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Identification of Nutrient Deficiencies at Calcareous Soils for Maize

Dedi Nursyamsi[1]

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ABSTRACT

Identification of nutrient deficiencies at calcareous soils for maize (D Nursyamsi): A pot experiment was conducted to identify nutrient deficiencies at calcareous soils for maize (*Zea mays*, L.) in green house of Indonesian Soil Research Institute using top soil (0-20 cm) samples taken from Bogor (Typic Hapludalfs) and Blora (Typic Haplustalfs). The experiment used Randomized Completely Block Design, minus one test with 12 treatments and three replications, as well as maize of P21 variety as plant indicator. The results showed that use of N, P, K, Zn, Cu, Fe, and Mn fertilizers increased soil macro nutrients, *i.e.*: soil total-N, Olsen-P, HCl-P, and HCl-K, as well as soil micro nutrients, *i.e.:* soil DTPA-Zn, Cu, Fe, and Mn at both tested soils. Use of maize straw compost increased soil organic-C, total-N, HCl-K, and exchangeable Ca at Typic Hapludalfs and increased only soil organic-C and total-N at Typic Haplustalfs. Use of animal manure compost increased soil organic-C, exchangeable Ca and Mg, and CEC. Use of N, P, K, S, Zn, Cu, Fe, and Mn fertilizers increased each plant nutrients uptake at the soils. Use of both organic matters increased plant N, P, K, and Fe uptake at Typic Hapludalfs as well as increased only plant N, P, and K uptake at Typic Haplustalfs. Identification result showed that maize growth suffered from N, P, and K deficiencies at Typic Hapludalfs as well as N and P deficiencies at Typic Haplustalfs. Beside the nutrients, soil organic matter was also found out as limiting factor for maize growth in the soils.

Keywords: Calcareous soils, maize, nutrient deficiency

INTRODUCTION

Plant growth depends on a favorable combination of several environmental factors, such as: light, mechanical support, heat, air, water, and nutrients. Except for light, soil can provide these factors to the plant. The best combination of these factors will provide growth and maximum crop yields. If one of these factors is not optimal then the factor will limit plant growth or in other words the plant growth can not increase higher without improving the limiting factor. This phenomenon is called the law of the minimum (Brady 1984). Among the factors of plant growth, the nutrient is often to become the most problem for optimal crop yields.

Acid soils (Inceptisols, Ultisols, and Oxisols) generally have a limiting factor, such as: deficiency of N, P, K, Ca, and Mg nutrients, and toxicity of Al and Fe. In addition, the soils generally have a low cation exchange capacity (CEC), so that the potential of leaching cation (K^+, NH_4^+, Ca^{2+}, and Mg^{2+}) is high. Meanwhile, neutral and alkaline soil (Alfisols, Molisols, and Vertisols) typically have limiting factors, such as: deficiency of N, P, and K nutrients as well as micro nutrients such as Fe, Cu, and Zn (Brady 1984; Havlin *et al*. 1999). Similarly, low soil organic matter often limits plant growth on soils in tropical regions, including Indonesia.

Calcareous soils, such as Mediteran (Alfisols) and Renzina (Molisols) soils have a wide distribution in Indonesia, ie each approximately 5,153 million ha and 9,913 million ha respectively. Alfisols spread in West Java, Central Java, East Java, West Nusa Tenggara, North Sulawesi, Central Sulawesi, South Sulawesi and Maluku, while Molisols spread in West Java, East Java, East Nusa Tenggara, East Kalimantan, Central Sulawesi, Southeast Sulawesi, Maluku and

[1]Indonesian Agricultural Environment Research Institute. Jl. Raya Jakenan-Jaken Km 05, PO Box 05, Jakenan, Pati 59162, Central Java, INDONESIA. E-mail: ddnursyamsi@yahoo.com.

Papua (Pusat Penelitian Tanah and Agroklimat 2000). Both soils are generally used for rainfed rice, upland crops (gogo rice, maize, soybeans, and green beans), upland (maize, cassava, and pecan), and sugar plantations, tobacco, and clove (Subagyo *et al*. 2000).

Alfisols are generally high in clay content (35-85%), neutral to alkaline in soil reaction (pH = 6.1-7.3), moderate to high in bases and CEC, and moderate to very high in base saturation (BS). Organic matter content of the topsoil is generally moderate to high, but its content of subsoil is low to very low. Similarly, potential P and K contents generally are moderate in topsoil and very low in subsoil. Meanwhile Molisols have a loamy to clay texture with clay content about 15-45%. Its soil reaction is rather acid to neutral with pH about 5.6-7.3. The other soil characteristics, such as: soil bases, CEC, organic matter, P and K content are relatively similar with those of Alfisols (Subagyo *et al*. 2000).

Identification of nutrient deficiencies for plant growth is one of the stages of soil test that must be carried out to develop site-specific fertilizer recommendation. Besides, these activities are also needed to determine the appropriate soil management technology. By knowing the factors that limits plant growth on a soil type, we can determine the appropriate treatment to improve soil productivity.

Given importance of nutrients for plant growth or adequacy of the fulfillment of nutrient for plants is a very important factor in the cultivation of agricultural crops. This can be achieved with the best when the cultivation considers the soil nutrient balance. Considering the above mention, it is needed to be done on the research aimed to identify nutrient deficiencies at calcareous soils for maize.

MATERIALS AND METHODS

Experiments were conducted in the Laboratory of Research and Soil Test and in Greenhouse of Indonesian Soil Research Institute, Bogor by using two bulk topsoil samples (0-20 cm) taken from Jonggol (Bogor) and Todanan (Blora). Sampling the soils based on the Soil Map of West Java and Central

Table 1. The properties of the topsoil (0-20 cm) samples taken from experiment locations.

Soil properties	Method/extraction	Typic Hapludalfs	Typic Haplustalfs
Teksture	Pipette		
Sand (%)		26	48
Silt (%)		32	27
Clay (%)		43	25
pH	H_2O (1:2.5)	5.47	7.01
	KCl 1 *N* (1:2.5)	4.01	6.24
Organic matter			
Org-C (g kg^{-1})	Kurmies	10.60	11.30
Total-N (g kg^{-1})	Kjedahl	1.20	1.00
C/N		9	13
Potential P dan K	HCl 25%		
P_2O_5 (mg kg^{-1})		1,780	1,480
K_2O (mg kg^{-1})		300	1,870
Available P (mg P_2O_5 kg^{-1})	Olsen	0.65	5.01
Cation	NH_4OAc 1 *N* pH 7		
Exch. Ca (Cmol(+) kg^{-1})		11.96	13.01
Exch. Mg (Cmol(+) kg^{-1})		2.22	0.95
Exch. K (Cmol(+) kg^{-1})		0.11	0.35
Exch. Na (Cmol(+) kg^{-1})		0.16	0.38
CEC (Cmol(+) kg^{-1})	NH_4OAc 1 *N* pH 7	24.97	13.98
Base Saturated (%)		58	> 100
Acidity	KCl 1 *N*		
Exch. Al (Cmol(+) kg^{-1})		5.00	0.00
Exch. H (Cmol(+) kg^{-1})		0.55	0.19

Table 2. The properties of organic matter derived from maize straw and animal manure compost.

Analysis	Method/extraction	Unit	Maize straw compost (OM1)	Animal manure compost (OM2)
Macro nutrients	Wet destruction			
N	H_2SO_4	g kg^{-1}	11.42	17.47
P	HNO_3 and $HClO_4$	g kg^{-1}	1.23	5.04
K	HNO_3 and $HClO_4$	g kg^{-1}	14.11	4.70
Ca	HNO_3 and $HClO_4$	g kg^{-1}	3.47	17.58
Mg	HNO_3 and $HClO_4$	g kg^{-1}	1.57	3.36
S	HNO_3 and $HClO_4$	g kg^{-1}	1.90	12.88
Micro nutrients	Wet destruction			
Fe	HNO_3 and $HClO_4$	mg kg^{-1}	327	8788
Mn	HNO_3 and $HClO_4$	mg kg^{-1}	369	684
Cu	HNO_3 and $HClO_4$	mg kg^{-1}	3	19
Zn	HNO_3 and $HClO_4$	mg kg^{-1}	14	106

Java Scale 1:250.000 (Lembaga Penelitian Tanah, 1966). Both soils have the same parent materials, namely limestone but agro-climate zone according to Oldeman (1975) is different, which is B1 (wet) and C2 (dry) for Bogor and Blora respectively.

The soil classification according to Lembaga Penelitian Tanah (1966) is the Mediteran, while based on a description of the soil profile in the field is Typic Hapludalfs, smooth, smectitic, isohiperthermic and Typic Haplustalfs, soft, chalky, mixed, semi-active, isohiperthermic for soil in Bogor and Blora respectively (Soil Survey Staff 1998). The results of preliminary analysis of both soil samples are presented in Table 1, while more detailed about soil chemical and mineralogical properties have been reported by Nursyamsi *et al.* (2007).

Experiments also used organic matter derived from maize straw (OM1) and animal manure (OM2) compost. The results of the analysis of organic matter are presented in Table 2. Further research carried out through 2 series of activities, *i.e.* a pot experiment in a greenhouse as well as soil and plant analysis in the laboratory.

Pot Experiments

Pot experiment in a greenhouse used the minus one test method, namely the complete nutrient treatment (N, P, K, S, Zn, Cu, Fe, and Mn) and complete nutrient treatments minus one of the nutrients. Addition of organic matters derived from maize straw (OM1) and animal manure (OM2) compost were also used to supplement the nutrient treatment. Nutrients of Ca and Mg were not tested because the nutrient levels in the soils are high so that no opportunity to be limiting plant growth. The dosages of each nutrient and organic matters tested were presented in Table 3.

Bulk soil samples were air-dried, ground, and sifted with a 2 mm sieve. Further each was weighed 1 kg absolute dry weight (105^{o}C) and inserted into a 1-gallon pot that has been labeled. Organic matters of maize straw and animal manure were firstly composted and mixed with the soils about 7 days before planting. All the inorganic fertilizers were made in the form of solution and given into the soil about 3 days before planting. The soils then were homogenized and the water content was maintained around field capacity by providing sufficient deionized water. Maize seeds of Pioneer-21 varieties (P21) which has been tested viability were buried into the soils 3 seeds pot^{-1}. Later at the age of the plant 1 week after planting (WAP), the plants were made to become 2 seeds pot^{-1}.

Observations were made of (1) Plant height and leaves number as well as wet and dry weight of plant shoots at the age of plant of 4 WAP, (2) Plant macro nutrient (N, P, K, and S) and micro nutrient (Zn, Cu, Fe, and Mn) uptake, as well as (3) Soil properties after harvest, ie: soil organic C and N as well as soil P, K, Ca, Mg, CEC, Zn, Cu, Fe, and Mn. Plants were harvested at the age of plant of 4 WAP by cutting the base of the plant, cleaned with deionized water,

Table 3. Experimental treatment of minus one test in a greenhouse.

Treatments	N	P	K	S	Zn	Cu	Fe	Mn	Organic matter
	………………………...……….. mg kg^{-1} ……………………………………								
Control	-	-	-	-	-	-	-	-	-
C + OM1	300	200	100	50	5	5	5	5	5000
C + OM2	300	200	100	50	5	5	5	5	5000
C (Complete)	300	200	100	50	5	5	5	5	-
C - N	-	200	100	50	5	5	5	5	-
C - P	300	-	100	50	5	5	5	5	-
C - K	300	200	-	50	5	5	5	5	-
C - S	300	200	100	-	5	5	5	5	-
C - Zn	300	200	100	50	-	5	5	5	-
C - Cu	300	200	100	50	5	-	5	5	-
C - Fe	300	200	100	50	5	5	-	5	-
C - Mn	300	200	100	50	5	5		-	-

weighed, and put into the oven at 70 °C temperature for 48 hours or until constant dry weight. Then, the plant samples were ground and put into labeled plastic bags so ready to be analyzed. Soil samples from each pot were cleaned from root residues, homogenized, and taken about 150 g for analysis in the laboratory.

Soil and Plant Analysis

Soil properties before the experiment included: soil texture of three fraction (pipette), H_2O and KCl pH (pH meter), organic-C (Kurmies), total-N (Kjedahl), P (HCl 25% and Olsen), K (HCl 25%), exchangeable cations, ie: Ca, Mg, and K (1 *N* NH_4OAc pH = 7), CEC (1 *N* NH_4OAc pH = 7), base saturation, as well as soil acidity, namely: exchangeable Al and H (KCl 1 *N*). While the analysis of soil samples after the pot experiment included: soil organic-C (Kurmies), total-N (Kjedahl), P (HCl 25% and Olsen), K (HCl 25%), exchangeable cations, ie: Ca, Mg, and K (1 *N* NH_4OAc pH = 7), CEC (1 *N* NH_4OAc pH = 7), base saturation, soil acidity, namely: exchangeable Al and H (1 *N* KCl), as well as soil micro-nutrient content, namely: soil Zn, Cu, Fe, and Mn (DTPA).

Plant macro-nutrient (N, P, K, and S) content as well as plant micro-nutrient (Zn, Cu, Fe, and Mn) content were established after one g of plant samples was digested with concentrated H_2SO_4 (for determination of N) and a mixture of concentrated HNO_3 and $HClO_4$ (for determination other than N). Furthermore the extraction was adjusted using deionized water up to 50 mL. Determination of N is done with semi-micro Kjedahl, P with vanado-molybdate yellow, S with spectrophotometry, while K, Zn, Cu, Fe, and Mn with atomic absorption spectrophotometry (AAS) method.

RESULTS AND DISCUSSION

Soil Properties

Effect of complete fertilizer (N, P, K, S, Zn, Cu, Fe, and Mn) and organic matter on soil properties of each soil were presented in Table 4. Complete fertilizer increased the soil total-N, Olsen-P, and HCl-P in both Typic Hapludalfs and Typic Haplustalfs. Soil total-N increased about 29% and 46% at Typic Hapludalfs and Typic Haplustalfs respectively. Similarly, soil Olsen-P increased significantly about 2,500% and 400% as well as soil HCl-P increased about 223% and 203% at Typic Hapludalfs and Typic Haplustalfs, respectively (Table 4).

Use of organic matter from maize straw compost increased soil organic-C, total-N, HCl-K, and exchangeable Ca at Typic Hapludalfs as well as increased only soil organic-C and total-N at Typic Haplustalfs. Soil organic-C content increased by about 18% and 17% at Typic Hapludalfs and Typic Haplustalfs, respectively. Similarly, soil total-N increased by approximately 77% and 16% at Typic Hapludalfs and Typic Haplustalfs, respectively. Meanwhile, soil HCl-K increased approximately 33% and exchangeable Ca approximately 16% at Typic Hapludalfs (Table 4).

Use of organic matter from animal manure compost increased soil organic-C, exchangeable Ca

Table 4. Effect of complete fertilizer and organic matter on soil properties after harvest at Typic Hapludalfs and Typic Haplustalfs.

Treatments	Kurmies	Kjeldahl	Olsen	HCl 25%		NH_4OAc 1 *N* pH 7			
	C	N	P_2O_5	P_2O_5	K_2O	K	Ca	Mg	CEC
	........($g\ kg^{-1}$).........		.........($mg\ kg^{-1}$).........			..........(Cmol(+) kg^{-1}).........			
Typic Hapludalfs									
Control	12.30	1.70	4	176	14	0.15	14.71	2.54	29.68
Complete	12.20	2.20	104	569	12	0.11	15.11	2.50	29.23
Complete + OM1	14.40	3.90	102	581	16	0.12	17.49	2.39	27.65
Complete + OM2	14.00	2.40	98	555	12	0.13	16.85	2.81	30.56
Typic Haplustalfs									
Control	13.00	1.30	32	149	54	0.26	15.50	0.68	14.80
Complete	12.80	1.90	159	452	52	0.24	17.11	0.45	14.30
Complete + OM1	15.00	2.20	155	465	50	0.24	17.52	0.52	14.13
Complete + OM2	14.70	2.10	163	512	52	0.24	16.48	0.56	16.94

and Mg as well as soil CEC at Typic Hapludalfs, while at Typic Haplustalfs, the organic matter improved soil organic-C, HCl-P, exchangeable Mg, and CEC. Soil organic-C content increased by about 15% at both soils. Soil exchangeable Ca increased approximately 12% as well as soil CEC increased approximately 5% and 18% at Typic Hapludalfs and Typic Haplustalfs respectively. Meanwhile, soil HCl-P increased by about 13% as well as soil exchangeable Mg increased approximately 24% at Typic Haplustalfs (Table 4).

Effect of minus one test treatment on soil nutrient content after harvest in both tested soils was presented at Table 5. The table showed that soil nutrient content at the treatment without using the nutrient was lower than nutrient treatments at both soils except soil total-N, exchangeable K, and DTPA-Cu at Typic Hapludalfs as well as soil HCl-K at Typic Haplustalfs. Soil Olsen-P and HCl-P at minus P treatment; soil DTPA-Cu at minus Cu treatment; soil DTPA-Fe at minus Fe treatment; and soil DTPA-Mn at minus Mn treatment at Typic Hapludalfs were lower than those at the complete fertilizer treatment. Similarly at Typic Haplustalfs, soil total-N at minus N treatment; soil Olsen-P and HCl-P at minus P treatment; soil DTPA-Zn at minus Zn treatment; soil DTPA-Cu at minus Cu treatment; soil DTPA-Fe at minus Fe treatment; and soil DTPA-Mn at minus Mn treatment were lower than those at complete fertilizer treatment (Table 5).

Use of a complete fertilizer improved the availability of soil nutrients needed by plants. Use of the fertilizers aimed to increase the availability of soil nutrients, especially the nutrient with low content in the soils, such as N, P, and K nutrients. At Typic Hapludalfs, soil total-N, Olsen-P, and exchangeable K was 1.20 $g\ kg^{-1}$, 0.65 mg $P_2O_5\ kg^{-1}$, and 0.11 Cmol(+) kg^{-1}, respectively. At Typic Haplustalfs each content was 1.00 $g\ kg^{-1}$, 5.01 mg $P_2O_5\ kg^{-1}$, and 0.35 Cmol(+) kg^{-1} for N, P, and K nutrient respectively (Table 1). Organic matter supplied to the soil was a source of soil organic C and N (Table 2). Similarly, decomposition of organic matter would produce organic acids which would result negative charge if the acids were dissociated (Tan 1998). As a result the use of organic matter into the soil could increase those variables. Addition of organic matter was also a source of nutrients K and Ca so that the soil K and Ca also increased. The content of K and Ca in maize straw compost was 14.11 and 3.47 $g\ kg^{-1}$, respectively as well as the content of both nutrients in animal manure compost was 4.70 and 17.58 $g\ kg^{-1}$, respectively (Table 2).

Plant Nutrient Uptake

Effect of use of a complete fertilizer and organic matter as well as minus one test treatment on plant macro and micro-nutrients uptake at Typic Hapludalfs was presented in Figure 1 A-D, while their effect at Typic Haplustalfs was presented in Figure 2 A-D. At Typic Hapludalfs, plant nutrients N, P, K, and S uptake increased sharply due to use of complete fertilizer. Further plant nutrient uptake increased if a complete fertilizer combined with organic matter (both maize straw and animal manure compost). Similarly, plant micro-nutrient Zn, Cu, Fe, and Mn uptake increased sharply due to use of a complete fertilizer. Plant micro-

Table 5. Effect of minus one test treatment on soil properties after harvest at Typic Hapludalfs and Typic Haplustalfs.

Soil Nutrients	Extraction	Unit	Treatment		
			Control	Complete	Complete-nutrients
Typic Hapludalfs					
N	Kjeldahl	g kg^{-1}	1.70	2.20	2.00
P	Olsen	mg kg^{-1} P_2O_5	4	104	5
	HCl 25%	mg kg^{-1} P_2O_5	176	569	200
K	NH_4OAc 1 *N*	Cmol(+) kg^{-1}	0.12	0.11	0.11
	HCl 25%	mg kg^{-1} K_2O	11	12	9
Zn	DTPA	mg kg^{-1}	1.46	2.22	1.05
Cu	DTPA	mg kg^{-1}	0.47	0.44	0.41
Fe	DTPA	mg kg^{-1}	1.87	3.19	1.91
Mn	DTPA	mg kg^{-1}	37.93	61.36	35.73
Typic Haplustalfs					
N	Kjeldahl	g kg^{-1}	1.30	1.90	1.20
P	Olsen	mg kg^{-1} P_2O_5	32	179	12
	HCl 25%	mg kg^{-1} P_2O_5	149	452	141
K	NH_4OAc 1 *N*	Cmol(+) kg^{-1}	0.25	0.24	0.16
	HCl 25%	mg kg^{-1} K_2O	54	52	50
Zn	DTPA	mg kg^{-1}	0.04	0.12	0.04
Cu	DTPA	mg kg^{-1}	0.11	0.22	0.11
Fe	DTPA	mg kg^{-1}	1.49	2.24	0.62
Mn	DTPA	mg kg^{-1}	1.07	4.96	0.97

nutrient uptake increased if a complete fertilizer combined with the organic matters, except plant Mn uptake did not increased by use of maize straw compost (Figure 1 A-B).

At Typic Hapludalfs, plant nutrients uptake at the complete fertilizer treatment minus one nutrient was generally lower than the uptake at complete fertilizer treatment. Plant N uptake at minus N treatment; P uptake at minus P treatment; K uptake at minus K treatment; S uptake at minus S treatment; Zn uptake at minus Zn treatment; Cu uptake at minus C treatment; and Mn uptake at minus Mn, all were lower than the uptake at complete fertilizer treatment.

Effect of complete fertilizer, organic matter, and minus one test treatment on plant macro and micro-nutrients uptake at Typic Haplustalfs showed relatively similar results with the uptake at Typic Hapludalfs. Among these treatments, minus N and minus P treatment decreased each plant nutrient uptake most drastically at both tested soils (Figure 1 A-D and 2 A-D). In addition it appears that the minus one nutrient treatment did not only decrease the relevant nutrient uptake, but also decreased the other nutrients uptake. As an example that minus N treatment decreased plant N uptake as well as P, K and S upake at both tested soils.

Plant Growth and Yield

Effect of use of a complete fertilizer, organic matter, and minus one test treatment on plant height and leaves number of maize grown at Typic Hapludalfs and Typic Haplustalfs were presented in Table 6. Table 6 showed that complete fertilizer significantly increased both variables at both tested soils. Use of organic matter maize straw and animal manure compost also tended to increase both variables at both tested soils.

Minus one test treatment significantly decreased the variables at both tested soils. Minus N treatment significantly decreased bot variables at Typic Hapludalfs, while at Typic Haplustalfs it did not. Minus P treatment significantly decreased bot variables at both tested soils. Meanwhile minus K, S, Zn, Cu, Fe, and Mn treatment, each did not effect significantly on the variables at both tested soils (Table 6).

Effect of a complete fertilizer, organic matter, and minus one test treatments on shoot dry weight of

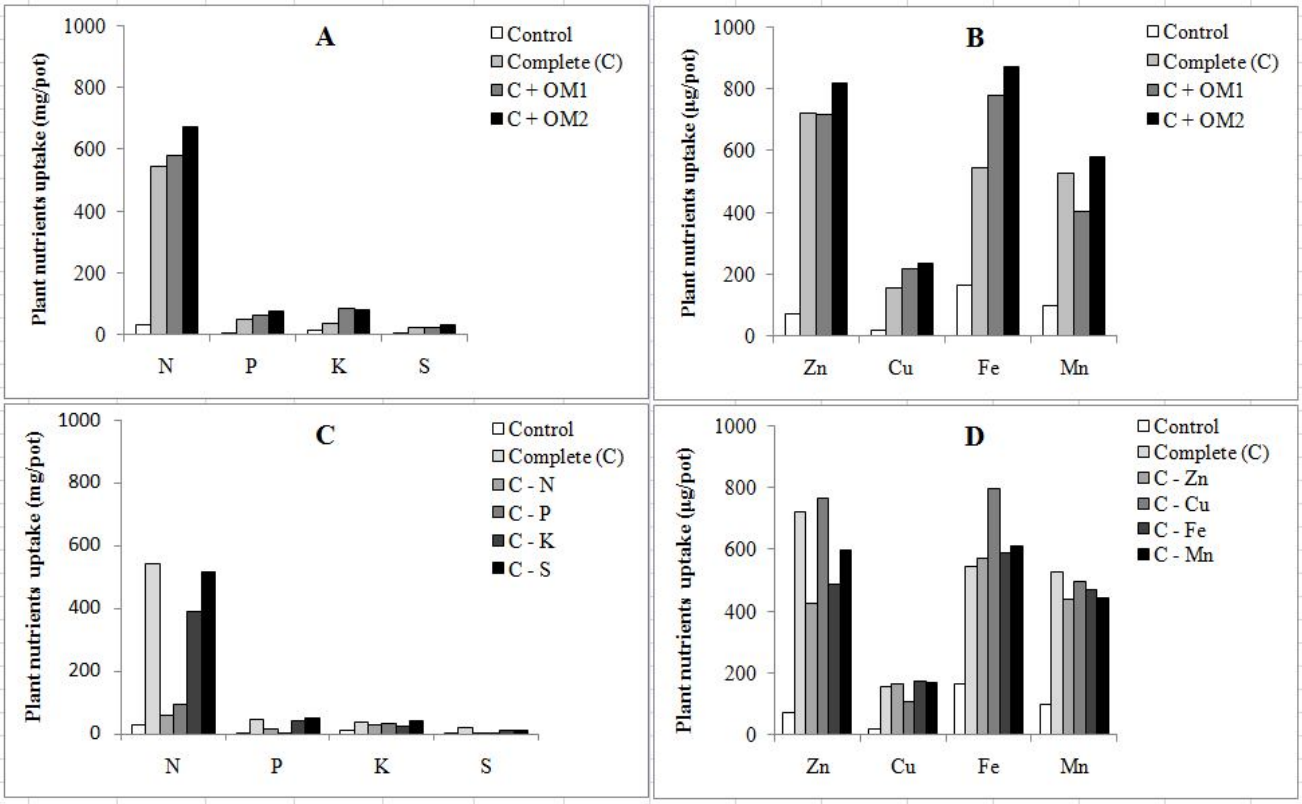

Figure 1. Effect of use of complete fertilizer and organic matter on plant macro-nutrient (A) and micro-nutrient (B) uptakes as well as effect of minus one test treatment on plant macro-nutrient (C) and micro-nutrient (D) uptakes at Typic Hapludalfs.

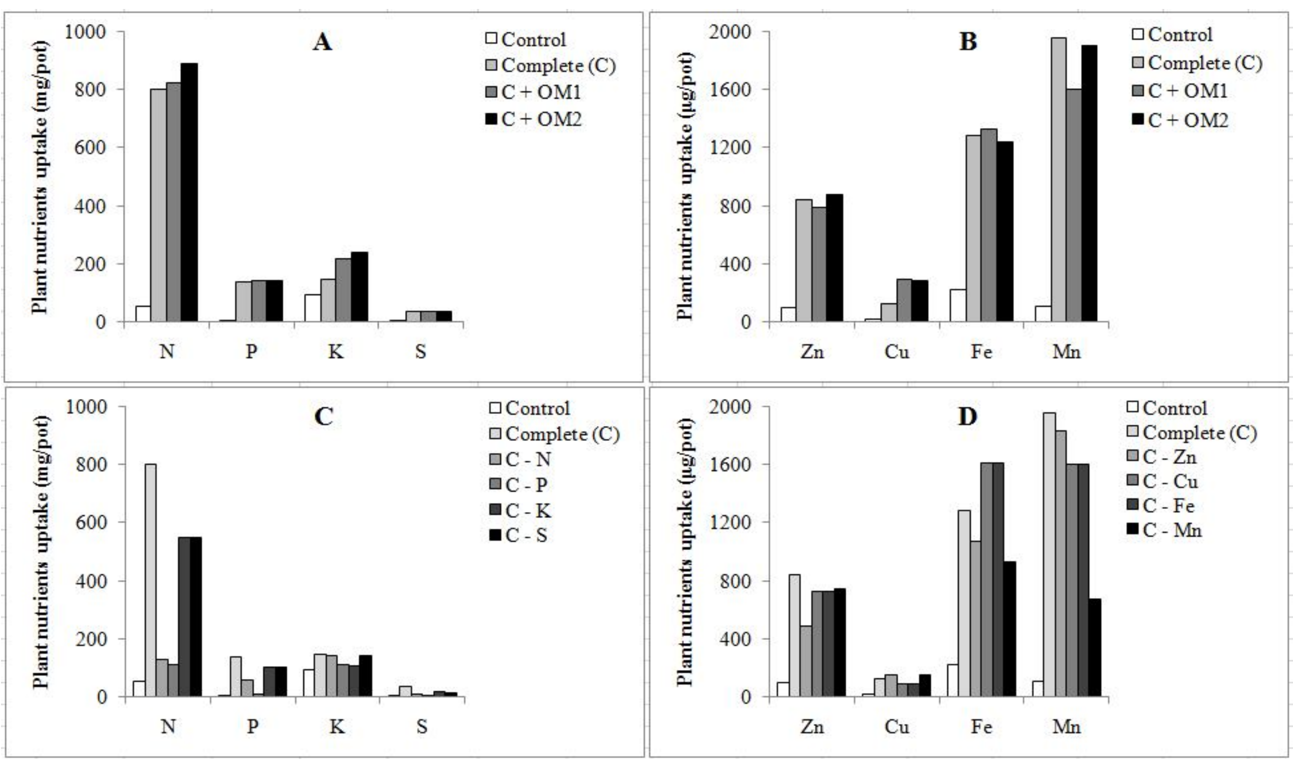

Figure 2. Effect of use of complete fertilizer and organic matter on plant macro-nutrient (A) and micro-nutrient (B) uptakes as well as effect of minus one test treatment on plant macro-nutrient (C) and micro-nutrient (D) uptakes at Typic Haplustalfs.

Table 6. Effect of a complete fertilizer, organic matter, and minus one test treatments on plant height and leaves number of maize at the age of 4 WAP at Typic Hapludalfs and Typic Haplustalfs.

Treatment	Typic Hapludalfs		Typic Haplustalfs	
	Plant height	Leves number	Plant height	Leves number
	cm	leaf	cm	leaf
Control	40.70 e	21.33 c	75.37 cd	19.67 c
C + OM1	96.33 a	25.33 ab	108.27 a-d	28.00 a
C + OM2	96.27 a	26.03 ab	110.77 abc	27.33 a
C (Complete)	91.43 ab	25.67 ab	111.93 ab	26.67 a
C - N	72.20 c	21.33 c	93.77 a-d	22.33 a
C - P	49.90 d	21.67 c	73.60 d	19.00 c
C - K	90.03 ab	26.33 ab	115.53 a	28.00 a
C - S	87.53 b	26.67 a	77.43 bcd	27.03 a
C - Zn	91.03 ab	25.33 ab	115.17 a	27.33 a
C - Cu	91.23 ab	25.00 b	114.80 a	27.33 a
C - Fe	90.43 ab	25.00 b	108.67 a-d	27.33 a
C - Mn	85.37 b	25.67 ab	115.27 ab	27.67 a
CV (%)	4.4	3.1	18.6	3.8

maize yield at Typic Hapludalfs and Typic Haplustalfs was presented in Figure 3. Use of a complete fertilizer significantly increased shoot dry weight of maize yield at both tested soils. The yield was higher if the use of complete inorganic fertilizer combined with organic matter maize straw or animal manure compost. Application of animal manure compost significantly increased maize yield at Typic Hapludalfs, whereas maize straw compost did not effect on the yield at both tested soils.

These soils had low levels of organic matter, ie only 1.06, and 1.13% at Typic Hapludalfs and Typic Haplustalfs respectively (Table 1). Thus, soil organic matter levels became limiting the maize growth. The soils required inorganic and organic fertilizer to support plant growth. Application of organic matter into the soils can increase the efficiency of inorganic fertilizer. Organic matters are instrumental in improving soil fertility due to improve soil chemical properties (supplying nutrients and soil negative charge), soil physical properties (improving soil structure, water retention, and aggregation) and soil biological properties (increasing microbes activities) (Havlin *et al.* 1999).

Minus one test treatment generally decreased shoot dry weight of maize yield at both tested soils. Minus N treatment significantly decreased shoot dry weight at both tested soils, while minus K treatment significantly decreased it only at Typic Hapludalfs. It showed that the plants suffered N, P, and K deficiencies at Typic Hapludalfs, while at Typic Haplustalfs only N and P nutrients which became limiting plant growth. Among the three nutrients, deficiency of P was found out as the main problem in the soils indicated by the maize yield at the treatment was the lowest compared to other treatments.

Identification on nutrient deficiencies at the soils indicated that N, P and K nutrients were the main limiting plant growth in maize, where P is the most prominent limiting nutrient. On acid soils with a low weathering rate (Inceptisol of Sukabumi and Typic Dystrudepts of Bogor), the three nutrients and soil organic matter were also a limiting plant growth (Nursyamsi *et al.* 2002; Kasno 2009). Similarly on acid soils with a high weathering rate (Oxisol of Pelaihari), in addition to these factors, Ca nutrient was also limiting the maize growth (Nursyamsi 2003; Sudriatna 2006). On Typic Epiaquands of Karanganyar, N, P, and K nutrients were also a factor limiting growth indicated by use of NPK fertilizer from single or compound fertilizer improved the availability of soil N, P and K nutrients. In addition, the fertilizer also significantly increased production and profitability of farming cucumber (Sukristionubowo *et al.* 2009).

Besides N, P, and K nutrients, a low level of soil organic-C was also a limiting plant growth at both tested soils. Greenhouse experiment using soil samples of Inceptisol from Ciherang showed that organic fertilizer increased the caisin yield about 16-

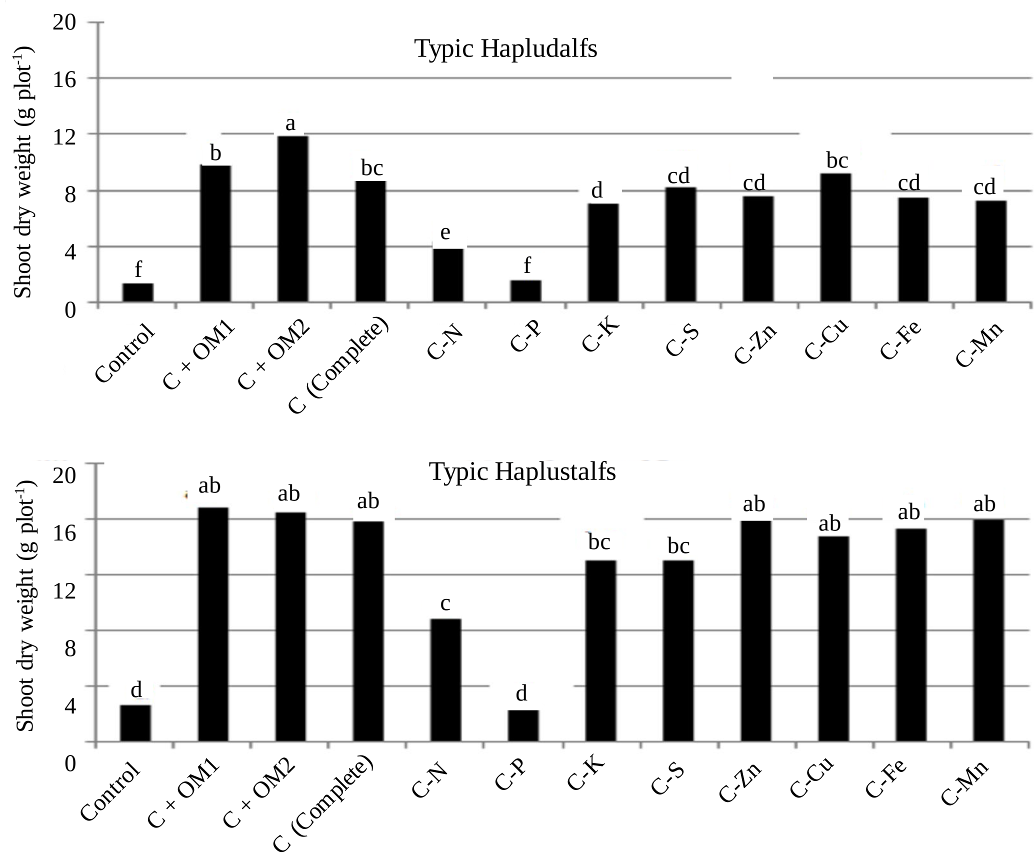

Figure 3. Effect of complete fertilizer, organic matter, and minus one test treatment on shoot dry weight of maize at the age of plant 4 WAP at Typic Hapludalfs and Typic Haplustalfs.

36% and increased the efficiency of NPK fertilizer (Widowati 2009). Similarly, at lightweight textured soil in Tanggamus District had the same limiting plant growth indicated by using chicken manure increased the soil organic-C, total-N, available P and K as well as increased caisin yield (Sarno 2009).

The both tested soils had the ability to supply P in soil solution was very low, although both soil contained high potential P (HCL-P). In general, the calcareous soils in tropical regions had the ability to adsorb P from moderate to high. The high ability of adsorb P correlated with soil characteristics such as soil Ca and Mg content, the number and type of clay minerals, organic matter, and others (Brady 1984). In such soils generally P was adsorbed by Ca more dominant than by Al and Fe (Nursyamsi and Setyorini 2009; Zhou and Li 2001). The low availability of P in soil solution also resulted in lower total other nutrient uptake. Phosphorus as a component of the activators energy affected the activity of other nutrient uptake, although other nutrients in the soil solution were available in sufficient quantities (Marschner 1995).

More than 90% of soil N derived from organic matter decomposition in the soil (Havlin *et al*. 1999). Meanwhile, the content of organic matter in tested soils was very low (Table 1) so that the availability of N in the soils was also low. In addition, N nutrient is also very mobile in the soil. Nitrogen nutrient in the form of ion (NH_4^+ and NO_3^-) is easily leached out from roots zone. Similarly, nutrient N is easily lost through a volatilization process producing NH_3 and denitrification process producing N_2O and N_2 (Havlin *et al*. 1999).

The low K nutrient availability in soil associated with the type of soil parent material, weathering rates, and leaching rates. The both tested soil materials derived from limestone and dominated by clay minerals smectite and kaolinite (Nursyamsi *et al*. 2007). K content in smectite is generally high so that both soils contain potential K (HCl-K) relatively high, namely 300 and 1,870 mg K_2O kg^{-1} at Typic Hapludalfs and Typic Haplustalfs respectively. The availability of K, however, is not so high, which is only 0.11 and 0.35 Cmol(+) kg^{-1} for Typic Hapludalfs and Typic

Haplustalfs respectively. Typic Hapludalfs had udic (moist) in moisture regime and B1 (wet) in agro-climate zone, whereas Typic Haplustalfs had ustic (dry) in moisture regime and C2 (dry) in agro-climate zone. The leaching rate in Typic Hapludalfs is higher than that in Typic Haplustalfs, thus soil K content in the first soil is lower than that in other soil.

The results of this study also showed that the organic matter treatment increased maize growth and yield. Although only visible trend to increase plant yield, but it had consistently indicated that the organic matter was a soil component that could improve soil productivity either directly or indirectly. Organic matter can improve the soil physical, chemical, and biological properties so the soil conditions become favorable for plant growth.

CONCLUSIONS

Use of N, P, K, Zn, Cu, Fe, and Mn fertilizers increased soil macro nutrients, *i.e.*: soil total-N, Olsen-P, HCl-P, and HCl-K, as well as soil micro nutrients, *i.e.*: soil DTPA-Zn, Cu, Fe, and Mn at both tested soils. Use of maize straw compost increased soil organic-C, total-N, HCl-K, and exchangeable Ca at Typic Hapludalfs and increased only soil organic-C and total-N at Typic Haplustalfs. Use of animal manure increased soil organic-C, exchangeable Ca and Mg, and CEC.

Use of N, P, K, S, Zn, Cu, Fe, and Mn fertilizers increased each plant nutrients uptake at the soils. Use of both organic matters increased plant N, P, K, and Fe uptake at Typic Hapludalfs as well as increased only plant N, P, and K uptake at Typic Haplustalfs.

Identification result showed that maize growth suffered from N, P, and K deficiencies at Typic Hapludalfs as well as N and P deficiencies at Typic Haplustalfs. Beside the nutrients, soil organic matter was also found out as limiting factor for maize growth in the soils.

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