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Soil test based fertilizer prescription with INM using target yield approach for mustard crop in *Vertisol* of Chhattisgarh Plain climatic zone

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Abstract
The investigation was under taken during rabi season 2017-18 and 2018-19 at Instruction Farm, College of Agriculture, Raipur (Chhattisgarh) for study the soil test based fertilizer prescription for mustard crop on the basis of grain yield, nutrient uptake and soil test data which were used for obtaining basic parameters *viz.*, nutrient requirement, contribution of nutrients from soil, fertilizer and organic manure. It was found that mustard crop required 1.54 kg N, 0.28 kg P and 1.70 kg K to produce one quintal grain yield. Fertilizer and soil test efficiencies were estimated 40.17, 28.17 and 102.14 percent and 35.02, 82.55 and 17.24 percent, respectively for N, P and K. The efficiency of FYM in terms of available nutrient was evaluated as 18.41, 6.27 and 10.79 percent, respectively for N, P and K. On the basis these parameters, fertilizer N, P_2O_5 and K_2O were derived for different targeted yield of mustard by using FYM as organic component in INM approach.

Keywords: STCR, INM, mustard, soil test

Introduction
Oilseed crops are major constituent of Indian agriculture system after cereals and legumes. Mustard is one of the most dominant oilseed crop next to groundnut in India. It contributes nearly 28.6% of the total oilseeds production in the country. Mustard is largely cultivated in Rajasthan, Gujarat, Haryana, Punjab, Odisha, West Bengal and Assam. In India mustard crop occupied an area of 60.06 lakh ha with a production of 80.41 lakh tones and productivity 1339 kg ha^{-1}. In Chhattisgarh, mustard is generally grown as rainfed crop after the rice and its sowing is dependent on harvesting of rice. In Chhattisgarh mustard crop occupied an area of 0.67 lakh ha with a production 0.54 lakh tonnes with an average productivity of 807 kg ha^{-1} (Anonymous, 2017) [1].

Fertilizers are generally applied to crops based on state level general fertilizer recommendations. However, the fertilizer requirement for a crop is not a static one and it may vary for the same crop from soil to soil and even from field to field on the same soil. Soil testing as a diagnostic tool, for identifies soil fertility constraints in particular area and to give specific fertilizer recommendation based on soil analysis of that area.

Keeping the above facts in view and the present investigation was carried out in *vertisol* to explain the significant relationship between soil test values and crop responses to fertilizer and to develop fertilizer prescription equations with IPNS for desired yield target of mustard crop.

Materials and Methods
A field experiment was conducted at the Instruction farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) on mustard crop (var.- Pusa Bold) during two consecutive rabi season in 2017-18 and 2018-19 in *Vertisol* which is locally known as *Kanhar* soil. The experimental soil was clayey in texture with 24.3% Sand, 21.4% silt and 54.3% clay, dark brown to black in color, neutral to alkaline in reaction due to presence of lime concretion in lower horizon. Some physico-chemical properties of experimental soil were analyzed which found 7.7 pH (1:2.5), 0.16 EC (dSm^{-1}), 36.02 CEC (c mol(p+) kg^{-1}), 5.7 Organic C (g kg^{-1}), 219 Available N (kg ha^{-1}), 18.2 Available P (kg ha^{-1}) and 495 Available K (kg ha^{-1}). The experiment was conducted under All India Coordinated Research project for Investigation on Soil Test Crop Response Correlation (STCR) and a special field technique developed by Ramamurthy *et al.*, (1967) [6] was used. The field was divided in to three equal long strips and low, medium and high fertility gradients (L0, L1 and L2) were created by applying the graded doses of N, P and K fertilizers. Variation in soil fertility with respect to N, P and K were created by applying 100-75-50 and 200-150-100, kg ha^{-1} of N, P_2O_5 and K_2O in L1 and L2

strip, respectively and keeping L0 strip as unfertilized (control). Fodder maize crop was grown during summer season 2015 as a preparatory crop so that fertilizer could interact with soil, plant and microbes and thus become a part of soil system. In this way the ranges of soil fertility were created. After the harvest of the fodder crop, the main complex experiment with SRI rice was conducted in subsequent *Kharif* season and mustard in subsequent *rabi* season. Each strip was further divided in to three equal sized blocks for three levels of FYM (0, 5 and 10 t ha^{-1}). The 24 selected fertilizer treatments constituted 4 levels of each of N (0, 60, 120 and 180 kg ha^{-1}), P_2O_5 (0, 40, 80 and 120 kg ha^{-1}) and K_2O (0, 40, 80 and 120 kg ha^{-1}). These were distributed in each block of the strips having 8 treatments in each block.

Grain and straw samples were analyzed for N, P and K content (Piper, 1966) [4] and total nutrient uptake was computed using grain and straw yield data. Using the data on grain yield, nutrient uptake, pre-sowing available soil nutrients and fertilizer doses applied the basic parameter, *viz*. nutrient requirement (kg q^{-1}), contribution of nutrients from soil and fertilizer sources were calculated as described by Ramamoorthy *et al.*, (1967) [6]. The contribution of nutrients from applied FYM was estimated by relating the yield with fertilizer nutrients and FYM. These parameters were used for the formulation of fertilizer adjustment equations for deriving fertilizer doses and the soil test based fertilizer prescription in the form of ready reckoners for desired yield target of mustard under N, P, K alone as well as IPNS.

Results and Discussion

Status of available NPK in soil

Before taking the main complex experiment with mustard during *rabi* season 2018 and 2019, the soil samples from each plot were taken and analyzed for available N, P and K. Table 1 reveals the range and means values of available nutrients (N, P and K) during two rabi seasons. Mean values on soil N ranged from 204.0-220.0 and 204.1-223.8 kg ha^{-1} during 2018 and 2019 *rabi* season, respectively. No variations in soil test N across the fertility strips in both the mustard seasons were observed. It may be due the mobile nature of the N in the soil. The level of soil P increased with respect to fertility strips from L0 to L2. Average soil P ranged from 13.4-24.6 and 15.7-26.5 kg ha^{-1} in two mustard seasons. The available K status did not reflect with respect to fertility strips indicating that the soil of experimental field is well supplied with K.

Response of mustard to added nutrients

The results (Table 2) showed the range and average values of mustard yields in relation to fertility strips during two mustard crop seasons. The ranges of mustard yields were recorded as 6.23-21.83 q ha^{-1} with average of 15.11 q ha^{-1} in L0 strip, 6.85-22.85 q ha^{-1} with average of 15.93 q ha^{-1} in L1 strip and 7.55-23.15 q ha^{-1} with average of 16.90 q ha^{-1} in L2 strip during first mustard season 2018. Similar trends were also observed during next rabi season 2019. The increase in mustard grain yields with respect to fertility strips may be due to fertility gradient in soil P status from L0 to L2 strip.

The relation of mustard yields with different plant nutrients as independent variables were derived by regression analysis for both the seasons of mustard crop to evaluate the yield variations due to various nutrients and presented in the Fig.1. Results indicate that the larger proportion of variation in the mustard grain yield during both the seasons was accounted for by N alone. Therefore, its quadratic term also similarly fit into the data as evidence from the higher R^2 value (0.874 and 0.897) with curvilinear equation in both (2017-18 and 2018-19) the seasons. High response of mustard was attributed to the high N requirement and being a mobile nature of this element, it is accessible to the plant in the root system sorption zone (Ramamoorthy *et al.*, 1967) [6].

Fertilizer P and K 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 mustard is lower than N. The curvilinear nature of mustard yield response to P application can therefore be attributed to the above facts. Similar yield variation was recorded when FYM also included with three major nutrients. This indicates that FYM contribution is very poor towards yield variation as the nutrient content and their release pattern may be lower. The mustard responses to fertilizer N, P, K and FYM during 2017-18 & 2018-19 have also been depicted in Fig.1.

Table 1: Range and average values of soil available N, P and K (kg ha^{-1}) before mustard.

Available nutrients	Fertility strips Rabi season 2017-18				Fertility strips Rabi season 2018-19			
Soil Nutrients	**L0**	**L1**	**L2**	**SD**	**L0**	**L1**	**L2**	**SD**
Alkaline $KMnO_4^-$ N	178.0-225.0 (204.0)	183.0-229.0 (210.0)	198.0-231.0 (220)	13.11	181.89-225.79 (204.09)	200.7-232.1 (219.66)	200.7-232.1 (223.77)	13.15
Olsen's P	9.1-17.0 (13.4)	10.3-31.1 (22.0)	19.4-29.6 (24.61)	6.10	7.77-22.40 (15.71)	14.84-30.46 (23.64)	18.13-31.36 (26.52)	6.10
Neutral normal Amm. acetate extractable K	432.0-510.0 (470.0)	461.0-511.0 (485.0)	451.0-530.0 (496.0)	21.67	421.0-519.0 (478.0)	464.0-523.0 (491.0)	445.0-539.0 (506.0)	24.25

(Data in parenthesis are mean values)

Table 2: Range and mean of grain yields of mustard in relation to fertility gradients.

Year	Fertility strips			All strips	SD	CV (%)
	L_0	L_1	L_2			
2017-18	6.23-21.83 (15.11)	6.85-22.85 (15.93)	7.55-23.15 (16.90)	6.23-23.15	4.78	29.93
2018-19	6.6-25.7 (16.96)	7.4-26.5 (17.97)	8.7-26.9 (19.11)	6.60-26.90	6.15	34.16

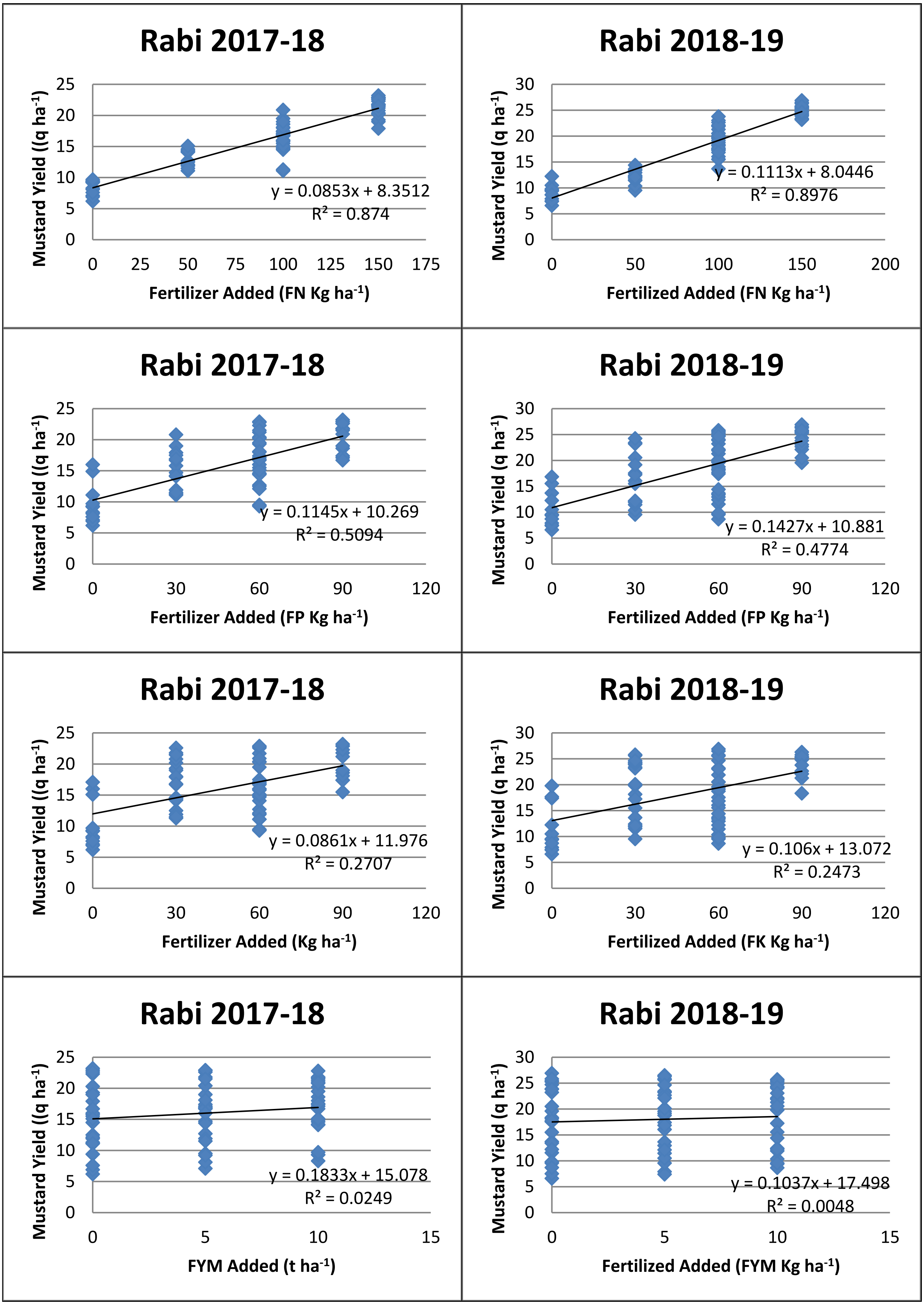

Fig 1: Response of mustard to different levels of FYM application and fertilizer N, P_2O_5 and K_2O.

Relationship between yield and nutrient uptake
A close association was observed between the yield of mustard and total N, P and K uptake during both the years. This relation was used to estimate the nutrient requirement for mustard (Table 3 and Fig.2). The nutrient requirement (NR) is defined as the amount of nutrient required to produce unit amount of yield. The nutrient requirement can be given by the regression coefficient (b1) of yield (Y) and total nutrient uptake (U).

$$Y = b1\ U \text{ or } U = 1/b1 * Y$$

Where, 1/b1 gives the NR (Nutrient Requirement)

Table 3: Relation of mustard yield (Y) with total nutrient uptake (U)

Nutrients	2017-18		2018-19	
	Y =b1 U	**R^2**	**Y =b1 U**	**R^2**
N	Y = 4.886 U	0.983	Y = 4.730 U	0.976
P	Y = 0.984 U	0.897	Y = 0.934 U	0.893
K	Y = 3.657 U	0.924	Y = 3.553 U	0.838

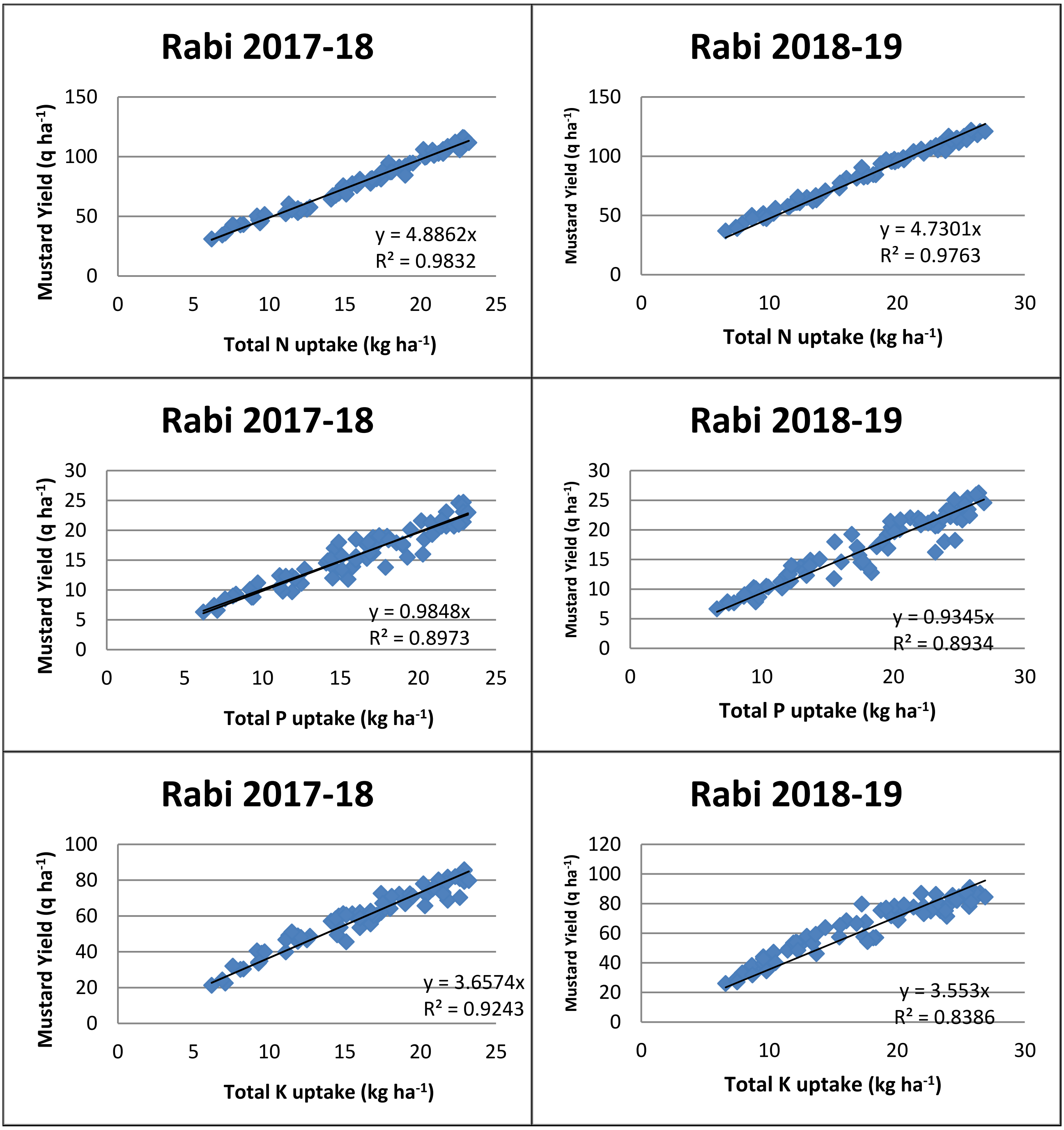

Fig 2: Relationship between mustard grain yield and total NPK uptake.

Efficiencies of fertilizer, soil test and FYM for mustard
The amount of nutrients absorbed by the crop decides a definite amount of biomass production. The average values based on two rabi season for nutrient requirement to produce one quintal of mustard grain was found to be 4.89 kg N, 0.98 kg P and 3.73 kg K, fertilizer efficiencies of N, P and K were estimated as 37.99, 23.94 and 82.88 per cent, respectively (Table 4). Similarly, average soil test efficiencies estimated

for N, P and K were as 21.95, 60.16 and 6.94 per cent, respectively. The efficiencies of organic source (FYM) were observed as 11.57% N, 7.85% P and 5.78% K.

High efficiency of applied fertilizer K observed due to higher uptake of this nutrient as soil K status was high in experimental field resulted poor response and due to luxury consumption high K uptake could be misleading the estimation of applied K efficiency hence can be treated as indefinable.

Table 4: Nutrient requirements, efficiencies of fertilizer, soil and FYM for mustard (var. Pusa Bold)

Nutrients	NR (kg q^{-1})			Fertilizer efficiency (%)			Soil test efficiency (%)			FYM efficiency (%)		
	2017	2018	Avg	2017	2018	Avg	2017	2018	Avg	2017	2018	Avg
N	4.90	4.87	4.89	37.59	38.38	37.99	20.79	23.11	21.95	7.70	15.44	11.57
P	1.00	0.96	0.98	24.19	23.68	23.94	59.38	60.94	60.16	7.89	7.81	7.85
K	3.72	3.74	3.73	80.48	85.27	82.88	6.50	7.38	6.94	4.51	7.04	5.78

Estimation of Fertilizer adjustment equation

Fertilizer adjustment equations were evolved for mustard crop to achieve a definite yield target based on the basic parameters *viz*. nutrient requirement, efficiencies of fertilizer, soil test and organic source (FYM). The following equations given in Table- 5 were evolved for mustard for fertilizer N, P_2O_5 and K_2O. Such kind of fertilizer prescription equation for different crops (rice, wheat, maize, mustard and rapeseed) have been documented by Milap-Chand *et al.,* (2006) [3], Srivastava *et al.,* (2017) [8].

Table 5: Fertilizer adjustment equations for Mustard (Pusa Bold) estimated based on response data

S. No.	Fertilizer adjustment equations
1	FN= 12.86 Y – 0.58 SN - 0.30 FYM
2	FP = 4.09 Y – 2.51 SP - 0.33 FYM
3	FK = 4.50 Y – 0.08 SK - 0.07 FYM

*Where FN, FP and FK are fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, Y = Targeted yield of Crop in q ha^{-1}, SN, SP and SK are soil test values for available N, P and K. FYM is Farm Yard Manure in t ha^{-1}.

Ready reckoners chart for fertilizer recommendations

The ready reckoners for mustard (*var.,* Pusa Bold) with the use of 5 tones of FYM are shown in Table 6. The maximum target of the crop may be fixed up to the level of maximum yield achieved in experimental field. Thus the targeted yield approach of fertilizer recommendation ensures nutrient balancing and suitable for different yield goals, soil fertility and resources of the farmer (Dev *et al.,* 1985) [2]. Several workers have also used this approach for fertilizer prescription (Rashid *et al.,* 1988; Powelson *et al.,* 1989) [7, 5].

Table 6: Ready reckoners for fertilizer recommendations based on soil test levels (kg/ha) with 5 tons of FYM for Mustard (var. Pusa Bold) in *Vertisols* of Chhattisgarh.

Soil Test values (kg/ha)			Yield Target of Mustard (q/ha)								
			14 (q/ha)			18 (q/ha)			22 (q/ha)		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	4	200	92	46	46	143	62	64	195	78	82
175	6	225	77	41	44	129	57	62	180	73	80
200	8	250	63	36	42	114	52	60	166	68	78
225	10	275	49	31	40	100	47	58	151	63	76
250	12	300	34	26	38	85	42	56	137	58	74
275	14	325	20	20	35	71	37	53	122	53	71
300	16	350	5	15	33	57	32	51	108	48	69
325	18	375	5	10	31	42	27	49	94	43	67
350	20	400	5	5	29	28	22	47	79	38	65
375	22	425	5	5	27	13	17	45	65	33	63
400	24	450	5	5	25	13	12	43	50	28	61

Conclusion

The fertilizer requirement reduced with the use of FYM resulting in the saving of chemical fertilizer. 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 hectare of land. 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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