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Assessment of Plant Growth and Productivity of Kabuli Chickpea Crop as Influenced by Organic, Inorganic Inputs and Biofertilizer Application under a Partially Reclaimed Sodic Soil

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ABSTRACT

Background: Kabuli chickpea or white chickpea has lower area and productivity compared to black chickpea types, especially in India which is the leading producer of chickpea across the globe. Sodic soils, common in regions like Uttar Pradesh, pose challenges to chickpea cultivation due to poor soil conditions and nutrient imbalances. Integrated use of organic, inorganic and biofertilizer inputs offers a promising approach to improving growth and yield of Kabuli chickpea in such degraded soils.

Methods: Field experiments were conducted during the *Rabi* seasons of 2023-24 and 2024-25 at the Agronomy Research Farm ANDUAT, Ayodhya, on the Kabuli chickpea crop. The experiment was laid out in a Randomized Block Design (RBD) with three replications and twelve treatment combinations. This investigation studied the growth and productivity of Kabuli chickpea as influenced by organic inputs, inorganic inputs and biofertilizers (Rhizobium and PSB).

Result: The integration of 50% recommended dose of fertilizers (RDP) with organic sources like FYM and vermicompost, in combination with Jeevamrit and biofertilizers (50% RDP + 25% P through FYM + 25% P through Vermicompost + Jeevamrit @ 500 L ha^{-1} +Biofertilizer) (T_{11}), significantly enhanced the growth attributes, yield attributes and yield of Kabuli chickpea.

Key words: Biofertilizers, Kabuli chickpea, Organic manure, Sodic soil, Sustainable agriculture.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a major pulse crop cultivated and consumed worldwide. Ranking third among pulses after beans and peas, chickpea is highly valued for its rich nutritional profile, offering easily digestible protein (21.10%), carbohydrates (61.50%) and fats (4.50%) (Anonymous, 2017). It is increasingly used as a plant-based protein alternative to animal sources. Chickpea is consumed in several forms, including whole grains, chickpea lentils soup (dal), sprouted seeds, green seeds and mature dry seeds and is a key ingredient in a variety of snacks, sweets and condiments. Based on seed characteristics like size, shape and color, chickpea is classified into Kabuli chickpea (also known as white chickpea or Garbanzo beans) and black chickpea (Bengal gram), both of which are cultivated globally. However, the area under cultivation, production and productivity of Kabuli chickpea are generally lower than black chickpea.

India is the world's leading chickpea producer, contributing over 75% to global production. The country grows chickpeas across 107.40 lakh hectares, producing 135.44 lakh tonnes, with an average yield of 1,261 kg ha^{-1} followed by countries like Australia, Turkey, Ethiopia and Russia are significant producers, with Ethiopia recording the highest productivity at 2,170 kg ha^{-1}, followed by Australia at 1,725 kg ha^{-1} (FAO Stat, 2022). In Uttar Pradesh, chickpea cultivation holds an important place in the agricultural sector, covering an area of 577 thousand hectares and producing 475.4 thousand tonnes with an average yield of 824 kg ha^{-1}. The state ranks fifth in chickpea production in India, following Madhya Pradesh, Rajasthan, Maharashtra and Andhra Pradesh. The crop is important for its nutritional richness, being a good source of protein, fiber and essential minerals. To boost productivity and sustainability, farmers

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in Uttar Pradesh are increasingly adopting organic farming practices and integrated nutrient management techniques (Rajbhar *et al.,* 2018).

Sodic soils, identified by their high exchangeable sodium percentage (ESP), negatively affect soil physical and chemical properties, leading to poor soil structure, reduced permeability, nutrient imbalances and diminished microbial activity. These adverse conditions hinder seed germination, root growth and nutrient absorption, ultimately reducing crop yields (Qadir *et al.,* 2006). Although physical and chemical soil amendments have been used to reclaim sodic soils, full reclamation remains a slow and costly process. Therefore, managing crop production in partially reclaimed sodic soils continues to be a major challenge (Minhas and Sharma, 2006).

Recently, the combined use of organic manures, biofertilizers and chemical fertilizers has garnered attention as a strategy to improve soil health, enhance nutrient use efficiency and support better crop performance, especially in degraded soils (Kumar *et al.,* 2014). Organic amendments such as farmyard manure (FYM) and vermicompost not only supply essential nutrients but also improve soil structure, increase microbial activity and enhance the soil's buffering capacity, helping to counteract the harmful effects of sodicity (Rengel and Damon, 2008). Meanwhile, inorganic fertilizers provide immediate nutrient availability and when carefully integrated with organic sources, they promote consistent plant growth and higher yields.

The current study focuses on investigating the combined effects of various organic and inorganic nutrient sources on the growth, yield and physiological performance of Kabuli chickpea cultivated in partially reclaimed sodic soils. The outcomes are expected to support the development of sustainable nutrient management practices for Kabuli chickpea production under sodic soil conditions.

MATERIALS AND METHODS

Experimental site, climate and initial soil properties

Field experiments were carried out during the Rabi seasons of 2023-24 and 2024-25 at the Agronomy Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Ayodhya, located in a sodicity affected area. The soil at the experimental site was moderately sodic, sandy loam in texture, with a pH of 8.20, an electrical conductivity (EC) of 0.334 dSm^{-1}, organic carbon content of 0.32%, low available nitrogen (137.65 kg ha^{-1}) and phosphorus (12.5 kg ha^{-1}) and medium potassium availability (215 kg ha^{-1}). The experimental site is situated in the subtropical Indo-Gangetic plains, the site features alluv*ia*l soils and lies between 24.4^o to 26.5^o N latitude and 82.12^o to 83.98^o E longitude, at an elevation of approximately 113 meters above mean sea level. The region experiences a tropical to subtropical climate with relatively stable seasonal temperature variations, where January records the lowest average temperatures and June the highest.

Experimental details

The experiment was set up in randomized block design (RBD) with 12 treatments under three replications. Treatments included a "Control" treatment (T_1); a treatment containing Recommended dose of fertilizers (RDF) @100% (T_2) comprising of N: P: K @ 20:40:20 kg ha^{-1} provided in the form of urea, DAP and MOP respectively; treatment T_3 comprised of 75% of the recommended dose of phosphorous (RDP) through DAP + 25% P through FYM; T_4 comprised of 75% RDP + 25% P through FYM + Jeevamrit @ 500 L ha^{-1}; T_5 comprised of 75% RDP + 25% P through FYM + Jeevamrit @ 500 L ha^{-1} + Biofertilizer (Rhizobium and PSB) applied through seed treatment @ 10 ml of 10^8 cfu of inoculum used to coat one kg of seeds; T_6 comprised of 75% RDP + 25% P through Vermicompost; T_7 contained 75 % RDP + 25% P through Vermicompost + Jeevamrit @ 500 L ha^{-1}; treatment T_8 comprised of 75% RDP + 25% P through Vermicompost + Jeevamrit @ 500 L ha^{-1} + Biofertilizer (Rhizobium and PSB) applied as above; T_9 contained 50% RDP + 25% P through FYM + 25% P through Vermicompost; treatment T_{10} comprised of 50% RDP + 25% P through FYM + 25% P through Vermicompost + Jeevamrit @ 500 L ha^{-1}; T_{11} comprised of 50% RDP + 25% P through FYM + 25% P through Vermicompost + Jeevamrit @ 500 L ha^{-1} + Biofertilizer (Rhizobium and PSB) applied as above; whereas T_{12} comprised of 50% P through FYM + 50% P through Vermicompost + Jeevamrit @ 500 L ha^{-1} + Biofertilizer (Rhizobium and PSB) applied as above. The chickpea variety, 'Pusa-3022', used in this experiment, is an extra-large seeded, high-yielding variety, released in 2016 for cultivation in the northwestern plains of India. It also exhibits resistance to *fusarium* wilt and Ascochyta blight. Soil amendments were applied at sowing time. Irrigation and weeding were carried out uniformly across all plots. The organic manures viz., Vermicompost, Farm yard manure, Jeevamrit and biofertilizers *viz.*, Rhizobium, PSB and chemical fertilizer *viz*, Urea, SSP and MOP were used among different treatments applied under the present investigation. The nutrient composition and quantity of these soil amendments is given in Table 1 and 2.

The observations on growth parameters were recorded at different stages of the plant growth. For recording various parameters 5 plants at random from net plot area were selected and tagged in each plot for taking observations on plant height. The yield attributing parameters like the number of primary and secondary branches ($plant^{-1}$) were recorded at 30 and 60 DAS respectively, while number of pods ($plant^{-1}$), dry matter accumulation of plant, hundred seed weight and yield (Grain, Stover and Biological yield) per hectare were recorded at harvest stage. The data collected from the experiment were subjected to statistical testing by following the 'Analysis of Variance Technique' as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant height

The pooled analysis showed a progressive increase in plant height at successive stages of crop growth. The differences among treatments were non-significant at 30 DAS but became significant from 60 DAS onwards (Table 3). The treatment T_{11} (100% RDF + Vermicompost @ 2 t ha^{-1} + PSB + Rhizobium) recorded the maximum plant height at all growth stages (13.25 cm at 30 DAS, 28.83 cm at 60 DAS, 52.84 cm at 90 DAS and 67.92 cm at harvest), which was at par with T_{10} and T_{12}. The minimum plant height was observed in the control (T_1). The increase in plant height under T could be attributed to the synergistic effect of inorganic fertilizers, organic manures and biofertilizers, which enhanced nutrient availability and stimulated vegetative growth. Similar findings were reported by Choudhary *et al*. (2017) and Kumar *et al.* (2020).

Yield attributes and yield-

Number of branches

Significant variations were observed in the number of primary and secondary branches due to nutrient management practices (Table 4). T_{11} recorded the highest number of primary (8.52) and secondary branches (15.74), whereas the lowest was observed under T_1 (control). The greater number of branches might be due to better nutrient uptake and enhanced meristematic activity induced by integrated nutrient application (Sharma *et al.,* 2018; Verma *et al.,* 2018).

Dry matter accumulation

The data indicated a significant influence of treatments on dry matter accumulation. Maximum dry matter (27.18 g plant^{-1}) was obtained in T_{11} which was at par with T_{10} (26.24 g plant^{-1}) and T_{12} (26.15 g plant^{-1}), while T_1 recorded the minimum (18.65 g plant^{-1}) (Table 4). Improved dry matter accumulation might be due to higher photosynthetic efficiency and nutrient assimilation under integrated nutrient management, corroborating the findings of Patel *et al*. (2020).

Number of pods per plant

The number of pods per plant was significantly influenced by treatments. T_{11} registered the highest number of pods (83.22 plant^{-1}), at par with T_{10} (80.05 plant^{-1}), while the lowest number (46.32 plant-1) was recorded under control (T_1) (Table 4). The better pod formation under T_{11} may be attributed to an increased number of branches and better flowering synchronization, as also reported by Kumar and Kushwaha (2020).

Seed index

Seed index did not show significant variation among the treatments. However, numerically higher seed index was observed in T_{11} (35.36 g), whereas the lowest was recorded in T_1 (31.01 g) (Table 4). These results are in agreement with the findings of Singh *et al.* (2021), who also reported minor influence of integrated nutrient management on seed weight.

Grain yield

Grain yield was significantly influenced by nutrient management practices. The highest grain yield was recorded under T_{11} (28.92 q ha^{-1}), at par with T_{10} (28.25 q ha^{-1}) and T12 (28.08 q ha^{-1}). The lowest yield was noted under T_1 (17.13 q ha^{-1}) (Table 5). The increase in yield could be attributed to better plant growth, highest number of pods and higher dry matter production. These results are in conformity with those reported by Yadav *et al.* (2021) and Choudhary *et al.* (2017).

Stover yield and biological yield

Significant differences were also observed in stover and biological yields. T_{11} produced the maximum biological yield (77.36 q ha^{-1}), followed by T10 (73.87 q ha^{-1}) and T_{12} (72.94 q ha^{-1}), while the lowest was observed in T_1 (Table 5). Enhanced stover and biological yields in integrated treatments may be due to better vegetative growth, which was in accordance with the findings of Verma *et al.* (2018). Harvest index was not significantly affected by treatments. However, numerically higher harvest index was recorded under T_2 (39.52%), followed by T_6 (39.03%). Similar observations

Table 1: Nutrient composition of Farm Yard Manure (FYM), Vermicompost, Jeevamrit used as organic inputs during 2023-24 to 2024-25.

Particular	N (%)		P (%)		K (%)	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
Farm yard manure	0.57	0.52	0.26	0.27	0.53	0.55
Vermicompost	2.18	2.21	1.31	1.24	1.73	1.81
Jeevamrit	1.23	1.18	0.173	0.186	0.238	0.252

Table 2: Quantity of FYM, vermicompost and jeevamrit as per P dose requirement during 2023-24 to 2024-25.

Particular	25% recommended Phosphorus		50% recommended Phosphorus	
	2023-24	2024-25	2023-24	2024-25
Farm yard manure (t ha^{-1})	3.84	3.70	7.69	7.40
Vermicompost (t ha^{-1})	0.763	0.806	1.52	1.61
Jeevamrit	@ 500 liter per hectare			
Biofertilizer	Rhizobium and PSB @ 10 ml per 1 kg of seed treatment.			

Table 3: Plant height (cm) at different stages as influence by organic, inorganic inputs and biofertilizer (Pooled data of 2023-24 to 2024-25).

Treatments	Plant height (cm)											
	30 DAS			60 DAS			90 DAS			At harvest		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	11.43	11.61	11.52	20.10	20.46	20.28	39.89	40.30	40.10	48.67	49.33	49.00
T_2	11.97	12.21	12.09	24.56	24.93	24.74	46.47	46.89	46.68	57.20	57.89	57.54
T_3	12.05	12.29	12.17	25.49	25.87	25.68	47.03	47.45	47.24	58.36	59.06	58.71
T_4	12.23	12.47	12.35	25.80	26.19	25.99	47.81	48.24	48.03	59.82	60.53	60.18
T_5	12.69	12.94	12.82	26.55	26.95	26.75	50.30	50.75	50.53	61.43	62.17	61.80
T_6	12.11	12.35	12.23	25.72	26.10	25.91	47.57	48.00	47.78	59.21	59.92	59.57
T_7	12.38	12.63	12.50	25.92	26.31	26.11	48.07	48.50	48.28	60.18	60.90	60.54
T_8	12.82	13.08	12.95	27.02	27.43	27.22	51.11	51.57	51.34	63.20	63.96	63.58
T_9	12.56	12.81	12.69	26.29	26.68	26.49	48.38	48.82	48.60	60.67	61.39	61.03
T_{10}	13.01	13.27	13.14	27.83	28.25	28.04	52.08	52.55	52.32	64.50	65.27	64.89
T_{11}	13.12	13.38	13.25	28.62	29.05	28.83	52.60	53.07	52.84	67.52	68.33	67.92
T_{12}	12.93	13.19	13.06	27.28	27.69	27.49	51.68	52.15	51.92	63.83	64.60	64.22
SEm±	0.40	0.41	0.29	0.84	0.85	0.60	1.58	1.59	1.12	1.96	1.98	1.39
CD (p=0.05)	NS	NS	NS	2.44	2.48	1.74	4.57	4.61	3.25	5.68	5.75	4.04

Table 4: Effect of different treatments on Number of branches, Dry matter accumulation, Number of pods and Seed index in Kabuli chickpea crop (Pooled data of 2023-24 to 2024-25).

Treatments	No. of branches ($plant^{-1}$)						Dry matter accumulation ($g\ plant^{-1}$)			No. of pods ($plant^{-1}$)			Seed index		
	Primary			Secondary			At harvest								
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	4.36	4.85	4.60	7.54	8.38	7.96	18.81	18.50	18.65	44.54	48.10	46.32	30.54	31.48	31.01
T_2	5.14	5.72	5.43	10.07	11.20	10.64	22.55	23.05	22.80	62.78	68.43	65.61	31.74	32.73	32.24
T_3	5.49	6.10	5.80	10.27	11.42	10.84	23.27	23.78	23.52	63.49	69.21	66.35	32.04	33.03	32.54
T_4	6.12	6.79	6.46	11.14	12.36	11.75	23.57	24.08	23.82	65.92	71.85	68.89	32.91	33.93	33.42
T_5	6.51	7.23	6.87	12.76	14.18	13.47	24.17	24.73	24.45	70.11	75.72	72.92	33.25	34.28	33.76
T_6	5.94	6.61	6.27	10.69	11.89	11.29	23.47	23.86	23.66	64.85	70.68	67.77	32.12	33.12	32.62
T_7	6.27	6.97	6.62	11.41	12.68	12.04	23.87	24.24	24.06	67.06	73.10	70.08	32.96	33.98	33.47
T_8	6.63	7.37	7.00	12.99	14.45	13.72	25.10	25.49	25.29	73.92	79.84	76.88	33.52	34.56	34.04
T_9	6.34	7.05	6.70	12.43	13.82	13.12	24.07	24.52	24.29	69.35	75.59	72.47	33.05	34.08	33.57
T_{10}	7.61	8.45	8.03	14.74	16.21	15.48	25.95	26.54	26.24	76.97	83.13	80.05	34.12	35.18	34.65
T_{11}	8.07	8.97	8.52	14.92	16.57	15.74	26.85	27.51	27.18	80.02	86.42	83.22	34.82	35.90	35.36
T_{12}	7.36	8.18	7.77	13.91	15.47	14.69	25.83	26.48	26.15	76.21	82.31	79.26	33.77	34.81	34.29
SEm±	0.21	0.23	0.16	0.40	0.44	0.30	0.78	0.80	0.56	2.24	2.43	1.65	1.060	1.093	0.76
CD (p=0.05)	0.61	0.68	0.46	1.16	1.28	0.86	2.26	2.31	1.62	6.50	7.04	4.79	NS	NS	NS

Table 5: Response of different treatments on grain yield, stover yield, biological (kg h^{-1}) yield and harvest index under Kabuli chickpea crop. (Pooled data 2023-24 and 2024-25).

Treatments	Yield (q ha^{-1})			Stover yield (q ha^{-1})			Biological yield (q ha^{-1})			Harvest index (%)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
T_1	17.26	17.01	17.13	27.00	26.75	26.88	44.26	43.76	44.01	39.00	38.87	38.93
T_2	22.50	23.28	22.89	34.77	35.28	35.03	57.27	58.56	57.91	39.28	39.75	39.52
T_3	22.74	23.53	23.14	35.41	36.07	35.74	58.16	59.60	58.88	39.11	39.48	39.30
T_4	23.88	24.71	24.29	37.85	38.51	38.18	61.73	63.22	62.48	38.68	39.08	38.88
T_5	25.40	26.28	25.84	40.26	40.84	40.55	65.66	67.12	66.39	38.68	39.15	38.92
T_6	23.49	24.30	23.90	36.97	37.69	37.33	60.46	61.99	61.23	38.85	39.20	39.03
T_7	24.29	25.13	24.71	39.06	39.54	39.30	63.35	64.68	64.01	38.35	38.86	38.60
T_8	26.06	26.85	26.46	43.35	43.98	43.67	69.41	70.83	70.12	37.54	38.84	38.19
T_9	25.12	25.99	25.56	40.11	40.92	40.51	65.23	66.91	66.07	38.51	38.84	38.68
T_{10}	27.76	28.74	28.25	45.14	46.10	45.62	72.90	74.85	73.87	38.08	38.40	38.24
T_{11}	28.41	29.42	28.92	47.91	48.98	48.44	76.32	78.40	77.36	37.23	37.53	37.38
T_{12}	27.61	28.56	28.08	44.38	45.33	44.86	71.99	73.89	72.94	38.35	38.65	38.50
SEm±	0.81	0.84	0.58	1.30	1.32	0.93	2.16	2.16	1.51	1.23	1.24	0.87
CD (p=0.05)	2.34	2.43	1.69	3.77	3.84	2.69	6.26	6.27	4.37	NS	NS	NS

were made by Patel *et al.* (2020), who reported little variation in harvest index due to integrated nutrient management practices.

CONCLUSION

Integrated nutrient management, involving the partial substitution of chemical fertilizers with organic manures, biofertilizers and liquid organic inputs like Jeevamrit, significantly enhances plant height, yield attributes and yields of Kabuli chickpea in partially reclaimed sodic soils. The integration of 50% of the recommended dose of phosphorus (RDP) with organic sources like FYM and vermicompost, in combination with Jeevamrit and biofertilizers, significantly recorded the highest plant height, number of branches, dry matter accumulation, pods per plant and grain and biological yields of Kabuli chickpea. The treatment T_{11} consistently outperformed the others, confirming the efficiency of integrated nutrient management in improving productivity under field conditions. These findings highlight the potential of integrated nutrient management to sustainably enhance chickpea productivity in partially reclaimed sodic soils.

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Disclaimers

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Conflict of interest

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