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Refinement of Soil Test Crop Response - Integrated Plant Nutrition System based Fertilizer Prescriptions for Pearl Millet Variety Grown Under Inceptisol

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A field experiment was conducted during rabi season of 2017-2018 on a mixed black calcareous soil (Typic Ustropept - Periyanackenpalayam soil series) at Eastern Block, Tamil Nadu Agricultural University, Coimbatore to refine the existing fertilizer prescription equations under Integrated Plant Nutrition System (IPNS) for hybrids to suit pearl millet variety. The experiment comprised of eleven treatments with three replications in Randomized Block Design. The experimental results revealed that there was a progressive increase in response from lower target to higher targets and the magnitude of response was higher under STCR-IPNS than under STCR-NPK alone treatments. Using the experimental data, the basic parameters *viz.,* nutrient requirement (NR), per cent contribution of nutrients from soil (Cs), fertilizers (Cf) and FYM (Cfym) towards total N,P and K uptake by pearl millet (*var.* CO 10) were computed based on targeted yield model. It was found that pearl millet variety requires 2.81, 1.33 and 2.53 kg of N, P_2O_5 and K_2O, respectively to produce one quintal of grain. The contribution of nutrients from soil, fertilizers and FYM for N was 26.36, 45.44 and 27.55 per cent; for P_2O_5 it was 38.51, 44.14 and 16.04 per cent and for K_2O it was 10.33, 87.45 and 40.15 per cent respectively. Making use of the refined basic parameters, Fertilizer Prescription Equations (FPEs) were developed under NPK alone and IPNS for pearl millet variety. Ready reckoner of fertilizer doses (nomograms) were formulated for a range of soil test values and for desired yield target *viz.,* 3.0, 3.5 and 4.0 t ha^{-1}. For an average soil test value of 180:24:460 kg ha^{-1} and yield target of 4.0 t ha^{-1}, 105, 51 and 25 kg of fertilizer N, P_2O_5 and K_2O is to be appiled along with FYM @ 12.5 t ha^{-1}. The extent of saving of inorganic fertilizers for pearl millet with the application of FYM @ 12.5 t ha^{-1} (with 21 % moisture, 0.64, 0.27 and 0.46 % N, P and K respectively) was 38, 22 and 25 kg of fertilizer N, P_2O_5 and K_2O respectively.

Key words: STCR-IPNS, Pearl millet, Fertilizer prescription equations.

Pearl millet (*Pennisetum glaucum* L.) is the world's hardiest warm season cereal crop (Reddy *et al.,* 2012) and it is the most widely cultivated cereal in India after rice and wheat and grown annually on 29 million ha in the arid and semi-arid regions of Asia, Africa and Latin America. India is the largest producer of pearl millet in Asia, both in terms of area (7.12 million ha) and production (9.9 million tonnes) with an average productivity of 1272 kg ha^{-1}.India had witnessed a major breakthrough in total production and productivity of pearl millet after the release of high yielding varieties (Yadav, 2016). In Tamil Nadu, pearl millet is cultivated in an area of 0.577 lakh ha with a production of 1.77 lakh tonnes and average productivity of 3077 kg ha^{-1} during 2015-16 and a blanket recommendation of 80:40:40 and 70:35:35 kg N, P_2O_5 and K_2O ha^{-1} for hybrids and varieties respectively along with FYM @ 12.5 t ha^{-1} is being followed for pearl millet in Tamil Nadu.

Fertilizer use in India is relatively low as compared to many other countries and NPK use ratio is highly imbalanced (6.7:2.7:1 in 2016-2017 *vs* an optimum ratio of 4:2:1) which has led to widespread negative nutrient balance in most Indian soils to the tune of 8-10 mt NPK (Satish Chander, 2014). Therefore, management of nutrients should be given proper attention to maintain or increase yields and sustain productivity. Fertilizer schedules should therefore be based on magnitude of crop response to applied nutrients at different fertility levels and therefore Soil Test Crop Response - Integrated Plant Nutrition System (STCR-IPNS) based fertilizer prescription plays a vital role in ensuring balanced nutrition to crops. These prescriptions are of practical importance for efficient and judicious use of fertilizers in increasing crop production and prescription for desired yield target of crops could be made based on resource availability of farmers (Dey and Santhi, 2014).

On account of the above facts, the present investigation was undertaken with a view to refine the existing Fertilizer Prescription Equations under IPNS for hybrids to suit pearl millet variety on Periyanaickenpalayam soil series based on the response of pearl millet (*var.* CO 10).

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Material and Methods

Field experiment was conducted during rabi season of 2017-2018 at Eastern Block, Tamil Nadu Agricultural University, Coimbatore with the experimental crop pearl millet (*var.* CO 10). The soil of the experimental field belongs to Periayanaickenpalayam soil series, taxonomically Vertic Ustropept, sandy clay loam in texture and mixed black calcareous. The initial fertility status of surface soil was medium in organic carbon, low in available N, high in available P and K, sufficient in available Cu and Mn and deficient in available Fe and Zn. The experiment comprised of eleven treatments *viz.,* T_1- STCR-NPK alone - 3.0 t ha^{-1}, T_2 - STCR-NPK alone– 3.5 t ha^{-1}, T_3- STCR-NPK alone - 4.0 t ha^{-1}, T_4-STCR-IPNS- 3.0 t ha^{-1}, T_5-STCR-IPNS-3.5 t ha^{-1}, T_6-STCR-IPNS-4.0 t ha^{-1}, T_7-FYM alone @6.25 t ha^{-1}, T_8-FYM alone @12.5 t ha^{-1}, T_{9-} blanket alone (100% RDF), T_{10} -Blanket + FYM @12.5 t ha^{-1}, T_{11} -Absolute control which were laid out in Randomized Block Design (RBD) with eleven treatments and three replications. For STCR treatments, the fertilizer doses were computed using the Fertilizer Prescription Equations developed under NPK alone and IPNS. For STCR-IPNS treatments, FYM was applied @ 12.5 t ha^{-1} basally. The quantities of N, P and K contributed through FYM was subtracted from the inorganic fertilizer doses and applied for STCR - IPNS treatments. The crop was grown to maturity following all the improved package of practices for pearl millet.

The pre-sowing soil samples were collected from each plot before imposing the treatments and the processed soil samples were analysed for available N, P and K status following the standard procedures (Subbiah and Asija,1956); Olsen *et al.*,1954) and Standford and English,1949) respectively. The crop was harvested at its maturity and grain and straw yields were recorded. Plant and grain samples were collected at harvest, processed and analysed for their N, P and K contents and total uptake of N, P and K by pearl millet was computed. The experimental data was subjected to statistical analysis with a view to elucidate the effect of varying fertilizer doses of N, P and K and IPNS on yield and N, P and K uptake. Using the experimental data of STCR and FYM alone treatments and absolute control, the basic parameters *viz.,* NR, Cs, Cf were calculated by adopting the methodology developed by Ramamoorthy *et al.,* (1967).

Nutrient requirement

Nutrient requirement is calculated as kg of N/ P_2O_5/ K_2O required per quintal (100 kg) of grain, expressed in (kg q^{-1}).

NR = (Total uptake of N or P_2O_5 or K_2O (kg ha^{-1})) / Grain yield (q ha^{-1}).

Where NR= Nutrient requirement

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

Cs = [(Total uptake of N or P_2O_5 or K_2O in control plot (kg ha^{-1})) / (Soil test value for available N or P_2O_5 or K_2O in control plot (kg ha^{-1}))] * 100.

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

Cf = {[(Total uptake of N or P_2O_5 or K_2O in treated plot (kg ha^{-1})) - (Soil test value for available N or P_2O_5 or K_2O in control plot (kg ha^{-1}) * Average Cs)] / Fertilizer N or P_2O_5 or K_2O applied (kg ha^{-1})} * 100.

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

Cfym = {[(Total uptake of N or P or K in FYM treated plot (kg ha^{-1})) – (Soil test value for available N or P or K in FYM treated plot (kg ha^{-1}) * Average Cs)] / Nutrient N/P/K added through FYM (kg ha^{-1})} * 100

Fertilizer prescription equations

Using the refined basic parameters, the fertilizer prescription equations (FPEs) were developed for pearl millet (*var.*CO 10) as furnished below.

STCR – NPK alone

FN = **{**[(NR / (Cf /100))*T] – [(Cs/Cf)*SN]}

FP_2O_5 = **{**[(NR / (Cf /100))*T] – [(Cs/Cf)*2.29SP]**}**

FK_2O = **{**[(NR / (Cf /100))*T] – [(Cs/Cf)*1.21SK]**}**

STCR – IPNS

FN = {[(NR / (Cf /100))*T] – [(Cs/Cf)*SN] - [(Cfym/Cf)*ON]}

FP_2O_5 = {[(NR / (Cf /100))*T] – [(Cs/Cf)*2.29SP] - [(Cfym/Cf)*2.29OP]}

FK_2O = {[(NR / (Cf /100))*T] – [(Cs/Cf)*1.21SK] - [(Cfym/Cf)*1.21OK]}

where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively; NR is nutrient requirement (N or P_2O_5 or and K_2O) in kg q^{-1}, Cs is per cent contribution of nutrients from soil, Cf is per cent contribution of nutrients from fertilizer, Cfym is percent contribution of nutrients from FYM, T is the yield target in q ha^{-1}; SN,SP and SK respectively are alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K in kg ha^{-1} and ON, OP and OK are the quantities of N, P and K supplied through FYM in kg ha^{-1}. These equations serve as a basis for predicting fertilizer doses for specific yield targets (T) of pearl millet (*var.*CO 10) for varied soil available nutrient levels.

Results and Discussion

Grain yield

Grain yield of the pearl millet ranged from 1180 to 3880 kg ha^{-1} (Table 1). The highest grain yield (3880 kg ha^{-1}) was registered in T_6 (STCR-IPNS- 4.0 t ha^{-1}) which was on par with T_3 (STCR-NPK alone – 4.0 t ha^{-1}) with grain yield of 3790 kg ha^{-1}. Next to T_6 and T_3, significantly higher grain yield (3400 kg ha^{-1}) was observed in T_5 (STCR- IPNS -3.5 t ha^{-1}) and it was on par with T_{10} (blanket + FYM @12.5 t ha^{-1}) and T_2 (STCR-NPK alone- 3.5 t ha^{-1}) by recording the

Table 1. Grain yield and nutrient uptake

Treatment	Grain Yield	UN	UP	UK	SN	SP	SK	FN	FP_2O_5	FK_2O	FYM (t ha^{-1})
		----------(kg ha^{-1})----------									
T_1-STCR – NPK alone – 3.0 t ha^{-1}	2710	72.91	14.33	57.71	181	24.2	463	92	44	20	0
T_2-STCR – NPK alone – 3.5 t ha^{-1}	3250	89.07	16.73	65.93	179	23.9	462	122	58	23	0
T_3-STCR - NPK alone - 4.0 t ha^{-1}	3790	107.53	21.92	69.75	184	23.9	466	152	72	39	0
T_4-STCR – IPNS – 3.0 t ha^{-1}	2850	77.17	14.97	58.98	183	23.6	461	50	19	20	12.5
T_5-STCR – IPNS – 3.5 t ha^{-1}	3400	92.48	18.36	66.40	182	24.0	463	80	33	20	12.5
T_6-STCR – IPNS – 4.0 t ha^{-1}	3880	110.07	24.83	71.51	180	24.0	465	110	47	20	12.5
T_7-FYM alone @6.25 t ha^{-1}	1880	52.34	12.34	57.11	182	23.1	456	0	0	0	6.25
T_8-FYM alone @12.5 t ha^{-1}	2200	63.61	13.75	57.47	181	23.5	455	0	0	0	12.5
T_9-Blanket 100% RDF	2410	69.93	14.07	57.58	182	23.4	456	70	35	35	0
T_{10}-Blanket + FYM @ 12.5 t ha^{-1}	3290	91.36	17.67	65.98	182	24.0	455	70	35	35	12.5
T_{11}-Absolute control	1180	43.63	9.63	44.79	180	23.7	456	0	0	0	0
SEd	150	3.07	1.27	1.79							
CD (P=0.05)	313	6.41	2.66	3.73							

grain yield of 3290 and 3250 kg ha^{-1}, respectively. Whereas T_{11} (absolute control) recorded (1180 kg ha^{-1}) significantly lowest yield as compared to all other treatments (Table 1). Similar trend of grain yield was recorded in pearl millet (Neha *et al.,* 2017).

Among the same yield targets, the grain yield under STCR-IPNS treatments was numerically higher than those under STCR-NPK alone due to application of NPK fertlisers along with FYM which might have provided a desirable soil condition for the root development, enhancing higher yield and nutrient uptake, crop growth and yield of maize (Sivaranjani *et al.,* 2018). This data clearly showed that along with inorganic fertlisers, organic manures also necessary to maintain optimum rhizosphere environment for sustaining pearl millet grain yield at higher level. Similar results were reported by Dapake (2014) and Neha *et al*. (2017).

Table 2. Basic parameters for pearl millet variety and fertilizer prescription equations

Parameters	Basic data		
	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	2.81	1.33	2.53
Per cent contribution from soil (Cs)	26.36	38.51	10.33
Per cent contribution from fertilizers (Cf)	45.44	44.14	87.45
Per cent contribution from FYM (Cfym)	27.55	16.04	40.15

Nutrient uptake

The N, P and K uptake ranged from 43.63 to 110.07 kg ha^{-1}, 9.63 to 24.83 kg ha^{-1} and 44.79 to 71.51 kg ha^{-1}, respectively. Among the eleven treatments, T_6 (STCR-IPNS- 4.0 t ha^{-1}) recorded the highest total N, P and K uptake (110.07, 24.83 and 71.51 kg ha^{-1}, respectively) and was found to be comparable with T_3 (STCR-NPK alone – 4.0 t ha^{-1}) with the uptake values of 107.53, 21.92 and 69.75 kg ha^{-1}, respectively). The lowest uptake of nutrients was registered in T_{11} (absolute control) (Table 1). The uptake of N was 4.87 and 1.31 fold higher than P and K respectively. Similar increase in nutrient uptake due to increased fertilizer doses was also supported by the findings of Udayakumar and Santhi (2017). The significant increase in P uptake was due to higher levels of phosphorus application which would have led to higher root proliferation of the crop (Verma *et al*., 2014). The increased uptake may be attributed to solubility action of organic acids produced during decomposition of FYM resulting in more release of N, P and K and also to contribution by this manure (Dwivedi *et al*., 2016).

Response of pearl millet

The response of pearl millet to different doses of fertilizer N, P_2O_5 and K_2O was assessed. The response varied from 700 kg ha^{-1} in FYM @ 6.25 t ha^{-1} to 2700 kg in STCR-IPNS-4.0 t ha^{-1}. The data showed that irrespective of STCR-NPK alone or STCR-IPNS, there was a progressive increase in response from lower target to higher targets and the magnitude of response was higher under STCR-IPNS than under STCR-NPK alone treatments. This formed the basis to compute the basic parameters and develop the fertilizer prescription equations under IPNS for pearl millet variety.

Nutrient requirement, contribution of nutrients from soil, fertilizers and FYM

Using the pre-sowing soil available N, P and K, fertilizer doses applied, grain yield and total N, P and K uptake, the basic parameters *viz.,* nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizers (Cf) and FYM (Cfym) were computed. The results emanated from the present investigation revealed that pearl millet *var.* CO 10 requires 2.81 kg N, 1.33 kg P_2O_5 and 2.53 kg K_2O for producing one

quintal of grain yield. The per cent contribution of N from soil was 26.36 and fertilizer was 45.44. With regard to P_2O_5, the percent contribution from soil was 38.51 and fertilizer was 44.14 while for K_2O, the per cent contribution from soil was 10.33 and from fertilizer was 87.45 per cent. The per cent contribution of nutrients from FYM was 27.55, 16.04 and 40.15 per cent N, P_2O_5 and K_2O respectively (Table 2).

Table 3. Soil test based fertilizer N, P_2O_5 and K_2O for desired yield targets of pearl millet under NPK alone and IPNS (kg ha^{-1})

Soil test values (kg ha^{-1})			STCR-NPK alone										STCR-IPNS								
			3.0 t ha^{-1}			3.5 t ha^{-1}			4.0 t ha^{-1}			3.0 t ha^{-1}			3.5 t ha^{-1}			4.0 t ha^{-1}		
SN	SP	SK	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O
180	16	380	81	59	33	112	74	47	143	89	62	43	37	18*	74	52	22	105	67	37
200	18	400	69	55	30	100	70	44	131	85	59	35*	33	18*	62	48	18*	93	63	34
220	20	420	58	51	27	89	66	41	119	81	56	35*	29	18*	51	44	18*	81	59	31
240	22	440	46	47	24	77	62	39	108	77	53	35*	25	18*	35*	40	18*	70	55	28
260	24	460	35*	43	21	65	58	36	96	73	50	35*	21	18*	35*	36	18*	58	51	25

*maintenance dose (50% of blanket dose; Blanket dose for pearl millet varieties:70:35:35 kg N, P_2O_5 & K_2O ha^{-1} respectively.

The data on NR, Cs, Cf and Cfym clearly revealed that relatively higher quantity of N followed by K_2O and P_2O_5 were required to produce unit quantity of pearl millet (*var.* CO 10). In case of contribution of nutrients from soil, relatively higher P was supplied by soil followed by N and K. The increase in supply of soil P was to the tune of 1.46 times of N and 3.72 times of K. With regard to Cf, fertilizer K_2O contributed relatively higher

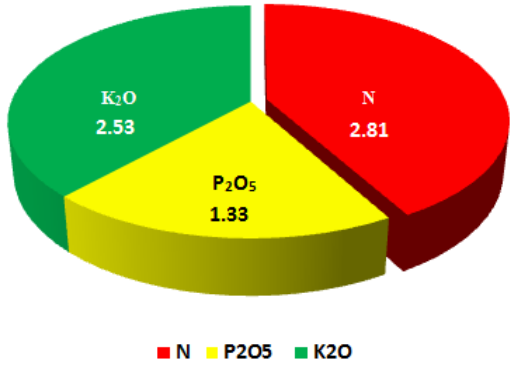

Fig.1. Nutrient requirement (kg q^{-1})

nutrients followed by fertilizer N and P_2O_5. Since the soil K is high the contribution of K from Fertilizer K_2O dominated a comparedto soil K. The present findings corroborated with the findings of Udayakumar and Santhi (2017), Praveena Katharine *et al.,* (2013) and Singh *et al.,* (2015).

Fertilizer prescription equations

Making use of the basic parameters *viz*., NR, Cs, Cf and Cfym, the Fertilizer Prescription Equations were developed under NPK alone and IPNS following the formulae as described earlier.

STCR-NPK alone			STCR-IPNS (NPK+FYM)		
FN	=	6.17 T - 0.58 SN	FN	=	6.17 T- 0.58 SN - 0.61 ON
FP_2O_5	=	3.02 T – 2.00 SP	FP_2O_5	=	3.02 T -2.00 SP - 0.83 OP
FK_2O	=	2.89 T – 0.14 SK	FK_2O	=	2.89 T -0.14 SK - 0.56 OK

where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively; T is the grain yield target in q ha^{-1} and SN, SP and SK respectively are alkaline $KMnO_4$–N, Olsen–P and NH_4OAc –K in kg ha^{-1}; ON, OP and OK are quantities of N, P and K in kg ha^{-1} supplied through FYM.

Soil test based fertilizer doses

Ready reckoners (nomograms) were formulated for a range of soil test values and for desired yield target of pearl millet under NPK alone and NPK plus FYM. A perusal of the estimate showed that when NPK alone was applied, for a soil test value of 180:24:460 kg ha^{-1} of $KMnO_4$- N, Olsen-P and NH_4OAc-K respectively, the fertilizer N, P_2O_5 and K_2O doses required to achieve a desired yield target of 3.0, 3.5 and 4.0 t ha^{-1} were 81, 43 and 21 kg ha^{-1}; 112, 58 and 36 kg ha^{-1} and 143, 73 and 50 kg ha^{-1} respectively. Whereas the fertilizer N, P_2O_5 and K_2O doses required when FYM @ 12.5 t ha^{-1} was applied along with NPK, the required fertilizer doses were 43, 21 and 18 kg ha^{-1}; 74, 36 and 18 kg ha^{-1} and 105, 51 and 25 kg ha^{-1} (Table 3).

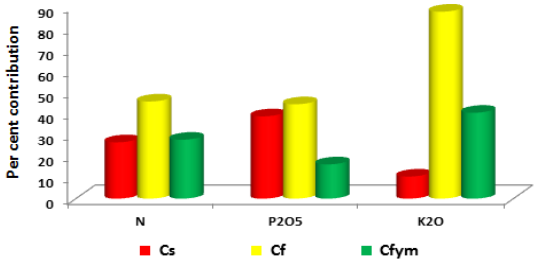

Fig.2. Per cent contribution of nutrients from soil, fertilizer and FYM

The extent of saving of inorganic fertilizers for pearl millet with the application of FYM @ 12.5 t ha^{-1} (with 21 % moisture, 0.64 %, 0.27 % and 0.46 % NPK respectively) was 38, 22 and 25 kg of fertilizer N, P_2O_5 and K_2O respectively. The per cent reduction in NPK fertilizers under IPNS also increased with increasing soil available NPK status and decreased with increase in yield targets. Similar trend of results were reported by Coumaravel (2012) and Sivaranjani *et al.* (2018).

The three yield target fixed in the treatments structure is to generate a database for computing basic parameters and develop fertlizer prescription equation. Therefore, using the experimental data

of the present investigation, the existing fertilizer prescription equations under IPNS for pearl millet hybrids were refined to suit pearl millet variety (CO 10) on Periyanaickenpalayam soil series - Vertic Ustropept of Tamil Nadu so as to prescribe fertilizer doses for desired yield targets.

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