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Evaluation of the Growth and Yield Performance of Maize as Influenced by Different Calcium Sources in Acid Soil

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Abstract

A field experiment was conducted in Biofuel Park, Madenur, Shanthigram hobli in Hassan district and both surface and subsurface soil were found to be acidic. Maize yield metrics were measured, including cob length, cob girth, number of grain rows per cob, number of grains per row, test weight and yield. Among the various calcium sources, application of dolomite @ 50 per cent LR along with elemental sulphur @ 100 kg/ha resulted in significantly higher cob length and girth (23.30 and 18.00 cm, respectively), followed by treatment with lime @ 50 per cent LR + Elemental S @ 100 kg/ha (22.80 and 187.00 cm, respectively) over the other treatments. The quantity of grains per row was dramatically impacted by the use of different calcium sources. The application of agricultural lime, dolomite and gypsum as calcium sources significantly raised the number of grains per row compared to the control (RDF only). Among the various calcium sources, dolomite at 50 per cent LR combined with elemental sulphur at 100 kg/ha resulted in considerably more grains per row (39.40). The use of agricultural lime, dolomite and gypsum as calcium sources boosted grain output substantially over control. Among the various calcium sources, application of dolomite @ 50 per cent LR together with elemental sulphur @ 100 kg/ha resulted in considerably greater grain yield (80.30 q ha^{-1}), followed by treatment with lime @ 50 per cent LR + Elemental S @ 100 kg/ha (72.88 q ha^{-1}) above the other treatments. The application of gypsum is intended to counteract subsoil acidity, but it also increases the availability of P and other nutrients while decreasing the toxicity of Fe, Al and Mn. In addition to neutralizing soil acidity, applied lime and gypsum may operate as a nutrient source and have been found to have an impact on maize yield characteristics.

Keywords : Acid soil, Lime requirement, Elemental sulphur, Dolomite

Maize (*Zea mays* L.) is becoming very popular cereal crop in India, because of the increasing market price and high production potential of hybrids in both irrigated as well as rainfed conditions. In India, about 50-55 per cent of total maize production is consumed as food, 30-35 per cent goes for poultry, piggery and fish meal industries and 10-12 per cent goes to wet milling industry (Arun Kumar *et al.*, 2007). The agricultural land in India spans across 9.26 million hectares and yields a total production of 23.67 million tons. Maize cultivation in Karnataka spans across 1.36 million hectares, yielding a productivity of 2921 kg per hectare (Anonymous, 2015). The best soils for maize are those that are neutral or near-neutral in pH. However, maize is grown on approximately 8 m. ha of acidic soils worldwide (Brewbaker, 1985 and Pandey & Gardner, 1992). On these soils maize yield is reduced due to Al or Mn toxicities, Ca, Mg, P and Mo deficiencies (Aldrich *et al*., 1975 and Borrero *et al*., 1995). Acid soils are also associated with phosphorus fixation because of increased iron, aluminium and manganese in the soils. All these factors contribute to severe reduction in maize crop yields (Nekesa *et al*., 2005; Dixit and Sharma, 2003).

Acid soils are base unsaturated soils having pH less than 6.5 which occur in heavy rainfall areas due to leaching of basic cations and acidic parent material. Acidic soils occupy about 44 million hectares in India and more than 12 lakh hectares in Karnataka state. Acidic soils restrict crop growth on 30-40 per cent of the world's cultivable land and up to 70 per cent of the world's land that could potentially be used for farming. These soils have low fertility because they contain excessive amounts of iron and aluminum, which are harmful minerals and lack essential nutrients such as phosphorus, calcium, magnesium and zinc.

The area affected by acidity in the world is estimated to be 3950 m ha, representing approximately 30 per cent of the total ice-free land (Sumner and Noble, 2003) and occurs in two global belts where they have developed under *udic* or *ustic* moisture regimes. The northern belt is dominated by Spodosols, Alfisols, Inceptisols and Histosols and the southern tropical belt consists largely of Ultisols and Oxisols. About 67 per cent of the acid soils support forests and woodlands and about 18 per cent are covered by savanna, prairie and steppe vegetation. Only 4.5 per cent (179 m ha) of the acid soil area across the globe is used for arable crops and another 33 m ha is utilized for perennial tropical crops (Uexkull and Mutert, 1995). Soil acidity is a major constraint for the successful production of important crop species in many parts of the world with subsurface soil acidity requiring specialized amelioration procedures (Sumner *et al.,* 1994). In severe cases, toxic levels of aluminum (Al^{3+}) or insufficient calcium (Ca^{2+}) in the acidic subsurface horizons markedly restrict or entirely prevent root proliferation and subsequent exploitation of water and nutrients (Foy, 1992).

Therefore, preventing or minimizing subsoil acidification on potentially acidic soils will be at least as important as amelioration of surface acidic soils. To achieve this, it is essential to understand the processes of subsoil acidification. Although the cause of subsoil acidification is not fully understood yet, recent studies suggest that acid production by plant roots and excess cation uptake, plays an important role in the development of subsoil acidification (Tang, 2004).

Conventional liming of the top soil may have little effect on subsoil acidity because the downward movement of lime is very slow. Such slow movement is probably a result of (i) Low solubility of lime, (ii) The consumption of OH ions released from lime by exchangeable H^+ and Al^{3+}, (iii) The reactions of OH^- ions with Fe and Al oxide minerals, which are abundant in most highly weathered soils, resulting in new adsorption sites and (iv) Lack of an accompanying anion. In cases (ii) To (iv), Ca is adsorbed onto exchange sites of the soil surface. On the other hand, deep incorporation of lime by physical means is costly and often undesirable, due to the exposure of the infertile subsoil. Thus in order to reduce the detrimental effects of subsoil acidity, specialized management strategies has been proposed which include surface incorporation of gypsum, phosphogypsum or organic manures.

In view of the above fact a study was undertaken to assess the effect of different calcium sources on growth and yield of maize in acid soil.

Material and Methods

A field experiment was conducted in acid soil having both surface and subsurface acidity at Biofuel Park, Madenur, Shanthigram Hobli of Hassan district to know the effect of different sources of calcium on growth and yield of maize in acid soil during *kharif* 2016. Physiography of the land was fairly uniform with a gentle gradient towards Southern side depicting midland. It is located in the Southern Dry Zone of Karnataka. The experiment was laid out in Randomized Complete Block Design (RCBD) with

9 treatments and 3 replications. The experimental and treatment details are as follows:

Location	:	Biofuel Park, Madenuru, Hassan
Statistical Design	:	RCBD
Number of Treatments	:	09
Number of Replications	:	03
Crop	:	Maize, Variety - Ganga Kaveri
Gross plot size	:	4.5 m × 4.8 m (21.6 m^2)
Net plot size	:	3.9 m × 3.6 m (14.04 m^2)
Spacing	:	60 cm x 30 cm
RDF	:	150:75:40 kg N, P_2O_5, K_2O ha^{-1}
Season	:	*Kharif* - 2016
Date of sowing	:	01-08-2016
Date of harvesting	:	02-12-2016

Treatment details

Treatment	Details
T_1	RDF (Control)
T_2	RDF + Lime @ 50 % LR
T_3	RDF + Lime @ 50 % LR + Elemental S @ 100 kg ha^{-1}
T_4	RDF + Dolomite @ 50 % LR
T_5	RDF + Dolomite @ 50 % LR + Elemental S @ 100 kg ha^{-1}
T_6	RDF + Gypsum @ 250 kg ha^{-1}
T_7	RDF + Gypsum @ 500 kg ha^{-1}
T_8	RDF + Gypsum @ 750 kg ha^{-1}
T_9	RDF + Gypsum @ 1000 kg ha^{-1}

*LR = Lime Requirement, FYM- common to all treatments. LR= 500 kg ha^{-1}

Five plants from each plot were randomly selected and labelled for recording growth and yield parameters at different growth stages *viz.*, 30, 60 days and at harvest stage of the crop. Growth parameters like plant height (cm), number of leaves $plant^{-1}$ and total leaf area ($cm^2 plant^{-1}$) were recorded. Yield parameters like length of five cobs was measured from the base to the tip of the cob and their average was expressed in centimetre (cm), cob girth was measured at centre of the cob by using vernier callipers and expressed in centimetres, the number of grain rows per cob and the number of grains per row was counted in each cob of five labelled plants and mean value was computed. The weight of hundred grains from five cobs was recorded and averaged and it was taken as test weight of maize and expressed in grams. At physiological maturity, cobs from each net plot were harvested separately. Cobs were de-hulled, air dried, shelled, cleaned and weighed and grain yield was worked out and expressed in quintals ha^{-1}.

RESULTS AND DISCUSSION

Plant Height (cm)

The maize plant height (cm) was influenced significantly at 60 DAS and at harvest and non-significantly at 30 DAS due to application of different calcium sources and is presented in Table 1. Application of agricultural lime, dolomite and gypsum as calcium sources increased the plant height significantly throughout the growth period over control. Increase in plant height with increase in dosage of gypsum was noticed up to 750 kg ha^{-1} and further increase to 1000 kg ha^{-1} resulted in decreased plant height non significantly. Throughout the growing period, significantly higher plant height (218.44 cm at 60 DAS and 220.10 cm at harvest) was recorded in T5 treatment (RDF + Dolomite @ 50 per cent LR + Elemental S) followed by T_3 treatment (RDF + Lime @ 50% LR + Elemental S) over control. T_3 treatment recorded a plant height of 217.90 cm at 60 DAS and 218.50 cm at harvest. The lowest (186.63 cm at 60 DAS and 190.30 cm at harvest) was recorded in treatment T_1 (RDF alone). Application of agricultural lime (T_3) and dolomite (T_5) along with elemental sulphur recorded significantly higher plant height compared to treatments without elemental sulphur (T_2 and T_4). T_2 recorded plant height of 208.30 cm at 60 DAS and 210.80 cm at harvest whereas T_4 recorded 203.37 cm at 60 DAS and 210.60 cm at harvest.

TABLE 1

Effect of calcium sources in acid soil on growth parameters of maize at different stages

Treatments	Plant height (cm)			Number of leaves $plant^{-1}$			Leaf area (cm^2 $plant^{-1}$)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1 : RDF (Control)	43.30	186.63	190.30	9.1	12.40	10.52	2450	6506.64	4373.76
T_2 : RDF + Lime @ 50 % LR	47.30	208.30	210.80	9.5	13.80	12.71	2753	7142.86	5475.75
T_3 : RDF + Lime @50 % LR + Elemental S @100 kg	49.50	217.90	218.50	8.5	14.55	13.77	3008	7593.36	5926.25
T_4 : RDF + Dolomite @ 50 % LR	47.40	203.37	210.60	9.0	13.40	12.70	2729	7107.98	5440.53
T_5 : RDF + Dolomite @ 50 % LR +Elemental S @ 100 kg ha^{-1}	46.90	218.44	220.10	8.3	15.10	13.90	2960	7680.07	6000.00
T_6 : RDF + Gypsum @ 250 kg ha^{-1}	46.40	200.73	210.30	8.6	13.90	12.53	2741	7028.24	5414.95
T_7 : RDF + Gypsum @ 500 kg ha^{-1}	47.50	211.53	214.10	9.3	13.94	12.95	2922	7336.23	5666.12
T_8 : RDF + Gypsum @ 750 kg ha^{-1}	49.80	212.83	214.50	9.3	14.10	13.44	2934	7533.89	5701.66
T_9 : RDF + Gypsum @ 1000 kg ha^{-1}	46.20	210.30	212.40	8.9	13.90	12.90	2805	7329.90	5552.82
S. Em±	2.31	0.803	0.620	0.3	0.309	0.244	204	27.681	111.545
CD (P = 0.05)	NS	2.40	1.85	NS	0.92	0.73	NS	82.98	334.41

Number of Leaves Per Plant

The number of leaves per plant was influenced significantly at 60 DAS and at harvest and non-significantly at 30 DAS due to application of different calcium sources and is presented in the Table 1. Application of agricultural lime, dolomite and gypsum as calcium sources increased the number of leaves per plant significantly throughout the growth period over control. Increase in number of leaves per plant with increase in dosage of gypsum was noticed up to 750 kg ha^{-1} (14.10 at 60 DAS and 13.44 at harvest).

Total Leaf Area (cm^2 $plant^{-1}$)

The total leaf area per plant was significantly influenced at 60 DAS and at harvest and non-significantly at 30 DAS due to application of different calcium sources and is shown in Table 1. Application of agricultural lime, dolomite and gypsum as calcium sources increased the total leaf area significantly throughout the growth period over control. Total leaf area per plant increased with increase in dosage of gypsum up to 750 kg ha^{-1} (7533.89 cm^2 $plant^{-1}$ at 60 DAS and 5701.66 cm^2 $plant^{-1}$ at harvest) and further increase to 1000 kg ha^{-1} (7329.90 cm^2 $plant^{-1}$ at 60 DAS and 5552.82 cm^2 $plant^{-1}$ at harvest) decreased the leaf area non-significantly. Throughout the growing period, significantly higher leaf area (7680.07 cm^2 $plant^{-1}$ at 60 DAS and 6000.0 cm^2 $plant^{-1}$ at harvest) was recorded in T5 treatment (RDF + Dolomite @ 50% LR + Elemental S) followed by T_3 treatment (RDF + Lime @ 50% LR + Elemental S) over control. T_3 treatment recorded total leaf area of 7593.36 cm^2 $plant^{-1}$ at 60 DAS and 5926.25 cm^2 $plant^{-1}$ at harvest. However, the lowest (6506.64 cm^2 $plant^{-1}$ at 60 DAS and 4373.76 cm^2 $plant^{-1}$ at harvest) was recorded in treatment T1 (RDF alone). Application of agricultural lime (T_3) and dolomite (T_5) along with elemental sulphur recorded significantly highest leaf area compared to without elemental sulphur T_2 and T_4 treatments. T_2 recorded leaf area of 7142.86 cm^2 $plant^{-1}$ at 60 DAS and 5475.75 cm^2 $plant^{-1}$ at harvest, whereas T_4 recorded 7107.98 cm^2 $plant^{-1}$ at 60 DAS and 5440.53 cm^2 $plant^{-1}$ at harvest.

Cob Length (cm)

The maize cob length was significantly influenced due to application of different calcium sources. Application of agricultural lime, dolomite and gypsum

TABLE 2

Effect of calcium sources on yield parameters of maize in acid soil

Treatments	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of grains per row	Test weight (g)
T_1 : RDF (Control)	17.80	15.10	14.50	27.33	28.91
T_2 : RDF + Lime @ 50 % LR	20.00	17.30	14.70	33.53	29.42
T_3 : RDF + Lime @ 50 % LR + Elemental S @100 kg	22.80	18.00	14.90	37.93	31.81
T_4 : RDF + Dolomite @ 50 % LR	19.90	17.20	14.60	31.27	29.32
T_5 : RDF + Dolomite @ 50 % LR + Elemental S @ 100 kg ha^{-1}	23.30	18.00	15.10	39.40	31.98
T_6 : RDF + Gypsum @ 250 kg ha^{-1}	19.10	16.60	14.60	29.87	29.15
T_7 : RDF + Gypsum @ 500 kg ha^{-1}	20.10	17.40	14.80	35.40	30.32
T_8 : RDF + Gypsum @ 750 kg ha^{-1}	21.10	17.90	14.90	36.20	30.35
T_9 : RDF + Gypsum @ 1000 kg ha^{-1}	20.02	17.30	14. 80	34.60	30.47
S. Em±	0.159	0.151	0.50	0.464	0.552
CD (P = 0.05)	0.478	0.453	NS	1.392	1.656

as calcium sources increased the cob length significantly over control and is presented in Table 2. Among the different calcium sources, application of dolomite @ 50 per cent LR along with elemental sulphur (T_5) recorded significantly highest cob length (23.30 cm) followed by T_3 treatment with Lime @ 50 per cent LR + Elemental S) (22.80 cm) over rest of the treatments. The lowest cob length (17.80 cm) was recorded in treatment T1 with RDF alone. Application of agricultural lime (T_3) and dolomite (T_5) along with elemental sulphur recorded significantly higher cob length compared to respective treatments without elemental sulphur (T_2 and T_4). Cob length of T_2 and T_4 were 20.00 and 19.90 cm, respectively. The cob length increased with increase in dosage of gypsum upto 750 kg ha^{-1} (21.10 cm) and further increase to 1000 kg ha^{-1} decreased the cob length to 20.02 cm.

Cob Girth (cm)

The maize cob girth was significantly influenced due to application of different calcium sources. Application of agricultural lime, dolomite and gypsum as calcium sources increased the cob girth significantly over control and is presented in Table 2. Among the different calcium sources, application of dolomite (T_5) and agricultural lime (T_3) @ 50 per cent LR along with elemental sulphur recorded significantly highest cob girth (18.00 cm) over rest of the treatments. The lowest cob girth (15.10 cm) was recorded in treatment T_1 with RDF alone. Application of agricultural lime (T_3) and dolomite (T_5) along with elemental sulphur recorded significantly higher cob girth compared to respective treatments without elemental sulphur (T_2 and T_4). Cob girth of T_2 and T_4 were 17.30 and 17.20 cm, respectively. The cob girth increased with increase in dosage of gypsum up to 750 kg ha^{-1} (17.90 cm) and further increase to 1000 kg ha^{-1} decreased the cob girth significantly to 17.30 cm.

Number of Grain Rows Per Cob

No significant differences were observed due to application of different calcium sources on number of grain rows per cob (Table 2). However, it ranged from 14.5 (RDF alone) to 15.1 (RDF + Dolomite @ 50% LR + Elemental S).

Number of Grains Per Row

The number of grains per row was significantly influenced due to application of different calcium sources. Application of agricultural lime, dolomite and gypsum as calcium sources increased the number of grains per row significantly over control and is shown in Table 2. Among the different calcium sources, application of dolomite @ 50 per cent LR along with elemental sulphur (T_5) recorded significantly higher grains per row (39.40) followed by T_3 treatment with Lime @ 50 per cent LR + Elemental S) (37.93) over rest of the treatments. The lowest grain row per cob (27.33) was recorded in treatment, T_1 with RDF alone. Application of agricultural lime (T_3) and dolomite (T_5) along with elemental sulphur recorded significantly higher grain rows per cob compared to respective treatments without elemental sulphur (T_2 and T_4). Grain rows per cob of T_2 and T_4 were 33.53 and 31.27, respectively. The grain rows per cob increased with increase in dosage of gypsum up to 750 kg ha^{-1} (36.20) and further increase to 1000 kg ha^{-1} decreased the grain rows per cob significantly to 34.60.

Test Weight (g)

Calcium sources greatly affected 100 grain weight data. Table 2 shows that calcium from agricultural lime, dolomite and gypsum raised test weight substantially over control. T_5 (dolomite @ 50% LR + elemental sulphur) had the highest test weight (31.98g), followed by T_3 (lime @ 50% LR + Elemental S) (31.81g). Treatment T_1 with RDF alone had the lowest test weight (28.91 g). Agricultural lime (T_3) and dolomite (T_5) with elemental sulphur had significantly greater test weights than T_2 and T_4. T_2 weighed 29.42 g and T_4 29.32 g. The test weight increased with gypsum dosage up to 750 kg ha^{-1} (30.35 g) and declined non-significantly to 30.47 g at 1000 kg ha^{-1}.

Grain Yield (q ha^{-1})

The effect of various treatments on grain yield is furnished in Table 3. Significant difference in grain yield of maize was observed due to application of different calcium sources at different rates. Application of agricultural lime, dolomite and gypsum as calcium sources increased the grain yield significantly over control. Among the different calcium sources, application of dolomite @ 50 per cent LR along with elemental sulphur (T_5) recorded significantly higher grain yield (80.30 q ha^{-1}) followed by T_3 treatment with Lime @ 50 per cent LR + Elemental S) (72.88 q ha^{-1}) over rest of the treatments and these two treatments were found significant difference with each other. The lowest grain yield (57.30 q ha^{-1}) was recorded in treatment T1 with RDF alone. Application of agricultural lime (T_3) and dolomite (T_5) along with elemental sulphur recorded significantly higher grain yield compared to respective treatments without elemental sulphur (T_2 and T_4). Grain yield of T_2 and T_4 were 67.60 and 63.56 q ha^{-1}, respectively. The grain yield increased with increase in dosage of gypsum up to 750 kg ha^{-1} (72.80 q ha^{-1}) and further increase to 1000 kg ha^{-1} decreased the grain yield non significantly to 70.05 q ha^{-1}.

Stover Yield (q ha^{-1})

The impact of several treatments on stover yield is provided in Table 3. Distinct variations in the amount of maize stover produced were noted as a result of utilizing various calcium sources at varying levels. Using agricultural lime, dolomite and gypsum as calcium sources boosted stover yield considerably. The stover yield was highest with dolomite @ 50 per cent LR and elemental sulphur (T_5), followed by T_3 with lime @ 50 per cent LR + Elemental S (89.63 q ha^{-1}). Both of these therapies were determined to be equivalent. Treatment T1 with RDF alone had the lowest stover yield of 75.07 q ha^{-1}. Combining agricultural lime (T_3) and dolomite (T_5) with elemental sulphur increased stover yield compared to T_2 and T_4. The stover yield of T_2 and T_4 was 81.57 and 79.27 quintals per hectare, respectively. Gypsum dose boosted stover output up to 750 kg ha^{-1} (89.46 q ha^{-1}) and thereafter dropped non-significantly to 84.06 qha^{-1}.

Harvest Index

The data regarding the harvest index is displayed in Table 3. The treatment T_5, which consisted of RDF + Dolomite at 50 per cent LR + Elemental S, had the greatest harvest index value of 0.47. This was significantly higher than the control. The treatment

TABLE 3

Effect of calcium sources on grain and stover yield and harvest index of maize in acid soil

Treatments	Yield (q ha^{-1})		Per cent increase in yield over control	HI
	Grain	Stover		
T_1 : RDF (Control)	57.30	75.07	-	0.43
T_2 : RDF + Lime @ 50 % LR	67.60	81.57	10.30	0.45
T_3 : RDF + Lime @ 50 % LR + Elemental S @100 kg	72.88	89.63	15.60	0.46
T_4 : RDF + Dolomite @ 50 % LR	63.56	79.27	6.30	0.45
T_5 : RDF + Dolomite @ 50 % LR + Elemental S @ 100 kg ha^{-1}	80.30	91.17	23.00	0.47
T_6 : RDF + Gypsum @ 250 kg ha^{-1}	58.22	75.92	0.90	0.43
T_7 : RDF + Gypsum @ 500 kg ha^{-1}	71.46	87.25	14.20	0.45
T_8 : RDF + Gypsum @ 750 kg ha^{-1}	72.80	89.46	15.50	0.45
T_9 : RDF + Gypsum @ 1000 kg ha^{-1}	70.05	84.06	12.80	0.44
S. Em±	2.31	2.67	-	0.01
CD (P = 0.05)	6.91	8.29	-	0.03

T3, which consisted of RDF + Lime at 50 per cent LR + Elemental S, had a harvest index value of 0.46, which was also significantly higher than the control. These two treatments were found to be comparable to the other treatments in terms of harvest index values. The control group had the lowest harvest index, which was measured at 0.43. The application of agricultural lime (T_3) and dolomite (T_5), in addition to elemental sulphur, resulted in a considerable improvement in the harvest index compared to treatments without elemental sulphur (T_2 and T_4).

The application of dolomite, lime and gypsum resulted in significantly increased growth and yield parameters, such as plant height, number of leaves per plant, total leaf area, cob length, cob girth, number of grain rows per cob, number of grains per row and test weight. These improvements were observed compared to the treatments that only received recommended dose of fertilizer (RDF). The use of amendments may have little impact on subsurface acidity due to the gradual downward migration of calcium and the mitigation of Fe and Al toxicity. This may also enhance the accessibility of other vital elements such as phosphorus, calcium, magnesium and zinc to the maize crop. Therefore, the treatments that underwent modifications exhibited superior grain production, stover output and harvest index compared to the other treatments.

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