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Effect of integrated nutrient management on yield and yield attributes of chickpea (*Cicer arietinum* L.)

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Abstract : TA field experiment was conducted to investigate the effect of Integrated Nutrient Management on Chickpea (Cicer arietinum L.) at the Instructional Farm, Rajasthan College of Agriculture, Udaipur, during the Rabi season of 2021-22. The experiment consisted of 12 treatments involving different combinations of nutrient management practices, including one control, to evaluate the effect of integrated nutrient management (INM) in chickpea based on soil analysis. The experiment was laid out in a randomised block design with three replications. The soil at the experimental site was clay loam in texture, slightly alkaline in reaction (pH 8.19), medium in available nitrogen (238.23 kg ha^{-1}) and phosphorus (17.20 kg ha^{-1}), and high in potassium (376.12 kg ha^{-1}) with a sufficient amount of DTPA extractable micronutrients. Among the treatments, the application of 75% recommended dose of fertilizers (RDF) combined with poultry manure (2.5 t ha^{-1}), phosphate-solubilising bacteria (PSB), and *Rhizobium* inoculation (T9) significantly enhanced plant height, dry matter accumulation, grain yield (1985 kg ha^{-1}), and haulm yield (2607.57 kg ha^{-1}) compared to the control. This treatment recorded a yield increase of 43.32% in grain and 41.66% in haulm over the control and was statistically at par with treatments T7 (75% RDF + vermicompost 3 t ha^{-1} + PSB + *Rhizobium*) and T8 (75% RDF + FYM 6 t ha^{-1} + PSB + *Rhizobium*). These findings highlight the potential of INM strategies in enhancing chickpea productivity and sustaining soil health.

Keywords: *Integrated Nutrient Management, chickpea, randomised block design, phosphate-solubilising bacteria, rhizobium*

Introduction

Pulse crops have a specific importance for the vegetarian population of our country because pulses are the major source of protein. Pulses are an important component in sustaining agricultural production, as pulse crops possess wide adaptability to fit into various cropping systems, improve soil fertility and physical health, and make the soil more porous due to their taproot systems (Verma, 2016). India is the largest producer and consumer of pulses. Gram (chickpea) is occupying the third position among the grain legumes in the world. Among the pulses, gram occupies a predominant position and is considered the "King of pulses". It originated in southeastern Turkey. Chickpeas are grown in 54 countries, with nearly 90 per cent of their area covered in developing countries. India is the largest producer of chickpea, which contributes 64.47% of the total chickpea production in the world. The area covered by chickpea is 11.97 million hectares, and production is 9.53 million tonnes. The total food grain production was approximately 329.68 million tonnes in 2022-23, out of which only 27.81 million tonnes were contributed by pulses (DAC& FW, 2023). It contains, on average, 22 per cent protein, 4.5 per cent fat, 63 per cent carbohydrate, 8.0 per cent crude fibre and 2.5 per cent

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ash. Yield and yield components analysis provides a framework for identifying potentially useful traits for yield improvement (Kobre *et al.,* 2010).

Chemical fertilisers have become increasingly expensive, making effective nutrient management vital not only for enhancing current agricultural yields but also for maintaining sustainable production and safeguarding the environment from risks associated with improper fertilizer use. The integrated application of chemical fertilizers with organic sources has been shown to improve the availability and uptake of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) in crops like chickpea (Deshpande *et al*., 2015). Organic manure is an excellent source of nutrients for the growth and development of microorganisms.

FYM improved the physical, chemical, and biological properties of the soil, along with increasing the availability of nutrients, and contains both macro- and micro-nutrients. Farmyard manure appears to increase crop yields directly, either by accelerating the respiratory process, enhancing cell permeability, and stimulating hormonal growth, or by a combination of these activities. It provides plant-availablenitrogen, phosphorus, potassium, and micronutrients such as Fe, S, Mo, and Zn to plants through biological decomposition. It increases the soil's physico-chemical characteristics and health. It includes 0.50, 0.17, and 0.55 per cent N, P, and K, respectively, on average (Gaur, 1991).

Vermicompost is a biologically stabilised organic material produced through the aerobic decomposition of organic matter, facilitated by the enzymatic activity within the gut of earthworms and the associated microbial community. It significantly improves the physicochemical properties of soil and enhances microbial activity, thereby promoting crop growth and yield. Vermicompost typically contains 0.80–1.10% nitrogen, 0.40–0.80% phosphorus (as P_2O_5), and 0.80–0.98% potassium. Additionally, it is rich in micronutrients, including copper (10–52 ppm), zinc (186.60 ppm), and iron (930.00 ppm). It also contains natural plant growth regulators such as auxins (e.g., NAA), cytokinins, and gibberellins, which further contribute to plant development.(Vasanthi& Kumaraswamy, 1999; Giraddi *et al*., 2006).Vasanthi and Subramanian (2004) observed that the highest concentrations of crude protein, N, P, and K, as well as uptake, were recorded with the application of vermicompost at 2 tons ha^{-1}, along with 100% of the recommended levels of N, P, and K.

Bio-fertilizers like Rhizobium belong to the family Rhizobiaceae, which are symbiotic in nature and fix nitrogen at 50-100 kg ha^{-1} in association with legumes only. It is useful for pulse legumes, such as chickpea, red gram, pea, lentil, and black gram, as well as oil-seed legumes like soybean and groundnut, and forage legumes like berseem and lucerne. *Rhizobium, Azotobacter* and *Azospirillum*, which in turn improve the nitrogen (N) as well as phosphorus (P) supply and other micronutrients (Zn, Fe, Cu, Mn), besides imparting resistance to plants against various soil-borne diseases and insect pest attacks.

Poultry manure is another important source of nutrients which plays a direct role in plant growth. Besides major nutrients, poultry manure also contains traces of micronutrients, which are generally not supplied by the commercial fertilisers but are essential for plant growth. It is well-documented that poultry manure is an excellent source of organic matter, which enhances the nutrient uptake of plants.

In a nutshell, chickpeas are a major pulse crop in India, valued for their high protein content and soil-enriching properties. However, declining soil fertility and imbalanced fertiliser use have led to stagnation in productivity. Integrated Nutrient Management (INM), which combines organic and inorganic nutrient sources, offers a sustainable approach to enhance crop yield while improving soil health. Review of literature suggests that this study is essential to evaluate the effectiveness of INM practices in optimising nutrient availability, improving yield attributes, and ensuring long-term agricultural sustainability in chickpea cultivation.

Materials and Methods

Experimental site and soil

The experiment was conducted at the Instructional Farm, Block B-2, Rajasthan College of Agriculture, Udaipur, located at 24° 35' North latitude and 74° 42' East longitude, at an altitude of 579.5 meters above mean sea level. It falls under agroclimatic zone IV-a, "Sub-Humid Southern Plain and Aravali Hills" of Rajasthan. Primary soil samples were collected from various locations within the experimental field to a depth of 30 cm prior to experimentation, and a composite soil sample was prepared. This was subjected to mechanical, physical, and chemical analysis to determine the physicochemical properties of the experimental soil. The data show that the soil of the experimental field was clay-loam in texture, slightly alkaline in reaction (pH 8.19), low in available nitrogen (238.23 kg ha^{-1}), and medium in phosphorus (17.20 kg ha^{-1}), while it had a high available potassium status (376.12 kg ha^{-1}).

Experimental design and treatments

The experiment was conducted during the 2020–21 rabi season using a randomised block design (RBD) with three replications. The randomized block design contain 12 treatments which includes control, Recommended dose of fertilizer (20:40:0), 100 % RDF + Vermicompost, 100% RDF + FYM, 100% RDF + Poultry manure, 100 % RDF + *Rhizobium* + PSB, 75 % RDF + Vermicompost + *Rhizobium* + PSB, 75 % RDF + FYM + *Rhizobium* + PSB, 75 % RD + Poultry manure + *Rhizobium* + PSB, 50% RDF + Vermicompost + *Rhizobium* + PSB, 50% RDF+ FYM + *Rhizobium* + PSB and 50% RDF + Poultry manure + *Rhizobium* + PSB. The chickpea var. GNG-2144 was sown in lines 30 cm apart.

Observations

The yield observations were recorded according to standard procedures. The seed yield, straw yield and biological yield were recorded from the net plot area of each treatment.

Statistical analysis

The data recorded for different parameters were analysed using the analysis of variance (ANOVA) technique for a randomised block design. The data obtained from the various characters under study were analysed using the method of analysis of variance, as described by Panse and Sukhatme (1985).The results are presented at a 5% level of significance (P = 0.05).

Results and Discussion

Effect of integrated nutrient management on yield attributes of chickpea

Number of pods per plant

The data presented in Table 1 showed that integrated nutrient management of the chickpea crop resulted in a significant effect on the number of pods per plant. The treatment of 75% RDF with Poultry manure + 2.5 t $ha^{-1,}$ *Rhizobium* and PSB (T_9) produced maximum number of pods per plant (79.27) while control (T_1) resulted in the minimum number of pods per plant (51.67). Furthermore, the treatments of 75% RDF + Vermicompost 3 t ha^{-1} + *Rhizobium* + PSB (T_7), 75% RDF + FYM 6 t ha^{-1}+ *Rhizobium* + PSB (T_8) and 100 % RDF + Poultry manure 2.5 t ha^{-1} (T_5) were remained statistically at par. Data revealed that the number of pods $plant^{-1}$ increased by 53.41, 47.49, 42.77 and 37.93 per cent in T_9, T_7, T_8 and T_5 over control T_1, respectively

Number of grains per pod

It is evident from data, Table 1 showed that the integrated nutrient management of chickpea recorded a significant increase in number of grains pod^{-1}. The treatment of 75% RDF with Poultry manure + 2.5 t ha^{-1}, *Rhizobium* and PSB (T_9) produced maximum number of pods $plant^{-1}$ (2.23) while control (T_1) resulted in the minimum number of pods $plant^{-1}$ (1.32) of chickpea crop at harvest stage. Furthermore, the treatments of 75% RDF + Vermicompost, 3 t ha^{-1} + *Rhizobium* + PSB (T_7), and 75% RDF + FYM, 6 t ha^{-1} + *Rhizobium*+ PSB (T_8) were remained statistically at par. Data revealed that the number of grain pod^{-1} increased by 76.51, 59.09 and 50.75 per cent in T_9, T_7 and T_8 over control T_1, respectively.

Table 1: Effect of Integrated nutrient management on yield attributes of chickpea

Treatments	Yield attributes		
	Number of seed pods^{-1}	Number of pods plant^{-1}	100seed weight (gm)
T_1 : Control	1.32	51.67	17.20
T_2 : RDF	1.34	58.43	18.10
T_3 :100% RDF + Vermicompost 3 t ha^{-1}	1.61	70.80	19.70
T_4 :100% RDF +FYM 6 t ha^{-1}	1.51	67.45	19.10
T_5 :100% RDF + Poultry manure 2.5 t ha^{-1}	1.68	71.27	20.50
T_6 :100% RDF +*Rhizobium* + PSB	1.45	64.63	19.10
T_7 :75% RDF + Vermicompost 3t ha^{-1} + *Rhizobium* + PSB	2.10	76.21	21.91
T_8 :75% RDF + FYM 6 t ha^{-1} + *Rhizobium* + PSB	1.99	73.77	21.80
T_9 : 75% RDF + Poultry manure 2.5 t ha^{-1} + *Rhizobium* + PSB	2.23	79.27	22.73
T_{10} :50% RDF + Vermicompost 3 t ha^{-1} + *Rhizobium* + PSB	1.39	61.23	18.60
T_{11}: 50% RDF + FYM 6 t ha^{-1} +*Rhizobium* + PSB	1.38	60.67	18.10
T_{12} : 50% RDF + Poultry manure 2.5 t ha^{-1} +*Rhizobium* + PSB	1.43	63.03	18.80
SEm±	0.83	2.756	0.440
CD (at 5%)	0.24	8.083	1.29

Weight of 100 grains (g)

The integrated nutrient management resulted in a significant increase in the weight of 100 grains (g) compared to the control (Table 1). The highest weight of 100 grain (g) was found to be 22.73 g with the treatment of 75% RDF with Poultry manure + 2.5 t ha^{-1}, *Rhizobium* and PSB (T_9)which is significantly higher than T_1 (control). Furthermore, the treatments of T_7 (75% RDF + Vermicompost 3 t ha^{-1} + Rhizobium + PSB) and T_8 (75% RDF + FYM 6 t ha^{-1} + Rhizobium + PSB) were statistically at par with T_9, indicating comparable effectiveness. The weight of 100 grains increased by 32.15,27.38 and 26.74 per cent in the treatments of T_9, T_7 and T_8 over control T_1, respectively. Organic matter also serves as a source of energy for soil microflora, which facilitates the transformation of inorganic nutrients held in the soil or applied in the form of fertilisers into a form that is readily utilised by growing plants. The beneficial effects of vermicompost addition are also related to improvement in soil physical properties (Kofoed, 1987). The beneficial response of vermicompost to yield attributes and yield might also be attributed to the availability of sufficient amounts of readily utilisable forms of plant nutrients throughout the growth period and especially at critical growth periods of the crop, resulting in better uptake, plant vigour and superior yield attributes (Brar & Pasricha, 1998).These findings corroborate the results of several other workers, including Ghanshyam et al. (2010), Singh et al. (2010), Singh et al. (2008), Ramawtar et al. (2013), and Singh et al. (2015), in chickpea.

Effect of integrated nutrient management on chickpea yield

Grain yield

The integrated nutrient management of the chickpea crop resulted in a significant effect on grain yield (Table 2).75 % RDF with Poultry manure+ 2.5 t ha$^{-1,}$ *Rhizobium* and PSB (T_9) produced maximum grain yield ($^{(}$1985 kg ha^{-1}) while control (T_1) resulted in the minimum grain yield (1385 kg ha^{-1}). Furthermore, the treatments 75% RDF + Poultry manure 2.5 t ha^{-1}+ *Rhizobium*+ PSB (T9), 75%RDF+ Vermicompost 3 t ha^{-1} + *Rhizobium*+ PSB (T_7), 75% RDF+ FYM 6 t ha^{-1}+ *Rhizobium*+ PSB (T_8) and 100%RDF + Poultry manure 2.5 t ha^{-1} (T_5) were remained statistically at par. Data revealed that the grain yield increased by 43.32, 37.83, 33.71, and 25.92 per cent in the treatments of T_9, T_7, T_8, and T_5, respectively, over the control T_1. The higher increase in these attributes and yields has been reported to be associated with there lease of macro and micro nutrients during the course of microbialde composition (Singh & Ram, 1992). This enhancement was mainly due to rendering the insoluble Phosphorusin to an available form. The enhanced availability of Phosphorus was favoured by increased uptake of Phosphorus and Nitrogen, which ultimately enhanced photosynthesis and consequently led to better growth parameters. The PSB is also known to produce vitamins, *viz*., indole acetic acid and gibberellin-like substances. The inoculation recorded higher yield attributes, which subsequently resulted in a higher yield. Similar statements have also been made by Thenua et al. (2010), Kumar et al. (2014), Gautam et al. (2017), Prajapati et al. (2017) and Kumawat et al.(2020).

Table 2: Effect of Integrated nutrient management on yield of chickpea

Treatments	**Grain yield (kg ha^{-1})**	**Haulm yield (kg ha^{-1})**	**Biological yield (kg ha^{-1})**
T_1 : Control	1385.00	1840.61	3225.62
T_2 : RDF	1392.00	1849.56	3241.56
T_3 :100% RDF + Vermicompost 3 t ha^{-1}	1686.00	2225.29	3911.29
T_4 :100% RDF +FYM 6 t ha^{-1}	1604.00	2120.49	3724.49
T_5 :100% RDF + Poultry manure 2.5 t ha^{-1}	1744.00	2299.41	4043.41
T_6 :100% RDF +*Rhizobium* + PSB	1526.00	2020.81	3546.81
T_7 :75% RDF + Vermicompost 3t ha^{-1} + *Rhizobium* + PSB	1909.00	2510.29	4419.29
T_8 :75% RDF + FYM 6 t ha^{-1} + *Rhizobium* + PSB	1852.00	2437.44	4289.44
T_9 : 75% RDF + Poultry manure 2.5 t ha^{-1} + *Rhizobium* + PSB	1985.00	2607.57	4592.57
T_{10} :50% RDF + Vermicompost 3 t ha^{-1} + *Rhizobium* + PSB	1489.00	1973.52	3462.52
T_{11}: 50% RDF + FYM 6 t ha^{-1} +*Rhizobium* + PSB	1432.00	1900.68	3332.68
T_{12}: 50% RDF + Poultry manure 2.5 t ha^{-1} +*Rhizobium* + PSB	1515.00	2006.75	3521.75
SEm±	88.179	125.646	199.422
CD (at 5%)	258.621	368.508	584.885

Haulm yield

The results indicate that the integrated nutrient management of the chickpea crop resulted in a significant effect on haulm yield. The treatment of 75% RDF + Poultry manure+ 2.5 t ha^{-1} + *Rhizobium* + PSB (T_9) produced maximum straw yield of 2607.57 kg ha^{-1}, while control (T_1) resulted the minimum straw yield of 1840.61 kg ha^{-1} . Furthermore, the treatments of 75% RDF + Vermicompost 3 t ha^{-1} + *Rhizobium* + PSB (T_7), 75% RDF + FYM 6 t ha^{-1} + *Rhizobium* + PSB (T_8) and 100% RDF + Poultry manure 2.5 t ha^{-1} (T_5) were remained statistically at par. Data revealed that the straw yield increased by 41.66, 36.38, 32.42, and 24.32 per cent in the treatments of in T_9, T_7, T_8, and T_5, respectively, over the control T_1.

Biological yield

It is evident from Table 2 that the integrated nutrient management of the chickpea crop had a significant effect on biological yield. The treatment of 75% RDF + Poultry manure + 2.5 t ha^{-1} + *Rhizobium* + PSB (T_9) produced maximum biological yield of 4592.57 kg ha^{-1}, while control (T_1) resulted in the minimum biological yield of 3225.62 kg ha^{-1}. Furthermore, the treatments of 75% RDF + Vermicompost 3 t ha^{-1} + *Rhizobium*+ PSB (T_7), 75% RDF + FYM 6 t ha-1 + *Rhizobium* + PSB (T_8) and 100% RDF + Poultry manure 2.5 t ha-1 (T_5) were remained statistically at par. Data revealed that the biological yield increased by 42.37, 37.0, 32.98, and 25.35 per cent in the treatments of T_9, T_7, T_8, and T_5, respectively, over the control T_1. The reasons for the distinct response to poultry manure over the rest of the organic materials may be explained partially by circumstantial evidence that poultry manure has a high status of available nutrients and an optimum C: N ratio and may contain hormones and has an enhanced level of enzymes (Tan *et al.,* 1971; Yadav and Jha, 1988). Another possible reason could be ascribed to the favourable effect on soil properties due to the formation of more humus colloidal complex coupled with higher nutrient content of poultry manure as compared to FYM, vermicompost, and it contributes directly to the nutrient pool of the soil (Singh and Abrol, 1987 and Babu *et al.,* 2007). The gradual release and steady supply of nutrients from poultry manure throughout the growth and development of plants maintained photosynthetic efficiency and metabolite production at a higher level. Later, the translocation of photosynthates to various sinks resulted in higher seed and stover yields. Similar findings were also reported by Devidayal and Agrawal (1999), Ranva and Singh (1999), Nehra and Grewal (2001), Pir *eta l.* (2005) and Laxminarayana and Patiram (2006).

Conclusions

The results of the present study clearly indicate that the application of 75% recommended dose of fertiliser (RDF) in combination with poultry manure (2.5 t ha^{-1}), Rhizobium, and phosphate-solubilising bacteria (PSB) significantly enhanced the yield-attributing traits of chickpea. This treatment resulted in a notable increase in the number of seeds per pod (2.23), the number of pods per plant (79.27), and 100-seed weight (22.73 g), with improvements of 76.51, 53.41, and 32.15 per cent, respectively, compared to the control. Furthermore, the same treatment significantly increased the grain yield (1985 kg ha^{-1}), haulm yield (2607.57 kg ha^{-1}), and biological yield (4592.57 kg ha^{-1}) by 43.32, 41.66, and 42.37 per cent, respectively, compared to the control. However, the effect on the harvest index was found to be non-significant. These findings suggest that integrated nutrient management involving reduced chemical fertiliser input supplemented with organic and biofertilizers can sustainably enhance chickpea productivity under field conditions.

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