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Influence of Microbial Enriched Organic Manures with Inorganic Nutrients on the Physiological Attributes and Yield of Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was conducted to study the integrated use of microbial enriched organic manures with inorganic fertilizers on the physiological attributes of chickpea in the School of Agricultural Science, Karunya Institute of Technology and Sciences, Coimbatore, India. The experiment was laid out in Randomized Block Design (RBD) with three replications, during the late rabi season of 2023. The outcome of the study delineates the substantial efficacy of treatment T_5 (100% N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1}) and T_4 (100% N: P_2O_5: K_2O + Microbial enriched FYM @12.5 t ha^{-1}) in significantly augmenting the physiological growth and development of chickpea crop, resulting in an improved yield of 12.76 q ha^{-1} and 12.59 q ha^{-1} respectively.

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Keywords: *Chickpea; Microbial enriched FYM; Microbial enriched vermicompost; crop growth rate; leaf area index; chlorophyll index.*

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.), also known as Bengal gram or Chana, stands as the fourth most significant pulse crop globally, belonging to the family Fabaceae. Chickpea plays a crucial role in the human diets worldwide with its nutritional richness encompassing protein, carbohydrates, fats, vitamins, and minerals [1]. According to FAO reports from 2021, chickpeas are cultivated across 158.71 lakh hectares, with India leading as the largest producer followed by Australia and Ethiopia. India's contribution amounts to 86% of the global chickpea production, with Tamil Nadu alone cultivating the crop across 4065 hectares (DES 2022-23) [2]. Chickpea cultivation thrives under specific soil conditions, yet challenges persist in some regions. For instance, in Coimbatore district, the status of organic carbon in the soil remains notably low, often measuring less than 0.5% organic matter (OM). Additionally, pH levels tend to be slightly to moderately alkaline, ranging from 7.3 to 8.5 [3]. These soil conditions pose unique considerations for farmers and necessitate tailored nutrient management strategies to optimize chickpea growth and yield. Typically grown as a rainfed crop during the *rabi* season, chickpea exhibits resilience to adverse weather conditions and aids in restoring soil fertility through symbiotic nitrogen fixation, facilitated by Rhizobium bacteria [4]. The utilization of microbial biofertilizers such as Rhizobium and Phosphorus Solubilizing Bacteria (PSB) proves highly effective in enhancing the growth and yield of chickpea through effective absorption of nitrogen and phosphorus by the crop. Rhizobium inoculation has been shown to significantly improve nodulation, and plant development, resulting in a 10-12% increase in grain yield when compared to un-inoculated crops [4]. Additionally, the application of organic manure like vermicompost and FYM, enhances the soil physical properties, stimulates microbial growth, and eventually improves soil fertility, contributing to better crop growth. On the other hand, application of microbial enriched organic manures of vermicompost and FYM, have a higher nutrient content, especially nitrogen and phosphorus, through the processes like nitrogen fixation and phosphate solubilisation [5]. Hence the use of microbial enriched organic manures for crop cultivation serves as a valuable resource for improving agricultural productivity and sustainability. While organic manures have many benefits for soil health and plant growth, there are some disadvantages too like slow release of nutrients, lower amount of nutrients when compared to inorganic fertilizers and bulky in nature, posing challenges in transportation and storage, especially for farmers with limited resources or space.

Under the present intensive farming conditions, these factors restrict the growers in using organic manures as lonesome nutrient source and it paves way for an integrated approach of nutrient management. Thus integrated nutrient management (INM) is a comprehensive approach which aims in maintaining soil fertility and ensure optimal plant nutrient supply by the combined use of inorganic fertilizers along with organic manures and biofertilizers to achieve higher crop productivity in an economically viable and environmentally friendly manner. This practice of integrated approach, aims to maintain soil health, optimize crop yield, and mitigate environmental risks associated with intensive cropping [5]. Furthermore, this approach has the potential to increase the fertilizer use efficiency, ultimately boosting the agricultural productivity. In a way it is not just about combining different nutrient sources together for crop cultivation but also about understanding and managing the complex interactions between these sources, the soil, and the crop to optimize the nutrient use efficiency and promote sustainable agriculture. Considering the aforementioned context, the research aimed to explore how combining chemical fertilizers with microbial enriched organic manures, such as vermicompost and Farmyard Manure (FYM), affects the physiological characteristics of chickpea crop. It was theorized that such an integrated method would improve the nutrient utilization efficiency, leading to a better growth and development of the crop. Additionally, the study sought to determine the most effective mix of integrated nutrient management techniques for enduring and sustainable chickpea crop cultivation.

2. MATERIALS AND METHODS

The study was conducted in the instructional farm of the School of Agricultural Sciences, Karunya Institute of Technology and Science, Coimbatore. The experimental site is positioned approximately at 10°56 'N latitude and 76°44 'E longitude, with an altitude of 474 meters above sea level. This location was chosen to represent the North-western zone of Tamil Nadu (Fig. 1), offering an appropriate setting for cultivating the chosen crop. The monsoon season typically begins in late June and lasts through September. During the crop period, the total precipitation recorded was 326.6 mm. The average maximum temperature of the location was 31.12 ^{o}C, accompanied by an average minimum temperature of 23.56 ^{o}C. The mean maximum relative humidity was 78.35%, while the average minimum relative humidity was 53.49%.

A field experiment was conducted during Rabi 2023. The soil of the experimental field was silt clay loam in texture, low in organic carbon (0.42%), medium in available nitrogen (312.4 kg ha^{-1}), available phosphorus (15.7 kg ha^{-1}) and potassium (195 kg ha^{-1}). The soil was alkaline in reaction with a pH of 8.10. The experiment was laid out in a randomized block design with three replicates and nine treatments. The treatments are: T_1 - 100% Recommended N: P_2O_5: K_2O, T_2 - 100% Recommended N: P_2O_5: K_2O + FYM @12.5 t ha^{-1}, T_3 -100% Recommended N: P_2O_5: K_2O + Vermicompost @ 6 t ha^{-1}, T_4 -100% RDF + Microbial enriched FYM @12.5 t ha^{-1}, T_5 -100% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1}, T_6 - 75% Recommended N: P_2O_5: K_2O + Microbial enriched FYM @ 12.5 t ha^{-1}, T_7 -75% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1}, T_8 -50% Recommended N: P_2O_5: K_2O + Microbial enriched FYM @12.5 t ha^{-1}, T_9 -50% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1}. The certified seeds of chickpea variety NBeG-49 at seed rate of 90 kg ha^{-1} were used in the experiment. Ridges and furrow method of cultivation was taken up, where the ridges were formed at a distance of 30 cm. The seeds were sown manually by maintaining a plant to plant spacing of 10 cm, dibbling one seed at a depth of about 3 to 4 cm, at 1/3 distance from the top ridge. A minor gap filling of chickpeas were carried out at 5 days after sowing to maintain a full plant population. The fertilizers were applied as per the treatments. The microbial enrichment of farmyard manure (FYM) and vermicompost involved inoculating bio-inoculants, specifically *Bacillus megatherium var. phosphaticum* (PSB) and *Rhizobium leguminosarum* (Rhizobium), at a

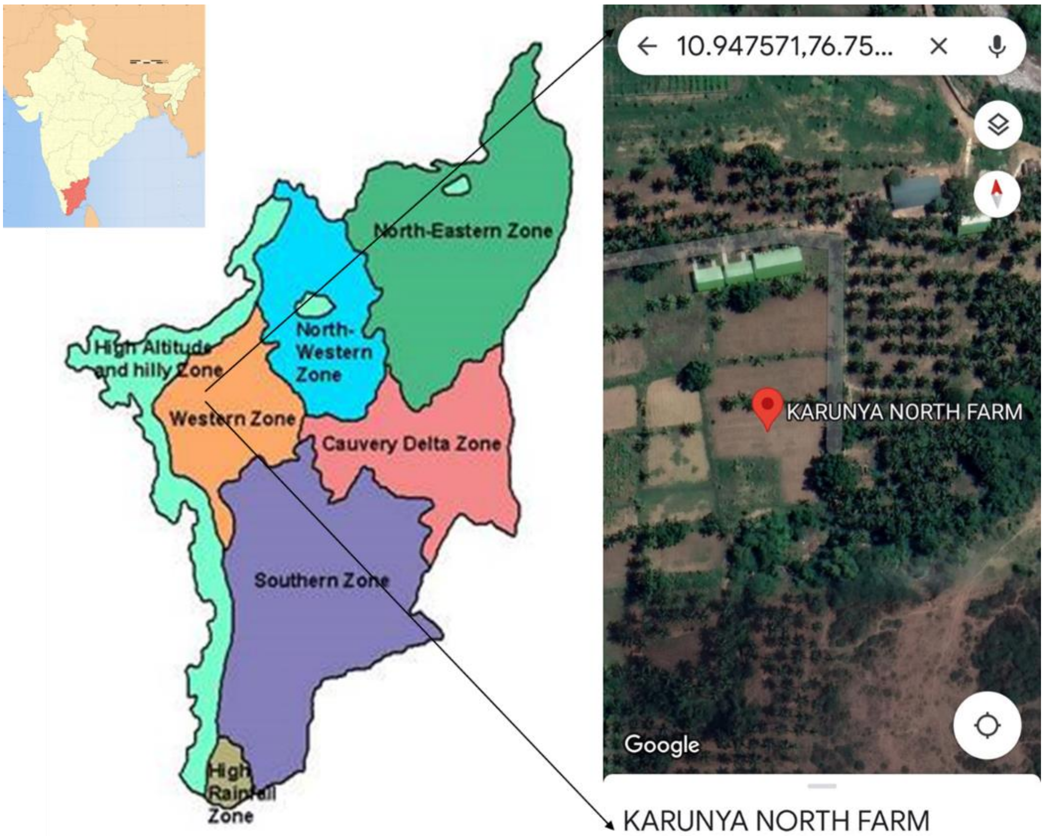

Fig. 1. Experimental Site Location during Rabi season of 2023-2024

ratio of 10 litres (5 litres of PSB + 5 litres of Rhizobium) per 50 kilograms of substrate. These microorganisms were then propagated on a large scale using conventional culture media such as Nutrient Agar (NA) for PSB and Yeast Extract Mannitol Agar (YEMA) for Rhizobium. The recommended dose of fertilizer followed for the study was 25 kg of nitrogen (N), 50 kg of phosphorus (P_2O_5), and 20 kg of potassium (K_2O) per hectare.

The data on physiological attributes were calculated by using formula given below,

(i) Leaf area index (LAI)

The LAI was worked out by using the following formula [6]:

$$LAI = \frac{\text{Leaf area}}{\text{Ground area } (m^2)}$$

Where,

Leaf area = L × B × N × K
L – Length of the leaf,
B – Breadth of the leaf,
N – Number of leaves,
K – Constant factor (0.75)

(ii) Chlorophyll index (SPAD)

The Soil Plant Analysis Development (SPAD) chlorophyll meter, was utilized for assessing the chlorophyll index of crops in the field, provides a straightforward and non-invasive means of estimating chlorophyll levels, especially in fields with standing crops. The measurement process involves placing the sample leaf into the device's measuring area, which is specifically designed to accurately measure small leaves measuring 2 × 3 mm, and then closing the measuring head.

(iii) Crop growth rate

The crop growth rate ($g^{-1}m^{-2}day$) for specified stage was calculated using the standard formula [7]:

$$CGR = \frac{W_2 - W_1}{p\,(t_2 - t_1)}$$

Where,

W_2 = Dry weight of crop plant at the time interval t_2
W_1 = Dry weight of crop plant at the time interval t_1
p = ground area occupied by the plant in m^2

The collected data were statistically analyzed according to the analysis of variance procedures appropriate for a randomized block design. Fisher's method of analysis of variance (ANOVA) was used to statistically analyse the experimental data acquired [8]. Critical Difference (CD) values were calculated wherever the ‘F’ test was found significant at 5 percent level.

3. RESULTS AND DISCUSSION

3.1 Leaf Area Index

The data on the mean leaf area index of chickpea recorded at 30 DAS, 45 DAS and 60 DAS are presented in Table 1 and Fig. 2. At 30 DAS, there were no significant differences in leaf area index among the treatments. The application of 100% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1} (T_5) registered a maximum leaf area index of 0.82 and 1.05 at 45 DAS, 60 DAS respectively. This was statistically on par with the 100% Recommended N: P_2O_5: K_2O + Microbial enriched FYM @12.5 t ha^{-1} (T_4). The treatments of 75% of recommended dose of N, P_2O_5 and K_2O with vermicompost and FYM were next in the order. The application of 100% Recommended N: P_2O_5: K_2O (T_1) recorded a lower leaf area index of 0.52, 0.71 at 45 DAS and 60 DAS respectively. The better performance of treatments T_5 and T_4 might be due to the synergistic combination of microbial enriched organic manures of vermicompost and FYM with the full recommended dose of inorganic nutrients, which might be likely responsible for the notable enhancement in Leaf Area Index (LAI), suggesting, better leaf development, and improved canopy growth. The results are in conformity with the findings of Tyagi and Singh (2019) and Dotaniya et al. (2022) where the authors have also reported that the combination of organic and inorganic nutrients have resulted in better LAI [9,5].

3.2 Chlorophyll Index

The data on the mean chlorophyll index of chickpea recorded at vegetative stage (30DAS), initial flowering stage (45DAS) and peak flowering stage (60) presented in Table 1 and Fig. 3. The application of 100% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1} (T_5) registered a maximum chlorophyll index of 45.27, 55.40, 66.30 at vegetative stage, initial flowering stage and peak flowering stage respectively. This was statistically on par with the

100% Recommended N: P_2O_5: K_2O + Microbial enriched FYM @12.5 t ha^{-1} (T_4). The treatments of 75% of recommended dose of N, P_2O_5 and K_2O with vermicompost and FYM were next in the order. The treatment with 100% recommended N: P_2O_5: K_2O (T_1) recorded a lower chlorophyll index of 17.20, 26.10, 29.20 at vegetative stage, initial flowering stage and peak flowering stage respectively. The higher chlorophyll index readings indicate higher nitrogen content in the crop. Thus applying microbial enriched organic manures of vermicompost and FYM with the full recommended dose of inorganic fertilizers results in efficient and timely supply of nitrogen to crop leading to a notable enhancement in chlorophyll content. The results corroborate with the findings of Tiwari et al. and Rawat et al. This improvement can also be attributed to the efficient rhizobium symbiosis in the chickpea crop as a result of full dose of inorganic nitrogen provided in the soil along with the microbial enriched organic manure [10,11].

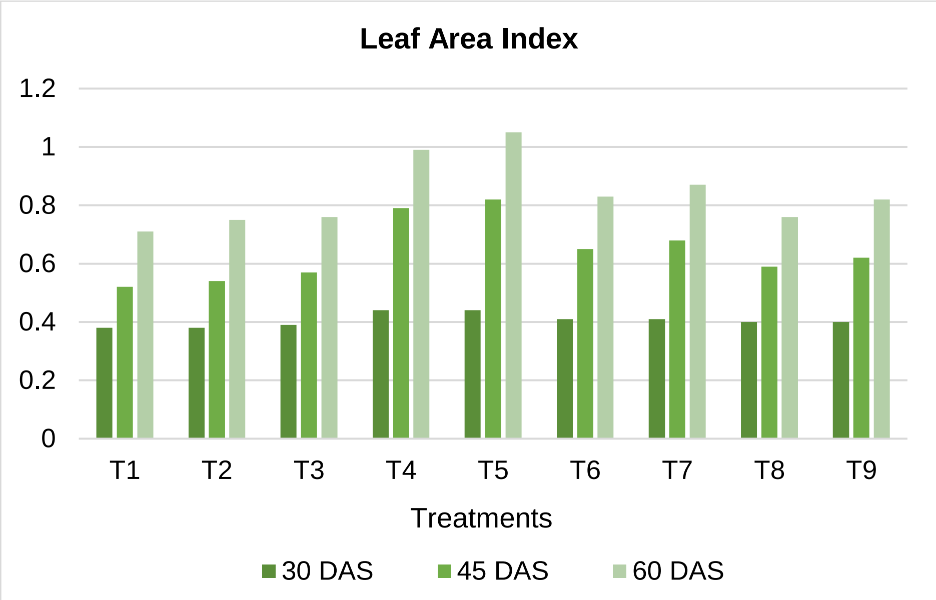

Fig. 2. Influence of microbial enriched organic manures on Leaf area index

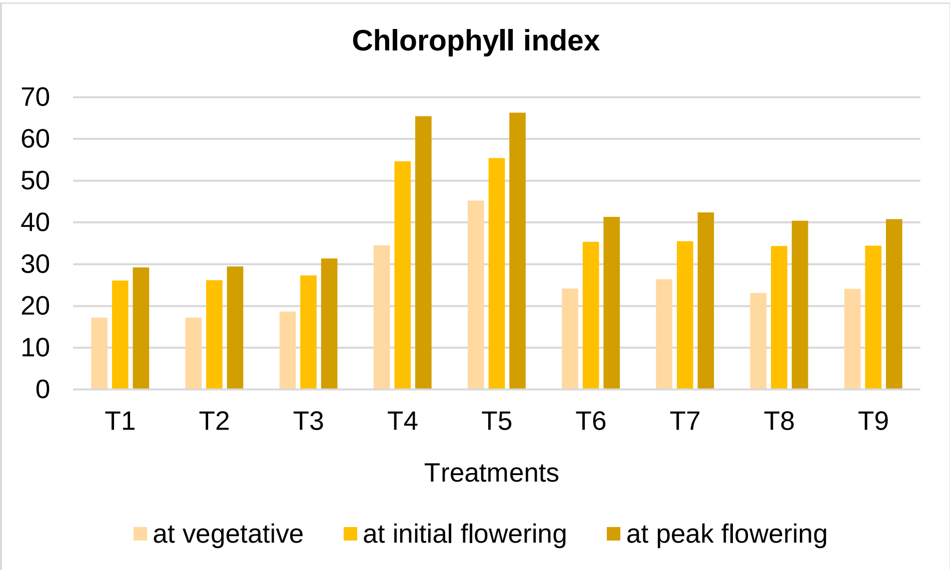

Fig. 3. Influence of microbial enriched organic manures on Chlorophyll index

Table 1. Influence of microbial enriched organic manures on physiological attributes of chickpea

Treatments	Leaf Area Index			Chlorophyll index			Crop Growth Rate			Yield (q ha^{-1})	
	30 DAS	45 DAS	60 DAS	at vegetative	at initial flowering	at peak flowering	30-45 DAS	45-60 DAS	60 DAS-harvest	Grain yield	Stover yield
T1	0.38	0.52	0.71	17.20	26.10	29.20	0.33	0.51	0.40	6.59	13.35
T2	0.38	0.54	0.75	17.20	26.20	29.50	0.38	0.52	0.42	6.67	13.54
T3	0.39	0.57	0.76	18.70	27.30	31.40	0.44	0.76	0.43	6.76	13.73
T4	0.44	0.79	0.99	34.50	54.70	65.50	0.83	1.76	0.98	12.59	24.98
T5	0.44	0.82	1.05	45.27	55.40	66.30	0.85	1.79	1.06	12.76	25.69
T6	0.41	0.65	0.83	24.20	35.40	41.30	0.57	1.19	0.65	8.72	18.83
T7	0.41	0.68	0.87	26.43	35.50	42.40	0.57	1.07	0.66	8.69	16.89
T8	0.40	0.59	0.76	23.10	34.40	40.43	0.54	1.11	0.58	8.39	16.28
T9	0.40	0.62	0.82	24.10	34.43	40.80	0.56	1.18	0.63	8.51	16.35
Mean	0.41	0.66	0.86	27.54	39.44	46.98	0.61	1.22	0.71	8.85	17.73
SE(d)	0.04	0.05	0.09	1.71	3.41	4.26	0.04	0.11	0.06	0.74	1.15
CD (p=0.05)	NS	0.11	0.18	3.54	7.07	8.84	0.09	0.23	0.12	1.59	2.47

T_1 - 100% Recommended N: P_2O_5: K_2O, T_2 -100% Recommended N: P_2O_5: K_2O + FYM @12.5 t ha^{-1}, T_3 -100% Recommended N: P_2O_5: K_2O + Vermicompost @ 6 t ha^{-1}, T_4 - 100% RDF + Microbial enriched FYM @12.5 t ha^{-1}, T_5 -100% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1}, T_6 - 75% Recommended N: P_2O_5: K_2O + Microbial enriched FYM @ 12.5 t ha^{-1}, T_7 -75% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1}, T_8 -50% Recommended N: P_2O_5: K_2O + Microbial enriched FYM @12.5 t ha^{-1}, T_9 -50% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1}

3.3 Crop Growth Rate

The data on the mean crop growth rate of chickpea recorded at 30 to 45 DAS, 45 to 60 DAS and 60 DAS to harvest stage of the chickpea crop are presented in Table 1 and Fig. 4. As a general trend, by observing the crop it is found that the crop growth rate was maximum during 45 to 60 DAS across all the treatments and it starts declining towards harvest, the application of 100% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1} (T_5) registered a maximum crop growth rate of 0.85, 1.79, 1.06 at 30 to 45 DAS, 45 to 60 DAS and 60 DAS to harvest stage respectively. This was statistically on par with the 100% Recommended N: P_2O_5: K_2O + Microbial enriched FYM @12.5 t ha^{-1} (T_4). The treatments of 75% of recommended dose of N, P_2O_5 and K_2O with vermicompost and FYM were next in the order. The sole application of 100% Recommended N: P_2O_5: K_2O (T_1) recorded a lower crop growth rate of 0.33, 0.51, 0.40 at 30 to 45 DAS, 45 to 60 DAS and 60 DAS to harvest stage respectively. This is because the crop growth rate is linearly related to the amount of nutrient applied and its absorption by the plant. Hence it can be inferred that by applying microbial enriched organic manures of vermicompost and FYM with the full recommended dose of, inorganic fertilizers ensured a balanced provision of all essential nutrients which could have enhanced the morphological and biochemical aspects of plant growth, resulting in improved physiological functions and a greater crop growth rate. The results corroborate with the findings of Tiwari *et al.* and Rawat et al., who have also reported that efficient supply of nutrients through integrated practices will correspondingly improve crop growth rates [10,11].

3.4 Crop Yield

The data on the crop yield of chickpea is presented in Table 1. The application of 100% Recommended N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1} (T_5) recorded the higher grain yield of 12.76 q ha^{-1} and stover yield of 25.69 q ha^{-1}. This was statistically on par with the 100% Recommended N: P_2O_5: K_2O + Microbial enriched FYM @12.5 t ha^{-1} (T4) and the application of 100% Recommended N: P_2O_5: K_2O (T_1) recorded the lower grain yield of 6.59 q ha^{-1} and stover yield of 13.35 q ha^{-1}. This improved yield could be attributed to the synergistic effects of inorganic and microbial-enriched organic additives, promoting nutrient balance and availability, possibly enhanced by the utilization of Rhizobium and PSB, thereby facilitating nitrogen fixation and phosphorus solubilization, ultimately enhancing the yield. The results corroborate with the findings of Tiwari et al. and Tripati et al. that the crop yield could be influenced by an improved nutrient balance and enhanced nutrient accessibility [10,12].

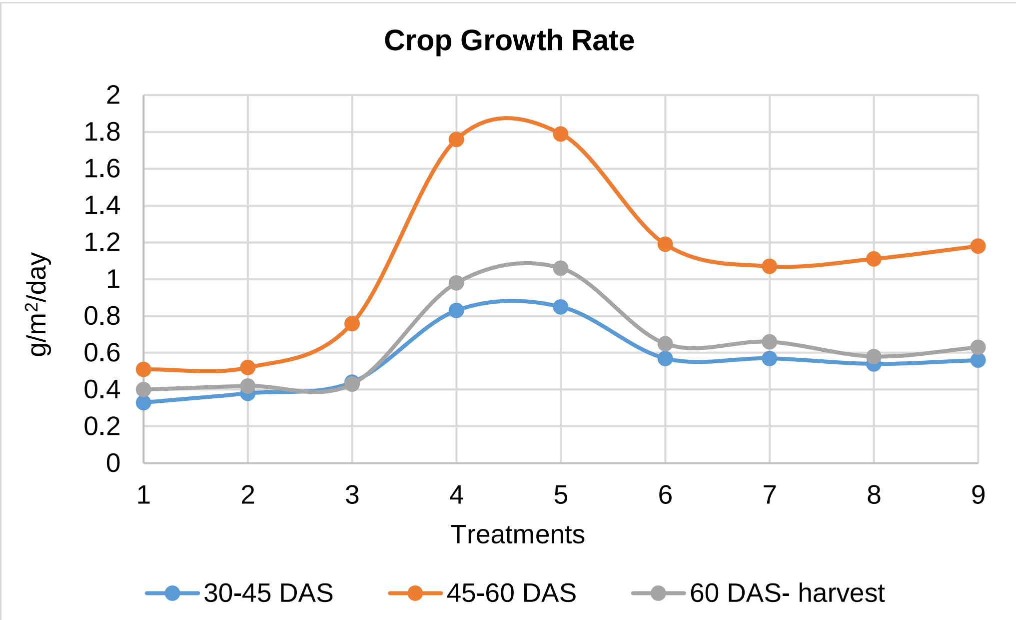

Fig. 4. Influence of microbial enriched organic manures on Crop growth rate

4. CONCLUSION

Based on the results of the experiment it can be concluded that the application of microbial enriched organic manures of vermicompost or FYM along with the full (100%) recommended dose of inorganic fertilizers provides a balanced mix of all essential nutrients for a better physiological growth and development of chickpea crop. On the other hand, reduced application of inorganic recommended dose of fertilizers by 25% with the inclusion of microbial enriched organic manures of vermicompost or FYM i.e., 75% N: P_2O_5: K_2O + Microbial enriched vermicompost @ 6 t ha^{-1} or 75% N: P_2O_5: K_2O + Microbial enriched FYM @ 12.5 t ha^{-1} stands second in order to influence a good physiological growth and yield of chickpea crop, rather than sole application of inorganic nutrients. Future long-term research studies can be taken up to assess the durability and adaptability of microbial enriched organic manures of vermicompost or FYM along with, inorganic fertilizers across various crop-weather conditions to establish more efficient strategies that are both economically viable and ecologically sound.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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