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 P₂O₅ and 5.22 kg K₂O. In the present investigation, the requirement of N was higher which is followed by K₂O and P₂O₅. 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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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 (N0P0K0), the second and third strips received one (N1P1K1) and two (N2P2K2) times the standard dose of N, P2O5 and K2O, 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 KMnO4-N [4], Olsen-P [5] and NH4OAc-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), P2O5 (0, 10, 20 and 30 kg/ha) and K2O (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 KMnO4-N, Olsen-P and NH4OAc-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/P2O5/K2O required (kg) per 100 kg of seed production, was expressed in kg/q.
NR = (Total uptake of N or P$_2$O$_5$ or K$_2$O (kg/ha))/Seed yield (kg/ha) 
Percent contribution of nutrients from soil ($Cs$) to total nutrient uptake:

$$Cs = \frac{(Total \ uptake \ of \ N \ or \ P_2O_5 \ or \ K_2O \ in \ control \ plot \ (kg/ha))/(Soil \ test \ value \ for \ available \ N \ or \ P_2O_5 \ or \ K_2O \ in \ control \ plot \ (kg/ha))) \times 100}{100}$$ (2)

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

$$Cf = \frac{((Total \ uptake \ of \ N \ or \ P_2O_5 \ or \ K_2O \ in \ treated \ plot \ (kg/ha)) \times \ Average \ Cs)/(Fertilizer \ N \ or \ P_2O_5 \ or \ K_2O \ applied \ (kg/ha))}{100}$$ (3)

Percent contribution from organics ($Co$):

CVC = (((Total uptake of N or P or K in vermicompost treated plot (kg/ha)) – (Soil test value for available N or P2O5 or K2O in vermicompost treated plot (kg/ha) × Average Cs))/Nutrient N/P/K added through vermicompost (kg/ha)) × 100 (4)

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$_2$O$_5$ and K$_2$O/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$_2$O$_5$ and 114 kg/ha of available K$_2$O. The soil available N, P$_2$O$_5$ and K$_2$O 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 P2O5 (kg/ha) | Available K2O (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 | 8.01   | 0.14                          | 104                 | 21.12                  | 126                   |
|                      | 8.13   | 0.18                          | 148                 | 27.24                  | 154                   |
|                      | 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              | N3P2K2              |
| N1P2K2                         | N2P2K2              | N3P2K2              |
| N2P3K2                         | N3P2K3              | N2P2K1              |
| N1P1K1                         | N1P2K1              | N1P1K2              |
| N2P1K2                         | N2P2K3              | N3P2K2              |
| N3P3K2                         | N3P3K3              | N2P1K1              |
| VC 2 (2.5 t/ha)                | 000                 | 000                 | 000                 |
| N3P3K1                         | N3P1K1              | N3P2K1              |
| N2P2K2                         | N3P2K2              | N1P2K2              |
| N3P2K3                         | N2P2K1              | N2P3K2              |
| N2P2K3                         | N1P1K1              | N2P1K1              |
| N1P1K2                         | N2P3K3              | N1P2K2              |
| N3P3K3                         | N2P1K2              | N3P2K2              |
| VC 3 (5 t/ha)                  | 000                 | 000                 | 000                 |
| N3P1K1                         | N3P2K1              | N3P3K1              |
| N2P2K2                         | N1P2K2              | N2P2K2              |
| N2P2K1                         | N2P3K2              | N2P2K3              |
| N1P1K1                         | N1P1K2              | N2P3K3              |
| N2P3K3                         | N2P1K2              | N3P3K2              |

Treatments: N1: 30 kg N/ha, N2: 60 kg N/ha, N3: 90 kg N/ha; P1: 10 kg P2O5/ha, P2: 20 kg P2O5/ha, P3: 30 kg P2O5/ha; K1: 10 kg K2O/ha, K2: 20 kg K2O/ha, K3: 30 kg K2O/ha; 0: control; VC 1, 2 & 3: vermicompost 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, P2O5 and K2O applied, the basic parameters were computed.

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.
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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 P2O5 and 5.22 kg K2O. In the present investigation, the requirement of N was higher, which is followed by K2O and P2O5. 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 P2O5 as compared to that by N and K2O. With regard to N and K2O, comparatively lower Cs was recorded which might be due to the preferential nature of Sesamum towards the applied N and K2O 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, P2O5 and K2O and followed the order of K2O > N > P2O5. The estimated percent contribution of nutrients from fertilizers (Cf) to total uptake clearly revealed the fact that the magnitude of contribution by fertilizer K2O was 2.62 times higher than P2O5 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, P2O5 and K2O).

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, P2O5 and K2O from vermicompost was computed. The estimated percent contributions of N, P2O5 and K2O from vermicompost (Cf) were 9.87, 6.74 and 18.65, respectively, for Sesamum which indicated that relatively higher contribution was recorded for K2O followed by N and P2O5. 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:

\[
\text{STCR-NPK alone} \quad FN = 22.08T - 0.21SN \quad (11)
\]
\[
FP = 4.44T - 0.14SP \quad (12)
\]
\[
FK = 5.28T - 0.06SK \quad (13)
\]
\[
\text{STCR-IPNS (NPK + Vermicompost)} \quad FN = 22.08T - 0.21SN - 0.54VCN \quad (14)
\]
FP = 4.44T – 0.14SP – 0.23VCP  
FK = 5.28T – 0.06SK – 0.25VCK

where, FN, FP and FK were fertilizer N, P₂O₅ and K₂O 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, P₂O₅ and K₂O 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 KMnO₄-N, Olsen-P and NH₄OAc-K, the fertilizer N, P₂O₅ and K₂O 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...
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.

### Acknowledgment

This work was carried out under part of AICRP on Soil Test Crop Response, ICAR at PJTSAU, Hyderabad-500 030, India.

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