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Short Communication

Influence of Organic and Inorganic Soil Amendments on Corn Root Growth and Soil Chemical Properties

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ABSTRACT

One of the main constraints to corn production on a highly weathered acid soil is aluminium (Al) toxicity. High Al concentration in acid soils restricts root growth by inhibiting cell elongation and cell division. The objective of this study was to determine the effects of inorganic and organic soil amendments on corn root growth and soil chemical properties. A laboratory experiment was conducted using Bungor series soil (Typic Paleudult) surface sampled (0 - 20 cm) from Puchong farm. Aliquot of the soil (600 g) was treated with legume residues (1% w/w), chicken manure (1% w/w), GML (4 t ha^{-1}), gypsum (4 t ha^{-1}) and control. The treated soils were moistened at field capacity (0.25 kg H_2O kg^{-1} soil) and allowed to react for 7 days. Corn seeds (*Zea mays* L.) were sown and after 5 days root length was measured. The results showed that soils amended with GML or chicken manure gave relatively high root length compared to other treatments. The GML and chicken manure treatments increased soil pH and decreased both the soil exchangeable Al and Al-saturation. Chicken manure had an additional ameliorative effect over lime in that it increased soil exchangeable Ca, Mg and K.

Keywords: aluminium, lime, chicken manure, acid soils, corn, amendments

INTRODUCTION

Grain corn is one of the most important food crops for animal feed industries. A large amount of the grain corn used in animal feed in Malaysia is imported. In 1993, the total import value of grain corn consumption in Malaysia was RM661 million. The total import value has increased to nearly RM1 billion (Yearbook of Statistics Malaysia 1996). Large amounts of ringgit have been spent annually to buy grain corn. Therefore, it is important for Malaysia to produce grain corn to reduce the import bill as well as for food security.

Approximately 72% of the land area of Malaysia consists of Ultisols and Oxisols soil orders. These soils are highly weathered, acidic, high in Al-saturation and low in both basic cations and cation exchange capacity. Aluminium toxicity appears to be the major constraint to corn production on these soils (Foy 1984). High Al concentration in soil restricts root growth by inhibiting root cell elongation and cell division (Marschner 1991). Aluminium toxicity is commonly overcome through liming as lime precipitates Al^{3+} into $Al(OH)_3$. Recently, many studies have been focusing on using organic

matter as a soil amendment for alleviating Al toxicity (Bessho and Bell 1992; Hue 1992; Harper *et al.* 1995). One advantage of using organic residues (waste) such as chicken manure or waste products from palm oil factories is solving the environmental pollution or disposal problem. The objective of this study was to determine the effects of inorganic and organic soil amendments on corn root growth and soil chemical properties.

MATERIALS AND METHODS

A laboratory experiment was conducted using Bungor Series (Typic Paleudult). The soil was sampled in bulk at a depth of 0 - 20 cm from Puchong farm, Universiti Putra Malaysia. The sampled soil was air-dried and crushed to pass through a 2.0-mm screen. The initial chemical properties of the soil are shown in Table 1. Soil samples (600 g) were treated with either organic or inorganic amendments. The total five treatments were: addition of legume residues (1% w/w), chicken manure (1% w/w), ground magnesium limestone

TABLE 1
Selected chemical properties of Bungor soil

Soil Parameters	
[+]pH	3.9
[++]EC	0.085 mmho cm^{-1}
[a]Exchangeable cations	— cmol(+)kg^{-1} —
Ca	0.27
Mg	0.14
K	0.23
CEC	8.89
[s]Al	1.37
[m]Micronutrients	— µg g^{-1} —
Fe	126.52
Mn	2.33
Cu	0.40
Zn	2.35

[+] pH was measured in 0.01M $CaCl_2$ at 1:1 soil to solution ratio.
[++] Electrical conductivity was determined in 1:1 soil to water ratio.
[a]Exchangeable cations and CEC were determined by leaching with 1 M NH_4OAc at pH 7.
[s]Exchangeable Al was determined by extraction with 1M KCl (Kamprath 1970).
[m]Micronutrients were determined by double acid method (Baker and Amacher 1982).

TABLE 2
Selected chemical analysis of the organic residues (dry weight basis)

Organic residues	Total [+]N (%)	C (%)	C/N	cmol(+) kg^{-1}			$\mu g\ g^{-1}$				[$] pH_w
				Ca	Mg	K	Fe	Mn	Cu	Zn	
Legume	1.7	85.3	50	0.48	1.37	1.0	526.3	31.7	9.3	232.7	5.8
Chicken	2.1	67.3	32	5.08	0.89	2.2	1483.3	365.0	210.8	515.8	8.0

[+]Nitrogen concentration was obtained by wet digestion method in concentrated H_2SO_4 (Jones *et al.* 1991).
[$]Other elements in the legume and non-legume were digested by dry ashing at 550°C and chicken dung was dissolved in dilute aqua regia (300 ml HCl and 100 ml HNO_3) (Jones *et al.* 1991).
[%]PH_w was measured in water at 1:1 organic residue to solution ratio.

(4 t ha^{-1}), gypsum (4 t ha^{-1}) and control. The chemical analysis of the organic residues used in this experiment is shown in Table 2. The treatments were arranged in a randomized complete block design and replicated four times. The treated soils were mixed thoroughly and placed in plastic mineral bottles covered with black cardboard to shelter the roots from direct sunlight. The soil samples were moistened to field capacity (0.25 kg H_2O kg^{-1} soil) with distilled water and allowed to react with the amendments for 7 days. After the incubation, two seeds of corn were sown in each sample and allowed to grow for 5 days under shade in the laboratory. After the growing period, corn roots were removed from the bottles and root lengths were recorded. Immediately after the root sampling, the soils were air-dried and ground to pass through a 2.0-mm screen. The soil samples were analysed for pH, electrical conductivity (EC) and soil exchangeable Al, Ca, Mg and K.

RESULTS AND DISCUSSION

Effect of Soil Amendments on Corn Root Length

The effects of inorganic and organic amendments on acid Bungor soil showed a significant increase on corn root length over the control (*Fig. 1*). The longest roots were observed for the GML treatment, followed by that of the chicken manure (CM). The corn root length in the soils treated with legume residue (LR) and gypsum were relatively similar. Plants with better root proliferation are of paramount importance, especially for nutrient absorption and to tap reserved underground moisture during water stress. Soil pH and exchangeable Al were the factors believed to control the root length of corn. This can be clearly seen from data of correlation analysis in Table 3. Root length was highly correlated with soil pH and exchangeable Al. No relationship was observed between root weight and soil parameters. Soil pH is the major factor

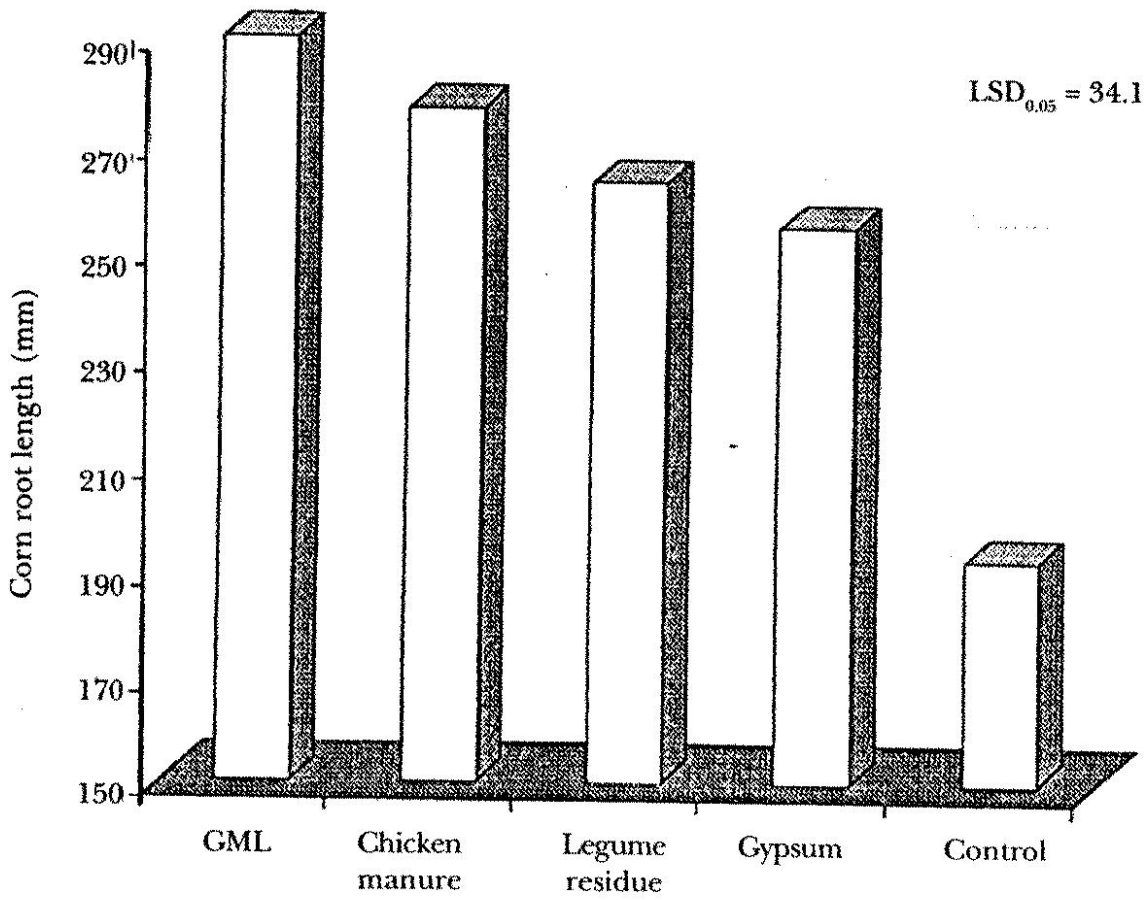

Fig. 1. Effects of soil amendments on corn root length

TABLE 3
Correlation between corn roots and soil parameters

Soil Parameters	Root Length	Root Weight
	r-values	
EC	0.25^{ns}	0.20^{ns}
pH	0.61**	0.25^{ns}
Al	–0.65**	–0.34^{ns}
Ca	0.36^{ns}	0.40^{ns}
Mg	0.53**	0.25^{ns}
K	0.30^{ns}	0.01^{ns}

(** - significant at $p < 0.01$)

controlling toxic Al^{3+} species (Kinraide 1991). In other words, lower soil pH causes more Al^{3+} to be solubilized, while higher pH precipitates Al^{3+} in the form of $Al(OH)_3$.

Effect of Soil Amendments on Soil Chemical Properties

The data in Table 4 show that soil treated with GML had the highest pH (5.3), followed by soil treated with chicken manure (5.0). The high pH values in these treatments resulted in reduction of exchangeable Al and Al-saturation. The Al-saturation for the two treatments was 4% compared to 76% for the control. Aluminium saturation of < 15% is favourable for corn growth (Kamprath 1970). The result shows that chicken manure is a good alternative to lime in reducing Al-saturation. A similar observation where chicken manure increased soil pH and inactivated soil Al has been reported by Hue (1992). However, no data were available on the longevity effect of chicken manure in reducing the soil exchangeable Al as compared to lime. Shamshuddin *et al.* (1998) showed the beneficial effects of liming on acid soils with ground magnesium limestone at 4 t ha^{-1} were observed for about eight years. Amending the soil with legume residue or gypsum only partially reduces Al-saturation.

The application of inorganic and organic amendments increased soil EC and exchangeable Ca and Mg (Table 4). The highest increase in EC and exchangeable Ca were shown in soils treated with chicken manure, while that for exchangeable Mg was in soil amended with GML. Chicken manure and legume residue increased soil exchangeable K while no significant increase was observed in the GML and gypsum treated soils compared to the control. The results indicate that additional ameliorative effects of amending acid soil with chicken manure are increases in exchangeable K, Ca and Mg and pH.

TABLE 4
Effects of soil amendments on soil pH, electrical conductivity (EC) and exchangeable soil cations

Treatments*	Soil pH	EC	Al	Ca	Mg	K	Al-saturation
	pH	mmho cm^{-1}		cmol(+) kg^{-1}			(%)
GML	5.3	0.5	0.20	3.02	1.63	0.05	4
CM	5.0	1.5	0.24	4.58	1.18	0.16	4
LR	4.8	0.4	0.93	1.34	0.38	0.14	33
Gypsum	4.2	0.9	1.37	3.70	0.24	0.05	26
Control	4.1	0.1	2.43	0.46	0.15	0.04	76
$LSD_{0.05}$	0.1	0.1	0.04	0.40	0.06	0.02	2

*GML = Ground magnesium limestone; CM = Chicken manure; LR = Legume residue

CONCLUSION

The study indicates that chicken manure has an ameliorative effect similar to lime. In addition, it increases the Ca, Mg and K concentrations in soil. Nevertheless, further research should be carried out to ascertain the longevity effect of chicken manure in reducing soil exchangeable Al as compared to lime.

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