Maize (*Zea mays*) Response to Phosphorus and Lime on Gas Flare Affected Soils.

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Abstract: Response of maize to phosphorus and lime was evaluated on two gas flare affected sites. The experimental design was a 2 x 2 x 4 factorial of 2 sites (S_1 and S_2), 2 P rates (0 and 30 kg P_20_5 ha^{-1}) and 4 lime rates (0, 1, 1.5 and 2.0 t ha^{-1}) in a CRD and replicated 3 times. Plant height, leaf area, dry matter yield, nutrient uptake (N and P) and residual soil properties (pH, Ca, Mg and P) increased with treatments up to 30 kg P_20_5 ha^{-1} and 1.5 t ha^{-1} lime combined rates in both sites. Maize performance and residual soil properties were better in S_2 than S_1 due its higher fertility status and distance (400 m) from the gas flare pit. Performance of all measured parameters were best using 30 kg P_20_5 ha^{-1} and 1.5 t ha^{-1} lime combined rates and hence could be the optimum rate for maize production in gas flare affected soils of the Niger Delta.
[Uzoho, B.U, G.E Osuji, E.U Onweremadu and Ibeawuchi I.I. Maize (*Zea mays*) Response to Phosphorus and Lime on Gas Flare Affected Soils. Life Science Journal 2010;7(4):77-82]. (ISSN: 1097-8135).

Keywords: maize; phosphorus; lime; Niger Delta

Introduction

Acid rain due to gas flaring is a significant source of soil acidity in the Niger Delta region of Nigeria and this also, has serious environmental effects on corrugated iron sheets.. As people (farmers) living in rural areas take water from this source, they can be harmed adversely health wise. Its effects include nutrient deficiency, toxicity of Al, Fe and Mn ions, depressed microbial activities, poor soil organic matter and low soil pH (Walna et al 2001, Isirimah et al. 2004). This manifests as poor growth, low yield and high mortality especially in crops grown close to gas flare sites (Evoh 2002). Goigi and Baruah (2001) observed that the inhibitory effect of gas flare on rice was severe 45 m to a flare site with intensity of damage increasing below 30 m. This constitutes serious threat to food security in the region, dominated by enormous gas flares and where population is high due to opportunities in the oil and gas industries.

Addition of Lime, phosphorus, gypsum and organic matter can be used to ameliorate the soil acidity (Ernani et al. 2002, White et al. 2006), with combined use of inputs being more effective. Combined application of lime and organic matter has been reported with success in Southwestern Nigeria (Busari et al 2005). Though the potentials of integrating lime and phosphorus has been reported elsewhere (Lelei 1999) its use in the Niger delta could be effective since P is often very limiting under acid conditions of tropical soils (Isirimah 2004). Effects of lime include an increase in soil pH, nutrient concentration and organic matter decomposition while phosphorus increases immediate soil P concentration by precipitating aluminum into insoluble aluminum phosphate (Lelei 1999). Presently, information concerning the combined use of lime and phosphorus to control soil acidity in the Niger Delta is scanty. The main objective of this study was therefore to evaluate the response of maize to phosphorus and lime on gas flare affected soils.

Material and Methods

Soil sample collection and laboratory analysis

Soil samples were collected at three depths (0 -15, 15 -30 and 30 -60 cm) from two sites; 1. a Typic Tropaquent (S_1) and 2. a Haplic Dystrudept (S_2) soil survey staff (1999) located less than 30 m and 400 m respectively from a gas flare pit of the Shell Petroleum development Company (SPDC) gas flow station in Egbema, Imo state. The samples were air dried, sieved through 2 mm diameter aperture and sub samples subjected to laboratory analysis. Result is presented in Table 1. Particle size distribution (Gee and Bauder 1986), organic carbon (Olsen and Sommers 1982), total nitrogen (Bremner and Malveney 1982), pH in 1: 2.5 soil/H20 ratio using a Jenway 5130 model pH meter, Exchangeable cations (Na, Ca, Mg, K, Al and H) (Juo 1981), available phosphorus (Olsen and Sommers1982) and ECEC by summation of exchangeable cations.

Pot studies

Pot studies under green house condition were conducted at the School of Agriculture, Federal University of Technology, Owerri (Lat 5^0 $21^/$ and 7^0 $15^/$) in 2005, using fine earth surface (0 -15 cm) samples from both sites. The experimental design was a 2 x 2 x 4 factorial in a CRD replicated 3 times. The factors were 2 sites; S_1 (located less than 30 m to the flare pit) and S_2 (located about 400 m to the flare pit), 2 P rates P_0 (control) and P_1 (30kg P_2O_5 ha^{-1}) as SSP and 4 lime rates; L_0 (control), L_1 (1.0), L_2 (1.5) and L_3 (2.0 t ha^{-1}) as $CaCO_3$. 10 kg soil samples of each site was weighed into separate pots (height: 25 cm and diameter: 24 cm), lime and P treatments as above, in addition to basal doses of 120 kg N ha^{-l} as urea and 30 kg K_2O ha^{-1} as muriate of potash were incorporated into the pots. A total of 48 pots were used. The soils were watered and 2 maize seeds (var. Oba super) which were later thinned to one seedling per pot, one week after planting were planted (WAP). The soils were maintained moist by watering every 4 days and the plants grown for 8 weeks. During the growth period, plant height and leaf area were measured at weekly intervals, starting from the second week after planting (WAP). Plant height was determined using a steel tape from the base to the collar of the last leaf. Leaf area was estimated by multiplying leaf length and width with 0.75 (Odiete et al 2000). Dry matter yield was determined on a balance after harvest by thoroughly washing plant material in tap water and air drying for 3 days before oven drying to constant weight at 65^0c. Plant materials were milled and P content determined after di- acid mixture (NHO_3 and $HClO_4$) digestion on a Spectronic 20 Colorimeter using vanadomybdo yellow method. Plant N was estimated after digestion with H_2SO_4 using micro – Kjeldahl distillation method. Plant N and P uptake were obtained by multiplying the dry matter weights with the plant N and P contents. Also P, Ca, Mg and pH of soils used for the experiment were analyzed using the methods for soil analysis as above. All data collected were subjected to statistical analysis using ANOVA and treatment means separated by Duncan Multiple Range Test at 5% probability.

Result and Discussions

Plant height and leaf area

Effects of treatments on plant height and leaf area are presented in Tables 2 and 3 respectively. Plant height differed significantly in the 5^{th}, 6^{th} and 7^{th} week after planting (WAP) with treatment interactions (soil/phosphorus/lime) compared to the control but not with those at the $2^{nd,}$ 3^{rd} and 4^{th} WAP. Interactions between site/phosphorus/lime significantly increased leaf area compared to the control except for S1 – 0 – 2.0, at $2^{nd,}$ 3^{rd} and 4^{th} and S1 – 30 – 0 at 2nd and 3^{rd} weeks after planting (WAP). Leaf area was generally high at all growth stages using 1.5 t ha^{-1} lime rates for the different P rates and sites. Largest leaf area occurred at S_2 irrespective of P and lime rates used. Differences in plant height and leaf area could be attributed to the effects of the treatments. Lime and phosphorus promote plant growth through improved soil conditions such as increased soil pH, nutrient availability, soil organic matter, soil solution P concentration and decreased aluminum toxicity and micronutrient accumulation (Lelei 1999, Ernani et al 2002, Busari et al 2005, White et al 2006). Superiority of S_2 over S_1 with respect to leaf area could be due to higher fertility status of the former than the later (Table 1). It could also be attributed to its distance from the flare pit. Inhibitory effect of gas flare on rice was severe 45 m and increased in intensity below 30 m to the flare site (Gogoi and Baruah 2001).

Table 1 Characterization of Gas flare affected Sites

Soil depth	Silt + Clay g/kg	TC -----	Na	K	Mg	Ca	ECEC	TN g/kg	Avail P mg/kg	OC g/kg	pH H_2O
			---------- Cmol/kg --------------								
A. S_1											
0 -15	140	LS	27.0	0.3	0.4	1.3	29.9	0.7	16.8	0.12	4.6
15 – 30	160	SL	21.7	0.3	0.2	1.0	25.7	0.6	8.1	0.12	4.4
30 – 60	220	SL	21.7	0.4	0.3	1.8	27.9	0.7	13.6	0.81	4.4
B. S_2											
0 – 15	150	LS	0.12	1.15	0.69	1.20	7.29	0.9	21.5	1.22	5.6
15 -30	190	SL	0.16	0.52	0.66	1.40	7.78	0.8	19.35	0.81	4.9
30 -60	240	SL	0.16	0.32	0.33	0.83	5.13	0.6	18.30	0.29	4.8

TN = Total nitrogen, Avail P = Available phosphorus, OC = Organic carbon,
TC = Textural class, LS = Loamy sand SL = Sandy loam

Table 2 Analysis of variance of the effect of treatments on plant height (g/pot)

Source of Variation	df	Weeks after planting					
		2	3	4	5	6	7
		F - Value					
A	1	61.06**	36.39**	90.06**	69.94**	137.87**	126.35**
B	1	35.20**	58. 51**	58.12**	67.80**	189.59**	194.36**
C	3	9.80**	9.76**	40.53**	63.32**	92.59**	97.13**
A x B	1	0.002ns	1.76ns	1.41ns	1.25ns	9.92**	9.98**
A x C	3	0.67ns	0.13ns	5.89**	3.38*	5.83**	6.67**
B x C	3	0.37ns	1.34ns	4.77**	10.03**	12.50**	13.26**
A x B x C	3	0.37ns	0.13ns	0.56ns	6.36**	3.41**	3.53**
CV (%)		8.79	12.89	10.99	10.43	10.79	10.56

** ---- Significant at 0.01, * ----- Significant at 0.05 and ns ---- Non significant.
A – Site, B --- Phosphorus and C --- Lime.

Table 3 Effect of treatment interactions on leaf area

Site	Treatments Phosphorus	Lime	Weeks after planting				
---	(kg ha^{-1})	(t ha^{-1})	2	3	4	5	7
S_1	0	0	12.07k	13.80k	14.20j	14.80r	17.36n
S_1	0	1.0	14.02j	15.70j	17.35h	18.14p	22.40m
S_1	0	1.5	15.00gh	19.40gh	22.80ef	26.23k	32.56j
S_1	0	2.0	13.00k	14.13k	16.26hj	17.53q	21.33m
S_1	30	0	13.00k	15.53jk	18.27gh	22.53n	25.30l
S_1	30	1.0	14.67hj	16.90j	19.20g	23.73n	27.97kl
S_1	30	1.5	16.20g	18.87h	24.32e	30.43j	41.23h
S_1	30	2.0	19.07e	20.77g	21.70f	25.13l	30.57k
S_2	0	0	18.20ef	53.23f	70.02d	115.17h	174.13g
S_2	0	1.0	20.47d	63.03e	98.43b	131.04d	217.40d
S_2	0	1.5	29.50b	84.13b	101.56a	139.33b	218.97d
S_2	0	2.0	28.00b	82.37c	96.73b	118.63g	214.47e
S_2	30	0	21.67d	62.67e	77.47c	119.57f	181.30f
S_2	30	1.0	25.03c	71.30d	99.53ab	136.57e	221.60c
S_2	30	1.5	33.03a	86.90a	98.83b	141.30a	241.40a
S_2	30	2.0	26.73c	83.13bc	96.40b	126.57e	224.43b

Means in a column followed by similar letters are not significantly different using Duncan multiple range test at 5% probability

Dry matter yield and Nutrient uptake

Dry matter yields and nutrient (nitrogen and phosphorus) uptake at different treatment rates are shown in Table 4. Yields increased significantly with treatment interactions compared to the control. In both sites, best yields were obtained using P and lime rates of 30 kg P_20_5 ha^{-1} and 1.5 t ha^{-1} respectively with yields in S_2 being higher than that in S_1. Depressed yield however occurred beyond these rates. Nitrogen and phosphorus uptake also followed the same trend as dry matter yield except that best P uptake in S_2 occurred at the highest P (30 kg P_20_5 ha^{-1}) and lime (2.0 t ha^{-1}) rates. Increased yield and N and P uptake with lime and P fertilizers have been reported by other workers (Newton and Valdinei1997, Lelei 1999, Busari et al 2005). This has been attributed to better soil amelioration by the amendments (Miranda and Rowell 1987). Sharma et al (2000) observed increased root volume, root mass density and root length due to phosphorus which enhanced nutrient especially P uptake, thereby significantly promoting the productivity of wheat in terms of dry matter and grain. Yields. Depressed yields and nutrient uptake after rates of best dry matter yield has been attributed to nutrient imbalance and over liming (Kogbe and Adediran 2003, Busari et al 2005). Higher yields and nutrient uptake in S_2 than S_1, could be related to the fertility soil status of the sites (Table1) and also to poor physico – chemical properties of S_1 over S_2. Poor physico – chemical properties have been reported on soils less than 100 meters to a gas flare site (Uzoho 2005).

Residual soil properties

Interaction of treatments on residual soil properties (Table 5) shows an increase in soil properties; soil pH, exchangeable Ca, Mg and available P with treatments compared to the control. For instance best pH in S_1 and S_2 were an increase of 3.4 and 1.9 units respectively over the control and occurred at the highest P and lime rates (30kg ha^{-1} P_20_5 and 2.0 tha^{-1} lime), just as soil P, Ca and Mg (S_2) Highest Mg in S_1 was at P and lime rates of 30kg P_20_5 ha^{-1} and 1.5 t ha^{-1} respectively. Increased soil pH, Ca, Mg and P due to lime and phosphorus has been reported by others and attributed to the effect of applied treatments (Ernani et al 2002, White et al. 2006). According to Lelei (1999), the raised soil pH after liming and application of phosphorus, enhanced the decomposition of organic matter and mineralization of N and P. Liming also encouraged the formation of calcium phosphates, increased mineralization of organic phosphate and consequent availability of phosphorus (Miranda and Rowell 1987). As expected the increase was better in S_2 than S_1.

Table 4 Mean dry matter yield, Nitrogen and phosphorus uptake as affected by treatment interactions.

Site	Treatments P	Lime ($t\ ha^{-1}$)	Dry matter yield g/pot	Nitrogen g/kg	Phosphorus mg/kg ($kg\ ha^{-1}$)
S_1	0	0	0.68m	0.005j	0.14j
S_1	0	1.0	1.26k	0.008j	0.37h
S_1	0	1.5	2.26g	0.022g	0.56g
S_1	0	2.0	1.51h	0.013h	0.39h
S_1	30	0	1.42j	0.037f	0.41gh
S_1	30	1.0	2.54f	0.098e	0.99f
S_1	30	1.5	3.16d	0.158c	1.30f
S_1	30	2.0	2.22g	0.153c	0.91f
S_2	0	0	1.48h	0.015h	0.44gh
S_2	0	1.0	2.62e	0.049f	1.06f
S_2	0	1.5	3.55b	0.116d	3.85e
S_2	0	2.0	3.24c	0.097e	4.41cd
S_2	30	0	1.13l	0.111d	4.26d
S_2	30	1.0	3.21c	0.160c	4.83c
S_2	30	1.5	6.27a	0.374a	12.98b
S_2	30	2.0	3.24c	0.201b	13.45a
LSD (0.05)			0.06	0.13	0.08

Means in a column followed by similar letters are not significantly different using Duncan multiple range test at 5% probability.

Table 5 Effect of treatment interactions on residual soil properties (pH, Ca, Mg and P)

Site -----	Treatments Phosphorus Kg P_20_5 ha^{-1}	Lime t ha^{-1}	pH H_20	Soil properties Ca ---- Cmol/kg ----	Mg mg/kg	P
S1	0	0	4.6n	0.5h	0.1e	9.41i
S1	0	1.0	4.7n	0.7g	0.2e	14.e
S1	0	1.5	5.9k	0.9fg	0.3e	16.4h
S1	0	2.0	6.6h	1.1ef	0.2e	18.7d
S1	30	0	6.8g	1.2def	0.3e	20.4c
S1	30	1.0	7.1f	1.3cde	0.5d	21.2ab
S1	30	1.5	7.5d	1.3cde	1.8a	21.6ab
S1	30	2.0	8.0b	1.5bcd	1.0c	22.2a
S2	0	0	5.2m	0.7g	0.1e	13.7j

S2	0	1.0	5.4l	0.9fg	0.3e	14.4g
S2	0	1.5	6.4j	1.2def	0.3e	14.5g
S2	0	2.0	6.9g	1.4cde	0.3e	15.3gh
S2	30	0	7.3e	1.5bcd	0.4de	16.4g
S2	30	1.0	7.7c	1.6abc	0.4de	17.3f
S2	30	1.5	8.1b	1.8ab	0.9c	18.2e
S2	30	2.0	8.3a	1.9a	1.4b	18.9d
LSD (0.05)			0.14	0.20	0.19	0.75

Means in a column followed by similar letters are not significantly different using Duncan multiple range test at 5% probability

Conclusion

Acidity in the soils is a serious health and environmental problem being higher in S_1 (less than 30 m to a flare pit than S_2 (about 400 m to flare pit). Integration of lime and phosphorus improved soil conditions through increase in plant height, leaf area, dry matter yield, nutrient uptake (N and P) and soil properties (pH, Ca, Mg and P). S_2 was generally better than S_1. In both sites (S_1 and S_2) combinations of 30 kg P_20_5 ha^{-1} and 1.5 t ha^{-1} lime rates gave best performance in all the measured parameters and could be optimum rate for maize production in the soils. Farmers living in this area should be given good sources of irrigation and drinking water.

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9/10/2009