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Short communication

Development of Targeted Yield Equations for Carrot (*Daucus carota*) in *Inceptisols* under the East and South East Coastal Plain Agro-climatic Zone of Odisha

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Carrot (*Daucus carota* L.) is a widely cultivated root vegetable. It belongs to the family *Apiaceae or Umbelliferae* and is native to central west Asia. Raw carrots are composed of 88% water, 9% carbohydrates, 0.9% protein, 2.8% dietary fibre, 1% ash and 0.2% fat and are the best source of carotene (Sarkar and Sharma, 2010) . Use of chemical fertilizers is very much essential to attain the maximum yield of carrot. Application of fertilizers based on soil test results brings real balance between the applied fertilizer nutrients and the soil available nutrients. The use of soil test based fertilizer recommendation is a must for sustainable farming (Rao and Srivastava, 2000). The relationships among soil test values, fertilizer recommendation and crop response to applied fertilizers were first established by Truog (1960) which was further simplified by Ramamoorthy *et al*. (1967) to suit Indian conditions. In Odisha, fertilizer prescription equations have been developed to achieve targeted yields of various crops like cabbage (Saren *et al*., 2015), chilli (Mishra *et al*., 2014), french bean (Pogula, 2016), green gram (Saren *et al*., 2018), black gram (Saren *et al*., 2017) and cowpea (Mishra *et al*., 2016). But, no such equations have been developed for carrot in Odisha conditions. Therefore, an attempt was made in this investigation to formulate fertilizer prescription equations for targeted yield of carrot.

The experiment was conducted in the Central Research Farm, Odisha University of Agriculture and Technology, Bhubaneswar under the east and south eastern coastal plain agro-climatic zone of Odisha having a latitude and longitude of 20° 15.937′ N and 85° 47.851′ E respectively. The climate is hot and humid. The site is characterized by medium land and the soil is sandy loam in texture both in surface and subsurface layers. The soil was moderately acidic (pH 5.45) reaction, medium in organic carbon, low in soil available N, medium in available P and low in available K. The soil of the experimental site belongs to *Inceptisol* and is classified as a fine, mixed and hyperthermic family of *Vertic Haplustepts*.

The experimental site (0.3 ha) was divided into 3 equal blocks during *Kharif* 2019 to create fertility gradient strips. Rice (cv. Lalat) was transplanted in strips with application of $N_0P_0K_0$ in Block-I, $N_{80}P_{40}K_{40}$ (Recommended dose) in Block-II and $N_{160}P_{80}K_{80}$ (twice the recommended dose) in Block-III. Soil samples were collected along with grains and straw samples at harvest. The blocks were ploughed and each block was subdivided into 24 subplots (5.5 × 4 m^2 each) during *Rabi*, 2019-20. The initial soil fertility status of each subplot was recorded. Considering 24 sub plots, 21 were treated with different treatment combinations (Table 1) of NPK fertilizers, two were applied FYM at 5 and 10 t ha^{-1} respectively and one sub plot was kept as absolute control in each block followed by sowing of carrot (*cv. Samson*) as the main crop.

The parameters needed for formulating fertilizer prescription equations for targeted yields were experimentally obtained for a given soil type, crop and agro-climatic condition. These parameters are as follows:

Nutrient requirement (NR) of economic produce,

$$NR\ (kg\ q^{-1}) = \frac{\text{Uptake of nutrient (kg ha}^{-1})}{\text{Yield (q ha}^{-1})}$$

The per cent contribution from soil available nutrients known as Cs,

$$Cs = \frac{\text{Total nutrient uptake in absolute control plot (kg ha}^{-1})}{\text{Soil test value of nutrients in control plot (kg ha}^{-1})}$$

The per cent contribution from applied fertilizer nutrient known as Cf.

Table 1. *Treatment details*

N Level (kg ha^{-1})	P Level (kg ha^{-1})	K Level (kg ha^{-1})
N_0 - 0	P_0 - 0	K_0 - 0
N_1 - 70	P_1 - 70	K_1 - 70
N_2 - 90	P_2 - 90	K_2 - 90
N_3 - 110	P_3 - 110	K_3 - 110
Treatment combinations		
$T_1 = N_0 P_2 K_2$	$T_8 = N_2 P_1 K_2$	$T_{16} = N_3 P_2 K_1$
$T_2 = N_1 P_1 K_1$	$T_9 = N_2 P_2 K_0$	$T_{17} = N_3 P_2 K_2$
$T_3 = N_1 P_1 K_2$	$T_{10} = N_2 P_2 K_1$	$T_{18} = N_3 P_2 K_3$
$T_4 = N_1 P_2 K_1$	$T_{11} = N_2 P_2 K_2$	$T_{19} = N_2 P_1 K_3$
$T_5 = N_1 P_2 K_2$	$T_{12} = N_2 P_2 K_3$	$T_{20} = N_3 P_3 K_2$
$T_6 = N_2 P_0 K_2$	$T_{13} = N_2 P_3 K_2$	$T_{21} = N_3 P_3 K_3$
$T_7 = N_2 P_1 K_1$	$T_{14} = N_2 P_3 K_3$	$T_{22} = N_0 P_0 K_0$ but FYM @ 10t ha^{-1}
	$T_{15} = N_1 P_3 K_2$	$T_{23} = N_0 P_0 K_0$ but FYM @ 5 t ha^{-1}
		$T_{24} = N_0 P_0 K_0$ (absolute control)

$$Cf = \frac{\text{(Total nutrient uptake of nutrient in fertilizer treated plot (kg ha}^{-1}\text{) - soil test value (kg ha}^{-1}\text{)} \times Cs)}{\text{(Fertilizer applied (kg ha}^{-1}\text{)}}$$

These parameters were then transformed into a workable equation as follows:

$$FD = \frac{(NR \times 100 \times T)}{Cf} - \frac{(STV \times Cs)}{Cf}$$

Where, FD = Fertilizer dose, T = Yield target (q ha^{-1}), STV = Soil test value

The range and average of initial soil test values, uptake of nutrients and root yield of carrot are presented in Table 2. The results showed that N uptake by the crop in Block-I varied between 53.4 and 100.5 kg ha^{-1} with an average of 81.3 kg ha^{-1}, which gradually increased with the progression of fertility gradients from Block-I to Block-III. In Block-II and Block-III, N uptake varied from 59.55 to 120.15 kg ha^{-1} and 63.13 to 123.1 kg ha^{-1} with average values of 91.70 and 100.13 kg ha^{-1}, respectively.

Likewise, the uptake of P by the crop in Block-I, Block-II and Block-III varied from 15.2 to 39.8 q ha^{-1}, 16.27 q ha^{-1} to 46.10 q ha^{-1} and 18.05 q ha^{-1} to 62.77 q ha^{-1}, respectively. The average uptake of P in Block-I, Block-II and Block-III were found to be 27.8 q ha^{-1}, 36.76 q ha^{-1} and 43.2 q ha^{-1}, respectively.

The uptake of the K by the crop was found to be ranged from 60.6 q ha^{-1} to 106.9 q ha^{-1}, 67.13 q ha^{-1} to 110.16 q ha^{-1} and 74.74 q ha^{-1} to 120.77 q ha^{-1} in Block-I, Block-II and Block-III respectively. The average uptake of K in Block-I, Block-II and Block-III were found to be 78.4 q ha^{-1}, 91.40 q ha^{-1} and 99.92 q ha^{-1}, respectively.

The uptake of N, P and K was found to be highest in the fertilizer dose at the rate of 110:110:110 - N:P_2O_5:K_2O kg ha^{-1}, respectively, irrespective of fertility gradient strips. The average uptake of all the nutrients N, P and K increased from Block-I to Block-III.

Soil test based fertilizer prescription equations for targeted yield of carrot (cv. Samson) were formulated using the basic parameters from the data of soil test values, yield of carrot and uptake of nutrient.

Targeted yield equations were formulated for carrot with and without organic matter and are presented in Tables 3 and 4. The prescribed fertilizer doses for carrot based on the targeted yield are presented in Table 5.

By using the fertilizer prescription equations, farmers can achieve a specific yield target of carrot based on the initial soil status and desired yield target set by them. This approach is superior to the blanket application of fertilizers and hence, it facilitates maintaining the soil health for sustainable crop production and enables the

Table 2. *Range and average yield of root and biomass of carrot, soil test values and NPK uptake*

Particulars	Fertility gradient strips			
		Block -I	Block -II	Block – III
Root yield (q ha^{-1})	Range	131.2 - 204.3	167.1 - 233.3	169.2 - 254.4
	Average	173.90	204.10	217.90
Biomass yield (q ha^{-1})	Range	71.7 - 150.4	95.5 - 191.9	95.7 - 210.2
	Average	115.10	137.80	148.70
Available N (kg ha^{-1})	Range	118.3 - 137	125.5 - 147.8	145.6 - 162.4
	Average	126.30	142.20	155.90
Available P_2O_5 (kg ha^{-1})	Range	21.3 - 31.4	26.4 - 35.9	33.8 - 39.5
	Average	25.50	31.90	36.70
Available K_2O (kg ha^{-1})	Range	93.9 - 107.8	102.4 - 118.5	112.5 - 123.6
	Average	99.20	107.60	118.50
N uptake (kg ha^{-1})	Range	53.4 - 100.5	59.6 - 120.1	63.13 - 123.1
	Average	81.30	91.70	100.13
P uptake (kg ha^{-1})	Range	15.2 - 39.8	16.3 - 46.1	18.1 - 62.8
	Average	27.80	36.76	43.20
K uptake (kg ha^{-1})	Range	60.6 - 106.9	67.1 - 110.2	74.7 - 120.8
	Average	78.40	91.40	99.92

Table 3. *Fertilizer prescription equations for carrot with FYM (IPNS)*

Parameters	NR (kg q^{-1})	Cs (%)	Cf (%)	Co (%)	Targeted yield equations
N	0.45	45	35	27	FN = 1.32 T - 1.28 SN - 0.79 ON
P_2O_5	0.41	49	26	45	FP_2O_5 = 0.69 T - 1.89 SP_2O_5 - 0.26 OP_2O_5
K_2O	0.54	45	50	23	FK_2O = 0.91 T − 0.90 SK_2O - 0.45 OK_2O

Where, ON, OP_2O_5 and OK_2O = kg N, P_2O_5 and K_2O added through organic sources.

Table 4. *Fertilizer Prescription equations for carrot without FYM*

Parameters	NR (kg q^{-1})	Cs (%)	Cf (%)	Targeted yield equations
N	0.46	45	35	FN = 1.32 T - 1.28 SN
P_2O_5	0.41	49	26	FP_2O_5 = 0.69 T - 1.89 SP_2O_5
K_2O	0.54	45	50	FK_2O = 0.91 T - 0.90 SK_2O

Where, FN, FP_2O_5 and FK_2O = kg fertilizer N, P_2O_5 and K_2O required; T = specific yield target in (q); SN, SP_2O_5 and SK_2O = kg soil available N, P_2O_5 and K_2O respectively; ON, OP_2O_5 and OK_2O = kg N,P_2O_5 and K_2O added through organic sources.

farmers to calibrate the requirement of costly fertilizer input depending upon the financial condition of the farmers, especially in Odisha condition.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

Table 5. *Prescribed fertilizer doses for carrot based on targeted yield concept*

Available soil nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1})								
			Targeted yield (160 q ha^{-1})			Targeted yield (185 q ha^{-1})			Targeted yield (210 q ha^{-1})		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
60	10	60	133	92	92	167	109	114	200	126	137
70	15	70	122	82	82	155	99	105	188	117	128
80	20	80	119	73	74	142	90	96	175	107	119
90	25	90	96	63	65	129	80	87	162	98	110
100	30	100	84	54	56	116	71	78	149	88	101
110	35	110	71	44	47	103	62	69	136	79	92
120	40	120	58	35	38	91	52	60	124	69	83
130	45	130	45	25	29	78	43	51	111	60	74
140	50	140	32	20	20	65	33	42	98	50	65
150	55	150	19	7	11	52	24	34	85	41	56

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