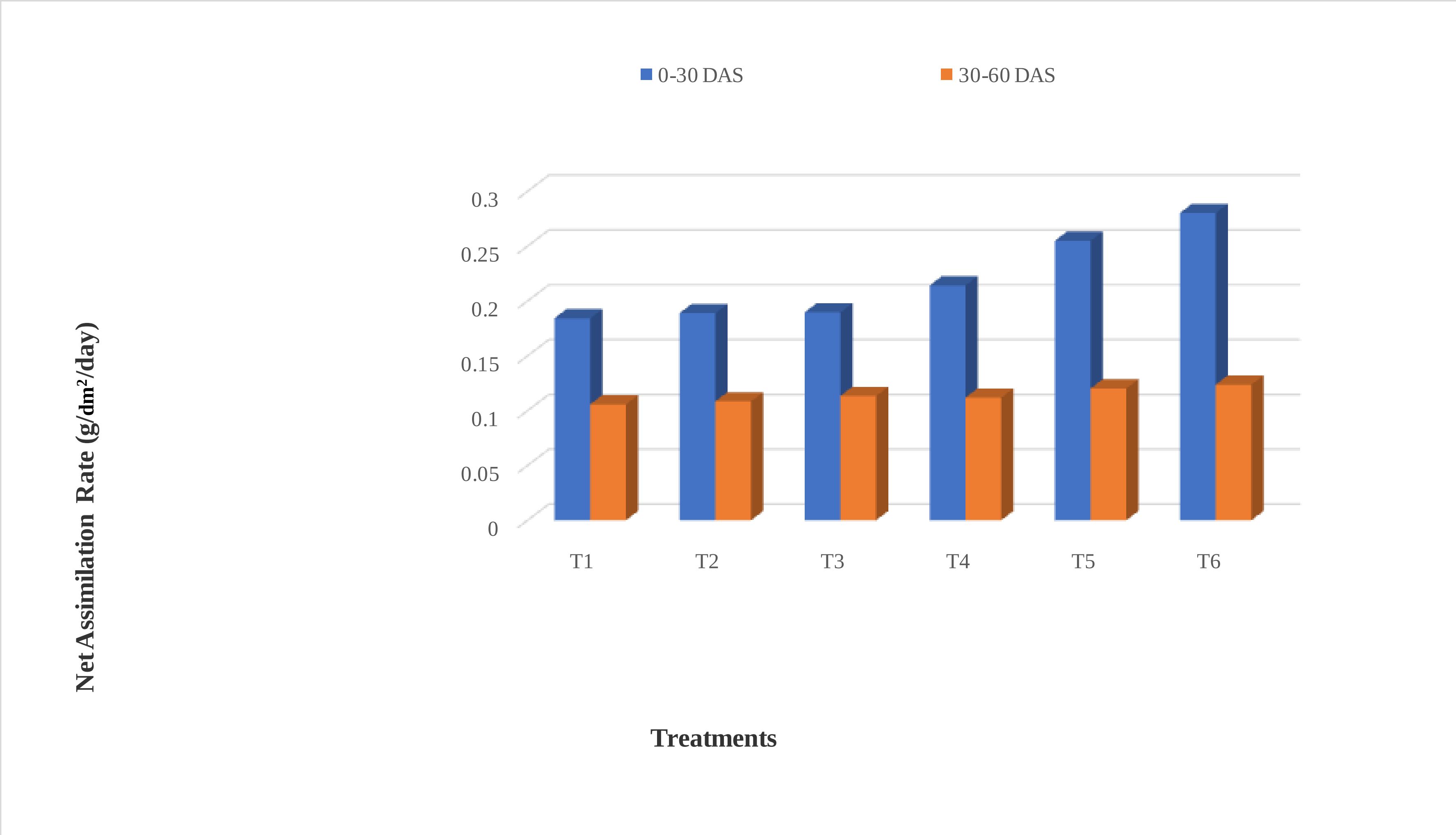

Fig.8. Effect of liquid biofertilizers on net assimilation rate (g/dm^2/day)

The data showed that net assimilation rate was comparatively higher during the period of 0-30 DAS and decreased thereafter. During growth period, the result indicated that at 0-30 DAS the higher net assimilation rate was observed in treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (0.28015 g/dm^2/day), followed by T_5 and T_4. And lowest net assimilation rate recorded in treatment T_1 (Absolute control) (0.184208 g/dm^2/day).

At 30-60 DAS also recorded the highest net assimilation rate in T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (0.123628 g/dm^2/day). And lowest net assimilation rate recorded in treatment T_1 (Absolute control) (0.105678 g/dm^2/day).

4.1.8 Effect of liquid biofertilizers on total dry weight g per plant

The data with respect to dry matter yield recorded at all the growth stages were presented in the Table 9 and graphically depicted in fig.9. The dry matter yield of soybean increased with advanced stages of growth up to maturity but it was decreasing at harvesting stage due to leaf shedding. The maximum dry matter yield was observed with treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) at all the growth stages of soybean. The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded significantly higher dry matter yield at 30 DAS (3.65 g), 60 DAS (12.19 g) and 90 DAS (25.67 g) over the other treatments and followed by treatments T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) (3.32 g 30 DAS, 11.62 g 60 DAS, 21.98 g 90 DAS) and T_4 (RDF + Inoculation of Rhizobium + PSB) (2.79 g 30 DAS, 10.51 g 60 DAS, 21.61 g 90 DAS). The lowest dry matter recorded in treatment T_1 (Absolute control).

Table 9. Effect of liquid biofertilizers on total dry weight g per plant

Tr. No.	Treatments	Days after sowing		
		30	**60**	**90**
T1	Absolute control	2.40	9.70	15.31
T2	Recommended dose of fertilizer	2.46	9.95	15.45
T3	RDF + Inoculation of Rhizobium	2.47	10.30	17.50
T4	RDF + Inoculation of Rhizobium + PSB	2.79	10.51	21.61
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	3.32	11.62	21.98
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	3.65	12.19	25.67
	S.Em.±	0.14	0.37	0.60
	C.D. at 5%	0.43	1.11	1.81
	GM	2.84	10.70	19.58

4.1.9 Effect of liquid biofertilizers on days to 50% flowering

The data with respect to 50% flowering recorded during flowering stages were presented in the Table 10 and graphically depicted in fig.10.

Table 10. Effect of liquid biofertilizers on days to 50% flowering

Tr. No.	Treatments	Days to 50% flowering
T1	Absolute control	45.40
T2	Recommended dose of fertilizer	45.20
T3	RDF + Inoculation of Rhizobium	44.20
T4	RDF + Inoculation of Rhizobium + PSB	41.68
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	40.85
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	40.25
	S.Em.±	1.32
	C.D. at 5%	3.98
	GM	42.93

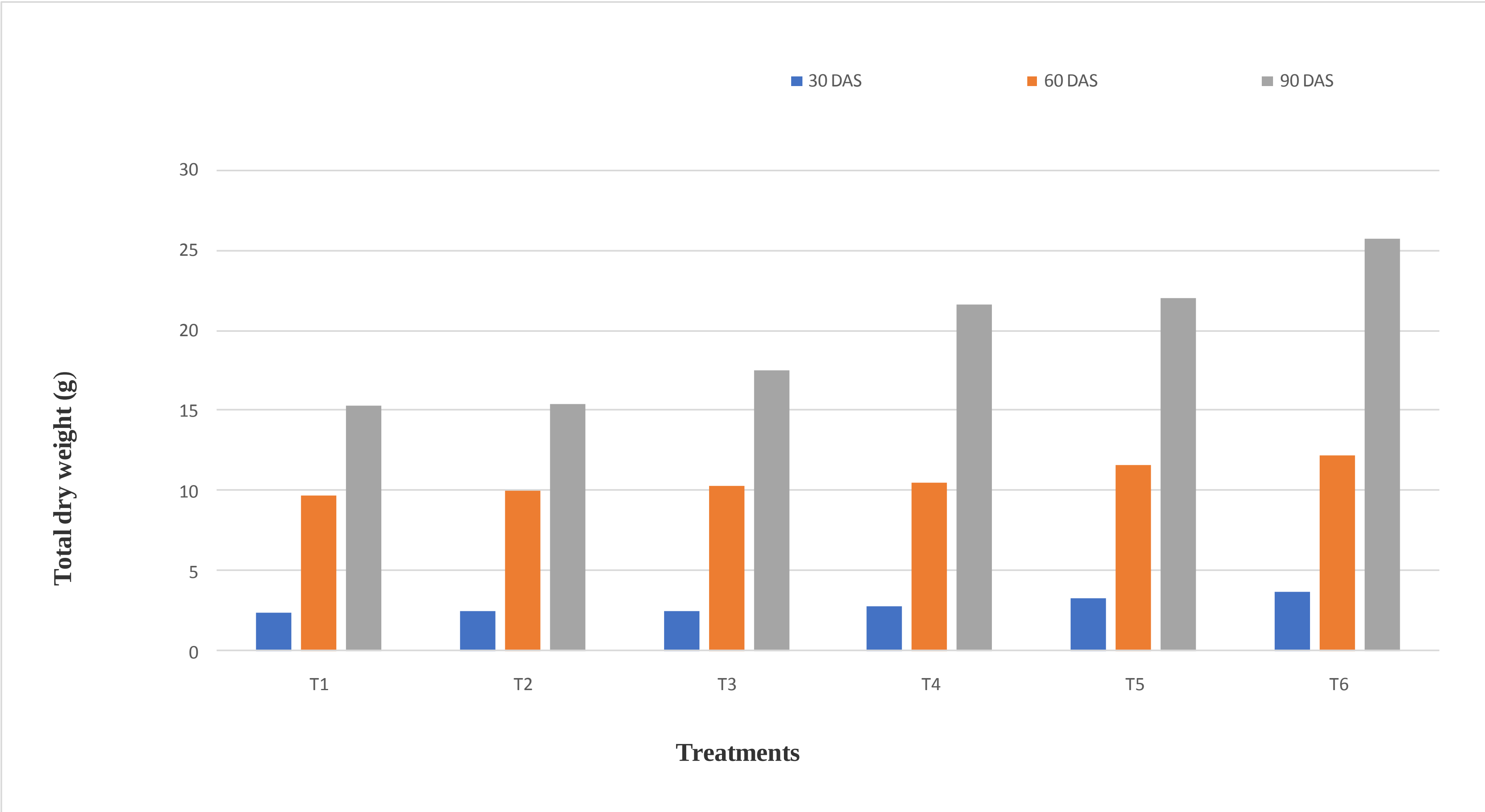

Fig.9. Effect of liquid biofertilizers on total dry weight g per plant

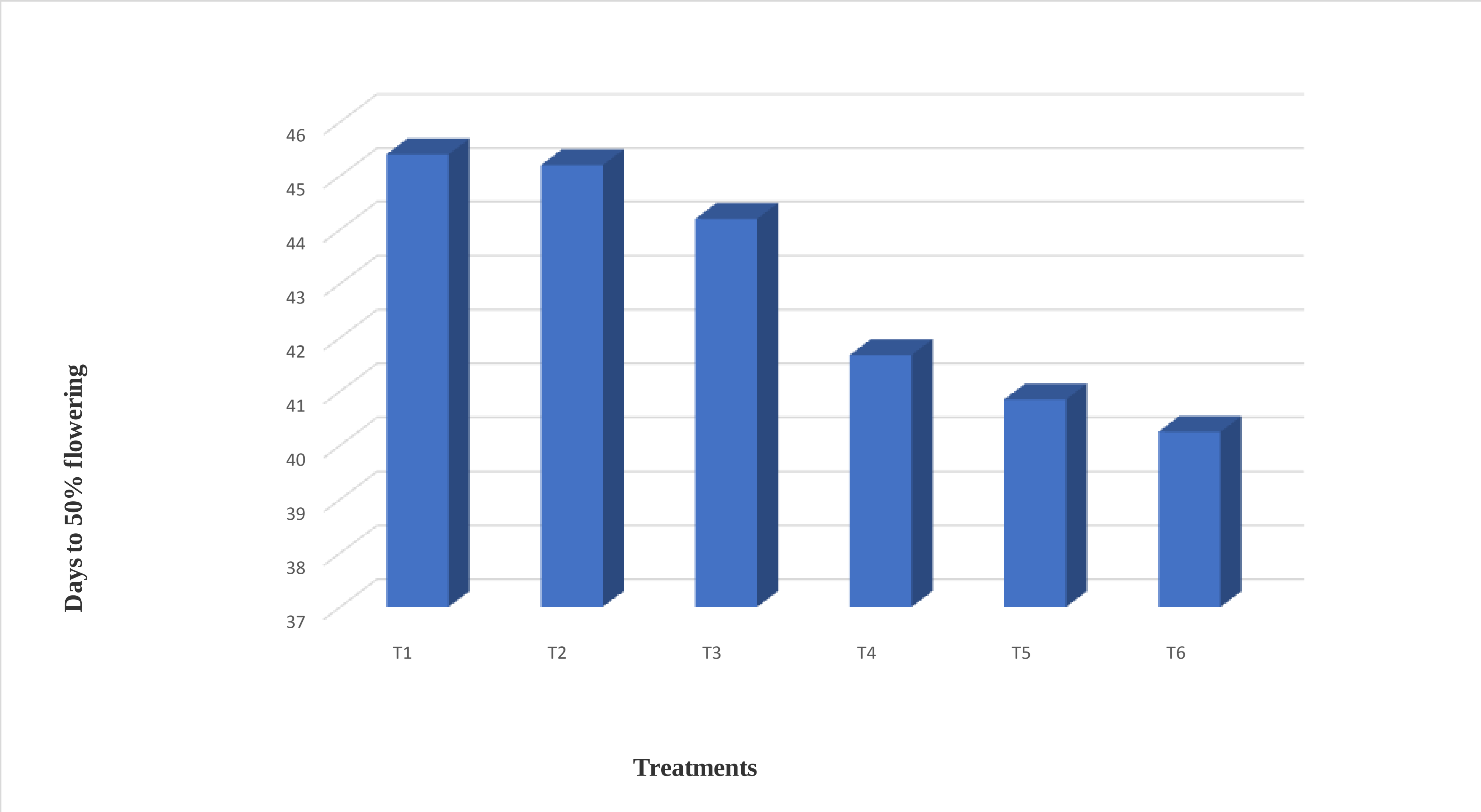

Fig.10. Effect of liquid biofertilizers on days to 50% flowering

The data revealed that almost all the treatments had reduced the days to 50% flowering as compared to control. Early flowering observed by 6 days earlier in T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (40.25 days) followed by treatments T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) (41.85 days) and T_4 (RDF + Inoculation of Rhizobium + PSB) (41.68 days). The most late flowering observed in treatment T_1 (Absolute control) (45.40 days).

4.2 Yield Attributes

4.2.1 Effect of liquid biofertilizers on number of pods per plant

The number of pods plant^{-1} were presented in Table 11 and graphically depicted in fig.11. It was revealed that the number of pods plant^{-1} were significantly affected due to seed treatment with combined liquid biofertilizers and recommended dose of fertilizers.

Table 11. Effect of liquid biofertilizers on number of pods per plant

Tr. No.	Treatments	No. of pods/plant
T1	Absolute control	25.90
T2	Recommended dose of fertilizer	27.95
T3	RDF + Inoculation of Rhizobium	28.60
T4	RDF + Inoculation of Rhizobium + PSB	28.75
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	29.80
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	30.50
	S.Em.±	0.86
	C.D. at 5%	2.59
	GM	28.58

The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded significantly higher number of pods (30.50 plant^{-1}) than other treatment.

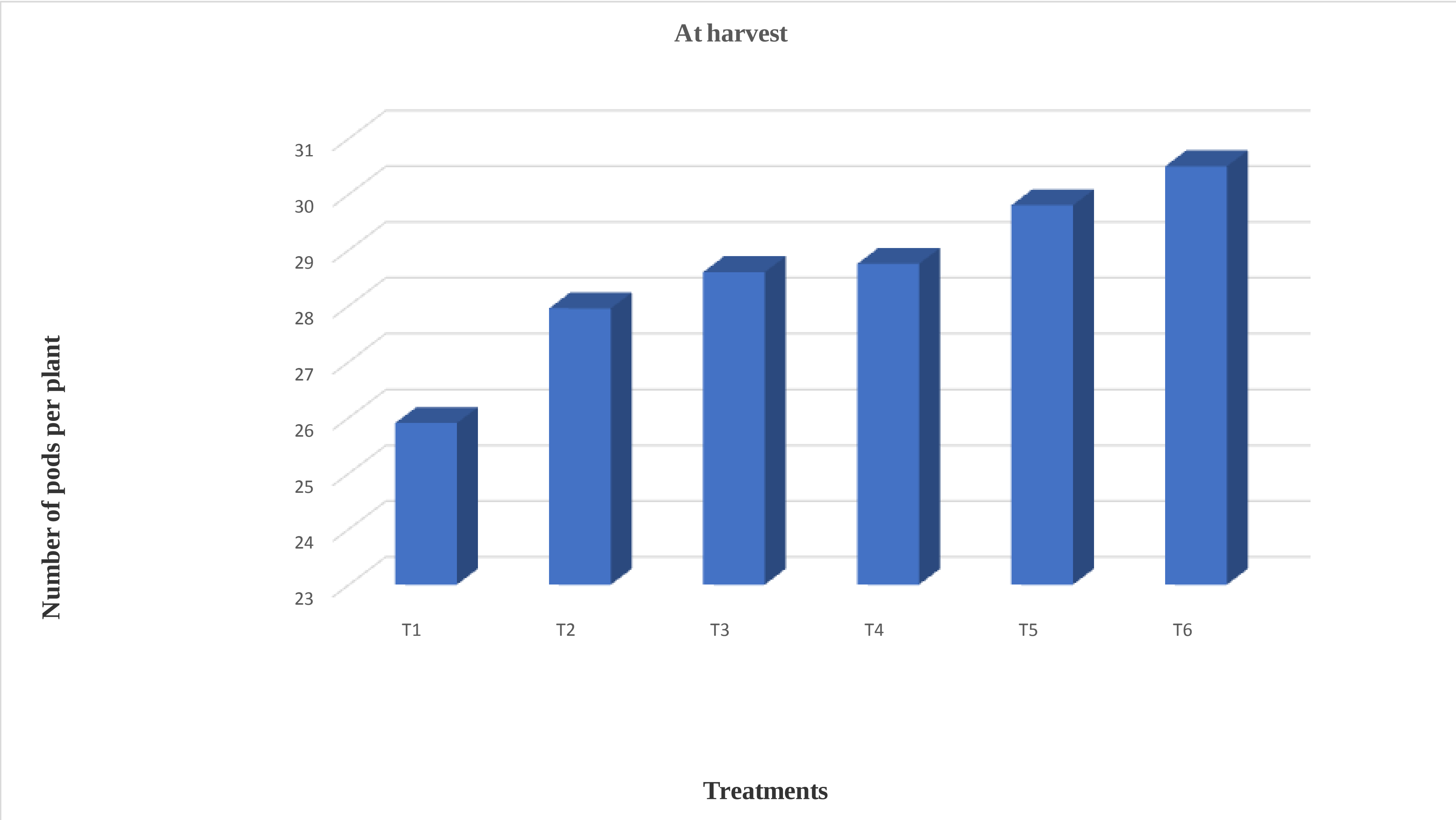

Fig.11. Effect of liquid biofertilizers on number of pods per plant

The treatments T_3 (RDF + Inoculation of Rhizobium) (28.60 pods plant^{-1}) and T_4 (RDF + Inoculation of Rhizobium + PSB) (28.75 pods plant^{-1}) were at par with each other. In respect of all the yield attributing characters significantly lower number of pods plant^{-1} were recorded with treatment T_1 (Absolute control) (25.90 pods/ plant).

4.2.2 Effect of liquid biofertilizers on test weight (g)

The test weight of seeds is presented in the Table 12 and graphically depicted in fig.12. which was found to be non -significant. Highest test weight of seeds was recorded by treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (11.18 g), followed by T_5 and T_4. The lowest test weight was recorded by T_1 (Absolute control) (10.55 g).

Table 12. Effect of liquid biofertilizers on test weight (g)

Tr. No.	Treatments	Test weight (g)
T1	Absolute control	10.55
T2	Recommended dose of fertilizer	10.65
T3	RDF + Inoculation of Rhizobium	10.77
T4	RDF + Inoculation of Rhizobium + PSB	11.03
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	11.10
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	11.18
	S.Em.±	0.19
	C.D. at 5%	NS
	GM	10.88

4.2.2 Effect of liquid biofertilizers on yield kg/plot

The seed yield (kg/plot) after harvesting are presented in the Table 13 and graphically depicted in fig.13. The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (2.35 kg/plot) was recorded significantly higher seed yield as compared to other treatments and followed by treatment T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing

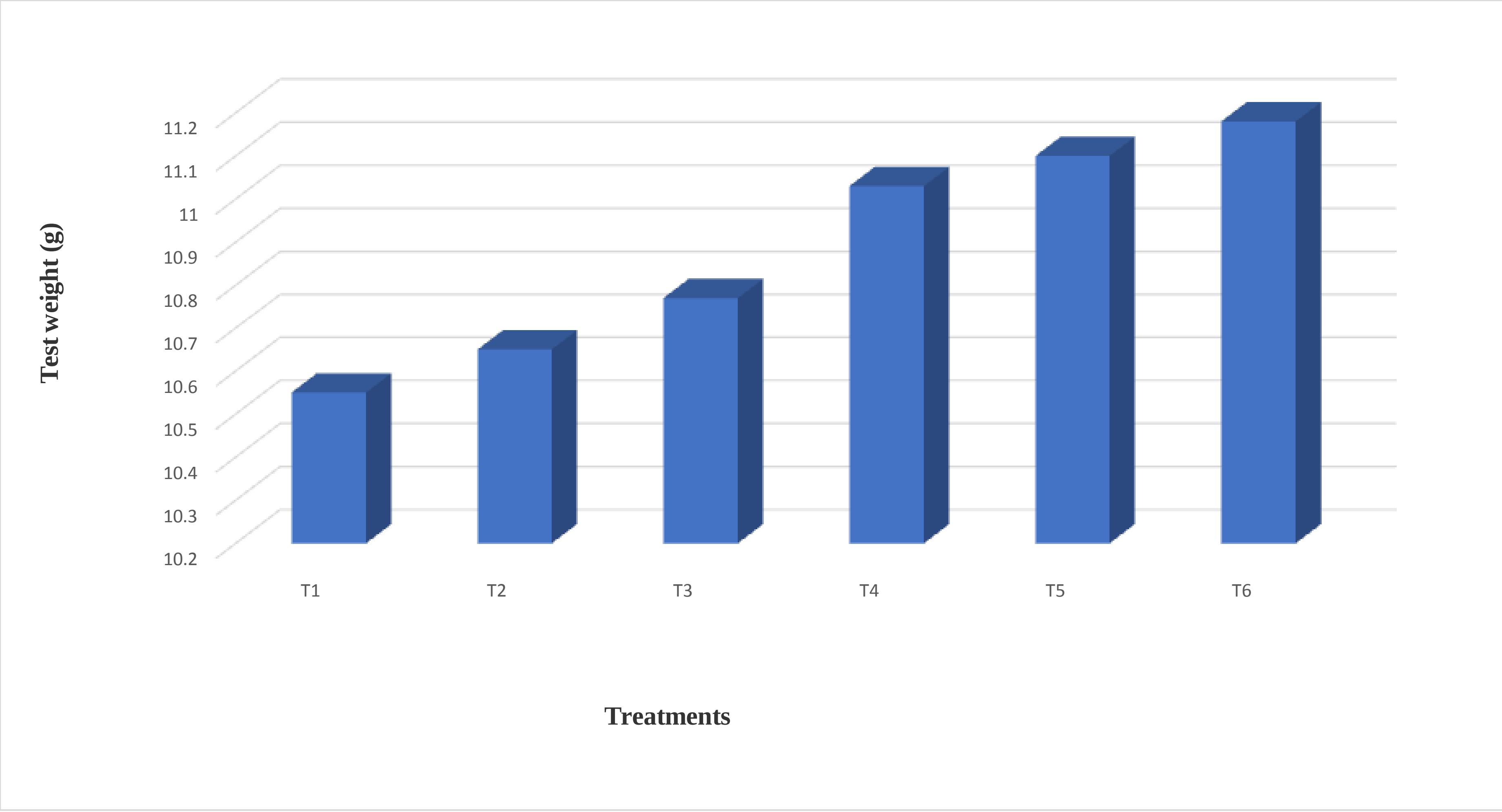

Fig. 12. Effect of liquid biofertilizers on test weight (g)

bacteria) (2.22 kg/plot) and T_4 (RDF + Inoculation of Rhizobium + PSB) (2.07 kg/plot). T_1-control (1.66 kg/plot) recorded significantly lower seed yield kg/plot.

The data on the seed yield (qt/ha) after harvesting is presented in the Table13 and graphically depicted in fig.13. The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (24.20 qt/ha) followed by T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) (22.81 qt/ha) was recorded significantly higher seed yield as compared to other treatments and T_1-control (17.10 qt/ha).

Table 13. Effect of liquid biofertilizers on yield kg/plot, qt/ha and Harvest index

Tr. No.	Treatments	Yield kg/plot	Yield qt/ha	Harvest Index %
T1	Absolute control	1.66	17.10	39.58
T2	Recommended dose of fertilizer	1.82	18.76	42.07
T3	RDF + Inoculation of Rhizobium	1.98	20.36	44.75
T4	RDF + Inoculation of Rhizobium + PSB	2.07	21.27	44.88
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	2.22	22.81	45.02
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	2.35	24.20	45.28
	S.Em.±	0.11	1.21	4.36
	C.D. at 5%	0.35	3.66	NS
	GM	2.02	20.75	43.59

The harvest index (%) is presented in the Table13 and graphically depicted in fig.13. which was found to be non-significant. Highest harvest index (%) was recorded by treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) (45.28 %), followed by T_5 and T_4. The lowest harvest index (%) was recorded by T_1 (Absolute control).

4.3 Quality / Biochemical Traits:

4.3.1 Effect of liquid biofertilizers on chlorophyll content in leaf

The chlorophyll content in leaf (m/g/cm^2) recorded at 30, 45, 60, 75 and 90 days after sowing were presented in Table 14 and graphically depicted in fig.14.

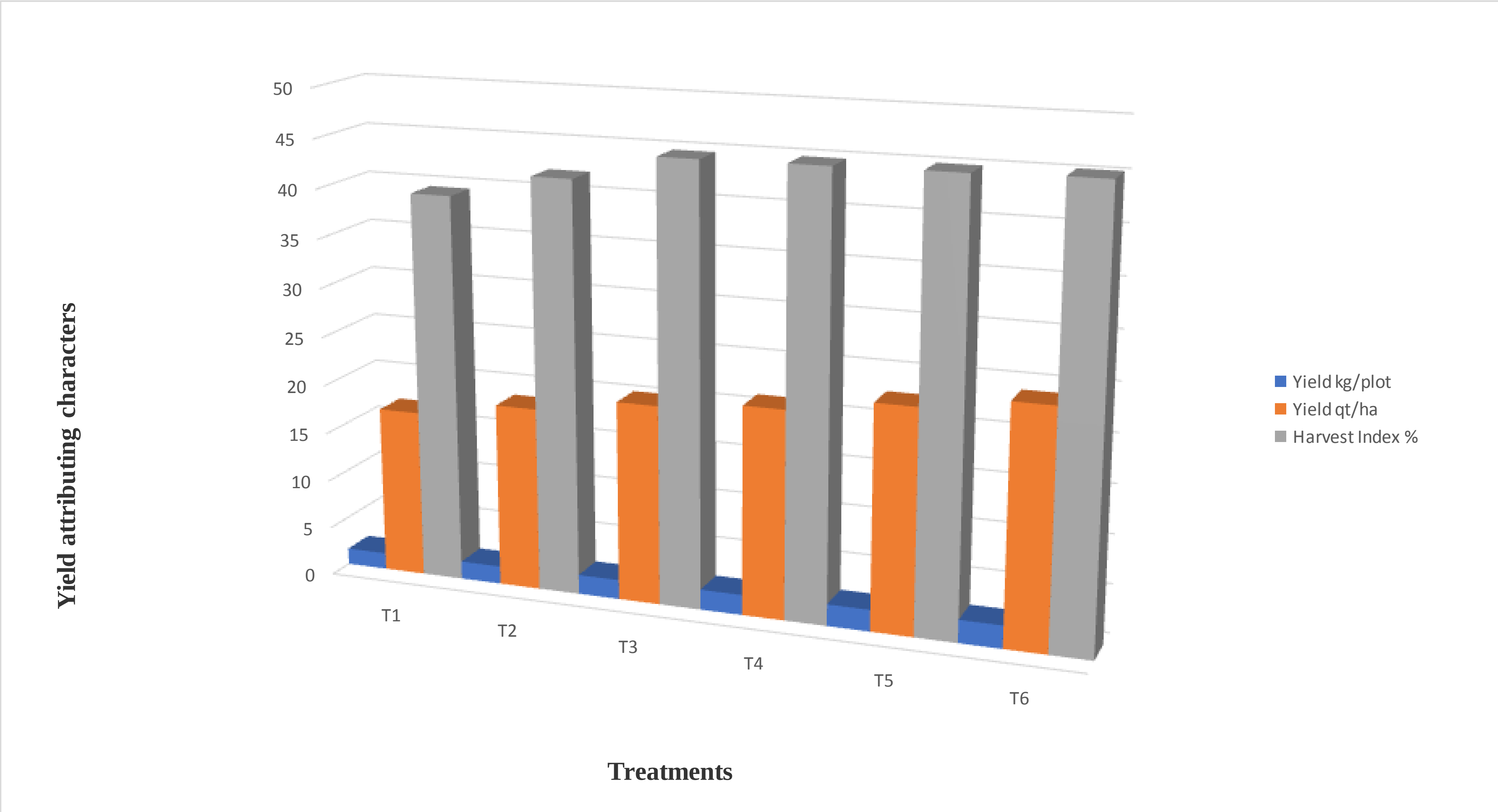

Fig.13. Effect of liquid biofertilizers on yield attributing characters

Table 14. Effect of liquid biofertilizers on chlorophyll content in leaf

Tr. No.	Treatments	Days after sowing				
		30	**45**	**60**	**75**	**90**
T1	Absolute control	31.00	37.63	42.21	43.83	25.66
T2	Recommended dose of fertilizer	31.31	38.38	44.41	44.02	26.89
T3	RDF + Inoculation of Rhizobium	32.75	40.03	45.47	46.78	27.05
T4	RDF + Inoculation of Rhizobium + PSB	32.42	41.76	46.52	47.06	27.46
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	33.49	42.03	47.71	48.26	29.73
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	35.87	44.51	48.93	50.45	31.31
	S.Em.±	0.98	1.30	1.41	1.45	0.93
	C.D. at 5%	2.97	3.92	4.25	4.37	2.79

The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded significantly superior chlorophyll content at 30 DAS (35.87), 45 DAS (44.51), 60 DAS (48.93),75 DAS (50.45) and 90 DAS (31.31) followed by T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) at 30 DAS (33.49), 45 DAS (42.03), 60 DAS (47.71), 75 DAS (48.26) and 90 DAS (29.73) over the other treatments. And the lower chlorophyll content was observed with treatment T_1 (Absolute control) at 30 DAS (31.00), 45 DAS (37.63) 60 DAS (42.21), 75 DAS (43.83) and 90 DAS (25.66).

4.3.2 Effect of liquid biofertilizers on oil content (%)

Oil content seed in percentage is presented in Table 15 and graphically depicted in fig.15. which was found to be non- significant.

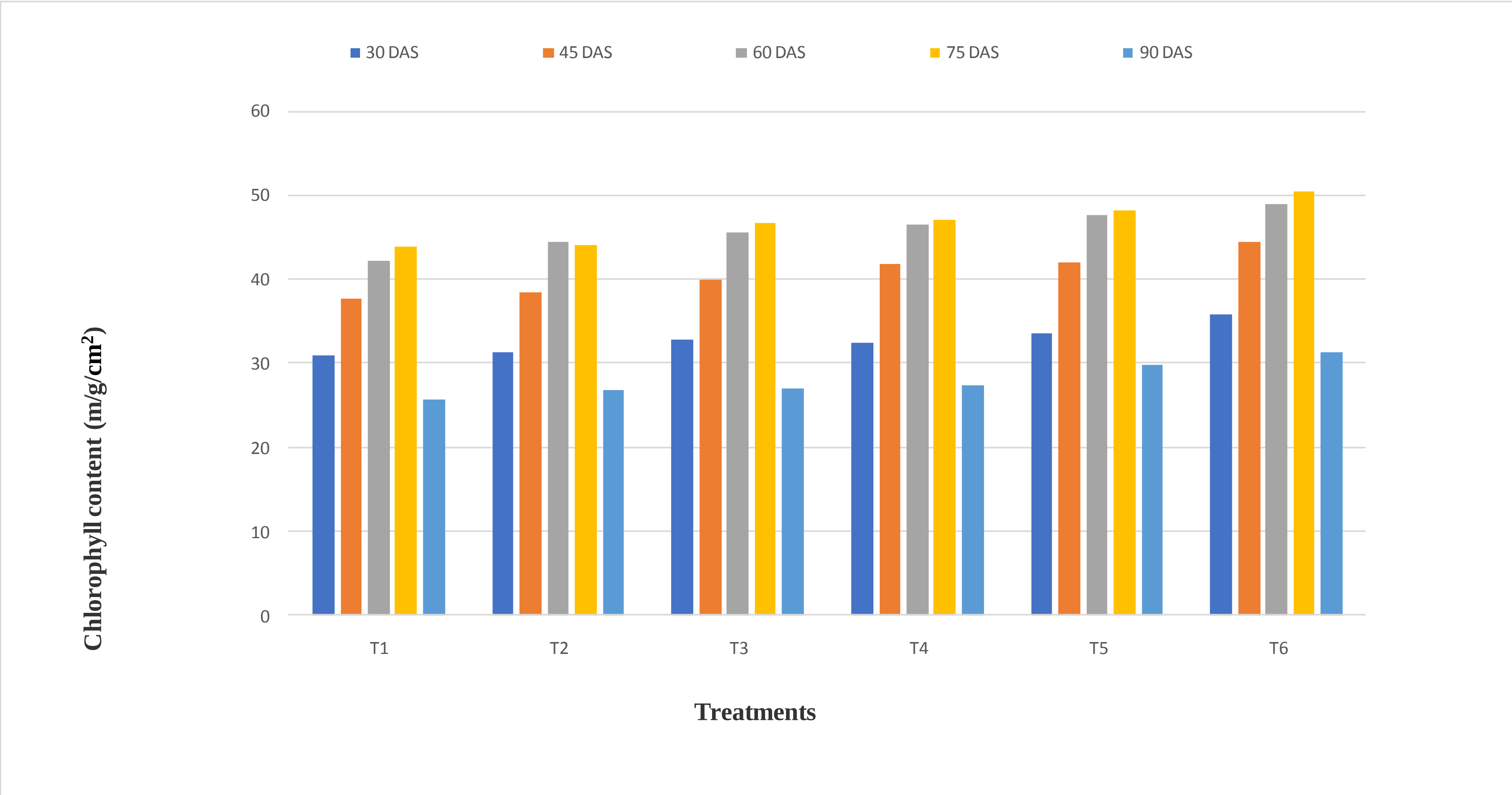

Fig.14. Effect of liquid biofertilizers on chlorophyll content in leaf

Table 15. Effect of liquid biofertilizers on oil content (%)

Tr. No.	Treatments	Oil content (%)
T1	Absolute control	17.13
T2	Recommended dose of fertilizer	18.18
T3	RDF + Inoculation of Rhizobium	18.39
T4	RDF + Inoculation of Rhizobium + PSB	19.53
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	19.75
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	19.93
	S.Em.±	0.65
	C.D. at 5%	NS

The higher oil content was recorded by treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (19.93%) followed by treatment T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) (19.75%) and (treatment T_4 (RDF + Inoculation of Rhizobium + PSB) (19.53%). Lowest oil content was recorded by treatment T_1 (Absolute control) (17.13 %).

4.3.3 Effect of liquid biofertilizers on protein content (%)

Protein content seed in percentage is presented in Table 16 and graphically depicted in fig.16. which was found to be non-significant.

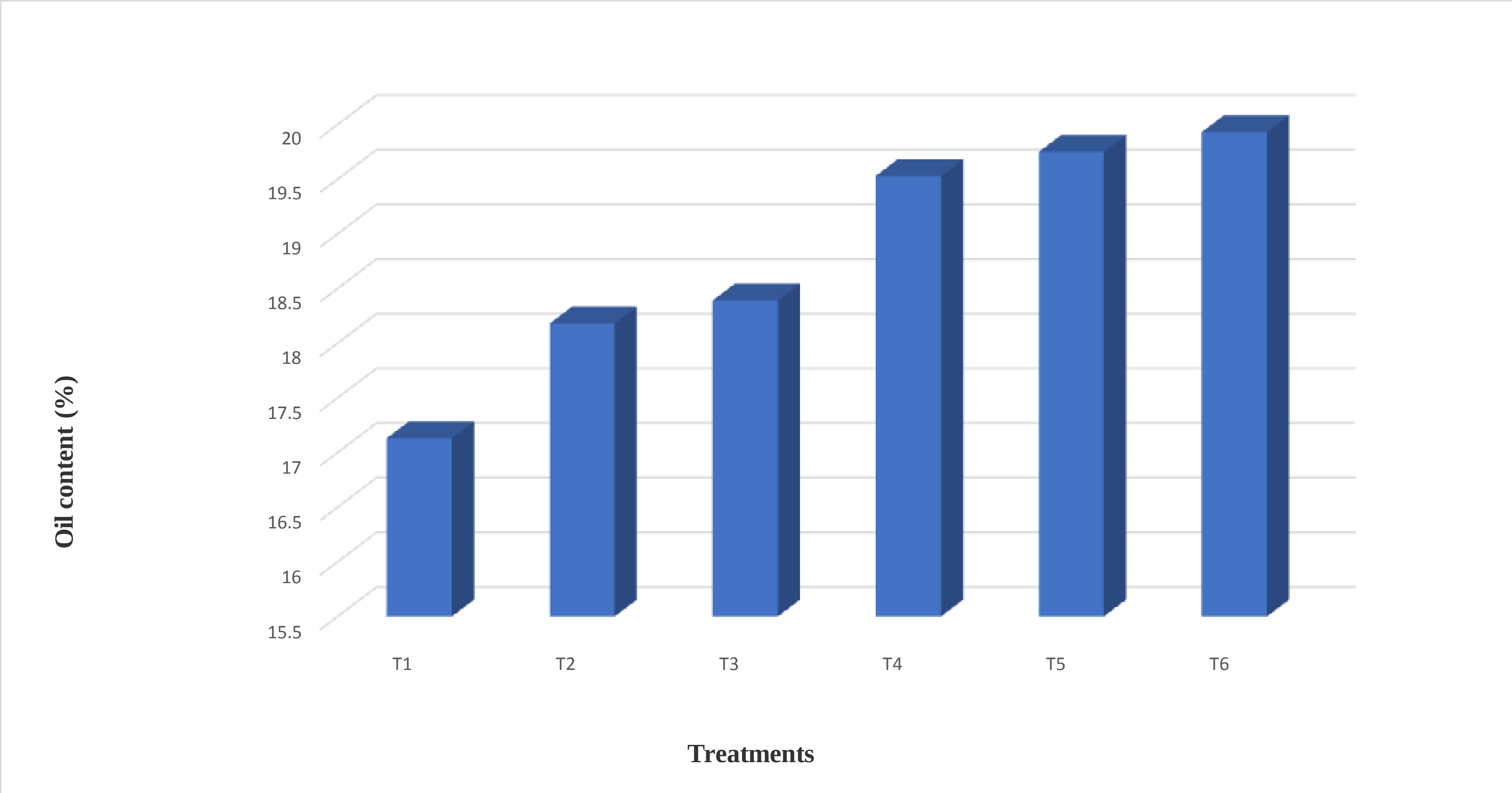

Fig.15. Effect of liquid biofertilizers on oil content (%)

Table 16. Effect of liquid biofertilizers on protein content (%)

Tr. No.	Treatments	Protein content (%)
T1	Absolute control	39.54
T2	Recommended dose of fertilizer	40.33
T3	RDF + Inoculation of Rhizobium	40.38
T4	RDF + Inoculation of Rhizobium + PSB	40.63
T5	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria	40.70
T6	RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers	40.94
	S.Em.±	0.29
	C.D. at 5%	NS

The higher protein content was recorded by treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) (40.94%), followed by treatment T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) (40.70%) and treatment T_4 RDF + Inoculation of Rhizobium + PSB) (40.63%). Lowest protein content was recorded by treatment T_1 (Absolute control) (39.54%).

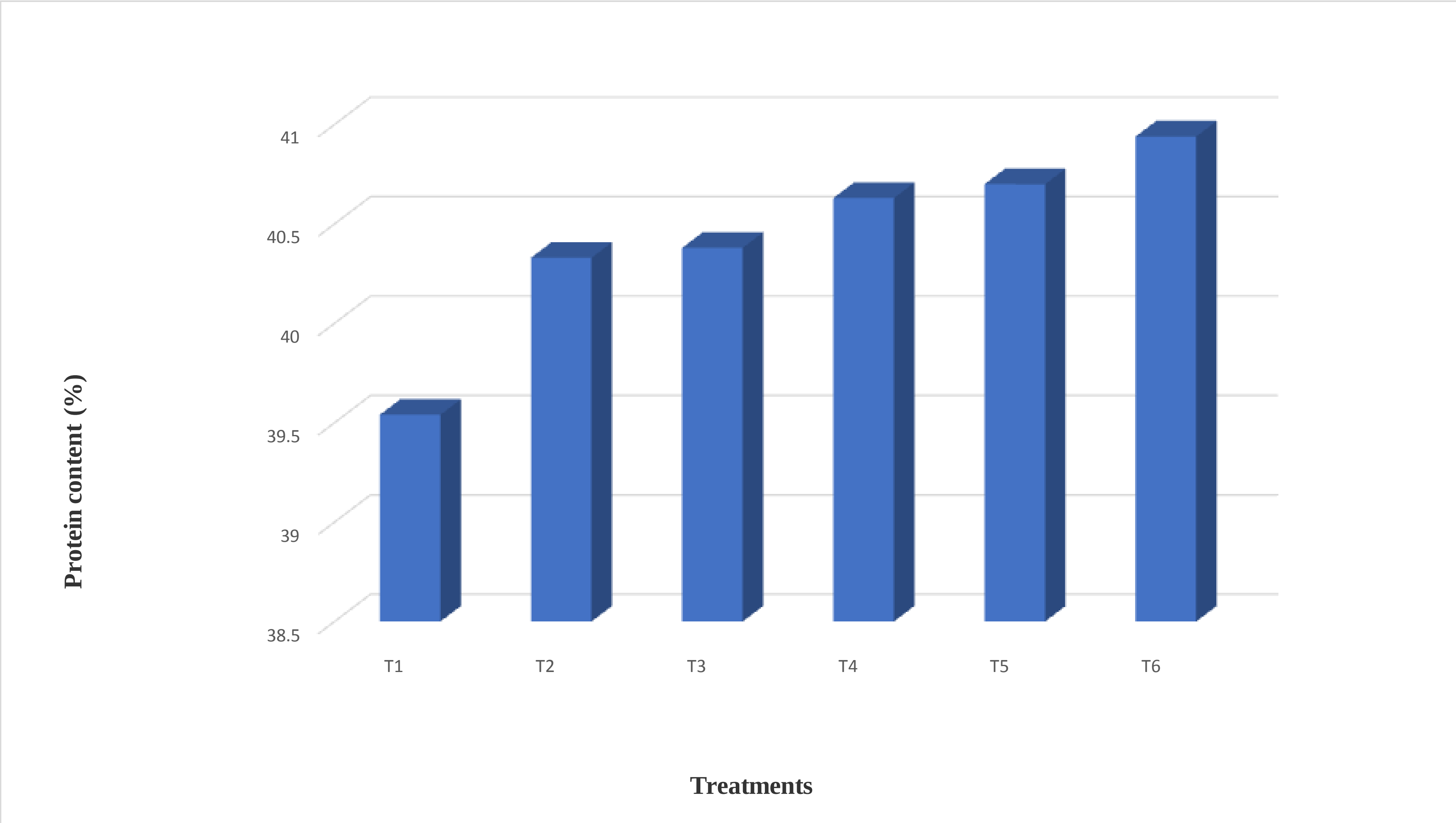

Fig.16. Effect of liquid biofertilizers on protein content (%)

Discussion

CHAPTER -V

DISCUSSION

The present investigation was undertaken to study the "Effect of liquid biofertilizers on morpho-physiology and yield attributes of soybean (*Glycine Max*. (L.) Merrill)". A field experiment was conducted during *kharif* season of 2019 with soybean variety MAUS-612 at instructional farm of Department of Agril. Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The results of this investigation are discussed in this chapter with reference to effect of liquid biofertilizers on morpho-physiology and yield attributes of soybean. An attempt has been made to support the present findings are discussed in this chapter under the following heads.

5.1 Morphological traits

5.1.1 Plant height, number of branches and leaf area

Increase in growth and yield attributes is the main function of balanced nutrients added in soil which support growth and development processes and in turn reflect in production of biomass.

The results of this experiment regarding plant height, number of branches and leaf area indicated that application of seed treatment with liquid biofertilizers in soybean had increased all these parameters as compared to control. In order to know the growth of crop, the data was recorded at various growth stages.

Plant height was increased continuously up to maturity. The rate of increase in plant height was maximum between 30 to 60 DAS indicating grand growth period. Thereafter, increase in plant height was very slow till maturity. The plants attained 28.70 cm of their maximum height at 30 DAS and up to 60 DAS plant attained 54.75 cm; thereafter the growth in terms of height was slower down.

Plant height and its rate of increase were found to be significant amongst different treatments. Application of T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) to soybean crop at 30 DAS and up to 60 DAS was higher in respect of plant height compared with rest of the treatments. Similarly other growth attributes *viz*., number of branches plant^{-1} and leaf area (cm^2) were also higher in same treatments. The increase in plant height may be due to better absorption and translocation of plant growth regulators to growing tip. These results are in conformity with Koushal *et al*. (2011), Jaga *et al*. (2015), Kaluram Kumawat *et al.* (2017), Daravath Raja *et al.* (2017).

It was observed from the data presented in Table 3 that number of branches plant^{-1} increased up to 60 DAS and remained constant till harvest. The rate of increase was high up to 30-60 days and remained same thereafter at harvest. The number of branches were influenced significantly by various treatments under study and treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded maximum number of branches (6.10) followed by T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria). However, treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) was significantly superior over rest of all treatments. Similar results were found by Sharma *et al*. (2009), Amit *et al*. (2010), Kaluram Kumawat *et al.* (2017), Darawat Raja *et al.* (2017).

The data leaf area (cm^2) plant^{-1} revealed that these increased rapidly between 30-60 DAS and decreased thereafter towards maturity due to drying and senescence of leaves. Treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) proved to be superior in higher leaf area (cm^2) plant^{-1} than other treatments.

5.2 Growth attributes

5.2.1 Relative growth rate, crop growth rate, net assimilation rate and leaf area index

As regards to the growth analysis, the significantly higher values of RGR, CGR, NAR and LAI were reported with application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6). Absolute control (T_1) found to be the least by having lower values for growth functions.

From the above results it was revealed that an age of crop growth *i.e.* at 30 to 60 DAS, treatment RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6) recorded significantly higher values of all the growth parameters followed by (T_5) RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria and (T_4) RDF + Inoculation of Rhizobium + PSB, while the lowest values of all the growth parameters were observed in treatment (T_1) Absolute control.

The maximum values of all the growth parameters in these treatments might be due to the application of liquid biofertilizers to the soybean crop which enhanced vegetative growth of soybean, which facilitated the crop to make optimum use of available underground resources.

However, at later stages *i.e.* 90 DAS significantly higher values of all the growth attributes were reported in application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6), while the lowest values were observed in Absolute control (T_1). Almost similar trend was observed in all the growth parameters. Similar results were found by Neelam Singh *et al*. (2018), Arnab Banerjee *et al.* (2012).

5.2.2 Total dry weight (g) per plant

It was observed from the data presented in Table 9 that, total dry matter accumulation plant^{-1} was found to be increased continuously with advancement in the age of the crop till harvest. The rate of increase in dry matter accumulation was faster between 30 to 60 DAS and thereafter increased with decreasing rate till harvest stage. Treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) recorded highest dry matter production plant^{-1} than the rest of treatments. The increase in total dry matter accumulation plant^{-1} may be due to profound effect of application of RDF, Rhizobium, PSB, Sulphur oxidizing bacteria and zinc solubilizers which supply nutrients, result into higher vegetative growth, increase in better absorption and translocation of plant nutrients by growing plants. These results are in conformity with Mekki *et al*. (2005), Anwar *et al*. (2010), Kumar *et al*. (2016), Ade *et al*. (2018).

5.2.3 Days to 50% flowering

Almost all the treatments had reduced the days to 50% flowering in treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) as compared to T_1 (Absolute control). The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) was found the earliest in case of days to 50% flowering followed by T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) and T_4 (RDF + Inoculation of Rhizobium + PSB).

5.3 Yield attributes

5.3.1 Number of pods per plant

Almost all the yield attributing characters *viz*., number of pods plant^{-1}, test weight, seed yield (kg plot^{-1}), seed yield (qt ha^{-1}), and harvest index (%) were significantly influenced by various treatments.

Application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6) recorded significantly higher number of pods plant^{-1}, test weight, indicating the more availability nutrients at crucial growth stages under this treatments ultimately improved all yield attributes besides increased rate of N, P, K and micronutrients absorption cumulatively helped the crop plants to produce more surface area for high photosynthetic rate as well as maximum translocation of photosynthesis from source to sink, subsequently resulted in improvement of all yield attributes. Because of synergetic effect among the yield attributes they benefited each other. Similar result was found by Mekki *et al*. (2005), Gupta *et al.* (2006), Koushal *et al*. (2011), Waghmare *et al*. (2012).

Seed yield was a function of yield attributes. Similarly, biological yield of crop plant has a close relationship with its economical yield. RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6) recorded significantly higher seed yield. This might be due to higher seed yield plant^{-1} which occurred from increased pod number. While the lowest number of pods plant^{-1}, test weight, seed yield (kg plot^{-1}) and seed yield (qt ha^{-1}) were recorded in Absolute control (T_1) due to lower availability of available nutrients. These results are in conformity with Waghmare *et al*. (2012), Shivran *et al.* (2012), Nagar *et al.* (2018).

5.4 Quality / Biochemical Traits

The effect of different treatments on chlorophyll content of leaf was found to be a significant. The treatment RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6) recorded higher chlorophyll content of leaf. Similar result was given by Selvakumar *et al*. (2009) and Jaga *et al*. (2015).

The effect of different treatments on protein content (%) was found to be non-significant. Treatment RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6) recorded higher protein content (40.94).

This results are in agreements with the results of Iraj Zarei1 *et al*. (2012), Waghmare *et al*. (2012), Neelam Singh *et al*. (2018) and Chaudhari *et al*. (2019).

The mean oil content (19.93%) was not influenced significantly with the application of different treatments. Treatment RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6) produced the highest value of oil content (19.93%). Mekki and Ahmed *et al*. (2005), Waghmare *et al*. (2012), Jaga *et al*. (2015), Neelam Singh *et al*. (2018) also recorded similar kind of results.

Summary and Conclusion

CHAPTER-VI

SUMMARY AND CONCLUSIONS

The present investigation entitled "Effect of liquid biofertilizers on morpho-physiology and yield attributes of soybean (*Glycine Max*. (L.) Merrill)" was conducted in *kharif* season of 2019 at instructional farm of Department of Agril. Botany, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani with soybean variety MAUS-612 to evaluate the effect of different liquid biofertilizers on growth, yield and quality of soybean.

The experiment was laid out on medium black soil, with six treatments, replicated four times in Randomized Block Design. The treatments consisted T_1-Absolute control, T_2- Recommended dose of fertilizer, T_3-RDF + Inoculation of Rhizobium, T_4-RDF + Inoculation of Rhizobium + PSB, T_5-RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria, T_6- RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizer (50 ml/10 kg).

The soybean cv. MAUS-612 was sowen on 4th July 2019 and harvested on 13th of October 2019. The seed treatment of all the treatments were done at the time of sowing with appropriate dose. Five plants per plot were selected randomly and observations were recorded for morphological traits, growth parameters, yield and yield attributing characters. The growth parameters i.e. LAI, RGR, NAR and CGR were calculated by using their specific formula. Protein and oil content was determined by analyzing seed samples and for chlorophyll content leaf samples selected and determined by using an instrument SPAD and analyzed.

The results clearly indicated that all the morphological traits, growth parameters, yield and yield attributing characters, quality and biochemical parameters were found to increase with the seed inoculation with liquid biofertilizers. The effect of different treatments was noticed on important growth parameters *viz.*, plant height, number of branches, leaf area, total dry matter accumulation and days to 50% flowering.

The above mentioned growth parameters *viz*. plant height, number of branches, leaf area, total dry matter accumulation and days to 50% flowering were recorded higher values with application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6) and the lower values of the above mentioned parameters were recorded by treatment T_1 (Absolute control) during the entire crop growth period. Also LAI, NAR, RGR and CGR were recorded the highest value with application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers (T_6) followed by T_5 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria) and the lower values of the above mentioned parameters were recorded by treatment T_1 (Absolute control). Similar kind of trend was observed with respect to yield and yield attributing characters and biochemical parameters

CONCLUSION

1. In the liquid biofertilizers treatments studies, the application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers this treatment was suitable for improving yield potential of the soybean cv. MAUS-612.
2. The mixed liquid biofertilizers treatments studies, plant height, number of branches, leaf area and 50% flowering increased due to application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers.
3. The mixed liquid biofertilizers treatments studies, growth parameters such as LAI, RGR, NAR and CGR recorded maximum value due to application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers as compared to Absolute control or other treatments.
4. Total dry weight per plant showed highly significant with treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) for seed.
5. Protein content, oil content and chlorophyll content in leaf was improved with application of RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers.
6. The treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers) was found maximum seed yield and yield attributing characters of soybean cv. MAUS-612.

These all conclusions are based on one season studies, they need further research on the same line.

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Thesis Abstract

THESIS ABSTRACT

Research topic	:	**“Effect of liquid biofertilizers on morpho-physiology and yield attributes of soybean (*Glycine Max*. (L.) Merrill)”**
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Year of award of degree	:	2020
Major subject	:	Agricultural Botany (Plant Physiology)
Total numbers of pages in thesis	:	
Total numbers of words in thesis abstract	:	241
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ABSTRACT

The experiment was conducted at instructional farm of Department of Agril. Botany College of Agriculture, Parbhani during *kharif* season 2019-2020. The soil was typical black cotton having medium fertility and fairly good drainage. The land having uniform topography was used to study the "Effect of liquid biofertilizers on morpho-physiology and yield attributes of soybean (*Glycine Max*. (L.) Merrill)". The experiment was laid out in Randomized Block Design with four replications and six treatments. Various morphological traits, growth parameters, yield and yield attributing characters and biochemical parameters were significantly affected due to different liquid biofertilizers.

The results of field experiment indicated that the morphological traits *viz.* plant height, number of branches, leaf area, dry weight, days to 50% flowering and growth parameters leaf area index, RGR, NAR and CGR were significantly increased due to application of treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers).

Yield attributing characters *viz.* number of pods per plant, test weight of seeds (g), seed yield kg/plot, seed yield qt/ha and harvest index significantly increased due to application of liquid biofertilizers T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers). The application of mixed liquid biofertilizers recorded significantly highest seed yield of soybean cv. MAUS-612. Similarly biochemical or quality parameters also significantly increased due to the application of treatment T_6 (RDF + Inoculation of Rhizobium + PSB + Sulphur oxidizing bacteria + Zinc solubilizers).

Appendix

APPENDIX

Weekly weather data 2019-20 (VNMKV, Parbhani Location)

WK	Period	Rainfall (mm)	Humidity (%)		Temperature (^oC)		EVP (Hrs.)	BSS (Hrs.)	W. V. (K/mph)
			AM	PM	Max.	Min.			
27	02 July-08 July	10.6	33.2	23.1	76	58	5.1	2.7	8.3
28	09 July-15 July	34.2	33.5	22.6	83	49	5.5	6.7	7.0
29	16 July-22 July	11.2	34.2	22.9	79	46	6.6	7.7	5.8
30	23 July-29 July	64.3	30.6	22.6	81	62	4.5	4.1	6.3
31	30 July-05 Aug.	85.4	28.1	21.8	92	85	2.1	1.2	6.6
32	06 Aug.-12 Aug.	62.2	30.5	22.0	89	65	4.0	3.5	6.2
33	13 Aug.-19 Aug.	9.7	32.3	21.5	80	57	4.6	5.4	4.6
34	20 Aug.-26 Aug.	1.2	32.2	22.0	80	56	5.6	6.5	6.0
35	27 Aug.-02 Sept.	78.0	31.2	21.5	88	59	4.6	5.6	4.7
36	03 Sept.-09 Sept.	13.2	30.1	21.6	83	70	2.9	2.0	4.7
37	10 Sept.-16 Sept	86.4	30.0	21.2	88	68	2.8	4.7	5.4
38	17 Sept.-23 Sept	118.8	30.9	21.9	94	67	2.3	5.1	3.5
39	24 Sept.-30 Sept	35.6	31.3	21.1	92	62	3.7	6.5	3.3
40	01 Oct.-07 Oct.	21.2	31.4	20.5	88	60	3.8	7.3	2.8
41	08 Oct.-14 Oct.	5.1	31.5	20.1	87	53	4.1	7	2.7
	Total Mean	637.1	471	326.4	1280	917	62.2	76	77.9

Vitae

VITAE

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A candidate for the degree
Of
MASTER OF SCIENCE (AGRICULTURE)
In
AGRIL. BOTANY (PLANT PHYSIOLOGY)
2020

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