Indian Journal of Agronomy **60** (2): 273–278 (June 2015)

Research Paper

Productivity, profitability and nutrient uptake of maize (*Zea mays*) as influenced by management practices in North-East India

RAKESH KUMAR[1]

ICAR Research Complex for North Eastern Hill Region, Nagaland Centre, Jharnapani, Medziphema 797 106

Received : July 2014; Revised accepted : June 2015

ABSTRACT

A field experiment was conducted during the 2 winter (*rabi*) seasons of 2010–11 and 2011–12 at Jharnapani, Medziphema, Nagaland, to evaluate the best management practices, i.e. mulching, liming and farmyard manures for maximizing the productivity, profitability, nutrient uptake and quality of winter maize (*Zea mays* L.). The experiment was laid out in a split-split plot design, having 24 treatment combinations of mulching and lime along with farmyard manures and replicated thrice. Application of straw mulches significantly increased all the growth and yield attributes, grain yield, protein content and nutrient uptake by maize. Among the levels of lime, higher grain yield (3.91 t/ha) and stover yield (4.24 t/ha) were noted with application of lime @ 0.6 t/ha. Similarly, significantly higher grain (3.79 t/ha) and stover yields (4.17 t/ha), nutrient uptake, protein yield of maize were recorded with application of farmyard manures @ 12 t/ha. Application of straw mulch along with 0.6 t/ha lime and FYM @ 12 t/ha recorded markedly higher total rainfall and effective rainfall use efficiency. Hence, straw mulching with 0.6 t/ha furrows lime and 12 t FYM/ha should be adopted to obtain the maximum grain yield, net profit and nutrient uptake by winter maize.

Key words: Farmyard manures, Grain yield, Lime, Maize, Soil health

Among the cereals, maize is an important cereal crop next to rice and wheat. It contributes significant role in global agricultural economy. About 80% of maize growing areas in India fall under rainfed sub-tropical climate. Maize is the second largest cereal crop being grown in Nagaland with the highest acreage (0.68 m ha) among the NEH state. Traditionally, both rice and maize grown as mono crops and land is kept fallow after harvesting of maize. Maize is being grown in *rabi* season suffers from soil-moisture stress during the cropping period due to poor moisture retention in the soil. Thereafter, second crop is quite not possible due to non-adoption of moisture-conserving techniques in this region (Chaudhary and Kumar, 2014). The poor adoption of water-conservation measures is one of the important factors**,** which restricts agricultural production and reduces the land-use efficiency. Crops grown during post-rainy season in Eastern Himalayas experiences water deficit (Saha and Ghosh, 2010). Application of available crop residues/starw mulch offers an opportunity to enhance the crop production, soil and water conservation, weed management and cropping intensity and productivity of the region. More favourable water regime manifested in higher yields makes mulching not only soil protective but economically favourable also. Despite beneficial effects of straw mulching, adoption of this practice is not common in the tribal farmers of North East India due to lack of utility and awareness. Nagaland is a potentially agriculture based economic state but have the acute problems of soil acidity coupled with high rainfall. Acidity induced soil-fertility problems tied with no use of inorganic fertilizers is responsible for low productivity of crop. Liming along with FYM is recommended to increase the phytoavailability of essential nutrients and ameliorates the acidity-induced fertility problems on such soil (Kumar *et al.*, 2012). Hence, a field experiment was conducted to assess the effect of mulch, lime and farmyard manure on productivity and profitability of winter maize under foothill condition of Nagaland.

MATERIALS AND METHODS

The experiment was carried out at agricultural research farm during the winter (*rabi*) season of 2010–11 and 2011–12. The experimental site Jharnapani, Medziphema was located between 25.45° N’ 93.53° E’ with a mean altitude of 295 m above mean sea-level. The soil of the experimental site was sandy loam in texture with acidic in

[1]**Corresponding author Email :** rakeshbhu08@gmail.com
[1]Scientist (Agronomy), ICAR RC for NEH Region, Nagaland Centre, Jharnapani, Medziphema 797 106

nature (*p*H 5.4) and has 0.79% organic carbon and 14.05 kg/ha available P and 201.2 kg/ha mineralizable N and 173.2 kg/ha available K. A total of 24 treatments were arranged in 3 replications using split-split plot design with 2 mulch (control and straw mulch) in main plot, 4 levels of furrow lime application (control, 0.2, 0.4 and 0.6 t/ha) in sub-plots and 3 levels of farmyard manures (4, 8 and 12 t/ha) in sub-sub plot. During 2010–11, the minimum and maximum temperature ranged from 9.7 to 24.0˚C and from 22.3 to 29.7˚C, respectively. A total amount of rainfall 250.5 mm was received during the cropping season. During 2011–12, the minimum and maximum temperature ranged from 10.4 to 24.2˚C and 20.9 to 30.6˚C, respectively and a total of 327.9 mm of rainfall was received. Farmyard manures (FYM: 0.53% N, 0.15% P and 0.56% K) were applied to the field 1 month before sowing of the crop as per the treatments. Similarly, liming was applied in furrow 2 weeks before sowing of the crop. Maize cv. 'Vijay composite' was sown with using the seed rate of 20 kg/ha and row spacing of 60 cm × 20 cm. A recommended dose of fertilizers, i.e. 80 kg N, 60 kg P and 40 kg K/ha, was applied as per treatment. Full doses of P and K and half of N were applied basal and remaining N were top dressed in 2 equal splits at knee high and tassel-emergence stages. Gap-filling and thinning were done within 15 days after sowing (DAS) of crop to maintain the optimum plant population. Pre-emergence application of atrazine @ 1.5 kg a.i./ha was applied to control the initial weed flushes. Plant height, dry-matter, stem girth/plant and root parameters were collected at harvest from random selected 5 plants. The grain and stover yields of maize were recorded in kg and converted into t/ha. All the chemical analyses of plants and soil were done by following the standard procedures. Protein content in grain was worked out by multiplying N content in grain with a factor 6.25. Total rainfall-use efficiency and effective rainfall-use efficiency were calculated by using the formulas and expressed as kg/ha/mm (Devasenapathy *et al*., 2008). Effective rainfall received during cropping period is measured by soil-moisture changes method.

RESULTS AND DISCUSSION

Growth attributes

Growth characters, *viz.,* plant height, dry-matter, number of leaves and stem girth/plant were increased significantly with straw mulching over no mulching (Table 1). Similarly, root parameters such as root length, weight and volume were also higher with straw mulching over no mulching. This might be owing to higher moisture status in soil for longer period under the mulching plot. Our finding confirm the results of Chaudhary and Kumar (2014). An increase in level of lime from 0 to 0.6 t/ha improved the plant height, dry matter, number of leaves and stem girth/plant. Application of lime @ 0.6 t/ha resulted in significantly more plant height and dry matter/plant, being 18.4 cm and 21.1 g more over the control, respectively. Applications of lime significantly influenced the root characters, viz. root length, weight and volume. The per cent increase in the root length, root dry weight and volume was 23.8, 14.8, 23.1 and 12.5, 9.0, 9.1 over control and 0.2 t lime/ha, respectively (Table 2). Kumar *et al.* (2012) also reported similar results in maize.

Table 1. Effect of mulching, lime and farmyard manures on growth and root characters of maize (pooled data of 2 years)

Treatment	Plant height (cm)	Leaves/ plant (Nos.)	Stem girth (cm)	Dry matter/ plant (g)	Root length (cm)	Root dry weight (g)	Root volume (c.c.)
Mulching							
Control	171.8	6.6	2.4	165.0	12.2	16.3	6.9
Mulch	187.7	7.6	2.6	182.6	13.2	17.6	7.9
SEm±	2.41	0.11	0.02	2.65	0.15	0.19	0.10
CD (P=0.05)	14.64	0.69	0.14	16.11	0.90	1.07	0.63
Lime (t/ha)							
Control	170.7	6.4	2.3	163.8	11.3	15.8	6.5
0.2	176.4	6.7	2.4	170.0	12.4	16.6	7.4
0.4	182.7	7.1	2.5	176.5	13.3	17.4	7.7
0.6	189.2	7.4	2.7	184.9	13.9	18.12	8.02
SEm±	1.66	0.09	0.02	1.81	0.13	0.21	0.08
CD (P=0.05)	5.13	0.27	0.08	5.59	0.37	0.67	0.23
FYM (t/ha)							
4	174.2	6.5	2.4	168.1	12.2	16.1	6.9
8	179.9	6.9	2.5	174.0	12.6	17.0	7.5
12	185.2	7.3	2.6	179.4	13.4	17.7	7.83
SEm±	1.54	0.08	0.02	1.76	0.11	0.19	0.07
CD (P=0.05)	4.45	0.24	0.07	5.08	0.32	0.51	0.18

Among the FYM levels, application of 12 t/ha resulted in the maximum plant height, which was 11.0 and 5.3 cm more than recorded with 4 and 8 t FYM/ha. Application of FYM @ 12 t/ha produced more dry-matter, number of leaves and stem girth, being 11.3 and 5.4 g, 0.8 and 0.5 number and 0.3 and 0.14 cm higher than 4 and 8 t FYM/ha, respectively. Significantly higher root length, root dry weight and root volume were recorded with 12 t FYM/ha over rest of the levels. This might be owing to additional amount of nutrient supplied by FYM as well as beneficial effects of decomposed organic matter that were derived in connection with physico-chemical properties of the soil.

Yield attributes and yield of maize

Cobs and cob weight/cob were markedly influenced by mulching. Straw mulching recorded 13.1% more cobs/plant and 11.8% more cob weight than no mulch. Similarly, grain and stover yields of maize increased significantly with mulching and the highest yield was recorded where straw mulch used (Table 2). The increases in grain and stover yield owing to mulching 0.5 and 0.8 t/ha higher over no mulch, respectively. This may be attributed to higher water regime and better water balance, which lead to vigorous growth and more yield attributes produced in mulch plot (Sharma *et al.,* 2010).

Yield attributes of maize, viz. number of cobs and cob weight, increased significantly with the increasing levels of lime up to 0.6 t/ha (Table 2). Application of lime 0.6 t/ha resulted in 25.6 and 17.6% more cobs/plant and 18.4 and 10.6% more cob than control and 0.2 t/ha, respectively. Among the lime levels, application of lime @ 0.6 t/ha resulted in the maximum grain and stover yield, which was 49.8, 24.3% and 30.8, 13.4% higher over the control and 0.2 t/ha, respectively. This might be owing to applied lime release the Ca^{2+}, which meet the demands and create favourable condition for better uptake of essential nutrient particularly P. Our results confirm those of Kumar *et al*. (2012).

Similarly, yield attributes such as number of cobs/plant were 31.2 and 12.2%, cob weight were 16.1 and 6.1% higher with FYM @ 12 t/ha as compared with 4 and 8 t FYM/ha. The maximum grain yield of 3.79 t/ha and stover yield 4.17 t/ha was observed under FYM @ 12 t/ha, being was 10.4 and 20.2% higher than 4 t FYM/ha. Improvement in yield of crop may be attributed to better nutrient availability resulting into higher the yield.

Economics

The maximum net returns and benefit: cost ratio were recorded under mulched plot, might be owing to increase in yields of maize. Similar findings were also reported in maize by Sharma *et al.* (2011). Among the levels of lime, application of 0.6 t lime/ha fetched the maximum net returns and benefit: cost ratio, which were significantly higher than the control. Application of FYM @ 12 t/ha brought substantial improvement in net returns and benefit: cost ratio of maize (Table 2). Application of FYM @ 12 t/ha fetched the higher net returns and benefit: cost ratio.

Table 2. Effect of mulching, lime and farmyard manure on yield attributes, yield, quality and economics of maize (pooled data of 2 years)

Treatment	Cobs/ plant (Nos.)	Cob weight (g)	Grain yield (t/ha)			Stover yield (t/ha)	Net return (×10³₹/ha)	Benefit: cost ratio	Protein content (%)	Protein yield (kg/ha)
			2011	2012	Pooled					
Mulching										
Control	1.22	103.0	2.95	3.04	2.99	3.47	11.46	1.35	9.5	283.8
Mulch	1.38	115.2	3.42	3.54	3.48	4.22	14.18	1.60	10.4	373.4
SEm±	0.02	1.63	0.04	0.05	0.04	0.05	0.21	0.02	0.14	7.69
CD (P=0.05)	0.10	9.93	0.24	0.30	0.26	0.26	1.25	0.15	0.85	46.80
Lime (t/ha)										
Control	1.17	99.4	2.57	2.64	2.61	3.41	10.12	1.35	8.9	232.7
0.2	1.25	106.4	2.95	3.03	2.99	3.74	11.74	1.44	9.6	287.8
0.4	1.31	113.1	3.37	3.51	3.44	3.99	13.73	1.52	10.2	355.5
0.6	1.47	117.7	3.85	3.97	3.91	4.24	15.69	1.59	11.0	438.3
SEm±	0.01	1.29	0.03	0.04	0.03	0.04	0.19	0.02	0.11	6.19
CD (P=0.05)	0.04	3.99	0.10	0.11	0.10	0.13	0.57	0.06	0.35	19.09
FYM (t/ha)										
4	1.12	100.6	2.65	2.74	2.70	3.46	10.58	1.40	9.3	251.5
8	1.31	110.0	3.16	3.29	3.22	3.91	12.86	1.48	9.9	327.4
12	1.47	116.8	3.74	3.83	3.79	4.17	15.03	1.55	10.5	406.8
SEm±	0.01	1.00	0.04	0.05	0.04	0.03	0.20	0.02	0.09	5.64
CD (P=0.05)	0.03	2.88	0.11	0.13	0.12	0.10	0.58	0.05	0.26	16.26

Nutrient uptake and quality

Mulching had significant influence on nutrient contents (N, P and K) in grain and stover over the control. Higher content of N, P and K in grain and N, P and K in stover were recorded under mulched plot. Further, straw mulch increased N, P and K uptake by grain and stover significantly over no-mulch (Table 5). Similarly, higher protein content and protein yield were observed with mulching, being which was 9.7 and 31.6% higher over the control. Similarly, lime had significant effect on nutrient contents (N, P and K) in grain as well as stover. Increase in the nutrient contents (N, P and K) due to lime @ 0.6 t/ha was 22.4, 25.3 and 24.4% in grain as well as 31.3, 34.9 and 20.5% higher in stover than the control. The higher N, P and K uptake by grain and stover was also recorded with 0.6 t lime/ha. Application of lime @ 0.6 t/ha topped the list by recording remarkably higher protein content (11%) and protein yield over preceding levels. Higher nutrient uptake was due to liming that helps in increase its availability in rhizosphere as reported by Rao and Shaktawat (2002).

Application of FYM significantly influenced N, P and K contents in grain and stover of maize. Application of 12 t FYM/ha showed 12.8% N, 23.4% P and 16.3% K higher in grain and 24.7% N, 31.0% P and 11.0% K more in stover than 4 t FYM/ha. The application of FYM up to 12 t/ha also significantly influenced N, P and K uptake by grain and stover of maize. Application of FYM @ 12 t/ha recorded the higher protein content (10.5%) and protein yield (406.8 kg/ha) followed by 8 t FYM/ha and the lowest with 4 t FYM/ha. Nutrient uptake by crop is determined by its nutrient content and yield and apparently yield is deciding factor for the uptake of nutrients by crop, which was in accordance with Rao and Shaktawat (2002).

Table 3. Interaction effect of lime and farmyard manure on grain yield (t/ha) in maize

Treatment	Farmyard manure (t/ha)			Mean
	4	8	12	
Control	2.21	2.64	2.97	2.61
0.2 t lime/ha	2.88	2.94	3.15	2.99
0.4 t lime/ha	2.82	3.49	4.01	3.44
0.6 t lime/ha	2.88	3.84	5.02	3.91
Mean	2.70	3.22	3.79	
		SEm±	CD (P=0.05)	
Lime at different levels of FYM		0.08	0.24	
FYM at different levels of lime		0.13	0.34	

Interaction effect

Different levels of lime and farmyard manures interaction was found significant in respect of grain yield (Table 2). Combined effect of 0.6 t lime/ha along with application of 12 t FYM/ha resulted in significantly higher grain yield than other combinations, whereas the lowest was recorded with no application of lime with 4 t FYM. Similarly, with respect to mulching and lime, straw mulch applied with 0.6 t lime/ha recorded significantly higher grain yield than remaining combinations (Table 4). This might be owing to favourable effect of lime coupled with congenial weather condition resulted in more yields.

Total and effective rainfall-use efficiency

Total rainfall-use efficiency and effective rainfall-use efficiency were observed the maximum with mulching and the minimum under control (Table 6). Similarly, the higher total rainfall-use efficiency and effective rainfall-use efficiency were noted with liming @ 0.6 t/ha and farmyard manure @ 12 t FYM/ha. This might be owing to mulch materials work *in-situ* moisture conservation and reduce the evaporation during the cropping period

Soil health

Significantly higher *p*H and soil organic carbon (SOC) was recorded with straw mulching than the control. Mulching improved the physico-chemical properties of the soil because of its favourable effect on soil moisture conservation, carbon enrichment and nutrient addition (Sharma *et al.*, 2011). Soil *p*H, SOC, mineralizable N and available P were significantly influenced by lime up to 0.6 t/ha. An incorporation of lime in furrows significantly increased the mineralizable N, available P and K over treatment without lime in ricebean under the acidic soil of Nagaland (Kumar *et al.,* 2014). Similarly, soil *p*H, SOC, mineralizable N, available P and K were significantly in-

Table 4. Interaction effect of mulching and lime on grain yield (t/ha) in maize

Treatment	Lime (t/ha)				Mean
	Control	0.2	0.4	0.6	
Control	2.60	2.79	3.20	3.37	2.99
Straw mulch	2.61	3.19	3.68	4.45	3.48
Mean	2.61	2.99	3.44	3.91	
			SEm±	CD (P= 0.05)	
Mulches at different levels of lime			0.04	0.14	
Lime at different levels of mulches			0.09	0.29	

Table 5. Effect of mulching, lime and farmyard manures on nutrient content and their uptake by maize (pooled data of 2 years)

Treatment	Nutrient content (%)						Nutrient uptake (kg/ha)					
	N		P		K		N		P		K	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
Mulching												
Control	1.51	0.85	0.244	0.120	0.311	1.27	45.4	29.7	7.4	4.2	9.4	44.0
Mulch	1.66	0.97	0.288	0.137	0.359	1.42	59.8	42.3	10.3	6.0	12.9	60.9
SEm±	0.02	0.01	0.004	0.002	0.006	0.02	0.73	0.72	0.22	0.07	0.29	1.04
CD (P=0.05)	0.11	0.09	0.024	0.014	0.034	0.12	4.42	4.33	1.32	0.45	1.78	6.34
Lime (t/ha)												
Control	1.43	0.80	0.237	0.109	0.295	1.22	37.2	27.3	6.1	3.7	7.6	41.5
0.2	1.53	0.87	0.256	0.123	0.329	1.29	46.1	32.7	7.7	4.7	9.9	48.6
0.4	1.63	0.94	0.275	0.134	0.349	1.39	56.9	38.3	9.8	5.5	12.4	56.1
0.6	1.75	1.05	0.297	0.147	0.367	1.47	70.2	45.7	11.8	6.4	14.7	63.5
SEm±	0.02	0.01	0.003	0.001	0.004	0.01	0.67	0.70	0.16	0.06	0.20	1.00
CD (P=0.05)	0.06	0.03	0.008	0.004	0.012	0.05	2.08	2.17	0.50	0.18	0.58	3.09
FYM (t/ha)												
4	1.49	0.81	0.239	0.113	0.308	1.27	40.2	28.2	6.3	3.9	8.3	44.0
8	1.58	0.92	0.264	0.125	0.338	1.35	52.4	37.0	8.9	5.1	11.3	53.6
12	1.68	1.01	0.295	0.148	0.360	1.41	65.1	42.8	11.4	6.3	13.9	59.8
SEm±	0.01	0.01	0.002	0.001	0.003	0.01	0.49	0.60	0.15	0.05	0.17	0.68
CD (P=0.05)	0.04	0.03	0.007	0.003	0.009	0.03	1.40	1.72	0.42	0.13	0.52	1.97

Table 6. Effect of mulching, lime and farmyard manures on rainfall-use efficiency and soil properties after crop harvest (pooled data of 2 years)

Treatment	Total rainfall use efficiency (kg/ha-mm)	Effective rainfall use efficiency (kg/ha-mm)	*p*H	Soil organic crbon (%)	Mineralizable N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Mulching							
Control	10.5	12.2	5.26	0.84	199.5	14.7	174.6
Mulch	12.2	14.2	5.78	0.94	213.8	16.1	178.4
SEm±	-	-	0.07	0.01	2.50	0.28	1.76
CD (P=0.05)	-	-	0.45	0.08	NS	NS	NS
Lime (t/ha)							
Control	9.2	10.7	5.12	0.79	188.6	13.7	174.9
0.2	10.5	12.2	5.38	0.86	200.8	15.0	175.3
0.4	12.1	14.0	5.65	0.93	213.0	15.6	177.5
0.6	13.7	16.0	5.94	0.98	224.1	17.2	178.4
SEm±	-	-	0.08	0.01	6.36	0.29	1.61
CD (P=0.05)	-	-	0.24	0.03	NS	0.89	NS
FYM (t/ha)							
4	9.5	11.0	5.12	0.79	197.7	14.3	171.0
8	11.3	13.2	5.40	0.90	207.3	15.4	175.5
12	13.3	15.5	6.04	0.97	215.0	16.4	183.0
SEm±	-	-	0.05	0.01	2.37	0.24	1.47
CD (P=0.05)	-	-	0.15	0.02	6.83	0.69	4.25

fluenced with applied FYM @ 12 t/ha. Kumari *et al.* (2011) reported that application of FYM in combination with fertilizer resulted in higher organic carbon content after the crop harvest.

It was concluded that to get harvest maximum yield and net profit, maize should be grown with straw mulching along with application of lime in furrow @ 0.6 t/ha and 12 t FYM/ha under rainfed condition of North-East India.

REFERENCES

Choudhary, V.K. and Kumar, P.S. 2014. Influence of mulching on productivity, root growth and weed dynamics of maize (*Zea mays*)-based cropping systems. *Indian Journal of Agronomy* **59** (3): 364–70.

Devasenapathy, P., Ramesh, T. and Gangwar, B. 2008. *Efficiency Indices for Agriculture Management Research*. pp. 6. New India Publishing Agency, New Delhi.

Kumar, R., Chatterjee, D., Pandey, A., Roy, A. and Kumar, M. 2014. Productivity, quality and soil health as influenced by lime in ricebean cultivars under foothills of North-eastern India. *The Crop Journal* **2**: 338–44.

Kumar, M., Khan, M.H., Singh, P., Ngachan, S.V., Rajkhowa, D.J., Kumar, A. and Devi, M.H. 2012. Variable lime requirement based on differences in organic matter content of iso-acidic soils. *Indian Journal of Hill Farming* **25** (1): 26–30.

Kumar, R., Deka, B.C., Baishya, L.K., Pandey, A. and Ngachan, S.V. 2012. Effect of mulching, liming and integrated nutrient management on production potential of *rabi* maize under rainfed condition of Nagaland. (In) *Extended Summaries,* vol.2. pp. 50–51. International Agronomy Congress during 26–30 November, 2012 at New Delhi, India.

Kumari, G., Mishra, B., Kumar, R., Agarwal, B.K. and Singh, B.P. 2011. Long-term effect of manure, fertilizer and lime application on active and passive pools of soil organic carbon under maize-wheat cropping system in an alfisol. *Journal of Indian Society of Soil Science* **59**(3): 245–50.

Rao, S.S. and Shaktawat, M.S. 2002. Effect of organic manure, phosphorus and gypsum on groundnut (*Arachis hypogaea*) production under rainfed condition. *Indian Journal of Agronomy* **47**(2): 234–41.

Saha, R. and Ghosh, P.K. 2010. Effect of land configuration on water economy, crop yield and profitability under rice (*Oryza sativa*)-based cropping system in north-east India. *Indian Journal of Agricultural Sciences* **80** (1): 16–20.

Sharma, A.R., Singh. R., Dhyani, S.K. and Dube, R.K. 2010. Effect of live mulching with annual legumes on performance of maize (*Zea mays*) and residual effect on following wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **55** (3): 177–84.

Sharma, P., Abrol, V. and Sharma, R.K. 2011. Impact of tillage and mulch management on economics, energy requirement and crop performance in maize-wheat rotation in rainfed sub humid Inceptisols, India. *European Journal of Agronomy* **34**: 46–51.