

Effect of customized fertilizer application on physiological aspects of chickpea (*Cicer arietinum* L.)

Abstract

It is predicted that India will require around 32 million tons of pulses to feed around 1.68 billion people by 2030. Therefore, improved technologies must be needed to increase production. An increase in physiological efficiency of crop is important to improve the productivity and production of crop. Hence, the experiment was carried out at Department of Plant Physiology, AB & MAP, College of Agriculture, IGKV, Raipur (Chhattisgarh) during *rabi* 2020-21. The experiment consists of five treatments with replicated four times in RBDS design and Indira chana 1 variety of chickpea used as a test crop. The study highlighted that the T₅ CFG 3 (NPKSZnMo) based on recommendation (125%) was found effective to minimize the phenophase like 50% flowering, physiological maturity significantly. Higher chlorophyll value was observed in T₅ CFG 3 (NPKSZnMo) based on recommendation (125%) and Maximum Fv/Fm (chlorophyll fluorescence) was observed in T₄ CFG 2 (NPKSZnMo) based on recommendation (75%). T₃ CFG 1 (NPKSZnMo) based on recommendation (100%) was also observed to effectively increase dry matter partitioning towards the economic sink and maximize crop growth rate, relative growth rate, economic (seed) yield, biological yield and harvesting index. Thus, it is proved that in comparison with the recommended doses of fertilizers application of CFGA has enhanced the plant yield.

Key words: Customized fertilizer, Recommended dose of fertilizer, Nutrient uptake, Chickpea

Introduction

The chickpea (*Cicer arietinum* L.) is a member of Fabaceae family, subfamily Faboideae. After beans and peas, chickpea is the world's third most important pulse crop. In 2019-20, the total production of chickpea in India was 11.08 million tons with yield 1142 Kg/ha and total area 9.68 million/ha (Anonymous AICRP report 2019-20). The total production of chickpea in Chhattisgarh was 88.19 thousand tones with total area 381.77 thousand ha and yield 231 Kg/ha. Chickpea (*Cicer arietinum* L.), like other pulse crops, is a major staple food in many poor countries, and chemical fertilizers are a critical input in chickpea farming. Pulse crops like chickpea must have phosphorus and sulfur for plant development, nodule formation, and nitrogen fixation. The physiological ability of plant like photosynthetic rate (Pn) and stomatal conductance (Gs) are improved by increase in fertilizer dose of plant which ultimately improves the economical yield of plant. Chickpea crop required all organic and inorganic nutrients in appropriate amount for the growth and development of chickpea. In general, farmers apply chemical fertilizers to

chickpea crop in an unbalanced and suboptimal dose because of lack of knowledge of the nutritional requirements to plant at specific area, variety and soil type. Customized fertilizer application is one of the most effective techniques to overcome this problem. Customized fertilizer is consisting of macro, secondary and/or micronutrient taken from both organic sources and inorganic sources. The Central Fertilizer Committee added customized fertilizers in the Fertilizer association of India, 1985 because it is innovative technology which made fertilizer area, soil, or crop-specific. Customized fertilizers are crop, soil, and area specific which maintains plant and soil health through suitable fertilization (Tiwari, 2010) [10]. In order to above facts the present investigation was done during *rabi* 2020-2021 on “Effect of customized fertilizer application on physiological aspects of chickpea (*Cicer arietinum* L.)” at AICRP Research Farm, IGKV, Raipur (C.G.) to find out best combination of customized fertilizer to improve performance of chickpea crop.

Material and method

The field experiment was performed during the *rabi* seasons of 2021-22 at the AICRP research Farm, IGKV, Raipur, Chhattisgarh. At the meteorological observatory, IGKV, Raipur, Chhattisgarh, weekly average meteorological data was recorded during the experimentation period. The total rainfall during experiment period was 29.84 mm with 9 rainy days was received during *rabi* season 2021 respectively. The maximum and minimum temperatures during experiment period was 40.4°C and 10.3°C with 9 rainy days during the *rabi* season, respectively. The soil at AICRP research farm was clayey (*Vertisols*), pH 7.2 which is neutral in nature, electrical conductivity (EC) 0.53 dS/m², being low in organic carbon (0.79%), Nitrogen (235 kg ha⁻¹), Phosphorus (11.33 kg ha⁻¹) and Potassium (383.8 kg ha⁻¹). The experimental trial was laid out in a randomized block design, four replications, to evaluate the effect of a customized fertilizer (CF) on desi chickpea (*Cicer arietinum* L.). The variety Indira chana 1 was used as test crop. The data was analyzed statistically by employing analysis of variance (ANOVA) for randomized block design. Field experiments consisted of five treatments and four replications. The treatments consist of five treatments which are furnished in table no.1.

Table 1 Treatments of experiment

T ₁	Recommended level of NPK, (N: P ₂ O ₅ : K ₂ O 20; 50; 20 kg ha ⁻¹)
T ₂	RDF 1 (Recommended level of NPKSZnMo 20:50:20:20:25:1kg ha ⁻¹)
T ₃	CFG 1 (NPKSZnMo 5.5:4.6:4.5:8.3:1.4:0.034 %)based on recommendation (100%) (100 kg ha ⁻¹)
T ₄	CFG 2 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034%) based on recommendation (75%) (75 kg ha ⁻¹)
T ₅	CFG 3 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034%) based on recommendation (125%) (125 kg ha ⁻¹)

The observation recorded physiological observation like chlorophyll value, chlorophyll florescence value, CGR (crop growth rate), RGR (relative growth rate), dry matter accumulation and yield to find out better

combination of customized fertilizer which response to plant growth and productivity of chickpea. The phenological traits were determined by visual observation. The chlorophyll value was taken by SPAD-502 meter by taking the mean of upper, middle, and lower leaf observations. Measurements with the SPAD-502 meter produce relative SPAD meter values that are proportional to the amount of chlorophyll present in the leaf. In order to convert these values into absolute units of chlorophyll concentration, calibration curves must be derived and utilized. Chlorophyll fluorescence analysis uses the Fv/Fm ratio as a sensitive indicator of plant photosynthetic performance. Lower values may indicate stress and/or photo-inhibition or indicate a downregulation of photosynthesis. The reading of chlorophyll fluorescence (Hansatech's Pocket PEA and Handy PEA) was taken at the 50% flowering stage, when most of the photosynthetic assimilates move toward the pod for their development and plant need more energy from photosynthesis. For dry matter accumulation traits, the sample was collected at different stages of the crop, like the vegetative stage, flowering stage, pod filling stage, and physiological maturity stage, and data was collected by taking the weight of different organs of the plant separately. The data of CGR ($\text{g m}^{-2} \text{ day}^{-1}$) and RGR ($\text{g}^{-1} \text{ plant}^{-1} \text{ day}^{-1}$) was taken by samples collected at different stages of crop and computed by using formula,

$$\text{Crop growth rate} = \frac{w_2 - w_1}{p(t_2 - t_1)}$$

Where, P = Ground area, W_1 = Dry weight of plant/ m^2 recorded at time t_1 , W_2 = Dry weight of plant/ m^2 recorded at time t_2 , t_1 and t_2 were the interval of time, respectively and it is expressed in $\text{g}/\text{m}^2/\text{day}$.

$$\text{Relative growth rate} = \frac{\ln w_2 - \ln w_1}{t_2 - t_1}$$

Where, In = Natural log, W_1 = Dry weight of plant/ m^2 recorded at time t_1 , W_2 = Dry weight of plant/ m^2 recorded at time t_2 , t_1 and t_2 were the interval of time, respectively and is expressed as $\text{g}/\text{g}/\text{day}$

The yield data was taken after harvesting and harvest index was calculated by formula,

$$\text{Harvest index} = \frac{\text{economic yeild}}{\text{Biological yeild}} \times 100$$

The collected data on numerous growth and yield factors was tabulated first, and then statistical analysis was performed (Gomez, K.A. and Gomez, A.A. (1984)[5]. The impact of different customized fertilizer treatments was tested with the F-test. The calculated "F" value is compared with the table F value at 5% LOS. If the calculated F value was greater than the table F value, then the difference was said to be significant and a critical difference was calculated for further comparison.

Result and discussion

The data of physiological attributes, dry matter accumulation, and phenological attributes was recorded at different growth stages of plant *i.e.*, (30DAS) vegetative stage, (60DAS) flowering stage, (90 DAS) podding stage and at harvest and reveal in table no. 2 and figure no. 1, 2, and 3 .

Physiological parameters

Dry matter accumulation

The dry matter accumulation at early stage of crops growth was slow and it increased at later stage of crop growth up to physiological maturity of crops in all the treatments. The superior treatment for dry matter accumulation was found T₄ CFG 2 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (75%) at vegetative stage. And at flowering stage, podding stage and at harvest T₅ CFG 3 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (125%) recorded significantly higher in dry matter accumulation which is on par with T₃ CFG 1 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (100%). Dry matter accumulation in chickpea showed significant variation among all treatments because customized fertilizer contains all micro and macronutrients which are essential mineral plant nutrient that critically contribute in the process of photosynthesis and transport of photo assimilate. Similar results were obtained by Dwivedi (2010) and Meshram's (2019)[3] research paper "Response of chickpea (*Cicer arietinum* L.) to customized fertilizer under Chhattisgarh condition".

Chlorophyll value

Higher chlorophyll values have been observed in (50.83) T₅ CFG 3 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (125%), which was equivalent to (50.45) T₃ CFG 1 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (100%) when compared for the control. The SPAD value was used to estimate the chlorophyll content of plant leaves. Namvar *et al.* (2013)[7] found that enhancing the concentration of nitrogen fertilizer in plants increased the chlorophyll content.

Chlorophyll fluorescence

The maximum Fv/Fm was observed in T₄ CFG 2 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (75%), while the minimum Fv/Fm was observed in T₁ RDF (recommended NPK level) (N: P₂O₅: K₂O 20:50:20 kg ha⁻¹). Chlorophyll fluorescence can be used to determine the maximum quantum efficiency of photosystem II. Fv/Fm is a normalized ratio calculated by dividing variable

fluorescence (minimum fluorescence) by maximum fluorescence. Generally, the recorded range of 0.79 to 0.84 approximates the optimal value for many plant species, with lower values indicating stress. The experimental value of 0.77 or lower might be due to observation at the flowering stage and lower irrigation.

Phenological parameters

According to analysis of variance there is no variation was observed significantly in various treatments of customized fertilizer combination. There was no significant variation seen in days required to germination and 50% flowering in RDF and in all combinations of customized fertilizer. The desired minimum days required to germination was observed in T₃ CFG 1 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (100%) (13.50 days) and T₁ RDF (recommended level of NPK) (N: P₂O₅: K₂O 20:50:20 kg ha⁻¹) (13.50 days). Least period required to 50% flowering was observed in T₃ CFG 1 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (100%). The additional doses of nitrogen extend the vegetative growth phase which results conversion of reproductive stage to flowering stage delayed (Rehman and Dunfu(2018)[8]. High dose of fertilizers had topmost number of days to flowering and days to maturity.

Yield parameters

The parameters of seed yield, stover yield and harvest index was furnished in table no. 1 and figure no. 3, respectively.

Seed yield

Maximum seed yield was observed in T₃ CFG 1 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (100%) (1764.6 kg ha⁻¹) which was similar with T₅ CFG 3 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (125%) (1744.5 kg ha⁻¹) and minimum seed yield T₁ RDF (recommended level of NPK) (N: P₂O₅: K₂O 20:50:20 kg ha⁻¹) (1465.85 kg ha⁻¹). Sekhon *et al.* (2012)[9] observed that different concentrations of customized fertilizer boosted wheat seed production considerably. This was because the crop not experiences any nutrient stress at any growth phase because of balanced nutrition and also enhanced vegetative development as well as growth parameters like number of branches and total dry matter production increased, which resulted in a good grain yield. Kavalappa (1989)[6] reported comparable findings.

Stover yield

The highest stover yield obtained in T₃ CFG 1 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034%) based on recommendation (100%) (2749.1 kg ha⁻¹) is on par with (2744.50 kg ha⁻¹) T₅ CFG 3 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034 %) based on recommendation (125%) as compared to other treatments. The best possible yield and biomass have been obtained through the effective use of NPK, S, and Zn. Increases in vegetative growth, such as plant height, dry matter production, straw yield, and branch count, could be the cause of the biomass increase.

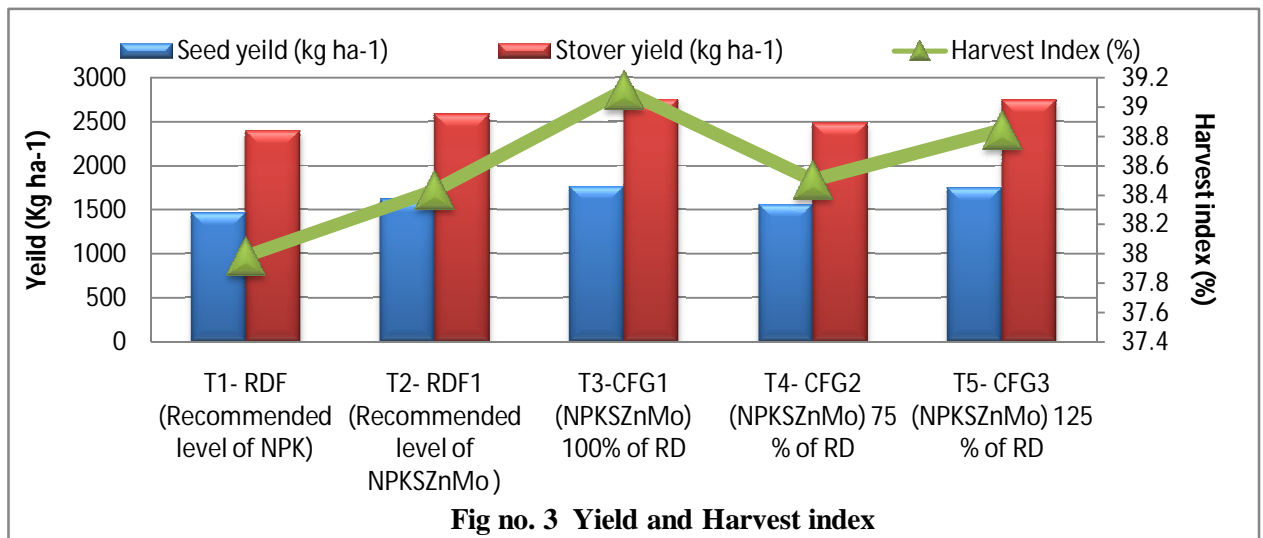
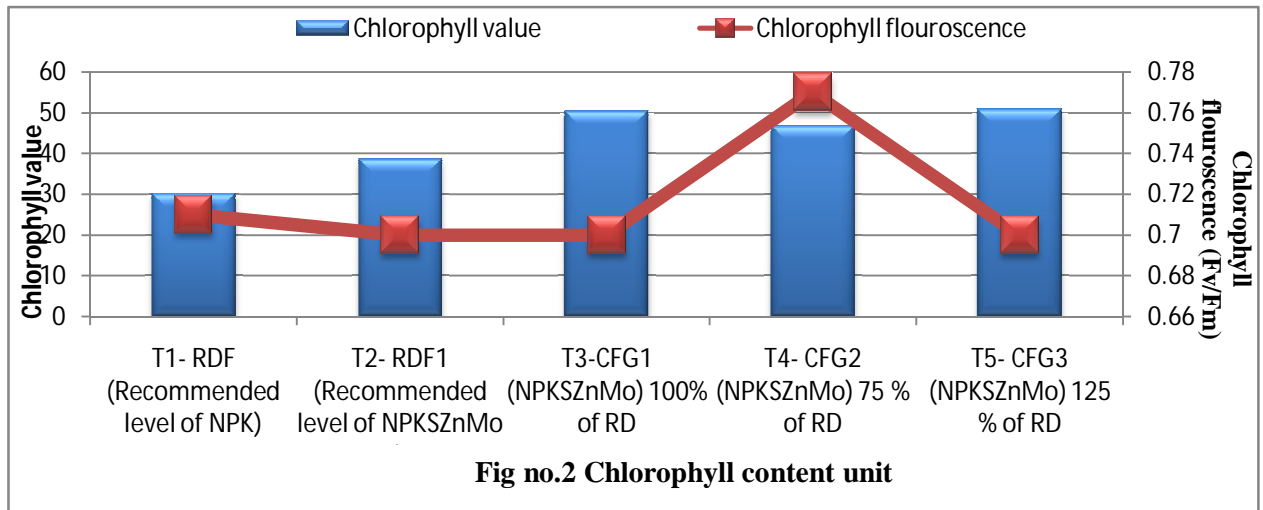
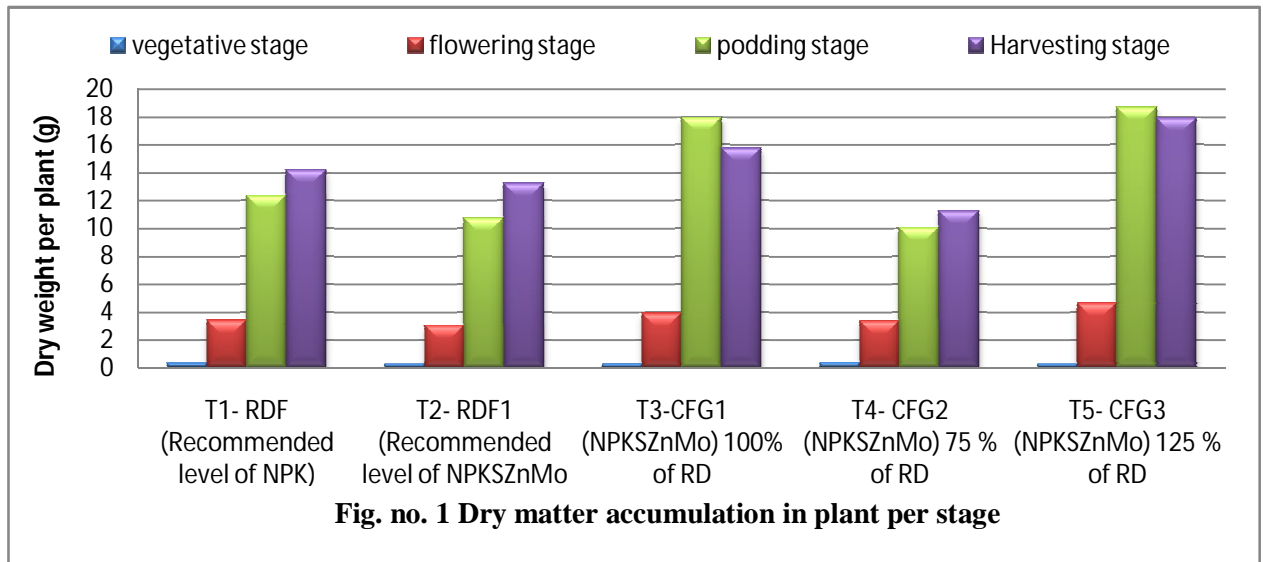
Harvest index

Harvest index is significant parameter for calculating the yield performance *via*. obtaining biological and economic yield. The maximum harvest index was obtained in T₃ CFG 1 (NPKSZnMo) based on recommendation (100%) (39.11%) and minimum results obtained in (37.98%) T₁ RDF 1 (Recommended level of NPKSZnMo) (N: P₂O₅: K₂O 20:50:20 kg ha⁻¹). This results are accordance with Dwivedi *et al.* (2019)[2].

Table 2 Effect of customized fertilizer application on physiological attributes, dry matter accumulation and yield

T	Dry matter accumulation				C(nmol/cm ²)	FV/FM	DTG	DTF (50%)	SY	STY	HI (%)
	V	F	P	H							
T ₁	0.34	3.39	12.34	14.18	30.19	0.71	13.50	57.00	1465.85	2394.21	37.98
T ₂	0.26	3.03	10.74	13.21	38.63	0.70	14.50	57.50	1612.86	2584.64	38.43
T ₃	0.28	3.90	17.95	15.75	50.45	0.700	13.50	56.25	1764.59	2749.11	39.11
T ₄	0.37	3.35	10.04	11.23	46.73	0.77	14.25	56.75	1555.05	2484.40	38.50
T ₅	0.27	4.63	18.69	17.90	50.83	0.70	14.50	57.25	1744.92	2744.50	38.84
M	0.30	3.66	13.95	14.46	43.36	0.71	14.05	56.95	1628.62	2591.37	38.04
C.D. (5%)	0.09	1.00	4.26	3.59	5.36	0.15	2.61	3.61	180.62	277.12	0.68
SE (m)±	0.03	0.32	1.38	1.16	1.74	0.05	0.84	1.17	58.62	89.93	0.22

T- Treatments, V- Vegetative stage, F-Flowering stage, P-Podding stage, H- Harrvesting, C- Chlorophyll contentnmol/cm², FV/FM value- Chlorophyll florescence, DTG- Days to germination, DTF- Days to 50% flowering, SY- Seed yield, STY- Stover yield, HI- Harvest index



Growth analysis parameters

The data on growth analysis *i.e.*, RGR, CGR and AGR were derived by using whole plant weight at 0-30 DAS (Vegetative stage), 30-60 DAS (flowering stage), 60-90 DAS (Podding stage) and 90-at harvest. It was found that these traits were affected by different combination of customized fertilizer and furnished in table no. 3 and figure no. 4 and 5.

Crop growth rate ($\text{g}^{-1} \text{m}^{-2} \text{day}^{-1}$)

The CGRs data reveals that non-significant variation observed at 0-30 DAS and 90 DAS-harvest but significant variation was observed in 30-60 and 60-90 DAS, respectively. The highest CGR rate was observed in 60-90 DAS after that it slowed down. T_5 CFG 3 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034%) based on recommendation (125%) was observed to be most effective in improving crop growth rate in between vegetative to reproductive phase *i.e.*, 30-60, 60-90 and 90-harvest.

CGR is most important analysis to check rate of photosynthesis, rate of respiration and canopy area interaction (Alam, Haider, 2005) [1]. From lower value, CGR reach at certain peak and later decline in last stage of growth of crop (Gupta and Gupta 2005) [4]. Crop growth rate is the amount of biomass gained by a crop over a period of time. At the start of the crop, the CGR was slow. At 60-90 DAS, the maximum CGR was recorded, followed by a decreasing trend at 90 DAS- harvesting at the harvest stage of crops, whereas at 0-30 DAS CGR was less then start increasing at 30-60. This suggests that the vegetative stage of the crop takes longer to collect dry matter as well as to translocate biomass from source to sink's than the reproductive stage.

Relative growth rate ($\text{g}^{-1} \text{plant}^{-1} \text{day}^{-1}$)

(RGR) Relative growth rate was observed significantly highest at 30-60 DAS. The RGR increased in T_3 CFG 1 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034%) based on recommendation (100%) ($0.00792 \text{ g plant}^{-1} \text{ day}^{-1}$) was at par T_5 CFG 3 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034%) based on recommendation (125%) ($0.003106 \text{ g plant}^{-1} \text{ day}^{-1}$) as compared to other treatments, whereas, at 90-harvesting days RGR was higher in T_3 CFG 1 (NPKSZnMo5.5:4.6:4.5:8.3:1.4:0.034%) based on recommendation (100%) (0.02493) as compared to T_1 RDF (Recommended level of NPK) (N: P_2O_5 : K_2O 20:50:20 kg ha^{-1}). The increase in RGR was registered rise in the levels of nitrogen and phosphorus.

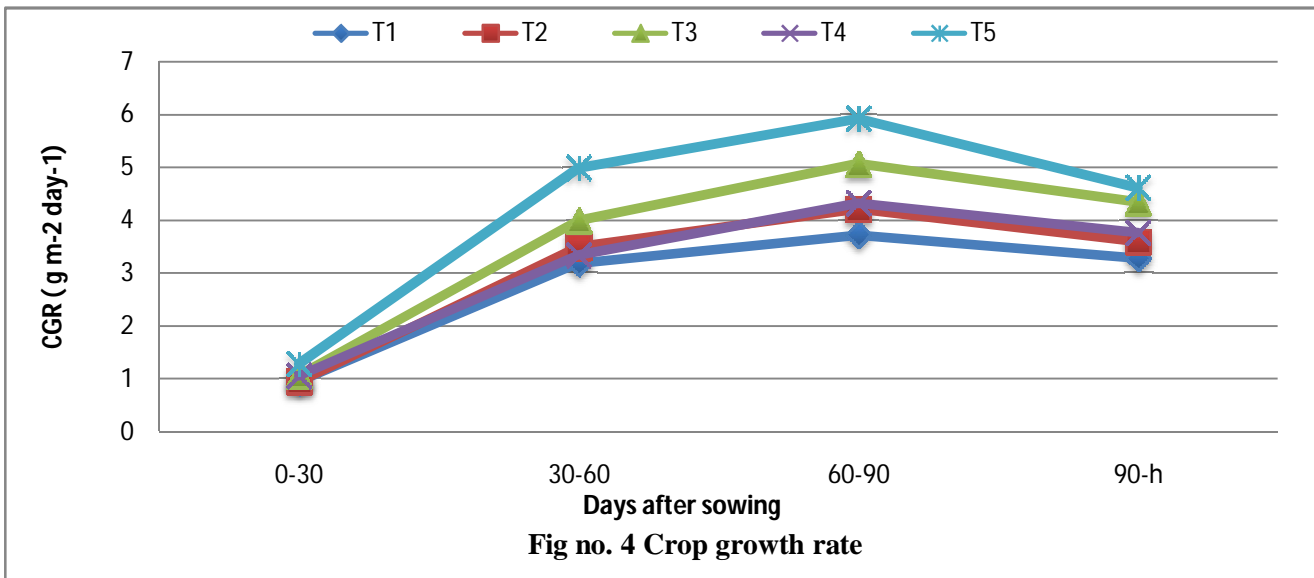
RGR was high in the initial phase of the crop's growth and gradually declined when it grew older. This could be because the ratio between alive and dead tissues is high in the early stages of plant growth, and almost entire cells of productive organs are active in vegetative matter production, resulting in a high RGR of plants, However, as plants get older, their tissues' metabolic process of cell

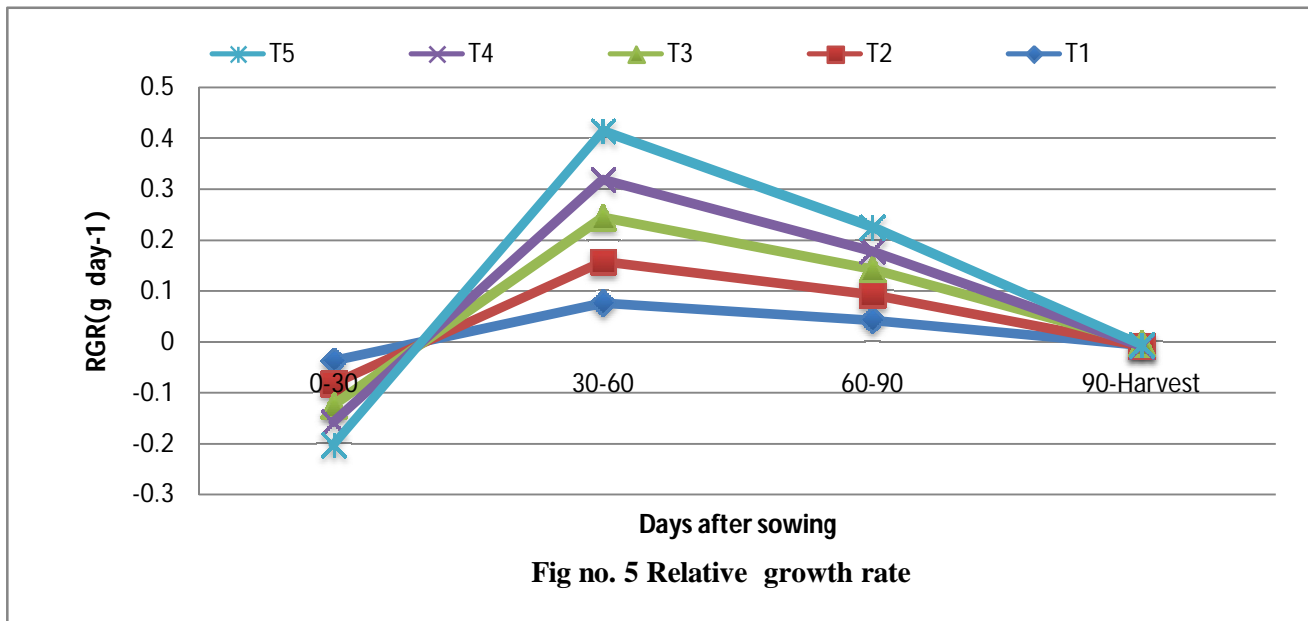
progressively reduced and they are unable to support the growth that leads to a drop in RGR (Zajac *et al.* 2005; Alam, Haider, 2006; Kibe *et al.* 2006) [1][11]. Likewise, according to Yasari and Patwardhan (2006) [10], a lower NAR could lead to a lower RGR in the future.

Table no.3 Effect of customized fertilizer application on Crop growth rate and Relative growth rate of crop

T	0-30 DAS	30-60 DAS	60-90 DAS	90-at harvest	0-30 DAS	30-60 DAS	60-90 DAS	90-at harvest
	Crop growth rate (CGR)				Relative growth rate (RGR)			
T ₁	0.9450	3.1880	3.7250	3.2830	0.01003	0.10598	0.26085	0.16688
T ₂	0.9530	3.4980	4.2130	3.6000	0.00858	0.05540	0.31508	0.14720
T ₃	1.0745	4.0000	5.0700	4.3530	0.01045	0.10944	0.46905	0.20000
T ₄	1.0630	3.3430	4.3280	3.7700	0.01208	0.09929	0.31606	0.19170
T ₅	1.2900	4.9950	5.9250	4.6180	0.00850	0.14520	0.53130	0.20100
M	1.0652	3.8048	4.6522	3.9248	0.00990	0.10300	0.37840	0.18100
C.D. (5%)	N/A	1.2520	1.3580	N/A	0.00200	0.02930	0.11700	0.05500
SE (m)±	0.1000	0.4020	0.4360	0.4130	0.00100	0.01340	0.05410	0.02500

T- Treatments, DAS- Days after sowing





Conclusion

The customized fertilizer application was most effective to improving the physiological efficiency of crop to improve the yield of chickpea. The customized fertilizer contain mixture of different micro and macronutrients with recommended dose which was efficient towards performance to dry matter partitioning and transport assimilates to source and sink to achieve maximum economic (seed) yield. It is reveal that the physiological trends such as chlorophyll unit, chlorophyll florescence, dry matter accumulation, growth analysis parameters such as CGR and RGR was found to be most effective in treatment T₅ CFG 3 (NPKSZnMo) based on recommendation (125%) but T₃ CFG 1 (NPKSZnMo) based on recommendation (100%) found to be most effective for production and efficient partitioning, this treatment is beneficial economically as compare to T₅ CFG 3 (NPKSZnMo) based on recommendation (125%) and other treatments.

Author contributions

Arti Manohar Ambhore: Conducted research trial, Observations, Data collection, collect reviews, Data analysis, Interpretation of results, Draft manuscript preparation, study conception and design.

Vaibhav Baburao Jadhav: Writing, editing and reviewed manuscript

Rajendra Ramesh Lipane: Writing, editing and reviewed manuscript

Dr. Pratibha Katiyar: critically reviewed the manuscript and served as scientific advisor.

Dr. G. P. Banjara: Contributed data or analysis tools, designing experiments, edited the manuscript, served as scientific advisor.

Dr. Dharmendra Khokhar: critically reviewed the manuscript.

Dr. Ravi. R. Saxena: Reviewed the analyzed data.

All authors reviewed the results and approved the final version of the manuscript

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Reference

1. Alam, M.Z. and Haider, S.A. 2006. Growth attributes of barley (*Hordeum vulgare* L.) cultivars in relation to different doses of nitrogen fertilizer. *Journal of Life and Earth Sciences.*, Vol. 1(2): 77-82.
2. Dwivedi S.K., Chitale S., Lakpale R. 2019. Response of chickpea (*Cicer arietinum*) to customized fertilizer under Chhattisgarh condition. *Indian Journal of Agronomy.* 64(1): 103-106.
3. Dwivedi, S. K. and Meshram, M. R. 2014. Effect of customized fertilizer on productivity and nutrient uptake of rice (*Oryza sativa*). *Indian J. Agron.* 59(2), 247–250. 59.
4. Gupta N. K., Gupta S. (2005). *Plant Physiology*. Oxford and IBH Publishing, pp. 580.
5. Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*, Second Edition, John Wiley and Sons, New York, p. 680.
6. Kavalappa, B.N. 1989. Intensive manuring and cropping programme on soil properties, crop yield, nutrient uptake and nutritive quality of finger millet in an alfisol of Bangalore. M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Bangalore.
7. Namvar A., Raouf seyed sharifi, khandan T. and Majid J. M. 2013. Seed Inoculation and Inorganic Nitrogen Fertilization Effects on Some Physiological and Agronomical Traits of Chickpea (*Cicer arietinum* L.) in Irrigated Condition. *Journal of Central European Agriculture*, 14(3), p.28-40

8. Rahman, K.A. and Zhang, D., 2018. Effects of fertilizer broadcasting on the excessive use of inorganic fertilizers and environmental sustainability. *Sustainability*, 10(3), p.759.
9. Sekhon, B.S., Kaur S. and Singh P. 2012. Evaluation of a customized fertilizer on wheat. *Indian J. Ecol.*, 39(1), 71–75.
10. Yasari, E., Patwardhan, A.M. 2006. Physiological analysis of the growth and development of Canola (*Brassica napus* L.) under different chemical fertilizers application. *Asian Journal of Plant Sciences*. ISSN: 1812-569.
11. Zajac, T., Grzesiak, S., Kulig, B. and Polacek, M. 2005. The estimation of productivity and yield of linseed (*Linum usitatissimum* L.) using the growth analysis. *Acta Physiologiae Plantarum*. Vol. 27(4A): 549-558.
12. Choudhary D, Rundla S, Jadhav R, Naga IR, Kumawat K, Sharma PK. Role of Biofertilizers in Chickpea: A Review. *Int. J. Environ. Clim. Change*. [Internet]. 2023 Sep. 8 [cited 2024 May 24];13(10):2590-5. Available from: <https://journalijecc.com/index.php/IJECC/article/view/2925>
13. Thakur R, Bisen NK, Shrivastava AK, Rai SK, Sarvade S. Effect of Integrated Nutrient Management on Chickpea Productivity and Soil Fertility Status under Rice – Chickpea Cropping System at Farmers Field of Balaghat District of Madhya Pradesh, India. *J. Exp. Agric. Int.* [Internet]. 2023 Dec. 30 [cited 2024 May 24];45(12):250-6. Available from: <https://journaljeai.com/index.php/JEAI/article/view/2285>
14. Lusiba S, Odhiambo J, Ogola J. Growth, yield and water use efficiency of chickpea (*Cicer arietinum*): response to biochar and phosphorus fertilizer application. *Archives of Agronomy and Soil Science*. 2018 May 12;64(6):819-33.