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Targeted Yield Concept Based Fertilizer Recommendation for Garlic (*Allium sativum* L.) in Black Soil of Madhya Pradesh

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ABSTRACT

Present investigation was carried out to study the effects of fertilizer application and soil test values on yield and nutrient status in garlic crop and to generate information for targeted yield and maximum economic yield. The field experiments were conducted at the research farm of Jawahar Lal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2009-10.

Inductive methodology was followed in which fertility gradients were created and garlic (var. G-323) was grown with varied levels of fertilizers ($N_0P_0K_0$, $N_1P_1K_1$ and $N_2P_2K_2$, where $N_1P_1K_1$ represents 150, 150, 60 kg ha^{-1} of N, P_2O_5 and K_2O respectively). The initial nutrient status and nutrient availability after harvest of crop was determined. The nutrient concentration and uptake were computed at harvest. These values were used to derive the nutrient requirement and targeted yield equation for garlic crop. The results of the present investigation revealed that, for production of one quintal of garlic bulb requires 2.23 kg N, 0.87 kg P and 2.02 kg K. The nutrient utilization efficiency of N, P and K from soil source was found 12, 66 and 26 percent respectively whereas the per cent utilization of primary nutrient applied through fertilizer was found 41, 36 and 51 percent for N, P and K, respectively. The fertilizers adjustment equations were derived for N, P and K with and without manure for garlic crop to achieve the targeted yield.

Key words: *Target Yield, nutrient use efficiency, nutrient requirement, fertilizer adjustment equation*

INTRODUCTION

Garlic is an important vegetable spices and medicinal crop with nutritive value and being cultivated under irrigated condition throughout India. Garlic known as *Allium sativum* and belongs to family Alliaceae. India is a largest producer of garlic and Madhya Pradesh is one of the important garlic producer state in the country. India, garlic is cultivated in 171.45 thousand hectares producing 923.25 thousand tonnes with an average yield of 5.23 tonnes ha^{-1} [7].

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India, ranks second in area and production in the world. In Madhya Pradesh, it is grown about 67.50 thousand hectares with total production of 360 thousand tonnes giving an average production of 5.43 tonnes ha^{-1}. Madhya Pradesh ranks first in area and production in India[7].

The total factor productivity is use as an important measure to evaluate the performance of production system and sustainability of its growth pattern. The total factor productivity depends on the level of investment, the overall infrastructure and technological advancement. Fertilizer is an important factor that determines the productivity of crops. The partial factor productivity of fertilizers is declining in intensive cropping systems in India. As a consequence, the annual compound growth rate of major cereal crops has declined from 1980s to 2000s. Such gloomy trend was also registered in case of pulses and oilseeds, while cotton exhibited even negative growth rate. Therefore, any practice which helps to economies the use of fertilizers will be of great practical value in present day agriculture. In this context, soil testing has to play a vital role because soil tests based fertilizer recommendation not only ensure the balanced nutrition of crops but also avoid the wasteful use of this expensive input. The shift towards profit oriented agriculture has further increased the need of soil test based fertilizer recommendations.

There are various approaches to determine the amount of fertilizer needed for different crops. Among the various methods of formulating soil test based fertilizer recommendations the one based on regression analysis with appropriate response function for maximum yield and maximum economic yields of crops and the other based on targeted yield concept for achieving desired yield goals depending upon farmer's resource investment capacities and management capabilities are important for quantitative soil testing. However, targeted yield concept has proved superior over others whose theoretical basis and proof was demonstrated by Ramamoorthy[9] and his associates at Indian agricultural research institute, New Delhi, is also unique in the sense that this method not only indicates soil test based fertilizer dose, but also the levels of yield the farmers can hope to achieve if good agronomy is followed in raising the crop. From the point of view of soil plant system, this approach is also unique in the sense that it provides the scientific basis for balanced fertilization not only between the soil and fertilizer nutrients, but also between the soil available nutrients themselves, and strikes a balance between fertilizing the crop and fertilizing the soil, leading to realization of desired yield and maintenance of soil fertility.

The soil test based fertilizer requirement through targeted yield approach has been computed for some important crops in Madhya Pradesh for example paddy in black soil, wheat in black soil, maize in shallow black soil, bajra in alluvial soil, soybean in medium black soil, gram in medium black soils, arhar in medium black soils, urid in black soils, linseed in medium black soils, safflower in medium black soils, mustard in medium black soils, mustard in alluvial soils, cotton in medium black soils, Niger in shallow and loam soils[18]. Recently, work has been done under IPNS mode for the crops like lentil and pea[1]. These fertilizer adjustment equations have been test verified in the farmer's fields and recommended to be used by the respective soil testing laboratories. In India also, several fertilizer adjustment equations have been evolved over the last 35 years for the important crops like rice, wheat, maize, cotton, sugarcane, soybean, pigeon-pea, gram etc. However, the work done so far mainly included the generation of soil test based fertilizer requirement only under the condition of the application of chemical fertilizers. The required information under conditions of joint application of organics and inorganic is scanty in vegetables and spices crops.

MATERIAL AND METHODS

Present investigation was aimed to study the effects of fertilizer application and soil test values on yield and nutrient status in garlic crop and to generate information for targeted and maximum economic yield. To achieve the above objectives, the field experiment was conducted at the research farm of Jawahar Lal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2009-10.

Location and climate

Jabalpur has a semi arid and sub tropical climate with a characteristic feature of dry summer and cold dry winter. It is situated at $23^0 10''$ North latitude and $79^0\ 57''$ E longitudes at 411.78 meters above the mean sea level. The average temperature varies between 25^0 and 35^0C and the relative humidity ranges between 70 to 80 percent. The total annual rainfall varies from 1200 to 1500mm with an average of 1254 mm, which mostly received during mid June to first week of October.

Initial soil characteristics of experimental site:

The soil of the experimental field is medium black belonging to Kheri series of fine montmorillonitic hyperthermic family of Typic Haplustert). The soil of experimental field is clay with pH 7.6 and non saline [EC- 0.16 dSm^{-1}]. The initial mineralizable N, available P and exchangeable K status were 317, 13 and 365 Kg ha^{-1}, respectively.

Field experiment:

Inductive methodology was conducted on Vertisols of central India with Garlic (Var. G-323) crop. The inductive methodology of Ramamoorthy *et al*[9] was followed in which three fertility gradients were created in the preceding season by dividing the experimental field into three equal strips which were fertilized with graded doses of NPK levels. An exhaust crop fodder (Jowar) was grown. By growing the exhaust crop the operational range of soil fertility was created in the fertility strips. After the harvest of exhaust crop each strip was divided in three equal blocks across the strip for two F.Y.M levels. Then each strip were divided into 30 plots and distributed fertilizers treatments in such a manner that every treatment was accommodated in each of gradient strip as well as in FYM blocks. As laid down in the technical programme of All India Coordinated Research Project for investigations on Soil Test Crop Response Correlation (I.C.A.R.), prior to raising the experimental crops in the selected field appreciable variation in soil fertility was artificially created and in about 3000 sq meter land area divided into three rectangular strips by application of $N_0P_0K_0$, $N_1P_1K_1$ and $N_2P_2K_2$, where $N_1P_1K_1$ represents 150, 150, 60 kg ha^{-1} of N, P_2O_5 and K_2O respectively. A preparatory Jowar (Chari) crop was grown and in the following season each strip was divided into 30 equal plots.

Farmyard manure was applied at two levels in such a way that each fertilizer treatment had opportunity to be with each level of FYM. The fertilizer treatment totaling to 24 and having different combination of N, P and K were distributed in each of the strip along with six control plots interspaced. The doses of fertilizer N, P_2O_5 and K_2O applied to garlic ranged from 40-120, 30-90 and 40-120, respectively with an interval of 40, 30 and 40 kg ha^{-1}, respectively. The total number of treatments were 24+6(Control) = 30.

Fertilizer schedule for garlic crop (2009-2010) four level of 0, 1, 2, 3, of each nutrient applied (kg/ha), nitrogen 0, 40, 80, 120, phosphorus 0, 30, 60, 90 and potash 0, 40, 80, 120 respectively and farm yard manure (t/ha) are 0, 10, 20. The sources of N, P, and K were urea, single superphosphate and muriate of potash, respectively.

The full doses of P and K fertilizers were applied as basal by broad cast and mixed thoroughly before sowing of the seed. Fifty per cent of N was applied as basal and rest was top dressed 30 days after sowing. Seeding was done at 25 cm apart in rows by drill keeping plant to plant distance at 10 cm. The matured crop was harvested and threshed for recording plot-wise yield after thorough sun-drying of bulb straw.

Soil and plant analysis:

Initial soil samples were collected from each gradient plot before imposition of the treatments and after harvest of the crop were analyzed for available soil nutrient contents. Soil was composited for each replicate, air dried, and ground to pass a 2-mm sieve prior to analysis. Available nitrogen in soil samples were determined by adapting the alkaline permanganate method of Subbiah and Asija[19]. Available P was determined colorimetrically after the extraction of 1 g soil with 20 ml 0.5 M sodium bicarbonate ($NaHCO_3$) for a half hour[8]. Exchangeable potassium was determined using a flame photometer following soil extraction with 1N ammonium acetate ($COOCH_3NH_4$)[3]. Similarly, the garlic bulbs and straw samples of the test crop were collected from each plot after harvest at maturity and dried thoroughly and were analyzed for total N, P and K contents following standard protocols outlined by Jackson[4]. The total nutrient uptake (N, P and K) was computed using nutrient concentration and yield values.

Computation of targeted yield based nutrient requirement of crop:

Uptake was calculated plot- wise for each crop based on actual concentration of nutrients in the collected plant samples. From the concentration of N, P, K, on dry matter basis, uptake of nutrients by the crops per hectare was obtained by multiplying the concentration expressed in per cent with yield of grain and straw and then totaling the figures. The nutrient requirement (kg q^{-1}), contribution from soil (CS) and contribution from FYM (CO) and contribution from fertilizers (CF) were then calculated as follows:

(i) Nutrient requirement of N, P and K for bulb production:

kg of nutrient required to produce one quintal of economic produce (NR) = Total uptake of nutrient (kg ha^{-1}) / Bulb yield (q ha^{-1})

(ii) Contribution of nutrient from soil:

Contribution from soil (CS) = Total uptake in control plots (kg ha^{-1})/ Soil test values of nutrient in control plots (kg ha^{-1}) X 100

(iii) Contribution of nutrient from fertilizer:

$$\text{Contribution of nutrient from fertilizer (CF)} = \frac{\text{Total uptake of nutrients in treated plots- (Soil test values of nutrients in fertilizer treated plots x CS)}}{\text{Fertilizer doses (Kg ha}^{-1}\text{)}} \times 100$$

(iv) Contribution of nutrient from FYM:

$$\text{Contribution of nutrient from FYM (CM)} = \frac{\text{Total uptake of nutrients in FYM treated plots- (Soil test values of nutrients in FYM treated plots x CS)}}{\text{Nutrient doses (Kg ha}^{-1}\text{) applied through FYM}} \times 100$$

(v) Fertilizer dose:

Fertilizer dose = [(NR/ % CF) X 100 X T (q ha^{-1})] - [(%CS/%CF) X Soil Test Values (kg ha^{-1})]

RESULTS

The effect of soil fertility and fertilization on the soil available N, P and K

The data on available soil nutrients in different fertility gradient strip are given Table 4.1.

Table 4.1: Descriptive statistics of available nutrients as influenced by soil fertility gradient strips

Variables	$L_{1/2}$ strip		L_1 strip		L_2 strip		Average	
	Control [kg ha^{-1}]	Treated [kg ha^{-1}]	Control [kg ha^{-1}]	Treated [kg ha^{-1}]	Control [kg ha^{-1}]	Treated [kg ha^{-1}]	Control [kg ha^{-1}]	Treated [kg ha^{-1}]
Available nitrogen	216-365	302-432	148-389	286-476	249-365	269-446		
Mean	274	334	292	340	310	353	292	332
% increase over control			6	2	13	5		
Available phosphorus	6.87-13.17	5.43-17.96	11.00-18.47	4.46-22.82	12.50-20.72	3.48-29.46		
Mean	9.86	11.07	13.87	12.59	16.87	15.46	13.53	13.04
% increase over control			40	13	71	39		
Available potassium	252-348	229-625	313-390	394-465	382-464	271-359		
Mean	304	353	346	360	426	408	358	373
% increase over control			13	2	40	15		

The available Nitrogen in control plots was observed 216-365, 148-389 and 249-365 kg ha^{-1} in $L_{1/2}$, L_1 strip and L_2 strip, respectively. Similarly, the treated plots values varied from 302 to 432 kg ha^{-1} in $L_{1/2}$ strip, from 286 to 476kg ha^{-1} in L_1 strip and from 269 to 446 kg ha^{-1} in L_2 strip and found in the order of $L_{1/2}< L_1< L_2$. The available phosphorus and exchangeable potassium varied from 6.87 to 29.46 kg ha^{-1} and 252 to 625 kg ha^{-1}, respectively under different stripes and fertilizers applications.

The effect of soil fertility and fertilization on N, P and K uptake by garlic

The data on N, P and K uptake by garlic are given in Table 4.2. The total N uptake in control plots (kg ha^{-1}) varied from 30.49 to 88.95 kg ha^{-1} in $L_{1/2}$ strip, from 28.91 to 139.81 kg ha^{-1} in L_1 strip and from 36.53 to 142.57 kg ha^{-1} in L_2 strip, while in treated plot the N uptake was ranged between 27.80 to 184.84 kg ha^{-1} in $L_{1/2}$ strip, 35.36 to 205.50 kg ha^{-1} in L_1 strip and 23.59 to 206.79 in L_2 strip and followed the order: $L_{1/2}<L_1< L_2$.

Table 4.2: Descriptive statistics of uptake of primary nutrients as influenced by soil fertility gradient strips

Total uptake (Kg ha^{-1})	$L_{1/2}$ strip		L_1 strip		L_2 strip		Average	
	Control	Treated	Control	Treated	Control	Treated	Control	Treated
Nitrogen	30.49-88.95 (46.68)	27.80-184.84 (86.33)	28.91-139.81 (52.64) 12	35.36-205.5 (89.50) 3	36.53-142.57 (66.47) 42	23.59-206.79 (103) 19	55.0	92.94
Phosphorous	4.44-12.42 (8.60)	6.12-26.20 (10.09)	7.05-13.88 (9.82) 14	6.19-28.94 (14.29) 41	6.74-14.13 (10.86) 26	8.83-29.09 (15.20) 50	9.76	13.19
Potassium	20.50-105.85 (47.52)	11.08-125.70 (57.79)	25.41-106.92 (54.33) 14	25.83-129.48 (58.54) 1	32.89-114.40 (61.49) 29	26.59-139.01 (61.95) 7	54.46	59.42

Figures within parenthesis indicate the mean value; Figures with metaphor indicate per cent increase over control

The total P and K uptake by garlic was ranged between 4.44 and 29.09 kg ha^{-1}; and 20.50 and 129.48 kg ha^{-1}, respectively under different stripes and fertilizers applications.

The effects of soil fertility gradient and fertilization on the yield of garlic

The effects of soil fertility gradient on the yield of bulb and straw are presented in Table 4.3. The bulb yield (t ha^{-1}) in control plots varied from 1.70 to 5.69 in $L_{1/2}$ strip, from 1.70 to 6.37 in L_1 strip and from 1.61 to 6.84 in L_2 strip. Their mean values (t ha^{-1}) followed the order as: $L_{1/2}$ (3.20) < L_1 (3.35) < L_2 (3.68). In treated plots the bulb yield (t ha^{-1}) varied from 1.60 to 7.65 t ha^{-1} in $L_{1/2}$ strip; from 1.44 to 6.88 t ha^{-1} in L_1 strip and from 1.99 to 7.65 t ha^{-1} and their mean value (t ha^{-1}) followed the order $L_{1/2}$ (3.73) < L_1 (3.83) < L_2 (4.04). On an average, yield [t ha^{-1}] of treated plots was more than the control plots i.e. 3.87 t ha^{-1}> 3.41 t ha^{-1}.

Table 4.3: Descriptive statistics of yield of garlic as influence by soil fertility gradient strips

Variable	$L_{1/2}$ strip		L_1 strip		L_2 strip		Average	
	Control	Treated	Control	Treated	Control	Treated	Control	Treated
Bulb Yield (t ha^{-1})	1.7-5.69 (3.20)	1.60-7.65 (3.73)	1.70-6.37 (3.35) 4	1.44-6.88 (3.83) 2	1.61-6.84 (3.68) 15	1.99-7.65 (4.04) 8	3.41	3.87
Straw Yield (t ha^{-1})	0.5-1.8 (0.90)	0.20-2.3 (1.18)	0.5-3.0 (1.30) 44	0.3-2.5 (1.40) 18	0.8-4.4 (1.70) 88	0.6-3.25 (1.64) 38	1.30	1.41

Figures within parenthesis indicate the mean value; Figures with metaphor indicate per cent increase over control

The range and mean of straw yield in different fertility gradient strip were given table 4.3. The straw yield (t ha^{-1}) in control plots varied 0.5 to 1.8 t ha^{-1} in $L_{1/2}$ strip, from 0.5 to 3.0 t ha^{-1} in L_1 strip and from 0.8 to 4.4 t ha^{-1} in L_2 strip. Their mean values [t ha^{-1}] followed the order $L_{1/2}$ (0.90) < L_1 (1.30) < L_2 (1.70). In treated plots the straw yield varied from 0.20 to 2.30 t ha^{-1} in $L_{1/2}$ strip; from 0.30 to 2.50 t ha^{-1} in L_1 strip and from 0.60 to 3.25 t ha^{-1} in L_2 strip. And their mean values followed the order as $L_{1/2}$ (1.18 t ha^{-1}) < L_1 (1.40 t ha^{-1}) < L_2 (1.64 t ha^{-1}). On an average straw yield in control plots was less than the yield obtained in treated plots i.e. 1.30 t ha^{-1} < 1.41 t ha^{-1}.

Nutrient requirement and utilization

The data pertaining to the nutrient requirement (kg of nutrient required to produce one quintal of economic produce) is presented in Table 4.4. The nitrogen, phosphorus, and potassium requirements are varied from 0.83 to 3.53 kg, 0.43 to 1.09 kg, and 0.48 to 3.69 kg, respectively. Their mean values are 2.23 kg N >2.02 kg K > 0.87 kg P.

Table 4.4. Nutrient requirement (kg of nutrient per quintal of economic produce) and utilization of soil nutrient from soil source (per cent)

Nutrient	Range		Mean		CV (%)	
	Nutrient requirement	Nutrient Utilization	Nutrient requirement	Nutrient Utilization	Nutrient requirement	Nutrient Utilization
Nitrogen	0.83-3.53	7-18	2.23	12	25	31
Phosphorus	0.43-1.09	49-85	0.87	66	13	21
Potassium	0.48-3.69	14-35	2.02	26	22	34

Utilization of soil nutrient from soil source

The descriptive statistics pertaining to the utilization of soil nutrient as per cent of its available nutrient content is presented in Table 4.4. The utilization of soil nutrient varied from 7 to 18 per cent nitrogen, 49 to 85 per cent phosphorus and 14 to 35 per cent potassium. Their mean values are 12 per cent N, 66 per cent P and 26 per cent K.

Utilization of soil nutrients from fertilizer source

The descriptive statistics of utilization of fertilizer by garlic, as per cent of its nutrient content is presented in Table 4.6. The garlic utilization of fertilization nutrient ranged from 29 to 49 per cent for N, 20 to 68 per cent P_2O_5 and 30 to 92 per cent for K_2O. Their mean values were as: K (51%) > N (41%)>P (36%). The ratio of utilization of fertilizer nutrients by garlic plant was 1.13N: 1P: 1.41 K.

Table 4.6: Utilization of primary nutrient (per cent) by garlic from applied fertilizer and organic source (FYM)

source

Nutrient	Range		Mean		CV (%)	
	Fertilizer source	FYM	Fertilizer source	FYM	Fertilizer source	FYM
Nitrogen	29-49	15-84	41	18	18	60
Phosphorus	20-68	59-87	36	68	41	15
Potassium	30-92	33-84	51	54	39	31

Utilization of nutrients from organic source (FYM)

The descriptive statistics of utilization of nutrients applied through FYM by garlic, as per cent of its nutrient content is presented in Table 4.6. The utilization of nutrients from FYM source ranged from 15 to 84 per cent for N, from 59 to 87 per cent P_2O_5 and 33 to 84 per cent for K_2O. Their mean values were as: P_2O_5 (68 %) > K_2O (54 %) > N (18%).

Basic data

The basic data, viz., nutrient requirement in kg for producing one quintal of garlic bulb (N.R.), the per cent nutrient utilization efficiency for soil (CSS), fertilizer (CFF) and FYM (CFFYM) have been calculated (as described elsewhere) and are presented in Table- 4.8 (a).

Table 4.8: Basic data with FYM and Without FYM

Parameter	Nitrogen		Phosphorus		Potassium	
	With FYM	Without FYM	With FYM	Without FYM	With FYM	Without FYM
N.R.(kg ha^{-1})	2.23	2.23	0.87	0.87	2.02	2.02
CSS (%)	12	12	66	66	26	26
CFFYM (%)	18	-	68	-	54	-
CFF (%)	41	34	36	23	51	32

The nutrient requirements of N, P_2O_5 and K_2O were 2.23, 0.87 and 2.02 kg ha^{-1} of garlic. The per cent nutrient utilization efficiencies from soil and fertilizer nutrients were found to be 12 and 41 for nitrogen, 66 and 36 for phosphorus (P_2O_5) and 26 and 51 for potassium (K_2O). Similarly, the per cent nutrient contribution of N, P_2O_5 and K_2O from FYM was 18, 68 and 54, respectively. The basic parameter, required for calculating fertilizer adjustment equation model (without FYM) for specific yield target, were also generated Table 4.8 (a). As regard to such situation, the utilization efficiency from fertilizer source were found to be 34 per cent for nitrogen, 23 per cent for phosphorus and 32 per cent for potassium.

Fertilizer adjustment equation for desired yield target of garlic

For calculating the fertilizer doses for any yield target on the basis of initial soil test values, the basic data given in Table – 4.8, have been transformed in the form of simple workable fertilizer adjustment equations Table 4.9 under different fertilization programme (in presence and absence of FYM). and based on these equations, Ready Reckoners were prepared. A Ready Reckoner showing optimum N, P and K fertilizer doses at varying soil test values for attaining yield targets of 3.0 t ha^{-1} of garlic yield is given in Table 4.9.

Table 4.9: Fertilizer adjustment equations with FYM and without FYM

With FYM	Without FYM
FN = 5.43 T – 0.29 SN – 0.43 FYM (N)	FN = 6.55T – 0.35 SN
FP_2O_5 = 2.41 T – 1.83 SP – 1.88 FYM (P)	FP_2O_5 = 3.79T –2.86SP
FK_2O = 3.96 T – 0.50 SK – 1.05 FYM (K)	FK_2O = 6.31T – 0.81SK
T = Target yield (t ha^{-1}),SN,SP,SK = Available nutrient content in soil (kg ha^{-1}),FYM (N), FYM (P), FYM (K) = Nutrient content (%)in FYM	T = Target yield (t ha^{-1}),SN,SP,SK = Available nutrient content in soil (kg ha^{-1})

The results clearly indicate that the fertilizer dose required for attending a specific yield target of garlic yield are decreasing with increasing soil test values. For producing 3.0 t ha^{-1} of garlic in Vertisols, the fertilizer doses required for the average soil test values 200, 10, and 300 Kg ha^{-1} N, P_2O_5 and K_2O, respectively were found to be 76, 13 and 0 Kg N, P_2O_5 and K_2O, respectively with 10 t FYM. Under without FYM manuring programme for the same target level and same soil fertility conditions, the fertilizer doses were found to be126,85and 0 kg N, P_2O_5 and K_2O, respectively.

DISCUSSION

Effect of soil fertility gradient on nutrient availability, uptake and bulb yield of garlic

The data on range and mean of soil test values and yield of treated and control plots (Table 4.1) revealed that available nitrogen based on alkaline potassium permanganate method ranged between 148 to 475 kg ha^{-1} with mean of 317 kg ha^{-1}, available phosphorus based on Olsen's method ranged from 3.5 to 29.4 with mean value of 13.28 kg ha^{-1}, and available potassium based on ammonium acetate method ranged between 229 – 625 kg ha^{-1} with a mean value of 365 kg ha^{-1}. The harvested bulb yield (table 4.3) in treated and control plots was found to range from 1.6 – 7.65 t ha^{-1} and 1.7 – 5.69 t ha^{-1} respectively. The available N, P and K contents in the soil was directly associated with the addition of graded levels of fertilizer nutrients in L_1 and L_2 strips (Table 4.1). The percent increase in available nutrients in L_1 and L_2 strips over $L_{1/2}$ strips was 6 and 13 percent for N 40 and 71 percent for P,13 and 40 percent for K. The percent increase in total uptake in L_1 and L_2 strips over $L_{1/2}$ strip was 12 and 42 percent for nitrogen, 14 and 26 percent for phosphorus and 14 and 29 percent for K. The nutrient uptake (kg ha^{-1}) and biomass production due to L_1 and L_2 over $L_{1/2}$ were 12 and 42 per cent for N ; 14 to 26 per cent for P and 14 and 29 per cent for K ; 4 and 15 per cent for bulb and straw yield . The similar trend was also observed in treated plots. All these observations clearly showed that the gradients created both for available nutrient and had direct influence on nutrient uptake and biomass production in different fertility strips. These results corroborate the findings reported by Sonar[16] in onion for black soils of Maharashtra, Tirkey and Puri[20] in garlic in Vertisols, Saxsena *et al*[11]., in onion and garlic in Mollisols.

A relative distribution of N, P, K content in bulb and in straw is depicted in (fig 4.3 and 4.4) indicates that for nitrogen: - bulb (2.23%) > straw (0.72%); for phosphorus: bulb (0.37%) > straw (0.04%) and for potassium: bulb (1.45%)> straw (0.33%). The K content in bulb was four times more than that in straw and the N content a accorded the narrowest ratio 3:1. Whereas, a very wide P distribution ratio in bulb to straw is amounted to be 9.2:1. Further based on relative nutrient contents in bulb the inference can be drawn that the ratios of relative distribution of N: P: K in economic produce is 6.02N:1P:3.9K.

A comparative view of the effect of organic and inorganic fertilization on nutrient contents and on total nutrients uptake have been evolved and depicted in (Fig. 4.2). The inorganic fertilization has definite superior edge over the effect of organic (FYM) fertilization on primary nutrient uptake values viz. the series can be shown as : N uptake – inorganic (92.94 kg ha^{-1}) > organic (55.26kg ha^{-1}) : P uptake – inorganic (13.19 kg ha^{-1}) > organic (9.76 kg ha^{-1}) and K uptake – inorganic (59.42 kg ha^{-1}) > organic (54.46 kg ha^{-1}) the reason could be that inorganic fertilization might have accentuated the production level of garlic. Whereas, solo application of organic (FYM) failed to attain that yield level which was give out by inorganic fertilization.

There is no dearth of doubt that the variability had existed in the soil test values and bulb yield of treated and control plots which is essential for developing a multiple repression model and targeted yield equations for calibrating optimum fertilizer doses.

Basic parameters and fertilizer adjustment equations

The basic data required for making fertilizer recommendations for targeted level of crop production (Table-4.8) indicates that the basic ingredients of this investigations are the exact nutrient requirements of the economic produce, the available nutrients (N, P, K) in the soil and their per cent utilization and reckoning on that basis the supply of the required quantity of fertilizers neither more or less. The targeted yield approach is based on the principle of balanced nutrition and the fertilizer dose based on this approach or (prescription – based fertilizer dose) takes into account nutrient removals, efficiency of nutrients present in the soil and of those added through fertilizers and possibly nutrient interactions as well, It is in this context that in soil test crop response investigations not only are yields targeted , but in the process precise use of fertilizers is also practiced, resulting in judicious use of fertilizers.

The nutrient requirement figures for each nutrient are based on the fact that there is a significant relationship between nutrient uptake and grain yield , in the normal range of soil nutrient status and fertilizer[15] substantiating the idea of a definite nutrient requirement for any given yield target . These figures are constant for a given set of soil –plant-climatic condition .The soil nutrient efficiency factors are specific for the soil – plant- agro-climatic complex. Similarly, the factors of fertilizer use efficiency are also specific for the soil – plant – agro - climatic complex, method, form and time of application of fertilizer. A perusal of data in (Table-4.8 (a)) shows that the nutrient requirements for N, P_2O_5 and K_2O where 2.23, 0.87, 2.02 kg per quintal of garlic bulb, respectively. The percent nutrient utilization efficiencies from soil, and fertilizer nutrient were found to be 12 and 41 per cent for Nitrogen, 66 and 36 per cent Phosphorus and 26 and 51 per cent for Potash. Similarly, the percent contribution of N, P_2O_5 and K_2O from FYM was 18, 68 and 54 percent respectively.

The data clearly showed that nutrient utilization efficiencies for soil followed the order: soil P (66%) > soil k (26%)> soil N (12%). Similarly the nutrient efficiencies for fertilizer followed the order: fertilizer N (41%)> fertilizer P (36%)> fertilizer K (51%). It can be observed that phosphorus utilization efficiencies for soil shared more than that of fertilizers. Whereas, the more share of fertilizer N and K as utilized by crop as compared to contribution of soil. The higher efficiencies of soil P_2O_5 in comparison to added might be because of hydrolysis of soil- Al[12], transformation of ferric - P to more soluble ferrous – P[5] and conversion of insoluble tri calcium-P to more soluble mono and diacalcium – P[6] under optimal soil moisture condition prevalent during season. Another reason for low efficiencies of fertilizer P_2O_5 with active Al and Fe with formation of insoluble P compounds such as a $Al(OH)_2H_2PO_4$ and Fe $(OH)_2$ H_2PO_4 .

The contribution of K_2O was 26 and 12 percent from soil and fertilizer, respectively (Table-4.9). The comparatively lower efficiency of soil K_2O may be attributed due to higher fixation and low availability on heavy texture soil, Particularly when soil which in K fixing clay mineral like illite and chlorite[14]. The low efficiency of soil available nutrient and applied fertilizer nutrients indicates than there is equally greater scope for improving these efficiency figures through investigations on the manipulation of soil properties through better cultural and other management practices as well as by identifying the best form method and time application of fertilizers.

Another important point of practical importance which emerges from these data is that in the multiple cropping programme based on efficiency figures soil and fertilizer nutrients, if a cropping sequence is chosen which succeeding crops having such contrasting powers the utilized soil and fertilizer nutrient and if the fertilizer is given more to the crop having greater utilization of fertilizer nutrients the utilization and response to applied fertilizer will be greatly increased, resulting ultimately in higher efficiency of applied fertilizer in a particular cropping sequence. Similar findings are in close agreement with those reported by Sharma *et al*[13]., for mustard in Inceptisols, Sreedevi *et al*[17]., for sunflower in Vertisols and Riazuddin[10] for castor, sunflower, groundnut on Entisols and Sonar for onion and Anonymous[2] for onion in Mollisols .

As described elsewhere the basic data in table 4.9 have been transformed into workable adjustment equations for calculating fertilizer doses for yield targets with and without under IPNS mode. Using these equations a ready reckoner was prepared for range of soil test values and for a yield target of 3.0 t ha^{-1} of Garlic table 4.9 (c) in Vertisols under different fertilizer programmes (with and without FYM). The optimum fertilizer doses were 126 kg N ha^{-1} and, 85 kg P_2O_5 ha^{-1} for an average soil test values of 200 kg N ha^{-1}, 10 kg P_2O_5 ha^{-1} and 250 kg K_2O ha^{-1}, respectively. Under IPNS mode i.e. in presence of 10 t FYM ha^{-1} the optimum fertilizer doses were curtailed and come down to 76 kg N ha^{-1} and 13 kg P_2O_5 ha^{-1} for same set of soil for the same level of yield target / production of garlic and similar set of soil fertility condition. Thus, application of 10 t FYM ha^{-1} has saved the quantity of inorganic mineral fertilizer by 50 kg N ha^{-1}, 72 kg P_2O_5 ha^{-1} and it can be deduced that there was saving of 5.0 kg N, 7.2 kg P on unit ton FYM applied. Further, the results clearly indicate that the fertilizer dose, required for attaining a specific yield target of Garlic, is decreasing with increasing soil test values. There is no need of the nitrogen, phosphorus, and potassic fertilizer at soil test values of 300 kg N ha^{-1}, 20 kg P ha^{-1} and 400 kg K ha^{-1} for production of 3 t ha^{-1} of Garlic. The findings of study indicate that in STCR – IPNS technology, the fertilizer doses are tailored to the requirements of specific yield targets of Garlic taking into account the contribution from soil, fertilizers and organic (FYM), thus avoiding either under or over use of nutrients.

A Ready Reckoner indicating optimum soil test based fertilizer doses has been derived for easy interpolation fertilizer doses for attaining different yield target based on such adjustment equation, a calibration chart can be prepared by the soil test laboratories for recommending the fertilizer doses for specific yield targets based of soil test values for a given soil- agro-climatic situation. It should be remember here that these doses are site specific. The wide spread acceptance of these will be largely depend on the applicability of the basic data to similar areas for getting yield targets, based of inductive approach. A skilled and competent use of the existing soil testing laboratories and extension infrastructure can lead us to increased crop production and fertilizer use efficiencies using the target oriented fertilizer schedule.

It is evident from above data with a wide range of soil test values, the fertilizer doses derived from targeted yield equations were found to be meaningful and can be used in large scale under farmer's field conditions.

Table 4.9(c): Ready reckoner of fertilizer doses at varying soil test values for specific yield target of 3.0 t ha^{-1} garlic under different manurial programme

Soil available Nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of 3.0 t ha^{-1}					
			10 ton FYM*			Without FYM		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	105	22	25	161	99	108
150	10	150	91	13	0	144	85	68
200	15	200	76	4	0	126	70	27
250	20	250	62	0	0	109	56	0
300	25	300	47	0	0	91	42	0
350	30	350	32	0	0	74	28	0

* FYM composition : N = 0.98 %, P_2O_5 = 0.34 %, K_2O = 0.64%

CONCLUSION

Nutrient requirement (N.R.) to produce one quintal, of garlic is 2.23 kg N, 0.87 kg P and 2.02 kg K. Soil efficiencies were as N 12 %, P 66% and K 26 %. Fertilizer use efficiencies were in order as K_2O (51%) > N (41%) > P_2O_5 (36%). Nutrient use efficiencies of FYM source followed the series as: P_2O_5 (68%) > K_2O (54%) > N (18%). Fertilizer adjustment equation (with FYM). FN = 5.43 T – 0.29 SN – 0.43 FYM (N), FP_2O_5 = 2.41T – 1.83 SP – 1.88 FYM (P), FK_2O = 3.96 T – 0.50 SK – 1.05 FYM (K). Fertilizer adjustment equation (without FYM).FN= 6.55T – 0.35 SN, FP_2O_5 = 3.79T – 2.86 SP, FK_2O = 6.31T – 0.81 SK, T = Target yield (q ha^{-1}) SN, SP, SK = Available nutrient contents in soil (kg ha^{-1}), FYM (N), FYM (P), FYM (K) = Nutrient contents (%) in FYM.

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