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Research Article

EFFECT OF INTEGRATED PLANT NUTRITION SYSTEM (IPNS) AND INITIAL SOIL FERTILITY ON YIELD AND NPK UPTAKE BY PEARL MILLET ON INCEPTISOL

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Abstract- With a view to study the effect of initial soil fertility and Integrated plant Nutrition System (IPNS) on the yield of pearl millet (TNAU Cumbu Hybrid CO 9) on Vertic Ustropept of Tamil Nadu, field experiments were conducted during 2015-16 by following Inductive methodology (fertility gradient concept). Variations in soil fertility with reference to soil available N, P and K was established among the three fertility strips with the addition of fertilizers at graded levels and by growing fodder sorghum as gradient crop (first phase). The second phase *viz*., the test crop experiment with pearl millet, consisted of four levels each of fertilizer N, P_2O_5 and K_2O and three levels of farm yard manure (FYM). The highest yield of 4079 kg ha^{-1} was recorded with 150:75:75 kg ha^{-1} of fertilizer N, P_2O5 and K_2O along with 12.5 t ha^{-1} of FYM in strip III with initial soil available NPK status of 218, 37, 392 kg ha^{-1} respectively. The grain yield as well as NPK uptake by pearl millet had increased with increase in initial soil fertility and with increase in the levels of fertiliser N, P_2O_5 and K_2O and FYM

Keywords- Inceptisol, IPNS, Nutrient Uptake, Pearl Millet, Soil Fertility and Yield

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Introduction

India's major challenge during 21st century is to produce enough food, fodder, fibre, fuel so as to meet the diversified need of the burgoeing human and animal population of the country. This requirement can be achieved through enhanced productivity of diversified crops, using improved technology and increased cropping intensity [1]. Integrated Plant Nutrition System (IPNS) is an approach through which the management of plant nutrition and soil fertility in cropping and farming systems is adapted to site characteristics and to locally-available resources. IPNS ensures that plant nutrition be environmentally, socially and economically viable. Concurrently it encourages, informs, trains and organizes farmers to increase crop production while sustaining soil productivity.

The post green revolution scenario of Indian agriculture encompasses many problems such as stagnation or even decline in production and productivity growth rates of major crops, deterioration of soil fertility, decline in factor productivity, low diversity of production systems and increasing cost of production. These constraints have cropped-up partially as a result of continuous cropping without proper nutrient management and indiscriminate use of agrochemicals on soil and crops [2].

Pearl millet is one of the staple cereal crop in arid and semi-arid regions of world. It is the only cereal crop which have the capacity of producing a good yield under the marginal environments and simultaneously responds to high management conditions. Pearl millet is the most widely cultivated cereal in India after rice and wheat. India witnessed a major breakthrough in total production and productivity of pearl millet after the release of high yielding [3].

At present, nutrient mining is a major threat for agricultural soil as there is wide gap between nutrient addition and nutrient removal, one of the reason for lower production is imbalanced use of fertilisers by the farmers without knowing soil fertility status and nutrient requirement of crop which causes adverse effect on soil and crop both in terms of nutrient toxicity and deficiency. This practice not only deteriorates the soil health but also led to economical loss for farmers [4]. Therefore, integration of fertilisers with organic resources becomes necessary. In the light of ever increasing prices of fertilisers, it becomes rather more important to evaluate the extent to which fertilisers need of the crops can be reduced through conjoint use of organic manures [5].

The continuous addition of organic manures along with inorganic fertilisers may stimulate mineralization and immobilization of plant nutrients and thereby affecting their availability in different organic and inorganic forms of soil [6]. Organic manures is a valuable and renewable nutrient source, but their application alone to soil is not adequate to meet the nutrient demand of the modern varieties of the crop. Nevertheless, their continuous application enhances not only the biological activity and their biomass, diversity and soil physical properties but also enhances resistant and resilience capacity of soil [7, 1]. Therefore, integration of inorganic fertilisers with organic manures may go a long way in maintaining sustainable production and enhancing soil health through their complementary effects.

By considering these facts field investigations were undertaken to study the effect of IPNS and initial soil fertility levels on yield and NPK uptake by pearl millet on an Inceptisol.

Materials and Methods

Field experiments were conducted during 205-16 to study the effect of IPNS and initial soil fertility levels on yield and NPK uptake by pearl millet (TNAU Cumbu Hybrid CO 9) on a Vertic Ustropept at farmer's holding of Coimbatore district.

Basic concept

The methodology adopted in this study is the 'prescription procedure' outlined by Truog (1960) [8] and modified by Rammamoorthy *et al*. (1967) [9] as 'Inductive

cum Targeted yield model' which provides a scientific basis for balanced fertilization between applied nutrients and soil available nutrients. Operational range of variation in soil fertility was created deliberately to generate data covering appropriate range of values for each controllable variable (fertilizer dose) at different levels of uncontrollable variable (soil fertility) which could not be expected at one place normally. Hence, in order to create fertility variations in the same field, a gradient experiment (phase I) was conducted prior to the test crop experiment (phase II) to reduce the heterogeneity in the soil population studied, management practices adopted and climatic conditions prevailing.

Experimental site

Field experiments were conducted at the farmer's holdings of Coimbatore district, Tamil Nadu on Inceptisol (Vertic Ustropept). The soil of the experimental field belongs to Periyanaickenpalayam series which is mixed black calcareous, moderately deep and well drained, sandy clay loam in texture with a pH of 8.10 and electrical conductivity (EC) of 0.14 dS m^{-1}. The initial soil available N, P and K status were 182, 16.5 and 346 kg ha^{-1}, respectively. The P and K fixing capacities of the soil were 100 and 80 kg ha^{-1}, respectively. Sufficient range of DTPA extractable iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) recorded.

Phase I-Gradient experiment

In the first phase, the field was divided into three equal strips and three artificial fertility gradients were created following Inductive methodology [9] by applying graded doses of N, P and K fertilisers so as to get an operational variation in one and the same field to evaluate the set relationship between the yield of the crop and fertility. Fodder sorghum was grown as exhaust crop (gradient crop) to stabilize the soil nutrients and to create equilibrium conditions. The graded dose of fertilisers for Strip I (SI), Strip II (SII) and Strip III (SIII) was $N_0P_0K_0$, $N_1P_1K_1$ and $N_2P_2K_2$, respectively. The standard dose of fertiliser P_2O_5 and K_2O were fixed based on the phosphorus and potassium fixing capacities of the soil and the standard dose of N is fixed as per the general recommendation for fodder sorghum (90 kg ha^{-1}). An operational range of soil test values in respect of available N, P and K were created.

Phase II- Test crop experiment

After the harvest of exhaust crop, the field was well prepared for the test crop *i.e.* pearl millet, without disturbing the fertility gradients. Each of these three strips were sub-divided into 24 plots, of which 21 plots in each strip received fertiliser treatments with various selected combinations and four levels of fertiliser N (0, 50, 100 and 150 kg ha^{-1}), P_2O_5 (0, 25, 50 and 75 kg ha^{-1}) and K_2O (0, 25, 50 and 75 kg ha^{-1}) while other three were kept as unfertilized (control). These treatments were randomly divided in three groups (A, B and C), each group encompassing seven fertiliser treatments and one control (unfertilized). Across the strip; each strip was divided into three equal blocks (I, II and III). Block II and III were treated with organic manure *viz.*, Farm Yard Manure (FYM) while block I is maintained without FYM. Quantity of organic manure (12.5 t ha^{-1}) in block III was doubled to that of block II (6.25 t ha^{-1}). The remaining three plots in each strip were kept as control [Fig-1]. By this way of both side randomisation all the 24 treatments occur randomly either taken from north to south or from east to west directions. The design of the experiment was Fractional Factorial and the treatment structure is given in [Table-1].

The fertiliser sources used were Urea, Single Super Phosphate and Muriate of Potash. Full dose of P_2O_5 and K_2O and 25 per cent of N was applied at the time of sowing and 50 and 25 per cent was top dressed at 15 and 30 days after sowing of pearl millet, respectively. Representative pre-sowing soil samples (0-15 cm) were collected from each of the 72 plots and were analyzed for available N, P and K before sowing of the crop by alkaline $KMnO_4$ method [10] and 0.5 M $NaHCO_3$ extractable P [11]. Available K in soil was extracted by neutral normal ammonium acetate [12] and determined flame photometrically. The grain and straw yields were recorded plot wise and grain and straw samples from each plot were analyzed for total N) [13], P and K [14] contents and uptake of N, P and K by pearl millet were computed.

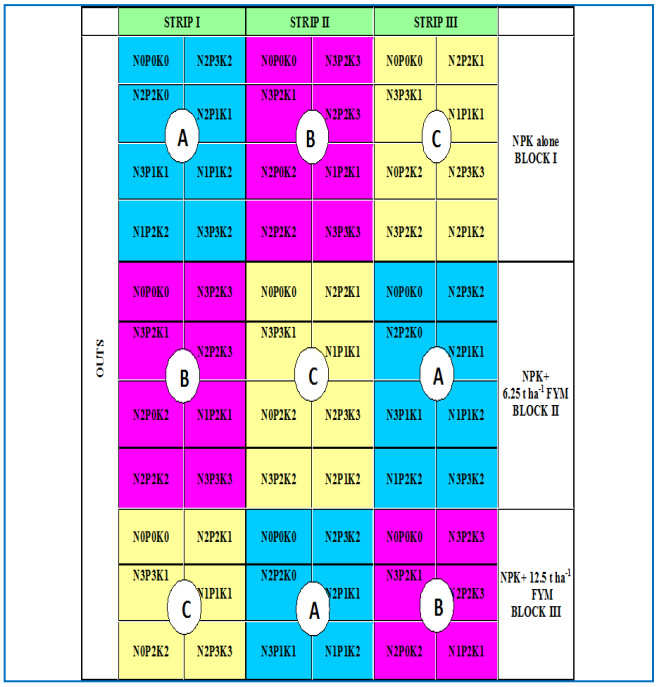

Fig-1 Layout of Test crop experiment with Pearl Millet

Table-1 *Treatment structure for test crop experiment (Pearl millet)*

Sl. No	Treatment combination			Levels of nutrients (kg ha^{-1})		
	N	P	K	N	P_2O_5	K_2O
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	2	2	0	50	50
5	1	1	1	50	25	25
6	1	2	1	50	50	25
7	1	1	2	50	25	50
8	1	2	2	50	50	50
9	2	1	1	100	25	25
10	2	0	2	100	0	50
11	2	1	2	100	25	50
12	2	2	2	100	50	50
13	2	2	1	100	50	25
14	2	2	0	100	50	0
15	2	2	3	100	50	75
16	2	3	2	100	75	50
17	2	3	3	100	75	75
18	3	1	1	150	25	25
19	3	2	1	150	50	25
20	3	2	2	150	50	50
21	3	3	1	150	75	25
22	3	3	2	150	75	50
23	3	2	3	150	50	75
24	3	3	3	150	75	75

Results and Discussion

The range and mean of initial soil test values, yield and NPK uptake in various fertility strips were given in [Table-2]. The range and mean values of initial soil test values, yield and nutrient uptake of NPK treated and NPK control plots were given in [Table-3].

Soil fertility

The results showed that pre-sowing soil test values of $KMnO_4$-N ranged from 168 to 176, 193 to 202 and 213 to 221 kg ha^{-1} with a mean of 172, 198 and 217 kg ha^{-1} in strip I, II and III, respectively. The pre-sowing soil test values of Olsen-P in strip I ranged from 12 to 14 with a mean of 13.0 kg ha^{-1}, from 24 to 29 kg ha^{-1} with a mean of 26 kg ha^{-1} in strip II and from 33 to 37 kg ha^{-1} with a mean of 36 kg ha^{-1} in strip III. The pre-sowing soil test values of NH_4OAc-K in strip I ranged from 326-

333 kg ha^{-1} with a mean of 330 kg ha^{-1}, from 367 to 373 kg ha^{-1} with a mean of 369 kg ha^{-1} in strip II and from 385 to 393 kg ha^{-1} with a mean of 388 kg ha^{-1} in strip III. The $KMnO_4$-N varied from 168 to 221 kg ha^{-1} with a mean of 196 kg ha^{-1}; Olsen-P from 12 to 37 kg ha^{-1} with a mean of 25 kg ha^{-1} and NH_4OAc-K from 326 to 393 kg ha^{-1} with a mean of 363 kg ha^{-1} in NPK treated plots. The range and mean of $KMnO_4$-N, Olsen-P and NH_4OAc-K in control plots were 168 to 216, 12 to 35 and 327 to 391 and 192, 24 and 362 kg ha^{-1}, respectively.

Table-2 *Initial soil available NPK, yield and NPK uptake by pearl millet in various strips of test crop experiment*

Parameters (kg ha^{-1})	Strip I		Strip II		Strip III		Overall			
							NPK Treated		NPK Control	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$-N	168-176	172	193-202	198	213-221	217	168-221	196	168-216	192
Olsen-P	12-14	13.0	24-29	26	33-37	36	12-37	25	12-35	24
NH_4OAc-K	326-333	330	367-373	369	385-393	388	326-393	363	327-391	362
Grain Yield	1303-3140	2583	1530-4030	3225	1703-4079	3395	2224-4079	3247	1303-2270	1811
N uptake	41.9-85.4	71.0	45.8-119.0	92.6	49.5-127.1	102.7	61.7-127.1	93.7	41.9-66.4	54.7
P uptake	5.02-16.3	12.8	7.87-23.2	17.9	10.8-25.7	20.5	10.7-25.7	18.1	5.02-14.1	10.3
K uptake	36.2-67.0	56.9	41.2-84.1	68.6	47.2-92.4	75.9	51.2-92.4	69.7	36.2-59.1	49.2

Table-3 *Initial soil available NPK, yield and NPK uptake by pearl millet in absolute control and FYM alone blocks*

Parameters (kg ha^{-1})	Absolute control		6.25 t FYM ha^{-1}		12.5 t FYM ha^{-1}	
	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$-N	168-213	191	171-216	194	168-213	191
Olsen-P	14-33	24	13-35	24	12-34	23.33
NH_4OAc-K	330-386	361	332-391	364	327-386	360
Grain Yield	1303-1703	1512	1623-2121	1884	1779-2270	2037
N uptake	41.9-49.5	45.7	50.1-61.6	56.5	57.9-63.0	60.7
P uptake	5.02-10.8	7.90	8.50-12.9	10.8	10.1-13.9	12.1
K uptake	36.2-47.2	41.5	45.8-55.5	51.2	49.8-59.1	54.9

In absolute control plots, the range of $KMnO_4$-N, Olsen-P and NH_4OAc-K were 168 to 213, 14 to 33 and 330 to 386 kg ha^{-1} with mean values of 191, 24 and 361 kg ha^{-1}, respectively. The range of $KMnO_4$-N, Olsen-P and NH_4OAc-K in 6.25 t FYM ha^{-1} alone plots were 171 to 216, 13 to 35 and 332 to 391 kg ha^{-1} with a mean of 194, 24 and 364 kg ha^{-1}, respectively. The range and mean values of 12.5 t FYM ha^{-1} alone plots were 168 to 213, 12 to 34 and 327 to 386 kg ha^{-1} and 191, 23 and 360 kg ha^{-1}, respectively [Table-3].

The per cent increase in $KMnO_4$-N status of SII over SI was 13.13 and SIII over SI and SII was 20.74 and 8.76. The increase in Olsen-P status of SII over SI was 50.0 and SII and SIII over SI and SII was 63.9 and 27.8 per cent, respectively. The per cent increase in NH_4OAc-K was 10.6 in SII over SI and 15.0 in SIII over SI and 4.90 per cent over SII. Due to the application of graded levels of fertilisers, notable fertility variations were recorded in various strips. The built-up of available N levels among various strips might be due to the better adsorption of NH_4^+ ions by organic and inorganic colloids of soil [15]. Similar trend of results was reported by Kadu and Bulbule (2007) [16] in finger millet on Typic Ustropept and Singh *et al*. (2014) [5] in wheat on Inceptisol.

Grain yield

The maximum and minimum yield in IPNS and NPK control plots were given in [Table-4]. Among the IPNS plots, the highest yield of 4079 kg ha^{-1} was recorded in the plot that received 150:75:75 kg ha^{-1} of fertiliser N, P_2O_5 and K_2O along with FYM in strip III with the initial soil available NPK status of 218, 37 and 392 kg ha^{-1}, respectively. The increase in grain yield was 48.5 per cent compared to the treatment that received 0:50:50 kg ha^{-1} of fertiliser N, P_2O_5 and K_2O along with 12.5 t ha^{-1} of FYM.

Table-4 *Effect of initial soil available NPK status and IPNS (NPK+FYM) on grain yield and N, P and K uptake by pearl millet (kg ha^{-1})*

S.No	Particulars	Strip	Soil Test Values (kg ha^{-1})			Fertiliser doses (kg ha^{-1})			FYM (t ha^{-1})	Yield (kg ha^{-1})	Total Uptake (kg ha^{-1})		
			N	P	K	N	P_2O_5	K_2O			N	P	K
NPK Treated plots													
1.	Minimum yield	I	176	13	330	0	50	50	12.5	2224	61.7	10.6	51.2
2.	Maximum yield	III	218	37	392	150	75	75	12.5	4079	127.1	25.7	92.4
NPK Control plots													
1.	Minimum yield	I	168	14	330	0	0	0	0	1303	41.9	5.02	36.2
2.	Maximum yield	III	213	34	386	0	0	0	12.5	2270	66.4	14.1	59.1

Among the NPK control plots, the highest grain yield of 2270 kg ha^{-1} was recorded in strip III with the application of FYM @ 12.5 t FYM ha^{-1} with the initial soil test values of 213, 34 and 386 kg ha^{-1} of NPK respectively. The lowest yield of 1303 kg ha^{-1} was recorded in strip I under absolute control with initial soil test values of 168, 12 and 326 kg ha^{-1} of available NPK respectively. Application of 12.5 t ha^{-1} of FYM alone has shown considerable improvement in grain yield and the increase in yield was 42.60 per cent over absolute control. The increase in grain yield in 6.25 t FYM ha^{-1} alone plots over absolute control plots was 19.75 per cent. Per cent increase of 12.5 t FYM ha^{-1} alone plots over absolute control and 6.25 t FYM ha^{-1} alone plot was 25.76 and 7.50, respectively.

This might be due to the improvement in physico-chemical properties of soil and supply of the nutrients in balanced amount and slow release of nutrients through integrated use of FYM, which helped to produce more numbers of grains/ear and ear length. The integrated use of fertilisers with organic manures might have enhanced the organic matter in soil that would have increased the grain yield availability of plant nutrients [4]. Geetha Kumari *et al*. (2011) [17] also reported that FYM application as compared to the NPK alone treatments enhanced physical, chemical and biological properties of soil. Further, the addition of organic manure also maintains regular supply of macro and micronutrients in soil resulting in higher yield. These results are in conformity with the earlier work [18, 2, 5]. The results indicated that higher grain yield could be achieved through integrated supply of nutrients from different sources. Similar, findings were reported by Meena *et al*. (2013) [19] and Saraswathi *et al*. (2015) [20].

Nutrient uptake

The data on nutrient uptake showed that N uptake ranged from 41.9 to 85.4 kg ha^{-1} with a mean of 71.0 kg ha^{-1} in strip I, from 45.8 to 119.0 kg ha^{-1} with a mean of 92.6 kg ha^{-1} in strip II and in strip III the N uptake ranged from 49.5 to 127.1 kg ha^{-1} with a mean of 102.7 kg ha^{-1}. The P uptake ranged from 5.02 to 16.3 kg ha^{-1} with a mean of 12.80 kg ha^{-1} in strip I, from 7.87 to 23.2 kg ha^{-1} with a mean of 17.9 kg ha^{-1} in strip II and in strip III, the P uptake ranged from 10.8 to 25.7 kg ha^{-1} with a mean of 20.5 kg ha^{-1}. The K uptake in strip I ranged from 36.2 to 67.0 kg ha^{-1} with a mean of 56.9, from 41.2 to 84.1 kg ha^{-1} with a mean of 68.6 in strip II and in SIII the K uptake ranged from 47.2 to 92.4 kg ha^{-1} with a mean of 75.9 kg ha^{-1}. The overall range and mean values of N, P and K uptake in NPK treated plots were 61.7 to 127.1, 10.7 to 25.7 and 51.2 to 92.4 kg ha^{-1} with a mean of 93.7, 18.1 and 69.7 kg ha^{-1} , repectively. The range and mean values of N, P and K uptake in over all control plots were 41.9 to 66.4, 5.02 to 14.1 and 36.2 to 59.1 kg ha^{-1} with a mean of 54.7, 10.3 and 49.2 kg ha^{-1}, respectively.

The range and mean values of N, P and K uptake in absolute control plots were 41.9 to 49.5, 5.02 to 10.8 and 36.2 to 47.2 kg ha^{-1} with the mean of 45.7, 7.90 and 41.5 kg ha^{-1}, respectively. The N, P and K uptake range from 50.1 to 61.6, 8.50 to 12.9 and 45.8 to 55.5 kg ha^{-1} in 6.25 t FYM ha^{-1} alone plots with the mean of 56.5, 10.8 and 51.2 kg ha^{-1}, respectively. The range and mean values of N, P and K uptake in 12.5 t FYM ha^{-1} alone plots were 57.9 to 63.0, 10.1 to 13.9 and 49.78 to 59.1 and 60.7, 12.1 and 54.9 kg ha^{-1}, respectively. The increase in N, P and K uptake in 6.25 t FYM ha^{-1} alone plots was 19.0, 26.8 and 18.8 per cent over absolute control plots. The increase in N, P and K uptake in 12.5 t FYM ha^{-1} alone plots over absolute control and 6.25 t FYM ha^{-1} alone plots were 24.7, 34.6 and 24.3 and 6.96, 10.6 and 6.80 per cent, respectively.

The increase in N uptake might be due to release of N as a result of decomposition of FYM. Addition of organic manure increased the microbial population which resulted in the enhanced availability of nitrogen. The total uptake of P by pearl millet increased with FYM application over control, which might be associated with physiological stimulation of plant rather than increased ramification of root system [21]. Sharma *et al*. (2016) [4] also recorded that highest P and K uptake of 22.8 and 184.3 kg ha^{-1}, respectively by pearl millet with soil test based fertiliser application along with 10 t FYM ha^{-1} indicating higher assimilation and uptake of P due to combined application of FYM with inorganic fertilisers. The higher nutrients uptake with FYM might be attributed to solubilisation of native nutrients, chelation of complex intermediate organic molecules produced during decomposition of added FYM, its mobilization and accumulation of different nutrient in different plant parts [7]. Addition of FYM along with inorganic fertilisers had a beneficial effect in increasing the K availability and similar results were reported by Sharma *et al*. (2015) [1].

Conclusion

It may be concluded from the present study that IPNS and initial soil fertility had profound effect on grain yield and NPK uptake by pearl millet as compared to application of inorganic fertilisers alone. Thus, application of fertiliser along with FYM can play a vital role in achieving high yield potential of pearl millet through its beneficial effect on nutrients supply and soil properties.

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Author Contributions

1. Corresponding Author (S. UDAYAKUMAR)– Designed the study and carried out the implementation including field work and analysis (both samples and data) and interpretation of data. Drafting the research work and revised it critically for important contents and approved the research paper for publication
2. Co-Author (R.SANTHI)– Acted as a guide (Chairperson) and provided substantial contribution to design the work to be carried out and contributed to interpretation of data and drafting the research work and critically reviewed the data and also approved the revised article to be published. This author also contributed equally to this work

Abbreviations

FYM - Farm Yard Manure
IPNS - Integrated Plant Nutrition System
K – Potassium
N – Nitrogen
P – Phosphorus

Conflict of Interest: None declared

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