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RESEARCH ARTICLE

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Soil Test Crop Response Based Integrated Plant Nutrition System for Hybrid Castor on an Alfisol

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ABSTRACT

Background: In the era of precision agriculture, application of fertilizer based on soil testing is an essential tool to prescribe nutrient doses for crops to improve nutrient use efficiency and yield of hybrid castor.

Methods: Field experiment was conducted in 2021 at the Tapioca and Castor Research station, Yethapur, region near Salem city, Tamil Nadu, India (11°35′N, 78°29′E). By adopting inductive cum targeted yield model fertilizer prescription equation (FPEs) were developed for hybrid castor under irrigated condition for Alfisol soil order. Initially soil fertility gradient were established with respect to soil available N, P and K nutrients and twenty four treatment were imposed in three fertility strips under factorial randomized design. The basic parameters [nutrient requirement (NR) and nutrients contributions from soil (Cs), fertilizer (Cf) and farmyard manure (Co)] were calculated from the field experimental data.

Result: The nutrient required for producing one quintal of hybrid castor seed yield was evaluated as 3.20 kg of nitrogen, 1.23 kg of phosphorus pentoxide (P_2O_5) and 3.28 kg of potassium oxide (K_2O). The study revealed that soil nutrient contribution was high in case of available phosphorus (41.87%), available nitrogen (21.56%) and available potassium (19.12%) respectively toward P, N and K nutrient uptake by hybrid castor. The nutrient contribution from farmyard manure (Co) towards the total uptake was 21.40% of N, 10.35% of P_2O_5 and 26.06 % of K_2O respectively. Using basic data, FPEs were developed for hybrid castor and ready reckoner were developed for operational range of soil test values for desired yield target under NPK alone and IPNS (NPK and FYM).

Key words: Fertilizer prescription, Hybrid castor, Nutrient requirement, Optimum yield, Precision agriculture.

INTRODUCTION

Castor (*Ricinus communis* L.) is the most important non edible industrial oilseed crop grown across the world in tropical, sub-tropical and warm temperate region. Castor oil has multifarious applications in production of wide industrial products ranging from medicines, aviation fuels, fuel additives, biopolymers and bio-diesel (Prasad, 2012). India is known as the world leader in castor seed and oil production and leads the international castor oil trade. Castor oil production in this country usually fluctuates between 250,000 and 350,000 tons per year. Approximately 86% of castor seed production in India is concentrated in Gujarat, followed by Andhra Pradesh and Rajasthan. Specifically, the regions of Mehsana, Banaskantha and Saurashtra/Kutch in Gujarat and the districts of Nalgonda and Mahboobnagar of Andhra Pradesh are the major areas of castor oil production in India (Shrirame *et al.*, 2011).

India is the world's largest producer of castor contributing to around 85 per cent of world's total production. In India, castor is cultivated in area of about 7.5 lakhs hectare with production of 1.19 million tonne in the year 2018- 2019. Average yield of castor in India is about 1594 kg hac^{-1} (www.indiastat.com). Also it meets more than 80 per cent of the demand of castor oil, thereby enjoying a dominant position in the world castor scenario.

In Tamil Nadu, castor was grown as a low input dry land crop in an area of 15,000 ha. Mostly used as a border or inter crops, where its drought - hardy nature helps to provide as cash for farming community and castor leaves provided for excellent green fodder for small ruminants. Castor growing areas in Tamil Nadu 1500 ha was mostly under rainfed condition and irrigated condition. Major limitation other than irrigation is varietal preferences. As farmers were growing different local varieties in intercrop, border crop and some parts as pure crop under rainfed condition and obtained very poor yield and less farm income.

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Hence, the study was undertaken with the objectives to formulate fertilizer prescription question for the high yielding castor hybrids as pure crop in terms of yield, acceptability and adoption potential for the local condition (Murugan and Akila, 2020).

Soil is an important part of successful agriculture, most precious natural resources and also the main basis for crop production activity. Imbalance in use of fertilizers not only deteriorates the soil quality but also affect the nutrient use efficiency. So to meet the increasing demand of agriculture, there is need to promote the balanced use of chemical fertilizers.

At this juncture, the prescription procedure outlined by Truog (1960) and modified by Ramamoorthy *et al.* (1967) as "Inductive cum Targeted yield model" provides a scientific basis for balanced fertilisation and balance between applied nutrients and soil available nutrients. Based on this concept, Soil Test Crop Response correlation studies under Integrated Plant Nutrition System (STCR-IPNS) were undertaken in different parts of India (Dey and Das, 2014) and Tamil Nadu (Santhi *et al*., 2017) and fertiliser prescriptions have been derived for desired yield targets of various major field and horticultural crops on different soil types. STCR-IPNS takes into account the nutrient requirement of crops, contribution of nutrients from soil, fertiliser and organic manures in deriving fertiliser prescriptions ensuring balanced nutrition to crops with sustained soil fertility. These prescriptions are of practical importance for efficient and judicious use of fertilisers in increasing crop production and in addition prescription for desired yield target of crops could be made based on resource availability of farmers (Dey and Santhi, 2014). Studies on Soil Test Crop Response based Integrated Plant Nutrition System (STCR-IPNS) have not yet been carried out for Hybrid castor in Tamil Nadu. Keeping the above facts in view, the present investigation on STCR-IPNS for Hybrid castor has been undertaken on *Alfisol* soil order in North Western Agro- climatic Zone of Tamil Nadu.

MATERIALS AND METHODS

Study area

The study site is located at the Tapioca and Castor Research Station, Yethapur Salem district, Tamil Nadu, India (11°35′N Latitude, 78°29′E Longitudes) at an altitude of 282 meters above mean sea level). In this study, the data from 72 plots were studied. Each plot size of about 25 m^2 and all are sown with the same hybrid YRCH-1 castor. The growing period for castor in our study was from June to November 2021.

Experimental soil (0-15 cm deep) was red in colour, sandy loam in texture, almost neutral (pH = 7.52), non-saline (EC 0.32 dS m^{-1}), with cation exchange capacity of 22.7 cmol (p+) kg^{-1} and non-calcareous in nature. The initial experimental soil had 0.61% of organic carbon, 210 kg ha^{-1} available alkaline potassium permanganate ($KMnO_4$) oxidizable nitrogen (N), 16.3 kg ha^{-1} Olsen phosphorus (P) and 245 kg ha^{-1} neutral normal ammonium acetate (NH_4OAc) exchangeable potassium (K), respectively. The DTPA extractable micronutrients status (*i.e*) zinc (Zn), iron (Fe), copper (Cu) and manganese (Mn) of experimental soil were in the sufficiency ranges.

In this study initially, fertility gradient was artificially created by applying three graded levels of fertilizers *i.e.*, level 1(N0P0K0), level 2 (N1P1K1) and level 3 (N2P2K2) and an exhaustive crop of dual-purpose sorghum (var. CO 30) was sown to improve the soil fertility and harvested at pre-flowering stage as fodder by adopting the inductive methodology developed by Ramamoorthy *et al.* (1967). The level of N was based on the recommendation of gradient crop. Based on the P and K fixing capacity of the experimental soils the levels of P and K were 100 and 80 kg ha^{-1}, respectively.

Pre-sowing and post-harvest soil samples were collected from each strip of gradient crop and analyzed for available nitrogen, available phosphorus and available potassium. Each strips were divided into 24 plots after the development of fertility gradient and soil samples were collected from all the seventy-two plots prior to castor sowing and analyzed for alkaline $KMnO_4$-N (Subbaiah, 1956), Olsen P (Olsen, 1954) and NH_4OAc-K (Stanford and English, 1949).

The experimental treatment structure was laid out in a fractional factorial design with three factors and four levels in each *i.e*, Nitrogen (0, 45, 90 and 135 kg ha^{-1}), Phosphorus (P_2O_5) (0, 20, 40 and 60 kg ha^{-1}) and Potassium (K_2O) (0, 20, 40 and 60 kg ha^{-1}) comprising twenty-four treatments (Table 1). Three levels of Farmyard manure (FYM) (no fym, fym @ 6.25 t ha^{-1}, fym @ 12.5 t ha^{-1}) were superimposed across the strips. 24 treatments were present in all the strips and treatments were randomized in such a way that consisted of 21 fertilizer treatments and three controls in either direction. The treatment structure is given in Table 1. FYM and phosphorus fertilizers were applied basally while nitrogenous and potassium fertilizer was applied in three splits (*i.e.*, 50% @ basal and 25% @ 30 DAS and 60 DAS). The crop was grown along with all the management practices. Castor capsules are harvested @ 90, 120 and 150 DAS and the capsules were sun-dried and seeds were dehulled. The samples from 120 DAS were processed and analyzed for Plant N (Humphries, 1956), P and K (Jackson, 1973) and the total uptake of NPandK was computed by multiplying the mineral content with the dry-matter yield.

The basic parameters *viz*., i) Nutrient requirement (NR). ii) Nutrient contribution from soils (Cs). iii) Nutrient contribution from fertilizers (Cf) were computed utilizing formula described and outlined by Ramamoorthy*et al.* (1967). iv) Nutrient contribution from farmyard manure (Co) were accounted using formula outlined by Santhi *et al.* (1999).

(i) Nutrient requirement for hybrid castor (kg q^{-1})

Kg $N/P_2O_5/K_2O$ required per quintal of hybrid castor seed production (NR) =

$$\frac{\text{Total uptake of } N/P_2O_5/K_2O \text{ (kg ha}^{-1}\text{)}}{\text{Castor seed yield}}$$

(ii) Percentage contribution of nutrient from soil to total uptake (Cs)

Percentage contribution of $N/P_2O_5/K_2O$ from soil (CS) =

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

(iii) Percentage contribution of nutrient from fertilizer to total uptake (Cf)

Percentage contribution of $N/P_2O_5/K_2O$ from fertilizer =

$$\frac{\text{Total uptake of } N/P_2O_5/K_2O \text{ in treated plot (kg ha}^{-1}\text{) - (Soil test velue for available } N/P_2O_5/K_2O \text{ in the treated plot (kg ha}^{-1}\text{)} \times \text{Average Cs}}{\text{Fertilizer } N/P_2O_5/K_2O \text{ applied (kg ha}^{-1}\text{)}} \times 100$$

(iv) Percentage contribution of nutrient from farmyard manure to total uptake (Co)

Percentage of contribution of $N/P_2O_5/K_2O$ from FYM =

$$\frac{\text{Total uptake of } N/P_2O_5/K_2O \text{ in FYM treated plot (kg ha}^{-1}\text{) - (Total uptake of } N/P_2O_5/K_2O \text{ in FYM treated plot (kg ha}^{-1}\text{)}}{\text{Nutrient N/P/K added through FYM (kg ha}^{-1}\text{)}} \times 100$$

Targeted yield equations

Fertilizer nitrogen (FN)

$$FN = \frac{\frac{NR}{Cf}}{100} T - \frac{Cs}{Cf} SN$$

$$FN = \frac{\frac{NR}{Cf}}{100} T - \frac{Cs}{Cf} SN - \frac{Co}{Cf} ON$$

Fertilizer phosphorus (FP_2O_5)

$$FP_2O_5 = \frac{\frac{NR}{Cf}}{100} T - \frac{Cs}{Cf} \times 2.29 \times SP$$

$$FP_2O_5 = \frac{\frac{NR}{Cf}}{100} T - \frac{Cs}{Cf} \times 2.29 \times SP - \frac{Co}{Cf} \times 2.29 \times OP$$

Fertilizer potassium (FK_2O)

$$FK_2O = \frac{\frac{NR}{Cf}}{100} T - \frac{Cs}{Cf} \times 1.21 \times SK$$

$$FK_2O = \frac{\frac{NR}{Cf}}{100} T - \frac{Cs}{Cf} \times 1.21 \times SK - \frac{Co}{Cf} \times 1.21 \times OK$$

Where,

FN, FP_2O_5 and FK_2O = Fertilizer N, P_2O_5 and K_2O (kg ha^{-1}) respectively.

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

Cs = Percentage contribution from the soil.

Cf = Percentage contribution from fertilizer.

SN, SP and SK = Soil test value for available N, P and K (kg ha^{-1}), respectively.

Co = Percentage contribution from FYM, ON, OP.

OK= Quantity of N, P_2O_5 and K_2O applied through FYM.

Utilising above stated equations FPEs were made and it serve as a basis for calculating fertilizer doses for desired yield targets (T) of hybrid castor for operational soil test values.

RESULTS AND DISCUSSION

The post-harvest soil available nutrient values revealed that the mean available soil nitrogen were 174 kg ha^{-1} in strip 1, 202 kg ha^{-1} in strip 2 and 221 kg ha^{-1} in strip 3. The mean available soil phosphorus were 10.8, 17.9 and 24.1 kg ha^{-1} in strip 1, strip 2 and strip 3 respectively. For available potassium, the mean values were 211, 242 and 256 kg ha^{-1} respectively (Table 2). The mean seed yield of hybrid castor YRCH-1 were 1860, 2134 and 2257 kg ha^{-1}. The nutrient

Table 1: Treatment structure for test crop experiment (Hybrid castor).

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	40	40
1	1	1	45	20	20
1	2	1	45	40	20
1	1	2	45	20	40
1	2	2	45	40	40
2	1	1	90	20	20
2	0	2	90	0	40
2	1	2	90	20	40
2	2	2	90	40	40
2	2	1	90	40	20
2	2	0	90	40	0
2	2	3	90	40	60
2	3	2	90	60	40
2	3	3	90	60	60
3	1	1	135	20	20
3	2	1	135	40	20
3	2	2	135	40	40
3	3	1	135	60	20
3	3	2	135	60	40
3	2	3	135	40	60
3	3	3	135	60	60

Table 2: Mean values of presowing soil available nutrients, seed yield and NPK nutrient uptake by hybrid castor.

	Soil test values (kg ha^{-1})			Seed yield	Castor total harvest (kg ha^{-1})		
	$KMnO_4$-N	Olsen P	NH_4OA-K		N uptake	P uptake	K uptake
Strip 1	174	10.8	211	1860	61.7	9.6	53.3
Strip 2	202	17.9	242	2128	68.2	11.4	57.5
Strip 3	221	24.1	256	2253	70.1	12.6	63.8

Table 3: Nutrient requirement and nutrient contributions from soil, fertilizer and farmyard manure for castor.

Parameter	Basic data		
	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	3.20	1.23	3.28
Contribution from soil (Cs) (%)	21.56	41.87	19.12
Contribution from fertilizers (Cf) (%)	30.83	26.67	52.14
Contribution from farmyard manure (Co) (%)	21.40	10.35	26.06

uptake ranged from 42.9 to 90.0 kg ha^{-1} for nitrogen, phosphorus ranged from 5.8 to 15.8 kg ha^{-1} and potassium uptake ranged from 40.4 to 85.3 kg ha^{-1} in strip 1- 3.

In the current study, the difference in hybrid castor seed yield and NPK uptake was due to the presence of variation on soil available nutrient status of N, P and K. The variation is the prerequisite for developing the fertilizer prescription equations using basic parameters for desired yield target. Sherene *et al*. (2016) and Santhi *et al*. (2011) reported similar existence of an operational range of available N, P and K for cotton under vertisol and beetroot on Alfisol.

Basic parameters

Basic parameters were calculated using the data on castor seed yield, NPK uptake, initial available soil nutrients and the fertilizers applied.

Nutrient requirement (NR)

The data revealed that the hybrid castor requires 3.20 kg of nitrogen, 1.23 kg of phosphorus (P_2O_5) and 3.28 kg of potassium (K_2O) for producing a 100 kg of hybrid castor seed (Table 3). Nutrient requirement trends were potassium > Nitrogen > phosphorus for the castor seed production. A similar trend of requirement was reported by Ahmed *et al*. (2001) in castor, Smitha John (2004) for cabbage and Agila *et al*. (2021) for tomato respectively.

Contributions percentage of nutrients from fertilizers (Cf), farmyard manure (Co) and soil (Cs) to total uptake

The soil nutrient contribution to the total uptake was computed using the above given formula in absolute control plot in each strip. The study revealed that soil nutrient contribution (Table 3) was high in case of available phosphorus (41.87%), followed by available nitrogen (21.56%) and soil available potassium recorded 19.12% contribution respectively towards P, N and K nutrient uptake by hybrid castor. A similar sort of soil contribution towards the plant uptake was reported by Mahajan *et al*. (2013) in rice in alluvial soil. In the case of fertilizer nutrients contribution, NPK fertilizer applied plots of all the strips were used to compute and results showed that fertilizer contribution towards nutrient uptake was in the trend K_2O > N > P_2O_5. The calculated Cf revealed that potassium fertilizer (52.12%) magnitude was 1.69 times more than the fertilizer nitrogen (30.83%) and 1.95 times more than the phosphorus fertilizer (26.67%). Comparing the contribution from soil vs fertilizer, greater contribution was recorded from the fertilizer than from the soil. Above results coincide with the report on fertilizer contribution towards aggregatum onion by (Sugumari *et al*., 2021) and (Katharine *et al*., 2013) on cotton.

From farmyard manure alone applied plots of all strips, the nutrient contribution from farmyard manure (Co) towards total uptake was computed. The results revealed that FYM contribution was 21.40% of N, 10.35% of P_2O_5 and 26.06% of K_2O respectively towards total nutrient uptake by hybrid castor following the trend K_2O> N > P_2O_5. Similar nutrient contribution from farmyard manure(Co) was reported by Madhavi *et al*. (2020) in sesame in Alfisol soil type. Similar trends for Cs, Cf and Co were reported by Madhavi *et al.* (2020) in sesame and Ahmed *et al.* (2001) in castor under Alfisol soil type.

Fertilizer prescription equations

The targeted yield model of hybrid castor was formulated using the basic parameters.

Inorganic fertilizer alone

$$FN = 10.38\ T - 0.70\ SN$$
$$FP_2O_5 = 4.62\ T - 3.60\ SP$$
$$FK_2O = 6.30\ T - 0.44\ SK$$

Inorganic fertilizer with FYM

$$FN = 10.38\ T - 0.70\ SN - 0.69\ ON$$
$$FP_2O_5 = 4.62\ T - 3.60\ SP - 0.89\ OP$$
$$FK_2O = 6.30\ T - 0.44\ SK - 0.60\ OK$$

where,

FN, FP_2O_5 and FK_2O = Fertilizer Nitrogen, Phosphorus and Potassium in kg ha^{-1}, respectively.

T = Desired yield target in q ha^{-1}; SN, SP and SK are soil available nutrients in kg ha^{-1}.

ON, OP and OK = The quantities of nitrogen, phosphorus and potassium supplied through farmyard manure in kg ha^{-1}.

Ahmed *et al*. (2001) documented the formulation of fertilizer prescription equations for castor crop under rainfed conditions at Palem, Mahbubnagar district of Andhra Pradesh. Santhi and her co-worker developed fertilizer prescription equations and documented for various crops like rice (Santhi *et al*., 1999), beetroot (Santhi *et al*., 2011), aggregatum onion (Santhi *et al.*, 2005) and sunflower (Santhi *et al*., 2004) in different parts Tamil Nadu.

Table 4: Soil test-based fertiliser recommendation for desired yield target of Hybrid Castor under inorganic alone and IPNS based fertilization.

Soil nutrient	Fertiliser doses (kg ha^{-1})					
	NPK alone	NPK+FYM @ 12.5 tha^{-1}	Per cent reduction over NPK alone	NPK alone	NPK+FYM @ 12.5 tha^{-1}	Per cent reduction over NPK alone
		Target 25 q ha^{-1}			**Target 27.5 q ha^{-1}**	
$KMnO_4$-N (kg ha^{-1})				**Fertilizer N (kg ha^{-1})**		
180	134	96	28	135**	122	10
200	120	82	32	135**	108	20
220	106	68	36	132	94	29
240	92	54	41	118	80	32
260	78	45*	42	104	66	37
280	64	45*	30	90	52	42
Olsen-P (kg ha^{-1})				**Fertilizer P_2O_5 (kg ha^{-1})**		
10	68**	56	18	68**	67	1
13	68**	45	34	68**	56	18
16	58	34	41	68**	45	34
19	47	23	51	59	35	41
22	36	22.5*	38	48	24	50
25	26	22.5*	13	37	22.5*	39
NH_4OAC-K (kg ha^{-1})				**Fertilizer K_2O (kg ha^{-1})**		
200	68**	39	43	68**	55	19
220	60	30	50	68**	46	32
240	51	22.5*	56	67	37	45
260	43	22.5*	48	58	28	52
280	34	22.5*	34	50	22.5*	55
300	25	22.5*	10	41	22.5*	45

(**maximum dose, * minimum dose. Blanket dose: 90:45:45 kg ha^{-1} of fertiliser N, $P_2O_5$and K_2O respectively along with 12.5 t ha^{-1} FYM for Hybrid Castor. A maintenance dose of 50 per cent of the blanket is recommended if the calculated fertiliser dose tends to fall below 50 per cent of the blanket. A maximum dose of 150 per cent if the calculated dose exceeds 150 per cent of the blanket.

Fertilizer prescriptions for desired yield target of hybrid castor under inorganic alone and IPNS based fertilization

A fertilizer prescription table was outlined for a yield targets of 25 and 27.5 q ha^{-1} based on the above given equations for a certain range of soil test values (Table 4). The table data exposed that the mineral nutrient requirement decreases with an increase in soil test value. *i.e.,* In case of Nitrogen and Potassium for every increase in 10 kg of soil available nutrient, there was an 8 kg and 4 kg decrease in fertilizer N and K_2O requirement respectively. Incase of phosphatic fertilizer there was a reduction of 14 kg of fertilizer for every 4 kg increase in soil available phosphorus. Table data also revealed that for every 250 kg increase in the target level of castor seed yield, an additional 28 kg, 11.54 kg and 15.5 kg of fertilizer nitrogen, phosphorus and potassium are required respectively for the same initial soil nutrient status.

CONCLUSION

In the present investigation, Fertilizer prescription equations (FPEs) were developed for both inorganic nutrition alone and under the Integrated Plant Nutrition System (IPNS) for the desired yield target for Alfisol of Tamil Nadu. The findings of the above study indicate that in STCR-IPNS technology, the fertilizer doses are tailored to the requirements of specific yield targets of hybrid castor taking into account the contribution from soil, fertilizers and organic manure. Hence, there will be a balanced supply of nutrients coupled with recycling of organic wastes avoiding either under-or over-usage of fertilizer inputs. Fertilizer recommendations based on this concept are more precise, quantitative and meaningful and farmers can also choose the desired yield target for hybrid castor according to their availability of resources and management conditions. Above equations should be used for the same or allied soil type and the maximum yield target should be based on the genetic characteristic of the hybrid which can be attained for that crop in that region. FPEs must be utilized in confined range of experimental soil test values and cannot be generalized.

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