International J. Seed Spices 8(2), July 2018:36-41

Fertilizer dose recommendation through soil test crop response study with integrated plant nutrient management system for fennel in an inceptisol

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Abstract

A field experiment was conducted on Inceptisol of Agricultural Research Farm, Banaras Hindu University, Varanasi during rabi 2017-18 by using integrated plant nutrient management system on the basis of STCR approach so as to get fertilizers recommendation equation for fennel. Soil test data, fennel grain yield and NPK uptake by fennel crop were used for achieving four important basic parameters, *viz.*, nutrients required to produce one quintal of fennel grain (NR), contribution of nutrients from fertilizers (%CF), contribution of nutrients from soil (%CS) and contribution of nutrients from organic matter-FYM (%C-OM). It was found that 4.37, 1.13 and 3.91 kg of N, P_2O_5 and K_2O, respectively were required for producing one quintal fennel grain yield. The per cent contribution of nutrients from soil, fertilizer and FYM were 14.1, 50.3 and 10.1 for N; 62.7, 54.1 and 3.5 for P_2O_5 and 13.2, 169.6 and 12.2 for K_2O, respectively. By using these basic parameters, ready reckoner of fertilizer doses was equipped for varying soil test values and desired yield targets of fennel grain yield for NPK alone and NPK with FYM.

Key words: Basic parameter, fennel, fertilizer, FYM, grain yield, nutrient and STCR.

Introduction

Fennel (*Foeniculum vulgare* Mill.) is one of popular seed spice in India mainly grown in Rabi season, locally known as saunf belongs to the family (*Apiaceae*). It is cultivated throughout the temperate and subtropical regions of the world for its aromatic seeds which are used for culinary purpose. Fennel is also highly recommended for diabetes, bronchitis and chronic coughs, treatment of kidney stones, and is considered to have diuretic, stomachic and galactogogue properties. In India, it is mainly cultivated in the states of Gujarat and Rajasthan and to some extent in Uttar Pradesh, Bihar, Madhya Pradesh, Punjab and Haryana. In India, area under fennel was 41368 hectare with production of 58265 ton and productivity of 1.40 t ha-1 in 2010-11 (SBI, 2011). The farm yard manure (FYM) seems to be directly responsible in increasing crop yields either by accelerating the respiratory process by increasing cell permeability by hormone growth action or by combination of all these processes. It supplies almost all nutrients available forms to the plants through biological decomposition. Indirectly it improves physical properties of soil such as aggregation of soil, permeability and water holding capacity. It is prepared from the dung of farm animals and contains all the essential elements one of the reasons for lower production is imbalanced use of fertilizers by the farmers without knowing soil fertility status and nutrient requirement of crop causes adverse effects on soil and crop both in terms of nutrient toxicity and deficiency (Ray *et al.*, 2000). Farmers are using excess chemical fertilizers to achieve higher yield but the decision on fertilizer use requires knowledge of the expected crop yield and response to nutrient application. It is a function of crop nutrient needs, supply of nutrients from indigenous sources and the short-term and long-term fate of the applied fertilizer nutrients (Dobermann *et al.*, 2003). Hence, there is a scope to increase the production of fennel by soil test crop response (STCR) correlation method, the fertilizer doses are recommended based on fertilizer adjustment equations which are developed after establishing significant relationship between soil test values and the added fertilizers. Fertilizers recommendation based on soil test crop response Correlation concept are more quantitative, precise and meaningful because combined use of soil and plant analysis are involved in it. It gives a real balance between applied nutrients and the available nutrients already present in the soil. Keeping the above facts in view and non-availability of STCR-IPNS data for fennel in eastern Uttar Pradesh this study was conducted.

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The objective of this study was to evolve the sound basis of fertilizer prescriptions for field fennel crop in alluvial soil (Inceptisol) at different soil fertility levels under the conditions of fertilizer scarcity and to ensure maximum fertilizer use efficiency. The study also intended to find the relationship between the nutrients supplied by the soil and added through organic and inorganic sources, their uptake and to develop a guideline for judicious application of fertilizers for desired yield target of fennel by using STCR model.

Material and methods

A field experiment was conducted taking fennel as test crop during Rabi 2017-18 on alluvial soil (Inceptisol) of Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The site is located in the Indo-Gangetic alluvial tract at 25018' N and 80036' E, at an altitude of 80.71 m above mean sea level (amsl). The climate of the region is subtropical, semi arid. The area receives an annual rainfall of 1130 mm, about 80% of which occurs from June to September. The mean maximum and minimum temperatures from November to April (chickpea season) are 38.3 and 6.8°C, respectively, to develop targeted yield equations following the procedure of Ramamoorthy *et al.*, (1967). In 2017, selected site of 1245.6 m^2 dimension was divided into three strips of equal size and in each strip, different fertilizer doses, low - 0, 0, 0, medium – 120, 60, 60 and high – 240, 120, 120 kg ha^{-1} of N, P_2O_5 and K_2O, respectively were applied to develop a fertility gradient, and sorgham variety deshi chari was grown as an exhaust crop on 20.05.2017 during Kharif for stabilizing fertility gradient. The crop was harvested at maturity in the succeeding season; field fennel variety – RF-125 was grown as test crop during Rabi 2017-18 with various fertility gradients. Each strip (made in the fertility gradient stabilizing experiment in the previous season) was divided into 24 (21 treated and 3 control plots) equal sized (2 x 2m) plots resulting in total of 72 (24 x 3) plots. Three blocks (A, B, C) comprising of 8 treatments were made within each strip randomized with farm yard manure levels. The field was prepared without any disturbance to the already created three fertility gradient strips (0X, X, 2X). Then each strip was sub divided into 24 plots of equal size. A set of 24 treatments out of which 21 treatments in combination with four levels of nitrogen (0, 40, 80 and 120 kg ha^{-1}), four levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}) four levels of potassium (0, 15, 30 and 45 kg ha^{-1}) and three levels of FYM (0, 5, 10 t ha^{-1}) and three controls were superimposed to different plots in each strip. The fertilizers used were urea, single super phosphate and muriate of potash. Full doses of P_2O_5 and K_2O were applied as basal while nitrogen was applied in two equal splits, half as basal and remaining half at 30 days after sowing. Plot-wise nutrient levels were tested before applying FYM and NPK. Soil samples (0-15 cm) from all the 72 plots were collected and analyzed for available N, by the alkaline permanganate method (Subbiah and Asija, 1956); available P, by Olsen et al., (1954) and available K, by ammonium acetate method (Hanway and Heidal, 1952) as described by Jackson (1973). Fennel crop was sown in lines at 45 cm apart, having 7 lines in a plot and recommended package of practices were followed. Fennel seed and stover yields were recorded separately, and plant samples were taken for estimation of N, P, and K contents for working out uptake by the crop. Plot-wise soil test data, fertilizers doses, yield and uptake were used for obtaining NR (nutrient required to produce one quintal fennel grain yield), %CS (per cent contribution of nutrients from soil), %CF (per cent contribution of nutrients from fertilizers) and %C-OM (per cent contribution of nutrients from organic matter), as per method described by Ramamoorthy *et al.*, (1967).

Nutrient requirement in kg q^{-1} of grain (NR) =

$$\frac{\text{Total uptake of nutrient (kg ha}^{-1}\text{)}}{\text{Grain yield (q ha}^{-1}\text{) in plot}}$$

Per cent contribution of nutrients from soil (% CS) =

$$\frac{\text{Total uptake of nutrient on control plot (Kg ha}^{-1}\text{)}}{\text{Soil test values of nutrient in control plot (Kg ha}^{-1}\text{)}} \times 100$$

Per cent contribution of nutrients from fertilizer without FYM (% CF) =

$$\frac{\text{Total uptake of nutrient (kg ha}^{-1}\text{) in fertilizer treated plot - Soil test values (kg ha}^{-1}\text{) of nutrient in fertilizer treated plot}}{\text{Nutrient dose applied through fertilizer (kg ha}^{-1}\text{)}} \times 100$$

Per cent contribution of nutrients from organic manure (%CFYM) =

$$\frac{\text{Total uptake of nutrient (kg ha}^{-1}\text{) in organic manure treated plot - Soil test values (kg ha}^{-1}\text{) of nutrient in organic plot}}{\text{Dose of nutrient added through FYM (kg ha}^{-1}\text{)}} \times 100$$

These parameters were used to develop equations for soil test based fertilizer recommendations for desired yield targets of field fennel under NPK alone as well as NPK plus FYM.

Results and discussion

Soil available nutrients and grain yield

The range and mean values of soil available nutrients and grain yield of field fennel in treated and control plots are furnished in Table 1. In the NPK treated plots (plots that received NPK alone or NPK plus FYM), $KMnO_4$ -N increased from 213.15 kg ha^{-1} in strip I to 265.44 kg ha^{-1} in strip III with a mean value of 239.30 kg ha^{-1}. The Olsen-P ranged from 12.99 kg ha^{-1} in strip I to 25.00 kg ha^{-1} in strip III with a mean value of 19.00 kg ha^{-1}, while the NH_4OAc -K status varied from 205.12 kg ha^{-1} in strip I to 240.27 kg ha^{-1} in strip III with a mean value of 222.70 kg ha^{-1}.

In the NPK treated plots that received NPK alone or NPK plus FYM, the yield of fennel ranged from 11.70-16.15 q ha^{-1} with a mean value 13.93 q ha^{-1}. In the overall control plots, the yield ranged from 6.70-11.30 q ha^{-1} with a mean value of 9.00 q ha^{-1}. In the overall control plot of three fertility gradients (Table 1), the $KMnO_4$ -N ranged from 200.40 to 231.20 kg ha^{-1} with a mean of 215.80 kg ha^{-1}, Olsen-P status ranged from 12.33 to 15.10 kg ha^{-1} with a mean value of 13.72 kg ha^{-1}, and the NH_4OAc -K status varied from 184.46-216.03 kg ha^{-1} with a mean value of 200.25 kg ha^{-1}. Though these soils are considered as fertile, they are low in nitrogen and humus and medium in phosphorus and potassium. Almost similar results were found by Bera *et al.*, (2006) and Dwivedi *et al.*, (2009) for on-farm evaluation of soil test based site specific nutrient management in fennel millet-based cropping systems on alluvial soils.

The above data clearly indicate the existence of operational range of soil test values for available N, P and K status and yield of treated and control plots, which is a prerequisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets. The equations are:

NPK alone

$FN = 8.68^* T - 0.28^* SN$

$FP_2O_5 = 2.08^* T - 1.16^* S P_2O_5$

$FK_2O\ 2.32^* T - 0.08^* S K_2O$

$FN = 8.68^* T - 0.28^* SN - 0.21^* ON$

$FP_2O_5 = 2.08^* T - 1.16^* S P_2O_5 - 0.06^* O P_2O_5$

$FK_2O = 2.32^* T - 0.08^* SK_2O - 0.07^* OK_2O$

F.N. = Fertilizer N (kg ha^{-1})

$F.P_2O_5$ = Fertilizer P_2O_5 (kg ha^{-1})

$F.K_2O$ = Fertilizer K_2O (kg ha^{-1})

T = Yield target (q ha^{-1})

Where - SN, SP and SK, respectively are alkaline $KMnO_4$ -N, Olsen-P and NH_4OAc -K in kg ha^{-1} and ON, OP_2O_5 and OK_2O are the quantities of N, P_2O_5 and K_2O in kg ha^{-1} supplied through FYM, respectively.

Basic parameters

The basic data *viz.*, nutrient requirement for producing one quintal grain of fennel, per cent contribution of nutrients from soil (%CS), fertilizer (%CF) and FYM (%CFYM) have been calculated (Table 2). These basic parameters were used for developing the fertilizer prescription equations under NPK alone and NPK plus FYM. The nutrient requirement of N, P2O5 and K2O were 4.37, 1.13 and 3.91 kg q^{-1} of grain, respectively. The % CS and % CF were found to be 14.05 and 50.30 for N, 62.65 and 54.08 for P_2O_5 and 13.24and 169.63 for K_2O. Similarly, the per cent contribution of N, P_2O_5 and K_2O from FYM was 10.38, 3.45 and 12.24, respectively. It was noted that contribution of potassium from fertilizer for fennel was higher in comparison to soil. This high value of potassium could be due to the interaction effect of higher doses of N, P coupled with priming effect of starter K doses in the treated plots, which might have caused the release of soil potassium, resulting in the higher uptake from the native soil sources by the crop (Ray *et al.*, 2000). Similar type of higher efficiency of potassic fertilizer was also reported for rice by Ahmed *et al.*, (2002). Contribution of nutrients from FYM is low which might be due to lower mineralization rate of FYM (Singh and Singh, 2014). However, in the case of P_2O_5, the contribution was more from soil than from fertilizer.

Table 1. Available nutrients in pre-sowing surface soil and yield of fennel crop

Parameters	NPK treated plots		Control plots	
	Range	Mean SEm±	Range	Mean SEm±
$KMnO_4$-N (kg ha^{-1})	213.15 - 265.44	239.30 ± 26.14	200.40 - 231.20	215.80 ± 15.40
Olsen-P (kg ha^{-1})	12.99 - 25.00	19.00 ± 6.00	12.33 - 15.10	13.72 ± 1.39
NH_4OAc-K (kg ha^{-1})	205.12 - 240.27	222.70 ± 17.58	184.46 - 216.03	200.25 ± 15.79
yield (q ha^{-1})	11.70 - 16.15	13.93 ± 2.23	6.70 - 11.30	9.00 ± 2.30

Table 2. Basic data and fertilizer adjustment equations of field fennel (var. RF-125) in inceptisol

Basic Data	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	4.37	1.13	3.91
Soil efficiency (%) or %CS	14.05	62.65	13.24
Fertilizer efficiency (%) or %CF	50.30	54.08	169.63
Organic efficiency (%) or %CFYM	10.38	3.45	12.24

Table 3: Estimation of soil test based fertilizer recommendation for 15 q ha^{-1}grain yield target of fennel crop

Soil test values (kg ha^{-1})			Fertilizer doses (kg ha^{-1}) under NPK alone			Fertilizer dose (kg ha^{-1}) under NPK+ FYM @ 10 t ha^{-1}		
SN	S P_2O_5	SK_2O	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O
180	10.0	140	79.80	19.60	23.60	69.30	17.80	20.80
200	15.0	160	74.20	13.80	22.00	63.70	12.00	19.20
220	20.0	180	68.60	8.00	20.40	58.10	6.20	17.60
240	25.0	200	63.00	2.20	18.80	52.50	0.40	16.00
260	30.0	220	57.40	0.00	17.20	46.90	0.00	14.40

An assessment of fertilizer doses were prepared based on these equations for a range of soil test values and for yield target of 15 q ha^{-1} of fennel (Table 3). For achieving this target with soil test values of 180:10:140 kg ha^{-1} of $KMnO_4$ -N, Olsen-P and NH_4OAc -K, the fertilizer N, P_2O_5 and K_2O doses required were 79.80, 19.60 and 23.60 kg ha^{-1}, respectively. When FYM (0.5, 0.3 and 0.5 per cent of N, P and K, respectively) was applied @ 10 t ha^{-1} along with NPK, the required fertilizer N, P_2O_5 and K_2O doses were 63.30, 17.80 and 20.80 kg ha^{-1}, respectively. Under IPNMS the required dose of fertilizer is low due to nutrient availability increased by FYM through mineralization. Singh *et al.* (2017) also reported that under integrated plant nutrient system, required dose of fertilizer to achieve desired yield target are reduced.

Fertilizer prescription equations were transformed into ready reckoner for requirements of fertilizer, say for yield target of 15 q ha^{-1} of fennel on soils with varying soil test value for both NPK applied with and without FYM. From findings of this investigation, it is obviously that vary with the soil test values, the fertilizer recommendation varies for the same level of crop production. Hence balanced fertilization through soil testing becomes essential for increasing crop production. Similar results were also found by Avtari *et al.*, (2010) for 2 t ha^{-1} yield of yellow mustard, Prakash and Singh (2013) in wheat, Regar and Singh (2014) in rice, Mishra *et al.*, (2015) in chick pea and Singh *et al.* (2015) in maize. It is obvious from these findings that there was net saving of fertilizers in each target and ultimately to reduce cost of cultivation.

Prediction of post-harvest soil available nutrients (N, P and K)

A Post-harvest prediction equation of soil test value can be used to make a fertilizer recommendation for entire cropping scheme. This is very useful because the soil of farmers' field under intensive farming cannot be tested for each crop for practical reasons. The interactions among the post-harvest soil test values, fertilizer applied doses, initial soil test values and grain yield from the treated plots for fennel crop are obtained in table 4.

Table 4. Prediction equations for post-harvest soil test value for fennel

Nutrient	R2	Multiple regression equation
N	0.80**	115.61+1.1530RY**+0.404691SN**+0.404691 FN*
P	0.76**	2.295719+0.281983RY*+1.01767SP**+0.038626FP**
K	0.85**	66.55525+0.505582RY**+0.656008 SK**-0.0211229 FK

** Significant at 1 % level: Here PHN, PHP and PHK stand for the post-harvest soil test values of N, P and K (kg ha^{-1}); RY is the yield of crop (q ha^{-1}), SN, SP and SK represent the initial soil test values of N, P and K (kg ha^{-1}) and FN, FP and FK represent the fertilizer doses of N, P_2O_5 and K_2O kg ha^{-1} applied.

Noticeably large R^2 values (significant at 1%) were obtained for these equations. This suggests that such regression equations can be applied with confidence for the prediction of available N, P, and K after fennel for making soil test based fertilizer recommendation for succeeding crops. Similar significances were also found by Verma and Singh (1991), and Bera *et al.*, (2006) for the three major nutrients.

Conclusion

Use of integrated plant nutrient management system resulted in saving of fertilizer nutrients in funnel crop. Target yield equations generated from STCR-IPNMS technology ensures not only sustainable crop production but also economise use of costly fertilizer inputs. Practice of fertilizing crops using fertilizer prescription equations needs to be popularized among farmers to achieve higher productivity, nutrient use efficiencies and profitability. It is also suggested that the trends observed in this study may hold true for broad generalization in the larger parts of the gangetic eastern plains that would serve as potent guide for efficient fertilizer management sustainably.

Acknowledgements

The authors are very grateful to Council of Science and Technology, Lucknow for providing financial assistance through project during the course of investigation.

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Received : March 2018; Revised : May 2018; Accepted : June 2018.