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Effect of integrated plant nutrient supply (IPNS) system on growth, yield attributes and quality parameters of pigeon pea (*Cajanus cajan* (L) Millsp.) in vertisol

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Abstract
The present field experiment was conducted at Research Farm, Department of Soil Science**,** College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during *Kharif* 2023-24 find out the effect of integrated nutrient management practices on growth and yield and quality parameters of pigeon pea (*Cajanus cajan* (L) Millsp.) in vertisol. The experiment was laid out in Randomized Block Design (RBD) with three replications. There are 8 treatments combinations. Seed treatment of Pigeon pea done with Rhizobium and PSB @ 10 ml kg^{-1} seed before sowing. Among all the treatments, Application of 100% RDF (N: P_2O_5: K_2O) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSo_4$ @ 25 kg/ha significantly superior to control in respect to growth parameters i.e. Plant height, Number of branches and Number of Pods. The highest protein content & test weight and seed & straw yield were obtained with 100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha followed by 100% RDF (N: P_2O_5: K_2O $kgha^{-1}$) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg and lowest seed and straw yield was registered in absolute control.

Keywords: IPNS, rhizobium, vermicompost, PSB, yield, vertisol

Introduction
Sustainable farming depends upon the successful management of resources (Inputs) for Agriculture production and to satisfy the human need. No system of farming will be sustainable unless it does not care the health of soil, which plays a pivotal role in crop production. One such approach is use of different integrated nutrient management systems which can save the soil, environment and farmer's limited resources. Integrating inorganic, organic and biofertilizer are essential in realizing the higher pigeon pea yield and reducing cost of production was reported by Reddy *et al*. (2011) [13]. The work of various research workers indicated that integrated nutrient management practices may play significant role to promote growth and productivity of pigeon pea in a sustainable basis as well as soil health. Farmers apply an enormous amount of synthetic fertilizers in the soil to meet the increasing demands of the growing population. The excessive utilization of chemical fertilizers will cause serious environmental impacts which will degrade the soil fertility. The major utilization of chemicals in agricultural systems can be decreased through the integrated use of fertilizers along with available manures and crop residues. Integrated nutrient management involves maintaining soil fertility and plant nutrient availability at optimal levels to sustain desired productivity by maximizing the advantages of all available sources of organic, inorganic, and biological fertilizers. This comprehensive approach ensures that farming not only becomes more productive and profitable but also engages in environmental sustainability and responsibility.

Materials and Methods
The field experiment was conducted in the Kharif season during years 2023-2024 on medium deep black soil at Research Farm, Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Geographically the location of experimental site was 190 38'N

latitude and 740 65'E longitude. The altitude was 427.25 meter above the mean sea level. The soils of the present experimentation were classified as Vertisol order belonging to Parbhani soil series which comprise of fine Montmorillonite isohyperthermic family of *Typic Haplusterts*. The soils were dominant in montmorillonite mineral followed by moderate amount of kaolinite type of mineral and traces of Illite mineral. Geographically Parbhani is situated at 409 m above mean sea level between $19^0$18' North latitude and $70^0$47' East longitude in Marathwada division of Maharashtra semi-arid climate. Parbhani is grouped under assured rainfall zone. The average rainfall of the district is 1014.01 mm. The mean daily maximum temperature varied from 28.8 to 34.2 °C and the mean daily minimum temperature varied from 11.4 to 24.0 °C. The mean daily maximum relative humidity varied from 80 to 94% and the mean daily minimum relative humidity varied from 25 to 87%.

Eight treatments were used in the experiment, viz. T_1 Absolute Control, T_2 RDF 25:50:25 (N: P_2O_5: K_2O kg ha^{-1}), T_3 100% RDF (N: P_2O_5: K_2O kg $ha^{-1)}$ + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg., T_4 75% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg., T_5 100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha, T_6 75% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha, T_7 100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + $ZnSO_4$ @ 25 kg/ha and T_8 Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg the experiment was laid out in a Randomized Block Design (RBD) with eight treatments and three replications. Seeds were sown at the rate of 15 kg ha^{-1} for soybean. The fertilizers were applied @ N: P_2O_5: K_2 O 25:50:25 kg ha^{-1} respectively. Urea, single super phosphate and muriate of potash were used as fertilizer sources.

Results and Discussion

Plant height & Number of branches

The data regarding the plant height was recorded at 30, 60, 90 and 120 DAS of crop are presented in Table 1. The treatment T_5 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) recorded significantly higher plant height at 30, 60, 90 and 120 followed by treatments T_3 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg) recorded at 30 DAS and T_6 (75% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha). Minimum plant height was recorded in treatment T_1 (Absolute control).similar results reported by Kumawat *et al.* (2013) [6] found that among the integrated nutrient management treatments, application of 100% RDF + 50% N through vermicompost + 5 kg Zn ha^{-1} and 50% RDF + 100% N through vermicomopst + 5 kg Zn ha^{-1} were equally effective and significantly superior to the rest of the treatments with respect to growth (plant height and branches $plant^{-1}$).

Table 1: Effect of Integrated Nutrient management on plant height (cm) & Number of Branches of pigeon pea

Tr no.	Treatment details	Plant Height (cm)				No of Branches			
		30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
T_1	Absolute Control	22.56	52.53	92.1	124.35	2.22	4.64	6.27	10.13
T_2	RDF 25:50:25 (N: P_2O_5: K_2O kg ha^{-1})	24.17	53.92	96.46	126.52	2.64	4.97	6.45	11.43
T_3	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	27.03	61.58	110.45	137.3	3.27	5.51	7.56	11.54
T_4	75% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	26.17	54.36	102.61	134.52	2.97	4.57	7.13	11.53
T_5	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha	27.45	66.33	114.62	142.32	3.05	5.75	7.62	11.82
T_6	75% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha	26.98	55.34	108.49	136.19	2.85	5.34	7.42	11.99
T_7	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + $ZnSO_4$ @ 25 kg/ha	25.62	54	102.45	133.58	2.80	5.03	6.97	11.75
T_8	Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	23.83	53.61	96.13	125.99	2.53	4.75	6.77	10.57
	S.Em. ±	0.26	2.02	2.04	2.08	0.14	0.20	0.19	0.35
	C.D. at 5%	0.78	6.13	6.18	6.31	0.42	0.60	0.58	1.05
	C.V%	1.76	6.20	3.43	2.72	8.61	6.78	4.73	5.27

The number of branches of pigeon pea influenced by application of integrated nutrient management practices at 30, 60, 90 and 120 DAS are presented in Table 2. The treatment T_5 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) at 30,60,90 and 120 DAS recorded maximum number of branches followed by treatment T_3(100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg) and T_6 (75% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha).Whereas, minimum number of branches of plant was observed in treatment T_1 (Absolute control) at 30,60,90 and 120 DAS and all other treatments were significantly superior to it. The increase in number of branches in RDF and integrated nutrient management practices with micronutrients could be due to cell and internodal elongation, increased plant metabolism, there by promoting vegetative growth which is positively correlated with to productivity of plant.

Effect of Integrated nutrient management on Number of pods, yield attributes and yield of pigeon pea

Number of pods

The data regarding number of pods of pigeon pea were recorded at harvesting stage of crop are presented in table 2. Result show that number of pods per plant was significantly effected due to the application of integrated nutrient

management. The maximum number of pods 241.81 plant^{-1} was recorded in treatment T_5 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) followed by T_3 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg) and T_6 (75% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) at harvesting stage. The remaining all treatments shown significantly maximum number of pods plant^{-1} than treatment T_1 (Absolute control) which noted 148.31 plant^{-1} minimum number of pods. It clearly indicated that the application of chemical fertilizers and well decomposed vermicompost and its combination, produces more number of pods per plant could be owing to higher availability of plant nutrients which is conductive for physical environment which consequently in complementary effect was increased dry matter accumulation in the reproductive parts and formation of higher sink capacity with the addition of organics and resulted increased in number of pods of pigeon pea. Similar results were also found by Rahevar *et al.* (2015) [12], Sarade *et al*. (2016) [14] and Kamalakannan (2017) [4].

Grain yield and Straw yield

The data related to grain yield (kg ha^{-1}) as influenced by the application of integrated nutrient management are presented in table 2. The treatment T_5 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) recorded significantly higher grain yield 1846.45 kg/ha than rest of the treatments. Whereas the minimum grain yield was observed in treatment T_1 (Absolute control) 1385.01 kg/ha of pigeon pea. All treatments were significantly superior to it. Treatment T_3 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg) and T_6 (75% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) are at par with T_5. (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha).

The data regarding the straw yield were recorded after harvesting stage of crop are presented in table 2. Results indicated that application of integrated nutrient management significantly enhanced the straw yield of crop. The maximum straw yield was recorded in treatment T_5 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) noted significantly higher 4782.57 kg/ha over rest of the treatments. Whereas the minimum straw yield was observed in treatment T_1 (Absolute control) and all other treatments were significantly superior to it. However, the resultant treatment T_5 followed by treatment T_3 and T_6.

The increase in yield attributing character and yield might be due to plants synthesize more photosynthates and storage organ like seeds was better developed by *Rhizobium* inoculation. The seed yield of pigeon pea further increased with the soil application of zinc sulphate. The positive effect of K on crop yield might also be due to its requirement in carbohydrate synthesis and translocation of photosynthesis and also may be due to improved yield attributing characters, shoot growth and nodulation. Similar results are in compliance with the findings of Jat *et al*. (2013) [3], Mukundgowda *et al*. (2015) [7], Patil and Dhonde (2009) [11], Khrogamy and Farnia (2009) [5], and Ali *et al*. (2007) [1], Buriro *et al*. (2015) [2].

Table 2: Effect of Integrated nutrient management on Number of pods, yield attributes and yield of pigeon pea.

Tr no.	Treatment detail	Number of Pods (plant^{-1})	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})
T_1	Absolute Control	148.31	1385.01	3430.94
T_2	RDF 25:50:25 (N: P_2O_5: K_2O kg ha^{-1})	187.77	1702.99	4326.1
T_3	100% RDF (N: P_2O_5: K_2O kg ha^{-}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	230.29	1815.26	4667.57
T_4	75% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	224.33	1771.59	4335.4
T_5	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha	241.81	1846.45	4782.57
T_6	75% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha	227.01	1806.1	4405.75
T_7	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + $ZnSO_4$ @ 25 kg/ha	203.63	1726.33	4333.9
T_8	Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	163.73	1696.36	4061.04
	S.Em. ±	2.82	58.49	81.37
	C.D. at 5%	8.56	177.44	246.85
	C.V%	2.40	5.89	3.28

Effect of Integrated nutrient management on Quality parameters of pigeon pea

Test weight & Protein content

The data related to protein content as influenced by the application of integrated nutrient management are presented in table 3. The treatment T_5 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) recorded significantly higher grain yield 21.15% than rest of the treatments. Whereas the minimum grain yield was observed in treatment T_1 (Absolute control) 17.75% of pigeon pea. all treatments were significantly superior to it. Treatment T_3 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg) and T_6 (75% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) are at par with T_5. (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha). The increased protein content in pigeon pea under

T_5 might be due to the role of nitrogen and sulphur which are integral part of protein and phosphorus is structural element of certain co-enzymes which are proteinaceous in nature. These findings were in close conformity with those reported by Ola *et al.* (2013) [8].

Table 3: Effect of Integrated nutrient management on quality parameters of pigeon pea

Tr. No.	Treatments	Quality Parameter	
		Test Weight (g)	Protein Content (%)
T_1	Absolute Control	9.18	17.75
T_2	RDF 25:50:25 (N: P_2O_5: K_2O kg ha^{-1})	8.80	19.95
T_3	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	9.95	20.92
T_4	75% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	9.84	19.73
T_5	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha	10.02	21.15
T_6	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha	9.51	20.81
T_7	100% RDF (N: P_2O_5: K_2O kg ha^{-1}) + $ZnSO_4$ @ 25 kg/ha	8.80	19.20
T_8	Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg	9.33	18.81
	SE(m) ±	0.30	0.85
	C.D at 5%	0.92	2.58
	C.V%	5.57	7.43

The data regarding the Test weight were recorded are presented in table 4. Results indicated that application of integrated nutrient management significantly enhanced the test weight of crop. The maximum test weight was recorded in treatment T_5 (100% RDF (N: P_2O_5:K_2O kg ha^{-1}) + Vermicompost @ 2.5 t/ha + Rhizobium @ 10 ml/kg + PSB @ 10 ml/kg + $ZnSO_4$ @ 25 kg/ha) noted significantly higher 10.02 g over rest of the treatments. Whereas the minimum straw yield was observed in treatment T_1 (Absolute control) 9.18 g. and all other treatments were significantly superior to it. However, the resultant treatment T_5 followed by treatment T_3 and T_6. Pal *et al*. (2016) [9] noted that application of 100% recommended dose of fertilizer (30:60:20 NPK kg ha^{-1}) + 2.5 t (vermicompost), recorded higher test weight (108.22 g). Similar results obtained by Pandey *et al*. (2015) [10]

Conclusion

Based on results, it was concluded that for obtaining maximum growth, protein content and yield attributes in Pigeon pea by application of 100% RDF along with vermicompost and biofertilizer is necessary which resulted increase in yield over control. 25% reduction of inorganic fertilizer along with application of vermicompost and biofertilizer resulted in maximizing the growth parameters and yield increase over control. This data clearly indicated that the application of vermicompost and biofertilizer reduces the 25% RDF in combination with minimum yield reduction over 100% RDF. The application of Vermicompost along with reduced dose of RDF maintains the nutrient balance in the soil. So for maintenance of ecological sustainability application of 75% RDF along with vermicompost and biofertilizer to Pigeon pea crop was found beneficial.

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