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Response of rainfed maize (*Zea mays*) to nitrogen management in mid hill acidic soils of Sikkim

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ABSTRACT

Two field experiments were conducted during 2005 and 2006 at Tadong, Sikkim to study the effect of nitrogen scheduling and integrated nutrient management on yield, nutrient uptake and economics of rainfed maize (*Zea mays* L.) under nine schedules of nitrogen application and 11 combinations of urea, farmyard manure (FYM) and *Azotobacter* seed inoculation for integrated nutrient management. Amongst the various schedules of N application ⅓ N side-band placement (SBP) at sowing + ⅓ N SBP 25 days after sowing + ⅓ N SBP 50 days after sowing recorded the highest grain yield (6.24 and 6.46 t/ha), NPK uptake (161.2 kg N/ha, 50.3 kg P/ha and 150.1 kg K/ha) and return/rupee investment (1.97). The yield increase was more pronounced with enhancement in proportion of N supply through urea from 40 to 80 kg N/ha and decrease in the quantity of farmyard manure from 20 to 10 t/ha. Integration of *Azotobacter* seed treatment + 10t FYM/ha + 40 kg N/ha 25 days after sowing + 40 kg N/ha 50 days after sowing was the best treatment with the highest grain yield (6.77 and 6.93 t/ha), NPK uptake (168.4 kg N/ha, 49.0 kg P/ha and 154.7 kg K/ha) and return/rupee investment (1.99). Integrated nutrient management resulted in higher residual soil nutrients.

Key words : Acidic soils, *Azotobacter*, Farmyard manure, Integrated nutrient management, Nitrogen scheduling

Nitrogen is one of the most important nutrients limiting maize production in the tropics. Nanjappa *et al.* (2001) reported that combined application of 50 or 75% recommended dose of fertilizer with 12 tonnes/ha FYM caused higher productivity of maize compared with the application of either only inorganic fertilizer or organic sources. Similarly, Rajeswari (2005) reported higher maize grain yield with the application of nitrogen through FYM along with urea as compared to sole application of urea and FYM, respectively. Ashok Kumar *et al.* (2005) recorded maximum yield of maize when 100% NPK was applied with FYM @ 10 tonnes/ha. Maize responded markedly to graded levels of FYM and showed spectacular response to integration of FYM and fertilizer (Brar *et al.,* 2001 and Karki *et al.,* 2005). Beneficial effects of application of NPK along with farmyard manure have been recorded on the productivity, N, P, and K uptake by the maize (Karki *et al.,* 2005) and available residual nutrient status of the soil (Sihag *et al.,* 2005). Farmers in Sikkim use their own variations with respect to nitrogen management in maize since similar reports on the effect of nitrogen management on maize or any integrated nutrient management recommendation is not available for Sikkim. Hence, this study was carried out to study the effect of nitrogen scheduling and integrated nutrient management on yield, nutrient uptake and economics of rainfed maize.

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MATERIALS AND METHODS

Two field experiments were simultaneously conducted on rainfed maize at ICAR Sikkim Research Farm, Tadong located at an altitude of 1400 m above mean sea level in the per-humid mid hill acidic soils during spring (pre-*kharif*) seasons of 2005 and 2006. The first experiment was laid out in a randomized block design with nine treatments: full N broadcast (B) at sowing (T_1), full N furrow applied at sowing (T_2), full N side-band placement (SBP) at 5 cm depth at sowing (T_3), ½ N broadcast at sowing + ½ N top-dressed 25 days after sowing (DAS) (T_4), ½ N furrow applied at sowing + ½ N furrow applied 25 DAS (T_5), ½ N SBP at sowing + ½ N SBP 25 DAS (T_6), ⅓ N broadcast at sowing + ⅓ N top-dressed 25 DAS + ⅓ N top-dressed 50 DAS (T_7), ⅓ N FA at sowing + ⅓ N FA 25DAS + ⅓ N FA 50 DAS (T_8), ⅓ N SBP at sowing + ⅓ N SBP 25 DAS + ⅓ N SBP 50 DAS (T_9) and no nitrogen (control) (T_{10}) in four replications.

The second experiment conducted simultaneously was also laid out in a randomized block design with 11 treatments 20 t FYM/ha, 10 t FYM/ha + 80 kg N/ha 25 DAS, 15 t FYM/ha + 60 kg N/ha 25 DAS, 20 t FYM/ha + 40 kg N/ha 25 DAS, 10 t FYM/ha + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS, 15 t FYM/ha + 30 kg N/ha 25 DAS + 30 kg N/ha 50 DAS, 20 t FYM/ha + 20 kg N/ha 25 DAS + 20 kg N/ha 50 DAS, *Azotobacter* seed inoculation (AST), AST + 40 kg N/ha 25 DAS, AST + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS, AST + FYM10t/ha + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS, and no nitrogen (control) and replicated four times. FYM contained 1.1%N, 0.4% P, and 0.8% K, 0.35% OC, and 18.2:1 C:N ratio.

In both experiments maize 'VL Sankul Makka 11' was sown at a spacing of 50cm x 25cm. Manual weeding was done in all plots till the grain filling stage. The clay loam soils had pH 5.3, organic carbon 2.04%, available N (alkaline $KMnO_4$) 224.2 kg/ha, available P_2O_5 (Brays' P) 29.3 kg/ha, available K (NH_4OAc extractable) 185.4 kg/ha and CEC 16.4 cmol(p^+)/kg. N, P and K were applied at the rate of 120, 60 and 40 kg/ha through urea, single super phosphate and muriate of potash, respectively with full P and K as basal dose. Dolomite was applied @ 2 t/ha two weeks prior to sowing in all the plots except control to raise the soil pH to 6.0. FYM was applied basally one week before sowing. Seeds were inoculated with Azotobacter and dried in shade before sowing.

RESULTS AND DISCUSSION

Growth and yield attributes

Different schedules of N application expressed significant effect on plant height, cob girth and length, grains/cob, grain weight/cob and test weight at harvest for all the treatments (Table 1) with the highest values recorded for side-band point placement of urea (SBP) at 5 cm depth as $^1/_3$ N SBP at sowing + $^1/_3$ N SBP 25DAS + $^1/_3$ N SBP 50 DAS. In all the three methods of N application lowest values observed for single dose were significantly lower than 2 and 3 split applications. Side-band point placement at 5 cm depth as single, two and three split application produced significantly higher values for height and yield attributes as compared to the respective broadcast and furrow application methods suggesting higher N availability and synchronization with different crop growth stages leading to higher production and translocation of photosynthates. Similar findings were reported by Shivay *et al.* (2002).

Integrated nutrient management significantly influenced the plant height and yield attributes (Table 2). All the treatments varied significantly from each other reflecting the advantage of N application. Two-split top dress @ 80 kg and 60 kg N/ha significantly improved the yield attributes for in conjunction with FYM. Integration of (*Azotobacter* seed inoculation (AST) + 10 t FYM + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS produced the highest plant height and yield determining parameters which resulted in the highest maize yield. *Azotobacter* seed inoculation and application of the entire N through FYM was ineffective in isolation suggesting inability for sustained N supply but significantly increased their influence upon integration with farmyard manure and urea.

Yield and economics

Different schedules of nitrogen application produced significantly higher maize grain yield than control which increased progressively from single to three split application (Table 1). Three split N application as $^1/_3$ N SBP at sowing + $^1/_3$ N SBP 25 DAS + $^1/_3$ N SBP 50 DAS recorded highest yield which was 15.5 to 98.4% higher than other schedules. Top-dressing through two and three splits produced 32.8 and 53.1% higher yield as compared to broad-

Table 1. Effect of method and time of nitrogen application on growth and yield attributes, yield and economics of maize (2 years pooled data)

Treatment	Plant height (cm)	Cobs/ha	Grain weight/cob (g)	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Nutrient uptake (kg/ha) N	P	K	Net return (×10³ ₹/ha)	Net B:C ratio
120 N basal	135.7	52,000	44.8	211	3.20	5.57	113.0	20.8	103.5	33.54	1.46
120 N FA	138.9	54,000	46.4	218	3.60	6.45	127.6	21.7	112.6	39.15	1.57
120 N SBP	142.0	55,000	47.4	221	3.90	6.88	131.6	23.9	116.2	41.40	1.53
60 N + 60 N	148.9	58,000	49.8	222	4.25	7.30	136.2	26.0	127.7	44.35	1.64
60 N FA + 60 N FA	151.8	60,000	51.1	225	4.78	7.60	141.8	28.7	134.7	48.63	1.74
60 N SBP + 60 N SBP	155.0	66,000	55.9	232	5.15	8.25	145.8	32.3	137.1	52.55	1.81
40 N + 40 N + 40 N	157.1	62,000	52.6	229	4.90	7.60	143.8	30.3	136.4	49.50	1.77
40 N FA + 40 N FA + 40 N FA	159.0	68,000	58.7	232	5.50	8.60	155.1	34.7	146.8	55.70	1.86
40 N SBP + 40 N SBP + 40 N SBP	160.2	74,000	62.4	241	6.35	9.25	161.2	38.3	150.1	62.95	1.97
Control	84.8	34,000	34.6	154	1.85	4.22	56.6	15.5	52.1	21.38	1.19
SEm±	0.7	515	0.7	1.1	0.16	0.28	0.9	0.3	0.6		
CD (P = 0.05)	1.9	1500	2.0	3.3	0.48	0.81	2.8	0.8	1.8		

FA : Furrow applied, SBP : Side band point placement cast of full N dose. Furrow application increased maize yield by 27.3 and 46.7% when applied in two and three splits. Similarly side-band placement in two and three splits increased grain yield by 30.3 and 60.8% over full dose basal application which perhaps pointed towards higher availability and synchronization of N supply during the crucial crop growth stages and lower leaching and surface run off losses. Stover yield increase under the influence of various N schedules was significantly higher over N_0 control. Stover production showed trend similar to grain yield with highest values recorded for the three-split schedules.

Integrated nutrient management through different combinations produced yields significantly different from each other and higher than N_0 control. Maize yield increased with application of fertilizer in conjunction with FYM. The yield increase was more pronounced with enhancement in proportion of N supply through urea from 40 to 80 kg N/ha and decrease in the quantity of FYM from 20 to 10 t/ha. Significant yield increase was recorded when two split top-dress N application which was 100 to 202.8% higher over control (Table 2). Seed inoculation with *Azotobacter* significantly augmented the yield of FYM + two split top-dress. Inclusion of 10 t FYM/ha with *Azotobacter* seed treatment followed by two split top-dress of N produced the highest grain yield which was 168.6% and 82.4% more than *Azotobacter* seed treatment and Azotobacter +40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS, respectively thus emphasizing the significance of FYM. Stover yield under the influence of integrated nutrient management was significantly higher for all treatments over control. Stover production trend was similar to grain yield with highest production recorded for *Azotobacter* + 10 t FYM/ha + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS. Increased plant height and dry matter accumulation with application of recommended dose of fertilizers or combined use of farmyard manure with nitrogen might have resulted because of higher uptake of nutrients due to release of sufficient amount of nutrients by mineralization at a constant level that in turn gave higher yields. The findings are in agreement with those of Pattanshetti *et al.* (2002) and Sankhyan *et al.* (2003).

Highest net return (₹ 62,950) and benefit:cost (1.97) was recorded for $^1/_3$ N SBP at sowing + $^1/_3$ N SBP 25 DAS + $^1/_3$ N SBP 50 DAS amongst the various N application schedules evaluated. The net return and benefit:cost increased with the number of splits of N application from one to three for all schedules. Integrated nutrient management with *Azotobacter* + 10 t FYM/ha + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS resulted in not only highest return of ₹ 67,550 but also at highest net return/Re. invested (1.99) as compared with all other treatments. The findings are in conformity with Brar *et al.* 2001 and Karki *et al.* 2005. *Azotobacter* seed inoculation and application of 20 t FYM/ha proved to be the most ineffective in terms of net return and B:C ratio.

Nutrient uptake and residual nutrient status

Three-split application of $^1/_3$ N SBP at sowing + $^1/_3$ N SBP 25 DAS + $^1/_3$ N SBP 50 DAS resulted in the maximum uptake of 161.2 kg N/ha which was significantly higher (3.9 to 43.6%) than all the other 1, 2 and 3-split N application schedules (Table 1). Total N uptake at harvest was significantly influenced by N fertilization with significant variation between schedules and over control. Furrow application in two and three splits increased N uptake by

Table 2. Effect of integrated nutrient management on growth and yield of maize (2 years pooled data)

Treatment	Plant height (cm)	Cobs/ ha	Grain weight/cob (g)	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Nutrient uptake (kg/ha)			Net return (×10³ ₹/ha)	Net B:C ratio
							N	P	K		
20 t FYM	133.8	50,000	44.4	207	2.70	4.80	80.3	20.5	76.2	28.75	1.46
10 t FYM + 80 N	148.7	55,000	50.3	224	4.20	7.10	124.5	25.7	115.9	43.50	1.61
15 t FYM + 60 N	145.6	53,000	49.3	221	4.00	6.75	117.5	23.8	109.4	41.50	1.53
20 t FYM + 40 N	142.7	52,000	46.8	216	3.60	5.50	107.7	21.6	100.1	36.20	1.45
10 t FYM + 40 N + 40 N	152.6	68,000	58.0	235	5.45	8.75	157.1	34.8	146.2	55.65	1.86
15 t FYM + 30 N + 30 N	155.0	61,000	51.8	227	4.85	7.80	139.8	28.9	130.1	49.55	1.65
20 t FYM + 20 N + 20 N	157.8	58,000	46.0	215	3.60	6.35	105.5	24.7	98.3	38.26	1.42
AST	128.7	48,000	43.3	199	2.55	4.50	74.9	18.8	69.6	26.85	1.41
AST + 40 N	138.9	52,000	45.6	212	3.50	5.05	99.3	24.7	92.3	34.60	1.50
AST + 40 N + 40 N	165.0	60,000	50.7	222	4.65	7.50	134.1	27.6	124.8	47.55	1.76
AST + 10 t FYM + 40 N + 40 N	166.5	76,000	62.9	250	6.85	9.80	168.4	34.0	154.7	67.55	1.99
Control	85.6	31,000	34.5	148	1.80	3.40	54.6	15.1	50.9	19.75	1.10
SEm ±	0.6	490	0.9	1.0	0.12	0.16	1.1	0.4	0.9		
CD (P = 0.05)	1.6	1300	3.0	2.9	0.36	0.48	3.4	1.1	2.8		

AST : *Azotobacter* seed treatment

10.2 and 19%, respectively over full basal application of full dose. N uptake increased by 10.8 and 22.5% when side band placement was done in two and three splits, respectively over basal application. This showed that band placement of fertilizer in the rhizosphere in three splits increased N uptake with higher availability during the different growth stages. The uptake of P and K at harvest was significantly impacted by the schedule of N application and ranged from 26.8 to 50.3 and 103.5 to 150.1 kg/ha, respectively. The trend of P and K uptake was similar to N with significant variations between various schedules and over control. The highest values were recorded for the $^1/_3$ N SBP at sowing + $^1/_3$ N SBP 25DAS + $^1/_3$ N SBP 50 DAS treatment.

Integrated nutrient management resulted in significantly different N uptake amongst the treatments (Table 2). Integration of FYM with urea resulted in significantly higher uptake in all the treatment combinations. *Azotobacter* + 10 t FYM/ha + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS recorded the highest uptake which was 7.2 to 69.6% higher than all other integrated nutrient management combinations. Application of 120 kg N/ha through FYM in organic equivalents and seed inoculation with *Azotobacter* effected lowest N uptake which pointed to their inability to synchronize N supply and fix sufficient N for all the growth stages. N uptake increased with application of fertilizer in conjunction with FYM. The increase was significantly higher with increase in the proportion of N supply through urea from 40 to 80 kg N/ha and decrease in the quantity of FYM from 20 to 10 t/ha. When top-dress N application was done in two splits the increase was 95.6% higher over 20 t FYM/ha. Similarly, when FYM + two split top-dress was superimposed where seeds were inoculated with *Azotobacter* the increase was 7.2 and 25.6%, respectively. Top-dressing of single and two split of urea over *Azotobacter* seed inoculation increased the N uptake by 32.6 and 79%, respectively. Inclusion of 10 t FYM/ha with *Azotobacter* followed by two split top-dress

Table 3. Effect of nitrogen management in maize on post-harvest soil properties (Pooled data of 2 years)

Treatment	pH	OC (%)	Available nutrients (kg/ha) N	Available nutrients (kg/ha) P_2O_5	Available nutrients (kg/ha) K	Soil nitrogen balance (kg/ha) Total avail. N (initial + applied fertilizer N)	Soil nitrogen balance (kg/ha) Total N uptake	Soil nitrogen balance (kg/ha) Net N loss/gain
Nitrogen schedules								
120 N broadcast	5.6	2.05	228.2	30.0	180.1	337.2	113.0	4.0
120 N FA	5.7	2.07	231.6	30.6	188.2	339.2	127.6	20.0
120 N SBP	5.6	2.08	233.4	30.8	189.5	335.0	131.6	30.0
60 N + 60N broadcast	5.8	2.07	234.5	30.8	189.0	339.4	136.2	31.3
60N FA + 60 N FA	5.7	2.09	232.1	31.4	190.4	336.5	141.8	37.4
60 N SBP + 60 N SBP	5.8	2.11	235.4	31.6	191.5	338.7	145.8	42.5
40 N + 40 N + 40 N broadcast	5.9	2.09	237.5	31.7	191.0	341.4	143.8	39.9
40 N FA + 40 N FA + 40 N FA	5.8	2.11	234.0	32.4	192.5	344.6	155.1	44.5
40 N SBP + 40 N SBP + 40 N SBP	5.9	2.13	239.4	33.3	194.4	341.5	161.2	59.1
Control	5.3	1.92	218.5	21.0	179.4	220.5	56.6	54.6
SEm±		0.01	0.6	0.1	0.4			
CD (P = 0.05)	NS	0.02	1.8	0.3	1.2			
Integrated nutrient management								
20 t FYM	6.2	2.10	229.3	30.2	188.2	330.5	80.3	- 20.9
10 t FYM + 80 N	6.0	2.09	233.2	30.4	191.1	340.2	124.5	17.5
15 t FYM + 60 N	6.1	2.11	236.3	30.5	194.7	336.6	117.5	17.2
20 t FYM + 40 N	5.8	2.12	239.4	30.8	196.6	340.8	107.7	6.3
10 t FYM + 40 N + 40 N	5.9	2.14	241.8	31.3	195.6	341.2	157.1	57.7
15 t FYM + 30 N + 30 N	5.8	2.15	243.4	31.7	197.5	337.4	139.8	45.8
20 t FYM + 20 N + 20 N	6.1	2.16	247.8	30.5	200.7	336.6	105.5	16.7
AST	5.8	2.07	226.6	30.1	184.0	331.2	74.7	- 29.7
AST + 40 N	5.8	2.09	237.5	31.4	187.0	340.4	99.3	- 3.6
AST + 40 N + 40 N	5.7	2.13	244.0	32.2	193.6	334.5	134.1	43.6
AST + 10 t FYM + 40 N + 40 N	6.0	2.17	253.5	33.1	198.4	342.2	168.4	79.7
Control	5.3	2.05	223.8	21.4	181.1	220.2	54.6	58.2
SEm±		0.01	0.7	0.2	0.5			
CD (P = 0.05)	NS	0.02	2.0	0.5	1.6			

FA: Furrow applied, SBP: Side band point placement AST: *Azotobacter* seed treatment of N produced the highest uptake of 168.4 kg/ha reflecting on the benefits of integration of sources of nutrition. The trend of P and K uptake was similar to N with significant variations between various schedules and over control. The highest P and K uptake values were recorded for *Azotobacter* + 10 t FYM/ha + 40 N 25 DAS + 40 N 50 DAS. Wu *et al.* (2005) reported that microbial inoculum increased the nutritional assimilation of plant (total N, P and K). The nutrient uptake by the crop is determined by its nutrient content and yield and apparently yield was a more vital deciding factor for the uptake of nutrients by the crop which was in accordance with Brar *et al.* 2001.

Organic carbon, and available nitrogen, phosphorus and potassium content in soil varied significantly with scheduling and INM combinations. The soil pH in both the experiments (Table 3) was raised from the initial 5.3 to 6.0 with the application of dolomite 2 t/ha. At the end of the N schedule study it was noticed that the soil pH showed a non-significant decrease in all the schedules perhaps under the influence of crop growth and nutrient leaching due to rains. Increasing split applications to two and three left higher residual nutrients. The soil pH remained almost unchanged in the integrated nutrient management study in all treatments except where FYM was excluded which pointed towards the buffering capacity of FYM. Higher residual nutrients was recorded with increasing levels of FYM perhaps due to the high C:N ratio of farmyard manure resulting in organic carbon build up in soil, and higher available nitrogen, phosphorus and potassium due to increased activity of microorganisms leading to greater mineralization of applied and inherent nutrients. Wu *et al*. (2005) reported improved soil properties, such as organic matter content and total N in soil with the use of *Azotobacter*. The findings of Tolessa *et al.* (2001) in respect of organic carbon and available N and K and Sihag *et al.* (2005) in respect of available P confirmed the results. The highest residual nutrients were recorded for $^1/_3$ N SBP at sowing + $^1/_3$ N SBP 25 DAS + $^1/_3$ N SBP 50 DAS and *Azotobacter* + 10 t FYM/ha + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS treatments amongst the different schedules and integrated nutrient management combinations evaluated. Nitrogen balance ranged from 4 to 59.1 kg N/ha with control having 54.6 kg N/ha since the N uptake was very low (Table 3). 20 t FYM, *Azotobacter* and *Azotobacter* + 40 N recorded negative balance of nitrogen perhaps reflecting on the microbial immobilization. *Azotobacter* + 10 t FYM/ha + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS resulted in the highest N balance (79.7 kg/ha).

Rainfed maize 'VL Sankul Makka 11' responded positively to different schedules of N application. N application as $^1/_3$ N SBP at sowing + $^1/_3$ N SBP 25DAS + $^1/_3$ N SBP 50 DAS performed the best amongst the various N application schedules evaluated. Integrated nutrient management study revealed that the treatment *Azotobacter* + 10 t FYM/ha + 40 kg N/ha 25 DAS + 40 kg N/ha 50 DAS is promising for optimizing maize production and productivity in mid hill acidic soils of Sikkim.

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