EFFECTS OF AMELIORANT COMPOSITIONS ON NITROGEN MINERALIZATION AND UPTAKE BY SWEET CORN IN DEGRADED PEATLAND

Efek Komposisi Amelioran pada Mineralisasi dan Serapan Nitrogen oleh Jagung Manis pada Lahan Gambut Terdegradasi

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ABSTRACT

Peat soil is characterized by poor nitrogen (N) availability. Ameliorants are expected to rectify this problem. This research aimed to study the effect of ameliorant on N availability and N uptake by sweet corn plant in degraded peatland. The experiment was conducted in the greenhouse in May-July 2011 and on peatland of Kalampangan Village, Palangkaraya, Central Kalimantan in September-December 2011. Burnt peat soil of Kalampangan was used in the greenhouse experiment and sweet corn was used as an indicator plant. The treatments consisted of two factors, i.e. compositions of ameliorants by weight (A1 = 80% chicken manure + 20% dolomite; A2 = 80% local farm weed + 20% dolomite; A3 = 80% mineral soil + 20% dolomite; A4 = 20% chicken manure + 20% local farm weed + 20% residue of Chinese water chestnut (*Eleocharis dulcis*) + 20% mineral soil + 20% dolomite; and A5 = 19% chicken manure + 71.5% mineral soil + 9.5% dolomite) and rates of those ameliorants (5, 10, 15, 20 and 25 t ha^{-1}). The experiment was arranged in a completely randomized block design with three replications. Data were collected every two weeks for five times. Observations were made on soil pH, available N (NH_4^+, NO_3^-), plant height, and N uptake in root and shoot. The results showed that treatment A1 increased soil pH and availability of NH_4^+ and NO_3^- in peat soils at the maximum vegetative stage. Treatment A1 provided the highest N availability and N uptake by the plant. Field experiment showed that N uptake increased with the plant yield. Optimum yield of fresh corn cob was obtained from treatment A1 at the rate of 20 t ha^{-1}. This research reconfirms the effectiveness of chicken manure and dolomite as peat soil ameliorant.

[***Keywords*:** Ameliorant, peatland, N availability, N uptake, sweet corn]

ABSTRAK

Ketersediaan nitrogen (N) dalam tanah gambut sangat rendah. Amelioran diharapkan dapat meningkatkan kesuburan tanah gambut terdegradasi. Penelitian ini bertujuan untuk mempelajari pengaruh amelioran terhadap ketersediaan N dan serapan N oleh tanaman jagung di lahan gambut terdegradasi. Penelitian dilaksanakan di rumah kaca Balai Penelitian Pertanian Lahan Rawa (Balittra) pada Mei hingga Juli 2011 dan percobaan lapangan di lahan gambut terdegradasi di Desa Kalampangan, Palangkaraya, Kalimantan Tengah pada September-Desember 2011. Percobaan rumah kaca dan lapangan menggunakan jagung manis sebagai tanaman indikator. Perlakuan terdiri atas dua faktor. Faktor pertama ialah kombinasi amelioran (A1 = pukan ayam 80% + dolomit 20%; A2 = gulma pertanian in situ *80% + dolomit 20%; A3 = tanah mineral 80% + dolomit 20%; A4 = pukan ayam 20% + gulma pertanian* in situ *20% + rumput purun tikus (*Eleocharis dulcis*) 20% + tanah mineral 20% + dolomit 20%, dan A5 = pukan ayam 19% + tanah mineral 71,5% + dolomit 9,5%). Faktor kedua ialah dosis amelioran, yaitu 5, 10, 15, 20, dan 25 t ha^{-1}. Perlakuan disusun dalam rancangan acak lengkap dengan tiga ulangan. Data dikumpulkan secara periodik setiap 2 minggu sebanyak lima kali, meliputi pH tanah, N tersedia (NH_4^+, NO_3^-), tinggi tanaman, dan pada akhir percobaan diamati serapan N pada akar dan tajuk. Hasil penelitian menunjukkan bahwa perlakuan A1 meningkatkan pH tanah serta ketersediaan NH_4^+ dan NO_3^- dalam tanah gambut pada tahap pertumbuhan vegetatif maksimum. Amelioran A1 mampu meningkatkan ketersediaan N dan serapan N tertinggi oleh tanaman. Percobaan lapangan menunjukkan bahwa serapan N meningkat seiring dengan hasil tanaman. Hasil optimum tongkol jagung segar diperoleh pada perlakuan amelioran A1 pada dosis 20 t ha^{-1}. Penelitian ini menegaskan efektivitas pukan ayam dan dolomit sebagai amelioran pada tanah gambut.*

[***Kata kunci*:** Amelioran, lahan gambut, ketersediaan N, serapan N, jagung manis]

INTRODUCTION

Peatland, covering an area of 14.9 million ha in Indonesia and distributed mostly in Kalimantan, Sumatra, Papua and Sulawesi (Ritung *et al.* 2011) has a great potential for agriculture. However, utilization of peatland for agricultural purposes faces problems involving both chemical and physical soil properties. Low yield of food crops grown on peatland generally related to poor soil chemical and physical characteristics, such as soil water saturation, soil acidity, toxicity and low nutrient content.

Nitrogen (N) is the most dynamic nutrient to undergo transformation affecting its availability for crops (Moller and Stinner 2009). N transformations include mineralization, immobilization, nitrification and denitrification, leaching and ammonia volatilization. Peatland reclamation through the development of drainage canals reduces the total N in the soil, of which the highest N loss occurs through leaching (Kurnain 2005). Nitrogen in peat soils mostly presents in organic forms that can be transformed into mineral ones such as NH_4^+, NO_3^- and NO_2^- (Otabbong and Linden 1993; Bothe *et al.* 2007). Nitrogen mineralization in peat soils is strongly influenced by environmental conditions, especially oxidation, reduction, soil pH and microbial activities (Keller *et al*. 2004).

According to Suhardi (2005), N mineralization in peat soil was further accelerated when the peat is converted to agricultural land. The more intense the mineralized N, the faster is N loss through leaching. Kurnain (2005) reported that ammonium content in peat forest soils was higher than that in agricultural land. Therefore, reclamation, land clearing and drainage canal construction should be done carefully to minimize their negative effects on peatlands, which would reduce their function as a growing medium for crops and as an environmental stabilizer. N mineralization of reclaimed peat soils reached 2-3 times higher than that of the unreclaimed ones (Zhu and Ehrenfeld 2000).

Peatland degradation could happen due to mismanagement during the reclamation and to fires. Degraded peatlands are characterized by decreased water holding capacity, low total organic carbon (TOC) and total-N, and increased soil acidity (Anshari 2010). Over-draining may cause peat surface to become so dry that it cannot re-absorb water (loss of its hydrophilicity) which in effect succumbs to fire. The frequent occurrences of fires on the degraded peatland further affect more on water level decline (Miettinen and Liew 2010).

Sustainable peatland management should include some kinds of soil ameliorant in addition to water table regulation. Ameliorant is a material added to the marginal soil to improve soil fertility to support plant growth (Attiken *et al.* 1998). Soil amelioration with lime at the rates of 5-5.2 t ha^{-1} increased pH of sapric peat from 3.34 to 4.5 (Masganti 2003; Supriyo 2006), whereas addition of 20 t ha^{-1} chicken manure increased corn yield (Utami 2010). Application of ameliorants consisted of 16 t ha^{-1} mineral soil + 1.5 t ha^{-1} calcite + 3 t ha^{-1} dolomite + 80 kg ha^{-1} iron increased soybean yield of 1.77 t ha^{-1} (Saragih 1996).

Research on the effect of amelioration on degraded peatlands using *in situ* material is still limited. The objective of this research was to evaluate the effect of several combinations of organic matter and dolomite based ameliorants on N availability and N uptake by sweet corn on peatland.

MATERIALS AND METHODS

The experiments were conducted in two phases, i.e. pot experiment at a greenhouse and field experiment on degraded peatland in Kalampangan Village, Palangkaraya, Central Kalimantan.

Greenhouse Experiment

The pot experiment was conducted at a greenhouse of the Indonesian Swampland Agriculture Research Institute (ISARI), Banjarbaru, South Kalimantan from May to July 2011. The soil used in the experiment was a degraded peat from Kalampangan Village, Palangkaraya, Central Kalimantan. The peat underwent burning in 1997 and remained as an idle land ever since. The soil has very low pH (around 3.53), high organic C (52.02%), low EC (0.103 mS cm^{-1}), very low available N (11.67 mg kg^{-1}), very low available P (6.25 mg kg^{-1}), low available K (0.217 $cmol^{(+)}$ kg^{-1}), low exchangeable Ca (3.725 $cmol^{(+)}$ kg^{-1}), low Mg (1.616 $cmol^{(+)}$ kg^{-1}), and having hydrophobic upper of 10 cm layer.

The ameliorant materials consisted of mineral soil (Spodosol), local farm weeds dominated by *Cynodon* grass, chicken manure, dolomite, and Chinese water chesnut (*Eleocharis dulcis*). The nutrient composition of the ameliorant is presented on Table 1.

The local farm weeds consisted of a mixture of weeds obtained from the study site, mainly *Cynodon* grass, *Ageratum* and *Borreria* weeds, as well as Chinese water chestnut (*E. dulcis*), an indigenous grass in tidal swampland. The ameliorant materials were formulated according to the following treatments, A1 = 80% chicken manure + 20% dolomite; A2 = 80% local farm weeds + 20% dolomite; A3 = 80% mineral soil + 20% dolomite; A4 = 20% chicken manure + 20% local farm weeds + 20% *E. dulcis* + 20% mineral soil + 20% dolomite; and A5 = 19% chicken manure + 71.5% mineral soil + 9.5% dolomite. Before application, these materials were mixed and composted for 2 weeks. The composted materials

Table 1. Nutrient composition of the ameliorants used in the study.

Ameliorant	Nutrient composition (% by weight)										pH
	C	N	P	K	C/N	Ca	Mg	Na	Fe	WC	
Chicken manure	31.93	1.64	0.64	1.26	19.49	5.30	2.32	1.15	1.80	10.56	7.17
Local farm weeds	44.86	0.94	0.25	1.02	47.66	0.91	0.26	1.02	0.04	20.02	4.45
Eleocharis dulcis	44.48	1.18	0.08	0.99	37.82	0.85	0.19	0.99	0.16	16.11	4.12
Mineral soil (Spodosol)	2.45	0.09	tu	tu	25.00	0.02	0.01	tu	0.03	5.39	4.56
Dolomite	tu	tu	tu	tu	-	22.83	8.86	tu	tu	tu	8.32

tu = undetected, WC = water content

with 90-100% moisture content were then put into polybags and mixed with peat soil. Soil moisture content of the mixture was 120% based on oven dry weight.

Five ameliorant combinations (A1, A2, A3, A4, A5) and five ameliorant rates (5, 10, 15, 20, 25 t ha^{-1} or equivalent to 11.36; 22.72; 34.08; 45.45; 56.8 g kg^{-1} soil; peat bulk density of 0.22 g cm^{-3}) were tested in a randomized block design. Sweet corn was planted in each polybag after 2 weeks of ameliorant application (May 24, 2011). NPK at the rate of 300 kg ha^{-1} or equivalent to 0.68 g kg^{-1} was applied at seed planting. Urea at the rate of 200 kg ha^{-1} equivalent to 0.45 g kg^{-1} was applied twice at 2 weeks after planting (WAP) and 4 WAP. Nutrient contents of the NPK were 9% N,13.5% P_2O_5 and 10.9% K_2O. Soil moisture was maintained at field capacity. Data were collected every 2 weeks for five times of observation of soil pH using glass electrode, available N (NH_4^+, NO_3^-) using Spectrophotometer (Balittanah 2005), plant height, and at the end of the experiment N uptake in the roots and shoot of sweet corn plant.

Field Experiment

The field experiment was conducted on the degraded peatlands in Kalampangan Village, Palangkaraya, Central Kalimantan in September-December 2011 using the best treatments from the greenhouse experiment, i.e. ameliorant combination A1, A4 and A5 with three dosages (15, 20, and 25 t ha^{-1}), control (without ameliorant + NPK), and farmers' practices. Farmers used ameliorant with the composition of 40% chicken manure + 40% mineral soil (Spodosol) + 20% ash at the rate of 20 t ha^{-1} and inorganic fertilizer in a form of urea at the rate of 700 kg ha^{-1} and NPK Phonska (N : P_2O_5 : K_2O) (15 : 15 : 15) of 600 kg ha^{-1}. The treatments were arranged in a randomized block design with three replications. NPK fertilizer used in the treatment contained 9% N, 13.5% P_2O_5 and 10.9% K_2O; applied at the rate of 300 kg ha^{-1}. Urea fertilizer was added at the rate of 300 kg ha^{-1} and applied on every plot at 2, 3 and 4 weeks after planting. Plot size was 2.5 m x 8 m. Seeds of sweet corn were planted at a spacing of 20 cm x 75 cm, one seed per hill. Data were collected periodically every 2 weeks for four times, including pH, NH_4^+ and NO_3^-. N contents in root and shoot samples were assessed from the harvested sweet corn plant.

RESULTS AND DISCUSSION

Greenhouse Experiment

Effect of Ameliorants on Soil pH

Ameliorant treatments at different combinations and rates did not significantly affect soil pH at the time of planting, but they did at the maximum vegetative stage. At planting, a higher rate of ameliorant, especially at 15 t ha^{-1} or higher increased soil pH (Table 2). Different compositions of ameliorants did not affect soil pH.

The rates of ameliorants affected soil pH; increase in the rate of ameliorants enhanced the soil pH with a quadratic relationship (Fig. 1). At maximum vegetative stage, application of ameliorants at 10 t ha^{-1} or more increased soil pH, but an increase in one unit pH was obtained at the ameliorant rates of 15-25 t ha^{-1}. No substantial increase in soil pH was observed when ameliorants were added from 15 to 25 t ha^{-1} as in the treatment A1 (80% chicken manure + 20% dolomite). Based on the equation of $Y = 0.001x^2 – 0.031x + 4504$, optimum rate of ameliorant A1 for soil pH at maximum vegetative stage was 15.5 t ha^{-1} (Fig. 1).

The increase in soil pH was most possibly due to the addition of dolomite in the ameliorants. Brown *et al.* (2007) stated that liming reduced soil acidity and improved the balance of nutrients so that nutrients could be absorbed by plants. Lime would provide a

Table 2. Effect of ameliorant on peat soil pH at planting time and maximum vegetative stage of sweet corn, Banjarbaru, South Kalimantan, 2011.

Treatment	Soil pH at planting time						Soil pH at maximum vegetative stage					
	Ameliorant rate (t ha^{-1})						Ameliorant rate (t ha^{-1})					
	5	10	15	20	25	Mean	5	10	15	20	25	Mean
A1	3.89	3.87	4.10	4.31	4.55	4.14 A	4.34 fgh	4.42 fgh	4.57 e-h	4.34f gh	4.92 b-f	4.42 A
A2	3.62	3.90	4.08	4.29	4.55	4.09 A	3.96 h	3.79 h	3.91 gh	4.56 d-e	4.21 f-g	4.09 A
A3	3.71	3.89	4.39	4.66	5.30	4.39 A	3.86 h	4.01 fgh	4.34 fg	4.58 d-f	4.11 f	4.18 A
A4	3.87	4.11	4.23	4.70	4.74	4.33 A	3.69 h	3.69 h	4.30 fg	4.34 fg	4.34 fg	4.12 A
A5	3.84	4.18	4.29	4.35	4.34	4.20 A	3.74 h	4.07 fg	4.28 fg	4.70 c-f	4.40 d-g	4.24 A
Mean	3.79 d	3.99 d	4.22 c	4.46 b	4.69 a		3.92	3.99	4.28	4.50	4.39	

A1 = 80% chicken manure + 20% dolomite, A2 = 80% local farm weeds + 20% dolomite, A3 = 80% mineral soil + 20% dolomite, A4 = 20% chicken manure + 20% dolomite + 20% local farm weed + 20% mineral soil + 20% *Eleocharis dulcis,* A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite.
The numbers followed by the same small letters in the same column indicate no significant difference between treatments, while the same capital letters in the same column indicate no significant difference between periods of observation by DMRT at α = 5%.

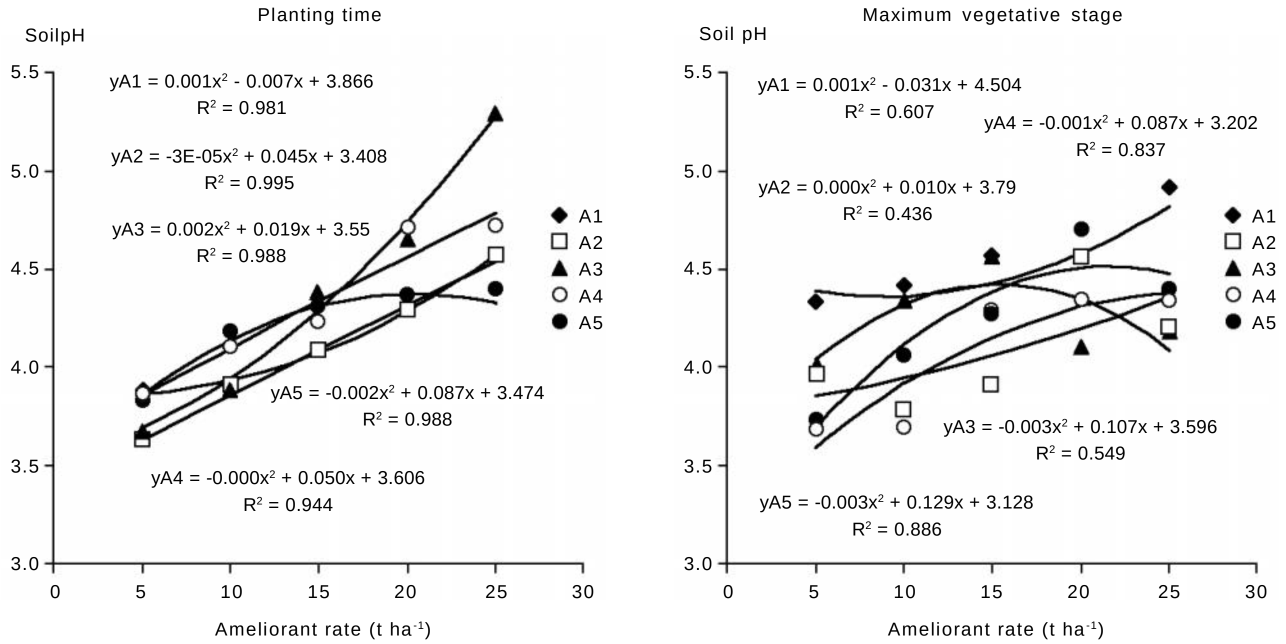

Fig. 1. Effect of ameliorant rate on peat soil pH at planting time and maximum vegetative stage of sweet corn, Banjarbaru, South Kalimantan, 2011. A1 = 80% chicken manure + 20% dolomite, A2 = 80% local farm weeds + 20% dolomite, A3 = 80% mineral soil + 20% dolomite, A4 = 20% chicken manure + 20% dolomite + 20% local farm weed + 20% mineral soil + 20% *Eleocharis dulcis,* A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite.

supply of OH^- into the soil solution, where OH^- with H^+ forms water, so the concentration of H^+ reduced and soil pH increased. The reaction is shown below:

$CaMg(CO_3)_2$ -------> $CaCO_3 + Mg^{2+} + CO_2 + H_2O$
$CaCO_3 + H_2O$ -------> $Ca^{2+} + HCO_3^- + OH^-$
H^+ (the soil solution) + OH^- -------> H_2O

Ameliorant rate determines the degree of changing of peat soil pH. At the rate of less than 5 t ha^{-1}, there seems to be no effect of ameliorants on soil pH. The higher the rate of ameliorants, the higher the alkali cations neutralizing the organic acids. However, lime application in peat soil should be carefully because increase in 5 units of pH would dissolve 26% of humin that lead to quick decomposition of organic materials in the soil (Maas 1993). Applying an excessive lime caused dispersion of the peat (Masganti 2003). For the peat soil conservation, lime rate should be limited to 4 t ha^{-1} (Maftu'ah 2012).

Effect of Ameliorants on NH_4^+ Availability

The availability of NH_4^+ was significantly influenced by the types of ameliorants. There was no interaction between types of ameliorants and its rate on the availability of NH_4^+ (Fig. 2). During the vegetative stage, increase in ameliorant rate as in the treatment A1 enhanced NH_4^+ concentration as shown in the equation of $Y = 0.115x^2 - 3.082x + 52.59$. The optimum rate was 26 t ha^{-1}, however the increasing rate from 15 to 25 t ha^{-1} showed no significant effect on the NH_4^+ concentration. At the end of vegetative stage, ameliorant rate showed no significant effect on the NH_4^+ concentration.

Ammonium is the first substance produced during N mineralization, which was influenced by the quality of organic matter such as C/N ratio, lignin and polyphenols. The rate of decomposition and mineralization of organic matter was determined by the chemical composition, physical structure, activity of microorganisms and environmental conditions (Tian 1992). Chicken manure (80%) as in the treatment A1 was the best organic ameliorant compared with other matters. It has low C/N ratio, high N content and low lignin and cellulose so that the rate of decomposition and the supply of NH_4^+ was more rapidly than the others. Nitrogen mineralization is affected by the quality of organic matter, as indicated by the C/N ratio (Bayley and Thormann 2005).

Effect of Ameliorants on NO_3^- Availability

Type of ameliorants affected the amount of NO_3^- formed. Nitrate was formed more at planting time compared to ammonium. At the ameliorant rate of 10 t ha^{-1} as in the treatments A2 and A4, nitrate was produced higher than that in the other treatments. However, at the highest rate (25 t ha^{-1}) as in the treatments A1 and A4, nitrate concentration was the highest, while at treatments A2 and A3 were the lowest. There was no explanation to the inconsistency of the kind of ameliorant effect. However, there was an indication that mineral soil ameliorant did not effectively release NO_3^- at planting time. Concentration of NO_3^- was influenced by the type and the rate of ameliorants. The rate of ameliorants affectted the availability of NO_3^-, where the increasing ameliorant rate gave a positive impact on the availability of NO_3^- for treatment A1 and A4 according to quadratic equation in Figure 3.

Generally, the highest concentration of NO_3^- was associated with the highest rate of ameliorants (25 t ha^{-1}), whereas the lowest rate of NO_3^- was correlated

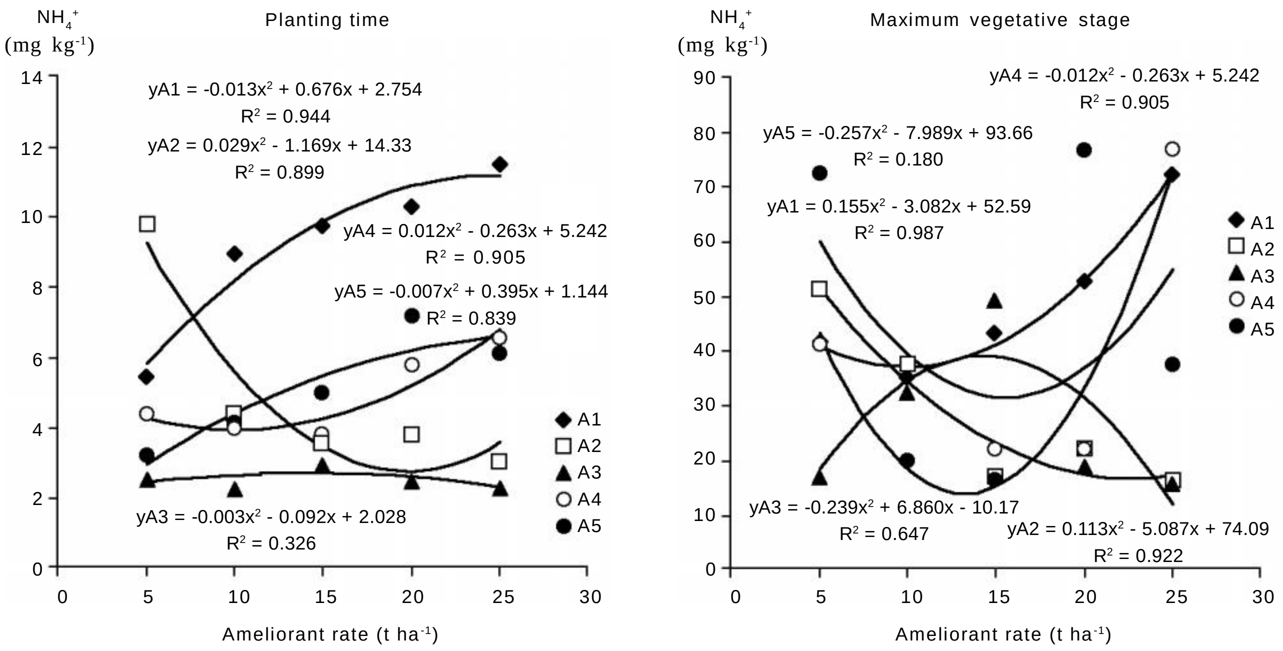

Fig. 2. Effect of ameliorant rate on peat soil NH_4^+ concentration at planting time and maximum vegetative stage of sweet corn, Banjarbaru, South Kalimantan, 2011. A1 = 80% chicken manure + 20% dolomite, A2 = 80% local farm weeds + 20% dolomite, A3 = 80% mineral soil + 20% dolomite, A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis,* A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite.

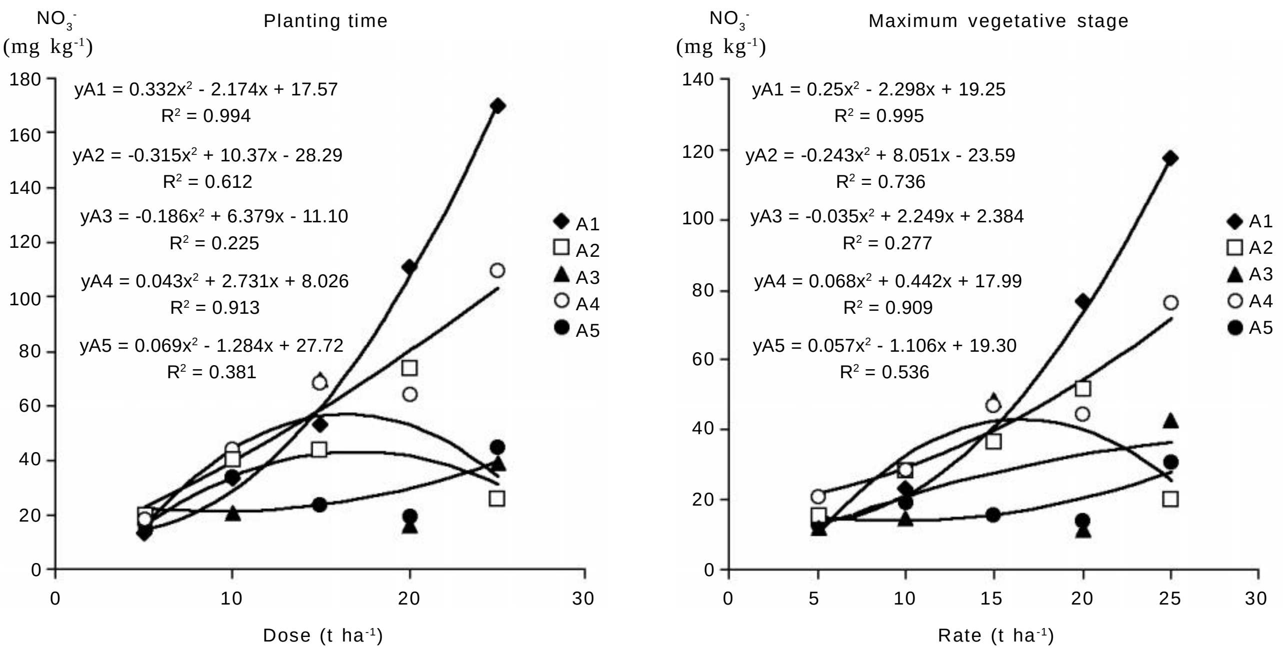

Fig. 3. Effect the ameliorant rate on peat soil NO_3^- concentration at planting time and maximum vegetative stage of sweet corn, Banjarbaru, South Kalimantan, 2011. A1 = 80% chicken manure + 20% dolomite, A2 = 80% local farm weeds + 20% dolomite, A3 = 80% mineral soil + 20% dolomite, A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis,* A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite.

with the lower rate of ameliorants (5 t ha^{-1}). Increase in the rate of ameliorants enhanced the amount of N that can be mineralized, so N availability also increased.

At maximum vegetative stage, NO_3^- concentrations were somewhat lower than those at planting time. However the A1 and A4 ameliorant treatments at the rate of 20 t ha^{-1} or higher produced relatively more NO_3^- than the other treatments.

Concentration of NO_3^- at each observation time was higher than that of NH_4^+. This seemed to be caused by conversion of NH_4^+ to NO_3^- (nitrification). NO_3^- formation was strongly influenced by soil pH, as indicated by a significant correlation between soil pH and NO_3^- content (Bothe *et al*. 2007). Conversion of NH_4^+ to NO_3^- could take place through chemoautotrophic and heterotrophic bacteria and fungi (de Boer and Kowalchuk 2001; Reddy and de Laune 2008). Nitrification process depends on several factors, including the populations of nitrifying microorganisms and the quality of environment such as the availability of NH_4^+, organic C, moisture, aeration, temperature and soil pH (Regina 1998; Jali 1999).

Effect of Ameliorants on N Uptake

N uptake was defined as the amount of N nutrient absorbed by plants. N uptakes differed significantly among the kind of ameliorants, both for that deposited in the roots and in the shoots (Table 3). The highest N uptake in the roots and in the shoots was showed by A1 treatment (80% chicken manure + 20% dolomite), followed by A4 and A5 treatments. A1 ameliorant with chicken manure as its main component provided higher NH_4^+ and NO_3^- than did other treatments.

Most of the N absorption into the plant was through the mass flow, where the root hairs play an important role in the inclusion of N in the plant. The lowest N uptakes in roots and shoots were indicated by A2 and A3 ameliorant treatments. Based on the incubation experiment, the lowest N availability was obtained from A3 and A4 treatments. These were strongly related with the quality of materials used as ameliorants. Chicken manure with the highest N content and lower C/N ratio released N faster compared with the other materials.

Table 3. N uptake by sweet corn shoot and root as affected by types and rates of ameliorants, Banjarbaru, South Kalimantan, 2011.

Treatments	N uptake in root (g kg^{-1})						N uptake shoot (g kg^{-1})					
	Ameliorant rate (t ha^{-1})						Ameliorant rate (t ha^{-1})					
	5	10	15	20	25	Mean	5	10	15	20	25	Mean
A1	0.01 h	0.21 a-d	0.22 abc	0.22 abc	0.26 a	0.19 A	0.19 ij	1.38 c-f	2.03 abc	2.52 a	2.66 a	1.76 A
A2	0.01 h	0.07 fgh	0.06 fgh	0.23 ab	0.12 c-f	0.09 B	0.11 j	0.42 hij	0.94 d-i	2.00 abc	1.59 bc	1.01 B
A3	0.11 d-g	0.11 d-g	0.16 a-f	0.13 b-f	0.11 d-h	0.12 AB	0.49 hij	1.12 d-h	1.27 c-g	1.22 d-h	1.09 d-h	1.29 AB
A4	0.09 e-h	0.07 fgh	0.13 b-f	0.19 a-e	0.23 ab	0.14 AB	0.73 e-i	0.64 f-i	1.26 c-g	2.34 ab	1.48 cde	1.29 AB
A5	0.01 h	0.13 b-f	0.16 a-f	0.21 a-d	0.21 a-d	0.14 AB	0.15 ij	1.09 d-h	1.14 d-h	2.58 a	2.33 ab	1.46 AB
Mean	0.05 c	0.12 b	0.14 ab	0.19 a	0.18 a		0.33 c	0.93 b	1.33 b	2.11 a	1.83 a	

A1 = 80% chicken manure + 20% dolomite, A2 = 80% local farm weeds + 20% dolomite, A3 = 80% mineral soil + 20% dolomite, A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis,* A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite.

The numbers followed by the same small letters in the same column indicates no significant difference between treatments, while the same capital letter in the same column indicates no significant difference between periods of observation by DMRT at α = 5%

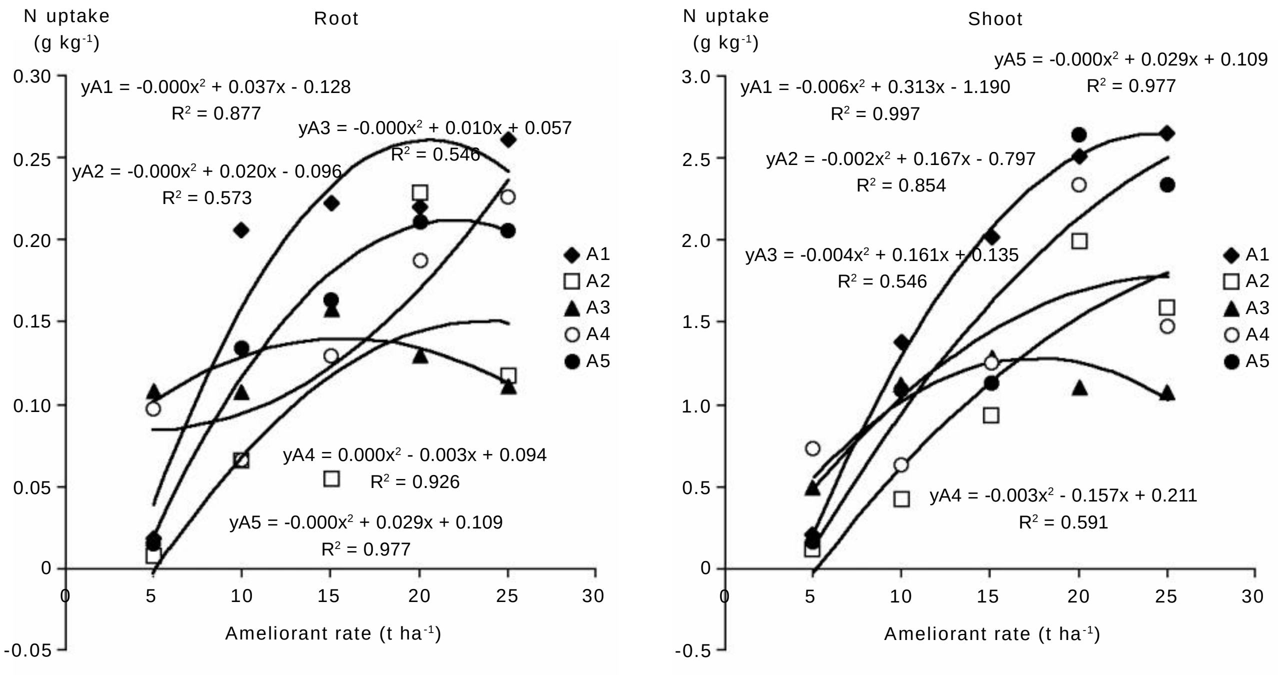

Fig. 4. Effect of ameliorant rates on total N uptake by sweet corn root and shoot, Banjarbaru, South Kalimantan, 2011. A1 = 80% chicken manure + 20% dolomite, A2 = 80% local farm weed + 20% dolomite, A3 = 80% mineral soil + 20% dolomite, A4 = 20% chicken manure + 20% dolomite + 20% local farm weed + 20% mineral soil + 20% *Eleocharis dulcis,* A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite.

Ameliorant rate significantly affected N uptake both in the roots and in the shoots (Fig. 4). The relationship between ameliorant rate and N uptake both in the roots and in the shoots were quadratic. The highest N uptake in the roots and in the shoots were indicated by A1, A4 and A5 treatments so that the treatments were further tested for the application in the field. Increasing rate of ameliorants up to 25 t ha^{-1} did not give significant effect, where the optimum ameliorant rate was 20 t ha^{-1}. At ameliorant rate of 5 and 10 t ha^{-1}, corn plants showed N deficiency, initially appeared in the young leaves then in the older leaves.

Field Experiment

Soil pH of the field experiment was changing over time, where there were significant influences attributed to the combinations of type and rate of ameliorants (Table 4). Ameliorants A1, A4 and A5 tended to show a noticeable decrease in soil pH at 4 WAP until harvest, possibly due to the dissociation of H^+ into the soil solution (Fig. 5).

Ameliorant A1 (80% chicken manure + 20% dolomite) at all rates (15, 20, 25 t ha^{-1}) and ameliorant A4 at a rate of 15 t ha^{-1} in the second week observation showed an increasing pH, but it was not significant compared to that observed at 0 WAP.

Table 4. Effect of ameliorants on peat soil pH in field experiment, Palangkaraya, Central Kalimantan, 2011.

Treatments	Soil pH				
	0 WAP	2WAP	4 WAP	6 WAP	Harvest
A1D3	5.02 ab	5.24 a	4.74 ab	4.12 ab	4.16 ab
A1D4	5.58 a	5.40 a	4.92 a	4.14 ab	4.20 ab
A1D5	5.18 ab	5.42 a	4.43 ab	4.36 a	4.34 a
A4D3	4.58 bc	4.83 a	4.60 ab	4.17 ab	4.30 a
A4D4	4.68 bc	4.79 ab	4.16 ab	4.06 ab	4.22 ab
A4D5	4.85 ab	4.70 ab	4.14 bc	4.15 ab	4.25 ab
A5D3	5.09 ab	4.70 ab	4.09 bc	3.93 abc	4.05 b
A5D4	5.32 ab	4.40 ab	4.29 ab	4.29 a	4.17 ab
A5D5	4.70 bc	4.29 ab	4.18 bc	3.78 bc	4.35 a
Control	3.43 d	3.59 c	3.54 c	3.50 c	3.45 c
Farmer's	3.74 d	4.40 ab	4.50 ab	4.28 ab	4.30 a
Mean	4.74	4.70	4.33	4.07	4.16

WAP = weeks after planting, A1 = 80% chicken manure + 20% dolomite; A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis*; A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite. D3 = 15 t ha^{-1}, D4 = 20 t ha^{-1}, D5 = 25 t ha^{-1}.

The numbers followed by the same letter in the same column indicates no significant difference between periods of observation by DMRT at α = 5%.

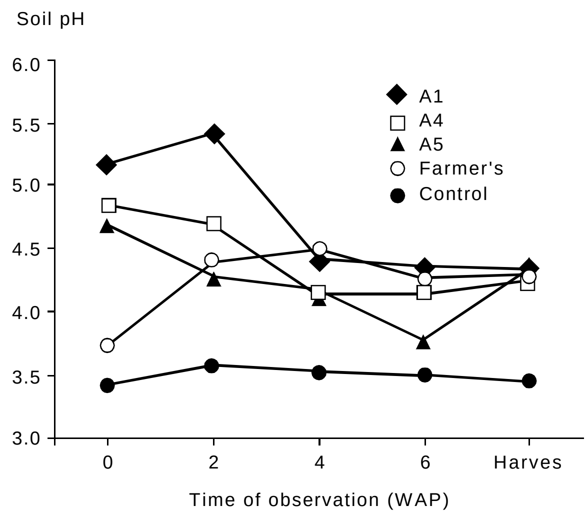

Fig. 5. Effect of ameliorants at the rate of 25 t ha^{-1} on peat soil pH, Palangkaraya, Central Kalimantan, 2011. A1 = 80% chicken manure + 20% dolomite; A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis*; A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite. D3 = 15 t ha^{-1}, D4 = 20 t ha^{-1}, D5 = 25 t ha^{-1}.

Effect of Ameliorants on N Availability in the Soil

Interaction of type and rate of ameliorants affected concentrations of NH_4^+ and NO_3^- in the soil (Table 5 and 6). Effect of ameliorants at the rate of 25 t ha^{-1} on NH_4^+ and NO_3^- concentrations in the soil are shown in Figure 6. The highest concentration of NH_4^+ and NO_3^- at early observation was indicated by ameliorant A1 (80% chicken manure + 20% dolomite), but the effect was inconsistent at other observation times. Chicken manure as an organic matter decomposed and mineralized N faster, releasing NH_4^+ at the beginning of the observation.

Increased availability of NH_4^+ at 4 WAP on almost all treatments due to the provision of supplementary urea occurred at 2, 3 and WAP. However, NH_4^+ concentrations declined at 6 WAP until harvest time and harvesting. The decrease in NH_4^+ concentration was not only due to absorption by plants, but also presumably due to the conversion of NH_4^+ to NO_3^-

Table 5. Concentration of NH_4^+ in peat soil at 0-15 cm depth as affected by ameliorants observed at planting until harvest of sweet corn, Palangkaraya, Central Kalimantan, 2011.

Treatments	NH_4^+ concentration (mg kg^{-1})				
	0 WAP	2 WAP	4 WAP	6 WAP	Harvest
A1D3	205 b	119 ab	117 ab	58 abc	64 a
A1D4	292 a	104 ab	105 ab	67abc	66 a
A1D5	215 b	206 a	179 ab	67abc	34 b
A4D3	63 c	159 a	54 b	75ab	18 b
A4D4	44 c	167 a	206 a	67abc	70 a
A4D5	72 c	95 b	148 ab	106a	70 a
A5D3	70 c	125 ab	167 ab	23bc	25 b
A5D4	78 c	89 b	152 ab	34bc	13 b
A5D5	76 c	168 a	224 a	41bc	12 b
Control	29 d	52 b	113 ab	10 c	21 b
Farmer	39 d	181 a	102 ab	76 ab	27 b
Mean	108	133	142	57	38

WAP = weeks after planting, A1 = 80% chicken manure + 20% dolomite; A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis;* A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite. D3 = 15 t ha^{-1}, D4 = 20 t ha^{-1}, D5 = 25 t ha^{-1}.

The numbers followed by the same letter in the same column indicates no significant difference between periods of observation by DMRT at α = 5%.

through nitrification. Changes in NH_4^+ to NO_3^- (nitrification) odds were heavy occurring in peatlands that has been reclaimed (Kurnain 2005). Ammonium is the first product during the process of mineralization. Ameliorant composition greatly affected the release of NH_4^+ derived from ameliorant materials. In aerobic condition, ammonification was faster than that in anaerobic condition (Reddy and de Laune 2008).

Table 6. Concentration of NO_3^- in peat soil as affected by ameliorants observed at planting until harvest of sweet corn, Palangkaraya, Central Kalimantan, 2011.

Treatment	NO_3^- concentration (mg kg^{-1})				
	0 WAP	2 WAP	4 WAP	6 WAP	Harvest
A1D3	241 b	279 bc	84 a	61 ab	9 c
A1D4	279 b	726 a	63 ab	69 a	23 b
A1D5	401 a	775 a	59 b	35 cd	29 ab
A4D3	139 c	217 c	46 ab	29 c	7 c
A4D4	251 b	289 b	38 ab	28 c	26 b
A4D5	238 b	253 bc	22 c	79 a	23 b
A5D3	255 b	341 b	27 c	46 ab	12 c
A5D4	243 b	335 ab	36 b	41 ab	19 bc
A5D5	171 c	498 a	35 b	52 a	17 bc
Control	9 d	82 c	24 c	6 c	14 c
Farmer	26 d	181 c	10 c	60 a	42 a
Mean	205.45	361.99	40.88	46.54	20.72

WAP = weeks after planting, A1 = 80% chicken manure + 20% dolomite; A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis*; A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite. D3 = 15 t ha^{-1}, D4 = 20 t ha^{-1}, D5 = 25 t ha^{-1}.
The numbers followed by the same letter in the same column indicates no significant difference between periods of observation by DMRT at α = 5%.

Ameliorants affected the concentration of NO_3^- in the soil at each time of observation (Table 6). The NO_3^- concentration decreased with the increasing ages of the plant. Nitrate is a form of nitrogen that is widely available in the newly opened peatlands, but it was easily leached from the rhizosphere due to the negatively charge ion, and it was easily transformed into N_2O and NO. The decrease in NO_3^- concentration may also caused by the presence of nitrite immobilization occurring in the non-biological reactions (Thorn and Mikita 2000).

At the beginning of the observation, the highest concentration of available N due to amelioration was shown by ameliorant A1 (80% chicken manure + 20% dolomite) at the rate of 25 t ha^{-1} and it was significantly different from that of 20 t ha^{-1}. However, the effects were inconsistent at different times of observations. Nitrogen in peat soil was very mobile and easily lost from the rhizosphere area (Kurnain 2005). At harvest time, the highest N available in the soil was found on farmers treatment, but it was not significantly different from A1D5 treatment.

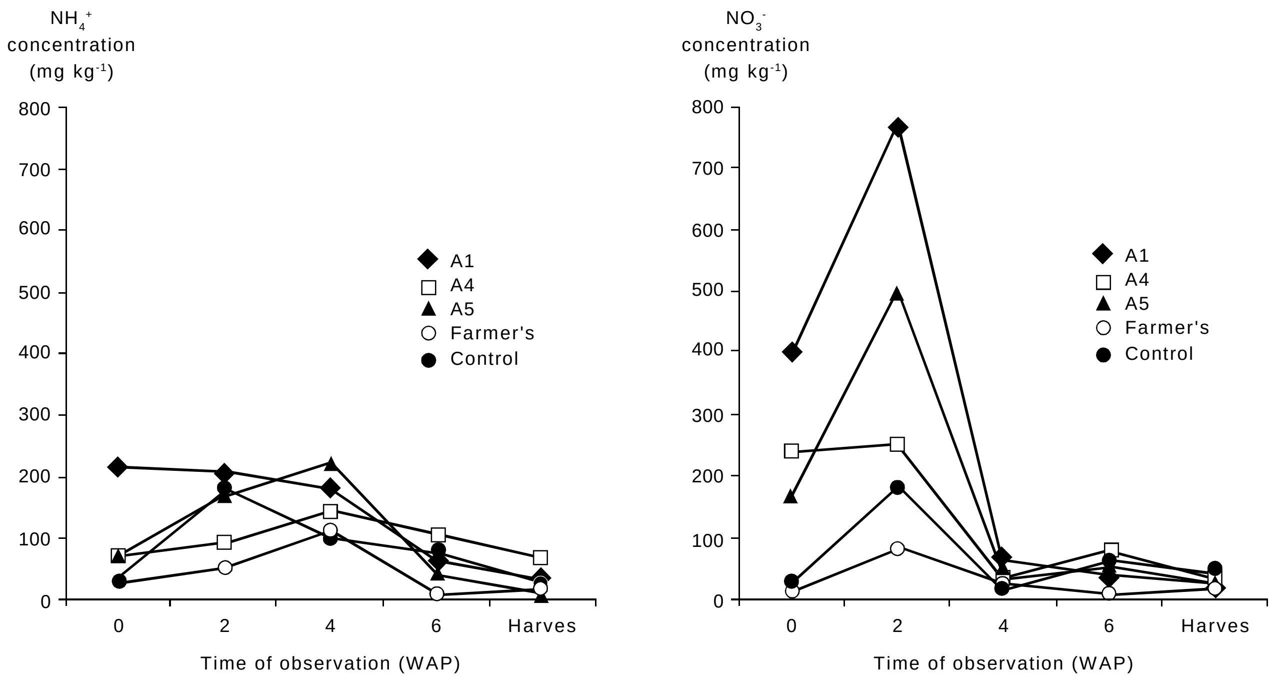

Fig. 6. Effects of ameliorants at the rate of 25 t ha^{-1} on NH_4^+ and NO_3^- concentrations in peat soil, Palangkaraya, Central Kalimantan, 2011. A1 = 80% chicken manure + 20% dolomite; A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis*; A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite. D3 = 15 t ha^{-1}, D4 = 20 t ha^{-1}, D5 = 25 t ha^{-1}.

Effect of Ameliorants on N Uptake

N uptake accumulated in the roots and in the shoots of maize plants showed significant differences among treatments (Table 7). The highest N uptake in the root was indicated by A1 ameliorant at the rate of 25 t ha^{-1}. The highest N uptake in the shoot was indicated by A1 ameliorant at the rate of 20 t ha^{-1}.

The increase in N uptake increased the yield of sweet corn. In this research, the highest yield of sweet corn (14.98 t ha^{-1} fresh cob) was shown by A1 ameliorant at the rate of 25 t ha^{-1}. This yield was not significantly different from A1 ameliorant at the rate of 20 t ha^{-1} as high as 13.86 t ha^{-1}.

The pattern of N uptake in the field experiment was similar to that of the greenhouse experiment, but in the field it had a higher value. The plant growth in the field was better than that at the greenhouse, partly due to the optimum intensity of solar radiation and temperature to support the plant growth. Corn is a C4 plant which requires considerable intensity of solar radiation to support growth and crop production (Bunyamin and Aqil 2009). Therefore, plant growth in the field experiment was better than that in the greenhouse at a comparable ameliorant and fertilizer treatments.

Table 7. Nitrogen concentrations and N uptake in the root and shoot of sweet corn plant in peatland treated with different kinds and rates of ameliorants, Palangkaraya, Central Kalimantan, 2011.

Treatment	N content (%)		N uptake (g $plant^{-1}$)	
	Shoot	Root	Shoot	Root
A1D3	1.73 ab	2.52 a	0.043 bc	3.550 a
A1D4	1.85 a	2.43 ab	0.049 b	3.606 a
A1D5	1.68 ab	2.47 a	0.055 a	3.535 a
A4D3	1.59 b	2.57 a	0.037 cd	3.545 a
A4D4	1.59 b	2.10 ab	0.038 cd	2.580 abc
A4D5	1.45 b	1.96 b	0.052 ab	2.900 ab
A5D3	1.73 ab	2.09 ab	0.036 d	1.603 c
A5D4	1.73 ab	2.29 ab	0.042 bc	3.540 a
A5D5	1.59 b	2.19 ab	0.038 cd	3.070 ab
Control	dead	dead	dead	dead
Farmer’s	1.85 a	2,28 ab	0.049 b	2.200 bc

WAP = weeks after planting, A1 = 80% chicken manure + 20% dolomite; A4 = 20% chicken manure + 20% dolomite + 20% local farm weeds + 20% mineral soil + 20% *Eleocharis dulcis*; A5 = 19.05% chicken manure + 71.45% mineral soil + 9.5% dolomite. D3 = 15 t ha^{-1}, D4 = 20 t ha^{-1}, D5 = 25 t ha^{-1}.
The numbers followed by the same letter in the same column indicates no significant difference between periods of observation by DMRT at α = 5%.

CONCLUSION

Organic matters and dolomite as ameliorants for peat soil increased soil pH and availability of NH_4^+ and NO_3^- at maximum vegetative stage of sweet corn. Ameliorants of 80% chicken manure and 20% dolomite provided the highest NH_4^+ and NO_3^- availability and N uptake in the roots and in the shoot of sweet corn and in general the availability and uptake increased with the higher rate of application. Ameliorant at the rate of 20 t ha^{-1} provided the optimum N uptake in the shoot. This composition and rate of ameliorant are is recommended for annual crops such as sweet corn in peat soil.

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