Journal of the Indian Society of Soil Science, Vol. 69, No. 2, pp 156-161 (2021)
DOI: 10.5958/0974-0228.2021.00040.2

Optimization of Integrated Nutrient Recommendations through Soil Test Crop Response Approach for Forage Oats (*Avena sativa* L.) in a Mollisol

Shalini Jhinkwan, Sobaran Singh*, Navneet Pareek and Poonam Gautam
Department of Soil Science, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, 263145, U.S. Nagar, Uttarakhand, India

A field experiment was conducted during the year 2018-19 to optimize integrated nutrient recommendations through soil test crop response approach for forage oats (*Avena sativa* L.) grown in a Mollisol of Uttarakhand. The experiment was conducted as per the technical programme and methodology of All India Coordinated Research Project (AICRP) on Soil Test Crop Response Correlation (STCR). Response of forage oats to selected combinations of three levels of farmyard manure (0, 5 and 10 t FYM ha^{-1}), four levels of nitrogen (0, 40, 80 and 120 kg N ha^{-1}), four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and four levels of potassium (0, 20, 40 and 60 kg K_2O ha^{-1}) at different soil fertility levels was studied. It was found that to produce one quintal forage yield, forage oats required 0.27 kg of N, 0.03 kg of P_2O_5 and 0.32 kg of K_2O with FYM. The per cent contributions of N, P_2O_5 and K_2O were 71.4, 33.7 and 59.9 from soil and 73.0, 7.51 and 90.4 from FYM, 89.6, 50.8 and 302.7 from chemical fertilizers and 102.4, 52.9 and 351.5 from conjoint use of chemical fertilizers with FYM. Using these data, fertilizer prescription equations were developed for adjusting fertilizer dose in forage oats for different range of soil test values and desired yield targets.

Key words: STCR, Mollisol, fertilizer prescription equations, forage oats, targeted yield, integrated nutrient recommendation

India supports nearly 20% of the world's livestock being the leader in cattle (16%) and buffalo (5.5%) population (Devi *et al*. 2014). The quantitative and qualitative availability of forage is the fundamental requirement of livestock and hence, is of prime important for livestock sector. The gap in feed and fodder production has been identified as one of the major components in achieving the desired level of livestock potential (Kumar *et al*. 2012). To fulfil the requirements of such a huge population of livestock with quality feed is a big challenge. In the lean period of winter season, forage oats (*Avena sativa* L.) is an ideal source of livestock feed. Its choice as a green fodder crop is attributed to its luxuriant growth, good palatability and highly nutritious nature. It has a short growth period. Thus, it can be very well taken within the 2-3 months gap period available after harvest of *kharif* crops and before the start of summer crops. It has quick growing ability, good regeneration ability with high dry matter content. Its green fodder contains about 10-12% protein and 30-35% dry matter (Handbook of Agriculture 2007).

Oats varieties differ widely in the rate of vegetative growth, regeneration ability and days to bloom and hence it is not possible to make a general recommendation. Hence, site and variety specific combination of organic and inorganic nutrient sources can be of vital importance in order to achieve economic and quality yield of fodder oats.

There are various approaches of fertilizer recommendations. Among them, the Soil Test Crop Response Correlation (STCR) approach based on targeted yield is cost-effective, sustainable and farmer's friendly. The STCR approach involves both soil analysis and plant analysis. Although there are several information on the STCR based fertilizer recommendations for cereal crops, but systematic studies have not been undertaken for recommendations of nitrogen (N), phosphorus (P) and potassium (K) fertilizers for the widely grown forage oats (var. Pant Forage Oat-3) in the Mollisol of Uttarakhand. Keeping all the above facts in mind and

*Corresponding author (Email: drsobaransingh@gmail.com)

economy of the forage oats, the present study was conducted to develop recommendation for adjusting fertilizers doses in forage oats for different range of soil test values (STVs) and desired yield targets.

Materials and Methods

A field experiment on forage oats (Var. Pant Forage Oat-3) under a maize-oats rotation was conducted during the year 2018-19 at N.E.B. Crop Research Centre of G.B. Pant University of Agriculture and Technology (GBPUA&T), Pantnagar, U.S. Nagar, Uttarakhand, India. The experimental soil belongs to the order Mollisol. The experiment was conducted as per the methodology approved by All India Coordinated Research Project (AICRP) on Soil Test Crop Response (STCR). In the first phase, fertility gradient was created by growing wheat crop and then maize crop was grown during *kharif* season of the year 2018 as the first crop under maize-oats rotation. After the harvest of maize, the already created fertility gradients (Strip I-Low, Strip II-Medium and Strip III-High) in the field were left undisturbed and the field was prepared for the oats crop. Each strip was further divided into total 24 plots of equal area *i.e.* 3×3 m^2. Within each strip, the total number of treated plots were 21 and 3 plots were taken as control.

The initial soil samples were collected from each plot before application of any treatment. The test crop (oats) was then sown after the application of the treatments. The experiment comprised of 24 treatments in each strip. Each treatment consisted of different combinations of 4 levels each of N (0, 40, 80 and 120 kg ha^{-1}), P (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and K (0, 20, 40 and 60 kg K_2O ha^{-1}) and three levels of farmyard manure (@ 0, 5 and 10 t FYM ha^{-1}). The crop was raised by following other recommended agronomic practices. All the observations were recorded as per the plan and the crop was finally harvested at 50% flowering stage. The soil samples were also collected after the crop harvest.

The soil samples were analyzed for available N by alkaline-$KMnO_4$ method as proposed by Subbiah and Asija (1956), available P by Olsen's method (Olsen *et al*. 1954), available K by ammonium acetate (NH_4OAc-K) method (Hanway and Heidel 1952) and organic carbon (OC) by Walkley and Black method (Walkley and Black 1934). For plant nutrients, the oats plant samples were collected at 50% flowering stage from each plot. The plant samples were dried under shade initially and then oven dried at 65±1 °C, ground by a Willey mill and analyzed for total N, P and K contents. Total N content in the ground plant samples was determined by micro-Kjeldahl method using concentrated H_2SO_4 and digestion mixture of K_2SO_4 and $CuSO_4$ (Jackson 1973). For determination of P and K contents, the plant samples were digested with di-acid mixture using HNO_3 and $HClO_4$ at 10:4 ratio (Piper 1967). The P content in the acid digest was determined by a spectrophotometer after developing vanado-molybdophosphate yellow colour, while K content in the acid digest was determined by a flame photometer after necessary dilution (Jackson 1973).

Using the dry matter yield and plant nutrients content, the nutrients uptake was calculated. Further, using the nutrient uptake data, green forage yield of oats, soil test values and applied fertilizer doses in both untreated (control) and treated plots (fertilized), the basic data *i.e*. nutrient requirement (NR), per cent contribution of N, P an K from soil (%CS), from FYM (%Cfym), from fertilizer without FYM (%CF) and from applied fertilizer with FYM (%CF*) for fertilizer prescription equations were calculated.

Fertilizer doses for the requirement of N, P_2O_5 and K_2O for targeted yields were also worked out as follows:

Without FYM: Fertilizer requirement equations for nutrients through fertilizer without FYM were calculated as:

$FN = (NR/Cf) \times 100T - (Cs/Cf) \times SN$

$FP = (NR/Cf) \times 100T - (Cs/Cf) \times SP$

$FP_2O_5 = (NR/Cf) \times 100 \times 2.29 \times T - (Cs/Cf) \times 2.29 \times SP$

$FK = (NR/Cf) \times 100T – (Cs/Cf) \times SK$

$FK_2O = (NR/Cf) \times 100 \times 1.21 \times T – (Cs/Cf) \times 1.2 \times SK$

With FYM: Fertilizer requirement equations for nutrients through conjoint use of chemical fertilizer and FYM were calculated as:

$FN = (NR/*Cf) \times 100\ T – (CS/Cf*) \times SN – (Cfym/Cf*) \times M$

$FP_2O_5 = (NR/Cf*) \times 100 \times 2.29 \times T – (CS/Cf*) \times 2.29 \times SP – (Cfym/Cf*) \times 2.29 \times M$

$FK_2O = (NR/Cf*) \times 100 \times 1.21 \times T – (CS/Cf*) \times 1.21 \times SK – (Cfym/Cf*) \times 1.21 \times M$

where, FN = Fertilizer N (kg N ha^{-1}), FP (FP_2O_5) = Fertilizer P (kg P_2O_5 ha^{-1}), FK (FK_2O) = Fertilizer K (kg K_2O ha^{-1}), T = Targeted green forage yield (q ha^{-1}), SN = Soil test value for available N (kg ha^{-1}), SP = Soil test value for available P (kg P_2O_5 ha^{-1}), SK= Soil test value for available K (kg K_2O ha^{-1}), and M = Concerned nutrient content in organic matter.

To derive optimum fertilizer doses for different yield targets of oats, the fertilizer adjustment equations were developed using the estimates of basic

Table 1. Range and mean of initial soil test values in different strips

Particulars	Strip I	Strip II	Strip III	Whole field
Organic carbon (%)	0.47-0.78 (0.62)	0.55-0.98 (0.72)	0.70-1.01 (0.86)	0.47-1.01 (0.73)
Alkaline $KMnO_4$-N (kg ha^{-1})	75.3-112.9 (95.7)	87.8-125.4 (104.8)	100.4-150.5 (122.0)	75.3-150.5 (107.5)
Olsen-P (kg ha^{-1})	14.3-20.6 (17.8)	17.7-22.9 (19.2)	10.8-31.7 (22.3)	10.8-31.7 (19.8)
NH_4OAc-K (kg ha^{-1})	117.6-160.2 (139.5)	128.8-177.9 (156.9)	144.5-171.4 (159.8)	117.6-177.1 (152.3)

**Values in parentheses indicate mean*

data. Using these equations, the soil test based fertilizer recommendations can be prescribed in the form of a ready reckoner for different yield targets.

Results and Discussion

Initial Soil Test Values

The initial soil samples were analyzed for available N, P and K. The range and mean soil test values (STVs) of OC, available N, P and K before sowing of experimental crop are given in table1. The OC content of the experimental soil varied from 0.47 to 1.01% with a mean value of 0.73%. The available N varied from 75.3 to 150.5 kg N ha^{-1} with a mean value of 107.5 kg N ha^{-1}, while available P content ranged from 10.8 to 31.7 kg P_2O_5 ha^{-1} with a mean value of 19.8 kg P_2O_5 ha^{-1} and available K ranged from 117.6 to 177.0 kg K_2O ha^{-1} with a mean of 152.3 kg K_2O ha^{-1}. The results showed that the OC, alkaline $KMnO_4$–N, Olsen-P and neutral normal NH_4OAc–K content of soil increased in the order of strip I < strip II < strip III of the experimental field which indicates that there was proper creation of fertility gradient with the application of graded doses of N, P and K.

Yield, nutrient content and uptake by oats

Strip-wise range and mean of fresh forage yield, dry matter yield, nutrient content (N, P and K) and uptake of forage oats are given in table 2. Fresh yield of forage oats in the experiment varied from 216.6 to 749.8 q ha^{-1} with a mean of 526.0 q ha^{-1}. Dry matter yield of oats in the experiment varied from 34.0 to 117.7 q ha^{-1} with a mean of 82.6 q ha^{-1}.

Nitrogen content of oats plant in the experimental field varied from 1.40 to 2.10% with an average of 1.75%. While, P content in oats plant in the experimental field varied from 0.13 to 0.28% with an average of 0.21% and K content of oats plant varied from 1.71 to 2.48% with an average of 2.04%. The results showed that fresh and dry matter yield of

Table 2. Range and average fresh and dry matter yield, nutrient content and average total nutrient uptake of forage oats

Particulars	Strip I	Strip II	Strip III	Whole Field
Fresh yield (q ha^{-1})	216.6-749.8 (518.7)	240.2-722.0 (524.0)	341.6-722.0 (535.3)	216.6-749.8 (526.0)
Dry matter yield (q ha^{-1})	34.0-117.7 (81.4)	37.7-113.4 (82.3)	53.6-113.4 (84.0)	34.0-117.7 (82.6)
N content (%)	1.47-1.96 (1.66)	1.19-1.96 (1.75)	1.40-2.10 (1.84)	1.40-2.10 (1.75)
P content (%)	0.13-0.23 (0.20)	0.15-0.26 (0.21)	0.17-0.28 (0.22)	0.13-0.28 (0.21)
K content (%)	1.83-2.10 (1.99)	1.71-2.23 (2.03)	1.86-2.48 (2.10)	1.71-2.48 (2.04)
N uptake (kg ha^{-1})	53.0-230.7 (137.2)	44.9-198.4 (145.9)	77.5-238.1 (155.9)	44.9-238.1 (146.3)
P uptake (kg ha^{-1})	4.90-26.5 (16.4)	6.16-25.4 (17.8)	9.45-29.7 (18.6)	4.90-29.7 (17.5)
K uptake (kg ha^{-1})	67.2-235.4 (162.2)	71.3-233.5 (168.5)	99.8-250.3 (178.0)	67.2-250.3 (169.7)

**Values in parentheses indicate average*

Table 3. Basic data for calculating fertilizer dose with and without FYM for targeted yield of forage oats

Particulars	Without FYM			With FYM		
	N	P	K	N	P	K
Nutrient required (kg q^{-1})	0.27	0.03	0.32	0.27	0.03	0.32
Per cent contribution from soil (%)	71.4	33.7	59.9	71.4	33.7	59.9
Per cent contribution from fertilizer (%)	89.6	50.8	302.7	102.4	52.9	351.5
Contribution from FYM nutrients (%)	-	-	-	73.0	7.51	90.4

*FYM contains 0.26% N, 0.13% P and 0.28% K.

oats increased with increasing soil fertility levels, indicating that yield is influenced by soil fertility levels. Also, the N, P and K content of plant increased with increase in soil fertility levels. The possible reason might be more consumption of nutrients from soil due to vigorous and faster vegetative growth of oats and higher uptake of nutrients with better root proliferation with increasing levels of soil fertility.

Strip-wise range and mean of nutrients uptake (N, P and K) by forage oats are given in table 2. It was observed that N uptake in the experimental field varied from 44.9 to 238.1 kg ha^{-1} with an average of 146.3 kg ha^{-1} while, P uptake varied from 4.90 to 29.70 kg ha^{-1} with an average of 17.45 kg ha^{-1} and K uptake varied from 67.2 to 250.3 kg ha^{-1} with an average of 169.6 kg ha^{-1}. The results showed that N, P and K uptake by oats increased with increasing levels of soil fertility *i.e.* strip III > strip II > strip I. The possible reason might be more consumption of nutrients from soil due to vigorous and faster vegetative growth of oats and better root proliferation with increasing levels of soil fertility. Similar increase in N uptake was reported earlier by other workers with increase in applied N levels (Legg and Stanford 1967). The uptake of P in oats also increased by application of FYM (Singh and Dahiya 1980). The P and K content of plant showed an increasing trend with concomitant increase in applied N (Pradhan 1987; Panda 1988). The results indicated that along with soil fertility levels, the amount of applied fertilizers and FYM also play a key role in influencing crop nutrients uptake.

Basic data for calculating fertilizer dose for targeted yield of forage oats

The basic data for calculating fertilizer dose with and without FYM for targeted yield of forage oats are given in table 3 .The nutrient requirement (NR) for production of one quintal of forage oats was 0.27 kg of N, 0.03 kg of P_2O_5 and 0.32 kg of K_2O. The NR values vary among different crops in different soils and climatic regions (Velayutham *et al.* 1985). Per cent contributions of N, P_2O_5 and K_2O from soils were 71.4, 33.7 and 59.9, respectively. The difference in efficiency of soil for supplying N, P and K may be due to the dynamic nature of soil and prevailing environmental conditions. The N, P and K contributions from fertilizers as percentage of their nutrients content were 89.6, 50.8 and 302.7 without FYM for N, P_2O_5 and K_2O, respectively. Here, the apparent efficiency of applied N was comparatively on the higher side and that of K was found more than 100%. This may be due to interaction effect of N and P and priming effect of starter dose of K in treated plots which resulted in the release of soil K from the non-labile pool to the labile pool, leading to the increased uptake from native soil sources by oats. Similar trends were also reported by Sachan *et al*. (1981) in laha (*B. Juncea*).

Per cent contribution of nutrients from applied FYM for N, P_2O_5 and K_2O were 73.0, 7.51 and 90.4, respectively. The probable reason for such higher contributions of N and K from FYM may be due to rapid mineralization of FYM in *tarai* conditions with application of inorganic fertilizers. The possible reason for low P efficiency may be attributed to formation of insoluble complexes with organic manures. The N, P and K contributions from fertilizers as percentage of their nutrients content were 102.4, 52.9 and 351.5 with FYM for N, P_2O_5 and K_2O, respectively. This indicated that nutrients contribution from fertilizers along with FYM were higher than without FYM and from soil. The application of FYM may have played a key role in enhancing the microbial population in soil which lead to the higher availability of nutrients and thereby increased the efficiency of added nutrients.

Fertilizer prescription equations

Soil test based fertilizer prescription equations for N, P and K were developed for desired target yield of forage oats with and without application of FYM using the basic data and presented in table 4. These fertilizer prescription equations could be used

Table 4. Soil test based fertilizer adjustment equations for targeted yield of forage oats

Without FYM	With FYM
FN = 0.301 T - 0.796 SN	FN = 0.263 T - 0.696 SN - 0.712 FYM-N
FP_2O_5 = 0.135 T - 1.518 SP	FP_2O_5 = 0.129 T - 1.458 SP - 0.324 FYM-P
FK_2O = 0.127 T - 0.239 SK	FK_2O = 0.110 T - 0.206 SK - 0.311 FYM-K

Where, T = Yield target (q ha^{-1}); SN, SP and SK = Alkaline $KMnO_4$-N (kg ha^{-1}), Olsen-P (kg ha^{-1}) and NH_4OAc-K (kg ha^{-1}), respectively; FYM-N = Amount of N applied through FYM, FYM-P = Amount of P applied through FYM, FYM-K = Amount of K applied through FYM, FN = Fertilizer dose of N (kg ha^{-1}), FP_2O_5 = Fertilizer dose of P (kg ha^{-1}), FK_2O = Fertilizer dose of K (kg ha^{-1}).

Table 5. Doses of nitrogen, phosphorus and potassium for different yield targets of forage oats with and without FYM

Soil test values (kg ha^{-1})	Fertilizer doses (kg ha^{-1}) without FYM			Fertilizer doses (kg ha^{-1}) with FYM		
	Yield target of forage oats (q ha^{-1})			Yield target of forage oats (q ha^{-1})		
	300	400	500	300	400	500
Alkaline $KMnO_4$-N			Fertilizer dose N (kg ha^{-1})			
100	10.8	40.9	71.0	-	17.2	43.6
150	-	1.00	31.0	-	-	8.75
200	-	-	-	-	-	-
250	-	-	-	-	-	-
Olsen-P			Fertilizer dose P_2O_5 (kg ha^{-1})			
15	17.8	31.3	44.8	13.0	26.0	39.0
20	10.2	23.7	37.2	5.70	18.7	31.7
25	2.57	16.1	29.6	-	11.4	24.4
30	-	8.49	22.0	-	4.09	17.1
NH_4OAc-K			Fertilizer dose K_2O (kg ha^{-1})			
120	9.55	22.2	34.9	-	10.5	21.4
140	4.80	17.5	30.2	-	6.42	17.3
160	0.04	12.7	25.4	-	2.32	13.3
180	-	7.98	20.7	-	-	9.16

for similar soils occurring in a particular agro-ecological region and targets chosen within the range of yield obtained in the present experiment. However, the prescription equations must be used within the range of experimental soil test values and cannot be extrapolated.

Ready Reckoner for fertilizer recommendation in forage oats

Fertilizer requirement of N, P and K at different STVs for the production of different yield targets of forage oats was calculated using the fertilizer prescription equations. The requirement of fertilizers with and without FYM and with are given in table 5. The results indicated that fertilizer nutrients doses increased with increased yield targets but decreased with increased STVs for the given nutrient. Similar trends were observed by Santhi *et al.* (2002) in onion crop grown in an Inceptisol and Arya and Gautam (2017) in tomato grown in a Mollisol. The results also indicated that application of FYM might have saved N, P and K fertilizers requirement as a part of crop nutrient need can be met through the nutrient of FYM and FYM also helps in increasing the efficiency of soil as well as fertilizer nutrients.

Conclusions

It may be concluded that soil test based fertilizer prescriptions equations generated under the present study could be helpful to farmers as per their resource availability to use fertilizers along with organic manures. Result of this investigation clearly shows saving of fertilizers as per soil test values, yield targets and conjoint use of fertilizers with organic manures.

Acknowledgement

The research work was carried out under AICRP on Soil Test Crop Response. The authors are grateful to Indian Council of Agricultural Research for providing financial assistance.

References

Arya, A. and Gautam, P. (2017) Soil test crop response based fertilizer requirements for tomato grown on Mollisol. *Environment and Ecology* **35**, 3009-3013.

Devi, U., Singh, K.P., Kumar, S. and Sewhag, M. (2014) Effect of nitrogen levels, organic manures and *Azotobacter* inoculation on yield and economics of multi-cut oats. *Forage Research* **40**, 36-43.

Handbook of Agriculture (2007) *Forage Crops and Grasses*. pp. 1354-1357.

Hanway, J.J. and Heidel, H. (1952) Soil analysis methods as used in Iowa State College Soil Testing Laboratory. *Iowa Agriculture* **57**, 1-31.

Jackson, M.L. (1973) *Soil Chemical Analysis*. Prentice Hall of India (Pvt.) Ltd., New Delhi.

Kumar, N., Kumar, S. and Arya. R.K. (2012) Effect of cultivars and plant geometry on dry fodder production of barley under various moisture regimes on raised bed planting. *Forage Research* **38**, 174-176.

Legg, J.O. and Stanford, G. (1967**)** Utilization of soil and fertilizer N by oats in relation to the available N status of soils 1. *Soil Science Society of America Journal* **31**, 215-219.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *United States Department of Agriculture Circular No.* 939.

Panda, A. (1988) Response of oat varieties to nitrogen and cutting management. *M.Sc. (Ag) Thesis*. Submitted to Orissa University of Agriculture and Technology, Bhubaneswar.

Piper, C.S. (1967) *Soil and Plant Analysis*. Asia Publishing House, Bombay, India.

Pradhan, S.K. (1987) Effect of different dates of sowing, levels of nitrogen and cutting management on growth and yield of fodder oats (*Avena sativa* L.). *M.Sc. (Ag) Thesis*. Orissa University of Agriculture and Technology, Bhubaneswar.

Sachan, R.S., Gupta, R.A., Ram, N. and Ram, B. (1981) Fertilizer requirement of laha (*Brassica juncea*) for pre-set yield targets in *tarai* soils of Uttar Pradesh. *Indian Journal of Agriculture Research* **15**, 193-196.

Santhi, R., Natesan, R. and Selvakumari, G. (2002) Soil test based fertilizer recommendations under IPNS for aggregatum onion in Inceptisols of Tamil Nadu. *Agropedology* I **12**, 141-147.

Singh, R. and Dahiya, S.S. (1980) Effect of farmyard manure and iron on dry matter yield and nutrients uptake by oats (*Avena sativa*). *Plant and Soil* **56**, 403-412.

Subbiah, B.V. and Asija, G.L. (1956) A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25**, 259-260.

Velayutham, M., Reddy, K.C.K. and Shankar, G.R.M. (1985) All India Coordinated Research Project on Soil Test Crop Response Correlation and its impact on agriculture production. *Fertiliser News* **30**, 81-95.

Walkley, A. and Black, I.A. (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **37**, 29-38.

Received 5 August 2020; Accepted 11 June 2021