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Soil Test Based Fertilizer Prescriptions through Inductive cum Targeted Yield Model for *Sesamum* on Alfisol

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Abstract: Studies on Soil Test Crop Response Based Integrated Plant Nutrition System (STCR-IPNS) were conducted for three years adopting the Inductive cum Targeted Yield Model, on alfisols of Unified Andhra Pradesh, Southern India during summer 2016-2018 in order to develop fertilizer prescriptions through IPNS for the desired yield targets of *Sesamum* under field conditions. The bases for making the fertilizer prescriptions *viz.* nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and vermicompost (CVC) were computed using the field experimental data. Making use of these basic parameters, the fertilizer prescription equations were developed under NPK alone and under IPNS for the desired yield targets of *Sesamum* for a range of soil test values. The quantity of fertilizers contributed by the application of vermicompost was assessed. Nutrient requirement to produce 100 kg of sesame seed was worked out to be 10.20 kg N, 3.90 kg P_2O_5 and 5.22 kg K_2O. In the present investigation, the requirement of N was higher which is followed by K_2O and P_2O_5. The requirement of N was 2.62 times higher than P and 1.95 times higher than K. The percent contribution of N, P and K was 12.25, 15.75 and 6.00 from soils, 41.68, 22.85 and 59.97 from fertilizer and 9.87, 6.74 and 18.65 from organic manures, respectively. Thus the Inductive cum Targeted Yield Model used to develop fertilizer prescription equations provides a strong basis for soil fertility maintenance consistent with high productivity and efficient nutrient management in farming for sustainable and enduring agriculture.

Key words: Fertilizer prescription equations, alfisol, Soil Test Crop Response Based Integrated Plant Nutrition System, *Sesamum*, yield target.

1. Introduction

With increase in the cost of fertilizer, it is imperative to reduce the quantity of fertilizer and increase their efficiency by way of getting higher yields per unit production. In this regard, targeted yield approach [1] provided a basis for such approach which takes into account available nutrient in the soils and crop needs. In the present philosophy of targeted yield approach, it is now possible to make fertilizer recommendation to the farmers considering their financial conditions and for the targeted yield of a crop. Sesame is an important economical oil seed crop for nation. India is the highest producer of sesame in the world which occupies an area of 1,420 thousand hectares with a production of 689 thousand tones and productivity of 485 kg/ha [2]. During 2016-2017 the cultivated area of sesame in unified Andhra Pradesh is about 85 thousand hectares and production 28 thousand tones with average productivity of 328 kg/ha

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[3]. No information is available on soil test crop response on sesame particularly in light soils of unified Andhra Pradesh and hence, the present investigation was conducted.

2. Materials and Methods

A field experiment was conducted on sesame during summer in years 2016-2018 at Agricultural Research Station, Uttukur, YSR Kadapah district, Andhra Pradesh, India using fertility gradient approach [1]. The approved treatment structure and layout design as followed in the All India Coordinated Research Project for Investigations on Soil Test Crop Response Correlation (AICRP-STCR) based on "Inductive cum Targeted Yield Model" [1] were adopted in the present investigation.

2.1 Fertility Gradient Experiment

Prior to the main experimentation, the first phase of experiment fertility gradient experiment was conducted by dividing into the three equal strips and three soil fertility gradients were prepared artificially by applying graded dose of N, P and K fertilizer so as to get large variation in one and the same field to evaluate the real relationship between yield of a crop yield and the soil fertility. The first strip (control variant) received no fertilizer ($N_0P_0K_0$), the second and third strips received one ($N_1P_1K_1$) and two ($N_2P_2K_2$) times the standard dose of N, P_2O_5 and K_2O, respectively, and a gradient crop of fodder maize (var. DHM 117) was grown. Pre-sowing and post-harvest soil samples were collected from each fertility strip and analyzed for alkaline $KMnO_4$-N [4], Olsen-P [5] and NH_4OAc-K [6].

2.2 Main Experiment

After harvest of exhaust crop, after confirming the establishment of fertility gradients in the experimental field, in the second phase of the field experiment, each strip was divided into 24 plots. The experiment was laid out in a fractional factorial design comprising 24 treatments in each strip and the test crop experiment with *Sesamum* was conducted with four levels each of N (0, 30, 60 and 90 kg/ha), P_2O_5 (0, 10, 20 and 30 kg/ha) and K_2O (0, 10, 20 and 30 kg/ha) and three levels of vermicompost (0, 2.5 and 5.0 t/ha). The experiment was conducted as per the approved guideline of AICRP-STCR and fertilizer recommendations were developed. The Integrated Plant Nutrient System (IPNS) treatments, *viz*., NPK alone, NPK + Vermicompost at 2.5 t/ha and NPK + Vermicompost at 5 t/ha were superimposed across the strips. There were 21 fertilizer treatments along with three controls which were randomized in each strip in such a way that all the treatments occurred in both the directions. The treatment structure and layout are given in Table 3. Full dose of P and half dose of N and K were applied at the time of sowing, while the remaining half dose of N was top dressing into split at 30 d and 45 d after sowing. The different doses of P at 10, 20 and 30 kg/ha were applied in the form of diammonium phosphate (DAP) as basal. The fertilizer materials used were urea, muriate of potash and DAP. The initial soil samples were drawn from 0-20 cm depth from each plot before application of fertilizer and analyzed for alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K [7]. The crop was grown to maturity, harvested and plot wise seed yield was recorded. The seed, plant and post-harvest soil samples were collected from each plot. The soil and plant samples were processed and analyzed and NPK uptake by *Sesamum* was computed using the dry matter. With the help of data on nutrients uptake, crop yields, fertilizer applied and soil test values before sowing of sesame, the basic data (nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and organics (Co)) were derived by formula and used for calculating fertilizer prescription [8].

2.3 Data Computation

Nutrient requirement (NR):

Dose of $N/P_2O_5/K_2O$ required (kg) per 100 kg of seed production, was expressed in kg/q.

NR = (Total uptake of N or P_2O_5 or K_2O (kg/ha))/ Seed yield (kg/ha) (1)

Percent contribution of nutrients from soil (Cs) to total nutrient uptake:

Cs = ((Total uptake of N or P_2O_5 or K_2O in control plot (kg/ha))/(Soil test value for available N or P_2O_5 or K_2O in control plot (kg/ha))) × 100 (2)

Percent contribution of nutrients from fertilizer (Cf) to total uptake:

Cf = (((Total uptake of N or P_2O_5 or K_2O in treated plot (kg/ha)) – (Soil test value for available N or P_2O_5 or K_2O in control plot (kg/ha) × Average Cs))/Fertilizer N or P_2O_5 or K_2O applied (kg/ha)) × 100 (3)

Percent contribution of nutrients from organics (Co) to total uptake:

Percent contribution from vermicompost (CVC):

CVC = (((Total uptake of N or P or K in vermicompost treated plot (kg/ha)) – (Soil test value for available N or P or K in vermicompost treated plot (kg/ha) × Average Cs))/Nutrient N/P/K added through vermicompost (kg/ha)) × 100 (4)

These parameters were used for developing fertilizer prescription equations for deriving fertilizers doses, and the soil test based fertilizer recommendations were prescribed in the form of a ready table for desired yield target of *Sesamum* under NPK alone as well as under IPNS.

2.4 Fertilizer Prescription Equations

Making use of these parameters, the fertilizer prescription equations were developed for *Sesamum* as furnished below:

Fertilizer N (FN):

FN = (NR/(Cf/100)) × T – (Cs/Cf) × SN (5)

FN = (NR/(Cf/100)) × T – (Cs/Cf) × SN – (CVC/Cf) × ON (6)

Fertilizer P (FP_2O_5):

FP_2O_5 = (NR/(Cf/100)) × T – (Cs/Cf) × 2.29SP (7)

FP_2O_5 = (NR/(Cf/100)) × T – (Cs/Cf) × 2.29SP – (CVC/Cf) × 2.29OP (8)

Fertilizer K (FK_2O):

FK_2O = (NR/(Cf/100)) × T – (Cs/Cf) × 1.21SK (9)

FK_2O = (NR/(Cf/100)) × T – (Cs/Cf) × 1.21SK – (CVC/Cf) × 1.21OK (10)

where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg/ha, respectively; NR is nutrient requirement (N or P_2O_5 or K_2O) in kg/q, Cs is percent contribution of nutrients from soil, Cf is percent contribution of nutrients from fertilizer, CVC is percent contribution of nutrients from vermicompost, T is the yield target in q/ha; SN, SP and SK, respectively are alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K in kg/ha and ON, OP and OK are the quantities of N, P and K supplied through vermicompost in kg/ha.

These equations serve as a basis for predicting fertilizer doses for specific yield targets (T) of *Sesamum* for varied soil available nutrient levels. On the basis of these equations, ready reckoner for different yield targets of *Sesamum* for different soil test values was developed.

3. Results and Discussion

The experimental findings of the study have been presented in following Tables 1-6.

3.1 Fertility Gradient Experiment

The crop had extremely low dry matter yield of 10.9 q/ha without application of fertilizers (Table 1). The production triggered to as high as 19.8 q/ha by the application of 200, 60 and 50 kg of recommended level of N, P_2O_5 and K_2O/ha. The high dose of twice the recommended level of fertilizers increased the dry matter yield to 19.8 q/ha in the fertility gradient experiment. Thus, it is observed that dry matter yield has highly risen from low fertility (0X strip) to high fertility (2X strip). The soil test values before growing exhaust crop was 101 kg/ha of available N, 20.02 kg/ha of available P_2O_5 and 114 kg/ha of available K_2O. The soil available N, P_2O_5 and K_2O after harvest of maize were 104, 21.12 and 126 kg/ha in 0X, 148, 27.24 and 154 kg/ha in 1X and 194, 35.16 and 196 kg/ha in 2X,

Table 1 Dry matter yield of maize under different strips.

Fertility gradient	Dry matter yield (q/ha)
0X	10.9
1X	14.6
2X	19.8

Table 2 Soil chemical properties before and after harvest of exhaust crop (maize).

	pH	Electrical conductivity (dS/m)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
Initial soil test values	8.14	0.12	101	20.02	114
Variation in soil properties under different treatments (0X, 1X and 2X) after harvest of the maize crop					
0X	8.01	0.14	104	21.12	126
1X	8.13	0.18	148	27.24	154
2X	8.16	0.22	194	35.16	196

Table 3 Layout plan of Soil Test Crop Response Based Integrated Plant Nutrition System (STCR-IPNS) experiment with *Sesamum* in light soils.

	0X	1X	2X
VC 1 (0 t/ha)	000	000	000
	N3P2K1	N3P3K1	N3P1K1
	N1P2K2	N2P2K2	N3P2K2
	N2P3K2	N3P2K3	N2P2K1
	N2P1K1	N2P2K3	N1P1K1
	N1P1K2	N1P2K1	N2P3K3
	N3P3K2	N3P3K3	N2P1K2
VC 2 (2.5 t/ha)	000	000	000
	N3P3K1	N3P1K1	N3P2K1
	N2P2K2	N3P2K2	N1P2K2
	N3P2K3	N2P2K1	N2P3K2
	N2P2K3	N1P1K1	N2P1K1
	N1P2K1	N2P3K3	N1P1K2
	N3P3K3	N2P1K2	N3P3K2
VC 3 (5 t/ha)	000	000	000
	N3P1K1	N3P2K1	N3P3K1
	N3P2K2	N1P2K2	N2P2K2
	N2P2K1	N2P3K2	N3P2K3
	N1P1K1	N2P1K1	N2P2K3
	N2P3K3	N1P1K2	N1P2K1
	N2P1K2	N3P3K2	N3P3K3

Treatments: N1: 30 kg N/ha, N2: 60 kg N/ha, N3: 90 kg N/ha; P1: 10 kg P_2O_5/ha, P2: 20 kg P_2O_5/ha, P3: 30 kg P_2O_5/ha; K1: 10 kg K_2O/ha, K2: 20 kg K_2O/ha, K3: 30 kg K_2O/ha; 0: control; VC 1, 2 & 3: vermicompost levels.

respectively (Table 2). The result of the above findings was in conformity with findings of Elli *et al.* [9] who also reported such increase in dry matter yield with increase in fertilizer levels.

3.2 Main Experiment

3.2.1 Requirement and Efficiency of Nutrients

In the targeted yield model, the basic parameters for developing fertilizer prescription equations for *Sesamum* are (i) nutrient requirement (NR) in kilogram per quintal of seed, percent contribution of available NPK from soil (Cs), fertilizers (Cf) and vermicompost (CVC). Making use of data on the yield of *Sesamum*, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O applied, the basic parameters were computed.

Table 4 Basic data and fertilizer prescription equation for *Sesamum*.

Basic data	N	P	K
Nutrient requirement (kg/q)	10.20	3.90	5.22
Soil efficiency (%)	12.25	15.75	6.00
Fertilizer efficiency (%)	41.68	22.85	59.97
Organic efficiency (%)	9.87	6.74	18.65

Nutrient requirement to produce one quintal of sesame seed was 10.20 kg N, 3.90 kg P_2O_5 and 5.22 kg K_2O. In the present investigation, the requirement of N was higher, which is followed by K_2O and P_2O_5. The requirement of N was 2.62 times higher than P and 1.95 times higher than K. Similar results were recorded by Verma *et al.* [10], Avtari *et al.* [11] and Dhruw *et al.* [12] in production of one quintal of mustard, the requirement of N was more than P and K.

The percent contribution of N, P and K was 12.25, 15.75 and 6.00 from soils, 41.68, 22.85 and 59.97 from fertilizer and 9.87, 6.74 and 18.65 from organic manures, respectively (Table 4).

3.2.2 Percent Contribution of Nutrients from Soil (Cs) and Fertilizers (Cf) to Total Uptake of *Sesamum*

The percent contribution of nutrients from soil (Cs) to the total uptake was computed from the absolute control plots and it expresses the capacity of the crop to extract nutrients from the soil. In the present study, it was found that the soil has contributed 12.25% of available N, 15.75% of available P and 6.00% of available K, respectively, towards the total N, P and K uptake by *Sesamum*. The nutrient contribution of the soil to *Sesamum* was relatively higher for P_2O_5 as compared to that by N and K_2O. With regard to N and K_2O, comparatively lower Cs was recorded which might be due to the preferential nature of *Sesamum* towards the applied N and K_2O than the native N and K. This is in accordance with Kadu *et al.* [13] on cotton in Maharashtra.

The percent contribution from fertilizer nutrients (Cf) towards the total uptake by *Sesamum* was 41.68, 22.85 and 59.97, respectively, for N, P_2O_5 and K_2O and followed the order of $K_2O > N > P_2O_5$. The estimated percent contribution of nutrients from fertilizers (Cf) to total uptake clearly revealed the fact that the magnitude of contribution by fertilizer K_2O was 2.62 times higher than P_2O_5 and 1.44 times as that of N. The contribution from fertilizers was higher than from the soil for all the three nutrients. The findings are closely accorded with those reported by Anon [14] for transgenic cotton on black calcareous soil. The contribution of nutrients towards the growth of the crop was higher from fertilizers than that of soil for all the three nutrients (N, P_2O_5 and K_2O).

3.2.3 Contribution of Nutrients from Vermicompost

With a view to evaluate the extent to which the fertilizer requirements of *Sesamum* can be reduced under IPNS, the contribution of nutrients from vermicompost is to be quantified. Accordingly, the fourth basic parameter for the targeted yield model, the percent contribution of N, P_2O_5 and K_2O from vermicompost was computed. The estimated percent contributions of N, P_2O_5 and K_2O from vermicompost (Cf) were 9.87, 6.74 and 18.65, respectively, for *Sesamum* which indicated that relatively higher contribution was recorded for K_2O followed by N and P_2O_5. The present findings corroborated with the findings of Santhi *et al.* [15] and Saranya *et al.* [16] and the response yardstick recorded was 3.14 kg/kg.

3.2.4 Fertilizer Prescription Equations for *Sesamum*

Soil test based fertilizer prescription equations for desired yield target of *Sesamum* were formulated using the basic parameters and are furnished below:

STCR-NPK alone

$$FN = 22.08T - 0.21SN \quad (11)$$

$$FP = 4.44T - 0.14SP \quad (12)$$

$$FK = 5.28T - 0.06SK \quad (13)$$

STCR-IPNS (NPK + Vermicompost)

$$FN = 22.08T - 0.21SN - 0.54VCN \quad (14)$$

$$FP = 4.44T - 0.14SP - 0.23VCP \quad (15)$$

$$FK = 5.28T - 0.06SK - 0.25VCK \quad (16)$$

where, FN, FP and FK were fertilizer N, P_2O_5 and K_2O in kg/ha. Here T is target in q/ha, SN, SP and SK are soil available N, P and K in kg/ha, VCN, VCP and VCK are N, P and K through vermicompost in kg/ha. The ready reckoners (Table 5) can be prepared for recommending fertilizer dose for specific yield targets of sesame with varying soil test values.

Fertilizer response is denoted by the functional relationship between increase in crop yield and added fertilizers. It can be expressed graphically or algebraically by an equation. Chand *et al.* [17] reported the superiority of the target yield concept over other practices for different crops as it gave higher yields, net benefit and optimal economic returns. The yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis in majority of the crops thus establishing the utility of the prescription equations for recommending soil test based fertilizer application to the farmers. With this background, in the present investigation, soil test based fertilizer prescription equations for desired yield target of *Sesamum* was developed using the basic parameters obtained. The data clearly revealed the fact that the fertilizer N, P_2O_5 and K_2O requirements decreased with increase in soil test values and increased with increase in yield targets. Similar results were noticed by Mishra *et al.* [18] and Singh *et al*. [19]. Realizing the superiority of the targeted yield approach, Santhi *et al.* [20] documented in a handbook the soil test and yield target based fertilizer prescriptions under IPNS for 25 crops comprising cereals, millets, pulses, oilseeds, sugarcane, cotton, vegetables, spices and medicinal crops on 14 soil series for Tamil Nadu.

3.2.5 Fertilizer Prescription under IPNS for Desired Yield Target of *Sesamum*

A ready reckoner table was prepared using these equations for a range of soil test values and for a yield target of 5 q/ha for *Sesamum* (Tables 5 and 6). For achieving an yield target of 5 q/ha of seed with a soil test value of 200, 50 and 200 kg/ha of $KMnO_4$-N, Olsen-P and NH4OAc-K, the fertilizer N, P_2O_5 and K_2O doses required were 68, 15 and 18 kg/ha, respectively, under NPK alone and 58, 13 and 15 kg/ha under IPNS (NPK + Vermicompost at 2.5 t/ha). Similarly for the target of 6 q/ha, the respective values were 90, 20 and 24 kg/ha under NPK alone and 80, 18 and 20 under IPNS. Under IPNS, the fertilizer savings were 10, 2 and 3 kg/ha, respectively, when vermicompost was applied at 2.5 t/ha along with NPK fertilizers.

In the present investigation, there was reduction in NPK fertilizers under IPNS with increasing soil fertility levels with reference to NPK. These could be achieved by integrated use of vermicompost with NPK fertilizers. The role of vermicompost is multidimensional ranging from building up of organic matter, maintaining favorable soil physical properties

Table 5 Ready reckoner for *Sesamum* with chemical fertilizers alone.

Soil test			Target yield-5 q/ha			Target yield-6 q/ha		
$KMnO_4$-N	Olsen-P	NH_4OAc-K	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O
100	10	100	89	21	22	111	25	28
125	20	125	84	19	21	106	24	27
150	30	150	79	18	20	101	22	26
175	40	175	74	17	19	96	21	25
200	50	200	68	15	18	90	20	24
225	60	225	63	14	17	85	18	23
250	70	250	58	12	16	80	17	22
275	80	275	53	11	15	75	15	21
300	90	300	47	10	14	69	14	20

Table 6 Ready reckoners for *Sesamum* with chemical fertilizers and vermicompost at 2.5 t/ha.

Soil test value			Target yield-5 q/ha			Target yield-6 q/ha		
$KMnO_4$-N	Olsen-P	NH_4OAc-K	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O
100	10	100	79	19	19	101	23	24
125	20	125	73	18	18	95	22	23
150	30	150	68	16	17	90	21	22
175	40	175	63	15	16	85	19	21
200	50	200	58	13	15	80	18	20
225	60	225	52	12	14	74	16	19
250	70	250	47	11	13	69	15	18
275	80	275	42	9	12	64	14	17
300	90	300	37	8	11	59	12	16

and balancing supply of nutrients. In the present investigation also, these factors might have contributed to the yield enhancement in *Sesamum* when NPK fertilizers are coupled with vermicompost. Similar trend of results were reported by Anon [14] in transgenic cotton.

4. Conclusions

To conclude, soil test based IPNS for desired yield targets of *Sesamum* was developed in alfisols of unified Andhra Pradesh taking into account the nutrient requirement and contribution of N, P and K from various nutrient sources (soil, fertilizer and vermicompost). The specific yield equation based on soil health will not only ensure sustainable crop production but will also steer the farmers towards economic use of costly fertilizer inputs. The fertilizer prescription equations developed using this model can be applied to alfisols of all tropical regions by substituting the soil nutrient status of the particular field. Moreover, the methodology adopted in the present investigation, i.e., “Inductive cum Targeted Yield Model” can very well be used to derive FPEs for any field or horticultural crop (except perennial crops) on any soil series.

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