

Original Research Article

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Calibration of Soil Test Based Balance Fertilizer Doses with FYM for Wheat under High Density Planting System in Midland Alfisols of Chhattisgarh Plateau

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ABSTRACT

Keywords

Alfisols, Nutrient requirement, Optimum fertilizer doses, Plant uptake, High density wheat, Soil tests, Yield target.

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An investigation was carried out to calibrate the soil test based balanced fertilizer doses with farm yard manure for wheat under high density planting system during rabi season 2016-17. Available nitrogen, phosphorus and potash before planting ranged between 197.6-257.2, 10.2-35.0 and 307.4-467.5 kg ha⁻¹, respectively. The larger proportion of variation (about 91%) in grain yield of wheat was accounted for fertilizer nitrogen alone. About 95 % of the grain yield variations were estimated due to fertilizer N and P only. The amount of nutrients required to produce one quintal of grain was found to be 2.00 kg N, 0.54 kg P and 1.91 kg K. The fertilizer efficiencies of N, P and K for high density wheat crop were estimated as 34.4, 22.0 and 72.1 per cent, respectively. The efficiencies of soil test for high density wheat were as 13.08 % N, 65.02 % P and 7.98 % K. The efficiencies of farm yard manure were observed as 13.7, 5.6, and 8.0 per cent for N, P and K, respectively. Based on these basic parameters viz. nutrient requirement, efficiencies of fertilizer, soil test and farm yard manure, fertilizer adjustment equations and a readyreconer were evolved which is useful to achieve a definite yield goal of wheat crop under high density planting system in similar soil and agro-climatic conditions.

Introduction

Wheat is a most important cereal crop in world and second most important crop in India after rice, which covers 31.19 million hectare area with production of 95.91 million tonnes and productivity of 3075 kg ha⁻¹ (Anonymous, 2014). In Chhattisgarh, wheat is generally cultivated; during *rabi* season after harvest of *kharif* rice, in 1.70 lakh ha area with production of 2.12 lakh tone with 1250 kg ha⁻¹ productivity, less than half of the

national productivity although climatic conditions particularly temperature is becoming favourable for wheat cultivation i.e. cool and long winter in plateau zone of Chhattisgarh (Sharma and Chaudhary, 2014).

The main reasons of low productivity are cultivation of medium to long duration paddy and delayed sowing of wheat after paddy with limited irrigation facilities and inadequate

technical knowledge of package and practices, including nutrient management. Generally wheat like other cool season crop is seeded early to take maximum period for growth and development toward maturity before the possible heat stress. However early sowing of wheat under rice-wheat system is generally not possible in low and midland situation because of time required for proper seed bed preparation for wheat crop. Late sown wheat suffers more winter injury, which produces fewer tillers and may ripen in lower grain weight and number of grains per plant. In this case farmers generally increases seed rate to counter the ill effects of late sowing. Several workers have reported benefits of high density planting of wheat in terms of yield, nutrient uptake and nutrient use efficiencies under late sown conditions (Hiltbrunner *et al.*, 2007; Drews *et al.*, 2009, Chen *et al.*, 2010).

Fertilizer is one of the costliest inputs in agriculture and the use of right amount of fertilizer is fundamental for farm profitability and environmental protection (Kimetu *et al.*, 2004).

To enhance farm profitability under different soil-climate conditions, it is necessary to have information on optimum doses for crops. Traditionally, to determine optimum fertilizer doses the most appropriate method are to apply fertilizer on the basis of soil test and crop response correlation studies using targeted yield approach to develop relationship between crop yields on the one hand and soil test values and fertilizer inputs on the other (Ramamoorthy *et al.*, 1967).

Theory of formulating optimum fertilizer recommendations for targeted yields was first given by Troug (1960) which was further modified by Ramamoorthy *et al.*, (1967) as "targeted yield model". For achieving a definite yield target of a crop, a definite

quantity of nutrients must be applied to the crop and this requirement of nutrients can be calculated by taking into consideration the contribution of native soil available nutrients and applied fertilizer nutrients (Subba Rao and Srivastava, 2001).

Use of organics to improve nutrient status, soil properties, enhance nutrient recovery, productivity of crops and optimum biological activities has been successfully demonstrated in recent literature (Regar and Singh, 2014, Sharma *et al.*, 2015 and Mandal *et al.*, 2016) but information is meagre on soil test based nutrient management in wheat under high density planting system. Such information will be helpful in improving yields and nutrient use efficiencies of wheat simultaneously maintaining and enhancing soil fertility.

Materials and Methods

The soil test crop response correlation study was conducted at Shaheed Gundadhoor College of Agriculture and Research Station, Jagdalpur, Bastar, Chhattisgarh, India, during the rainy season (kharif) 2016. Bastar is situated between 17° 46' and 20° 34' N latitude and between 80° 15' and 82° 15' E longitude with altitude ranging from 550 to 760 m above mean sea level on the eastern plateau, which is characterized by undulating topography having complex and heterogeneous physiographic settings.

The average normal annual rainfall of the area is about 1440 mm but its distribution is very erratic. Wheat is the major *rabi* crop of the Bastar region grown under semi irrigated conditions. The farmers adopt traditional methods of cultivation with very little use of fertilizers and plant protection measures. *Alfisols* are the most abundant soils in Bastar region, accounted for 45% of geographical and 50% of the potentially productive land area.

Fertility gradient experiment

Before conducting the main experiment, the fertility-gradient-stabilizing experiment was conducted. The field was divided into three equally long strips (50 m × 16.66 m) denoted as L0, L1, and L2. The variation in soil fertility with respect to N, P, and K nutrients was created by applying 150–100–100 and 300–200–200 kg ha⁻¹ of N, phosphorus pentoxide (P₂O₅) and potassium oxide (K₂O) respectively in L1 and L2 strips respectively, keeping the L0 strip as unfertilized (control). The hybrid fodder maize was grown during the previous summer season as an exhaust crop so that the fertilizer applied could interact with soil, plant, and microbes and thus become a part of the soil system. In this way, by growing an exhaust crop, a wide range of soil-test values was created in the fertility strips, which were evaluated in terms of variations in grain yield, nutrient uptake, and soil-test values. The exhaust crop was harvested after 30 days of sowing

STCR experiment

After harvest of the exhaust crop, the main experiment on high density wheat (variety: GW- 273) was conducted in the subsequent winter season 2016-17 on the site of fertility gradient experiment. Each strip (made in the fertility-gradient-stabilizing experiment in the previous season) was divided into 24 plots (21 fertilizer treatments + 3 control plots), resulting in 72 plots. Three blocks (A, B, C) comprising 8 treatments were made within a strip randomized with farmyard manure levels. These treatments comprised various selected combinations of levels of nitrogen (0, 60, 120, 180 kg N ha⁻¹), phosphorus (0, 40, 80, 120 kg P₂O₅ ha⁻¹), potassium (0, 40, 80, 120 kg K₂O ha⁻¹), and farmyard manure (0, 5, 10 tons of farmyard manure ha⁻¹) and were randomized in each of the three strips. The fertilizer materials used were urea, single

superphosphate, and muriate of potash. Full doses of P₂O₅ and K₂O were applied as basal at the time of sowing of the crop. The fertilizer N was applied in three equal splits, one third as basal, one third as top dressing at 21 days after sowing (DAS), and the remaining one third as top dressing at the flowering stage. Before application of fertilizer, FYM at 0, 5, and 10 ton ha⁻¹ as per treatments structure were applied and thoroughly mixed in soil. The crop was sown at a spacing of 15 cm × 5 cm. The soil samples at 0-0.15 m deep were collected from each plot before and after sowing of test crop, dried, passed through a 2-mm sieve, and analyzed for physicochemical characteristics as described by Jackson (1973). The soil available N was analyzed by alkaline permanganate method (Subbaiah and Asija, 1956), available P by Bray (1948) method, and available K by the ammonium acetate method (Hanway and Heidal, 1952). The plant sampling was done according to the procedure followed by Witt *et al.*, (1999). In the targeted yield approach for formulating fertilizer recommendations, the basic data [nutrient requirement (NR) (kg q⁻¹), percentage contribution from the soil available nutrients (CS, %), and the percentage contribution from the applied fertilizer nutrients (CF, %)] were derived and used to calibrate the fertilizer adjustment equations (Velayutham *et al.*, 1985a; Rao and Srivastava, 2000):

$$F \text{ (kg ha}^{-1}\text{)} = \frac{NR \text{ (kg q}^{-1}\text{)}}{CF} \times Y \text{ (q ha}^{-1}\text{)} - \frac{CS}{CF} \times S \text{ (kg ha}^{-1}\text{)} - \frac{CFYM}{CF} \times FYM \text{ (t ha}^{-1}\text{)}$$

where F is fertilizer (kg ha⁻¹), NR is nutrient requirement of N or P₂O₅ or K₂O kg q⁻¹ produce, Cs is percent contribution from soil, Cf is percent contribution from fertilizer, CFYM is percent contribution from FYM, S is soil-test value for available N, P, or K (kg ha⁻¹), Y is yield target (q ha⁻¹), and FYM is farmyard manure (t ha⁻¹). A standard regression procedure was used to relate the

soil test and fertilizer with crop yield response (Draper and Smith, 1998). The nutrient requirement, soil, fertilizer, and farmyard manure efficiencies were derived as discussed by Velayutham *et al.*, (1985b) and Maruthi Sankar (1986).

Results and Discussion

The experiments were conducted with the basic assumption that fertilizer recommendation would depend on the crop response, in which spatial variability has to be minimized for every independent variable affecting crop yield except for the nutrient in question, although many non-fertility variables (*viz.*, soil texture, soil bulk density, available water content) and other fertility variables would significantly impact the crop yield (Kastens *et al.*, 2003).

As per the approach suggested by Ramamoorthy (1967), variation in soil fertility was deliberately created by adding graded fertilizer doses and maize was sown as exhaust crop during summer season, 2016 so that the added nutrients may naturally transform in to the soil system. Fodder yield of maize in different fertility strips (Table 1) indicated that gradient in fertility level exists. After harvest of fodder maize crop, soil samples were analyzed from each strip. Maize yield and soil test data (Table 1) showed that there were little variations in soil test N (alkaline $\text{KMnO}_4\text{-N}$). However, the variations in Bray's P were quite marked and ammonium acetate extractable-K did not reflect variations in different fertility strips.

Gradient with respect to P was observed quite marked, as the nature of P is immobile and subjected to fix in soil particularly high in alfisols. Phosphorus ions react very quickly with soil constituents to form insoluble compounds depending on the nature of soil, and thus remains in soil. However, there was

no gradient created with respect to N and K as the nature of N in soil is very dynamic and its different forms are subjected to losses through leaching volatilization and de-nitrification. The high K status of the experimental field soil and maintenance of its dynamic equilibrium might be the possible reason for almost the same soil test K levels in all strips.

Soil available nutrients

Soil samples from each plot were taken before conducting the main experiments during *Rabi* season and analyzed for available N, P and K (Table 2). Mean values of available N ranged from 197.6-257.2 kg. The level of soil P increased with respect to fertility strips from L0 to L2. Average available P ranged from 10.2- 35.0 kg ha^{-1} . Similarly, the mean values of available K status were recorded in the range from 307.4-467.5 kg ha^{-1} .

The soil test data indicate that available N, P and K varied with different fertility strips although available N and K variations with respect to fertility strip were marginal however, available P variation in different strips were quite marked and it increased across the fertility strips. Gradient with respect to available P was observed clearly due to immobile nature of P and fixed with soil constituents to form insoluble compounds depending on the nature of soil and thus remains in soil.

However, there was no gradient created with respect to N and K as the nature of N in soil is very dynamic and its different forms are subjected to losses through leaching, volatilization and de-nitrification. Average K status of the experimental field soil was in medium level and maintenance of its dynamic equilibrium might be the possible reason for almost the same mean soil test K levels in all strips.

Crop response to added nutrients

The data in Table 3 showed the range and average values of grain yield of wheat in relation to three fertility strips. The overall wheat grain yield was recorded in the range of 7.9-49.5 q ha⁻¹ with an average of 33.1 q ha⁻¹. The standard deviation (SD) and coefficient

of variation (CV%) were observed higher in L0 strip and declined under L1 and L2 strip indicating thereby that the yield variations were higher in L0 strip due to soil nutrients variation. The increase in yield with respect to fertility strips may be due to creation of fertility gradient with respect to soil P from L0 to L2.

Table.1 Fertilizer doses to create fertility gradient and fodder yield of maize in different strips before main complex experiment

Fertility Strips	Fertilizer doses (kg ha ⁻¹)			Fodder yield (t ha ⁻¹)	Post-harvest soil test values (kg ha ⁻¹)		
	N	P ₂ O ₅	K ₂ O		SN	SP	SK
L ₀	0	0	0	8.3	217	13.3	372
L ₁	150	100	100	20.8	220	17.8	390
L ₂	300	200	200	25.6	226	26.4	401

Table.2 Range and mean values of available N, P and K (kg ha⁻¹) before *Rabi* season, 2016-17 with high density wheat crop

Fertility Strips	Minimum	Maximum	Average	SD	CV (%)
Alkaline KMnO₄-N (kg ha⁻¹)					
L ₀	200.7	234.7	212.3	10.4	4.9
L ₁	197.6	233.3	216.4	40.1	18.5
L ₂	200.7	257.2	222.5	44.1	19.8
All strips	197.6	257.2	217.1	12.3	5.6
Bray's-P (kg ha⁻¹)					
L ₀	10.2	17.5	14.3	2.4	16.6
L ₁	12.3	23.7	18.3	4.2	22.9
L ₂	14.0	35.0	25.8	6.7	25.9
All strips	10.2	35.0	19.6	6.4	32.8
NH₄OAc-K (kg ha⁻¹)					
L ₀	333.2	408.5	369.6	21.6	5.8
L ₁	332.2	443.3	388.9	74.1	19.0
L ₂	307.4	467.5	396.9	84.4	21.3
All strips	307.4	467.5	385.5	37.8	9.8

Table.3 Range and mean of grain yields of high density wheat during *Rabi* season, 2016-17 in relation to fertility strips

Fertility Strips	Grain yield (q ha ⁻¹)			SD	CV %
	Minimum	Maximum	Average		
L ₀	7.9	44.7	31.3	12.3	39.3
L ₁	9.7	46.8	33.1	12.5	37.6
L ₂	11.9	49.5	34.0	12.4	36.4
All strips	7.9	49.5	33.1	12.0	36.3

Table.4 Selected regression model to account for yield variation of high density wheat

S. No	General regression models for high density wheat	R ²
1	$y = 14.067 + 0.178 FN$	0.910
2	$y = 12.553 + 0.24 FN - 0.0003 FN^2$	0.921
3	$y = 19.166 + 0.2105FP$	0.509
4	$y = 18.293 + 0.2629 FP - 0.0004 FP^2$	0.512
5	$y = 23.477 + 0.1577 FK$	0.269
6	$y = 21.72 + 0.2591 FK - 0.0009 FK^2$	0.281
7	$y = 31.682 + 0.3038 FYM$	0.011
Nutrient substitution models for high density wheat		
8	$Y = 12.160 + 0.152 FN + 0.070 FP$	0.948
9	$2 Y = 11.948 + 0.151 FN + 0.066 FP + 0.010 FK$	0.949
10	$Y = 10.429 + 0.151FN + 0.066 FP + 0.010 FK + 0.304 FYM$	0.960
11	$Y = 12.548 + 0.178 FN + 0.304 FYM$	0.922
12	$Y = 0.495 - 0.064 SN + 0.175 FN$	0.914
13	$Y = 13.905 + 0.339 SP + 0.190 FP$	0.536

Where, FN, FP and FK are fertilizer N, P₂O₅, and K₂O (Kg ha⁻¹) respectively. FYM is Farm Yard Manure (t ha⁻¹). SN, SP and SK are soil test values for available N, P and K (kg ha⁻¹). Y is crop yield.

Table.5 Relation of high density wheat yield (Y) with total nutrient uptake (U)

Nutrient	Y = b1 U	R ²	NR (kg q ⁻¹)	Fertilizer Efficiency (%) E _f	Soil Test Efficiency (%) E _s	FYM* Efficiency (%) E _{FYM}
N	$y = 0.495 UN$	0.96	2.00	34.35	13.08	13.69
P	$y = 1.867 UP$	0.78	0.54	22.01	65.02	5.60
K	$y = 0.527 UK$	0.92	1.91	72.05	7.98	7.96

*Nutrient content in FYM: 0.3% N, 0.30 % P and 0.8 % K

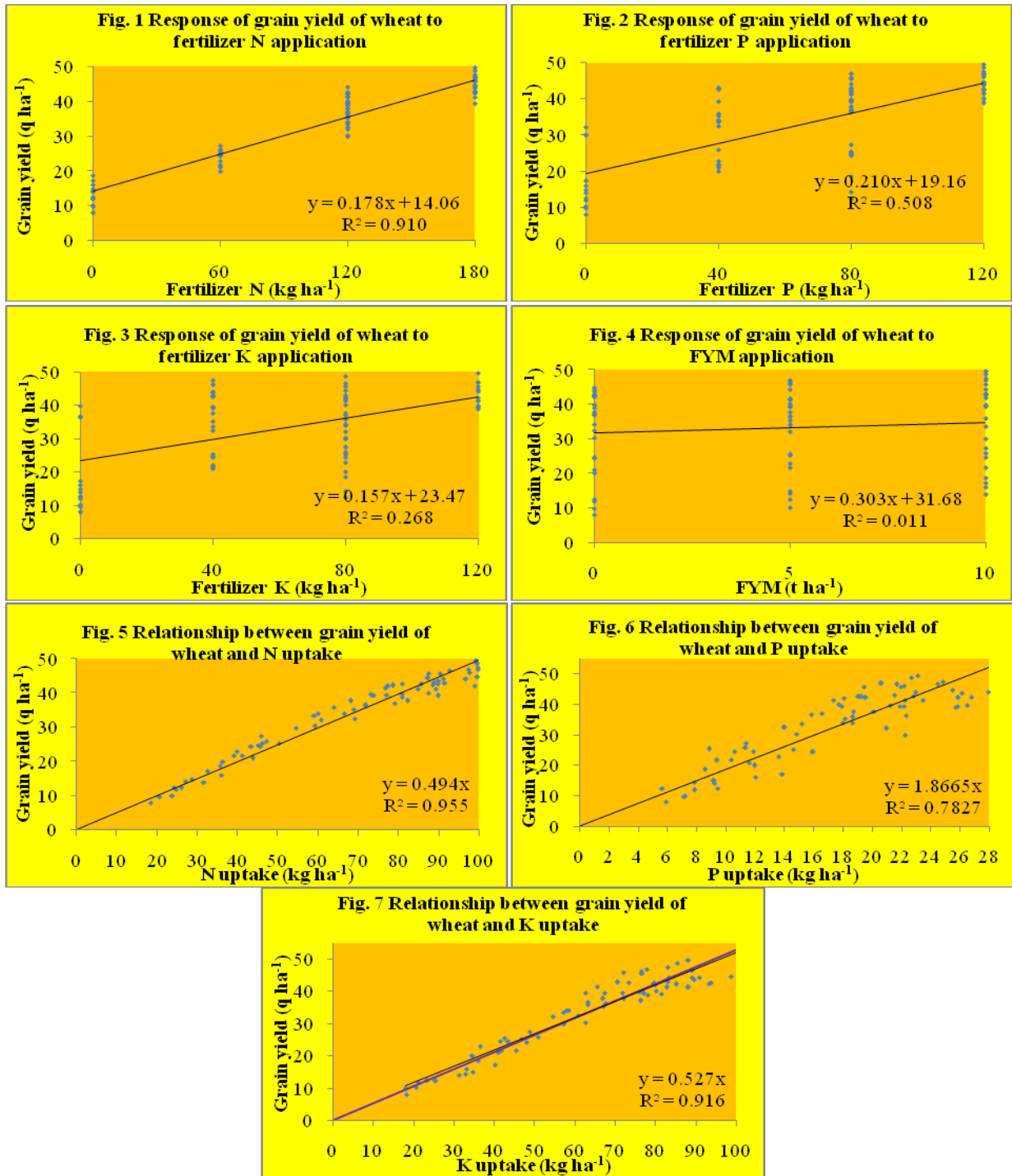
Table.6 Fertilizer adjustment equations

1	$FN = 5.82 Y - 0.38 SN - 0.40 FYM$
2	$FP = 2.48 Y - 2.95 SP - 0.25 FYM$
3	$FK = 2.65 Y - 0.11 SK - 0.11 FYM$

Where, FN, FP and FK are fertilizer N, P₂O₅ and K₂O (Kg ha⁻¹) respectively. FYM is Farm Yard Manure (t ha⁻¹). SN, SP and SK are soil test values for available N, P and K (kg ha⁻¹). Y is grain yield in q ha⁻¹.

Table.7 Ready reckoner for soil test based fertilizer N, P₂O₅ and K₂O recommendation for high density wheat (GW-273) in alfisols with 5 tonnes of FYM

Soil Test values (kg/ha)			Yield Target of Wheat (q/ha)								
			20			30			40		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	4	200	51	34	25	109	59	52	168	83	78
175	6	225	42	28	22	100	53	49	158	77	75
200	8	250	32	22	20	90	47	46	149	72	73
225	10	275	23	16	17	81	41	43	139	66	70
250	12	300	13	10	14	71	35	41	130	60	67
275	14	325	4	4	11	62	29	38	120	54	64
300	16	350	0	0	9	52	23	35	111	48	62
325	18	375	0	0	6	43	17	32	101	42	59



The crop responses to fertilizer N, P, K and FYM have been depicted in Figure 1 to 4 which showed good crop response to the fertilizer N and P application whereas response to K application was less consistent. Crop response to FYM application was not quite marked as shown in Figure 4. The

relation of grain yield of wheat with different plant nutrients as independent variables were derived by regression analysis to evaluate the yield variations due to various nutrients (Table 4). The larger proportion of variation in grain yields was accounted for by N alone. Higher crop response to N was attributed to

the high N requirement and being mobile nature of this element, it is easily accessible to the plants in the root system sorption zone (Ramamoorthy *et al.*, 1967). Fertilizer P₂O₅ and K₂O were the next to explain the rest of variations. The P ions react very quickly with soil constituents to form insoluble compounds and are thus rendered immobile in the soil. Furthermore, the requirement of P nutrient in wheat was lower than N (Table 7). The yield variation due to FYM application was also accounted very poor correlation. However, 94.8 % of the yield variations were estimated due to fertilizer N and P only as reflected in the equation given in Table 4. Curvilinear relation of fertilizer N and P did not reflect on yield variations.

Relationship between yield and nutrient uptake

The yield of high density wheat crop was showed the close association with total N, P and K uptake (Table 5). This relation was used to estimate the nutrient requirement for high density wheat (Table 5). The nutrient requirement (NR) is defined as the amount of nutrient required to produce per unit amount of yield. The nutrient requirement can be given by the regression coefficient (b₁) of yield (Y) and total nutrient uptake (U).

$$Y = b_1 U \text{ or } U = 1/b_1 * Y$$

Where, 1/ b₁ gives the NR.

The amount of nutrients absorbed by the crop decides a definite amount of biomass production. Nutrient requirement for high density wheat crops have been estimated based on conventional and regression methods which are almost similar values and are shown in the Table 7 and depicted graphically in Figures 5 to 7 showing a close association between crop yields and nutrient uptake with almost a linear relationship. The

amount of nutrient required to produce one quintal of high density wheat grain was found to be 2.00 kg N, 0.54 kg P and 1.91 kg K. The nutrient requirement is also estimated by the conventional method as given below:

$$NR \text{ (kg q}^{-1}\text{)} = \frac{\text{Total Nutrient Uptake (kg ha}^{-1}\text{)}}{\text{Grain Yield (kg ha}^{-1}\text{)}}$$

This parameter gives better results with the regression method which is being followed in present study. Several workers have reported the nutrient requirement of different crops at various places. Ramamoorthy *et al.*, (1967) reported for wheat crop which required 2.5 kg N, 0.8 kg P₂O₅ and 1.0 kg K₂O for one quintal of grain production.

Ahmed and Reddy (2002) reported that the nutrient requirement (kg q⁻¹) of N, P₂O₅ and K₂O were found to be 1.88, 1.09 and 2.79, respectively for producing one quintal of rice yield. Gautam *et al.*, (2006) reported that the nutrient requirement (kg q⁻¹) of N, P₂O₅ and K₂O were found to be 1.78, 0.37 and 2.11, respectively for producing one quintal of rice yield. Regar and Singh (2014) reported that the nutrient requirements (kg q⁻¹) of N, P₂O₅ and K₂O for producing one quintal of rice yield in *Inceptisols* were found to be 2.56, 0.56 and 2.21, respectively.

Efficiencies of fertilizer, soil test and FYM

The efficiencies of fertilizer, soil test and FYM were estimated by using the conventional methods with the help of software developed by AICRP on STCR, Indian Institute of Soil Science, Bhopal (MP). The fertilizer efficiencies of N, P and K for high density wheat crop were estimated as (Table 5) 34.35, 22.01 and 72.05 per cent, respectively. The efficiencies of soil test for high density wheat was recorded as 13.08% N, 65.02%P and 7.98% K. The efficiencies of organic source (FYM) were observed as

13.69, 5.60, and 7.96 per cent N, P and K for high density wheat crop. The chemical analyses of organics were recorded for NPK @ 0.3: 0.3:0.8 percent, respectively.

It is well known that approximate $2/3^{\text{rd}}$ of the applied fertilizer N lost through leaching, volatilization, de-nitrification and by run-off. Similarly, a large fraction of applied fertilizer P is fixed in soil by reacting with dominant cations present in the soil like Fe, Mn, Ca, Mg etc. High efficiency of applied fertilizer K observed seems to be due to higher uptake of this nutrient as luxury consumption. Soil test efficiencies for N and K were recorded less than fertilizer sources and reverse trend was seen in case of soil test P. Ramamoorthy *et al.*, (1967) reported the efficiency of soil N, P and K were 37, 14 and 44.0 per cent, respectively and the efficiency of fertilizer N, P and K were 34, 41 and 36 per cent, respectively. Similarly Gautam *et al.*, (2006) reported that the per cent contribution to rice from soil was 31.09, 28.39 and 37.21; from applied farmyard manure 30.01, 9.13 and 54.74 and from fertilizer 31.63, 40.50 and 180.81 for N, P, and K respectively. Regar and Singh (2014) reported that the percent nutrient contribution from soil, fertilizer and FYM in an *Inceptisols* were found to be 26.35, 51.17 and 26.14; 54.03, 36.35 and 75.68; and 18.59, 3.10 and 8.56 for nitrogen, phosphorus and potassium, respectively for rice yield in *Inceptisols* of Uttar Pradesh.

Estimation of fertilizer adjustment equations

Based on the basic parameters *viz.* nutrient requirement, efficiencies of fertilizer, soil test and organic source (FYM), fertilizer adjustment equations were evolved for high density wheat crop to achieve a definite yield goal. The following equations (Table 6) were evolved for high density wheat for fertilizer N, P₂O₅ and K₂O.

Ready reckoners for fertilizer doses to high density wheat

The ready reckoners for high density wheat with the use of 5 tonnes of FYM are shown in Table 7. The application of chemical fertilizer with FYM in integrated manner has beneficial effect by several ways in terms of soil fertility and physical properties improvement and higher fertilizer use efficiencies. It is further evident that the fertilizer requirements decreased with increase in soil test values. Therefore, a slightly lower yield target may be considered for a poor resource farmers to obtain maximum profit per unit cost spent on fertilizer, whereas, a higher yield target for a resourceful farmers who are interested for maximum potential production per unit area. Hence, for maintaining soil fertility, it is necessary to choose appropriate yield targets and fertilizer use practices that achieve the twin objectives of high yield and maintenance of soil fertility.

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