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Optimization of organic and inorganic nitrogen for rainfed maize (*Zea mays*) in dry sub-humid Inceptisols

VIKAS ABROL, G.R. MARUTHI SANKAR*, PEEYUSH SHARMA AND MAHINDER SINGH

All India Co-ordinated Research Project for Dryland Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology, Rakh Dhiansar, Jammu 180 012

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ABSTRACT

A field experiment on maize (*Zea mays* L.) was conducted in rainy season (*kharif*) during 1998 to 2005 with a set of nine fertilizer treatments in separate blocks of maize, blackgram and maize + blackgram under dry sub-humid inceptisols of Jammu. An attempt was made to select an efficient treatment that has maximum sustainability over years, apart from optimizing organic and inorganic fertilizer N for different crop-seasonal rainfall situations to attain maximum maize yield. The analysis of variance indicated that treatments differed significantly from each other every year and also pooled over years. Treatment-wise regression models of yield were calibrated as a function of crop-seasonal rainfall and crop-growing period to assess the sustainability of treatments. Application of N @ 60 kg/ha proved superior in maize and maize + blackgram blocks, whereas 15 kg N (*Leucaena*) + 20 kg N (urea) was superior in blackgram block. A pooled regression model of yield as a function of rainfall, crop-growing period and fertilizer N was used to derive optimum fertilizer N at different rainfall situations. The inorganic and organic N ranged from 44 to 57 kg/ha and 23 to 27 kg/ha respectively at 700 mm rainfall, and from 56 to 73 kg/ha and 27 to 31 kg/ha respectively at 1,100 mm rainfall for attaining maximum maize yield in different blocks. The corresponding doses of inorganic and organic N ranged from 39 to 49 kg/ha and 18 to 22 kg/ha at 700 mm compared with 51 to 65 kg/ha and 22 to 26 kg/ha at 1,100 mm for attaining economic yield of maize.

Key words: Crop seasonal rainfall, Optimization, Regression, Sustainable yield index

Maize (*Zea mays* L.) is an important cereal grown under rainfed conditions in semi-arid alfisols of Andhra Pradesh and Karnataka, semi-arid vertisols of Madhya Pradesh, Maharastra and Rajasthan; dry sub-humid Inceptisols of Uttar Pradesh, Punjab and Jammu region; and moist sub-humid alfisols of Orissa and Jharkand states. The crop has less water requirement and is grown in shallow to medium soils having low water-holding capacity. It is grown as an intercrop with pulses and oilseeds in different regions of the country. Among different variables, the quantity of rainfall and its distribution during the crop-growing period significantly influences the crop yield under dryland conditions. Stability of different maize genotypes under semi-arid alfisols of Andhra Pradesh was examined by Reddy *et al.* (1998). The productivity of crops in Jammu region has been affected due to decline in production and recycling of organic matter. The long-term experiments have established that neither chemical fertilizers alone nor the organic sources exclusively can achieve sustainability of crop production (Singh and Biswas, 2000). Permanent manurial trials on different crops are conducted under All India Coordinated Research Project for Dryland Agriculture to identify a suitable combination of organic and inorganic sources of N fertilizer. The organic source would provide sustainable crop yield, apart from reducing the input cost and improving the soil health over the years. Sankar and Reddy (2000) and Sankar *et al.* (2002) assessed the performance of different input variables, apart from stability of genotypes, over years in a semi-arid alfisol. An efficient combination of organic and inorganic fertilizer with maximum sustainability could be identified based on a statistical model of treatment effects on yield (Vittal *et al.*, 2003; Sankar and Reddy, 2005). The model could also be used for deriving optimum fertilizer N for different crop-seasonal rainfall situations (Draper and Smith, 1998).

MATERIALS AND METHODS

A field experiment was conducted in three blocks of maize 'Kanchan Hybrid–517', blackgram 'Pant U-19' and

***Corresponding author** (Email: gmsankar@crida.ernet.in)

Present address: [1]Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad 500 059, Andhra Pradesh

maize + blackgram with nine fertilizer N treatments during rainy season (*kharif*) (July to October) 1998 to 2005 in a dry subhumid inceptisol at Rakh Dhiansar in Jammu. The experiment was conducted in a permanent site at the research station located at latitude 32^0 39' North, longitude 74^0 53' East and altitude 332 m above mean sea-level. The study was conducted to identify a superior fertilizer treatment for attaining sustainable maize yield over the years. The soil was sandy loam with pH of 6.5, organic C 0.25%, available soil N 170 kg/ha, soil P 12.8 kg/ha and soil K 130 kg/ha. The annual rainfall ranged from 741 mm in 2005 to 1,259 mm in 2003, with a mean of 1,008 mm and variation of 15.8%. Compared with the annual rainfall, the crop-seasonal rainfall ranged from 719 mm in 2002 to 998 mm in 2003, with a mean of 778 mm and variation of 16.1% during 8 years. Jammu has monsoon climate with 80 to 85% rainfall occurring between June and September. The earliest date of sowing maize was 20 June in 2001, and the farthest was 9 July in 2003; and the earliest date of harvesting maize was 17 September in 2001, and the farthest was on 11 October in 2004. In blackgram the earliest date of sowing was 20 June in 2001, and the farthest was 10 July in 2003. The earliest date of harvest was 26 September in 2001, and the farthest was on 22 October in 1999. The crop-growing period ranged from 76 (2005) to 96 days (2004), with a mean of 89 days and variation of 6.7% for maize compared with 88 (1998) to 109 days (1999), with a mean of 98 days and variation of 7.2% for blackgram. The annual rainfall, crop-seasonal rainfall, dates of sowing and harvest and the crop-growing period (CGP) are given in Table 1.

The field was divided into three blocks for maize, maize + blackgram and blackgram, and each block was further divided into nine plots for superimposing the fertilizer treatments for maize. The treatments were randomized and superimposed to plots in each block in randomized block design with three replications. The recommended practices of row x plant spacing of 60 x 30 cm and 30 x 15 cm and seed rate of 20 and 15 kg/ha were adopted for maize and blackgram respectively. The treatments superimposed for maize were: T_1, control; T_2, 60 kg N/ha; T_3, 30 kg N/ha; T_4, 25 kg N/ha (compost); T_5, 15 kg N (compost) + 10 kg N/ha (urea); T_6, 15 kg N (compost) + 20 kg N/ha (urea); T_7, 15 kg N (*Leucaena*) + 10 kg N/ha (urea); T_8 15 kg N (*Leucaena*) + 20 kg N/ha (urea); and T_9, 15 kg N (compost) + 10 kg N/ha (*Leucaena*). A uniform P dose of 30 kg/ha was applied to blackgram in all plots. Compost with 0.36% N content was applied in treatments 3 weeks before sowing and green leaves (*Leucaena*) with 3.4% N content at the time of sowing. Nitrogen 50% through urea as per treatment and P 100% were applied at sowing, and the remaining N was top-dressed at knee-high and before tasselling stages. Observations were recorded on grain yield at harvest of the crops. The yield of blackgram was converted to maize-equivalent yield on price basis for comparing the effect of treatments.

The effects of fertilizer treatment on yield could be tested based on analysis of variance (Gomez and Gomez, 1985). The treatment-wise regression models of yield could be calibrated as a function of crop-seasonal rainfall (CRF) and crop-growing period (CGP) for each block. The regression model of yield can be given as:

$$Y = \alpha \pm \beta_1 (CRF) \pm \beta_2 (CRF^2) \pm \beta_3 (CGP) \pm \beta_4 (CGP^2) \quad ... (1)$$

In (1), α is intercept and β_1 to β_4 are regression coefficients of effects of variables on yield. Using mean yield of a treatment 'i' ($\hat{A}_i$) over years, prediction error (Φ_i) based on regression model, and maximum yield (Y_{max}) attained in the study, the sustainable yield index 'η' of treatment 'i' can be given as :

Table 1. Dates of sowing and harvest of maize and rainfall received in different years

Year	ARF (mm)	CRF (mm)	CRF (%)	Date of sowing	Date of harvest	CGP
1998	1,140	746	65.5	8-7-98 (8-7-98)	3-10-98 (3-10-98)	88 (88)
1999	875	762	87.1	6-7-99 (6-7-99)	4-10-99 (22-10-99)	91 (109)
2000	1,061	817	77.0	2-7-00 (2-7-00)	27-9-00 (14-10-00)	88 (105)
2001	948	846	89.2	20-6-01 (20-6-01)	17-9-01 (26-9-01)	90 (99)
2002	986	719	72.9	4-7-02 (6-7-02)	4-10-02 (11-10-02)	93 (98)
2003	1,259	998	79.2	9-7-03 (10-7-03)	8-10-03 (19-10-03)	92 (102)
2004	1,055	781	74.0	8-7-04 (8-7-04)	11-10-04 (8-10-04)	96 (93)
2005	741	554	74.8	8-7-05 (8-7-05)	21-9-05 (7-10-05)	76 (92)
Mean	1,008	778	77.5		89 (98)	
CV(%)	15.8	16.1	10.0		6.7 (7.2)	

Date of sowing and harvest of blackgram are given in parentheses
CV=coefficient of variation (%)
ARF=Annual rainfall; CRF=crop seasonal rainfall; CGP=crop growing period

$$h_i = [(\hat{A}_i - \Phi_i) / (Y_{max})] * 100 \quad \ldots\ldots\ldots (2)$$

The rank sum of each treatment is derived by assigning the ranks to mean yield, coefficient of determination (R^2), prediction error (Φ) and sustainable yield index (η). Based on rank sum, the treatment with the lowest rank sum could be identified for attaining sustainable yield. A pooled regression model of yield through linear and quadratic variables of crop-seasonal rainfall, crop-growing period, inorganic and organic N, and interaction of rainfall and fertilizer can be given as:

$$Y = \alpha \pm \beta_1 (CRF) \pm \beta_2 (CRF^2) \pm \beta_3 (CGP) \pm \beta_4 (CGP^2) \pm \beta_5 (FN) \pm \beta_6 (FN^2) \pm \beta_7 (ON) \pm \beta_8 (ON^2) \pm \beta_9 (FN)(CRF) \pm \beta_{10} (ON)(CRF) \quad \ldots\ldots (3)$$

In Equation 3, α is intercept and β_1 to β_{10} are regression coefficients measuring the effects of variables on yield. Based on the model, optimum fertilizer N could be derived for attaining sustainable yield at different crop seasonal rainfall situations in a dry sub-humid inceptisol.

RESULTS AND DISCUSSION

Effect of fertilizer

Mean maize-equivalent yield along with coefficient of variation and increase in yield over the control in maize, blackgram and maize + blackgram blocks during eight years are given in Table 2. The F-test indicated that the treatments differed significantly for the yield attained in each block. The mean yield and yield increase were maximum in maize block, followed by maize + blackgram and blackgram blocks. In maize block, a minimum yield of 1.02 t/ha was attained in the control in 1998, whereas a maximum of 4.16 t/ha was attained with the application of 60 kg N/ha (urea) in 2000. The mean yield of a treatment ranged from 1.29 t/ha for the control with variation of 28.7% to 3.11 t/ha for 60 kg N/ha (urea) with variation of 23.4%. The increase in maize-equivalent yield over the control ranged from 33.4% for 25 kg N/ha (compost) to 58.3% for 60 kg N/ha (urea), ith a mean of 43.3% and variation of 19.8%. The next best was 15 kg N/ha (compost) + 20 kg N/ha (urea), with a mean yield of 2.52 kg/ha, variation of 22.7% and yield increase of 48.7% over the control.

In blackgram block, a minimum yield of 0.52 t/ha was attained with the application of 15 kg N (compost) + 20 kg N (urea) in 1998, whereas a maximum of 2.26 t/ha was attained with 15 kg N (compost) + 10 kg N (*Leucaena*) in 2000. The mean yield of a treatment over the years ranged from 0.89 t/ha for the control with variation of 38% to 1.39 t/ha for 15 kg N (*Leucaena*) + 20 kg N (urea) with variation of 35.2%. The increase in yield ranged from 22.7% for 30 kg N/ha (urea), to 35.8% for 15 kg N (*Leucaena*) + 20 kg N/ha (urea) with a mean of 31.5% and variation of 13.2%. Application of 15 kg N (*Leucaena*) + 20 kg N (urea) gave a maximum increase in maize-equivalent yield of 35.8% over the control, followed by that of 15 kg N (*Leucaena*) + 10 kg N (urea), with a mean yield of 1.30 t/ha, variation of 45.8% and increase in yield of 31.1% over the control.

In maize + blackgram block, a minimum yield of 0.66 t/ha was attained in the control in 1998, a maximum of 3.39 t/ha was attained by 15 kg N (*Leucaena*) + 20 kg N (urea) in 2001. The control gave a minimum mean yield of 1.03 kg/ha with variation of 40.1%, whereas 60 kg N/ha (urea) provided a maximum of 2.03 kg/ha with variation of 30.4% over the years. The yield increased by 24.9% for 15 kg N (compost) + 10 kg N/ha (*Leucaena*) to 49.3% for 60 kg N/ha (urea) with a mean of 32.6% and variation of 26.4%. The application of 60 kg N/ha (urea) gave a maximum yield increase of 49.3% over the control. It was followed by that of 15 kg N (*Leucaena*) + 20 kg N (urea), with a mean yield of 1.85 kg/ha, variation of 45.4% and yield increase of 44.5% over the control.

Regression models of yield

Treatment-wise regression models of maize-equivalent yield through crop-seasonal rainfall and crop-growing period were calibrated for assessing the effects of variables on yield attained in each block. The block-wise regression coefficients of variables and coefficient of determination (R^2) of each treatment are given in Table 3. The regression model of the control gave maximum predictability of 0.96, whereas the model of 30 kg N/ha (urea) gave a minimum of 0.39 in maize block. The models of both the control and 30 kg N/ha (urea) gave maximum predictability of 0.57, whereas that of 15 kg N (compost) + 20 kg N/ha (urea) gave minimum predictability of 0.33 in blackgram block. The model of 15 kg N (*Leucaena*) + 10 kg N/ha (urea) gave the maximum predictability of 0.79, whereas that of 25 kg N/ha (compost) gave minimum predictability of 0.52 in maize + blackgram block.

The linear and quadratic regression coefficients of crop-seasonal rainfall were significant in the model of 15 kg N (*Leucaena*) + 10 kg N/ha (urea) in maize block; and in those of 30 kg N/ha (urea), 15 kg N (compost) + 20 kg N/ha (urea), 15 kg N (*Leucaena*) + 10 kg N/ha (urea) and 15 kg N (*Leucaena*) + 20 kg N/ha (urea) in maize + blackgram block. In maize block, the prediction error ranged from 113 kg/ha for the control to 633 kg/ha for 30 kg N/ha (urea), whereas blackgram block, it ranged from 340 kg/ha for the control to 665 kg/ha for 25 kg N/ha (compost). In maize + blackgram block, it ranged from 314 kg/ha for 15 kg N (*Leucaena*) + 10 kg N/ha (urea) to 652 kg/ha for 15 kg N (*Leucaena*) + 20 kg N/ha (urea) based on the models.

Table 2. Treatment-wise regression models of maize-equivalent yield in different blocks

Treatment	Maize	Blackgram	Maize + blackgram
Control	Y = 28516 – 4.3 (CRF) + 0.01 (CRF^2) – 629.6 (CGP)+ 3.68 (CGP^2); R^2=0.96**	Y = –2391 + 18.63 (CRF) – 0.01 (CRF^2) – 90.22 (CGP) + 0.44 (CGP^2) ; R^2=0.57	Y = 2153 + 29.98 (CRF) – 0.02 (CRF^2) – 267.66 (CGP) + 1.24 (CGP^2); R^2=0.63
60 kg N/ha (urea)	Y = 437 + 30.65 (CRF) – 0.02 (CRF^2) – 207.7 (CGP) + 0.87 (CGP^2); R^2=0.74*	Y = 2030 + 2.74 (CRF) – 0.01 (CRF^2) – 85.67 (CGP) + 0.67 (CGP^2) ; R^2=0.50	Y = 20888 + 49.23 (CRF) – 0.03 (CRF^2) – 823.07 (CGP) + 4.12 (CGP^2); R^2=0.70*
30 kg N/ha (urea)	Y = –29100 – 10.58 (CRF) + 0.01 (CRF^2) + 761.47 (CGP) – 4.07 (CGP^2); R^2=0.39	Y = 25307 + 37.37 (CRF) – 0.02 (CRF^2) – 870.95 (CGP) + 4.69 (CGP^2); R^2=0.57	Y = 11796 + 52.99 * (CRF) – 0.03 * (CRF^2) – 637.87 (CGP) + 3.05 (CGP^2); R^2=0.70*
25 kg N/ha (compost)	Y = 14577 + 19.54 (CRF) – 0.01 (CRF^2) – 467.02 (CGP) + 2.51 (CGP^2); R^2=0.63	Y = 18898 + 40.75 (CRF) – 0.02 (CRF^2) – 741.35 (CGP) + 3.95 (CGP^2); R^2=0.36	Y = 8731 + 47.07 (CRF) – 0.03 (CRF^2) – 531.45 (CGP) + 2.52 (CGP^2); R^2=0.52
15 kg N (compost) + 10 kg N/ha (urea)	Y = 6934 + 27.72 (CRF) – 0.02 (CRF^2) – 348.81 (CGP) + 1.75 (CGP^2); R^2=0.69	Y = 30787 + 41.44 (CRF) – 0.02 (CRF^2) – 1025.86 (CGP) + 5.52 (CGP^2); R^2=0.53	Y = 19774 + 54.89 (CRF) – 0.03 (CRF^2) – 843.72 (CGP) + 4.19 (CGP^2); R^2=0.71*
15 kg N (compost) + 20 kg N/ha (urea)	Y = 1503 + 33.6 (CRF) – 0.02 (CRF^2) – 263.64 (CGP)+ 1.26 (CGP^2); R^2=0.58	Y = 15182 + 18.66 (CRF) – 0.01 (CRF^2) – 497.45 (CGP) + 2.79 (CGP^2); R^2=0.33	Y = 20112 + 59.57 * (CRF) – 0.03 * *(CRF^2) – 876.98 (CGP) + 4.34 (CGP^2); R^2=0.74*
15 kg N (*Leucaena*) + 10 kg N/ha (urea)	Y = 58884 + 40.4 * (CRF) – 0.02 * (CRF^2) – 1662.31 (CGP) + 9.22 (CGP^2); R^2=0.78*	Y = 28411 + 51.92 (CRF) – 0.03 (CRF^2) – 1052.91 (CGP) + 5.61 (CGP^2); R^2=0.53	Y = 13827 + 47.3 * (CRF) – 0.03 * (CRF^2) – 640.48 (CGP) + 3.09 (CGP^2) ; R^2=0.79*
15 kg N (*Leucaena*) + 20 kg N/ha (urea)	Y = 34342 + 36.3 (CRF) – 0.02 (CRF^2) – 1056.8 (CGP) + 5.79 (CGP^2); R^2=0.59	Y = –21214 – 19.98 (CRF) + 0.01 (CRF^2) + 617.33 (CGP) –3.02 (CGP^2); R^2=0.46	Y = 47829 + 98.63 * (CRF) – 0.06 * (CRF^2) – 1799.92 (CGP) + 9.1 (CGP^2); R^2=0.74*
15 kg N (compost) + 10 kg N/ha (*Leucaena*)	Y = 14070 + 22.85 (CRF) – 0.01 (CRF^2) –481.52 (CGP) + 2.49 (CGP^2); R^2=0.66	Y = 30841 + 47.68 (CRF) – 0.03 (CRF^2) – 1073.86 (CGP) + 5.72 (CGP^2); R^2=0.52	Y = 6876 + 44.65 (CRF) – 0.03 (CRF^2) – 473.34 (CGP) + 2.2 (CGP^2); R^2=0.67

*Significance at P=0.05, ** significance at P=0.01; R^2=Coefficient of determination

Sustainable yield index

Using the mean yield of a treatment, it was observed that the maximum yield of 4.16 t/ha was attained with 60 kg N/ha (urea) in maize 2.26 t/ha in blackgram and 3.39 t/ha in maize + blackgram block in 2000; and through prediction error based on regression model of the treatment, the sustainable yield index of treatments was found to range from 28.4% for the control to 61.2% for 60 kg N/ha (urea) in maize block; 24.5% for the control to 37.2% for 15 kg N (*Leucaena*) + 20 kg N/ha (urea) in blackgram block; and 19% for control to 44.6% for 60 kg N/ha (urea) in maize + blackgram block (Table 2).

Based on the ranks assigned to mean yield, prediction error, coefficient of determination and sustainable yield index of treatments, 60 kg N/ha (urea) was found efficient with lowest rank sum of 40, followed by 15 kg N (*Leucaena*) + 10 kg N/ha (urea) with 41 under all the 3 blocks. Application of 60 kg N/ha (urea) was found superior for attaining maximum mean yield and sustainable yield index in both maize and maize + blackgram blocks, whereas it was the second best for prediction error and sustainable yield index in blackgram block. Application of 25 kg N/ha (compost) was the least preferred treatment, with maximum rank sum of 81 based on the study.

Optimization of fertilizer N

The pooled regression model of maize-equivalent yield attained by treatments was calibrated through linear and quadratic variables of crop-seasonal rainfall, crop-growing period, inorganic and organic fertilizer N along with interaction of fertilizer, and the crop-seasonal rainfall was calibrated for each block. The regression model of yield in maize block had a maximum and significant predictability of 0.76 with a prediction error of 362 kg/ha, followed by that of 0.69 with an error of 360 kg/ha in maize + blackgram block and 0.42 with an error of 391 kg/ha in blackgram block. The linear and quadratic coefficients of crop-seasonal rainfall and linear coefficient of inorganic and organic fertilizer N had a significant effect on maize-equivalent yield in all the three blocks. Using pooled regression models, the inorganic and organic N fertilizer-adjustment equations were derived for attaining the maximum and economic yield of maize. The estimates of regression coefficients, coefficient of determination, prediction error and fertilizer-adjustment equations of organic and inorganic N are given in Table 4. Using the fertilizer-adjustment equations, optimum organic and inorganic fertilizer N doses were derived for attaining the maximum and economic maize yield at different crop-seasonal rainfalls (Table 5). The optimum inorganic N was maximum in blackgram block and minimum in maize block, whereas organic N was maximum in blackgram block and minimum in maize + blackgram block for maximum yield. However, organic N was maximum in maize block and minimum in maize + blackgram block for economic yield. At a rainfall of 700 mm, optimum inorganic N for maximum yield ranged from 44 to 57 kg/ha, whereas organic N ranged from 23 to 27 kg/ha. At 900 mm the inorganic N ranged from 50 to 65 kg/ha, whereas organic N ranged from 25 to 29 kg/ha. At 1,100 mm the inorganic N ranged from 56 to 73 kg/ha, whereas organic N ranged from 27 to 31 kg/ha based on the study. Similarly, at a rainfall of 700

Table 3. Mean yield, coefficient of variation, yield increase over the control, prediction error and sustainable yield index of treatments in different blocks

Statistic	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Maize									
Mean yield (t/ha)	1.29	3.11	2.19	1.94	2.07	2.52	2.05	2.48	1.20
CV (%)	28.7	23.4	24.1	20.5	22.7	22.7	20.2	23.6	29.5
Increase (%)		58.3	40.9	33.4	37.5	48.7	36.8	47.9	35.3
Error (t/ha)	0.11	0.56	0.63	0.37	0.39	0.57	0.30	0.58	0.52
SYI (%)	28.4	61.2	37.4	37.9	40.2	47.1	42.1	45.8	35.5
Blackgram									
Mean yield (t/ha)	0.89	1.25	1.16	1.26	1.26	1.24	1.29	1.39	1.17
CV (%)	38.0	32.7	38.2	43.4	40.3	35.5	45.8	35.2	47.5
Increase (%)		28.6	22.7	28.8	29.0	28.0	31.1	35.8	23.3
Error (t/ha)	0.34	0.44	0.44	0.67	0.53	0.55	0.63	0.55	0.59
SYI	24.5	35.9	31.6	26.2	32.3	30.5	29.7	37.2	25.6
Maize + blackgram									
Mean yield (t/ha)	1.03	2.03	1.40	1.47	1.46	1.57	1.54	1.85	1.37
CV(%)	40.1	30.4	35.7	40.2	37.4	33.2	29.0	45.4	38.8
Increase (%)		49.3	26.6	30.2	29.5	34.7	33.4	44.5	24.9
Error (t/ha)	0.38	0.51	0.42	0.63	0.45	0.41	0.31	0.65	0.47
SYI (%)	19.0	44.6	29.0	24.9	29.8	34.4	36.2	35.3	26.5

Table 4. Pooled regression models of maize-equivalent yield in different blocks

Block	Multiple regression model	Error	Fertilizer equation
Maize	Y = 14182 + 20.95 * (CRF) – 0.01 * (CRF^2) – 483.99 (CGP) + 2.61 (CGP^2) + 7.78 * (FN) – 0.17 (FN^2) + 26.44 * (ON) – 0.69 (ON^2) + 0.01 (FN) (CRF) + 0.01 (ON) (CRF); R^2=0.76**	362	FN= 23 + 0.03 (CRF) – 2.94 (Z) ON= 19 + 0.01 (CRF)– 0.72 (Z)
Blackgram	Y = 13966 + 26.48 ** (CRF) – 0.02 ** (CRF^2) – 535.66 (CGP) + 2.93 (CGP^2) + 7.05 * (FN) – 0.12 (FN^2) + 17.78 * (ON) – 0.45 (ON^2) + 0.01 (FN) (CRF) + 0.01 (ON) (CRF); R^2=0.42**	391	FN= 29 + 0.04 (CRF) – 4.17 (Z) ON= 20 + 0.01 (CRF)– 1.11 (Z)
Maize + blackgram	Y = 16824 + 53.2 ** (CRF) – 0.03 ** (CRF^2) – 766.05 (CGP) + 3.76 (CGP^2) + 3.96 * (FN) – 0.11 (FN^2) + 17.62 * (ON) – 0.55 (ON^2) + 0.01 (FN) (CRF) + 0.01 (ON) (CRF); R^2=0.69**	360	FN= 18 + 0.05 (CRF) – 4.55 (Z) ON= 16 + 0.01 (CRF)– 0.91 (Z)

Y=Grain yield (kg/ha); FN; fertilizer N (kg/ha); CRF; crop-seasonal rainfall (mm); CGP; crop-growing period; ON; organic N (kg/ha); R^2=coefficient of determination; Z; ratio of cost of fertilizer (Rs/kg) and value of maize (Rs/kg); Cost of fertilizer N=Rs10.8/kg; cost of organic N=Rs 33.5/kg; value of maize=Rs 6/kg

Table 5. Optimum fertilizer N for maximum and economic yield of maize at Rakh Dhiansar

Crop-seasonal rainfall (mm)	Optimum fertilizer N (kg/ha) at different crop-seasonal rainfall					
	Maize		Blackgram		Maize + blackgram	
	FN	ON	FN	ON	FN	ON
			Maximum yield			
700	44	26	57	27	53	23
800	47	27	61	28	58	24
900	50	28	65	29	63	25
1,000	53	29	69	30	68	26
1,100	56	30	73	31	73	27
			Economic yield			
700	39	22	49	21	45	18
800	42	23	53	22	50	19
900	45	24	57	23	55	20
1,000	48	25	61	24	60	21
1,100	51	26	65	25	65	22

mm, optimum inorganic N ranged from 39 to 49 kg/ha, while organic N ranged from 23 to 27 kg/ha for attaining economic maize yield. At 900 mm the inorganic N ranged from 45 to 57 kg/ha, whereas organic N ranged from 20 to 24 kg/ha. At 1,100 mm the inorganic N ranged 51 to 65 kg/ha, whereas organic N ranged from 22 to 26 kg/ha based on the study.

This study has given scope for: (i) modelling the effects of crop seasonal rainfall and fertilizer N and their interaction on maize yield; (ii) identifying an efficient treatment for attaining maximum sustainable yield; and (iii) precisely optimizing the organic and inorganic fertilizer N at different crop seasonal rainfall in dry sub-humid inceptisol.

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