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Statistical Investigation on Cultural cum Manurial Experiments

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SUMMARY

Under the project of Agricultural Field Experiments Information System, the experimental data relating to agricultural field experiments conducted at various research stations in the country are being collected at IASRI, New Delhi. By analyzing the data of individual experiments, it was found that interaction effects of cultural practices × fertilizer were significant in 47% of the experiments conducted on sugarcane and vegetables crops, 27% of experiments on cereals, 20% of experiments on pulses and cotton and 18% of experiments on oilseeds. By combined analysis of the groups of experiments, it was observed that interaction effects of cultural practices × fertilizer application of NPK alone or in combination were significant in 20% of groups of experiments. Almost in all the groups of experiment, fertilizer application has significant effect whereas in 70% of groups of experiments cultural practices have significant effects on crop production.

Cultural practices play significant role in improving the crop production. On the basis of coefficient of determination (R^2) and root mean square error (RMSE), Complete Quadratic Response Surface model was found good fitted model for cultural cum manurial experiments when cultural practices were quantitative in nature. Change in the levels of cultural treatment brings in the change in the doses of fertilizer. It means doses of fertilizer for the particular crop change as per various levels of cultural treatment. Responses of fertilizer also change as per various levels of cultural treatment.

Key words : Cultural practices, Fertilizer, Agricultural Field Experiments.

1. INTRODUCTION

Fertilizer is a very costly input for crop cultivation. Most of the Indian farmers are poor and they can not afford high amount and more application of fertilizer. Cultural practices which are the low cost technology will be helpful to reduce the quantity of fertilizers for crop cultivation and increase the yield of the various crops. Cultural practices may play catalytic role in improving the crop production. It is expected that response of fertilizer will vary with various levels of cultural treatment. The cultural practices included in the treatment are date of sowing, spacing, method of sowing, time of application of fertilizer, mulching, dates of harvesting, number of seeds or seedling/hill and method of ploughing or cultivation etc. Singh *et al.* (1986) studied on plant geometry and nitrogen fertilization of hybrid sorghum. Khandey and Thakur (1992) studied on the response of nitrogen in the presence and absence of FYM and Zinc. A quadric response curve $y = a+bx+cx^2$ was fitted by orthogonal polynomial method for both seasons and pooled analysis was done. Rajinder Kaur *et al.* (1992) published a report on statistical evaluation of fertilizer requirement according to date of sowing. Aggarwal and Bansal (1998) studied robust response surface design for quantitative and qualitative factors. A large number of experiments are conducted on cultural practices alone or in combination with manures and varieties. Several improvement measures such as use of fertilizers, manures, improved varieties of seeds, cultivation practices, irrigation and plant protection etc. are being recommended to shift up agricultural production. There is a need to explore yield enhancing techniques as the production of food grains is stagnant for the last 7-8 years in the country. Keeping this in view, this study was undertaken. This study will be useful to Statisticians and

Agronomists for planning and designing of cultural cum manurial experiments with identification of optimum levels of cultural practices and fertilizers for various crops.

2. MATERIAL AND METHODS

Under the Project of Agricultural Field Experiments Information System, the experimental data relating to agricultural field experiments conducted at various research stations are being collected at IASRI. Depending upon the nature of treatments tried, experiments had been classified in various types such as Manurial (M), Cultural (C), Irrigational (I), Disease, pest & weed control measures (D) and their combinations with variety, irrigation and cultural practices etc. if any. From the total reported data (excluding purely varietal experiments) of 14000 experiments till June 2000, it was found that 927 of them were cultural cum manurial experiments. The percentage of designs adopted in these experiments for R.C.B., factorial R.C.B., split-plot and split-split-plot were 17.26, 43.15, 38.08 and 1.51 respectively. Among these experiments 377 experiments were rejected due to incomplete results and other information which were required for this project. Among remaining 550 experiments, 122 experiments have the R.C.B. and 428 experiments have the factorial structure of treatments in R.C.B. and split plot design.

For the purpose of present study, the data of cultural cum manurial experiments in Table 1(a), 1(b), 1(c) and 1(d) have been utilized. Four hundred twenty eight experiments had the factorial structure of treatments. In these experiments, one factor is cultural practice such as spacing, seed rates, dates of sowing, dates of harvesting, method of sowing or planting, method of ploughing etc. while the other factors are fertilizers. Plot-wise yield data were used. These experiments have been further analyzed for the study of presence of interactions between fertilizer and cultural practices, thereby suggesting to fit a suitable response surface and also to carry out the pooled analysis of cultural cum manurial trials conducted with same set of treatment factors over the years/locations for various crops.

Methodology for combined analysis of groups of experiments for which error variances were found homogeneous

To carry out the combined analysis, the groups of experiments were identified which were conducted at the same research station with same set of treatments for two or more than two years. After completing the analyses of individual experiments, homogeneity of their experimental error variances was tested for each group by Bartlet's test of homogeneity of variances. Combined analysis has been done for those groups of experiments where error variances were found homogeneous, as in the following.

Let us consider an experiment with two factors A and B with levels a and b respectively conducted in full factorial in R.C.B. and independently repeated over a period of p seasons. Let r be the number of replications of the experiment in each season. We assume that the seasons under study provide a representative sample of the entire population of seasons in the experimental area. The linear model for the yield y_{ijk} was considered as under

$$y_{ijk} = \mu + p_i + \alpha_j + \beta_k + (\alpha\beta)_{jk} + (p\alpha)_{ij} + (p\beta)_{ik} + (p\alpha\beta)_{ijk} + e_{ijk}$$
$$(i = 1,2,...p; j = 1,2,...a; k=1,2,...,b)$$

where α_j, β_k and $(\alpha\beta)_{jk}$ represent the effects of factors A, B and the interaction AB, $(p\alpha)_{ij}$, $(p\beta)_{ik}$ and $(p\alpha\beta)_{ijk}$ represent the effect of interaction of factors A, B and AB with years and e_{ijk} is the experimental error averaged over r replications of the respective season.

Response Surface Models (Combined over all the seasons)

In agricultural field experiments a response is thought to be affected by a number of quantitative input factors like N, P_2O_5, K_2O, cultural practices, irrigation etc. Suppose an experimental programme is undertaken so as to determine the level at which each of these factors must be set in order to optimize the response in some sense. To achieve this we postulate that the response is a function of input variables i.e.

$$y_u = \phi (x_{1u}, x_{2u}, ...x_{ku}) + e_u$$

where u = 1,2..., N represents the N observations and x_{iu} is the level of the ith factor in the uth observation. The function ϕ describes the form in which the response and the input variables are related and e_u is the experimental error associated with the uth observation. A knowledge of function ϕ gives a complete summary of the results of the experiment and also enables us to predict the response for values of the x_{iu} that are not included in the experiment. If the function ϕ is known then using the method of calculus, one may obtain the

Table 1(a). Crop-wise distribution of factorial experiments showing the number in which various cultural practices used

Crops (Cereals)	Total no. of all types of experiments	No. of experiments conducted with RCB	No. of experiments conducted as factorial experiments	Factorial experiments showing the number in which various cultural practices used							
				Date of sowing	Spacing	Seed rate	Harvesting times	Method of sowing	Time of application of fertilizer	Mulching	Others
Paddy	70	21	49	6	19	8	-	16	6	-	-
Wheat	80	32	48	1	6	19	-	15	2	-	-
Bajra	26	9	17	-	-	1	-	4	-	-	11
Maize	14	3	11	-	1	-	-	-	-	2	8
Sorghum	29	3	26	-	10	4	-	5	1	-	16
Barley	3	3	-	-	-	-	-	-	-	-	-
Total	222	71	151	7	36	32	-	40	9	2	25

Table 1(b). Crop-wise distribution of factorial experiments showing the number in which various cultural practices used

Crops (Pulses)	Total no. of all types of experiments	No. of experiments conducted with RCB	No. of experiments conducted as factorial experiments	Factorial experiments showing the number in which various cultural practices used							
				Date of sowing	Spacing	Seed rate	Harvesting times	Method of sowing	Time of application of fertilizer	Mulching	Others
Gram	21	6	15	1	2	5	-	-	-	-	7
Greengram	17	5	12	-	1	-	-	-	-	-	11
Blackgram	24	12	12	-	2	-	-	1	-	2	7
Pigeonpea	12	-	12	-	-	-	-	-	-	2	10
Pea	9	-	9	-	4	-	-	-	-	-	5
Rajma	2	-	2	-	2	-	-	-	-	-	-
Total	85	23	62	1	11	5	-	1	-	4	40

Table 1(c). Crop-wise distribution of factorial experiments showing the number in which various cultural practices used

Crops (Oilseeds)	Total no. of all types of experiments	No. of experiments conducted with RCB	No. of experiments conducted as factorial experiments	Factorial experiments showing the number in which various cultural practices used							
				Date of sowing	Spacing	Seed rate	Harvesting times	Method of sowing	Time of application of fertilizer	Mulching	Others
Soybean	26	12	14	3	7	-	-	-	-	-	4
Sesamum	11	-	11	1	11	-	-	-	-	-	-
Sunflower	10	-	10	3	5	-	-	-	-	-	2
Safflower	7	-	7	4	1	-	-	-	-	2	-
Linseed	1	-	1	1	-	-	-	-	-	-	-
Nagli	4	-	4	-	3	-	-	1	-	-	-
Rai	3	2	1	-	-	-	-	1	-	-	-
Mustard	22	2	20	2	10	-	-	-	-	3	5
Toria	3	-	3	1	2	-	-	-	-	-	-
Niger	6	-	6	6	-	-	-	-	-	-	-
G.Nut	16	5	11	-	4	-	-	-	-	-	6
Total	109	21	88	21	43	-	-	2	-	5	17

Table1(d). Crop-wise distribution of factorial experiments showing the number in which various cultural practices used

Crops (Cash Crops)	Total no. of all types of experiments	No. of experiments conducted with RCB	No. of experiments conducted as factorial experiments	Factorial experiments showing the number in which various cultural practices used							
				Date of sowing	Spacing	Seed rate	Mulching	Harvesting times	Method of sowing	Time of application of fertilizer	Others
Cotton	20	-	20	-	16	-	-	-	4	-	-
S.Cane	48	7	41	2	4	6	1	22	-	-	6
Tobacco	20	-	20	4	12	-	-	-	-	4	-
Total	88	7	81	6	32	6	1	22	4	4	6
Vegetables	46	-	46	3	38	1	-	-	3	-	1
G. Total	550	122	428	38	160	44	12	22	50	13	89

values of $x_1, x_2, \ldots, x_k$ which give the optimum response. In practice mathematical form of ø is not known; we, therefore, often approximate it, within the experimental region, by a polynomial of suitable degree in variables x_{iu}. The adequacy of the fitted polynomial is tested through the usual analysis of variance. If the above function ø is of degree one in x_{iu}'s, i.e.

$$y_u = \beta_o + \beta_1 x_{1u} + \beta_2 x_{2u} + \ldots + \beta_k x_{ku} + e_u$$

We call it a first-order response model in $x_1, x_2 \ldots x_k$. If above function takes the form

$$y_u = \beta_0 + \sum_{i=1}^{k} \beta_i x_{iu} + \sum_{i=1}^{k} \beta_{ii} x_{iu}^2 + \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} \beta_{ij} x_{iu} x_{ju} + e_u$$

We call it a second-order (quadratic) response surface. In the linear function, the optimum of the response exists at the boundary values of the input factors, while in the second order response surfaces, the optimum values could be found inside the range of the input factors. Henceforth, we shall concentrate on the second order response surface which has been extensively used in agricultural experiments.

An attempt is made to fit suitable response surface model to obtain the optimum level of cultural practices as well as fertilizer for various crops. For this purpose three types of models were fitted for the cultural cum manurial experiments. These models are given as

(i) $y = a + bx + cx^2 + dz + e$

(ii) $y = a + bx + cz + dx^2 + ez^2 + fxz + e$

(iii) $y = a + bx + cz + dx^2 + fxz + e$

where y is observed yield and x and z are the inputs for fertilizer and cultural practices respectively. Only those cultural practices were involved in the model which are of quantitative nature e.g. mulches, seed rates, spacing, duration of crops (times of harvesting) etc. The output-input relationship was established by fitting a suitable response surface model to the yield data. The response surface model was found to be good fitted model on the basis of coefficient of determination (R^2) and root mean square error (S.E.).

3. RESULTS AND DISCUSSION

The analysis of individual experiments revealed that there was nearly equal number of experiments in which the main effects of cultural practices and fertilizer application were significant. In cereals, pulses, cotton, sugarcane and oilseeds, the number of experiments was 3-20% more wherein main effects of fertilizer application gave significant results than the cultural practices. But for vegetable crops the number of experiments were (10-20%) higher than the fertilizer application where main effects of cultural practices gave significant results. Interaction effects of cultural practices × fertilizer were observed to be significant in 47% of the experiments conducted on sugarcane and vegetable crops, 27% of experiments on cereals, 20% of experiments on pulses and cotton and 18% of experiments on oilseeds. By Combined Analysis for groups of experiments, it was observed that interaction effects of cultural practices × fertilizer application of NPK alone or in combination were significant in 20% of groups of experiments. Almost in all the groups of experiment, fertilizer application has significant effect whereas in 70% of groups of experiments, cultural practices have significant effects on crop production.

Cultural practices play very significant role in improving the crop production. On the basis of coefficient of determination (R^2) and root mean square error (S.E.) Complete Quadratic Response Surface model was found to be good fitted model for cultural cum manurial experiments when cultural practices are quantitative in nature. For getting optimum yield of various crops, optimum level of fertilizers and cultural practices should be used (Table 2). It was also observed that change in the levels of cultural treatment brings in the change in the doses of fertilizer (Table 3). It means doses of fertilizer for the particular crop change as per various levels of cultural treatment. Responses of fertilizer also change as per various levels of cultural treatment.

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Table 2. The best fitted response surface for factorial experiments based on coefficient of determination (R^2) and root mean square error (S.E.).

1. State: Andhra Pradesh; Crop: Sugarcane-C0.7706

Model II — Value of R^2: 0.9882; S.E.: 27.13

$$Y = -7327.3905 + 2.8636K + 1275.500D - 0.008K^2 - 48.900D^2 - 0.0700KD$$
$$(725.7649) \quad (0.9182) \quad (104.2689) \quad (0.0017) \quad (3.7144) \quad (0.0606)$$

Optimum level of K_2O (K) = 119.73 kg/ha
Optimum level date of harvesting (D) = 12.96 months after transplanting
Predicted yield at optimum points = 1106.87 Q/h

2. State: Bihar; Crop: Sugarcane B.0.91

Model II — Value of R^2: 0.9757; S.E.: 13.59

$$Y = -32909.38 + 0.8037K + 715.4300D - 0.0073K^2 - 33.0500D^2 + 0.1074KD$$
$$(401.7402) \quad (0.4672) \quad (70.0407) \quad (0.0007) \quad (3.0383) \quad (0.0384)$$

Optimum level of date of harvesting (D) = 11.04 months after transplanting
Optimum level of K_2O (K) = 135.89 kg/ha
Predicted yield at optimum point = 795.92 Q/ha

3. State: Karnataka; Crop: Tobacco-FCH6005

Model II — Value of R^2: 0.9105; S.E.: 38.76

$$Y = 1165.1111 - 32.4500M + 41.3167S + 0.6583M^2 - 0.3417S^2 - 0.2900MS$$
$$(884.3456) \quad (24.0242) \quad (28.5269) \quad (0.2741) \quad (0.2741) \quad (0.1938)$$

Optimum level of Manure(M) = 34.72 kg/ha of N with (2.1/2) times dose of P_2O_5 and K_2O
Optimum level of spacing(S) = 45.73 cm.
Predicted yield at optimum points = 1548.51 Kg/ha

4. State: Maharashtra; Crop: Sorghum-M-35-1

Model II — Value of R^2: 0.9198; S.E.: 71.76

$$Y = 308.7333 + 11.3627N + 86.0563M - 0.1536N^2 - 7.2000M^2 + 0.7498NM$$
$$(53.7994) \quad (3.7264) \quad (23.7139) \quad (0.0647) \quad (2.8705) \quad (0.3472)$$

Optimum level of Nitrogen(N) = 59.08 kg/ha
Optimum level of crop residue (M) = 9.05 tonns/ha
Predicted yield at optimum points = 1033.90 kg/ha

5. State: Maharashtra; Crop: Sugarcane CO.7527

Model II — Value of R^2: 0.8594; S.E.: 50.01

$$Y = 244.4097 + 3.3038K + 129.3870H - 0.0087K^2 - 4.6775H^2 - 0.0179KH$$
$$(472.7385) \quad (1.0753) \quad (73.2074) \quad (0.0027) \quad (2.7959) \quad (0.0707)$$

Optimum level of K_2O (K) = 175.89 kg/ha
Optimum level of time of harvesting (H) = 13.49 months after transplanting
Predicted yield at optimum points = 1407.9 Q/ha

6. State: Maharashtra; Crop: Wheat-HD 2189

Model II — **Value of R^2**: 0.8994 — **S.E.**: 115.58

$Y = 300.1833 + 33.6687F + 11.3587S - 0.0950F^2 - 0.02935S^2 - 0.0275FS$
(1300.3161)(11.7902) (15.3679) (0.0442) (0.0534) (0.0365)

Optimum level of fertilizer (F) = 160.0388 Kg/ha of N with half doses of P_2O_5 and K_2O
Optimum level of seed rate(S) = 118.5954 kg/ha
Predicted yield at optimum points = 3667.88 kg/ha

7. State: Maharashtra; Crop: Tobacco S-20

Model II — **Value of R^2**: 0.9078 — **S.E.**: 77.51

$Y = 201.3975 + 2.4080N + 34.2265S - 0.0364N^2 - 0.3135S^2 + 0.0139NS$
(485.8950) (4.9351) (14.8670) (0.0559) (0.1074) (0.0535)

Optimum level of Nitrogen (N) = 55.54 kg/ha
Optimum level of spacing (S) = 43.625cm.
Predicted yield at optimum points = 1204.52 kg/ha

8. State: Maharashtra; Crop: Nagli-B-11

Model I — **Value of R^2**: 0.9738 — **S.E.**: 58.98

$Y = 1107.4083 + 19.2847N - 10.2460R - 0.1327N^2$
(62.0915) (2.1320) (1.6572) (0.0272)

Optimum level of Nitrogen (N) = 72.68 kg/ha
Predicted yield at optimum points = 1483.76 kg/ha

9. State: U.P.; Crop: Sugarcane Co S-767

Model I — **Value of R^2**: 0.8788 — **S.E.**: 28.32

$Y = 499.8571 + 1.9750K - 1.3500H - 0.0056K^2$
(55.8986) (0.3646) (4.4782) (0.0017)

Optimum level of K_2O (K) = 177.55 kg/ha
Predicted yield at optimum points = 691.39 Q/ha

10. State: U.P.; Crop: Mustard Varuna

Model II — **Value of R^2**: 0.9420 — **S.E.**: 132.32

$Y = -137.0092 + 15.9384N + 9.5638R - 0.0540N^2 - 0.0453R^2 - 0.0210NR$
(718.7838) (3.4673) 19.6975) (0.0153) (0.1296) (0.0335)

Optimum level of N = 133.11 kg/ha
Optimum level of row spacings (S) = 74.7cm.
Predicted yield at optimum points = 1280.96 kg/ha

11. State: U.P.; Crop: Soyabean-Gaurav

Model II — **Value of R^2**: 0.6478 — **S.E.**: 150.62

$Y = -1550.8458 + 26.0523N + 113.9581R - 0.2412N^2 - 1.0262R^2 - 0.1731RN$
(2282.9689) (16.3830) (92.6000) (0.1674) (0.9223) (0.9233)

Optimum level of N = 35.14 kg/ha
Optimum level of row spacings (S) = 52.56cm.
Predicted yield at optimum points = 1901.54 kg/ha

12. State: U.P.; Crop: Mustard R.K.148

Model II

Value of R^2: 0.9975 **S.E.**: 22.80

$$Y = -196.0000 + 18.9667N + 24.3222R - 0.1284N^2 - 0.2644R^2 - 0.0187RN$$
$$(142.5372)\ (0.9617)\ (0.5463)\ (0.0064)\ (0.0719)\ (0.0152)$$

Optimum level of N = 70.69 kg/ha
Optimum level of row spacings (S) = 43.49.cm.
Predicted yield at optimum points = 100.35 kg/ha

13. State: Maharahstra; Crop: Sorghum-SN-504

Model II

Value of R^2: 0.7056 **S.E.**: 187.48

$$Y = 1436.8750 + 15.8700N + 7.1083P - 0.1308N^2 - 0.03790P^2 + 0.0127NP$$
$$(306.6284)\ (6.9645)\ (6.1155)\ (0.7500)\ (0.0293)\ (0.0375)$$

Optimum level of Nitrogen (N) = 65.78kg/ha
Optimum level of plant population (P) = 104.88 thousands plants/ha
Predicted yield at optimum levels = 2331.60 kg/ha

14. State: Maharahstra; Crop: Sorghum SPV-504

Model II

Value of R^2: 0.8936 **S.E.**: 106.81

$$Y = 1553.6250 + 15.7500N + 10.4693P - 0.1424N^2 - 0.0324P^2 - 0.0019NP$$
$$(174.6951)\ (3.9679)\ (3.4842)\ (0.0427)\ (0.0167)\ (0.0214)$$

Optimum level of Nitrogen (N) = 54.23 kg/ha
Optimum level of plant population (P) = 159.87 thousands plants/ha
Predicted yield at optimum levels = 817.58 kg/ha

Note : Figures in the parenthesis indicate standard errors of respective coefficients.

Table 3. Optimum dose of fertilizer and corresponding yield of various crops at various levels of cultural practices by using quadratic response surface

S.No.	State/Name of Research Station	Crop/Variety/ Season	Name and levels of cultural practices	Optimum level of fertilizer (kg/ha)	Yield
1.	Andhra Pradesh Agril. Res. Stn. Anakapalli	Sugarcane CO. 7706 Irrigated	Harvesting Time 12 months after planting 14 - do - 16 -do- 12.96 -do- (optimum level)	 123.4 kg/ha K_2O 114.8 kg/ha K_2O 106.3 kg/ha K_2O 119.7 kg/ha K_2O	 1061.90Q/ha 1053.38 Q/ha 654.91Q/ha 1106.87Q/ha
2.	Bihar S. Cane Res. Instt., Pusa Smastipur	Sugarcane BO.91 Irrigated	10 -do- 11 -do- 12 -do- 13 -do- 11.04 -do- (Optimum level)	128.6 kg/ha K_2O 135.9 kg/ha K_2O 143.3 kg/ha K_2O 150.6 kg/ha K_2O 135.9 kg/ha K_2O	760.67Q/ha 795.90Q/ha 766.53Q/ha 671.50Q/ha 795.9Q/ha
3.	Karnataka Tobacco Res. Stn. Hunsur	Tobacco FCH-6005 Kharif	Spacing 40 cm. 50 cm. 60 cm. 45.73 cm. (Optimum level)	 33.5 kg/ha N 35.7 kg/ha N 37.9 kg/ha N 34.7 kg/ha N Note-Two half times dose of P_2O_5 and K_2O was given with nitrogen	 1534.26 kg/ha 1539.60 kg/ha 1470.26 kg/ha 1548.51 kg/ha
4.	Maharashtra Regional S.Cane Res. Stn. Kolhapur	Sugarcane Irrigated	Harvesting dates 10 months after planting 12 -do- 14 -do- 16 -do- 13.49(Optimum level)	 179.5 kg/ha K_2O 177.5 kg/ha K_2O 173.5 kg/ha K_2O 171.4 kg/ha K_2O	 1350.23 Q/ha 1397.57 Q/ha 1406.74 Q/ha 1378.60 Q/ha 1408.00 Q/ha
5.	Dry Farming Res. Stn. Sholapur	Sorghum M.35-1 Kharif Rainfed	Quantity of residue used for mulching 0 tons/ha 2.5 -do- 5.0 -do- 7.5 -do- 9.05 -do- (Optimum level)	 36.98 kg/ha N 43.08 kg/ha N 49.19 kg/ha N 55.29 kg/ha N 59.08 kg/ha N	 518.87 kg/ha 809.52 kg/ha 930.70 kg/ha 1018.77 kg/ha 1033.90 kg/ha
6.	College of Agril. Kolhapur	Wheat HD 2189 Rabi Irrigated	Seed rates 100 kg/ha 125 kg/ha 150 kg/ha 175 kg/ha 118.60 kg/ha	 162.73 kg/ha N 159.11 kg/ha N 155.49 kg/ha N 150.87 kg/ha N Note-Half times dose of P_2O_5 and K_2O was given with nitrogen	 3658.75 kg/ha 3666.00 kg/ha 3641.67 kg/ha 3581.91 kg/ha 3667.88 kg/ha

7.	Agril. Res. Stn. Digraj (Sangli)	Tobacco S-20 Kharif Irrigated	Spacing 45 cm. 60 cm. 90 cm. 43.62 cm. (Optimum level)	41.66 kg/ha N 44.53 kg/ha N 50.26 kg/ha N 55.54 kg/ha N	1178.16 kg/ha 1200.00 kg/ha 864.61 kg/ha 1204.52 kg/ha
8.	Maharashtra Mahatama Phule Agril. Univ. Rahuri	Sorghum 'SPV.504 Kharif Rainfed	Plant Population 40 thousand plants/ha 80 -do- 120 -do- 160 -do- 104.88 -do- (Optimum level)	62.6 kg/ha N 64.5 kg/ha N 66.4 kg/ha N 68.4 kg/ha N 65.78 kg/ha N	2173.13 kg/ha 2308.17 kg/ha 2313.39 kg/ha 2216.56 kg/ha 2331.60 kg/ha
9.	-do-	-do-	Plant Population 40 thousand plants/ha 80 -do- 120 -do- 160 -do- 159.87 -do- (Optimum level)	55.03 kg/ha N 54.77 kg/ha N 54.50 kg/ha N 54.23 kg/ha N 54.23 kg/ha N	2359.58 kg/ha 2620.30 kg/ha 2774.41 kg/ha 2817.58 kg/ha 2817.58 kg/ha
10.	U.P. Allahabad Agril. Instt. Allahabad	Mustard Varuna Rabi Irrigated	Row spacings 50 cm. 75 cm. 100 cm. 74.7 cm. (Optimum level)	137.80 kg/ha N 132.99 kg/ha N 128.10 kg/ha N 133.11 kg/ha N	1254.95 kg/ha 1280.00 kg/ha 1256.00 kg/ha 1280.96 kg/ha
11.	-do-	Soybean Gaurav Kharif Irrigated	Row spacings 40 cm. 50 cm. 60 cm. 52.56 cm. (Optimum level)	39.65 kg/ha N 36.06 kg/ha N 32.48 kg/ha N 35.14 kg/ha N	1740.75 kg/ha 1887.52 kg/ha 1834.53 kg/ha 1901.54 kg/ha
12.	-do-	Mustard R.K. 148 Rabi Unirrigated	Row spacings 30 cm. 45 cm. 60 cm. 43.5 cm. (Optimum level	71.67 kg/ha N 70.58 kg/ha N 69.49 kg/ha N 70.69 kg/ha N	954.40 kg/ha 1000.00 kg/ha 937.88 kg/ha 1003.35 kg/ha