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Fertilizer prescription equations for targeted yield of soybean (*Glycine max* L.) in Vertisol of Telangana, India

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Abstract
A field experiment was conducted for three years during *kharif*, 2017-18 to 2019-20 at the Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad district of the Professor Jayashankar Telangana State Agriculture University, Telangana State, under All India Coordinated Research Project on the soil test crop response correlation. The experiment was conducted in "two-phases". In the first phase soil fertility gradient was developed by dividing the experimental field into "three strips" and applying graded doses of fertilizers in them and growing of exhaust crop maize. In the second phase, *i.e.* next season main crop soybean was raised as per the programme. Response to selected combinations of "three-levels" of vermicompost (0, 2.5 and 5 t ha^{-1}), "four-levels" of nitrogen (0, 30, 60 and 90 kg ha^{-1}), four levels of phosphorus (0, 30, 60 and 90 kg ha^{-1}) and four levels of potassium (0, 20, 40 and 60 kg ha^{-1}) at different fertility levels of soybean was studied. In the present investigation, the total seed yield ranged from 1089 to 2834 kg ha^{-1}. The nutrient requirement for production of one quintal of soybean seed was found to be were 5.53 kg nitrogen, 0.67 kg phosphorus and 2.89 kg potassium. The percent contribution of nitrogen, phosphorus and potassium was 31.84, 33.48 and 11.27 from soil, whereas from chemical fertilizer it was 68.27, 33.13 and 75.96 and conjoint use of chemical fertilizer with vermicompost, it was 11.81, 3.57 and 9.08, respectively. With the help of these data fertilizer recommendations at different yield targets and soil test value can be calculated. Findings from present study can successfully be utilized as an effective guide for efficient and balanced fertilizer recommendations for the larger parts of Vertisols of Telangana state and other parts of India having similar agro-climatic conditions and soils.

Keywords: soybean, fertilizer prescription equations, soil test crop response, Vertisols

Introduction

Soybean is an important global crop and has very high nutritional value containing 40-45 % protein and 18-22% oil. This crop is gaining popularity on account of its unique characteristics and adaptability to various agro climatic conditions of the Indian soils. In India, Soybean is grown in an area of 11.67 million hectare with an annual production of about 8.59 million tonnes and productivity of 737 kg ha^{-1} (Agricultural Statistics at a Glance, 2016) [1]. Soybean has become an important oilseed crop in Northern Telangana Zone of Telangana State in a very short period with approximately 1.5 lakh ha area under its cultivation. There has been an unprecedented growth in soybean.

Fertilizer is among the costliest inputs in agriculture and the use of the right amounts of fertilizer is fundamental for farm profitability and environmental protection (Kimetu *et al.,* 2004) [14]. The annual consumption of fertilizers (N, P_2O_5 and K_2O) has increased from 0.07 million tons in 1951-52 to more than 28 million tons in 2010-11 and per hectare consumption has increased from less than 1.0 kg in 1951-52 to the level of 135.0 kg in 2010-11 (Karsangla and Gohain, 2015) [13], the nutrient use efficiency has gone down from 16 kg food grain produced per kg NPK applied during 1970's to 8 kg food grain produced per kg NPK applied during 1990's and around 6 kg now due to increasing deficiency of secondary and micronutrient (Tiwari *et al*., 2013) [20].

Fertilizer recommendation based on soil test crop response correlation (STCR) concept is more quantitative, precise and meaningful because the combined use of soil and plant analysis is involved in it. While developing the STCR targeted yield equation contribution of nutrients from soil, fertilizer and organics are taken in to consideration. Similarly, by taking these into consideration nutrient requirement (NR) to produce a quintal of grain or any economic produce are considered. It gives a real balance between applied nutrients and the available nutrients already present in the soil. Besides, it takes into account the farmer's ability to invent for raising the crops (Basavaraja *et al.*, 2016) [6].

Besides balanced nutrition of growing crops, this approach gives due consideration to soil fertility and strikes a real balance between the nutrients already available in the soil and those required by the crops to achieve a predetermined yield target. The present studies were, therefore, under taken with a view of evolving soil test and targeted yield based fertilizer recommendation for soybean and test their adoptability in Vertisols under field condition.

Materials and Methods

A field experiment was carried out at the Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad district, Telangana

State to develop a scientific basis for prescribing fertilizer recommendations for soybean with maize (*var.* DHM 117) as gradient and soybean (*Var.* Basar) as main crop during 2017-18 to 2019-20. The experiment was conducted as per the approved guidelines of All India Co-ordinated Research Project (AICRP) on Soil Test Crop Response Correlations (STCR) based on "Inductive cum Targeted Yield Model".

Gradient experiment

Prior to the main crop experimentation, the fertility gradient experiment was conducted by dividing the experimental field into three rectangular strips (0X, 1X and 2X). The layout of the experiment was based on the fertility gradient approach developed by Ramamoorthy *et al.* (1967) [15]. The needed variation in soil fertility levels was deliberately created by dividing the field into three equal strips (0X, 1X and 2X) which were applied with zero dose, recommended dose (100, 60 and 50 kg ha^{-1}) and double dose (200, 120 and 100 kg ha^{-1}) of NPK were applied in 0X, 1X and 2X strip respectively. An exhaustive crop of maize was grown to enable the applied fertilizer to undergo transformation in the soil by plant and microbes. Maize was harvested at 60 DAS and recorded the dry matter yield. Similarly, soil samples were also collected and analyzed to check the fertility gradient developed.

Main crop experiment

After the establishment of fertility gradient in the experimental field, each fertility strip was divided into three blocks to impose three levels of vermicompost (OM_1– 0 t ha^{-1}, OM_2 – 2.5 t ha^{-1} and OM_3 – 5.0 t ha^{-1}). The experiment was laid out in mixed factorial randomized design comprising of 21 treated plots and 3 control treatments in each strips covering totally 72 plots which comprised of 63 treated plots and 9 control plots and soybean crop was tested with four levels of N (0, 30, 60 and 90 kg ha^{-1}) P (0, 30, 60 and 90 kg ha^{-1}) and K (0, 20, 40 and 60 kg ha^{-1}). A half dose of N fertilizer along with a full dose of P and K was applied at soybean sowing and remaining half dose of N was applied at 30 DAS. Before applying the vermicompost and NPK, soil samples (0-20 cm) from all these plots were collected and analysed for alkaline-$KMnO_4$-N outlined by Subbaiah and Asija (1956) [19]; Olsen's-P and NH_4OAC-K method as described by Jackson (1973) [11].

At harvest, seed and stover yield was recorded from all the plots, and expressed in kg ha^{-1}. Representative plant samples were collected from the test crops, washed thoroughly with running water followed by double distilled water. The plant samples were then dried at 60 ^{0}C to attain a constant weight, ground and analysed for nitrogen, phosphorus and potassium contents by following standard procedure outlined by Jackson (1973) [11] and nutrient uptake was computed.

Data computation

Initial soil data, yield and nutrient uptake by the crop were used for obtaining nutrient required to produce a quintal of seed yield (NR), contribution of nutrients from the soil (% CS), contribution of nutrients from fertilizers (% CF) and contribution of nutrients from organic matter (COM) using following formulae.

NR (Kg of nutrient / q of grain) = Total nutrient (NPK) uptake (kg ha^{-1}) by grain + straw / Grain yield or any economic produce (q ha^{-1})

% CS = Nutrient uptake (NPK)(kg ha^{-1}) by grain + straw in control plot / Soil test values (Av.NPK) in control plot (kg ha^{-1}) X 100

% CF={Nutrient uptake by grain+straw in fertilized plot in kg ha^{-1}} - {[Soil test values in fertilized plot in kg ha^{-1}] X [% Contribution (NPK)from soil]} X 100 / Nutrient doses applied in treated plot (kg ha^{-1}) X 100

% COM ={Total uptake of NPK in organic plot (kg ha^{-1})}−{[Mean CF of control plot] X [STV in organic plot (kg ha^{-1})]}100 / Amount of NPK added through vermicompost (kg ha^{-1}) X 100

These basic parameters were transformed into simple, workable fertilizer adjustment equations for calculating specific yield target based on soil test values following the procedure of Ramamoorthy *et al.* (1967) [15].

Targeted yield equation

$$F = \frac{NR}{CF/100} \times T - \frac{CS}{CF} \times S - \frac{COM}{CF} \times M$$

F = Fertilizer dose of N, P_2O_5 and K_2O in kg ha^{-1}
T = Yield target in q ha^{-1}
S = Soil test values for available nutrient in kg ha^{-1} (N, P or K)
M = Nutrient content in organic matter in kg ha^{-1} (N, P or K)

Results and Discussion

Fertility gradient experiment

The crop had extremely low dry matter yield of 10.5 q ha^{-1} without application of fertilizers (Table 1). The production triggered to as high as 17.8 q ha^{-1} by the application of 200, 60 and 50 kg of recommended level of N, P_2O_5 and K_2O ha^{-1}. The high dose of twice the recommended level of fertilizers increased the dry matter yield to 17.8 q ha^{-1} 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 201 kg ha^{-1} of available N, 68 kg ha^{-1} of available P_2O_5 and 324 kg ha^{-1} of available K_2O. The soil available N, P_2O_5 and K_2O kg ha^{-1} after harvest of maize were 185, 60 and 338 kg ha^{-1} in 0X, 192, 69 and 327 kg ha^{-1} in 1X and 191, 67 and 349 kg ha^{-1} in 2X respectively (Table 2). The result of the above findings was in conformity with findings of Ellis *et al.*, (1997) [9] who also reported such increase in dry matter yield with increase in fertilizer levels.

Table 1: Dry matter yield of maize under different strips

Fertility Gradient	Dry matter Yield (q ha^{-1})
OX	10.5
1X	15.2
2X	17.8

Table 2: Soil chemical properties before and after harvest of exhaust crop (Maize)

Particulars	pH	EC	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Before sowing	8.14	0.324	201	68.02	324
After harvest of the maize crop					
Treatments	pH	EC	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
OX	8.04	0.32	182	54.63	317.48
1X	8.12	0.32	185	59.50	338.14
2X	8.19	0.37	191	66.67	348.62

Main experiment

Strip-wise range and mean values of yield, nutrient uptake and soil test values of are given in Table 3. The seed yield of soybean ranged between 1089 and 2632 with mean of 2119 kg ha^{-1} in 0X strip, 1145 and 2615 with mean of 2141 kg ha^{-1} in 1X strip. Whereas in 2X, 1281 and 2834 with mean of 2336 kg ha^{-1}. The highest seed yield of 2632 kg ha^{-1} obtained in treatment 60:90:60 NPK with 5 t ha^{-1} of vermicompost in 0X strip, highest seed yield of 2615 kg ha^{-1} obtained in treatment 60:90:40 NPK with 5 t ha^{-1} of vermicompost in 1X strip and highest seed yield of 2834 kg ha^{-1} obtained in treatment 90:90:60 NPK with 5 t ha^{-1} of vermicompost in 2X fertility gradient strip respectively.

Table 3: Yield and Nutrient uptake by soybean (kg ha^{-1}) in various strips

Parameters	OX		1X		2X	
	Range	Mean	Range	Mean	Range	Mean
Seed yield	1089 to 2632	2119	1145 to 2615	2141	1281 to 2834	2336
Stover yield	1318 to 2932	2379	1410 to 2789	2372	1452 to 3042	2590
N uptake	53 to 149	114	59 to 160	119	65 to 173	135
P uptake	5 to 18	13	7 to 22	14	7 to 26	18
K uptake	27 to 82	61	31 to 82	62	32 to 91	70
Soil Nitrogen	189 to 227	209	202 to 227	215	202 to 239	222
Soil Phosphorous	18 to 28	23	21 to 31	25	20 to 34	27
Soil Potassium	260 to 307	292	289 to 318	303	295 to 325	312

Maximum seed and stover yield of soybean was obtained in strip III followed by strip II and I. The result of the above findings was in conformity with findings of Singh *et al.*, (2006) [18] and Bagavathi *et al.*, (2019) [4] in rice, Santhi *et al*., (2002) [17] in onion, Salunkhe *et al.*, (2018) [16] in chick pea and Tripathi *et al.*, (2018) [21] in Urd bean. It is stated that a crop which is grown under favourable environment is bound to produce better yields, provided the nutrient supply is matching with nutrient accumulation that occurs in the crop (Basavaraja *et al.*, 2016) [6]. The strip –wise average nutrient uptake was in the order III >II > I for N, P and K. The result indicated that a wide variability existed in the soil test values, grain yield and nutrient uptake which is a pre-requisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets (Santhi *et al*., 2002) [17].

The average levels of available nutrients were found to increase with increasing fertility strips and the highest content was recorded in strip III. The increase in N could be due to the addition of double dose of NPK fertilizers than the single dose and control. The increased availability of P and K may be due to the application of graded levels of phosphatic and potassic fertilizers either at par with or over and above the P and K fixing capacity of the experimental field. Similar buildup of P and K was noticed by Coumaravel (2012) [7] and Bagavathi *et al*. (2013) [5].

Basic parameters

The basic data of nutrient requirement, contribution of soil available N, P and K and contribution of fertilizer NPK were calculated as per the procedure given by Dev *et al.* (1985) [8].

Nutrient requirement (NR)

The data on nutrient requirement of soybean are reported in table 3. The production of one quintal of soybean, the nutrient required were 5.53 kg N, 0.67 kg P and 2.89 kg K. Similar results were reported by Jadhav *et al*. (2009) [12].

Contribution of nutrients from the soil (CS %)

The contribution from soil in respect of N for soybean was 31.84 per cent, for P it was 33.48 per cent and for K it was 11.27 per cent. These results corroborate with the findings of Jadhav *et al*. (2009) [12].

Contribution of nutrients from fertilizers (% CF)

The data in respect of per cent contribution of N, P and K from fertilizers for soybean are presented in Table 3 the per cent contribution of N, P and K fertilizer without vermicompost were 68.27, 33.13 and 75.96 per cent respectively.

Contribution of nutrients from organic matter (COM)

The percent contribution from vermicompost, the data represented in Table 4. The contribution of N, P and K nutrient through vermicompost were 11.81, 3.57 and 9.08 per cent respectively. These results are corroborate with the findings made by Gaur *et al.* (1984) [10].

Table 4: Values of basic parameters used for developing STCR based fertilizer prescription equations.

Basic Data	N	P_2O_5	K_2O
NR (Kg of nutrient per q of grain)	5.53	0.67	2.89
CS (%)	31.84	33.48	11.27
CF (%)	68.27	33.13	75.96
COM (%)	11.81	3.57	9.08

Fertilizer prescription equations for yield targeting in soybean

Based on the basic parameters, fertilizer prescription equations for targeted yield of soybean under NPK alone as well as NPK + vermicompost were formulated and are furnished in Table 5. On the basis of these equations, a ready reckoner was prepared for making fertilizer recommendations for different soil test values to meet specified yield target of 25 q ha^{-1} and 30 q ha^{-1} of soybean under NPK alone and NPK + vermicompost (Table 6). Based on the fertilizer prescription equations for NPK alone, fertilizer N, P_2O_5 and K_2O recommendation were found in the range between 30 to 93, 30 to 60 and 27 to 45 respectively for yield target of 25 q ha^{-1}, 54 to 117, 30 to 75 and 38 to 56 respectively for attaining the yield target of 30 q ha^{-1} at the different levels of soil test values. When vermicompost was applied along with NPK fertilizers, fertilizer requirement of N, P_2O_5 and K_2O was found in the range of 26 to 89, 28 to 59 and 25 to 43 kg ha^{-1}, respectively at the same level of soil test values. Similar results were also reported by Anjali Basumatary *et al*. (2015) [2] and Avtari *et al*. (2010) [3]. Use of vermicompost resulted in saving of fertilizer nutrients in soybean. Practice of fertilizing soybean crop using fertilizer prescription equations developed would help in achieving higher productivity, nutrient use efficiency and profitability.

Table 5: Soil test based fertilizer prescription equations for targeted yield of soybean

FN =	4.84 X T - 0.28 X STVN - 0.10 X M
FP =	2.82 X T - 1.01 X STVP - 0.11 X M
FK =	2.12 X T - 0.08 X STVK - 0.07 X M

T= Yield target; STVN= Soil test value nitrogen; STVP= Soil test value phosphorus; STVK= Soil test value potassium; M= Nutrient content in organic matter.

Table 6: Ready reckoner for yield target of 25 and 30 q ha^{-1} under NPK alone and IPNS

STVs			N: P_2O_5: K_2O alone		N: P_2O_5: K_2O + 5 t vermicompost ha^{-1}	
Km-N	Ols-P	Am-K	25q/ha	30q/ha	25q/ha	30q/ha
100	10	100	93:60:45	117:75:56	89:59:43	113:73:54
125	15	125	86:55:43	110:69:54	82:54:41	106:68:52
150	20	150	79:50:41	103:64:52	75:49:39	99:63:50
175	25	175	72:45:39	96:59:50	68:44:37	92:58:48
200	30	200	65:40:37	89:54:48	61:39:35	85:53:46
225	35	225	58:35:35	82:49:46	54:34:33	78:48:44
250	40	250	51:30:33	75:44:44	47:28:31	71:43:42
275	45	275	44:30:31	68:30:42	40:28:29	64:28:40
300	50	300	37:30:29	61:30:40	33:28:27	57:28:38
325	55	325	30:30:27	54:30:38	26:28:25	50:28:36

Conclusions

From the present study, it concluded that, soil test based fertilizer prescription equation developed by taking into account the nutrient requirement and contribution of nutrients from fertilizer and organic manures for soybean crop can be well adopted in Vertisols of Nizamabad and adjoining areas having similar soil and agro-climatic conditions.

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