International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 992-995

Received: 25-07-2019
Accepted: 27-08-2019

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Performance of integrated fertilizer prescriptions for garlic (*Allium sativum* L.) through targeted yield model in Mollisols of Tarai regions of Uttarakhand

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Abstract
The response of garlic (*Allium sativum* L.) to the selected combinations of 4 levels of each fertilizer N, P and K and 3 levels of FYM with simultaneous variations in initially available soil forms of these nutrients were studied under technical programme of AICRP on Soil Test Crop Response (STCR) calibration in an Aquic Hapludoll of Crop Research Centre of GBPUA&T, Pantnagar, Uttarakhand. In a preparatory trial i.e. first phase during kharif season, the whole plot was divided into 3 equal strips and fertility gradients were created artificially and in the second phase every strip was further sub-divided into 24 equal plots of 2m x 2m having 21 treated and 3 control plots in the main experiment in Rabi season with garlic as test crop. The response of garlic var. 'Pant Lohit' under selected treatment combinations 4 levels for each N (0, 75, 100 and 125 kg/ha), P (0, 25, 50 and 75 kg/ha), K (0, 25, 50 and 75 kg/ha) and 3 levels of FYM (0, 10 and 20 t/ha) was studied. Results showed that the bulb and leaves yield with plant and soil analysis data were utilized to formulate equations each for chemical alone and integrated mode of fertilizer prescription connecting the fertilizer doses with varying yield targets at different fertility levels. The validity of these equations has been tested in the verification trial. Targeted and actual yields have been shown within ± 4.17% and target yield gave higher yield, net benefit and B/C ratio with or without FYM over farmer's practice.

Keywords: Garlic, soil test crop response, yield target, fertilizer adjustment equation

Introduction
Soil testing provides sound information about the fertility and productivity of the soil. Efficient fertilizer use is necessarily not only for increasing agriculture production but also for realizing the maximum return from the investment on fertilizer at individual farmer's level. Once the nutrient requirements of particular crop have been assessed it ensures optimum crop production, improved quality of the produce, maintenance of soil health and proper use of nutrient resources available with the farmers. Fertilizer recommendation for pre-set yield targets is a unique technique applicable under conditions of fertilizer resource constraint for efficient and judicious use of fertilizer and soil nutrients (Ramamoorthy and Velayutham, 2012) [9]. In this technique, fertilizers are recommended separately for different plots of a holding on the basis of soil tests and pre-set uniform yield targets depending upon the availability of fertilizer input. The efficiency of applied fertilizer nutrient and the nutrient already present in the soil is very much location specific and calibrations are needed for every set of soil- crop-climate complex under optimal agronomic practices. The production and productivity of garlic in India is still lower due to improper nutrient management, excessive use of inorganic fertilizers and lack of adoption of new improved production technologies. Non availability of information on fertilizer recommendation for garlic crop in Mollisols of Uttarakhand prompted the present investigations to be undertaken.

Materials and Methods
The experimental plot was located on a silty clay loam soil and classified as Aquic Hapludoll (Deshpande *et al*., 1991) [2]. In a preparatory trial i.e. in first phase during kharif season, the whole plot was divided into 3 equal strips and fertility gradients were created artificially through differential application of fertilizers and growing maize as a fertility gradient stabilizing crop in the preceding crop season to enable thorough interaction between the

nutrients in the soil and those added through fertilizer. In the second phase every strip was further sub-divided into 24 equal plots of 2m x 2m having 21 treated and 3 control plots in the main experiment in Rabi season with garlic as test crop. The response of garlic variety 'Pant Lohit' under selected treatment combinations 4 levels for each N (0, 75, 100 and 125 kg/ha), P (0, 25, 50 and 75 kg/ha), K (0, 25, 50 and 75 kg/ha) and 3 levels of FYM (0, 10 and 20 t/ha) were studied. Before fertilizer application, soil samples from individual plots at 0-15 cm depth were collected and analyzed for Alkaline $KMnO_4$ oxidizable nitrogen (Subbiah and Asija, 1996) [12], Olsen's Phosphorus (Olsen *et al*, 1984) and ammonium acetate extractable potassium (Hanway and Heidal, 1952) [3]. Full dose of P and K was applied at the time of planting and half the dose of N was applied as basal and remaining half was applied 30 days after transplanting. At physiological maturity, bulb and leaves samples were collected and processed. These samples were analyzed for total N, P and K contents (Jackson, 1993) [5]. Using soil and plant analysis and yield data, the equations connecting fertilizer requirements of N, P and K and yield targets of garlic were worked out in the following manner.

i. Fertilizer dose equations for nutrients through chemical fertilizer alone

$$FD = \frac{NR}{CF} \times 100\ T - \frac{CS}{CF} \times STV$$

ii. Fertilizer dose equations for nutrients through conjoint use of chemical fertilizer and FYM

$$FD = \frac{NR}{CF} \times 100\ T - \frac{CS}{CF} \times STV - \frac{C_{FYM}}{CF} \times M$$

Where,
FD = Fertilizer dose Kg ha^{-1}, NR = Nutrient requirement of nitrogen, phosphorus and potassium, CF = Percent contribution of concerned nutrient from fertilizer, CS = Percent contribution of concerned nutrient from soil, C_{FYM} = Percent contribution of concerned nutrient from FYM, T = Targeted yield (q ha^{-1}), STV = Soil test values for available NPK kg ha^{-1}, M = Concerned nutrient content in organic matter.
To test the validity of equations for garlic 'Pant Lohit', verification trial was conducted in Rabi season. Five treatments with 3 replications were taken viz. farmer's practice, GRD (general recommended dose), FYM 20 t/ha, 12 t /ha target and 12 t /ha target + 20 t FYM/ha

Results and Discussion
In the present investigation, the soil test values ranged from 151.2 to 241.8, 54.3 to 84.2 and 147.8 to 208.3 with the mean values of 186.6, 66.7 and 176.27 for N, P and K kg ha^{-1} respectively. Garlic bulb yield varied between 6.9 to 16.1 t ha^{-1} with the mean of 11.53 (Table 1). Thus for targeted yield approach yield concept and soil test values are taken into account while making fertilizer recommendation.
The basic data for calculating fertilizer dose with or without FYM for targeted yield of garlic are given in Table 2. The perusal of these data indicate that 1.4, 0.1 and 2.1 kg of N, P and K are required to produce 1 quintal garlic bulbs. Kadam and Sonar (2016) [6] were found the values of nutrient requirement of 1.1 kg N, 1.2 kg P_2O_5 and 2.0 kg K_2O for the production of one quintal of onion bulb. The utilization efficiency of soil available N (Alkaline $KMnO_4$), P (Olsen's P) and K (NH_4OAC-K) were 62.1, 18.2 and 102.0 per cent, respectively. The values of fertilizer efficiency were 50.2, 18.5 and 201.6 for without FYM and 48.4, 15.5 and 162.0 per cent with FYM for N, P and K respectively. The values of per cent contribution from applied FYM were 11.0, 0.73 and 7.70 for N, P and K respectively. The recorded values of more than hundred for potassium is due to interaction effect of N and P and priming effect of K in the treated plots.
Final computations by using these basic data following simple fertilizer adjustment equations for targeted yield of garlic for both with or without FYM were worked out.

1. Without FYM
   Nitrogen dose (kg ha^{-1}) = 2.83 T – 1.24 SN
   Phosphorus dose (kg ha^{-1}) = 0.76 T – 0.98 SP
   Potassium dose (kg ha^{-1}) = 1.017 T – 0.506 SK
2. With FYM
   Nitrogen dose (kg ha^{-1}) = 2.9 T- 1.28 SN-0.227 FYM-N
   Phosphorus dose (kg ha^{-1}) = 0.90 T- 1.68 SP-0.47 FYM-P
   Potassium dose (kg ha^{-1}) = 1.27 T- 0.635 SK-.048 FYM-K

T = Yield target (q ha^{-1}), SN = Alkaline $KMnO_4$-N, SP = Olsen's-P (kg ha^{-1}), SK = Amm. Ac.-K (kg ha^{-1}), FYM-N = Nitrogen content in FYM, FYM-P = Phosphorus content in FYM, FYM-K = Potassium content in FYM (FYM on dry weight basis)
Fertilizer prescription equations were transformed in to ready reckoners for requirement of fertilizer for yield targets of 12 t ha^{-1} of garlic on soils with varying soil test values for both with or without FYM (Fig.1-3). Fertilizer rates decrease with increasing the soil test values. It is obvious from these findings that there was net saving of fertilizers with the use of FYM.
The validity of the targeted yield equations developed for garlic was tested by conducting verification trial on the same location. The results of verification trial showed that there is fairly close similarity between the yield targeted and those actually obtained (Table 3). Among the treatments targets of 12 t ha^{-1} and 20 t FYM ha^{-1} at par and target of 12 t ha^{-1} + 20 t FYM ha^{-1} gave significantly higher yield with 12 t ha^{-1} over farmers' practice. The variation in yield obtained from the targeted yield ranged from -4.17 to +3.33%. The farmers' practice of fertilizer application was the least efficient in producing bulb yield of garlic. Net profit of target yield of 12 t ha^{-1} with FYM was Rs. 55691 and without FYM was Rs. 77191. Fertilizer application based on targeted yield approach was found to be superior over general recommended dose (GRD). This might be due to efficiency factor tended to increase in crop yield (Sekhon *et al.*, 1997) [11]. Similar results were also reported by Kadam and Sonar (2016) [6], Hariprakash and Subramanian (1994) [4] and Anonymus (2000) [1] in various vegetable crops. Cost benefit and response ratio of yield target 12 t ha^{-1} with or without FYM. The higher values of cost benefit and response ratio were found with yield target of 12 t ha^{-1} with and without FYM. The results are confirmity with the results of Reddy and Ahmad (1999) [10] who observed higher benefit cost ratio through targeted yield approach in comparison to farmers' practice and general recommended dose in groundnut grown on rice fallows of Jagital in Andhra Pradesh and Milapchand *et al.* (2006) [7] also found similar results with mustard and rapeseed in Punjab.

Table 1: Range and mean values of yield (t ha^{-1}) and soil test values of Garlic cultivar Pant Lohit under different fertility strips

Particulars	Strip I	Strip II	Strip III	Mean
Bulb yield (t ha^{-1})	6.9-12.5 (9.7)	7.4-15.7 (11.6)	10.5-16.1 (13.3)	11.53
Alkaline $KMnO_4$-N (kg ha^{-1})	151.2-185.6 (171.2)	168.2-194.6 (183.3)	185.3-241.8 (205.3)	186.6
Olsen's P (kg ha^{-1})	54.3-81.8 (59.1)	64.2-77.6 (69.5)	58.9-84.2 (71.6)	66.8
Am. Ac K (kg ha^{-1})	147.8-177.0 (160.7)	166.9-188.2 (175.2)	174.7-208.3 (192.9)	176.3

Table 2: Basic data for assessing fertilizer dose without and with FYM for targeted yield of Garlic

Particulars	Without FYM			With FYM		
	N	P	K	N	P	K
Nutrient required (kg q^{-1})	1.4	0.1	2.1	1.4	0.1	2.1
Contribution from soil * (%)	62.1	18.2	102.0	62.1	18.	102.0
Contribution from applied fertilizer with FYM (%)	50.2	18.5	201.6	48.4	15.5	162.0
Contribution from applied FYM nutrients (%)	-	-	-	11.0	0.73	7.7

* Soil test values at (0-15 cm depth) Alkaline $KMnO_4$-N (kg ha^{-1}), Olsen's-P (kg ha^{-1}) and Amm. Ac.-K (kg ha^{-1})

Table 3: Economics of valedictory trial of garlic cultivar Pant Lohit

Treatments	Fertilizer dose N-P-K-FYM (kg/ ha)	Actual mean Yield (t /ha)	Additional yield (t /ha)	Value of additional yield (Rs.)	Cost of fertilizer (Rs.)	B/C ratio	Net benefit (Rs.)	Response ratio	Yield deviation (%)
Farmer's Practice	60-0-0-0	9.2	-	-	-	-	-	-	-
GRD	100-50-50-0	9.7	0.5	12500	2854	3.38	9646.0	2.5	-
FYM 20t/ha	0-0-0-20	9.5	0.3	7500	1000	6.50	6500.0	7.5	-
Target 12 t ha^{-1}	102-28-32-0	11.5	2.3	57500	1808.9	30.79	55691.1	14.2	-4.17
Target 12 t ha^{-1} +20 t FYM/ha	102-28-32-20	12.4	3.2	80000	2808.9	27.48	77191.1	15.9	+3.33
CD (1%)		1.84							

Rate= N- 10.5, P_2O_5 -18.5 and K_2O 7.08 Rs /kg., Garlic bulbs =Rs 25000 /t (2016-17)

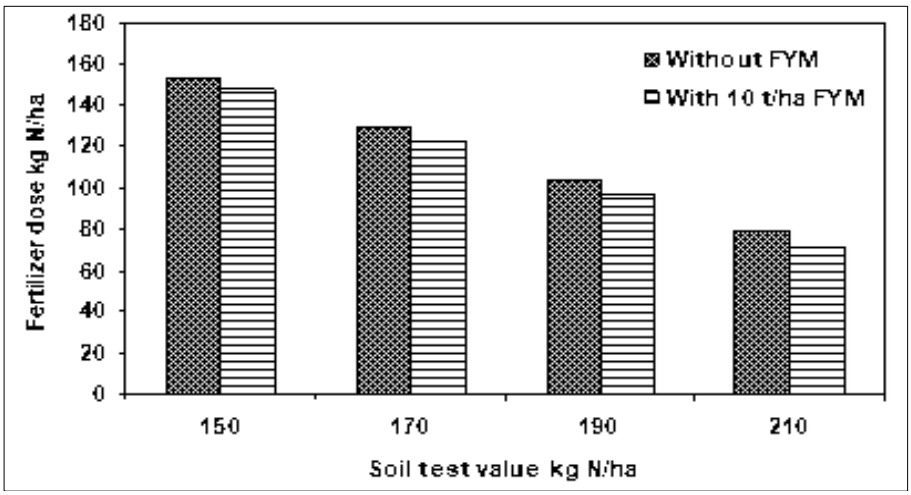

Fig 1: N requirement of garlic for 12 t/ha yield target

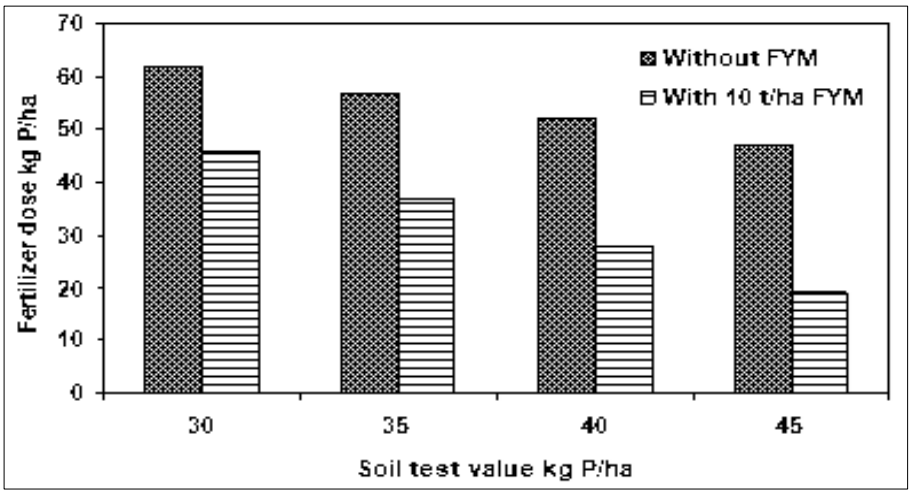

Fig 2: P requirement of garlic for 12 t/ha yield target

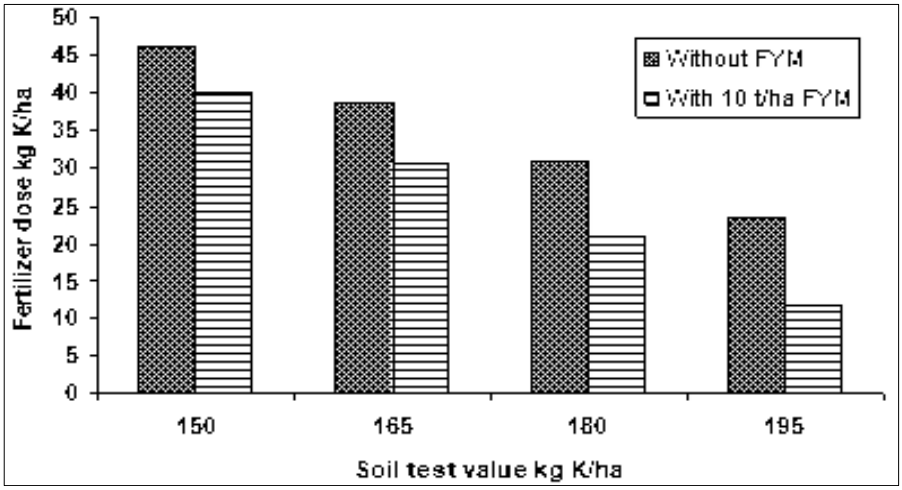

Fig 3: K requirement of garlic for 12 t/ha yield target

Conclusions

The fertilizer applied on the basis of yield targets provided higher benefit to cost ratio, indicating superiority over other methods of fertilizer application. The application of fertilizer on the basis of yield targets is meaningful, precise and eco-friendly. These equations therefore, could be used for making fertilizer recommendations for targeted yields of garlic cultivar Pant Lohit in Mollisols of tarai regions of Uttarakhand. The concept may prove useful in many other garlic growing area of the country.

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