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Reconstruction of fertiliser prescription equations for hybrid bhendi under drip fertigation through STCR-IPNS approach on Inceptisol

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Abstract
A field experiment was conducted on Palaviduthi soil series (*Typic haplustalf*, Red non- calcareous, sandy loam soil) by adopting the Soil Test Crop Response (STCR) under Integrated Plant Nutrition System (IPNS) approach during rabi season of 2021-22 with the main objective of reconstruction of fertiliser prescription equations for hybrid bhendi (COBhH-4) under drip fertigation using the existing fertiliser prescription equations for bhendi variety grown under conventional method fertiliser application and surface irrigation on a Periyanaickenpalayam soil series (*Vertic Ustropept*, Mixed black calcareous, clay loam soil). The field experiment consisted of eleven treatments *viz*., absolute control, FYM @6.25 and @ 12.5 alone, STCR-NPK alone and STCR-IPNS for targeted yield of 18, 20 and 24 t ha^{-1}, blanket recommendation with 100% RDF (200:100:100 kg NPK ha^{-1}) and 100% RDF + 12.5 t ha^{-1} FYM which were replicated thrice in randomized block design (RBD). The basic parameters *viz.*, nutrient requirement (NR), contribution of nutrients from soil (Cs), fertiliser (Cf) and farmyard manure (Cfym) were calculated from field experiment data. It has been found that the nutrient requirement (NR) for producing one quintal of bhendi fruit 0.52 kg of N, 0.18 kg of P_2O_5 and 0.59 kg of K_2O were required. The per cent contribution of nutrients from soil (Cs) as 22.63, 28.69 and 10.03 of N, P_2O_5 and K_2O respectively, per cent contribution from fertilisers (Cf) as 39.34, 22.65 and 55.18 of N, P_2O_5 and K_2O respectively and per cent contribution from FYM (Cfym) as 35.79 for N, 9.40 for P_2O_5 and 27.58 for K_2O. Using these basic parameters, the fertiliser prescription equations were reconstructed by adopting Soil Test Crop Response under Integrated Plant Nutrition System (STCR-IPNS) and nomograms were formulated for the suitable yield target of hybrid bhendi for a range of soil test values under drip fertigation.

Keywords: STCR-IPNS, FPEs, hybrid bhendi, drip fertigation, Palaviduthi soil series

Introduction
People preference towards the consumption of high value products such as meats, eggs, dairy products, vegetables, fruits and nuts is raising day by day than the grain produce and the demand was anticipated to raise more than 100 per cent by the year 2030 (ICAR, 2011) [1]. Bhendi (*Abelmoschus esculentum* L.) is an important vegetable crop in India and a good source of nutrition such as carbohydrates, fats, protein, minerals and vitamins in our diet (Satyanarayana, 2002) [2]. Bhendi is grown in India over an area of 546 thousand hectares with the production of 6700 thousand MT and productivity is 12.27 MT ha^{-1}. The major bhendi producing states are Andhra Pradesh, West Bengal, Assam, Bihar, Orissa, Tamil Nadu and Maharashtra. In Tamil Nadu, bhendi is produced in an area of 36.01 thousand ha having production of 293.07 thousand MT with a productivity of 8.97 MT ha^{-1}. Due to increasing demand, farmers use heavy doses of fertilisers to get higher yield especially for vegetables; the imbalanced fertilization of nutrients results in poor crop growth, low yield and quality. The best method to fulfil the growing need for vegetables is to produce more by using the available resources judiciously by advocating improved techniques.
Applying the right amount of irrigation water at the right time is crucial for making the most efficient use of any irrigation system, as either excessive or inadequate irrigation reduces yield due to leaching of nutrients and water stress respectively. Drip fertigation technique achieves water and fertiliser use efficiency by supplying irrigation water and fertiliser nutrients during the entire period of crop growth. The doses of fertiliser depends on knowledge of the predicted crop response to nutrients from fertiliser application in terms of crop nutrient requirements,

nutrient availability from indigenous sources, short-term and long-term destiny of the applied fertiliser nutrients (Dobermann and Fairhurst, 2000) [3]. The fundamental idea behind Soil Test Crop Response and Integrated Plant Nutrient System (STCR-IPNS) is the preservation and potential enhancement of soil fertility for sustaining crop yield through the combined use of organic manure, inorganic fertiliser and bio-fertiliser. For a hybrid bhendi crop, the STCR-IPNS fertiliser recommendation technique is paired with fertigation technology in an effort to enhance utilization of both fertiliser nutrient and irrigation water concurrently.

Materials and Methods

The study consisted of field experiment to reconstruct the fertiliser prescription equations for hybrid bhendi (COBhH-4) under drip fertigation on Palaviduthi soil series, (*Typic Rhodustalf*) during rabi 2021-22 at farmer's holding in Thondamuthur village, Coimbatore district. The soil of the experimental field is red, non-calcareous, sandy loam, slightly alkaline (pH- 7.52), non-saline (EC-0.09), low in organic carbon (3.2 g kg^{-1}), low in $KMnO_4$ (168 kg ha^{-1}), medium in Olsen-P (21.8 kg ha^{-1}) and high in NH_4OAc- K (381 kg ha^{-1}); with respect to DTPA-extractable micronutrients, sufficient in iron (6.36 mg kg^{-1}), copper (1.27 mg kg^{-1}) and manganese (15.35 mg kg^{-1}) and deficient in zinc (0.32 mg kg^{-1}).

The experiment was conducted on randomized block design with three replications comprised of eleven treatments T1: Absolute control, T2: FYM alone @6.25 t ha^{-1}, T3: FYM @12.5 t ha^{-1}, T4: STCR-NPK alone- 18 t ha^{-1}, T5: STCR-NPK alone- 21 t ha^{-1}, T6: STCR-NPK alone- 24 t ha^{-1}, T7: STCR-IPNS-18 t ha^{-1}, T8:STCR-IPNS- 21 t ha^{-1}, T9: STCR-IPNS-24 t ha^{-1}, T10: Blanket (100% RDF), T11: Blanket (100% RDF) + FYM 12.5 t ha^{-1}. The doses of fertilisers for STCR treatments were calculated on the basis of existing Fertiliser Prescription Equations (FPEs) for bhendi variety under the conventional method of fertilisers application and surface irrigation on Perianaickenpalayam soil series (*Vertic Ustropept*, mixed black calcareous, clay loam soil). For the supply of nitrogen, phosphorus and potassium to bhendi crop urea, single super phosphate and muriate of potash were applied. The entire dose of phosphate (P_2O_5) has been applied as basal at the time of sowing and the nitrogen (N) and potassium (K_2O) were applied through drip fertigation at an interval of seven days (Anant Bahadur *et al.*, 2009) [4] as per treatment schedule starting from 0 to 110 days after sowing. A composite FYM sample was drawn and analysed for moisture, N, P and K content and were 30%, 0.51%, 0.22% and 0.52% respectively.

Bhendi seeds were sown at 45 *X* 30 cm spacing on 31st January 2022 and after sowing routine cultural operations were followed as per TNAU Crop Production Guide 2020. The crop was grown to maturity, fruits were harvested and plot wise green fruit and stalk yields were recorded. The fruit, plant and post-harvest soil samples were collected from each plot, processed and analysed for nutrient content like N (Humphries, 1956) [18], P and K (Jackson, 1973) [19]. The N, P, and K uptake by bhendi was computed using the dry matter yield recorded and nutrient content analysed. From the yield data of bhendi, uptake of N, P and K, initial soil test values for available N, P and K and doses of fertiliser N, P_2O_5 and K_2O applied for the treatment T1 to T9, the basic parameters *viz.*, nutrient requirement (NR), contribution of nutrients from soil (Cs), fertiliser (Cf) and farmyard manure (Cfym) were calculated as outlined by Ramamoorthy *et al.*, 1967 [5] and fertiliser prescription equations were developed.

Table 1: Mean and range of fruit yield, initial soil test values, uptake of N, P and K and response of hybrid bhendi under drip fertigation

Treat No.	Treatment details	Fruit Yield	UN	UP	UK	SN	SP	SK	FN	FP_2O_5	FK_2O	FYM	Response
		t ha^{-1}	kg ha^{-1}									t ha^{-1}	t ha^{-1}
T1	Absolute control	8.2	38.5	6.7	38.4	170	23.2	383	0	0	0	0	-
T2	FYM alone @6.25 t ha^{-1}	9.5	46.6	7.4	44.5	169	23.2	379	0	0	0	6.25	1.3
T3	FYM alone @12.5 t ha^{-1}	10.6	53.6	8.3	50.3	170	21.2	381	0	0	0	12.5	2.4
T4	STCR - NPK alone - 18 t ha^{-1}	14.7	82.3	11.0	73.2	168	23.2	378	122	65	75	0.0	6.5
T5	STCR - NPK alone - 21 t ha^{-1}	17.3	98.0	13.8	90.0	170	23.1	383	164	81	128	0.0	9.1
T6	STCR - NPK alone - 24 t ha^{-1}	19.6	111.7	16.5	105.8	169	22.9	381	199	96	181	0.0	11.4
T7	STCR-IPNS - 18 t ha^{-1}	16.1	90.2	12.3	81.5	170	21.4	383	122	65	75	12.5	7.9
T8	STCR-IPNS - 21 t ha^{-1}	18.8	106.6	15.3	99.5	168	21.4	380	164	81	128	12.5	10.6
T9	STCR-IPNS - 24 t ha^{-1}	21.3	121.8	18.3	116.9	167	21.3	383	199	96	181	12.5	13.1
T10	Blanket (100% RDF)	16.6	92.1	12.8	84.7	169	23.1	380	200	100	100	0.0	8.4
T11	Blanket (100% RDF) + FYM 12.5 t ha^{-1}	18.3	104.1	14.9	95.9	170	22.5	382	200	100	100	12.5	10.1
Mean		15.6	86.0	12.5	80.1	169	22.4	381					
Range		8.2-21.3	38.5-121.8	6.7-18.3	38.4-116.9	167-170	21.2-23.2	378-383					
S.Ed		0.35	1.83	0.34	2.45								
CD (P=0.05)		0.74	3.8	0.7	5.1								

Results and Discussion

Fruit yield

The fruit yield ranged from 8.2 to 21.3 t ha^{-1} due to imposition of different treatments. Maximum fruit yield of 21.3 t ha^{-1} was obtained from the treatment T9: STCR-IPNS-24 t ha^{-1} followed by fruit yield of 19.6 t ha^{-1} obtained from T6: STCR-NPK alone -24 t ha^{-1}. The treatment T8: STCR-IPNS -20 t ha^{-1} obtained yield of 18.8 t ha^{-1}, which remained on par with the fruit yield of T11 blanket (100% RDF) + FYM 12.5 t ha^{-1} (18.3 t ha^{-1}) followed by T5: STCR-NPK alone -21 t ha^{-1} (17.3 t ha^{-1}). These treatments were superior from the treatments *viz.*, T10: blanket (100% RDF) and T7: STCR-IPNS-18 t ha^{-1} having fruit yield of 16.6 t ha^{-1} and 16.1 t ha^{-1} respectively, which remained on par with each other. These treatments were followed by the treatment T4: STCR-NPK alone-18 t ha^{-1} of 14.7 t ha^{-1}. Above mentioned treatments were superior to the rest of the treatments *viz.*, T3: FYM alone @12.5 t ha^{-1} followed by T2: FYM alone @6.25 t ha^{-1} which obtained fruit yield of 10.6 t ha^{-1} and 9.5 t ha^{-1} respectively and they were significantly different. Where in the minimum fruit yield obtained from absolute control (T1) was 8.2 t ha^{-1}.

It was observed that FYM applied along with STCR-NPK *i.e.*, STCR-IPNS was found to be significantly effective in increasing the yield of bhendi as compared to STCR-NPK alone. The yields were higher with integrated use of inorganic fertilisers and FYM than with the use of either of these separately (Karma Dema Dorji *et al*., 2011) [6]. The increase in yield could be attributed to the fact that the nutrients were more readily available, when organic and inorganic fertilisers were combined (E. K. Eifediyi, 2010) [7]. The better response under drip fertigation can achieve higher yield as compared to traditional method of applying fertilisers with surface irrigation (Mahendran *et al*., 2009 [8] and Govindarasu *et al*., 2013) [9].

Nutrient uptake

The nutrient uptake ranged from 38.5 to 121.8 kg ha^{-1} for N, 6.7 to 18.3 kg ha^{-1} for P and 38.4 to 116.9 kg ha^{-1} for K. The maximum uptake of nutrients was in T9 (STCR-IPNS-24 t ha^{-1}) with N, P and K uptake of 121.8, 18.3, and 116.9 kg ha^{-1} respectively, which was followed by T6 (STCR-NPK alone-4 t ha^{-1}) having N, P and K uptake of 111.7, 16.5, and 105.7 kg ha^{-1} respectively. These treatments were followed by T8 (STCR-IPNS-21 t ha^{-1}) and T11 (blanket (100% RDF) + 12.5 t ha^{-1} FYM), having nutrient uptake of 106.6 and 104.1 kg N ha^{-1}, 15.3 and 14.9 kg P ha^{-1} and 99.5 and 95.9, kg K ha^{-1}, respectively which remained on par with each other. These treatments were followed by T5 (STCR-NPK alone-21 t ha^{-1}) with nutrient uptake of 98.0, 13.8 and 90.0 kg ha^{-1} of N, P and K respectively. The treatments T5 was followed by T10 (blanket (100% RDF)) and T7 (STCR-IPNS-18 t ha^{-1}), which recorded nutrient uptake of 92.1 and 90.2 kg ha^{-1} of N, 12.8 and 12.3 kg ha^{-1} of P and 84.7 and 81.5 of kg ha^{-1} K and remained on par among them and was followed by T4 (STCR- NPK alone-18 t ha^{-1}) having uptake 82.3, 11.0 and 73.2 kg ha^{-1} of N, P and K respectively. The treatment T3 (FYM @12.5 t ha^{-1}) was followed by T2 (FYM @6.25 t ha^{-1}) and recorded the nutrient uptake of 53.5 and 46.6 kg ha^{-1} of N, 8.3 and 7.4 kg ha^{-1} of P and 50.3 and 44.5 kg ha^{-1} of K respectively. Absolute control recorded the lowest uptake of 38.5 kg ha^{-1} of N, 6.7 kg ha^{-1} of P and 38.4 kg ha^{-1} of K. This uptake pattern observed among the treatments were in similar line with those observed by Ravikiran *et al*., 2018 [10], Kanchana *et al*., 2020 [11], Mohanapriya *et al*., 2020 [12] and Agila *et al*., 2021 [13]. The NPK uptake increased with increasing soil application rate of these nutrients, which corroborate with Majeeduddin Solangi *et al*., 2015 [14]. Application of organic manures not only increased the supply of nutrients to plants, besides mobilizing of unavailable nutrients into available form due to improvement in soil physic-chemical and biological properties, further it increased the activity of soil enzymes (Singh *et al*., 2006) [15].

Response of bhendi

The response of fruit yield to fertiliser was estimated by deducting the fruit yield of the absolute control from the yield of each treatment and found to range from 1.3 to 13.1 t ha^{-1}. When comparing the STCR-IPNS treatments to STCR-NPK treatments with the same yield targets, it was discovered that the response was greater in the STCR-IPNS treatments. These results were similar to the response trend given by Agila *et al*., (2021) [13] and Paravathi *et al.,* (2021) [16].

Basic Parameters (Table 2)

The basic parameters of the targeted yield model were estimated using the information on the yield of bhendi, total uptake of N, P and K, initial soil test values for soil available N, P and K and doses of fertiliser N, P_2O_5 and K_2O applied for the treatments T1 to T9. The basic parameters of fertiliser prescription equations for bhendi are the nutrient requirement (NR) in kilogrammes per quintal of bhendi, the contribution of the nutrients that are already present in the soil (Cs), the nutrients present in the fertiliser (Cf) and farmyard manure (Cfym). To produce one quintal of bhendi fruit 0.52 kg of N, 0.18 kg of P_2O_5 and 0.59 kg of K_2O were required when the fertiliser was supplied through drip fertigation. The per cent contribution of soil and fertilisers were 22.63 and 39.34 for N, 28.69 and 22.65 for P_2O_5 and 10.03 and 55.18 for K_2O. The per cent contribution of N, P and K from FYM were 35.79, 9.40 and 27.58 respectively.

Table 2: Basic parameters for hybrid bhendi under drip fertigation

	N	P_2O_5	K_2O
NR	0.52	0.18	0.59
Cs %	22.63	28.69	10.03
Cf %	39.34	22.65	55.18
Cfym %	35.79	9.40	27.58

The basic parameters *viz*., NR, Cs, Cf and Cfym exposed that comparatively greater quantity of K_2O was indispensable to produce one quintal of bhendi under drip fertigation followed by N and P_2O_5. Phosphorus contribution from soil was relatively higher than N and K contribution. The P contribution from soil augmented to the degree of 1.27 times of N and 2.86 times of K. Contribution from fertilisers was superior in K followed by N and P. The trend observed in the contribution of nutrients from fertiliser in the present study was in harmony with observations made by Coumaravel (2012) [17] for maize-tomato sequence, Muralidhara *et al.* (2007) [27] for tomato, Agila *et al*., (2021) [13] for tomato and Paravathi *et al*., (2021) [18] for onion.

Refined fertiliser prescription equations for hybrid bhendi under drip fertigation

Soil test-based fertiliser prescription equations for desired yield target of bhendi were formulated using the basic parameters:

STCR-NPK Alone	**STCR-IPNS (NPK+ FYM)**
FN = 1.32T - 0.58 SN	FN = 1.32T - 0.58 SN - 0.91 ON
FP_2O_5= 0.78 T - 2.90 SP	FP_2O_5= 0.78 T - 2.90 SP - 0.95 OP
FK_2O = 1.07 T - 0.22 SK	FK_2O = 1.07 T - 0.22 SK - 0.60 OK

Where, FN, FP_2O_5 and FK_2O are fertiliser N, P_2O_5 and K_2O in kg ha^{-1}, respectively; 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}.

Fertiliser prescriptions for hybrid bhendi under drip fertigation: The FPEs constructed were used to derive fertiliser prescription for hybrid bhendi grown under drip fertigation for a range of soil test values and desired yield targets of 18, 21 and 24 t ha^{-1}. The fertiliser prescriptions for both NPK alone and IPNS were computed and presented in table 3. When FYM (with 30% moisture, 0.51% N, 0.22% P and 0.52% K content) was applied @ 12.5 t ha^{-1}, the quantity of fertiliser saved corresponds to 41, 18 and 28 kg N, P_2O_5 and K_2O. The fertiliser dosage increased when yield targets were high and decreased with soils of high available nutrients.

Similar trends were observed by Ravikiran *et al*., (2018) [10]. The fertiliser prescription equations developed for hybrid bhendi under drip fertigation can be recommended for large scale adoption after validation.

Table 3: Soil test-based fertiliser doses for desired yield targets of hybrid bhendi under STCR-NPK alone and STCR-IPNS

Initial Soil Test Values			STCR-NPK Alone									STCR-IPNS								
			18 t ha^{-1}			21 t ha^{-1}			24 t ha^{-1}			18 t ha^{-1}			21 t ha^{-1}			24 t ha^{-1}		
N	P	K	FN	P_2O_5	K_2O	FN	P_2O_5	K_2O	FN	P_2O_5	K_2O	FN	P_2O_5	K_2O	FN	P_2O_5	K_2O	FN	P_2O_5	K_2O
150	10	260	151	111	135	191	134	167	231	158	199	111	93	107	150	116	139	190	140	171
160	12	280	146	105	131	185	128	163	225	152	195	105	87	103	144	111	135	184	134	167
170	14	300	140	99	126	180	123	158	219	146	190	100*	81	98	139	105	130	178	128	162
180	16	320	134	94	122	174	117	154	213	140	186	100*	76	94	133	99	126	173	122	158
190	18	340	128	88	117	168	111	149	208	134	181	100*	70	89	127	93	121	167	116	154
200	20	360	123	82	113	162	105	145	202	129	177	100*	64	85	121	87	117	161	111	149

*Maintenance dose -50% of blanket dose; Blanket-200:100:100 kg N, P_2O_5 and K_2O.

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