E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(12): 692-700
Received: 15-11-2024
Accepted: 16-12-2024

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Residual effect of integrated nitrogen management of sorghum on growth, yield attributes, yield and quality of chickpea

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i12Sj.2332

Abstract
A field experiment entitled, **"**Residual effect of integrated nitrogen management of sorghum on growth, yield attributes, yield and quality of chickpea" was carried out during two consecutive *kharif* and *rabi* seasons of 2022-23 and 2023-24 on loamy sand soil of Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The treatment consisted of integrated nitrogen management *viz*., T_1: absolute control, T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha), T_3: 25% RDN through FYM + 75% RDN through urea, T_4: 50% RDN through FYM + 50% RDN through urea, T_5: 25% RDN through castor shell compost + 75% RDN through urea, T_6: 50% RDN through castor shell compost + 50% RDN through urea, T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*, T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*, T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea, T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* to sorghum in *kharif* season as main plot treatments replicated four times in randomized block design. During *rabi* season each main plot treatment was split into two sub plot treatments with two levels of fertilizers dose *viz*., F_0**:** Control, F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha) to chickpea resulting in twenty treatment combinations replicated four times in split plot design. The results showed that application of 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* to sorghum had significant residual effect on the chickpea and significantly influenced *viz*., number of branches per plant (5.65), number of pods per plant (53.57), seed (2042 kg/ha) and stover (2644 kg/ha) yield, net return (₹ 88218/ha) and BCR (3.54) of chickpea. Among the levels of fertilizer dose directly applied to chickpea in *rabi* season, significantly higher values of seed (2144 kg/ha) and stover (2766 kg/ha) yield, net return (₹92218/ha) and BCR (3.51) were obtained under the application of RDF (20:40:00 kg N:P_2O_5:K_2O/ha). Thus, application of 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* to sorghum, while chickpea crop should be fertilized with RDF (20:40:00 kg N:P_2O_5:K_2O/ha).

Keywords: Sorghum, chickpea, FYM, Castorshell compost, *Azotobacter*

Introduction
Generally, fertilizer dose is recommended on the basis of individual crop response. Crops grown in fixed cropping sequence behave differently than grown individually. Such existing system of fertilizer recommendation ignores the carry over effects of the manures or fertilizers applied to the preceding crops. Organic sources of nutrients applied to the preceding crops benefit the succeeding crops to a great extent. Hence, it is essential that the cultivators are made aware of profitability of integrated nutrient management under sequence. Sorghum-chickpea is one of the important and stable crop sequences under assured water supply to meet the food and fodder requirement of the farmers. Chickpea (*Cicer arietinum* L.) is the most important pulse crop of India contributing about 30% of total pulse acreage and about 40% of total pulse production of the nation. In India, it is grown in an area of 10.47 million ha with the production of 12.26 million tonnes with an average productivity of 1171.6 kg/ha (Anonymous, 2023[b]). Madhya Pradesh, Maharashtra, Rajasthan, Andra Pradesh, Uttar Pradesh, Karnataka and Gujarat contribute about 95% of chickpea production in India.

In Gujarat, it is grown in an area of 7.64 lakh ha with the production of 1.29 million tonnes and productivity of 1699 kg/ha (Anonymous, 2023[a]). Chickpea is the premier food legume crop in India. Among the pulses, chickpea is the second important pulse crop in the world after dry beans (*Phaseolus vulgaris* L.). Chickpea is commonly known as gram and Bengal gram and also in India, locally known as "*Chana"*. The flowers of chickpea are typical papilionaceous and mostly self-pollination occurs but cross-pollination may occur to the extent of about 5 to 10% due to agency of insects. The Indian grams have been known as *desi* or brown gram (*Cicer arientinum* L.): In this group the color of the seed ranges from yellow to dark brown. Seed size is usually small. It is the most widely grown group. Plants are small with good branching ability.

Chickpea is a good source of energy, protein, minerals (Especially potassium, phosphorus, calcium, magnesium, copper, iron and zinc), vitamins (Especially vitamin B), fiber and also contains potentially health beneficial phytochemicals. The protein concentration of chickpea seed ranges from 18.0 to 22.0% for deshi type and 12.6 to 29.0% for kabuli type, which is commonly 2–3 times higher than that of cereal grains. Chickpea exhibits higher lipid content than other pulses. Lipid content in seed of the deshi and kabuli type ranges from 2.9 to 7.4% and 3.4 to 8.8%, respectively. Carbohydrates are the major nutritional component in chickpea, with 61 to 62% in deshi type and 54 to 71% in kabuli type. Leaves consist of mallic and oxalic acids are very useful for stomach ailments and blood purification. Since, chickpea is high in fiber, low in sodium and fat and also cholesterol free, it is beneficial for the prevention of coronary and cardiovascular diseases in human and hence, considered as healthy food (Yadav *et. al*., 2007) [18]. It may also lower blood cholesterol levels due to high content of soluble fibre and vegetable protein. Furthermore, the nitrogen-fixing properties of pulses improve soil fertility, which increases and extends the productivity of the farmland. By using pulses for intercropping and cover crops, farmers can also promote farm biodiversity and soil biodiversity. Pulses can contribute to climate change mitigation by reducing dependence on the synthetic fertilizers used to introduce nitrogen artificially in to the soil. Greenhouse gases are released during the manufacturing and application of these fertilizers and their overuse can be detrimental to the environment.

The organic manures like FYM and castor shell compost are natural sources of slow release nutrients and inclusion in nutrient management has become necessity to improve the soil fertility and to sustain the productivity. FYM is a traditional source, most readily available and widely used by the farmers since time immemorial. Farmyard manure refers to the decomposed mixture of dung and urine of farm animals, litter and leftover material from roughages or fodder fed to the cattle. On average well decomposed farmyard manure contains 0.5% N, 0.2% P_2O_5 and 0.5% K_2O. FYM increases the N-use efficiency of the crop and the status of organic carbon, available N, P and trace elements in the soil. FYM also improves the physical condition of the soil. Castor shells are poor in N (1.86%) but rich in K (4.50%), while castor cake is rich in N (7.54%), but poor in K (0.66%). Due to the low nitrogen content, castor husks performed badly when used as organic fertilizer or as filling ingredient without being mixed with N-rich material (Lima *et al*., 2013). The well decomposed castor shell compost contains 2.24% N, 0.82% P_2O_5, 1.74% K_2O with pH 7.33 and EC 0.16 dS/m (Annual Report, 2020).

On the other hand bio-fertilizers are cheaper, pollution free and renewable source of nutrients supply. Introduction of beneficial microorganisms into soil in a capacity of biofertilization could increases plant growth by providing nutrients in available forms. Biofertilizers can produce beneficial substances such as the plant hormones indole acetic acid, gibberellins and cytokinins. *Azotobacter* bacteria are free living non-photosynthetic aerobic N2- fixing bacteria which activate nitrogen cycle in the rhizosphere, and produce vitamins as thiamine and riboflavin and hormones as indole acetic acid, gibberellic acids and cytokinins.

Materials and Methods

A field experiment was conducted at Agronomy Instructional Farm of the Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during the *kharif* and *rabi* seasons of 2022-23 and 2023-24, entitled with "Residual effect of integrated nitrogen management of sorghum on growth, yield attributes, yield and quality of chickpea". The experiment was laid out in a randomized block design comprising of 10 treatments *viz.*, T_1: absolute control, T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha), T_3: 25% RDN through FYM + 75% RDN through urea, T_4: 50% RDN through FYM + 50% RDN through urea, T_5: 25% RDN through castor shell compost + 75% RDN through urea, T_6: 50% RDN through castor shell compost + 50% RDN through urea, T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*, T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*, T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea, T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* to sorghum replicated four times in a gross plot size of 6.0 m × 9.0 m. Sorghum crop variety 'GJ 43' was sown in June with recommended package of practices during both the years. Sowing of sorghum was done with recommended seed rate of 12 kg/ha by maintaining 45 cm distance between the rows. The application of fertilizer for sorghum was applied as per fertilizer treatment. According to content of nutrient, FYM and castor shell compost were applied to sorghum crop as per treatments at least 13 days before sowing and incorporated into the soil. Recommended dose of fertilizers (80: 40: 00: kg N: P_2O_5: K_2O ha^{-1}) were applied through urea and SSP as per the treatments. 25% inorganic N was applied at basal and remaining 75% as three equal split at 20, 40 and 60 DAS. Seeds of sorghum were treated 10 ml *Azotobacter* per kg seed in specific treatments at the time of sowing. During *rabi* season each main plot treatment was spited in to two sub-plot treatments with two levels of fertilizer dose *viz.*, F_0**:** Control, F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha) to chickpea resulting in twenty treatment combinations replicated four times in split plot design. Using chickpea crop variety 'GJG 5' seeds were sown manually at 45 cm row apart by maintaining the seed rate of 60 kg/ha and the seeds were sown in previously opened furrow and seeds were properly covered with soil and light irrigation was applied in each plot immediately after sowing. The observation on plant growth, yield attributes and yield were recorded as per standard procedure. Economics was worked out on the basis of prevailing market prices of inputs and output obtained from each treatment. The data were statistically analyzed for various characters as described by (Panse and Sukhatme, 1967) [11].

Results and Discussion

1. Effect on growth attributes

The mean data on plant population, plant height, number of branches per plant, number of root nodules per plant and fresh and dry weight of root nodules per plant of chickpea as affected by different treatments in pooled study are presented in Table 1 to Table 4.

Table 1: Effect of different treatments on plant population and plant height of chickpea (Pooled of 2 year)

Treatments	Plant population per metre row length		Plant height (cm) at harvest
	30 DAS	At harvest	
Main plot: Nitrogen management in sorghum			
T_1: Absolute control	10.01	8.94	48.32
T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha)	10.21	9.14	50.94
T_3: 25% RDN through FYM + 75% RDN through urea	10.22	9.18	50.25
T_4: 50% RDN through FYM + 50% RDN through urea	10.53	9.15	50.89
T_5: 25% RDN through castor shell compost + 75% RDN through urea	10.31	9.20	49.48
T_6: 50% RDN through castor shell compost + 50% RDN through urea	10.34	9.37	50.77
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	10.43	9.33	48.51
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	10.42	9.31	48.60
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	10.29	9.27	50.45
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	10.32	9.29	51.16
S. Em. ±	0.19	0.18	1.23
C. D. (P=0.05)	NS	NS	NS
C. V. %	7.23	7.93	9.86
Sub plot: Fertilizer dose in chickpea			
F_0**:** Control	10.21	9.12	47.76
F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha)	10.41	9.32	52.11
S. Em. ±	0.07	0.07	0.40
C. D. (P=0.05)	NS	NS	1.13
Significant interactions:	-	-	-
C. V. %	6.33	7.24	7.13

Table 2: Effect of different treatments on number of branches per plant and number of root nodules per plant of chickpea (Pooled of 2 year)

Treatments	Number of branches per plant	Number of root nodules per plant at 45 DAS
Main plot: Nitrogen management in sorghum		
T_1: Absolute control	4.78	15.50
T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha)	5.33	16.17
T_3: 25% RDN through FYM + 75% RDN through urea	5.52	17.01
T_4: 50% RDN through FYM + 50% RDN through urea	5.60	16.08
T_5: 25% RDN through castor shell compost + 75% RDN through urea	5.43	16.96
T_6: 50% RDN through castor shell compost + 50% RDN through urea	5.58	17.24
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	4.93	18.02
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	5.05	20.22
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	5.55	18.58
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	5.65	18.52
S. Em. ±	0.11	0.40
C. D. (P=0.05)	0.31	1.12
C. V. %	8.11	9.09
Sub plot: Fertilizer dose in chickpea		
F_0**:** Control	4.76	16.39
F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha)	5.93	18.47
S. Em. ±	0.04	0.14
C. D. (P=0.05)	0.10	0.38
Significant interactions:	-	S
C. V. %	6.12	6.97

Table 3: Effect of interaction (T x F) on number of root nodules per plant of chickpea (pooled data)

Number of root nodules per plant		
F / **T**	F_0	F_1
T_1	14.72	16.28
T_2	15.16	17.18
T_3	16.23	17.78
T_4	15.83	16.33
T_5	15.71	18.22
T_6	17.01	17.48
T_7	16.93	19.12
T_8	18.18	22.27
T_9	17.17	20.00
T_{10}	17.02	20.10
S. Em. ±	0.43	

C. D. (P=0.05)	1.21

T_1: absolute control, T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha), T_3: 25% RDN through FYM + 75% RDN through urea, T_4: 50% RDN through FYM + 50% RDN through urea, T_5: 25% RDN through castor shell compost + 75% RDN through urea, T_6: 50% RDN through castor shell compost + 50% RDN through urea, T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*, T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*, T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea, T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*, F_0: Control, F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha)

Table 4: Effect of different treatments on fresh and dry weight of root nodules per plant of chickpea (Pooled of 2 year)

Treatments	Fresh weight of root nodules per plant (mg)	Dry weight of root nodules per plant (mg)
Main plot: Nitrogen management in sorghum		
T_1: Absolute control	93.00	24.93
T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha)	97.04	25.86
T_3: 25% RDN through FYM + 75% RDN through urea	102.16	27.16
T_4: 50% RDN through FYM + 50% RDN through urea	96.58	25.63
T_5: 25% RDN through castor shell compost + 75% RDN through urea	101.85	26.85
T_6: 50% RDN through castor shell compost + 50% RDN through urea	103.53	26.56
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	108.12	28.83
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	115.62	31.66
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	111.49	29.72
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	111.27	29.56
S. Em. ±	2.61	0.55
C. D. (P=0.05)	7.41	1.57
C. V. %	10.05	7.98
Sub plot: Fertilizer dose in chickpea		
F_0**:** Control	98.42	25.96
F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha)	109.71	29.40
S. Em. ±	0.93	0.19
C. D. (P=0.05)	2.63	0.53
Significant interactions	-	-
C. V. %	7.98	6.00

Residual effect of nitrogen management of sorghum

It is evident from the Table 1 that plant population (at 30DAS and harvest) and plant height of chickpea measured at harvest was found non-significant due to nitrogen management treatments to preceding sorghum crop in pooled study. While, application of 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* (T_{10}) to preceding sorghum crop gave significantly higher number of branches per plant (5.65) to chickpea during pooled study. This might be due to application of 100% RDN through organic source to preceding sorghum crop improved the available nutrient status of soil and favorable effect of soil properties might be supplied the plant nutrients in adequate amount throughout the growth period of chickpea crop, which improved the plant growth in terms of branches per plant. It may be due to the fact that more nutrient availability under these treatments resulted into increased conversion of carbohydrates into protein which in turn elaborated into protoplasm and cell wall material increased the size of the cell, which expressed morphologically in terms of growth attributes. Similarly, the beneficial residual effect of addition of organic sources under cropping system on growth attributes recorded by Gawai and Pawar (2006) [6] and Patil *et al*. (2008) [12] in sorghum-chickpea cropping system.

However, Significantly more number of root nodules per plant (20.22), fresh weight (115.62 mg) and dry weight (31.66 mg) of root nodules in chickpea was noted with the application of (T_8) 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter* to preceding sorghum. This might be due to the integration of organic and inorganic nutrient sources increase availability of nutrients to plant and result of this root biomass and number of root nodules per plant increase. The present findings are in close agreement with the results obtained by Mohankumar and Hiremath (2015) [10] in maize-chickpea, Mansuri (2016) [9] in rice-chickpea and Mangaraj *et al*. (2020) [8] in rice-chickpea.

Effect of fertilizer dose in chickpea

The mean data presented in Table 1 to Table 4 indicated that the plant height of chickpea at harvest (52.11 cm), number of branches per plant (5.93), number of root nodules per plant (18.47), fresh (109.71 mg) and dry weight (29.40 mg) of root nodules in chickpea were recorded significantly the highest with the treatment (F_1) RDF (20:40:00 kg N:P_2O_5:K_2O/ha) in pooled study. The increase in growth parameters due to apply 100% RDF through inorganic fertilizer provide adequate availability of nutrients resulted in rapid synthesis of carbohydrates and consequently converted into protoplasm and thereby smaller portion available for cell wall formation. This has served consequences of increase in size of cell, which is expressed morphologically through increase in plant height. An increase in plant height due to application of 100% RDF was also observed by Mansuri (2016) [9], Ratnam (2016) [14] and Bhadoria (2018) [4] in chickpea. Adequate availability of nutrients resulted in sufficient formation of photosynthates can promote the metabolic activities, accelerates cell division and formation of merismetic tissues ultimately produced more number of branches per plant and root nodules per plant. The present findings are in close agreement with the results obtained by Ratnam (2016) [14] in chickpea and Sahu *et al*. (2020) [15] in chickpea.

Interaction effect

The data on interaction effect due to nitrogen management treatments applied to preceding sorghum and different fertilizer dose in chickpea crop (T × F) in case plant population (at 30 DAS and harvest), plant height at harvest, fresh and dry weight of root nodules were found to be non significant in pooled study of experimentation. While, Significantly higher number of root

nodules per plant (22.27) of chickpea at flowering was recorded under the treatment combination of 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter* and RDF (20:40:00 kg $N:P_2O_5:K_2O$/ha) (T_8F_1) during pooled study.

2.Effect on yield attribute

The mean data of yield attribute of chickpea as affected by different treatments are presented in Table 5.

Table 5: Effect of different treatments on number of pods per plant and seed index of chickpea (Pooled of 2 year)

Treatments	Number of pods per plant	Seed index (g)
Main plot: Nitrogen management in sorghum		
T_1: Absolute control	43.53	19.31
T_2: RDF (80:40:00 kg $N:P_2O_5:K_2O$/ha)	50.60	20.37
T_3: 25% RDN through FYM + 75% RDN through urea	52.39	20.09
T_4: 50% RDN through FYM + 50% RDN through urea	53.11	20.33
T_5: 25% RDN through castor shell compost + 75% RDN through urea	51.57	19.71
T_6: 50% RDN through castor shell compost + 50% RDN through urea	52.93	20.29
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	46.97	19.36
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	47.94	19.43
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	52.59	20.19
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	53.57	20.44
S. Em. ±	1.15	0.34
C. D. (P=0.05)	3.27	NS
C. V. %	9.12	6.74
Sub plot: Fertilizer dose in chickpea		
F_0: Control	44.79	19.08
F_1: RDF (20:40:00 kg $N:P_2O_5:K_2O$/ha)	56.25	20.83
S. Em. ±	0.38	0.10
C. D. (P=0.05)	1.07	0.29
Significant interactions	S	-
C. V. %	6.67	4.64

Residual effect of nitrogen management of sorghum

A critical examination of data (Table 5) indicated that application of 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* (T_{10}) to preceding sorghum recorded significantly higher number of pods per plant (53.57) of succeeding chickpea, which remained at par with treatment of T_9 (52.59), T_4 (53.11), T_6 (52.93), T_3 (52.39), T_5 (51.57) and T_2 (50.60) in pooled study. Application of organic sources to the preceding sorghum crop owing to improve the physico-chemical properties of soil and mineralization resulted in to higher availability of plant nutrients throughout the growth period of succeeding crop resulted in profused vegetative growth which produced more photosynthates and better translocation from source to sink reflected in more number of pods per plant. Gawai and Pawar (2007) [5] and Patil *et al*. (2008) [12] in sorghum-chickpea cropping sequence. While, data narrated in Table 5 revealed that the nitrogen management treatments to preceding sorghum crop was non-significantly affected on seed index (g) of chickpea.

Effect of fertilizer dose in chickpea

A study of data furnished in the **Table 5** disclose that application of RDF (20:40:00 kg $N:P_2O_5:K_2O$/ha) (F_1) to chickpea registered significantly higher number of pods per plant (56.25) and seed index (20.83 g) at harvest in pooled results. Application of adequate amount of nutrient to crop increased vegetative growth of chickpea, which resulted in more production of photosynthetes supplied to sink site and ultimately reflected in to higher numbers of pod per plant. The improvement in yield attributes may be attributed to profuse nodulation, leading to increased N fixation, energy transformation and metabolic process of plants leading to better sink development. Similar findings were in accordance with Rajesh (2010) [13], Shukla *et al*. (2013) [16], Mansuri (2016) [9], Ratnam (2016) [14] and Sahu *et al*. (2020) [15] in chickpea.

Interaction effect

The data on interaction effect are furnished in Table 6 clearly indicated that the interaction effect due to nitrogen management treatments applied to preceding sorghum and different fertilizer dose to chickpea crop was found significant in pooled study for number of pods per plant of chickpea. Treatment combination of $T_{10}F_1$ (50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* and RDF (20:40:00 kg $N:P_2O_5:K_2O$/ha) recorded significantly higher number of pods per plant (58.13) in pooled results, which remained at par with the treatment combination of T_4F_1 (57.80), T_6F_1 (57.47), T_9F_1 (56.93), T_3F_1 (56.76), T_2F_1 (56.38), T_5F_1 (55.74) and T_7F_1 (55.16). Residual effect of organic manures applied to preceding sorghum crop combined with the direct application of nitrogen fertilizer to chickpea increased numbers of pod per plant, might be due to the increased supply of all the essential nutrients by organic manures and inorganic fertilizer resulted in higher manufacture of food and its subsequent partitioning towards sink, which leads to higher number of pods per plant in chickpea. These findings are in close conformity with Gawai and Pawar (2006) [5] and Patil *et al*. (2008) [12] in sorghum-chickpea cropping sequence.

3. Effect on seed and stover yield

The mean data of **seed and stover yield** of chickpea as affected by different treatments are presented in Table 7.

Residual effect of nitrogen management of sorghum

A cursory glance over data presented in Table 7 indicated that effect of nitrogen management treatments applied to sorghum was found significant on seed and stover yield of chickpea in pooled study. Application of 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* (T_{10}) to preceding sorghum crop produced significantly higher seed (2042 kg/ha) and stover yield (2644 kg/ha) of chickpea crop in pooled study. Treatment T_{10} remained at par with treatments T_4, T_6, T_9, T_3, T_5 and T_2 during pooled study. The percent increase

in seed yield of chickpea with treatments T_4, T_6, T_9, T_3, T_5, T_2, T_8 and T_7 was 23.01, 22.04, 20.54, 20.30, 18.97, 16.08, 10.06 and 7.89 percent over the treatment T_1 on the basis of pooled data. The percent increase in stover yield of chickpea with treatments T_4, T_6, T_9, T_3, T_5, T_2, T_8 and T_7 was 22.69, 21.34, 20.23, 20.09, 18.60, 15.49, 10.11 and 7.05 percent over the treatment T_1 on the basis of pooled data. Significantly lower seed (1660 kg/ha) and stover yield (2155 kg/ha) of chickpea was recorded by the treatment T_1 (absolute control).

Application of 100% RDN through organic manures to sorghum crop improved the available nutrients status of soil, which might increase the availability of plant nutrients during crop growth period ultimately improved growth *viz.* plant height, number of branches per plant and yield attributes *i.e.* number of pods per plant. Thus, overall improvement in growth and yield attributes reflected in to higher seed and stover yield.

This might be due to increase in various physiological processes of plant as well as increased crop photosynthesis which ultimately enhanced production of photosynthates and allocation of photosynthates towards the economic part. The results of the present investigation are also corroborated by Gawai and pawar (2006) [5] and Patil *et al*. (2008) [12] in sorghum-chickpea cropping system.

Effect of fertilizer dose in chickpea

An appraisal of data in Table 7 indicated that the treatment F_1 (RDF 20:40:00 kg N:P_2O_5:K_2O/ha) produced significantly higher seed (2144 kg/ha) and stover yield (2766 kg/ha) over treatment F_0 (control) (1708 and 2223 kg/ha seed and stover yield, respectively) in pooled study, respectively. The magnitude of increase in seed and stover yield of chickpea was to the tune of 25.52 and 24.42 percent, respectively by (F_1) RDF (20:40:00 kg N:P_2O_5:K_2O/ha) over the treatment F_0 (control) on the basis of pooled data.

This might be due to adequate supply of plant nutrients under these treatment improved growth and yield attributes significantly which reflected in higher seed yield. The increase in yield due to N and P might be attribute to improvement in vegetative growth due to better availability of nutrients at vital growth period and greater synthesis of carbohydrate and their translocation. The results are in line with the earlier results reported by Walley *et al*. (2005), Rajesh (2010) [13], Shukla *et al*. (2013) [16] and Arvadiya *et al*. (2014) [13] in chickpea. Adequate availability of plant nutrients increased vegetative growth in terms of plant height and number of branches per plant, which resulted in higher stover yield. Results are supported by Shukla *et al*. (2013) [16] Mansuri (2016) [9] and Ratnam (2016) [14] in chickpea.

Interaction effect

A scrutiny of data (Table 8 and Table 9) revealed that treatment combination of $T_{10}F_1$ (50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* and RDF (20:40:00 kg N:P_2O_5:K_2O/ha) recorded significantly higher seed and stover yield (2214 and 2871 kg/ha, respectively) of chickpea crop during pooled study. This could be attributed to use of organic sources of fertilizer to preceding sorghum crop and inorganic nitrogenous fertilizer to chickpea increased the overall growth attributes leading to higher stover yield under treatment combination of $T_{10}F_1$. The result was in accordance with those reported by Gawai and Pawar (2006) [5] and Patil *et al*. (2008) [12] in sorghum-chickpea cropping sequence.

4. Effect on protein content

The data on protein content of chickpea seed as influenced by different treatments are presented in Table 7.

Residual effect of nitrogen management of sorghum

A perusal of data presented in Table 7 revealed that the different treatments of nitrogen management applied to preceding sorghum crop failed to exert any significant impact on the protein content of chickpea during both the years and in pooled study.

Effect of fertilizer dose in chickpea

Application of 100% RDF (20:40:00 kg N:P_2O_5:K_2O/ha) (F_1) resulted in significantly higher protein content (21.04%) in pooled result over treatment (F_0) control (18.97%). Treatment F_1 realized 10.91 per cent higher protein content than that of F_0 in pooled study.

This might be due to adequate availability of nitrogen throughout the growth period under treatment F_1increased nitrogen content in grain. Moreover, nitrogen plays an important role in synthesis of amino acids which is constituent of protein. Results are supported by Arvadiya *et al*. (2014) [13] and Bhadoria (2018) [4] in chickpea.

Interaction effect

Interaction effect between different treatment applied to sorghum and chickpea (T × F) did not exert significant effect on protein content of chickpea in pooled study.

5.Effect on economics

The data on economics of chickpea as influenced by different treatments are furnished in Table 10.

Residual effect of nitrogen management of sorghum

From the data presented in Table 10, it could be inferred that the maximum net realization (₹88218 /ha) and BCR (3.54) of chickpea were gained with the application of 50% RDN through FYM + 50% RDN through castor shell compost + *Azoto bacter* (T_{10}) to sorghum crop followed by treatment T_4 (₹87254/ha net realization and 3.52 BCR).The minimum net realization (₹27743/ha) and BCR (1.58) of wheat was noted under the application of 100% RDN through vermicompost (G_3) to groundnut. The minimum net realization (₹65239/ha) and BCR (2.88) of chickpea was noted under the treatments T_1 (absolute control).

This has clearly brought out that application of organics sources to preceding sorghum crop has an additional advantage to enhance the overall net returns of chickpea. Beneficial effect of these treatments on seed yield might be resulted in higher net realizations and BCR.

Similar findings were reported by Gudadhe (2008) [6] in cotton-chickpea cropping sequence and Mansuri (2016) [9] in rice-chickpea cropping sequence.

Effect of fertilizer dose in chickpea

The maximum net realization (₹92218/ha) and BCR (3.51) of chickpea were recorded under the application of RDF (20:40:00 kg N:P_2O_5:K_2O/ha) (F_1), whereas, the treatment F_0 noted minimum net realization (₹70267/ha) and BCR (3.16) of chickpea.

Application of sufficient quantity of nitrogen through inorganic fertilizer increased yield, which resulted in better remuneration. Similar findings were reported by Patil *et al*. (2008) [12], Rajesh (2010) [13] and Shukla *et al*. (2013) [16] in chickpea.

Table 6: Effect of interaction (T x F) on number of pod per plant of chickpea (pooled data)

Number of pod per plant		
F / T	F_0	F_1
T_1	33.53	53.54
T_2	44.81	56.38
T_3	48.02	56.76
T_4	48.42	57.80
T_5	47.41	55.74
T_6	48.39	57.47
T_7	38.78	55.16
T_8	41.30	54.59
T_9	48.26	56.93
T_{10}	49.02	58.13
S. Em. ±	1.19	
C. D. (P=0.05)	3.37	

T_1: absolute control, T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha), T_3: 25% RDN through FYM + 75% RDN through urea, T_4: 50% RDN through FYM + 50% RDN through urea, T_5: 25% RDN through castor shell compost + 75% RDN through urea, T_6: 50% RDN through castor shell compost + 50% RDN through urea, T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*, T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*, T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea, T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*, F_0: Control, F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha)

Table 7: Effect of different treatments on seed and stover yield, harvest index of chickpea (Pooled of 2 year)

Treatments	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Protein content (%)
Main plot: Nitrogen management in sorghum				
T_1: Absolute control	1660	2155	43.39	18.98
T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha)	1927	2489	43.60	19.89
T_3: 25% RDN through FYM + 75% RDN through urea	1997	2588	43.55	20.21
T_4: 50% RDN through FYM + 50% RDN through urea	2026	2627	43.57	20.34
T_5: 25% RDN through castor shell compost + 75% RDN through urea	1975	2556	43.61	20.33
T_6: 50% RDN through castor shell compost + 50% RDN through urea	2016	2615	43.55	20.34
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	1791	2307	43.68	19.75
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	1827	2373	43.45	19.94
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	2001	2591	43.58	19.90
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	2042	2644	43.57	20.35
S. Em. ±	59	76	0.32	0.34
C. D. (P=0.05)	166	215	NS	NS
C. V. %	12.15	12.15	2.95	6.79
Sub plot: Fertilizer dose in chickpea				
F_0**:** Control	1708	2223	43.44	18.97
F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha)	2144	2766	43.67	21.04
S. Em. ±	15	22	0.10	0.13
C. D. (P=0.05)	43	62	NS	0.38
Significant interactions	S	S	-	-
C. V. %	7.03	7.85	2.07	6.02

Table 8: Effect of interaction (T x F) on seed yield of chickpea (pooled data)

Seed yield (kg/ha)		
F / T	F_0	F_1
T_1	1283	2038
T_2	1707	2147
T_3	1831	2164
T_4	1851	2202
T_5	1812	2138
T_6	1845	2188
T_7	1478	2106
T_8	1575	2080
T_9	1835	2168
T_{10}	1871	2214
S. Em. ±	47.88	
C. D. (P=0.05)	135.43	

Table 9: Effect of interaction (T x F) on stover yield of chickpea (pooled data)

Stover yield (kg/ha)		
F / T	F_0	F_1
T_1	1705	2606
T_2	2209	2770
T_3	2376	2800
T_4	2404	2850
T_5	2349	2764
T_6	2395	2835
T_7	1919	2696
T_8	2086	2661
T_9	2370	2812
T_{10}	2419	2871
S. Em. ±	69.27	
C. D. (P=0.05)	195.95	

Table 10: Effect of different treatments on economics of chickpea under nitrogen management (Average of 2022-23 and 2023-24)

Treatments	Yield (kg/ha)		Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	BCR
	Seed	Stover				
Main plot: Nitrogen management in sorghum						
T_1: Absolute control	1660	2155	34677	99916	65239	2.88
T_2: RDF (80:40:00 kg N:P_2O_5:K_2O/ha)	1927	2489	34677	115925	81248	3.34
T_3: 25% RDN through FYM + 75% RDN through urea	1997	2588	34677	120190	85513	3.47
T_4: 50% RDN through FYM + 50% RDN through urea	2026	2627	34677	121931	87254	3.52
T_5: 25% RDN through castor shell compost + 75% RDN through urea	1975	2556	34677	118826	84149	3.43
T_6: 50% RDN through castor shell compost + 50% RDN through urea	2016	2615	34677	121363	86686	3.50
T_7: 25% RDN through FYM + 50% RDN through urea + *Azotobacter*	1791	2307	34677	107746	73069	3.11
T_8: 25% RDN through castor shell compost + 50% RDN through urea + *Azotobacter*	1827	2373	34677	109981	75304	3.17
T_9: 25% RDN through FYM + 25% RDN through castor shell compost + 50% RDN through urea	2001	2591	34677	120421	85744	3.47
T_{10}: 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter*	2042	2644	34677	122895	88218	3.54
Sub plot: Fertilizer dose in chickpea						
F_0**:** Control	1708	2223	32583	102850	70267	3.16
F_1: RDF (20:40:00 kg N:P_2O_5:K_2O/ha)	2144	2766	36771	128989	92218	3.51

Conclusion

Based on the findings of two years of experimentation, it is concluded that for securing higher grain yield and net profit from chickpea crop under integrated nitrogen management, apply 50% RDN through FYM + 50% RDN through castor shell compost + *Azotobacter* with RDF (20:40:00 kg N:P_2O_5:K_2O/ha) in loamy sand.

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