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Targeted Yield Model-based Balanced Nutrient Recommendation for Barnyard Millet on Inceptisol of Tamil Nadu

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ABSTRACT

Background: Barnyard millet is one of the significant small millets cultivated in India. It has provided a good source of nutrients. Its production is low in low fertile soil. For that study undertaken into supplying balanced nutrition to achieve maximum yield by following soil test crop response-based fertilizer prescription equation.

Methods: The Inductive methodology adopted in the field experiment for developing a scientific basis of fertilizer prescription for barnyard millet was performed on Periyanaickenpalayam soil series of Inceptisol soil order of Tamil Nadu during 2019-2020. The initial soil available nutrient status, grain yield, total nutrient uptake by barnyard millet and fertilizer N, P_2O_5 and K_2O and FYM applied were taken into account for calculating four basic parameters for developing fertilizer prescription equation *viz.,* nutrient requirement (NR) to produce 100 kg of barnyard millet grains, the contribution of nutrients from soil (Cs), fertilizer (Cf) and FYM (Cfym).

Result: The fertilizer prescription equations and ready reckoner were developed to prescribe fertilizer dosage for a range of soil test values for specific yield target of barnyard millet on Inceptisol. It can be adopted on the Periyanaickenpalayam soil series of Tamil Nadu and also in regions with allied soil types.

Key words: Barnyard millet, Fertilizer prescription equations, Inceptisol, STCR-IPNS, Yield target.

INTRODUCTION

Barnyard millet is one of the important crops among the small millets *viz*., foxtail millet, pearl millet, little millet, proso millet, finger millet, *etc.* It is a short duration crop that can grow in adverse environmental conditions and can withstand various biotic and abiotic stresses. Barnyard millet grain is a good source of carbohydrate, fibre, protein, low glycemic index and most notably, contains more micronutrients (zinc and iron) compared to other major cereals. India is the biggest producer of barnyard millet, both in terms of area (0.146 mha^{-1}) and production (0.147 mt) with average productivity of 1034 kg ha^{-1} during the last three years (IIMR, 2018).

Maintenance of soil health and improvement of crop productivity is essential to meet the increasing food demand which is a serious issue prevailing all over the world. The low level of productivity of crops is due to the supply of low level of input and imbalanced use of fertilizers by the farmers without knowing soil fertility status and nutrient requirement of the crop which causes adverse effects on soil and crop in terms of nutrient toxicity and the deficiency (Yousaf *et al.,* 2017). The decision on fertilizer use requires knowledge of the expected crop yield, soil nutrient status and efficiency of fertiliser (Dobermann *et al.,* 2013). To solve all these problems, one of the sustainable nutrient management techniques such as “Soil Test Crop Response based Integrated Plant Nutrition System (STCR-IPNS)” can be applied for sustained soil health and higher crop productivity (Subba Rao and Lenka, 2020).

The targeted yield approach-based application of the fertilizers concept by Truog (1960) and later refitted by Ramamoorthy *et al.* (1967). Velayutham (1979) stated that targeted yield-based fertilizer prescription is an exclusive method that not only suggests soil test-based fertilizer application but also yields target orient. This approach considers the soil nutrient deficiency and the nutrient sources are applied proportionally to the degree of nutrient deficiency in soil (Das *et al*., 2016). The soil test-based recommendation of fertilisers mingled with IPNS considers specific soil type, crop, variety and fertiliser management. The fertiliser prescription equations for inorganic fertilisers and integrated nutrient application under STCR-NPK alone and STCR-IPNS for various crops were developed by carrying out several field experiments and documented by Muralidharudu *et al.* (2011), Dey and Bhogal (2016) and Santhi *et al.* (2017). The fertiliser prescription equations were developed after establishing a significant relationship between soil test values and the added fertilizers.

The nutrient application by STCR-IPNS has been considered as a better approach when compared to the general blanket recommendation and also improves the fertilizer use efficiency and soil health. The fertilizer prescription equations for hybrid pearl millet (Udayakumar and Santhi, 2017) on Inceptisol and maize (Suresh and Santhi, 2018) were

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developed. However, there is a shortfall of information regarding the fertilizer prescription equations for small millets in Tamil Nadu. Therefore, the present research work was endeavoured to develop integrated fertiliser prescription equations for barnyard millet on Inceptisol of Tamil Nadu to achieve higher productivity as well as soil health sustainability.

MATERIALS AND METHODS

Field experiment site

The present investigation was conducted at Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu with fodder sorghum (*var.* CO 30) as gradient crop and barnyard millet (*var*. MDU 1) as test crop during 2019-2020. The experimental field soil comes under Inceptisol belonging to Periyanaickenpalayam soil series, taxonomically referred to as Vertic Ustropept, which is mixed black calcareous and sandy clay loam in texture. The soil characteristics stated that the soil was moderately alkaline (pH 8.30) and non-saline (EC 0.49 dSm^{-1}). Considering initial soil fertility status, the soil was low (172 kg ha^{-1}) in $KMnO_4$-N, medium (21.0 kg ha^{-1}) in Olsen-P and high (505 kg ha^{-1}) in NH_4OAc -K.

Fertility gradient experiment

The fertility gradient experiment should be conducted prior to the test crop experiment as per the inductive methodology proposed by Ramamoorthy *et al.* (1967). It was conducted by dividing the experimental field into three equal rectangular strips. The fertility gradients were created by applying graded doses of fertilizers of N, P_2O_5 and K_2O on the strips. The strip - I was left unfertilized (control), Strip - II received the blanket recommendation of N while, P_2O_5 and K_2O were applied based on the fixing capacities of soil which were 100 and 80 kg ha^{-1}, respectively and strip III received double dose fertilisers as that of Strip-II. The exhaustive crop fodder sorghum was grown which renders the fertilizers to undergo a transformation in soil. The crop was harvested at the fodder stage in each fertility strip and green fodder yield was recorded.

Test crop experiment

After confirming the establishment gradient, the main experiment was conducted with barnyard millet (*var*. MDU 1) as a test crop. The experimental design used was fractional factorial randomized block design. In the experimental field, each strip was divided into three sub-strips to impose three levels of organic manures such as FYM at the rate of 0, 6.25 and 12.5 t ha^{-1}. The experimental field layout is given in Fig 1. The test crop was grown by superimposing 24 treatment combinations with N, P-$_2O_5$ and K_2O each at four different levels *viz.,* N (0,20,40 and 60 kg ha^{-1}), P_2O_5 (0,10, 20 and 30 kg ha^{-1}) and K_2O (0, 20, 40 and 60 kg ha^{-1}). Among the 24 plots, all the 21 selected treatment combinations along with three controls were superimposed in each strip. The treatment structure is given in Table 1. The crop is grown to maturity. After harvesting the crop, the grain and straw yield of barnyard millet was recorded plot-wise under each treatment in all the three fertility strips.

Soil samples were collected before sowing of the crop, prior to FYM and fertilizer application, which were processed and analysed for $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al.,* 1954) and NH_4OAc-K (Hanway and Heidal, 1952). After harvesting the gradient crop(sorghum) and test crop (Barnyard millet), plant and grain samples were collected plot-wise, processed and digested to determine the nutrient uptake (Tandon, 2001).

Computation of basic parameters

The grain yield of barnyard millet, soil test values, nutrient uptake and fertilizer N, P_2O_5 and K_2O and FYM were taken into consideration for computing basic parameters *viz.,* the nutrient requirement (NR) in kg q^{-1}, the contribution from soil (Cs), the contribution from fertilizer (Cf) and contribution from FYM (Cfym), expressed in percentage. The calculation was done as recommended by Ramamoorthy *et al.* (1967) and the contribution from FYM (Cfym) was calculated as prescribed by Santhi *et al.* (1999).

Nutrient requirement (NR)

kg of Nor P_2O_5 or K_2O required per quintal (100 kg) of grain yield production, expressed in (kg q^{-1}).

$$NR = \frac{\text{Total uptake of N or } P_2O_5 \text{ or } K_2O \text{ (kg ha}^{-1})}{\text{Grain yield (q ha}^{-1})}$$

Per cent contribution of nutrients from soil to total nutrient uptake (Cs)

$$Cs = \frac{\text{Total uptake of N or } P_2O_5 \text{ or } K_2O \text{ in control plot (kg ha}^{-1})}{\text{Soil test value for available N or } P_2O_5 \text{ or } K_2O \text{ in control plot (kg ha}^{-1})} \times 100$$

Per cent contribution of nutrients from fertilizer to total nutrient uptake (Cf)

$$Cf = \frac{\left[\begin{array}{c}\text{Total uptake of N or } P_2O_5 \text{ or} \\ K_2O \text{ in the treated plot (kg ha}^{-1})\end{array}\right] - \left[\begin{array}{c}\text{Soil test value for available N or } P_2O_5 \text{ or} \\ K_2O \text{ in control plot (kg ha}^{-1})\end{array}\right] \times \text{Average Cs}}{\text{Fertilizer N or } P_2O_5 \text{ or } K_2O \text{ applied (kg ha}^{-1})} \times 100$$

Per cent contribution of nutrients from organics to total nutrient uptake (Co)

Per cent contribution from FYM (Cfym)

$$Cfym = \frac{\left[\begin{array}{c}\text{Total uptake of N or } P_2O_5 \text{ or} \\ K_2O \text{ in FYM treated plot (kg ha}^{-1})\end{array}\right] - \left[\begin{array}{c}\text{Soil test value for available N or } P_2O_5 \text{ or} \\ K_2O \text{ in FYM treated plot (kg ha}^{-1})\end{array}\right] \times \text{Average Cs}}{\text{Nutrient N or } P_2O_5 \text{ or } K_2O \text{ added through FYM (kg ha}^{-1})} \times 100$$

Fertilizer prescription equations

Making use of these parameters, the Fertilizer Prescription Equations (FPEs) were developed for barnyard millet as furnished below:

Fertilizer nitrogen (FN)

$FN = [(NR/(Cf/100)) \times T] - [(Cs/Cf) \times SN]$
$FN = [(NR/(Cf/100) \times T] - [(Cs/Cf) \times SN] - [(Cfym/Cf) \times ON]$

Fertilizer phosphorus (FP_2O_5)

$FP_2O_5 = [(NR/(Cf/100)) \times T] - [(Cs/Cf) \times 2.29\ SP]$
$FP_2O_5 = [(NR/(Cf/100) \times T] - [(Cs/Cf) \times 2.29\ SP] - [(Cfym/Cf) \times 2.29\ OP]$

Fertiliser potassium (FK_2O)

$FK_2O = [(NR/(Cf/100) \times T] - [(Cs/Cf) \times 1.21\ SK]$
$FK_2O = [(NR/(Cf/100) \times T] - [(Cs/Cf) \times 2.29\ SK] - [(Cfym/Cf) \times 1.21OK]$

Where,
N or P_2O_5 or K_2O are fertilizer N or P_2O_5 or K_2O in kg ha^{-1} and ON, OP and OK are the quantities of N, P and K supplied through FYM in kg ha^{-1}, respectively.

The relationship between the soil test values, crop yield and fertilizer dosage were derived by standard regression procedure (Draper and Smith, 1998). The present research study considers the varying grain yield of barnyard millet by the application of different fertilizer dosages keeping out other factors of soil and crop management practices as constants.

RESULTS AND DISCUSSION

Test crop experiment

The experimental soil test value, grain yield and nutrient uptake by barnyard millet under different strips are mentioned in Table 2 and 3. The soil available $KMnO_4$ - N was 161,195 and 221 kg ha^{-1} from Strip I to Strip III. Similarly, Strip I, Strip II and Strip III soil test values for Olsen - P were 15.4, 28.9 and 39.1 kg ha^{-1} and NH_4OAc- K were 472,514 and 533 kg ha^{-1}, respectively. The overall soil available $KMnO_4$- N, Olsen -P

Table 1: Treatment structure for test crop experiment (Barnyard millet).

Treatment combination			Levels of nutrients (kg ha^{-1})		
N	P	K	N	P_2O_5	K_2O
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	2	2	0	20	40
1	1	1	20	10	20
1	2	1	20	20	20
1	1	2	20	10	40
1	2	2	20	20	40
2	1	1	40	10	20
2	0	2	40	0	40
2	1	2	40	10	40
2	2	2	40	20	40
2	2	1	40	20	20
2	2	0	40	20	0
2	2	3	40	20	60
2	3	2	40	30	40
2	3	3	40	30	60
3	1	1	60	10	20
3	2	1	60	20	20
3	2	2	60	20	40
3	3	1	60	30	20
3	3	2	60	30	40
3	2	3	60	20	60
3	3	3	60	30	60

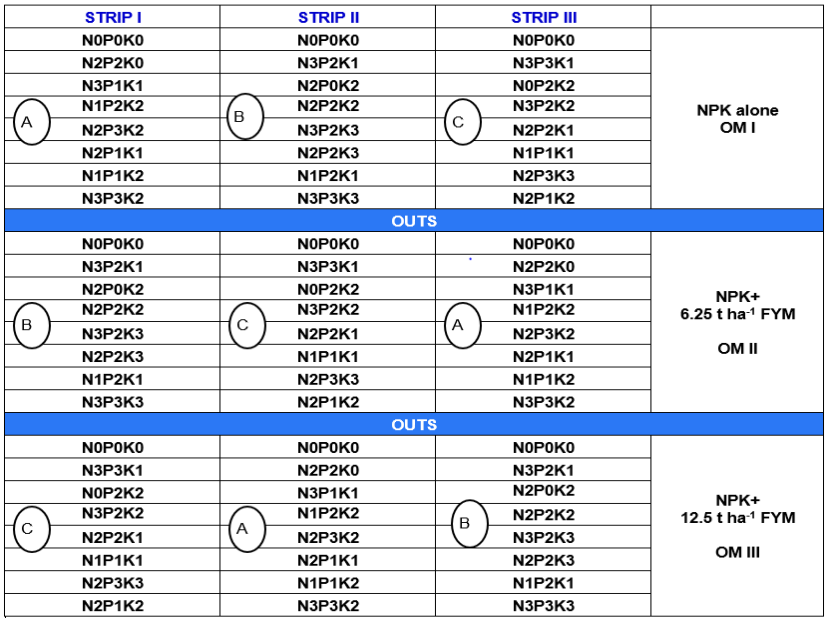

Fig 1: Field layout of test crop experiment.

and NH_4OAc - K in NPK treated and control plots were 193,28 and 508 and 189,25 and 505 kg ha^{-1}, respectively.

The average barnyard millet yield was 2213 kg ha^{-1} (mean of 72 plots) and 1914, 2297 and 2428 kg ha^{-1} in Strip-I, Strip-II and Strip-III, respectively and overall control and NPK treated plots were 1390 and 2330 kg ha^{-1}. The higher fertility status led to higher grain yield as well as nutrient uptake. The N uptake values were 45.55,57.50 and 69.97 kg ha^{-1} in Strip-I, Strip-II and Strip-III, respectively. Parallelly, Strip-I, Strip-II and Strip-III reported P and K uptake values as 9.70, 13.16 and 15.22 kg ha^{-1} and 45.44, 53.25 and 59.03 kg ha^{-1}, respectively. The average values of N, P and K uptake in overall control and NPK treated plots were 48.0, 9.6 and 40.3 and 59.0, 13.1 and 54.3 kg ha^{-1}, respectively. These results agree with Singh *et al*. (2016), Udayakumar and Santhi (2017) and Kumar *et al.* (2018).

The variation in grain yield attributed to the application of different fertilizer dosages was evaluated by regression analysis by finding the relationship between grain yield and fertilizer with N, P_2O_5 and K_2O which was significant ($P<0.01$). Regression analysis between N, P_2O_5 and K_2O fertiliser and grain yield revealed that N was responsible for 65.1% of grain yield, P and K were responsible for 44.5% and 32.2% of grain yield, respectively (Fig 2). The plant assimilation of applied nitrogen fertilizer was better compared to P_2O_5 and K_2O; it may be due to the mobile nature of nitrogen which in turn accounted for higher grain yield of barnyard millet. The integrated application of organic manures along with inorganic fertilizers was comparatively found better in increasing the grain yield than the application of inorganic fertilizers alone.

Basic parameters

The amount of nutrient required to produce one unit quantity of yield is defined as nutrient requirement (NR). The amount of nutrients (N, P_2O_5 and K_2O) vital for producing hundred kg of grain yield was found as 2.58 kg of N, 1.31 kg of P_2O_5 and 2.80 kg of K_2O (Table 4). From the data, the order of nutrient requirement was $K_2O>N>P_2O_5$. Fig 3 shows a linear relationship between barnyard millet grain yield and N, P and K uptake. Similarly, the results were in accordance with the findings of Santhi *et al*. (2011) and Sellamuthu *et al*. (2015). The soil available nutrient contribution (Cs) was reported as 23.33% N, 32.61% P_2O_5 and 7.01% K_2O, respectively. Among the three nutrients, the soil contribution

Table 2: Range and mean values of yield of barnyard millet and N, P and K uptake in relation different soil fertility strips.

Particulars		Strip-I	Strip-II	Strip-III
Grain yield (kg ha^{-1})	Range	1056-2380	1218-2966	1350-2940
	Mean	1914	2297	2420
	SD	357	439	413
	CV (%)	18.67	19.10	17.10
N uptake (kg ha^{-1})	Range	36.10-52.37	44.36-76.87	46.73-79.20
	Mean	45.55	57.50	69.97
	SD	3.71	8.09	7.20
	Cv (%)	8.15	14.07	10.29
P uptake (kg ha^{-1})	Range	5.26-12.73	8.94-17.0	11.10-18.10
	Mean	9.70	13.16	15.22
	SD	1.84	2.07	1.91
	Cv (%)	18.95	15.74	12.55
K uptake (kg ha^{-1})	Range	28.86-57.46	35.75-72.12	37.36-76.85
	Mean	45.44	53.25	59.03
	SD	6.28	8.68	9.65
	Cv (%)	13.83	16.30	16.35

Table 3: Pre-sowing soil available N, P and K, yield and N, P and K uptake by barnyard millet in control and NPK treated plots of test crop experiment (overall).

Parameters	NPK treated plots		Control plots	
	Range (kg ha^{-1})	Mean (kg ha^{-1})	Range (kg ha^{-1})	Mean (kg ha^{-1})
$KMnO_4$-N	157-224	193	157-221	189
Olsen-P	13-41	28	13-39	25
NH_4OAc-K	470-538	508	470-530	505
Grain yield	1588-2966	2330	1056-1716	1390
N uptake	42.9-79.2	59.0	36.1-63.4	48
P uptake	8.14-18.1	13.1	5.26-12.8	9.6
K uptake	40.7-76.9	54.3	28.9-48.9	40.3

towards P_2O_5 is high, followed by N and K_2O. The per cent contribution of N, P_2O_5 and K_2O from fertilizers (Cf) was 32.69, 44.72 and 64.66 which follows the order of K_2O> P_2O_5>N. The organic manure (FYM) contribution (Cfym) was recorded as 22.32% for N, 15.72% for P_2O_5 and 30.21% for K_2O, respectively and it contributes more towards K_2O. The results also in line with the findings of Santhi *et al.* (2011) and Sellamuthu *et al.* (2015) who observed a similar trend of relatively higher nutrient contribution towards K_2O rather than N and P_2O_5 from both fertilizer and FYM. It revealed that the contribution of nutrient sources for grain yield was higher from fertilizer sources than from soil available nutrients. Similar results were reported by Ray *et al*. (2000) in jute, rice and wheat; Basavaraja *et al*. (2017) in finger millet and Saren *et al*. (2017) in blackgram. Based on initial soil test values, crop yield and nutrient uptake by barnyard millet, the basic parameters were computed. The fertilizer prescription equations were developed for barnyard millet on Inceptisol using these basic parameters to get precise yield target and are furnished in Table 4.

Ready reckoner

The ready reckoners were prepared (Table 5) based on the fertilizer prescription equations, may be at different soil test values for different yield targets of barnyard millet under the NPK alone and NPK-IPNS condition. Nomograms were formulated for desired yield targets 2.5 and 3.0 t of barnyard millet for a range of soil test values under NPK alone and IPNS (NPK plus FYM @ 12.5 t ha^{-1}). The results indicated that to produce 2.5 and 3.0 t ha^{-1} of grain yield for a soil test

Table 4: Basic data for calculating optimum fertilizer dose for barnyard millet cultivation.

Nutrients	NR (kg q^{-1})	Cs (%)	Cf (%)	Cfym (%)	Fertilizer prescription equations	
					STCR-NPK alone	STCR-IPNS
N	2.58	23.33	32.69	22.32	FN= 7.89T-0.71SN	FN= 7.89T-0.71SN-0.71ON
P	1.31	32.61	44.72	15.75	FP_2O_5= 2.93T-1.67SP	FP_2O_5= 2.93T-1.67SP-0.87OP
K	2.8	7.01	64.66	30.21	FK_2O= 4.34T-0.13SK	FK_2O= 4.34T-0.13SK-0.57OK

Table 5: Soil test-based fertiliser doses for desired yield target of barnyard millet under NPK alone and NPK + IPNS.

Parameter	Grain yield target of 2.5 t ha^{-1}			Grain yield target of 3.0 t ha^{-1}		
	NPK alone alone (kg ha^{-1})	NPK + FYM @12.5 t ha^{-1}	Reduction over NPK alone (kg ha^{-1})	NPK alone (kg ha^{-1})	NPK + FYM @12.5 t ha^{-1}	Reduction over NPK alone (kg ha^{-1})
$KMnO_4$=N						
200	55	22*	60.0	66**	60	9.1
210	48	22*	54.2	66**	53	19.7
220	41	22*	46.3	66**	46	30.3
230	34	22*	35.3	66**	38	42.4
240	27	22*	18.5	66	31	53.0
250	22*	22*	0.0	59	24	59.3
Olsen-P						
16	33**	30	9.1	33**	33**	0.0
18	33**	26	21.2	33**	33**	0.0
20	33**	23	30.3	33**	33**	0.0
22	33**	20	39.4	33**	33**	0.0
24	33	16	51.5	33**	31	6.1
26	30	13	56.7	33**	27	18.2
NH_4OAc-K						
450	30**	25	16.7	30**	30**	0.0
475	30**	22	26.7	30**	30**	0.0
500	30**	19	36.7	30**	30**	0.0
525	30**	15	50.0	30**	30**	0.0
550	30**	12	60.0	30**	30**	0.0
575	30**	10*	66.7	30**	30	0.0

(NB: **maximum dose;*maintenance dose; Blanket dose: 44:22:20 kg ha^{-1} of fertiliser N, P_2O_5 and K_2O respectively for barnyard millet. If the calculated fertiliser dose tends to fall below 50 per cent of the blanket, a maintenance dose of 50 per cent of the blanket is recommended. If the calculated dose exceeds 150 per cent of the blanket, a maximum dose of 150 per cent of the blanket is recommended).

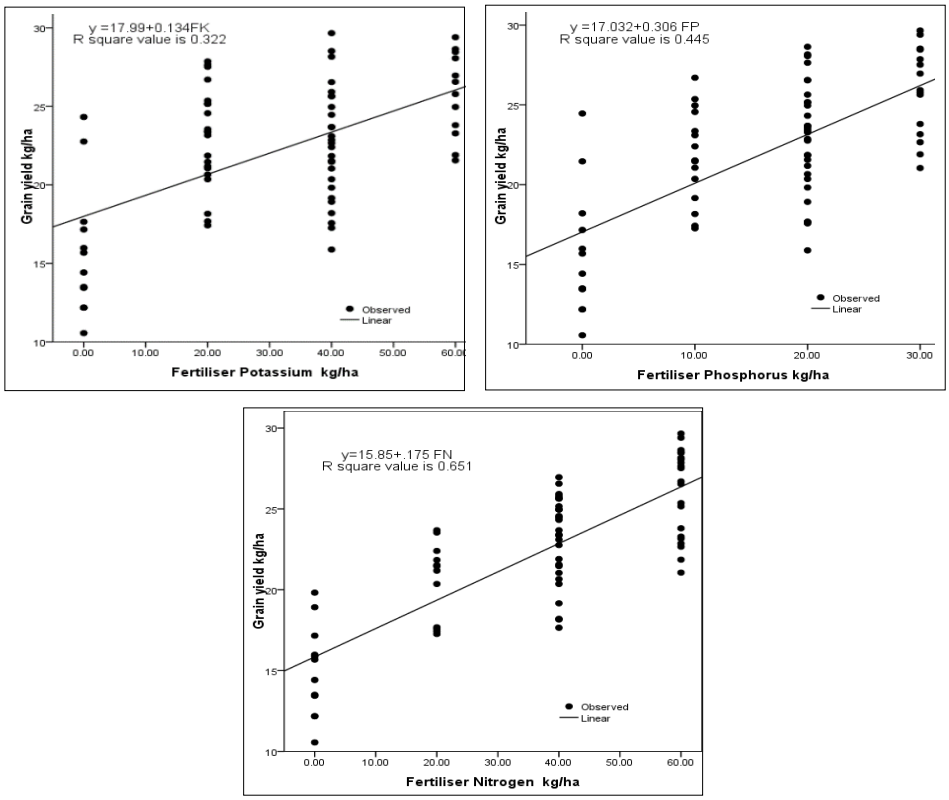

Fig 2: Relationship between grain yield and NPK fertilisers at various levels.

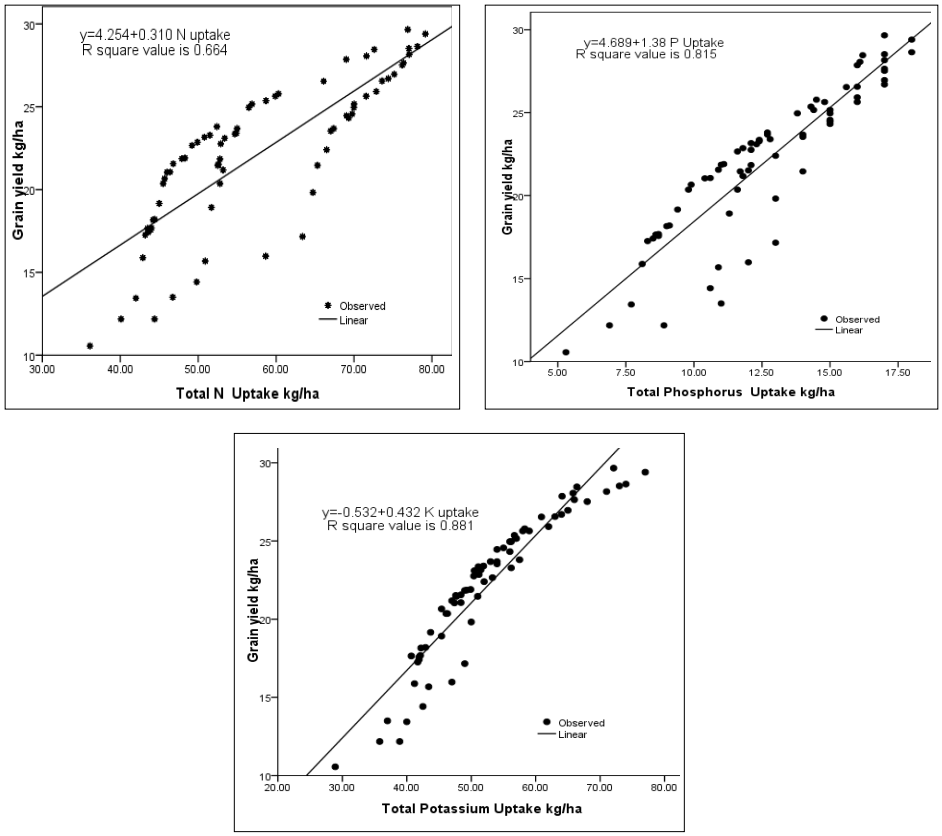

Fig 3: Relationship between the barnyard millet yield and nutrient uptake.

value of 220:24:500 kg ha^{-1} of $KMnO_4$-N, Olsen-P and NH_4OAc-K, the amount fertilizer N, P_2O_5 and K_2O doses required was 41, 33 and 30 and 66, 33 and 30 kg ha^{-1}, respectively. Whereas, the application of FYM (26 per cent moisture and 0.56, 0.23 and 0.47 per cent of N, P and K) @ 12.5 t ha^{-1} along with NPK fertilizer, the amount of N, P_2O_5 and K_2O doses required was 22,16 and 19 kg ha^{-1} and 46, 31 and 30 kg ha^{-1} for the yield target of 2.5 and 3.0t ha^{-1} under the same soil test values. Consequently, the application of FYM has contributed 35, 17 and 25 kg of fertiliser N, P_2O_5 and K_2O, respectively. Udayakumar and Santhi (2017) also reported that application of farmyard manure at 12.5 t ha^{-1} together with chemical fertilizer resulted in a saving of 40, 24 and 28 kg ha^{-1} N, P_2O_5 and K_2O respectively in pearl millet.

Ready reckoners exposed that increasing the yield target, increases the fertilizer dose for similar soil test value, whereas the increasing soil test value decreases the fertilizer doses. In comparison with the application of inorganic fertilizer along with FYM and application of inorganic fertilizer alone, there was a notable reduction in fertilizer amounts when applied along with FYM, due to the nutrient supplement through FYM. The per cent reduction of fertilizers were increasing when applied along with FYM and also increasing the soil test values. A similar inclination of results was reported by Singh *et al*. (2018).

CONCLUSION

The present experiment revealed that Soil Test Integrated Plant Nutrition System-based Fertilizer Prescription Equations developed improves the yield of barnyard millet. It has been elucidated that STCR-IPNS is a balanced way of supplying nutrients through contribution from the soil, fertilizer and farmyard manure for achieving specific yield target of barnyard millet. By the way, the farmers will be benefited from rationalised usage of fertilizers, increased fertilizer use efficiency and recycling the farm wastes. Also, farmers can utilize the fertilizer prescription equations for specific yield targets based on their financial condition on similar soil series existing in Tamil Nadu.

Conflict of interest: None.

REFERENCES

Basavaraja, P.K. and Saqeebulla, H.M., Dey, P. (2017). Integrated fertilizer prescription equations for finger millet (El*eusine coracana* L.) through inductive cum targeted yield model on an alfisol. Int. J. Curr. Microbiol. App. Sci. 6(7): 2571-2580.

Das, K.N. and Basumatary, A., Ahmed, S. (2016). Targeted: yield precision model assessment for rice-rice crop sequences in farmers' fields in humid, sub-tropical north eastern India. J. Soil Sci. and Plant Nutr. 16(1): 31-47.

Dey, P. and Bhogal, H. (2016). In: Progress Report (2013-16) of the All India Coordinated Research Project for Investigation on Soil Test Crop Response Correlation, Indian Institute of Soil Science, Bhopal. pp. 1-224.

Dobermann, A., Witt, C., Abdulrachman, S., Gines, H.S., Nagarajan, R., Son, T.T., Wang, P.S., Tan, G.H. *et al.* (2003). Soil fertility and indigenous nutrient supply in irrigated rice domains of Asia. Agron. J. 95: 913-923.

Draper, N.R., Smith, H. (1998). Applied Regression Analysis. New York. Willy.

Hanway, J.J. and Heidal, H. (1952). Soil analysis methods as used in Iowa State College. Agriculture Bulletin. 57: 1-13.

IIMR (2018). Annual Report 2017-18. Hyderabad: Indian Institute of Millets Research.

Kumar, R.R., Singh, Y.V., Singh, S.K. and Dey, P. (2018). Fertilizer recommendations developed through soil test crop response studies with integrated plant nutrient management system for field pea in an inceptisol. J. Indian Soc. of Soil Sci. 66(3): 318-323.

Muralidharudu, Y., Mandal, B.N., Sammi Reddy, K. and Subba Rao, A. (2011). In: Progress Report of the All India Coordinated Research Project for Investigation on Soil Test Crop Response Correlation. Indian Institute of Soil Science, Bhopal. pp 11-61.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of Available Phosphorous in Soils by Extraction with Sodium Bicarbonate. Circular US Dept. of Agriculture, 1400 Independence Ave. S.W., Washington DC. p.939.

Ramamoorthy, B., Narasimham, R.L. and Dinesh, R.S. (1967). Fertilizer application for specific yield target of sonara-64 wheat. Indian Farming. 17: 43-45.

Ray, P.K., Jana, A.K., Maitra, D.N., Saha, M.N., Chaudhury, J., Saha, S. and Saha, A.R. (2000). Fertilizer prescriptions on soil test basis for jute, rice and wheat in a typic ustochrept. J. Indian Soc. Soil Sci. 48: 79-84.

Santhi, R., Bhaskaran, A. and Natesan, R. (2011) Integrated fertiliser prescriptions for beetroot through Inductive cum targeted yield model on an Alfisol. Commun. Soil Sci. Pl. Analysis. 42: 1905-1912.

Santhi, R., Sellamuthu, K.M., Maragatham, S., Natesan, R., Arulmoziselvan, K., Kumar, K. and Dey, P. (2017). Soil Test and Yield Target Based Fertiliser Prescriptions for Crops-An Overview of Outreach Activities in Tribal Villages of Tamil Nadu (in Tamil), AICRP-STCR, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore.

Santhi. R. Selvakumari, G. and Perumal, R. (1999). Soil test-based fertilizer recommendation under integrated plant nutrition system for rice-rice-pulse cropping sequence. J. Indian Soc. Soil. Sci. 47: 288-294.

Saren, S., Mishra, A. and Dey, P. (2017). integrated nutrient management and formulation of targeted yield equations for black gram (*Vigna mungo* L.). Curr. Sci. 113: 314-317.

Sellamuthu, K.M., Santhi, R. Maragatham, S. and Dey, P. (2015). Validation of soil test and yield target based fertilizer prescription model for wheat on Inceptisol. Res. on Crops. 16: 53-58.

Singh, S.R. (2016). Soil Test Crop Response: Concepts and Components for Nutrient Use Efficiency Enhancement. In: Biofortification of Food Crops. Springer India. pp. 237-246.

Singh, Y.V., Singh, S.K., Srivastava, D.K., Singh, P. and Jatav, H.S. (2018). Fertilizer dose recommendation through soil test crop response study with integrated plant nutrient management system for fennel in an Inceptisol. Inter. J. Seed Spices. 8(2): 36-41.

Subba Rao, A. and Lenka, N.K. (2020) Developments on soil health management in India as mirrored through sustained researches and policy interventions. Indian J. Ferti. 16(12): 1230-1242.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for determination of available nitrogen in soil. Curr. Sci. 25: 259-260.

Suresh, R. and Santhi, R. (2018). Soil test crop response based integrated plant nutrition system for maize on vertisol. Int. J. Curr. Microbiol. App. Sci. 7(8): 1631-1641.

Tandon, H.L.S. (2001). Methods of Analysis of Soils, Plants, Waters and Fertilizer, Fertilizer Development and Consultation Organization, New Delhi, India.

Truog, E. (1960). Fifty Years of Soil Testing. Transactions Seventh International Congress Soil Science. 3: 46-57.

Udayakumar, S. and Santhi, R. (2017). Soil test based integrated plant nutrition system for pearl millet on an Inceptisol. Res. on Crops. 18(1): 21-28.

Velayutham, M. (1979). Fertiliser recommendation based on targeted yield concept-problems and prospects. Fert. News. 24: 12-20.

Yousaf, M., Li, J., Lu, J., Ren, T., Cong, R., Fahad, S., Li, X. (2017). Effects of fertilization on crop production and nutrient-supplying capacity under rice-oilseed rape rotation system. Sci. Rep. 7: 1270.