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Optimizing Integrated Plant Nutrient Supply through STCR Approach for Targeted Yield of Forage Oat (*Avena sativa* L.) in an Inceptisols

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

During *Rabi* 2018-19, an Inceptisol field test was conducted at the Agriculture Research Farm at Banaras Hindu University, Varanasi, using STCR technique, from which fertiliser recommendation equations for oat (*Avena sativa* L.) may be developed. Soil test results, oat fresh forage yield and NPK uptake by oat crop were used to attain four essential basic parameters, *i.e.,* nutrients required to produce one quintal of fresh forage (NR), fertilizer contribution of nutrients (% CF), soil nutrient contribution (% CS) and organic matter contribution from FYM (CFYM). A quintal of fresh forage required 0.26, 0.04, and 0.30 Kg of N, P_2O_5 and K_2O, respectively. Soil Nutrient Contribution Proportions (CS%): 35.81, 48.44, and 64.87 N, P_2O_5, and K_2O, respectively. N, P_2O_5, and K_2O percent added through fertilizer alone (CF %) and FYM alone (CFYM) were 59.17, 47.38, and 115.25; 24.19, 5.82, and 2.33, respectively. The ready reckoner doses of fertilizer were emphasized on these specific criteria for various soil test values and required to make recommendations for fresh forage oat yields for NPK alone and NPK + FYM.

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1. INTRODUCTION

Oat (*Avena sativa* L.) belongs to the *Poaceae* family of plants. Asia is the originator, and it has spread to many places throughout the world. Russia, Australia, Germany, France, and the United States are among the countries involved in its production. It is a minor crop that is grown for both feed and grain. In terms of global cereal production, oat ranks sixth behind wheat, corn, rice, barley, and sorghum. The global cereal output, gross production, and productivity forecasts are 12.86 mha, 27.28 mt, and 21.21 q ha^{-1}, respectively [1]. It is largely grown at the foot of the Himalayas in India's northern states. Temperate and subtropical climates are ideal for its growth. Its choice as a green forage has lustrous growth, good flavors, and a nutritious character due to its high food quality [2,3]. It is used as a portion of food in both green and dry forms. It can also be converted into silage and hay to feed animals when there is not enough grain available. One of the causes of decreased growth, which has adverse consequences for soil and crops, is farmers' unbalanced fertiliser use without knowing the level of soil fertility and crop nutrient needs (Singh and Biswas, 2000). “Farmers apply excess chemical fertilizer to increase yields, but making this decision requires knowledge of the predicted crop production and response to the nutrient application. It depends on the yield supplements, the availability of supplements from local sources along with the current and long-term fate of the fertilizer supplements used” [4]. As a result of the soil test crop response (STCR) relationship technique, there is a potential to increase oat yield. Fertilizer portions are advised based on fertilizer change circumstances generated after the soil test crop response (STCR) approach. Because it necessitates the integrated use of soil and plant evaluation, the fertilizer proposal based on STCR approach is more quantitative, solid, and substantial. It creates a true balance between the nutrients added and the supplements that are naturally present in the soil [5,6]. Remembering the above realities and the non-accessibility of STCR-Integrated Plant Nutrients Supply (IPNS) information for forage oat in Varanasi, All India Coordinated Research Project on STCR (AICRP-STCR) solution of Uttar Pradesh developed fertilizer equations based on target yield of oat in Inceptisols.

2. MATERIALS AND METHODS

At the Agricultural Research Farm, Banaras Hindu University, Varanasi, during Rabi 2018-19, a field experiment was conducted to develop targeted yield equations in an Inceptisol, following the protocol of Ramamurthy et al. [7]. To determine a fertility gradient, the 1269.6 m^2 site chosen in 2018 was divided into three strips of similar size and different fertilizer doses were added to each strip, 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. Sorghum (*var. M.P. chari*) was grown as an exhausting crop during *Kharif* 2018 to balance the fertility gradient. The crop was harvested when it reached its maturity. In Rabi season 2018-19, *oat* (*var: UPO-212*) was cultivated as a test crop in the same area. Every strip was divided into 24 equal-sized plots (21 treated and 3 control plots) (4m x 3m), yielding a total of 72 plots (288m). Within each randomized strip, the urea, single superphosphate, and muriate of potash randomized treatments were given in three (A, B, and C) blocks, each containing eight treatments using N, P_2O_5, K_2O, and FYM. P_2O_5 and K_2O was added as a basal dose and N was applied in two split doses, half as basal and the other half at 30 days after sowing. Plot-specific nutrient levels were tested before the application of FYM and NPK by the following methods:

Available nitrogen	Subbiah and Asija, (1956)
Available phosphorus	Olsen et al. [8]
Available potassium	Hanway and Heidel [9]

The soil samples collected from all 72 plots were analyzed by different method *viz.* alkaline permanganate method (Subbiah and Asija, 1956) for available N, available P_2O_5 by 0.5M $NaHCO_3$ Method [8] and K_2O by ammonium acetate [9]. Oat was sown in 30cm x 10cm in a plot. To estimate the quantity of N, P and K for cultivation purposes, a dry oat yield was recorded and the plant samples were taken. The method as defined by Ramamurthy et al. [7] was used to obtain nutrients required for the production of fresh oats; percent CS (percentage of soil nutrients contribution), percent CF (percentage of fertilizer nutrient contribution) and percent CFYM (percentage of organic matter contribution).

Table 1. Levels of nitrogen, phosphorus, potassium and FYM used in test crop experiment

S. No.	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	FYM (t ha^{-1})
1	0	0	0	0
2	40	20	10	5
3	80	40	20	10
4	120	60	30	-

2.1 Method of Developing the Basic Data

1. Nutrient requirement in kg q^{-1} of fresh forage yield (NR)

$$= \frac{Total\ uptake\ of\ the\ nutrient\ (kg\ ha-1)\ in\ plot}{Fresh\ forage\ yield\ (q\ ha-1)\ in\ plot}$$

2. Per cent contribution of nutrients from soil (%CS)

$$= \frac{Total\ uptake\ of\ nutrient\ in\ the\ control\ plot\ (kg\ ha-1)}{Soil\ test\ values\ of\ nutrient\ in\ control\ plot\ (kg\ ha-1)} \times 100$$

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

$$= \frac{\begin{pmatrix} Total\ uptake\ of\ nutrient \\ (kg\ ha-1)\ in\ fertilizer \\ Treated\ plot \end{pmatrix} - \begin{pmatrix} Soil\ test\ values \\ (kg\ ha-1)\ in\ fertilizer \\ treated\ plot\ \times\ \%CS/100 \end{pmatrix}}{Nutrient\ dose\ applied\ through\ fertilizer\ (kg\ ha-1)} \times 100$$

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

$$= \frac{\begin{pmatrix} Total\ uptake\ of \\ nutrient\ (kg\ ha-1) \\ in\ organic\ manure \\ Treated\ plot \end{pmatrix} - \begin{pmatrix} Soil\ test\ values \\ (kg\ ha-1)\ of\ nutrient \\ in\ fertilizer\ treated \\ plots\ \times\ \%CS/100 \end{pmatrix}}{Dose\ of\ nutrient\ added\ through\ FYM\ (kg\ ha-1)} \times 100$$

These variables were used to create equations for soil test-based fertilizer recommendations for forage oat yield targets under NPK alone and NPK + FYM.

3. RESULTS AND DISCUSSION

3.1 Soil Available Nutrients and Fresh Forage Yield

Table 2 shows the range and average values of the required soil nutrients and the fresh yield of oat in the plots under management and control. $KMnO_4$-N increased from 219 kg ha^{-1} in the strip I to 269 kg ha^{-1} in strip III in the NPK control plots (NPK plots receiving NPK alone or NPK + FYM) with a medium value of 244 kg. Olsen-P ranged from 24.48 kg ha^{-1} in strip I to 36.24 kg ha^{-1} for strip III with an average of 30.36 kg ha^{-1}, whereas NH_4OAc-K ranged from 201 kg ha^{-1} in strip I to 238 kg ha^{-1} for strip III with an average of 219.5 kg ha^{-1}.

In NPK-treated plots that received either NPK alone or NPK + FYM, the fresh forage oat yield ranged from 383 to 648 q ha^{-1}, with a mean value of 515.5 q ha^{-1}. In the control plots , the yield ranged from 247 to 400 q ha^{-1}, with a mean value of 323.5 q ha^{-1}. Within the three total control plots, $KMnO_4$-N ranged from 206 to 257 kg ha^{-1} with a mean of 231.5 kg ha^{-1}, Olsen-P ranged from 18.10 to 28.81 kg ha^{-1} for a mean value of 23.45 kg ha^{-1}, and NH_4OAc-K varying from 191 to 226 kg ha^{-1} with a mean value of 23.45 kg ha^{-1}.

Field evaluation of soil site-specific nutriemt management in oat under millet trimming frameworks on alluvial soils was discovered by Bera et al. [10] and Dwivedi et al. [11]. The above data clearly demonstrates the concept of the operational arrangement of soil test values for usable N, P, and K status and yield of treated and control plots, which is required for the estimation of the fertilizer recommendation, for the adjustment of fertilizer equations.

NPK Alone

FN = 1.44 T – 0.61 SN
FP_2O_5 = 1.08 T – 1.02 SP_2O_5
FK_2O = 1.26 T – 0.56S K_2O

NPK + FYM

FN = 1.44 T – 0.61 SN – 0.41 ON
FP_2O_5 = 1.08 T – 1.02 SP_2O_5 – 0.12 OP_2O_5
FK_2O = 1.26 T – 0.56 SK_2O – 0.04 OK_2O
FN = Fertilizer N (kg ha^{-1})
FP_2O_5 = Fertilizer P_2O_5 (kg ha^{-1})
FK_2O = Fertilizer K_2O (kg ha^{-1})
T = Yield target (qha^{-1})

Where, SN, SP_2O_5 and SK_2O, are the soil test values estimated by alkaline $KMnO_4$-N, Olsen-P as P_2O_5 and NH_4OAc-K method as K_2O in kg ha^{-1}, respectively 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.

Table 2. Available nutrients in pre-sowing soil and yield of oat crop

Parameters	NPK treated plots		Control plots	
	Range	Mean ± SEm	Range	Mean ± SEm
Available N (kg ha^{-1})	219-269	244 ± 2.34	206-257	231.5 ± 1.75
Available P_2O_5 (kg ha^{-1})	24.48-36.24	30.36 ± 0.84	18.10-28.81	23.45 ± 0.53
Available K_2O (kg ha^{-1})	201-238	219.5 ± 1.66	191-226	208.5 ± 0.60
Yield (q ha^{-1})	383-648	515.5 ± 7.85	247-400	323.5 ± 2.19

3.2 Basic Parameters

The level of soil contribution (percent CS), fertilizer (percent CF), and FYM (percent CFYM) is computed for the production of one quintal of oat forage (Table 3). These basic parameters were used to plan the fertilizer recommendation for both NPK alone and NPK + FYM. N, P_2O_5, and K_2O nutrient requirements for forage oat were 0.26, 0.04, and 0.30 kg q^{-1}, respectively. The rate CS and percent CF of N, P_2O_5, and K_2O, respectively, were 35.81, 48.44, 64.87 and 59.17, 47.38, and 115.52. “Similarly, the contributions of N, P_2O_5, and K_2O rates from FYM were 24.19, 5.82, and 2.33, respectively. The uptake of K from fertilizer was found to be higher than that of soil. This high K value could be attributed to the synergistic effect of higher N, and P portions combined with the preparing effect of starter K dosages in the treated packages, which may have prompted soil K to be delivered, resulting in higher yield from local soil sources” [12]. Rice has also been found to have a comparative type of higher K-fertilizer proficiency in alluvial soils [13]. Because of the lower FYM mineralization rate, the FYM contribution is minimal [14]. On account of P_2O_5, in any case, the uptake was more from soil than from fertilizer.

Based on these equations, fertilizer doses were calculated for a range of soil test values and an oat yield target of 700 q ha^{-1} (Table 4).

These results clearly show that there was a net reduction in fertiliser use in each area, which eventually decreased the cost of cultivation.

3.3 The Expectation of Post-harvest Soil Test Values (N, P and K)

A fertilizer recommendation for the entire cropping plan can be made based on the post-harvest soil test values. This is useful because, for obvious reasons, the soil of farmers fields under intensive cultivation cannot be tested for each yield. Table 5 shows the relationships between post-harvest soil test values, fertilizer applied dosages, Initial soil test values, and new forage yield from the oat crop-treated plots.

Table 3. Basic data and fertilizer adjustment equations of forage oat (*var.UPO-212*) in Inceptisol

Basic Data	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	0.26	0.04	0.30
Soil efficiency (%) or %CS	35.81	48.44	64.87
Fertilizer efficiency (%) or %CF	59.17	47.38	115.52
Organic efficiency (%) or %CFYM	24.19	5.82	2.33

Table 4. Estimation of soil test-based fertilizer recommendation for 700 q ha^{-1} fresh forage yield target of oat crop

Soil test values (kg ha^{-1})			Fertilizer dose (kg ha^{-1}) under NPK alone			Fertilizer dose (kg ha^{-1}) With NPK+ FYM @ 10 t ha^{-1}		
SN	SP	SK	FN	FP	FK	FN	FP	FK
180	10	180	195.82	49.08	78.36	175.37	45.39	77.55
200	15	200	183.71	43.97	67.13	163.27	40.28	66.32
220	20	220	171.61	38.86	55.89	151.16	35.17	55.09
240	25	240	159.50	33.74	44.66	139.06	30.06	43.86
260	30	260	147.40	28.63	33.43	126.95	24.95	32.62
280	35	280	135.29	23.52	22.20	114.85	19.83	21.39
300	40	300	123.90	18.41	10.97	102.74	14.72	10.16

SP = Soil available P as P_2O_5, and SK = Soil available K as K_2O

Table 5. Prediction equations for post-harvest soil test value for oat

Nutrient	R^2	Multiple regression equation
N	0.79**	PHN=114.55+0.0487RY**+0.4609SN**+0.1391FN*
P	0.68**	PHP=11.71+0.0289RY*+0.8500SP**- 0.0308FP**
K	0.90**	PHK=67.31+0.7148RY**+1.1956SK**+0.0109FK

*** 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 oat fresh forage yield (q ha^{-1}), SN, SP_2O_5 and SK_2O 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} required*

Significantly higher R^2 values (at 1% level) were acquired for these conditions. This suggests that such relapse conditions can be used to predict available N, P, and K after oat for making soil test-based fertilizer recommendations for future yields. Comparative significances were likewise found by Bera et al. [10] and Luthra et al. [15] for the three significant supplements.

4. CONCLUSIONS

The use of an advanced plant nutrient management scheme has resulted in fertilizer nutrients being saved in oat crops. Instruments in the IPNS system not only ensure efficient crop development but also reduce the use of high-cost fertilizer inputs. STCR-produced target yield equations are critical to popularize the practice of fertilizing crops with fertilizer prescription equations among farmers to increase production, nutrient quality, and profitability. In a test farm, an experiment is carried out in an experimental plot, which may or may not be extended to the entire Gangetic plain, and there may be some variation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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