Effect of initial soil fertility and integrated Plant Nutrition System on yield and NPK uptake by barnyard millet

ABSTRACT

This study examined the effect of soil fertility and Integrated Plant Nutrition System (IPNS) on the yield of barnyard millet (*var.* MDU 1) on the field of Eastern Block Farm in Tamil Nadu Agricultural University. Coimbatore. based on the inductive technique (fertility gradient concept). Among the three fertiliser strips, the first phase of the experiment involved adding graded fertilisers and growing fodder sorghum as a gradient crop to develop soil fertility variations. During the second phase, the barnyard millet test crop experiment included four levels each of N, P_2O_5, and K_2O fertilizers, plus three levels of farmyard manure (FYM). The results show that overall yield recorded in the highest initial fertility strip III. The highest yield of 2966 kg ha^{-1} was obtained with 60:30:40 kg ha^{-1} of N, P_2O_5, and K_2O along with 12.5 t ha^{-1} of FYM in strip II with initial soil available NPK status 198, 31, and 521 kg ha^{-1}, respectively. The lowest yield 1056 kg ha^{-1} was recorded in strip I under absolute control and the initial soil test values were 157, 13 and 470 kg ha^{-1} of $KMnO_4$-N, Olsen-P and NH_4OAc-K, respectively. Application of 12.5 t ha^{-1} of FYM alone increased yield of barnyard was 27.73 per cent over absolute control. Barnyard millet grain production and NPK uptake rose when initial soil fertility and fertiliser N, P_2O_5, K_2O, and FYM levels increased.

Key words: Barnyard millet, Initial Soil fertility. IPNS, Nutrient uptake,

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 burgeoning human and animal population of the country. This demand may be met by higher agricultural production of diverse crops, improved technologies, and greater cropping intensity [1]. The Integrated Plant Nutrition System (IPNS) is a method of managing plant nutrition and soil fertility in cropping and agricultural systems that is tailored to site features and locally accessible resources. IPNS guarantees that plant nutrition is ecologically, socially, and economically sustainable. Concurrently, it motivates, informs, trains, and organises farmers to improve the crop yield while maintaining soil fertility.

After the green revolution, Indian agriculture is faced with many challenges, including stagnant or even declining production and productivity growth rates of major crops, deteriorated soil fertility, declining factor productivity, low diversity of production systems and rising production costs as a result of continuous cropping without proper nutrient management and the indiscriminate use of agrochemicals on soil and crops, these constraints have emerged [2].

At the moment, nutrient mining is a major threat to agricultural soil because there is a large gap between nutrient addition and nutrient removal. One of the reasons for lower production is farmers' imbalanced use of fertilisers without knowing soil fertility status and crop nutrient requirements, which causes adverse effects on soil and crop both in terms of nutrient toxicity and deficiency. This practice not only deteriorated the soil health but also led to economical loss for farmers [3]. Therefore, integration of fertilisers with organic resources becomes necessary. The overall strategy for increasing crop yields on a sustainable basis could be the conjunctive use of organic and inorganic sources of nutrients, along with other complementary measures. Organics are known to have favourable effects on soil structure, texture, and tilth and facilitate quick and greater availability of plant nutrients.

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 [2].

The constant addition of organic manures combined with inorganic fertilisers may accelerate mineralization and immobilisation of plant nutrients, altering their availability in various organic and inorganic forms of soil. 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 [4]. 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 barnyard millet on an Inceptisol.

MATERIALS AND METHODS

A field experiment was conducted with barnyard millet (*var.* MDU 1) during 2019-2020 on Vertic Ustropept at Eastern Block farm of Tamil Nadu Agricultural University, Coimbatore Tamil Nadu. The surface soil of the experimental field is mixed black-calcareous, sandy clay loam in texture with pH 8.3, electrical conductivity (EC) 0.49 dS m^{-1}. The initial soil available N ($KMnO_4$-N), P (Olsen-P) and K (NH_4OAc-K) status were 175, 21.0 and 505 kg ha^{-1}, respectively. The P and K fixing capacities of the soil were 100 and 80 kg ha^{-1}, respectively. The DTPA extractable iron (Fe), zinc (Zn), and copper (Cu) were sufficient in availability while manganese (Mn) was in the sufficiency range.

The fertility gradient in the experimental field was created using inductive methodology [5]. The experimental field was divided into three equal strips with N0P0K0 (S I), N1P1K1 (S II), and N2P2K2 (S III) levels, and a gradient crop of fodder sorghum (var. CO 30) was grown. Twenty-four soil samples were collected from each strip before and after the gradient crop was harvested and analysed for alkaline $KMnO_4$-N, Olsen-P, and NH_4OAc-K, and the soil test values were compared. Strip yields of fodder were recorded, and plant samples were collected and analysed for N, P, and K content, as well as N, P, and K uptake values. The data on post-harvest soil available N, P, and K, fodder yield, and N, P, and K uptake confirmed the formation of a soil fertility gradient among the three strips.

Following the development of soil fertility gradients, each strip was split into 24 plots, each of which included twenty-four treatments with four levels of N (0, 20, 40, and 60 kg ha^{-1}), P_2O_5 (0, 10, 20, and 30 kg ha^{-1}) and K_2O (0,10, 20, and 30 kg ha^{-1}) (0, 20, 40, and 60 kg ha^{-1}). The fractional factorial design was used for the test crop experiment, and the treatment structure is shown in Table 1. Each strip included twenty-four treatments, for a total of seventy-two plots, nine of which were NPK control plots and sixty-three of which were NPK treated plots. FYM @ 0, 6.25, and 12.5 t ha^{-1} IPNS treatments were placed across the strips. The treatments were randomised such that all 24 treatments might occur in any direction, and the test crop barnyard millet was cultivated (both side randomization). The initial surface soil samples from all plots were collected and analysed for alkaline $KMnO_4$-N, Olsen P, and NH_4OAc-K status. Grain and straw yields were recorded, and plot-specific grain and straw samples were analysed for total N [6], P and K [7] contents, as well as the uptake of N, P, and K by barnyard millet.

Table-1 Treatment structure for test crop experiment (barnyard 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	20	40
5	1	1	1	20	10	20
6	1	2	1	20	20	20
7	1	1	2	20	10	40
8	1	2	2	20	20	40
9	2	1	1	40	10	20
10	2	0	2	40	0	40
11	2	1	2	40	10	40
12	2	2	2	40	20	40
13	2	2	1	40	20	20
14	2	2	0	40	20	0
15	2	2	3	40	20	60
16	2	3	2	40	30	40
17	2	3	3	40	30	60
18	3	1	1	60	10	20
19	3	2	1	60	20	20
20	3	2	2	60	20	40
21	3	3	1	60	30	20
22	3	3	2	60	30	40
23	3	2	3	60	20	60
24	3	3	3	60	30	60

RESULT 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 data on pre-sowing soil test values revealed that the $KMnO_4$-N values were 157 to 165, 188 to199, and 216 to 224 kg ha^{-1} with mean of 161,195 and 221 kg ha^{-1} in strip I, II, and III, respectively. The pre-sowing soil test value of Olsen-P in strip I ranged from 13.0 to 17.0 with 15.4 kg ha^{-1}, from 25 to 31 kg ha^{-1} with a mean 28.9 kg ha^{-1} in strip II and from 36 to 41 kg ha^{-1} with a mean of 39.0 in strips III. For NH_4OAC-K in strip I ranged from 470 to 478 kg ha^{-1} with a mean values of 473 kg ha^{-1} in strips I, from 512 to 521 kg ha^{-1} with a mean of 516 kg ha^{-1} and from 529 to 538 kg ha^{-1} with a mean value of 533 kg ha^{-1}.

The $KMnO_4$-N varied from 157 to 224 ka ha^{-1} with a mean of 193 kg ha^{-1}. Olsen-P from13 to 41 kg ha^{-1} with a mean of 28 kg ha^{-1} and NH_4OAC-K from 470 to 538 kg ha^{-1} with a mean of 508 kg ha^{-1} in NPK treated plots. In control plots range and mean value of $KMnO_4$-N, Olsen-P and NH_4OAC-K were 157 to 221, 13 to 39 and 470 to 530 and 189, 25 and 505 kg ha^{-1}.

In absolute control plots, the range of $KMnO_4$-N, Olsen-P and NH_4OAC-K were 157 to 221, 13 to 36 and 476 to 529 kg ha^{-1} with mean values of 189, 25 and 506 kg ha^{-1}, respectively. The range of $KMnO_4$-N, Olsen-P and NH_4OAC-K in 6.25 t FYM ha^{-1} alone were 157 to 221, 13 to 37 and 471 to 530 kg ha^{-1} with mean of 189, 25 and 505 kg ha^{-1}, respectively. The range and mean value of 12,5 t FYM ha^{-1} alone plots were 160 to 216, 14 to 39 and 470 to 529 kg ha^{-1} and 188, 26 and 504 kg ha^{-1},

Due to the application of graded levels of fertilizers, notable fertility variations were recorded in various strips which were due to the application of graded levels of fertilizer N, P_2O_5 and K_2O. The increase in $KMnO_4$-N status of SII over SI was 21.11 per cent and SIII over SI was 37.3 and SIII over SII was 13.3 per cent. The increase in available N in soil owing to the greater adsorption of NH_4^+ ions by organic and inorganic colloids of the soil may be attributable to the better adsorption of NH_4^+ ions by organic and inorganic colloids of the soil [8].

The percent increase in Olsen-P of SII over SI was 87.7 percent, SIII over SI was 153.9 percent, and SIII over SII was 35.3 percent (Table 2). The enhanced availability of P may be ascribed to the administration of phosphatic fertiliser at graded levels that are either equal to or greater than the experimental field's P fixing capability; otherwise, more P would have remained in the soil solution [9].

In case of NH_4OAc-K the per cent increase was 9.1 in SII over SI, 12.7 in SIII over SI and 3.3 in SIII over SII (Table 2). The possible reasons are due to (i) the application of graded levels of potassic fertilizers either on par with or over and above the K fixing capacity of the soil and (ii) the probable retention of the added K by the soil colloids in the exchangeable form [10]. The outcome of the gradient experiment clearly showed that an operational range of soil test values was recorded in the present study and the magnitude of increase was higher for P followed by N and K.

Table 2. Pre-sowing soil available N, P and K, yield and N, P and K uptake by barnyard millet in NPK treated and control plots of test crop experiment (stripwise)

Parameters	Strip I		Strip II		Strip III		Treated plot		Control plot	
	Range	Mean	Range	Mean	Range	Mean	Range	mean	Range	mean
	---------------------------------------(kg ha^{-1}) ---------------------------------------									
$KMnO_4$-N	157-165	161	188-199	195	216-224	221	157-224	193	157-221	189
Olsen-P	13-17	15.4	25-31	28.9	36-41	39.1	13-41	28	13-39	25
NH_4OAc-K	470-478	473	512-521	516	529-538	533	470-538	508	470-530	505

Grain Yield	1588-2380	1914	1218-2966	2297	1350-2940	2428	1588-2966	2330	1056-1716	1390
N uptake	36.1-52.4	45.5	44.4-76.9	57.5	46.7-79.2	70.0	42.9-79.2	59.0	36.1-63.4	48
P uptake	5.26-12.7	9.70	8.94-17.0	13.2	11.1-18.1	15.2	8.14-18.1	13.1	5.26-12.8	9.6
K uptake	28.9-57.5	45.4	35.8-72.1	53.2	37.4-76.8	59.0	40.7-76.9	54.3	28.9-48.9	40.3

Table3. Initial soil available NPK, yield and NPK uptake by barnyard millet in absolute control and FYM alone blocks

Parameter kg ha^{-1}	**Absolute control**		**6.25 t Fym ha^{-1}**		**12.5 t Fym ha^{-1}**	
	range	**mean**	**Range**	**mean**	**Range**	**Mean**
KMnO4-N	157-221	189	157-221	189	160-216	188
Olsen- P	13-36	25	13-37	25	14-39	26
NH4OAc-K	476-529	506	471-530	505	470-529	504
Grain yield	1056-1350	1208	1218-1598	1419	1344-1716	1543
N uptake	36.10-46.73	42.40	40.12-58.67	49.54	42.00-63.39	51.10
P uptake	5.26-11.10	8.43	6.94-12.16	9.91	7.65-12.84	10.45
K uptake	28.86-37.36	33.99	38.90-46.98	42.79	39.97-48.89	44.09

Grain Yield

The mean grain yield of barnyard millet was 1914, 2297 and 2428 kg ha^{-1}, respectively in strips I, II, and III. The mean yield increase in SII over SI was about 20.01 per cent and SIII over SI was 26.85 per cent and SIII over SII was 5.70 per cent (Table 2).

The maximum and minimum yield in IPNS plots and NPK control plots were given in Table 4. Among IPNS plots, the highest yield of 2966 kg ha^{-1} was recorded in the plot that received 60:30:40 kg ha^{-1} of fertilizer N, P_2O_5 and K_2O along with 12.5 t ha^{-1} of FYM in strip II with initial soil available NPK status of 198, 31 and 521 kg ha^{-1} respectively. The per cent increase in yield was 69.96 as compared to the treatment that received 0:20:40 kg ha^{-1} of N, P_2O_5, K_2O and 12.5 t ha^{-1} FYM.

Table.4 Effect of pre-sowing soil available N, P and K status and IPNS (NPK+FYM) on grain yield and N, P and K uptake by barnyard millet

S. N	**Particulars**	**Strip**	**Soil Test Values**	**Fertiliser doses (kg ha^{-1})**	**FYM (t ha^{-1})**	**Grain Yield**	**Total Uptake (kg ha^{-1})**

o			(kg ha^{-1})							(kg ha^{-1})			
			SN	**SP**	**SK**	**FN**	**FP_2O_5**	**FK_2O**			**UN**	**UP**	**UK**
						NPK Treated plots							
1.	Minimum yield	I	162	17	473	0	20	40	12.5	1588	42.9	8.1	41.2
2.	Maximum yield	II	198	31	521	60	30	40	12.5	2966	76.9	17.0	72.1
						NPK Control plots							
1.	Minimum yield	I	157	13	476	0	0	0	0	1056	36.1	5.3	28.9
2.	Maximum yield	III	216	39	529	0	0	0	12.5	1716	63.39	12.8	48.9

Among the NPK control plots (Table 3), the highest grain yield of 1716 kg ha^{-1} was recorded in strip III with the application of FYM @ 12.5 t ha^{-1} with initial soil test values of 216, 39 and 529 kg ha^{-1}of $KMnO_4$-N, Olsen-P and NH_4OAc-K, respectively. The lowest yield of 1056 kg ha^{-1} was recorded in strip I under absolute control and the initial soil test values were 157, 13 and 473 kg ha^{-1} of $KMnO_4$-N, Olsen-P and NH_4OAc-K, respectively.

Application of 12.5 t ha^{-1} of FYM alone has shown considerable improvement in yield and the increase in yield was 27.73 per cent over absolute control. The increase in grain yield in 6.25 t ha^{-1} alone plots over absolute control plots was 17.46 per cent, per cent increase of 12.5 t FYM ha^{-1} alone plots over 6.25 t FYM ha^{-1} alone plot was 8.73, respectively.

This could be due to an improvement in the physico-chemical properties of the soil and the supply of nutrients in balanced amounts, as well as the production of slow nutrients through the integrated use of FYM, which helped to produce more grains and ear length. The combined use of fertilisers and organic manures may have increased soil organic matter, which would have increased grain yield availability of plant nutrients [1] . FYM application, as compared to NPK alone treatments, improved the physical, chemical, and biological properties of soil, according to [11]. Further more, the addition of organic manure also maintains regular supply of macro and micronutrients in soil resulting in higher yield. These findings are consistent with previous research (Sharma and Subenia. [12], Singh *et al.,* [13], Gupta *et al*., [14]). The findings suggested that higher grain yields could be obtained by integrating the supply of nutrients from various sources. Saraswathi *et al*. [15] found similar results.

Nutrient uptake

The data on nutrient uptake showed that the N uptake ranged from 36.1 to 52.4 kg ha^{-1} with a mean of 45.5 kg ha^{-1} in strip I, from 44.4 to 76.9 with a mean of 57.5 kg ha^{-1} in strip II and from 46.7 to 79.2 kg ha^{-1} with a mean of 70.0 kg ha^{-1} in strip III. The P uptake ranged from 5.26 to 12.73 kg ha^{-1} with a mean of 9.70 kg ha^{-1} in strip I, from 8.94 to 17.0 with a mean of 13.2 kg ha^{-1} in strip II and from 11.1 to 18.1 kg ha^{-1} with a mean of 15.2 kg ha^{-1} in strip III. The K uptake ranged from 28.9 to 57.5 kg ha^{-1} with a mean of 45.4 kg ha^{-1} in strip I, from 35.8 to 72.1 with a mean of 53.2 kg ha^{-1} in strip II and from 37.4 to 76.8 kg ha^{-1} with a mean of 59.0 kg ha^{-1} in strip III. The overall range and mean values N. P and K uptakes of treated plots were 42.9 to 79.2, 8.14 to 18.1 and 40.7 to 76.9 kg ha^{-1} with mean values of 59.0, 13.1 and 54.3 kg ha^{-1}, respectively. In all NPK control plots, range and mean values of N.P and K were 36.1 to 63.4, 5.26 to 12.8 and 28.9 to 48.9 kg ha^{-1} with mean of 48.0, 9.6 and 40.3 kg ha^{-1}, respectively.

In absolute control plots, the range and mean values of N, P and K uptakes were 36.10 to 46.73, 5.26 to 11.10 and 28.86 to 37.36 kg ha^{-1} with a mean of 42.40, 8.43 and 33.99 kg ha^{-1}, respectively. The N, P and K uptakes range from 40.12 to 58.67, 6.94 to 12.16 and 38.90 to 46.98 kg ha^{-1} in 6.25 t FYM ha^{-1} alone plots with mean of 49.54, 9.91 and 42.79 kg ha^{-1}, respectively. The range and mean of N, P and K uptakes from 12.5 t FYM ha^{-1} alone plots were 42.00 to 63.39, 7.66 to 12.84, and 39.97 to 48.89 kg ha^{-1} and 52.10, 10.45 and 44.09 kg ha^{-1}, respectively.

The increase in N, P and K uptake in 6.25 t FYM ha^{-1} alone plots was 16.85, 17.56 and 25.90 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 22.89, 23.94 and 29.73 and 5.17, 5.43 and 3.04 per cent, respectively.

The findings clearly demonstrated that combining FYM and inorganic sources increased barnyard millet yield. This could be because FYM application has better physical, chemical, and biological properties than NPK alone treatments [11]. Furthermore, IPNS could have accelerated carbohydrate synthesis and improved carbohydrate translocation from sink to source, potentially leading to increased yield. These findings agreed with those of Harikrishna *et al*. [16] for tomato, Prabu *et al*. [17] for okra, and Hiremath et al. [18] for paprika.

The lowest uptake (42.9, 8.1 and 41.2 kg ha^{-1} N, P and K) was recorded with the application of 0:20:40 kg ha^{-1} in strip I with initial soil test values of 163, 12 and 454 kg ha^{-1} of $KMnO_4$-N, Olsen- P and NH_4OAc-K respectively. This revealed the effect of nutrients from soil, inorganic, and organic sources on barnyard millet uptake, and similar findings were published by Coumaravel *et al* [19] and Udayakumar and Santhi [20] The current study's findings clearly show that initial soil fertility and IPNS had a significant impact on grain yield and nutrient uptake by barnyard millet.

Conclusion

The current study suggests that IPNS and initial soil fertility had a greater impact on grain yield and NPK uptake by barnyard millet than inorganic fertiliser alone. This might be due to integrated nutrient application, higher microbial population, and high organic carbon, organic form of nutrients are converted to inorganic. Thus. Fertilizer use in conjunction with FYM can play an important role in obtaining higher yield potential of barnyard millet due to its good effect on nutrient supply and soil characteristics.

DISCLAIMER

The products used for this research are commonly and predominantly used in our area of study and country. There is no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for litigation but knowledge advancement. Also, the research was not funded by the producing company rather, it was financed by the personal efforts of the authors.

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