



Productivity, economics and soil fertility under different maize (*Zea mays*) varieties as influenced by soil ameliorating practices in North Eastern hill region of India

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Received: 07 November 2016 ; Accepted: 25 March 2018

ABSTRACT

A field experiment was conducted during *khariif* seasons of 2011 and 2012 at ICAR Research Complex for NEH Region, Umiam (966 m above mean sea level), Meghalaya, to identify suitable maize varieties and nutrients management practices for higher maize productivity. Results revealed that, application of recommended dose of fertilizer (RDF, 80:26.2:33.2 kg NPK/ha) along with furrow application of lime @ 250 kg/ha + FYM @ 5 t/ha produced the highest grain yield (4.70 and 4.87 tonnes/ha in 2011 and 12, respectively) followed by RDF + furrow application of lime @ 500 kg/ha. Grain yield obtained under RDF + lime@ 250 kg/ha + FYM@ 5 t/ha was 38.0 and 31.3% higher than that of RDF alone for the year 2011 and 2012, respectively. There was no significant effect of varieties on grain yield of maize although RCM 1-3 recorded relatively higher grain yield followed by RCM 75. The ameliorating practices significantly improved the soil chemical properties such as soil pH, soil available N and P, soil organic carbon and significantly reduced exchangeable Al and exchangeable acidity. The variety RCM 1-3 with RDF + furrow application of lime (250 kg/ha) + FYM (5 tonnes/ha) was found superior as compared to other treatments.

Key words: Acid soil, Al toxicity, Economics, Maize, North eastern hill region, Yield

Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Maize is the second most important crop in the North Eastern Hill (NEH) region of India after rice (Layek *et al.* 2015). It is cultivated in an area of about 0.17 m ha in NEH region with productivity of 1.50 tonnes/ha, which is lower than the India's national average productivity of 1.84 tonnes/ha (Layek *et al.* 2015). Inadequate plant nutrition, soil acidity and cultivation of local cultivars are major limitations for higher productivity of maize (Das *et al.* 2010). The farmers of the region have small and marginal holdings and cultivate maize, mainly in uplands and sloping lands (Das *et al.* 2014). Out of many challenges to increase maize productivity, the soil acidity is most important. On global basis, acid soils are known to limit maize yields in nearly 40% of the arable land (Gudu *et al.* 2005). Major threats to sustainable soil productivity related to soil acidity are (i) H⁺, Al and Mn toxicities, (ii) low availability (P, Mo) and supply of nutrients (N, Ca, Mg), and (iii) high nutrient (base) losses (Manoj-Kumar *et al.* 2012). One of the key elements of sustainable cropping systems is the integration of maize cultivars with high tolerance to soil acidity and which make the most efficient

use of the nutrients supplied by soil and fertilizer. Acid soils are usually excessive in soluble Al and Mn and deficient in P, Ca, Mg and Mo that may cause their reduced uptake and lead to nutrient imbalances in plants (Clark and Baligar 2000). Lime application along with integrated nutrient management provides good opportunity to increase the availability of essential nutrients to plants and ameliorate the other acidity-induced fertility constraints in acid soils (Manoj-Kumar *et al.* 2012).

Liming of acid soil has been suggested as the best method to attain and maintain a suitable pH for the growth of crops (Slattery and Coventry 1993). Benefits of liming includes improved nitrogen fixation and availability of essential nutrients (Ca, P, Mo) and decrease solubility of toxic elements, viz., Al and Mn (Haynes and Ludeke 1981). Moreover, the use of liming materials would potentially be a cost-effective measure for resource-poor farmers of the region. Amelioration of acid soil by lime can raise soil pH, improve soil properties and subsequently improve plant growth and productivity (Conyers 2006). Addition of organic residues to acid soils reduces the phytotoxicity of Al (Haynes and Mokolobate 2001). The general recommended dose of lime (blanket application) for acidic soil of North East India is very high (2-10 tonnes/ha) and not being popular among the farming communities due to high cost and difficulty in transportation in hilly terrain (Patiram 1991). Integration

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of agronomic and soil amelioration practices (furrow application with reduced doses) along with selection of suitable acid tolerant maize cultivars/varieties are the need of hour for sustainable maize production in acid soils of the region. Integration of soil amendments together with acid soil-tolerant maize cultivar can offer a sustainable and comprehensive strategy for the management of acid soils and enhancing maize productivity in the region. Hence, high yielding maize varieties available in the region were tested for acidity tolerance under different management practices. It was hypothesized that integrated application of farmyard manure (FYM) and furrow application of lime along with recommended dose of fertilizers can improve the growth and productivity of maize and ameliorate the ill effects of Al toxicity and acidity related soil problems.

MATERIALS AND METHODS

A field experiment was carried out during rainy/*kharif* seasons (April to October) in 2011 and 2012 at Agronomy Research Farm, ICAR Research Complex for NEH Region, Umiam, Meghalaya located at latitude 25° 41' 23" N, longitude of 91°55' 19" E and an elevation of 966 m above sea level. Treatments comprised four soil ameliorating practices, viz. recommended dose of fertilizer (RDF) [80:26.2:33.2 kg NPK/ha], RDF+liming (furrow application @ 500 kg/ha), RDF+FYM in furrow (10 tonnes/ha), RDF+liming (furrow application @250 kg/ha)+FYM (5 tonnes/ha) and five high-yielding maize cultivars, viz. Vijay composite, RCM 1-1, RCM 1-3, RCM 75 and RCM 76 were tested in a completely randomized block design under three replications. The gross plot size was 5.0 m × 4.0 m. The maize crop was sown in third week of April, with a row to row and plant to plant spacing of 50 cm × 25 cm. Full dose of P and K, and half dose of N were applied at the time of sowing and, the remaining half of N was top dressed in two split doses at 30 and 60 days after sowing (DAS). The N was applied through urea, while P and K were applied through single super phosphate and muriate of potash, respectively. Lime was applied in furrows a day before sowing and properly mixed in the soil. All recommended agronomic practices were followed during crop growth and the grain and stover yields were recorded at the time of harvesting of crop. For economic calculations all the costs involved in carrying out farm operations and inputs were worked out individually for each treatment and taken as cost of cultivation. The revenue generated from the maize crop by way of grain and stover were taken as gross return and the difference between gross return and cost of cultivation was taken as net return. The ratio between gross return to cost of cultivation was computed as benefit: cost ratio (B:C ratio). Cost of cultivation and returns were calculated based on the prevailing market price of the input and produce during 2011 and 2012. Economic yield was divided by biological yield and multiplied by 100 for calculating the harvest index and expressed as percentage (%).

Soil samples were collected from each plot (0-15 cm soil depth) before sowing and after harvesting of maize. The

pH of the soil was determined by using a digital pH meter having glass electrode, in 1:2.5 soil-water suspensions (Jackson 1973), available N by the alkaline permanganate method (Subbaiah and Asija 1956), available P by Bray's extraction method (Bray and Kurtz 1945) using spectrophotometer. Soil organic carbon (SOC) concentration was determined by the Walkley and Black method (Nelson and Sommers 2005). The soil of the experimental field was sandy loam in texture and initial status of soil is low in available N (246.4 kg/ha), low in available P (28.9 kg/ha), SOC (1.71%) and strongly acidic in reaction (pH 4.81). Exchangeable acidity and exchangeable Al were extracted by shaking the soil samples with 1 M KCl for 2 h and determined by titration with 0.05 M NaOH using phenolphthalein as indicator (McLean 1965).

Data obtained from maize for two consecutive years of study were statistically analyzed using the F-test as per the procedure given by Gomez and Gomez (1984). Critical difference (CD) values at P=0.05 were used to determine the significance of differences between means.

RESULTS AND DISCUSSION

Yield contributing parameters

Yield attributes like cob length (cm), rows/cob, grains/cob, grain weight/cob and test weight (1000 kernels weight) were significantly influenced by various soil amelioration practices during both the years of experimentation (Table 1). The cob length (cm), grain rows/cob, grains/cob, grain weight/cob and test weight were recorded significantly higher with RDF (80:26.2:33.2 kg NPK/ha)+lime (furrow application @ 250 kg/ha) + FYM (5 tonnes/ha) followed by RDF+lime (furrow application @ 250 kg/ha) as compared to RDF alone. Application of RDF+FYM in furrow (10 tonnes/ha) recorded statistically similar yield attributes to that of RDF+lime (furrow application @ 250 kg/ha) +FYM (5 tonnes/ha). However, different soil ameliorating practices during both the years had no effect on the test weight as it is mainly governed by the genetic factors. In the year 2011, cultivar RCM 75 recorded the highest cob length and no. of rows/cob whereas; in 2012 RCM 76 recorded the highest cob length. However, the highest number of grain/cob, grain weight/cob and test weight was recorded in RCM 1-3 in both the years. The cob length, rows/cob and grain weight/cob remained statistically non-significant among different maize varieties.

Productivity

Soil amelioration had significant effect ($P < 0.05$) on yield of maize (Table 2). The highest grain yield of maize (4.07 and 4.86 tonnes/ha, in year 2011 and 2012, respectively) was recorded under RDF (80:26.2:33.2 kg NPK/ha) +lime (furrow application @ 250 kg/ha) +FYM (5 tonnes/ha) followed by RDF+lime (furrow application @ 250 kg/ha) and RDF +FYM in furrow (10 tonnes/ha) which were significantly higher than RDF alone. Grain yield under RDF+lime+FYM was 38.0 and 31.3% higher than that of RDF alone for the year 2011 and 2012, respectively. The

Table 1 Effect of soil ameliorating practices and varieties on yield attributes of maize

Treatment	Cob length (cm)		Grain rows/cob		Grains/cob		Grain weight/cob (g)		Test weight (g)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
<i>Soil ameliorating practices</i>										
RDF	14.0	14.0	12.3	11.8	316	343	76.4	81.9	269.6	266.9
RDF + Lime	15.5	16.3	12.6	12.6	364	409	92.6	92.2	271.3	267.7
RDF + FYM	15.1	15.2	12.7	12.4	362	386	92.2	88.2	273.9	276.0
RDF + Lime + FYM	16.0	17.1	12.9	12.9	376.	412	97.6	95.4	282.2	277.9
SEm±	0.37	0.40	0.28	0.22	7.61	10.97	3.84	3.22	7.80	7.10
CD (P=0.05)	1.07	1.13	NS	0.62	21.8	31.4	11.0	9.23	NS	NS
<i>Varieties</i>										
Vijay Composite	15.0	15.5	12.5	12.2	358	385	89.3	89.1	263.4	254.9
RCM 1-1	15.0	15.4	12.3	12.3	362	349	84.9	81.6	253.8	237.6
RCM 1-3	15.4	15.0	12.9	12.6	365	413	95.7	94.7	287.7	291.0
RCM 75	15.4	15.5	13.1	13.0	360	397	90.7	90.7	284.5	289.2
RCM 76	14.8	16.8	12.3	12.1	327	394	87.7	91.0	281.8	287.9
SEm±	0.42	0.44	0.31	0.24	8.51	12.27	4.30	3.60	8.70	8.00
CD (P=0.05)	NS	NS	NS	NS	24.4	35.1	NS	NS	24.9	22.8

RDF: Recommended dose of fertilizer

Table 2 Effect of soil ameliorating practices and varieties on yield and economics of maize

Treatment	Grain yield (t/ha)		Stover yield (t/ha)		Harvest index (%)		Net return ($\times 10^3$ ₹/ha)		B:C ratio	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
<i>Soil ameliorating practices</i>										
RDF	2.95	3.70	9.22	10.1	24.6	26.6	15.17	24.03	1.53	1.84
RDF + Lime	3.84	4.58	11.2	12.0	26.0	27.7	26.63	34.92	1.90	2.17
RDF + FYM	3.48	4.20	10.7	11.5	24.9	26.3	19.75	26.78	1.62	1.84
RDF + Lime + FYM	4.07	4.86	11.8	13.0	25.7	27.4	28.88	38.13	1.94	2.24
SEm±	0.12	0.17	0.25	0.38	0.76	1.06	1.50	1.93	0.05	0.06
CD (P=0.05)	0.35	0.48	0.7	1.08	NS	NS	4.29	5.53	0.14	0.18
<i>Varieties</i>										
Vijay Composite	3.39	4.16	10.8	11.9	23.9	26.3	20.41	29.43	1.67	1.97
RCM 1-1	3.60	4.08	10.5	11.3	26.1	26.5	22.56	27.90	1.75	1.92
RCM 1-3	3.86	4.58	11.0	12.1	26.4	27.4	26.09	34.48	1.86	2.14
RCM 75	3.53	4.48	11.6	12.1	23.4	26.9	22.10	33.38	1.75	2.10
RCM 76	3.54	4.25	9.79	11.0	26.8	27.9	21.17	29.64	1.69	1.98
SEm±	0.14	0.19	0.28	0.42	0.85	1.19	1.68	2.16	0.06	0.07
CD (P=0.05)	NS	NS	0.79	NS	2.45	NS	4.80	6.19	0.16	0.21

RDF: Recommended dose of fertilizer

results suggested that liming along with integrated nutrient management practices had increased maize productivity over no liming (Manoj-Kumar *et al.* 2012a). However, there was no significant effect on grain yield of maize was observed due to different varieties. In year 2011, maize variety RCM 1-3 yielded higher grain yield followed by RCM 1-1 and RCM 75. In year 2012, RCM 1-3 yielded highest grain yield followed by variety RCM 75 and RCM 76. Among the soil amelioration practices, stover yield was recorded significantly higher under RDF+lime+FYM as

compared to other treatments in both the cropping seasons. Maize variety RCM 75 yielded maximum stover yield and was followed by RCM 1-3. However, harvest index was not significantly influenced by different soil amelioration practices but significantly influenced by different maize varieties in the year 2011 only. It was mainly due to the fact that harvest index is mainly governed by the genetic factors (Layek *et al.* 2015). RCM 76 variety recorded highest harvest index as compared to other maize varieties in both the seasons.

Table 3 Effect of soil ameliorating practices and varieties on available N and P, soil organic carbon (SOC), pH, exchangeable Al and exchangeable acidity soils of maize

Treatment	pH(1:2.5)		Soil organic carbon (%)		Available N (kg/ha)		Available P (kg/ha)		Exchangeable Al (cmol (+)/kg)		Exchangeable acidity (cmol (+)/kg)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
<i>Soil ameliorating practices</i>												
RDF	4.77	4.75	1.69	1.68	250.3	251.0	27.9	30.0	1.28	1.30	1.56	1.49
RDF + Lime	4.96	5.00	1.74	1.74	256.4	258.6	30.8	33.7	1.09	1.05	1.39	1.21
RDF + FYM	4.83	4.86	1.74	1.80	267.5	274.8	31.1	33.3	1.16	1.11	1.46	1.35
RDF + Lime + FYM	4.98	5.03	1.77	1.79	270.3	275.0	31.8	35.2	1.07	1.04	1.37	1.19
SEm±	0.02	0.08	0.03	0.03	4.84	5.77	0.44	0.84	0.03	0.03	0.03	0.05
CD (P=0.05)	0.06	0.21	NS	0.07	13.9	16.5	1.25	2.39	0.08	0.08	0.09	0.14
<i>Varieties</i>												
Vijay Composite	4.92	4.76	1.74	1.74	264.3	265.7	29.1	32.7	1.11	1.07	1.48	1.23
RCM 1-1	4.90	4.93	1.76	1.73	262.8	265.3	30.7	32.8	1.01	1.10	1.43	1.28
RCM 1-3	4.89	4.98	1.72	1.74	256.6	265.3	30.4	33.4	1.25	1.15	1.50	1.34
RCM 75	4.85	5.00	1.71	1.77	263.8	265.4	30.8	33.4	1.18	1.18	1.44	1.38
RCM 76	4.86	4.87	1.74	1.77	258.2	262.4	31.0	33.0	1.19	1.14	1.38	1.33
SEm±	0.02	0.08	0.03	0.03	5.41	6.45	0.49	0.93	0.03	0.03	0.04	0.06
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Initial soil values: SOC= 1.71%, pH= 4.81, Available N= 246.4 kg/ha, Available P= 28.9 kg/ha, RDF: Recommended dose of fertilizer

Economics

In general net return was higher with RDF (80:26.2:33.2 kg NPK/ha)+lime (furrow application @ 250 kg/ha)+FYM (5 tonnes/ha) compared to RDF alone during both the years. However, the highest net returns of maize was obtained from the RDF+lime+FYM (28.88 × 10³ ₹/ha and 38.13 × 10³ ₹/ha during 2011 and 2012, respectively) as compared to other soil ameliorating practices. Among the maize varieties, RCM 1-3 recorded significantly higher net returns (26.09 × 10³ ₹/ha and 34.48 × 10³ ₹/ha during 2011 and 2012, respectively over other of varieties. Similarly, application of RDF+lime+FYM gave higher B:C ratio than that of RDF for both years of experimentation. Therefore, RDF+lime+FYM was better option for getting higher productivity of maize and returns as compared to application of RDF alone. The cultivation of RCM 1-3 gave higher B:C ratio as compared to other maize varieties. The higher net return as well as B:C ratio in 2012 as compared to 2011 was due to higher yield obtained in the second year of the experimentation (2012).

Soil fertility status

In comparison with the antecedent value, there was a marked improvement in soil fertility status after two cropping cycles with the application of soil ameliorants. The different soil fertility parameters such as soil pH, soil available N and P were significantly influenced by soil amelioration practices except for SOC in the year 2011. However, varieties had no effect on soil pH, available N, P and SOC concentration. Application of RDF (80:26.2:33.2 kg NPK/ha)+lime (furrow application @ 250 kg/ha)+FYM (5 t/ha) recorded statistically higher soil pH followed by application of RDF + lime (furrow application @ 250 kg/

ha) as compared to RDF alone. Thus, application of lime along with RDF + FYM, can raise soil pH which may be associated with the presence of basic cations (Ca²⁺ and Mg²⁺) (Fageria *et al.* 2007) and anions (CO₃⁻) in lime that are capable to exchange H⁺ from exchange sites to form H₂O + CO₂. Cations occupy the space left behind by H⁺ on the exchange leading to the rise in pH. RDF+lime+FYM had recorded higher SOC concentration, available N and available P than those under RDF alone as liming can increase phosphate availability by stimulating mineralization of soil organic phosphorus (Haynes 1992). RDF alone recorded the lowest SOC, available N and P.

However, upon comparison with the initial soil data there was marked decrease in exchangeable Al (meq/100 g of soil) and exchangeable acidity were observed under soil ameliorating practices in both the years (Table 3). Significantly lower exchangeable Al and exchangeable acidity were observed under RDF+lime+FYM followed by RDF+lime and RDF+FYM (furrow application @ 10 tonnes/ha) over RDF alone. Both exchangeable Al and acidity were the highest under RDF only. Maize varieties could not influence exchangeable Al and exchangeable acidity significantly though; RCM 1-3 and RCM 75 recorded relatively higher values of these parameters as compared to other maize varieties in the year 2011 and 2012, respectively. Exchangeable acidity of the soil significantly decreased with liming as compared to no-liming. RDF+lime+FYM recorded the minimum exchangeable acidity and exchangeable aluminum (Table 3). This decrease may be due to increased replacement of Al by Ca in the exchange site subsequent precipitation of Al as Al (OH)₃, due to liming of soil (Havlin *et al.* 1999). Moreover, an increase in soil

pH results in precipitation of exchangeable and soluble Al as insoluble Al hydroxides thus reduces concentration of Al in soil solution (Ritchie 1989).

Thus, the study suggested that application of RDF (80:26.2:33.2 kg NPK/ha) +lime (250 kg/ha in furrows) + FYM (5 t/ha in furrows) [RDF + lime + FYM] substantially improves maize growth and productivity besides brought positive change in soil chemical properties. RCM 1-3 and RCM 75 performed relatively better and gave higher net return over other maize varieties. Thus, integrated use of RDF along with furrow application of lime (250 kg/ha) and FYM (5 tonnes/ha) and cultivation of high yield varieties like RCM 1-3 and RCM 75 are recommended for sustainable maize production in the hilly ecosystem of NEH region of India and other similar ecosystems.

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