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ASSESSMENT OF GROWTH INDICES, CANOPY CHARACTERISTICS AND WATER RELATIONS IN CHICKPEA (*Cicer arietinum* L.) UNDER LIQUID BIOFERTILIZER SEED TREATMENTS

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ABSTRACT

The current study was carried out during the *Rabi* season of 2024-2025 at Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh, India to study the influence of liquid biofertilizer treatments for seed of chickpea (*Cicer arietinum* L.) variety JG 36 on growth attributes and physiological traits. The experiment was set up with nine treatments in randomized block design with three replications. Parameters studied were crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), biomass duration (BMD), chlorophyll content index (CCI), normalized difference vegetation index (NDVI), radiation interception, membrane stability index (MSI) and relative water content (RWC). It was found that the responses to the treatments differed depending on the parameter measured and the crop growth stage. Jawahar KSB (T_5) had the highest CGR (0.037) during 30-60 days after sowing (DAS). However, Jawahar *Trichoderma* (T_9) showed the maximum CGR (0.027) during 60-90 DAS. The maximum RGR for the period of 30-60 DAS was found in treatment T_5 (0.043), whereas the maximum RGR (0.028) for the period of 60-90 DAS was found in Jawahar EM culture (T_3). In case of NAR, Jawahar PSB (T_4) and Jawahar KSB (T_5) recorded maximum values for the period of 30-60 DAS (0.0003605 and 0.0003595, respectively), while treatment T_3 recorded maximum NAR (0.000196) during the period of 60-90 DAS. Treatment T_8 recorded maximum BMD during both periods (30-60 DAS-132.60, 60-90 DAS-363.60). The maximum value of chlorophyll content index was recorded in treatment T_8 at 45 DAS (51.97), 60 DAS (50.60) and 90 DAS (45.63). The maximum value of NDVI and radiation interception during the period of 90 DAS were recorded in treatment T_4 (NDVI-0.82, Radiation interception-582.67). Treatment T_4 recorded the maximum MSI during 60 DAS (48.14%) and 90 DAS (49.16%). In case of RWC, the highest value during 60 DAS was recorded by treatment T_3 (91.80%), whereas treatment T_8 recorded maximum RWC during 90 DAS (79.04%). As a whole, the results revealed the varying response of chickpea towards biofertilizer seed treatment during different growth stages and with respect to various physiological parameters. With respect to NDVI, radiation interception, and MSI, Jawahar PSB was effective while for BMD, CCI and RWC at a later growth stage, Jawahar *Rhizobium* worked best. This clearly depicts the necessity of studying more growth and physiological parameters for biofertilizer seed treatments in chickpea.

Key words : Chickpea, Growth indices, NDVI, Radiation Interception, Water relations.

Introduction

Chickpea (*Cicer arietinum* L.) is an important legume which plays an important role in nutritional security and sustainable agriculture. The seed contains high levels of protein along with other essential nutrients, thus forming an important part of diet, especially in India. Besides being important for nutrition, the chickpea also improves soil fertility through symbiotic nitrogen fixation. However,

crop growth and productivity are determined by many other factors such as nutrient supply, environment and the efficiency of plants in capturing and utilizing nutrients available in the environment. Thus, the study of physiological mechanisms of crop growth is crucial in order to determine the most appropriate practices of crop management. Growth analysis of the crop gives useful information about the efficiency of plants at various growth stages. Crop growth rate (CGR) is defined as an increase in dry mass per unit ground area per unit of time, while relative growth rate (RGR) is defined as an increase in dry mass of the plant relative to its existing dry mass. The net assimilation rate (NAR) is defined as the rate of dry mass accumulation per unit leaf area per unit of time.

Growth analysis during different growth stages can be used to understand the variation in growth performance and the physiology of chickpea under various management strategies. The other factor that significantly influences growth performance is radiation interception because it is the energy captured by the plants during photosynthesis. The normalized difference vegetation index (NDVI), which is estimated from spectral reflectance values, is a widely used technique for measuring green vegetation cover. Growth analysis together with radiation interception would enable the assessment of canopy development and radiation interception by the plant. Differences in these variables could explain variations in growth performance among the crops.

Membrane stability index (MSI) and relative water content (RWC) are two important indicators that reflect the physiological state of plants under changing environmental conditions. MSI stands for membrane stability, whereas RWC represents the water status of the plant. The stresses in the environment may affect membrane integrity and the water relationships in plants and thus interfere with their normal functioning and development. Investigation of these parameters at various stages of growth of the crops will enable to detect the differences between the treatments used on crops.

Biofertilizers are biological agents which contain beneficial microorganisms that could enhance nutrient availability and affect plant growth through various means. The rhizobia are involved in biological nitrogen fixation, while PSB and KSB could increase the availability of nutrients in the soil. Some other microbial inoculants, such as *Azospirillum*, *Pseudomonas*, EM culture and *Trichoderma*, could also affect the physiology of plants through their growth-promoting properties. Application of these microbial inoculants to seeds could affect the accumulation of biomass, canopy formation, radiation capture, membrane stability and water balance of the plants. However, the nature and consistency of these effects might differ based on the microbial inoculant, growth stage of the plants and environment.

Biofertilizers have been used for improving crop performance however, their impacts on growth indices and physiological parameters of chickpea have to be assessed through the growth stages. Assessing CGR, RGR, NAR, NDVI, radiation interception, MSI, and RWC together could give a comprehensive picture of the crop growth, canopy behaviour and physiological condition of the plant in response to different biofertilizer seed treatments.

Materials and Methods

Experimental field and treatments

This field experiment was carried out during the *Rabi* season of 2024-2025 at the Experimental Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh, India using the variety of chickpea (*Cicer arietinum* L.) JG 36. Nine treatments were included, out of which one treatment was the control without treatment and the remaining eight treatments were based on liquid biofertilizer seed treatments in a randomized block design (RBD) with three replications.

Table 1 : Treatment details of the experiment.

Treatment	Treatment details
T_1	Control
T_2	Seed treatment with Vitavax @ 5g kg^{-1} seed + Jawahar *Rhizobium*@ 20 ml kg^{-1} seed
T_3	Seed treatment with Jawahar EM culture @ 20 ml kg^{-1} seed
T_4	Seed treatment with Jawahar PSB @ 20 ml kg^{-1} seed
T_5	Seed treatment with Jawahar KSB @ 20 ml kg^{-1} seed
T_6	Seed treatment with Jawahar *Azospirillum*@ 20 ml kg^{-1} seed
T_7	Seed treatment with Jawahar *Pseudomonas* @ 20 ml kg^{-1} seed
T_8	Seed treatment with Jawahar *Rhizobium* @ 20 ml kg^{-1} seed
T_9	Seed treatment with Jawahar *Trichoderma* @ 20 ml kg^{-1} seed

Growth parameters

Crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and biomass duration (BMD) were determined based on dry weight and leaf area

measurement taken at different sampling periods.

Crop growth rate (CGR): It is the measure of the increase in dry weight per unit ground area per unit time and was estimated using the method described by Watson (1952).

$$CGR = W_2 - W_1/P\ (t_2 - t_1)\ (gcm^{-2}days^{-1})$$

Relative growth rate (RGR): RGR refers to the increment of dry matter with respect to the biomass already present at a particular time period and was determined according to the method of Watson (1952):

$$RGR = LnW_2 - LnW_1/t_2 - t_1\ (gg^{-1}\ days^{-1})$$

Biomass duration (BMD): BMD refers to the persistence of biomass for a particular time period and was determined according to the trapezoidal method described by Roberts *et al.* (1985):

$$BMD = \frac{W_2 + W_1}{2} x(T_2 - T_1)\ (gdays)$$

Canopy and chlorophyll-related parameters

Normalized difference vegetation index (NDVI): NDVI was determined with an NDVI meter which recorded reflected radiation in the red and near-infrared parts of the spectrum, then perform the NDVI calculation internally a pre-programmed formula.

Chlorophyll content index (CCI): CCI was determined through a portable chlorophyll meter (Minolta SPAD-502 as mentioned in the experiment protocol). Readings were taken from the middle region of selected leaves and their averages were used in the data analysis.

Radiation interception: Light intensity above the canopy of crop plants and on the ground surface was measured with a lux meter. The light transmission ratio (LTR) was calculated according to Yoshida (1972):

LTR (%)= Light intensity at a ground surface /Light intensity above canopy × 100

Membrane stability index (MSI)

The membrane stability was determined by the use of the electrical conductivity technique as described by Premchandra *et al*. (1990). The leaf samples were first trimmed into uniform sizes and immersed in test tubes filled with double distilled water. One sample was then heated in a water bath from 40 to 45°C for 30 minutes, while the other sample was heated at 100°C for 10-15 minutes.

The electrolyte leakage relative to the membrane injury percentage was then determined as:

Membrane injury index = Conductivity at 45^0C / Conductivity at 100^0 C × 100

Relative Water Content (RWC)

The relative water content was measured following the procedure of Barrs and Weatherley (1962). First, fresh leaves were weighed to calculate the fresh weight (FW). After that, they were put into distilled water until they attained turgidity, then weighed to calculate turgid weight (TW). Finally, the samples were dried in an oven at 85°C until constant weight was attained to determine dry weight (DW).

The calculation of RWC was done using the formula:

RWC = Fresh Weight – Dry Weight / Turgid Weight – Dry Weight × 100

Statistical analysis

The results from the experiment were subjected to the analysis of variance (ANOVA) suitable for randomized block design. Means of treatments were compared through the critical difference (CD) at 5% level of significance.

Results and Discussion

Crop Growth Rate

CGR of chickpea differed among the two growth periods, possibly due to variation in leaf area index and dry matter accumulation. In 30-60 DAS growth period, the maximum CGR was obtained from T_5 (Jawahar KSB) (0.037 g m^{-2} day^{-1}), followed by T_6 (Jawahar *Azospirillum*) and T_8 (Jawahar *Rhizobium*) (0.036 g m^{-2} day^{-1} each), whereas the minimum was obtained from T_9 (Jawahar *Trichoderma*) (0.019 g m^{-2} day^{-1}). The higher CGR under treatment T_5 is possibly due to higher nutrient uptake and vegetative growth. In the 60-90 DAS growth period, the maximum CGR was found under treatment T_9 (Jawahar *Trichoderma*) (0.027 g m^{-2} day^{-1}), while the minimum was observed under T_6 (Jawahar *Azospirillum*) (0.009 g m^{-2} day^{-1}). The higher CGR under T_9 in the latter growth period, despite having low CGR in the former one, is possibly due to stage specific variation in dry matter accumulation. The CGR is affected by leaf area index, solar radiation interception and photosynthesis. But if the amount of the canopy is too high, then there will be chances of leaf shading, which reduces the contribution of photosynthesis from the lower leaves, while there may be limitations in dry matter formation due to senescence of the leaves during later stages of growth. The effect of boron and biofertilizers on the growth and productivity of summer black gram has been studied by Jyothika *et al.* (2023).

Net Assimilation Rate

The NAR of chickpea differed among various seed biofertilizer treatments in both periods of growth. In the

Table 2 : Effect of seed treatment using liquid biofertilizers on Crop Growth Rate and Net Assimilation rate.

Treatment	Crop Growth Rate at 30-60 DAS	Crop Growth Rate at 60-90 DAS	Net Assimilation Rate at 30-60DAS	Net Assimilation Rate at 60-90DAS
T_1	0.024^{bc}	0.019^{ab}	0.0001923^{bcd}	0.000167^{abc}
T_2	0.026^{bc}	0.019^{ab}	0.0001666^{cd}	0.000175^{ab}
T_3	0.023^{c}	0.023^{a}	0.0001279^{d}	0.000196^{a}
T_4	0.027^{b}	0.019^{ab}	0.0003605^{a}	0.000115^{cd}
T_5	0.037^{a}	0.010^{c}	0.0003595^{a}	0.000132^{bcd}
T_6	0.036^{a}	0.009^{c}	0.0003356^{a}	0.000104^{d}
T_7	0.035^{a}	0.013^{bc}	0.0003106^{abc}	0.000083^{d}
T_8	0.036^{a}	0.010^{c}	0.0003408^{ab}	0.000074^{d}
T_9	0.019^{d}	0.027^{a}	0.0002461^{abcd}	0.000180^{ab}
SEm±	**0.001**	**0.00247**	**0.000045**	**0.0000180**
CD(P≤5%)	**0.003**	**0.00741**	**0.000135**	**0.0000539**

Table 3 : Effect of seed treatment using liquid biofertilizers on Relative Growth Rate.

Treatment	Relative Growth Rate at 30-60 DAS	Relative Growth Rate at 60-90 DAS	Relative Growth Rate at harvest -90 DAS
T_1	0.021^{bc}	0.025^{ab}	0.485^{a}
T_2	0.017^{c}	0.025^{ab}	0.436^{a}
T_3	0.012^{c}	0.028^{a}	0.629^{a}
T_4	0.035^{a}	0.016^{bcd}	0.684^{a}
T_5	0.043^{a}	0.018^{bcd}	0.450^{a}
T_6	0.039^{a}	0.015^{cd}	0.569^{a}
T_7	0.033^{ab}	0.012^{d}	0.392^{a}
T_8	0.031^{ab}	0.010^{d}	0.617^{a}
T_9	0.022^{bc}	0.023^{abc}	0.504^{a}
SEm±	**0.003849**	**0.002917**	**0.094611**
CD(P≤5%)	**0.011538**	**0.008744**	**0.283643**

period of 30-60 days after sowing, the maximum NAR was observed in T_4 (Jawahar PSB) (0.0003605) and in T_5 (Jawahar KSB) (0.0003595), while the minimum value was recorded in T_3 (Jawahar EM culture) (0.0001279). In the period of 60-90 days after sowing, there was a decline in NAR in most of the treatments, where the highest value was found in T_3 (Jawahar EM culture) (0.000196), and the lowest value was found in T_8 (Jawahar *Rhizobium*) (0.000074). The decrease in NAR in the latter stage can be due to the age of the crop, leaf senescence, more shading in the crop canopy and alteration in assimilate partitioning due to reproductive growth. The relatively higher NAR in T_3 in 60-90 days after sowing indicates that NAR of T_3 was better maintained in the later stage of growth. According to Moinuddin *et al.* (2014), an investigation was done about the impact of nitrogen and phosphorus biofertilizers along with phosphorus fertilizer on growth and physiological attributes of chickpea.

Biomass duration

There were significant differences in the Biomass Duration (BMD) among the biofertilizer treatments of the seeds during both periods. From 30-60 days after sowing (DAS), BMD ranged from 78.85 to 132.60 grams, with maximum BMD recorded in T_8 (Jawahar *Rhizobium*) (132.60 grams), followed by T_7 (Jawahar *Pseudomonas*) (117.50 grams), while minimum BMD was obtained in T_1 (Control) (78.85 grams). BMD in T_8 was 68.2% more than that of control during the early period, showing more biomass during the early period of growth. From 60-90 DAS, BMD ranged between 287.40 to 363.60 grams, with maximum BMD in T_8 (Jawahar *Rhizobium*) (363.60 grams), followed by T_4 (Jawahar PSB) (358.10 grams), T_3 (Jawahar EM culture) (357.85 grams) and T_5 (Jawahar KSB) (351.70 grams), which were on par with T_8. Minimum BMD was obtained in T_1 (Control) (287.40 grams). High BMD in T_8 during both periods may be due to better nutrient uptake and biomass accumulation due to *Rhizobium* inoculation. Effects of fertilization and microbial preparations on chickpea productivity were analyzed by Yeremko *et al.* (2024), which could serve as background data in assessing the impact of microbial inoculants in chickpea growing. Nevertheless, the results of that research have to be confirmed prior to any comparison with current BMD experiments.

Relative Growth Rate

The Relative Growth Rate (RGR) was found to vary significantly among the biofertilizer seed treatments during the intervals of 30-60 and 60-90 DAS but was statistically non-significant during the period of 90 DAS to harvest.

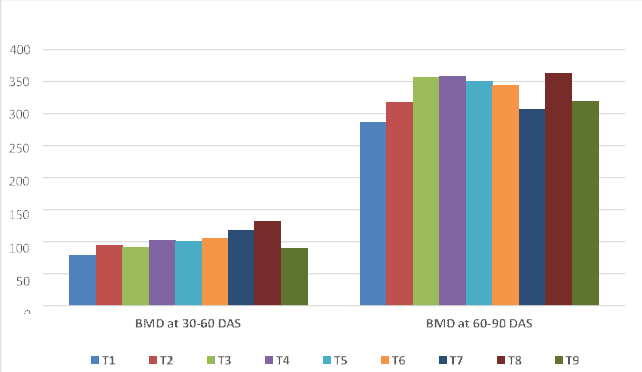


Fig. 1 : Effect of seed treatment using liquid biofertilizers on BMD at 30-60 DAS and 60-90 DAS.

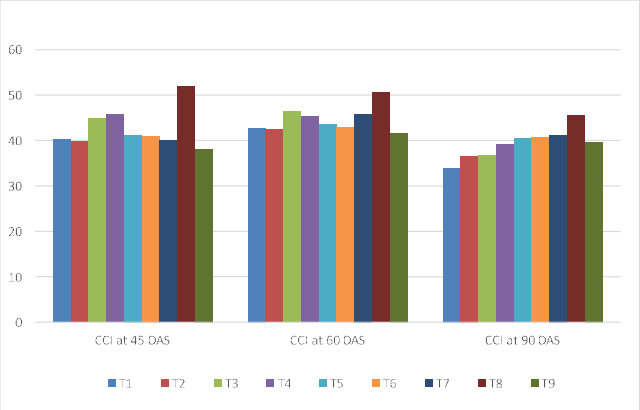


Fig. 2 : Effect of seed treatment using liquid biofertilizer on Chlorophyll Content Index at 30, 60 and 90 DAS in Chickpea.

In the case of the first interval (30-60 DAS), the maximum value for RGR was recorded for T_5 (Jawahar KSB) (0.043 g^{-1} day^{-1}), followed by T_6 (Jawahar *Azospirillum*) (0.039 g^{-1} day^{-1}) and T_4 (Jawahar PSB) (0.035 g^{-1} day^{-1}, whereas the minimum value for RGR was recorded for T_3 (Jawahar EM culture) (0.012 g^{-1} day^{-1}). This increase in RGR in T_5 may be due to high relative dry matter accumulation during the vegetative growth period. In the second period (60-90 DAS), the maximum value of RGR was found for T_3 (Jawahar EM culture) (0.028 g^{-1} day^{-1}), followed by T_1 (Control) and T_2 (Vitavax + Jawahar *Rhizobium*) (0.025 g^{-1} day^{-1}), whereas the minimum value was found for T_8 (Jawahar *Rhizobium*) (0.010 g^{-1} day^{-1}). The increase in the value of RGR in T_3 at this stage, despite having a lower value in the first interval, shows a stage-specific difference in RGR. The period between 90 DAS to harvest was characterized by no statistically significant differences among the treatments, even though T_4 (Jawahar PSB) had the numerically highest RGR value of 0.684, followed by T_3 (Jawahar EM culture) (0.629) and T_8 (Jawahar *Rhizobium*) (0.617), whereas T_7 (Jawahar *Pseudomonas*) had the numerically lowest value (0.392). The numerical difference observed does not necessarily imply a statistically significant advantage of any treatment over others. Singh *et al.* (2017) conducted an experiment to study the effect of Meso *Rhizobium*, plant growth-promoting rhizobacteria and phosphorus on growth indices of desi chickpea. This study offers pertinent literature in relation to growth promotion of chickpea by microbial inoculants.

Chlorophyll Content Index

Chlorophyll Content Index (CCI) is one of the key parameters used to measure leaf greenness and chlorophyll content, which plays a role in the efficiency of photosynthesis. In the current experiment, treatments with biofertilizers had significant effects on CCI at 45, 60 and 90 DAS. From among all the treatments, T8 (Jawahar *Rhizobium*) had the maximum CCI values of 51.97, 50.60, and 45.63 at 45, 60 and 90 DAS, respectively, showing that this treatment maintained maximum chlorophyll content in leaves for the duration of crop development. On 45 DAS, T_4 (Jawahar PSB) (45.73) and T_3 (Jawahar EM culture) (44.90) showed relatively higher CCI values, while T_9 (Jawahar *Trichoderma*) had the minimum CCI value of 38.20. Similarly, T_3 (Jawahar EM culture) (46.50), T_7 (Jawahar *Pseudomonas*) (45.87) and T_4 (Jawahar PSB) (45.33) showed relatively higher CCI values at 60 DAS. By 90 DAS, CCI decreased in almost all treatments, which might be due to leaf senescence. Nonetheless, T_8 had a relatively high CCI compared to other treatments, with T_1 (Control) having the lowest (34.00). Relatively higher CCI levels under treatment T_8 could have been attributed to the efficient acquisition of nutrients and retention of chlorophyll-containing leaves as a result of inoculation with *Rhizobium*. Availability of sufficient nutrients aids in chlorophyll production and photosynthetic enzymes, hence supporting the growth of crops and dry matter formation. Momeni *et al.* (2021) conducted research on the impact of salicylic acid and biofertilizers on the physiology and yield of chickpea under rainfed condition, while Namvar *et al.* (2011) carried out research on the impact of nitrogen fertilizers on growth and yield of chickpea.

Normalized difference Vegetation Index and Radiation interception

There were noticeable differences noted among the seed treatment with biofertilizer on normalized difference vegetation index (NDVI) and radiation interception at 90 days after sowing (DAS). The NDVI value ranged between 0.72 to 0.82, with T_4 (Jawahar PSB) being the highest (0.82) followed by T_8 (Jawahar *Rhizobium*) (0.81) and the lowest values were observed in T_7 (Jawahar

Pseudomonas) and T_9 (Jawahar *Trichoderma*) (0.72 each). There was 10.8% higher NDVI in T_4 as compared to T_1 (Control) (0.74); however, T_4 and T_8 were statistically on par. These higher values may denote comparatively good characteristics of canopy and more green vegetation cover. Differences were also seen in radiation interception, which varied from 437.33 to 582.67 in the measured units. Highest radiation interception was observed in T_4 (Jawahar PSB) (582.67) followed by T_3 (Jawahar EM culture) (546.67), T8 (Jawahar *Rhizobium*) (539.33) and T_5 (Jawahar KSB) (538.33), which were statistically on par with T_4. The lowest value in numeric was observed in T_6 (Jawahar *Azospirillum)* (437.33) and T_7 (Jawahar *Pseudomonas*) (439.00). There was approximately 29.8% higher radiation interception in T_4 as compared to T_1 (Control) (448.67). Increased interception of the radiation received could play a role in photosynthetic carbon assimilation and dry matter formation in favorable conditions. Carril *et al*. (2024) applied the methods of multispectral, thermographic and spectroradiometric analyses to estimate the biostimulatory effect of wood distillate in field grown chickpea, emphasizing the applicability of spectral analysis to assess crop responses to biostimulants. In a similar manner, Yousefi *et al*. (2020) tested radiation use efficiency and growth parameters in mungbean genotypes in biological fertilizer treatments, which could serve as an example of the impact of biological materials on plant growth. All of these sources are relevant background for discussing differences in NDVI and radiation interception in the present experiment in chickpeas.

Membrane Stability Index

Use of liquid biofertilizers greatly affected the membrane stability index (MSI) of chickpea at 60 and 90 DAS. At 60 DAS, the MSI values varied from 42.99 to 48.14 %, where the maximum MSI was recorded for T_4 (Jawahar PSB) (48.14%), followed by T_7 (Jawahar *Pseudomonas*) (47.98%) and T_8 (Jawahar *Rhizobium*) (47.23 %). The MSI values for T_4 and T_7 were statistically at par, while the minimum MSI was found in case of T_6 (Jawahar *Azospirillum*) (42.99%). The MSI of T_4 was 8.2% higher as compared to T_1 (Control) (44.50%), showing comparatively higher membrane stability under the treatment of Jawahar PSB. At 90 DAS, the MSI values varied from 40.12 to 49.16%, where the maximum MSI was recorded for T_4 (Jawahar PSB) (49.16%), followed by T_3 (Jawahar EM culture) (48.54%) which were statistically at par. The lowest MSI value was observed for T_9 (Jawahar *Trichoderma*) (40.12%), followed by T_6 (Jawahar *Azospirillum*) (41.50%) and T_2 (Vitavax + Jawahar *Rhizobium*) (41.76%). The MSI

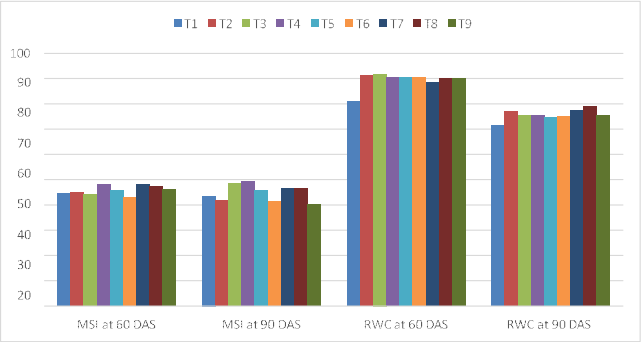


Fig. 3 : Effect of seed treatment using liquid biofertilizer on MSI and RWC at 60 and 90 DAS.

Table 4 : Effect of seed treatment using liquid biofertilizers on NDVI and Radiation Interception at 90 DAS.

Treatment	NDVI at 90 DAS	Radiation interception at 90 DAS
T_1	0.74^{c}	448.67^{bcd}
T_2	0.75^{bc}	499.67^{abcd}
T_3	0.75^{bc}	546.67^{a}
T_4	0.82^{a}	582.67^{a}
T_5	0.75^{bc}	538.33^{abc}
T_6	0.73^{c}	437.33^{d}
T_7	0.72^{c}	439.00^{d}
T_8	0.81^{ab}	539.33^{ab}
T_9	0.72^{c}	502.00^{abcd}
SEm±	**0.02**	**27.61**
CD(P≤5%)	**0.06**	**82.80**

under T_4 was approximately 12.9% and 22.5% higher as compared to T_1 (Control) (43.54%) and T_9, respectively. Membrane integrity is a significant aspect of stress physiology in plants because environmental stresses may impair the membrane structure and hinder physiological processes. Kundu *et al*. (2025) have explored the function of arbuscular mycorrhizal fungi in dealing with salinity stress in chickpea, while Shahid *et al*. (2025) have analyzed the impact of zinc amendments and zinc solubilizing beneficial microorganisms in overcoming lead toxicity in chickpea. Both these studies have provided useful background regarding the role of beneficial biological agents in chickpea under stress conditions; however, their results cannot be compared directly to the MSI responses of the current study.

Relative Water Content

The relative water content (RWC) was highly significant among the various biofertilizer seed treatments at both 60 and 90 days after sowing (DAS). The range of RWC varied between 81.10 and 91.80% at 60 DAS. The highest RWC (91.80%) was obtained in treatment T_3 (Jawahar EM culture), followed by T_2 (Vitavax +



Plate 1 : Measuring of NDVI.



Plate 2 : Measuring of RI.

Jawahar *Rhizobium*) (91.20%) and T_6 (Jawahar *Azospirillum*) (90.49%). The various biofertilizer treatments were statistically similar but registered higher RWC compared to the control treatment (T_1) (81.10%). Treatment T_3 had higher RWC (13.2%) compared to the control. In terms of relative water content, T_8 (Jawahar *Rhizobium*) had the highest RWC (79.04%), followed by T_7 (Jawahar *Pseudomonas*) (77.57%) and T_2 (Vitavax + Jawahar *Rhizobium*) (77.04%) at 90 DAS. Treatment T_8 had an approximate 10.5% higher RWC compared to the control (71.51%). Nevertheless, treatment T_8 was statistically similar to treatments T_2, T_3, T_4, T_7 and T_9. The decrease in RWC from 60 to 90 DAS in all the treatments could be related to crop growth and environmental changes, though this needs to be proven by actual measurement. It can be noted that relatively higher RWC in treatments T_3 at 60 DAS and T_8 at 90 DAS shows the different response of the treatments to the growth stage of the crop. Bera *et al.* (2013) studied the impact of biofertilizer and homobrassinolide on RWC and yield of lentil, while Kundu *et al*. (2025) evaluated the impact of AM fungi on the mitigation of salinity stress in chickpea.

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