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Research Paper

Integrated plant nutrient supply modules for enhancing crop growth, productivity and nutrient balance in maize - chickpea cropping sequence

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ABSTRACT

A long-term field study was conducted to evaluate integrated plant nutrient supply (IPNS) system in maize-chickpea cropping sequence. In this study, twelve IPNS modules of Soil Test Crop Response (STCR) based fertilizers, recommended dose of fertilizers (RDF), farmyard manure (FYM), poultry manure (PM), urban compost (UC), maize residue (MR) and *Gliricidia loppings* (GL) were investigated. Results indicated that plant height, dry biomass, yield parameters (cob length and girth, grains/cob and 1000-grains weight) and yields (grain and stover) of maize significantly (p=0.05) improved with IPNS module (75% NPK +5 t FYM) and increased 31.8 and 23.8% grain yield over the RDF and 100% NPK of STCR, respectively. In chickpea, the higher plant height, dry biomass, pods/plant and yields (grain and straw) were obtained with the residual fertility of FYM @ 25 t/ha every year and followed by IPNS module (75%NPK +5 t FYM). However, residual fertility of PM and UC based IPNS modules also considerably improved the crop growth and yields of chickpea. Substantially higher system productivity was also noticed with 75% NPK +5 t FYM and followed 75% NPK +1 t PM based IPNS modules which was 1.86 and 0.99 t/ha higher than RDF. A positive nutrient balance was recorded with addition of higher level FYM only (25 t/ha) Whereas, a negative nutrient balance was noticed for N and K in all plots excluding higher level of organic manures. However, there has been substantial build-up of N, P and K in plots receiving 25 t FYM every year. The additional supply of nutrients (organic + inorganic) is crucial for positive nutrients balance. Thus, STCR based fertilizers (75% NPK) along 25% nutrients through organic manures (FYM and PM) sustained the crop yield while the addition of FYM (25 t/ha) is essential for a positive balance of nutrients in the soil.

Key words: Chickpea, Crop yield, IPNS-modules, Maize, Organic manures, Nutrient balance

Increasing long-term productivity of agro-ecosystem is of paramount importance for more and better-quality food (Meena *et al*., 2016). Currently, India's food grain production is in surplus with about 315.7 million tonnes (Economic survey, 2022-23), however, the total food grain demand of unabated population growth of the country will reach 333 million tonnes in 2050, according to a report. Maize-chickpea is the most promising cropping system and provides food, feed and fodder for both humans and animals. India produced 31.5 million tonnes of maize grain from 9.9 million ha area with an average yield of 3195 kg/ha of maize during 2020-21, while, chickpea is the major legume crop in winter season and it grows about 9.9 million ha area producing 12.0 million tonnes with yield of 1217 kg/ha (Economic survey, 2022). Generally, maize is a crop that requires large amounts of nutrients throughout its growth season in order to produce high yields (Meena *et al*., 2019). The amount of nutrients applied through fertilizers or other sources is much lower than the nutrients removed by crops, which ultimately results in a deterioration of the soil health (Singh and Wanjari, 2013). The fertilizers cost is one of the barriers for use of fewer nutrients than that required to achieve targeted crop yields. Several past studies have indicated a declining trend in the crop yield of with continuous adoption of cereal-based cropping system (Singh and Wanjari, 2013; Bhattacharyya *et al*., 2016; Meena *et al*., 2019). Therefore, it is crucial to incorporate a cereal-legume crop rotation along with balanced fertilization to maintain the high soil fertility. Animals' organic wastes are valuable resources, especially as it pertains to nourishing crops with nutrients. The available nutrient (NPK) supply from organic sources was approximately 5 million tonnes in 2011 and it would rise to 7.75 million tonnes by 2025. (FAO, 2005). It is essential to proper supply of nutrients through organic manures in order to prevent the negative effects of chemical fertilisers

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and to maintain environmental quality (Narayan *et al*., 2014). Organic manures also play important role inhabiting beneficial bacterial population thus making the nutrients available to plants (Meena *et al*., 2015). Crop residues are also a potential source of nutrients for agroecosystems (Meena *et al*. 2019). Mulching also improved the soil properties due to beneficial effect on soil moisture conservation, carbon enrichment and nutrient addition (Jat *et al*., 2018). The integration of fertilizers along with organic manures is very crucial to maintain soil health and sustaining crop productivity. Hence, we focused on a diverse array of IPNS modules based on fertilizers, manures, urban compost, *Gliricidia loppings*, and soil test-based fertiliser (STCR) dose to develop the most effective nutrient management modules for enhancing crop growth, productivity, and nutrient balance in the maize-chickpea system.

MATERIALS AND METHODS

The rainy and winter seasons (2016-17 to 2019-20) experimental trials was conducted at ICAR–Indian Institute of Soil Science, Bhopal, Madhya Pradesh (23º18´N, 77º24´ E, 485 m above msl). The sub-humid climate of the area features hot summers, mild, dry winters, and a humid monsoon season with an average annual rainfall of 1130 mm. The soil at the test site was an *isohyperthermic*, Typic haplustert with a deep, heavy clayey texture, pH 7.8, electrical conductivity 0.17 dS/ m, and soil organic carbon (SOC) of 0.45% with 193.8 kg/ha available N, 12.86 kg/ha P, and 498.2 kg/ha K, respectively. In this trial, 12 IPNS modules *viz*., T_1- No fertilizer/ manure in both crops (Control), T_2- Recommended dose of fertilizers (Maize-120- 60-30; Chickpea- 20-60-20 kg NPK/ha), T_3-Soil Test Crop Response (STCR) based on target yield (Maize- 5 t/ha and Chickpea 1.5 t/ha) fertilizer dose, 142.5-57.5-50 kg NPK ha^{-1} in maize and chickpea raised as residual crop, T_4-STCR based 75% NPK in maize and chickpea raised as residual crop, T_5-STCR based 75% NPK + FYM 5 t/ ha and chickpea raised as residual crop, T_6- STCR based 75% NPK+ 1 t/ha poultry manure (PM) and chickpea raised as residual crop, T_7- STCR based 75%NPK + 5 t/ha urban compost (UC) and chickpea raised as residual crop, T8-STCR based 75% NPK+ MR (maize residue) and chickpea raised as residual crop, T_9- MR +1 t PM+2 t/ha *Gliricidia loppings* and chickpea raised as residual crop*,* T_{10}- MR + 5t FYM+2 t/ha *Gliricidia loppings* chickpea raised as residual crop, T_{11}-20 t FYM in maize (20t/ha) and chickpea (5t/ha), T12- STCR based 75% NPK +20t FYM (every four years) and chickpea raised as residual crop, were tested in a RBD for maize (Pro-agro 4212) and chickpea cultivar (JG 315) cropping sequence with 20m x 5m plots replicated thrice. Various sources of nutrients were imposed according of IPNS modules. Full dose of P_2O_5 and K_2O were applied through SSP (Single super phosphate) and MOP (muriate of potash), respectively. Whereas, 50% of N were applied through urea before of sowing of crop and 50% remaining amount of N was top-dressed in two splits at knee-high and tasseling stages in maize. The organic sources of nutrients were supplied on the N-basis and its composition on dry weight basis were 0.59, 0.36 and 1.39% (urban compost), 0.72, 0.45, and 0.70% (farmyard manure), 2.98, 0.28 and 1.86 % (*Gliricidia loppings*) and 2.97, 0.85, 1.26 (poultry manure) of the total N, P_2O_5 and K_2O respectively. The maize and chickpea were sown at recommended spacing by tractor drawn seed drill during respective seasons. Standard recommended agronomic protocols were followed for the maize and chickpea cultivation during entire period of study. Growth, yield attributes, and yields of both crops (maize and chickpea) were recorded at the time of harvesting. To compare the IPNS modules, maize equivalent yield (MEY) of chickpea was determined based on market price using following formula.

$$MEY= Yn\ (Pn)/\ Pm$$

Were, Y_X is the marketable yield of n (t/ha), Pn is the market price of crop n, and Pm is the market price of maize.

After the crop cycle, plant samples were analysed for total N, P, and K by using standard methods. Consequently, nutrient uptake was estimated by multiplying nutrient contents with seed and straw/ stover yields. The nutrient balance was computed based on fertilizer addition and removal (uptake). Data were analyzed using statistical techniques outlined by Gomez and Gomez, 1984.

RESULTS AND DISCUSSION

IPNS modules on growth and yield attributes of maize

The growth parameters and yield attributes of maize significantly (p=0.05) varied with application of diverse IPNS modules (Table 1). In general, the pooled of 4 years' data revealed that plant height and dry biomass and yield parameters such as cob length and girth, grains/cob and 1000 grains weight significantly improved with the application of STCR based IPNS module (75% NPK +5 t FYM) and followed by 100% STCR NPK dose than no fertilization. This might be as a result of better nutrient absorption, which promoted maize growth and production (Shirale *et al*., 2018). However, 1000-grain weight and harvest index could not be influenced by the applied IPNS modules. Results of four-year data showed that growth and yield attributes of maize were higher with IPNS module (75% NPK +5 t FYM) as compared to 100% NPK based on STCR and RDF. The performance of growth and yield parameters under FYM based IPNS modules might be due to proper nutrition in the form of macro and micro nutrients which are compulsory for better growth and development

(Lal *et al*., 2019). Over the years, the integration of NPK with PM, UC, and *Gliricidia loppings* (GL) was more or less inferior to FYM in respect to growth and yield-contributing parameters (Table 1).

IPNS modules on maize yields

The results showed that maize grain, stover and biological yield was considerably improved with IPNS module (75% NPK +5 t FYM) followed by 100% STCR and RDF over the control or no fertilization in the respective years (Table 1). IPNS module (75% NPK +5 t FYM) increased 31.8 and 23.8 % grain yield and 11.34 and 2.54 % stover yield over the RDF and 100% NPK based on STCR, respectively. The increase in maize's grain and stover yield could be attributed to an increased availability of nutrients from FYM, which leads to higher dry biomass assimilation, production, and partitioning (Meena *et al*., 2013). Poultry manures (PM) based IPNS module also increased the grain and stover yields of maize over the years as compared to chemical fertilization and increased 16.5 and 9.38% grain yield over the RDF and 100% NPK based on STCR. Whereas, the integration of urban compost, maize residue, and *Gliricidia loppings* had no effect on maize yields. Application of FYM in small quantity (5 t/ha) is more beneficial rather than applied in one go and forget for next few years. Among the different organic manures, yield performances at different treatments seemed to have better linkages with freshly applied N (rather than total NPK) taking both organic and inorganic sources into account (Shirale *et al*., 2018).

IPNS modules on growth, yield attributes and yields of chickpea

Results showed that growth, yield attributes and yields of chickpea differed significantly on residual fertility of different IPNS modules over control (Table 2). The tallest height, dry biom-

Table 1. Growth, yield attributing parameters and yield of maize influenced by the IPNS modules (Pooled over 4 years')

Treatment	Plant height at maturity (cm)	Dry biomass at maturity (g/plant)	Cob length (mm)	Cob girth (mm)	Grains/ Cob	1000-grains weight (g)	Grain yield (t/ha)	Stover yield (t/h)	Biological yield (t/h)	Harvest index
T_1- Control	120.5	139.4	13.07	10.2	285	187.7	2.21	3.41	5.62	0.39
T_2- Recommended dose of fertilizers (RDF)	142.9	183.3	17.13	12.9	436	201.1	4.30	7.23	11.53	0.37
T_3- STCR based fertilizer dose (STCR)	145.0	192.8	17.43	13.3	456	203.2	4.58	7.85	12.43	0.37
T_4- STCR based 75% NPK in maize and chickpea raised as residual crop	138.4	177.4	16.07	12.2	441	198.9	3.83	7.12	10.95	0.35
T_5- STCR based 75% NPK + FYM 5 t/ha and chickpea raised as residual crop	146.5	205.7	18.73	14.5	495	219.2	5.67	8.05	13.72	0.41
T_6- STCR based 75% NPK+ 1 t/ha poultry manure (PM) and chickpea raised as residual crop	145.3	200.8	18.07	14.1	482	213.8	5.01	7.64	12.65	0.40
T_7- STCR based 75%NPK + 5 t/ha urban compost (UC) and chickpea raised as residual crop	144.6	179.0	16.10	12.8	421	204.5	4.53	7.18	11.71	0.39
T_8- STCR based 75%NPK + maize residue (MR) and chickpea raised as residual crop,	142.0	166.9	15.93	12.9	416	201.3	4.06	6.53	10.59	0.38
T_9- MR +1 t PM+2 t/ha *Gliricidia loppings* and chickpea raised as residual crop,	132.5	166.7	15.22	13.0	351	196.1	3.49	5.15	8.64	0.40
T_{10}- MR + 5 t FYM+2 t/ha *Gliricidia loppings* chickpea raised as residual crop,	125.3	170.6	15.73	12.9	383	197.4	3.56	5.52	9.08	0.39
T_{11}-20 t FYM in maize and FYM 5 t/ha (Every year) in chickpea (every year)	138.0	186.7	17.13	13.7	433	202.6	3.99	7.39	11.38	0.35
T_{12}- STCR based 75%NPK + FYM 20 t/ha (once in every 4 years)	147.3	193.4	17.89	14.0	471	204.4	4.83	7.44	12.27	0.39
SE±	4.9	4.5	0.41	0.35	12.10	6.82	0.19	0.29	0.40	NS
CD (P=0.05)	13.7	13.4	1.12	1.03	32.12	20.2	0.56	0.88	1.18	NS

Table 2. Residual effect of IPNS modules on crop growth, yield parameters and yields of chickpea (Pooled over 4 years')

Treatment	Plant height (cm)	Dry biomass (g/m2)	Pods/ plant	Seeds/ pod	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index
T_1- Control	42.4	145.0	48.67	1.38	1.23	2.15	3.38	0.36
T_2- Recommended dose of fertilizers (RDF)	62.2	177.8	71.33	1.40	1.80	3.52	5.32	0.34
T_3- STCR based fertilizer dose (STCR)	61.5	173.6	61.67	1.35	1.75	3.34	5.09	0.34
T_4- STCR based 75% NPK in maize and chickpea raised as residual crop	51.7	155.0	64.33	1.33	1.68	2.82	4.50	0.37
T_5- STCR based 75% NPK + FYM 5 t/ha and chickpea raised as residual crop	61.2	178.8	69.33	1.38	1.98	3.69	5.67	0.35
T_6- STCR based 75% NPK+ 1 t/ha poultry manure (PM) and chickpea raised as residual crop	51.3	167.0	70.00	1.31	1.90	3.22	5.12	0.37
T_7- STCR based 75%NPK + 5 t/ha urban compost (UC) and chickpea raised as residual crop	54.6	160.7	68.33	1.35	1.84	3.53	5.37	0.34
T_8- STCR based 75%NPK + maize residue (MR) and chickpea raised as residual crop,	53.7	172.6	64.67	1.35	1.53	3.03	4.56	0.34
T_9- MR +1 t PM+2 t/ha *Gliricidia loppings* and chickpea raised as residual crop,	54.5	168.8	71.00	1.42	1.89	3.45	5.34	0.35
T_{10}- MR + 5 t FYM+2 t/ha *Gliricidia loppings* chickpea raised as residual crop,	56.2	170.4	78.67	1.27	1.78	3.20	4.98	0.36
T_{11}-20 t FYM in maize and FYM 5 t/ha (Every year) in chickpea (every year)	62.8	178.4	72.67	1.43	2.07	3.60	5.67	0.37
T_{12}- STCR based 75%NPK + FYM 20 t/ha (once in every 4 years)	61.6	165.2	67.33	1.28	1.90	3.63	5.53	0.34
SE±	1.94	5.26	4.92	0.08	0.08	0.16	0.20	NS
CD(P=05)	5.73	15.54	14.51	NS	0.23	0.47	0.59	NS

ass, pods/plant and yields of chickpea (grain and straw yield) were obtained with the residual fertility of FYM @ 20 t/ha along with direct application of FYM @5 t/ha in every year to chickpea (T11) and followed by residual fertility of IPNS module (75% NPK +5 t FYM). However, residual fertility of PM and UC based IPNS module also considerably improved the crop growth and yields. The higher growth and yields under residual fertility of IPNS modules This might be due to the availability of all necessary nutrients for the healthy growth of plants. Over the years, FYM-based IPNS modules have shown superiority over PM and UC-based IPNS modules, as FYM contains all required nutrients and boosts crop growth and productivity (Meena *et al*., 2013). The chickpea's growth parameters were also increased by the application of RDF (NPK), probably as a result of the rapid availability of vital nutrients for crop use, which are crucial for better crop growth (Gangir *et al*., 2022). Among the yield and yield-attributing characters, seeds/pod and harvest index were not much influenced by the residual fertility of the preceding crop and also the direct application of nutrient management practices (Lal *et al*., 2014). Also, results revealed that the residual effect of 20 t/ha FYM and the IPNS module (75% NPK + 5 t FYM) increased grain and straw yields of chickpea by 0.84 and 0.75 t/ha over the control, respectively. (Table 2). This might have occurred as a result of the advantageous effects of applied organic manures, particularly FYM, which enhanced rhizospheric development and nutrient absorption, thereby increased chickpea biomass production (Lal *et al*., 2017; Gangir *et al*., 2022; Dotaniya *et al*., 2022).

IPNS modules on system yield

The system yield was distinctly higher under the IPNS module (75% NPK +5 t FYM) (11.20 t/ha) as compared to SCTR based 100% NPK and RDF (Table 3). However, lowest system productivity was recorded in control plots. Poultry manure

Table 3. Maize equivalent yield of chickpea (MEY), system productivity as influenced by diverse IPNS modules under maize-chickpea cropping sequence (Pooled over 4 years')

Treatment	MEY of chickpea	System productivity	Increase/decrease in system productivity over RDF
	(t/ha)		
T_1- Control	3.44	5.65	-
T_2- Recommended dose of fertilizers (RDF)	5.03	9.34	-
T_3- STCR based fertilizer dose (STCR)	4.89	9.47	0.13
T_4- STCR based 75% NPK in maize and chickpea raised as residual crop	4.70	8.53	-0.81
T_5- STCR based 75% NPK + FYM 5 t/ha and chickpea raised as residual crop	5.54	11.20	1.86
T_6- STCR based 75% NPK+ 1 t/ha poultry manure (PM) and chickpea raised as residual crop	5.31	10.33	0.99
T_7- STCR based 75%NPK + 5 t/ha urban compost (UC) and chickpea raised as residual crop	5.15	9.68	0.34
T_8- STCR based 75%NPK + maize residue (MR) and chickpea raised as residual crop,	4.28	8.34	-1.00
T_9- MR +1 t PM+2 t/ha *Gliricidia loppings* and chickpea raised as residual crop,	5.29	8.78	-0.56
T_{10}- MR + 5 t FYM+2 t/ha *Gliricidia loppings* chickpea raised as residual crop,	4.98	8.53	-0.81
T_{11}-20 t FYM in maize and FYM 5 t/ha (Every year) in chickpea (every year)	5.79	9.78	0.44
T_{12}- STCR based 75%NPK + FYM 20 t/ha (once in every 4 years)	5.31	10.14	0.80
SE±	0.22	0.41	-
CD(P=0.05)	0.66	1.23	-

Price of maize and chickpea 18.7 and 52.3 Rs/kg, respectively during 2022-23 were used to calculate the MEY.

(PM) based IPNS module (75% NPK + 1 t/ha PM) also registered higher system productivity as compared to RDF, 100% NPK based STCR and integration of only organic sources of nutrients. The IPNS module (75% NPK +5 t FYM) recorded 1.86 t/ha and 1.73 t/ha higher system yield than RDF and 100%STCR based NPK, respectively. Furthermore, the results revealed that application of higher amount of FYM at 20 t/ha once in four years along with 75% STCR based fertilizers also increased the system productivity (10.14 t/ha) than RDF and STCR based fertilization. The higher system productivity under the IPNS modules might be due to impact of balanced nutrition to crop plant in the form of all essential nutrients during plant growth and development (Meena *et al*., 2022). Lower yield under organic modules was probably due to incomplete nutrition, as organic sources of nutrients have a high C/N ratio and a lower mineralization rate (Jat *et al*., 2012). Therefore, higher productivity under IPNS indicates that complete and judicious nutrition is utmost important to achieve the target yield in any cropping system.

IPNS modules on nutrient removal/uptake by crops

Total output by system in-terms of nutrient removal/uptake by crops were improved with applied IPNS modules (Table 4). Among the different IPNS module, the highest total N (201.2 kg/ha), P (63.5 kg/ha) and K (176.3 kg/ha) uptake by maize-chickpea system was recorded under the IPNS module (75% NPK +5 t FYM) while lowest N (80.4 kg/ha), P (22.7 kg/ha) and K (71.8 kg/ha) uptake was noticed in control plots. The improvement in N, P and K uptake may be attributed due to complete and balanced nutrition based on soil test based chemical fertilizers along with organic manures, which regulates the higher nutrient uptake (Meena *et al*., 2012). Furthermore, results revealed that the PM based IPNS module (75% NPK + 1 t/ha PM) also registered higher nutrient uptake as compared to RDF, 100%STCR based NPK, and integration of only organic sources of nutrients.

IPNS modules on nutrient balance

The influence of different IPNS modules on the nutrient balance under maize – chickpea cropping system has been studied. The results showed that there was a negative (Table 4) N and K balance in all plots excluding T11 treatment where higher amount (25 t FYM every year) of organic manures was supplied in both crops. P balance was

Table 4. Effect of IPNS modules on nutrient balance in maize–chickpea system after cropping cycle

Treatment	Total input applied (kg/ha /year)			Total removal by system (kg/ha)			Nutrient balance (kg/ha)		
	N	P	K	N	P	K	N	P	K
T_1- Control	0	0	0	80.4	22.7	71.8	-80.4	-22.7	-71.8
T_2- Recommended dose of fertilizers (RDF)	140	120	50	171.6	57.8	158.5	-31.6	62.2	-108.5
T_3- STCR based fertilizer dose (STCR)	142.5	57.5	50	168.5	60.2	165.0	-26.0	-2.7	-115.0
T_4- STCR based 75% NPK in maize and chickpea raised as residual crop	106.9	43.2	37.5	143.9	51.4	128.1	-37.0	-8.3	-90.6
T_5- STCR based 75% NPK + FYM 5 t/ha and chickpea raised as residual crop	139.9	61.4	73.3	201.2	63.5	176.3	-61.3	-2.1	-103.0
T_6- STCR based 75% NPK+ 1 t/ha poultry manure (PM) and chickpea raised as residual crop	136.2	51.4	50.2	184.0	56.1	152.4	-47.8	-4.7	-102.2
T_7- STCR based 75%NPK + 5 t/ha urban compost (UC) and chickpea raised as residual crop	137.7	61.7	108.3	157.9	54.0	147.8	-20.2	7.6	-39.5
T_8- STCR based 75%NPK + maize residue (MR) and chickpea raised as residual crop,	130.9	53.9	69.0	135.6	44.1	118.7	-4.7	9.8	-49.7
T_9- MR +1 t PM+2 t/ha *Gliricidia loppings* and chickpea raised as residual crop,	96.9	23.3	71.6	133.0	45.5	128.9	-36.1	-22.2	-57.3
T_{10}- MR + 5 t FYM+2 t/ha *Gliricidia loppings* chickpea raised as residual crop,	100.6	33.3	94.7	128.5	46.0	132.7	-27.9	-12.7	-38.0
T_{11}-20 t FYM in maize and FYM 5 t/ha (Every year) in chickpea (every year)	162	62	179.5	152.8	53.5	173.4	9.2	8.5	6.1
T_{12}- STCR based 75%NPK + FYM 20 t/ha (once in every 4 years)	146.5	57.6	80.4	174.1	58.9	160.2	-27.6	-1.3	-79.8

positive while using RDF, IPNS modules, and high quantity of FYM was provided. The probable reason for the higher nutrient balance under balanced fertilization might be attributable to the addition of higher crop and root biomass and the advantageous effects of biological nitrogen fixation. (Behera *et al.*, 2007). The adoption organic manures in every season were not only saved the costly N fertilizer but also maintained highest positive nutrient balance in the soil (Singh *et al.*, 2022). Furthermore, a similar result was also observed in P balance in soil. The application of 20 t FYM/ha in every season maintained the highest P balance in soil, whereas, higher negative P balance (-71.8 kg/ha) was recorded in control plots. In case of K balance, there was a negative balance in all treatment except T11 treatment, where higher amount of FYM was received every year (25 t/ha). The negative K balance in the maize-chickpea system may be impacted by inadequate supply of K nutrition. (Singh *et al.*, 2022). Results indicated that there has been substantial build-up of N, P and K in plots receiving 25 t/ha FYM every year as compared to chemically mediated plots.

Therefore, it can be concluded that adoption of IPNS module (75% NPK +5 t/ha FYM) noticeably improved the growth, yield attributes, yields, system yield and nutrient uptake as compared to RDF. Residual fertility of organic manures had significant impact on chickpea growth and yield parameters, hence, it can be grown magnificently under residual fertility of IPNS modules with much higher yield without addition of any fertilizers. While, exclusive supply of greater quantity of FYM maintained the nutrient balance in soil. Thus, STCR based IPNS module is the best nutrient management technology for sustainable crop production.

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