CHICKEN MANURE COMPOSTS AS NITROGEN SOURCES AND THEIR EFFECT ON THE GROWTH AND QUALITY OF KOMATSUNA (*Brassica rapa* L.)

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ABSTRACT

Environmental issues on the excessive use of chemical fertilizer and energy shortage in recent years have led to the renewed interest in using organic materials. The return of animal manure into crop fields is considered to be one of the most effective methods in reducing the use of industrially produced chemical fertilizer as well as utilizing the mineral nutrients in crop production waste. The use of animal manure as fertilizer, due to the availability of the nutrients contained in organic materials, has been of concern to agronomists and promoted in recent years in an attempt to increase the amount of soil organic matter and eventually to improve land productivity. The study was conducted in two consecutive experiments to observe the effect of five chicken-manure composts with different nitrogen content and to investigate their residual effect on crop yield and its quality. Chicken-manure composts (Ch-1 to Ch-5) were applied to 2 kg soil of Andisol in pot experiments and Komatsuna (*Brassica rapa* L.) vegetable was used as a sink of mineralized-N from chicken-manure composts. Unmanured pot was used as control, whereas pot fertilized with urea was used as standard of comparison for chemical fertilizer. Potassium chloride (KCl) and triple super phosphate (TSP) were added in the urea treatment to assure good initial growth. In the second experiment, KCl and TSP were added again at the same rate to the urea pot (U-1). However, compost was not applied in the second batch of chicken-manure compost treatments. The addition of chicken-manure composts resulted in significant differences in yield compared with control, but Ch-3 and Ch-5 did not have significant differences with urea. The residual effect of the chicken manures still resulted in increased Komatsuna yield for Ch-3 and Ch-5, and it enhanced yield significantly compared to residual urea (U-1); whereas the other treatments exhibited lower yield than those in the first batch of experiment. The increase in Komatsuna yield of Ch-3 and Ch-5 treatment in the second batch of the experiment might be caused by the higher N mineralization rate wherein residual inorganic N remained in the soil after the first batch of the experiment. Nitrate accumulation in plant was induced by increased N mineralization in soils. The application of Ch-3 and Ch-5 and urea increased greatly nitrate accumulation in Komatsuna plant, while Ch-1, which had slower N mineralization, induced smaller nitrate accumulation. The content of glucose and reducing sugar tended to be lower with the increase of the nitrate content in Komatsuna.

Key words: mineralization, chicken-manure compost

INTRODUCTION

Environmental issues on the excessive use of chemical fertilizer and energy shortage in recent years have led to the renewed interest in using organic materials, such as animal manure (Huang and Uri, 1994; Chambers, Smith and Pains, 2000). The returning of animal manure into crop fields is considered to be one of the most effective methods in reducing the use of industrially produced chemical fertilizer as well as utilizing the minerals nutrients in the wastes for crop production.

Animal manure usually contains a large amount of nitrogenous compounds, which are easily mineralized to ammonia or nitrate (University of Minnesota Extension, 2002). In other words, animal manures have been used as a means to improve the chemical, microbiological, and physical aspects of soil fertility and to increase crop production (Khaliq *et al*., 2006; Palm *et al*., 2001; Soumare *et al*., 2003;), which the returning of animal manure into soil were not the only means of adding nitrogen, but the most important means to add other nutrients (Andrew and Foster, 2007; Commoner, 2009; Mahmoud *et al*., 2009; Parr and Colacicco, 1987). Furthermore, animal manure have an ecological advantage in the development of sustainable agriculture (Khaliq *et al*., 2006). However, mismanagement of manure can have a substantial impact on our water, soil, and air resources. When used appropriately, manure has nutritive and economic value (Colaccio, 1982; Khaliq *et al*., 2006; Schmitt and Rehm, 1992).

Based on the above explanation, it is expected that animal manures can offset the use of chemical fertilizer which consume high cost oil energy. However, the value of animal manures is determined by the content of available nutrients for crop growth and of contributing to "extra" effects on crop production. In most circumstances, the uptake of nitrogen by a growing plant and the accumulation of mineral nitrogen in soil are both preceded by, and dependent on nitrogen mineralization. Mineral N is uptaken by plants in the forms of NO_3^--N and NH_4^+-N (Marschner, 2003). The differences in plant yield responses to the various forms of N fertilizer are due mainly to the differences in the N losses from the soil (Seidel *et al.,* 2007) rather than differences in the type of N form uptaken (Abassi *et al.,* 2005). Greenhouse-incubated soil provides a means by which estimates of greenhouse rates of mineralization. Despite its simplicity, artefacts may be introduced by the method which alters the rate of mineralization, or other nitrogen transformation. Furthermore, these artefacts (such as the change of soil water potential) can affect the magnitude of opposing process such as immobilization and denitrification, or in fact the rate of mineralization itself (Cassman and Munns, 1980).

This study was conducted in two consecutive experiments under greenhouse conditions and the various chicken-manure composts were used to observe the effect of chicken-manure composts as N source and their residual N effects on yield and quality of the crop compared with chemical fertilizer (urea).

MATERIALS AND METHODS

Five types of chicken manure compost with varying nitrogen content (Table 1) and soil of Andisol were used in these experiments. The chemical fertilizer as basal fertilization were KCl and triple superphosphate (TSP).

Table 1. The chemical properties of various composted chicken manure

Compost	Total N (%)	Org. C (%)	C/N	pH (H_2O)	NH_4-N (mg/100g)	NO_3-N (mg/100g)
Ch-1	2.31	26.5	11.5	9.1	38.4	0
Ch-2	3.43	29.3	8.54	7.0	365	0
Ch-3	6.53	31.3	4.79	7.7	441	0
Ch-4	3.90	29.2	7.48	8.0	421	0
Ch-5	6.16	33.9	5.50	6.8	261	0

Nitrogen mineralization and crop yield

The first batch of the experiment was carried out to observe the effect of chicken-manure composts with different N content on the N mineralization, yield and quality of crop. The chicken-manure compost was equivalent to 1 g of N per pot added to each pot of 2.5 kg moist soil of Andisol ($\simeq$ 2 kg oven-dry weight). Pots without manure were used as control (Ch-0), whereas pot fertilized with urea was the standard of comparison for inorganic fertilizer. The amount of nitrogen as urea, K_2O as potassium chloride, and P_2O_5 as triple super phosphate added to soil are 0.5 g pot^{-1}, respectively. The treatment was conducted in four replications and one pot was not sown with Komatsuna seeds to observe nitrogen mineralization under greenhouse conditions.

The chicken manure composts were thoroughly mixed with moist soil in each pot at the beginning of the experiment, and then incubated for a week before sowing. To substitute the loss of soil moisture during incubation, water was added to each pot until the initial soil weight was reached. On sowing, 20 seeds of Komatsuna (*Brassica rapa* L.) were sown per pot at a depth 0.5 cm to act as a sink for mineralized N. On the following week, Komatsuna plants were thinned out and five plants were retained in each pot. Soil inorganic N in the pot which was not sown with Komatsuna seeds was determined at 1, 7, 14, 21, 28, 35, 42, 49, 56 days after compost incorporation. Mineral N was extracted from moist soil with 1 *N* KCl and determined by Flow Injection Analysis (FIA).

At harvest, the shoots of Komatsuna cut and weighed, and then two plants for each pot cleaned of adhering soil by flotation in distilled water, weighed and dried at 60^o C and milled into powder for chemical analysis. The shoots of three Komatsuna plants were cut and separated between leaf and stem. For each of them were cut into small pieces manually and weighed with the same proportion, and then analyzed immediately for nitrate contents, glucose and reducing sugar. The contents of reducing sugars were determined by micro-copper titrimetric method.

At the end of pot experiment, the roots of plants were taken with care, washed with distilled water, and then weighed the fresh-weight and the dry-weight of 60^o C. At the beginning of pot experiment and after harvesting, the soils were taken and a part of these soils immediately analyzed in moist condition for inorganic N content (NH_4^+-N and NO_3^--N), while another part of the soil sample was dried at 35^o C for chemical analysis.

Residual effect of chicken manure composts

After harvest of the first batch (56 days after sowing), the soil in each pot was mixed thoroughly and roots were removed. Komatsuna seeds were sown as in the first batch of pot experiment. Compost was not applied in the chicken-manure compost treatments of the second batch of pot experiment. In another urea treatment (Treatment U-2), urea was added using the same amount of N applied in the earlier experiment, but in the urea pot of U-1 was only added again by KCl and TSP as same rate as the above mentioned. Basal fertilizer of KCl and triple super phosphate were likewise added using the same amount as in the earlier experiment in treatment U-2 to assure the initial growth of plant.

Experimental Design and Statistical Analysis

A completely randomized design with four replications, was used in all experiments. One pot was not sown with Komatsuna seeds to observe nitrogen mineralization under greenhouse conditions. The effect of chicken-manure composts on yield, dry matter of Komatsuna, N uptake, and the content of nitrate, glucose, and reducing sugar were processed by analysis of variance. The significance of the treatment differences for those parameters mentioned above was assessed by Tukey test (5%).

RESULTS AND DISCUSSION

Nitrogen Mineralization from Chicken-manure Composts

Various chicken-manure composts applied to soil provided varying levels of N mineralization during incubation under greenhouse conditions (Fig. 1). During the first week of mineralization, NH_4^+-N concentration in the soil applied with N-rich manure composts, increased rapidly than the others. The increase in NH_4-N concentration was due to the mineralization of soluble organic compounds. A decrease of inorganic N in soil during incubation resulted by the decrease of NH_4^+-N that was not accompanied by a parallel increase of NO_3^-N (data was not shown).

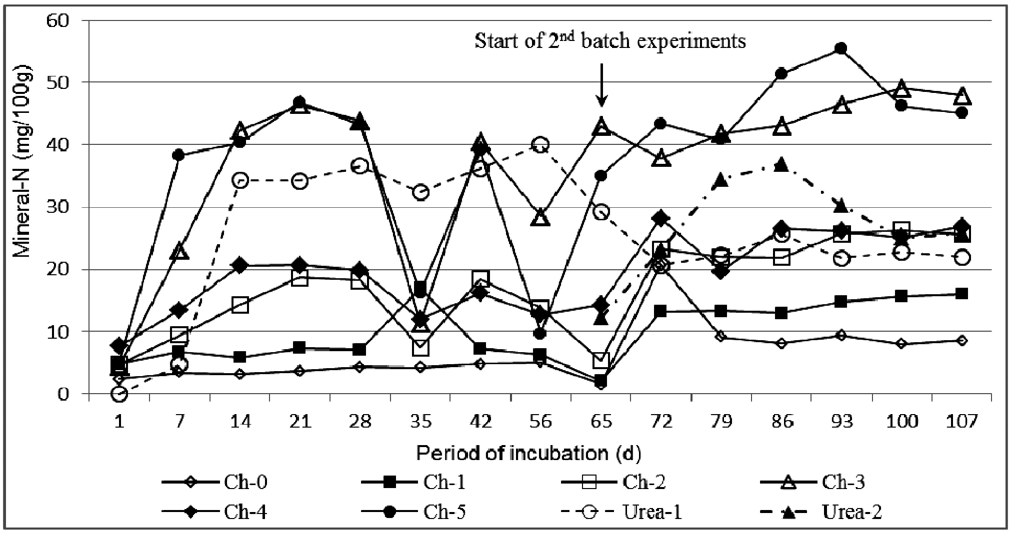

Fig. 1. Nitrogen mineralization of various chicken-manure composts during incubation under greenhouse conditions

The mineralization rate of chicken-manure compost during incubation period depended on the N content of the organic compound of composts. Comparison of results among the treatments of chicken-manure compots showed considerable and consistent differences in decomposition rates. Either in the first batch or in the second batch of the experiment, the most rapid decomposition of chicken-manure compost was recorded for Ch-3, Ch-4, and Ch-5, but the treatment of Ch-1 had the slowest N mineralization rate. The slowest N mineralization rate of Ch-1 was probably due to the smaller amount of mineralizable N in Ch-1 which resulted in smaller amount of available N. The critical N content required for immediate net mineralization of N to occur was calculated at 1.73% and the critical C/N ratio was 20 (Frankenberger and Abdelmagid, 1985; Iritani and Arnold, 1960). The N contents of the chicken-manure composts studied here were all above this critical N concentration and all had C/N ratios below 20. It was thus expected that the N mineralization of the composts studied would correlate well with their initial N content or C/N ratio. Our results, however, only partly followed such a trend, for example the proportion of the N released from Ch-1 much less than that released from Ch-2 and Ch-4 although the composts had similar C/N ratios. It was probably due to the inclusion of compost with a large unmineralizable or recalcitrant compounds. Total N content of Ch-3 and Ch-5 were almost three times higher than that of Ch-1. Apparently, the higher N content of Ch-3 and Ch-5 resulted more immediate N mineralization as compared to the other treatments. The higher mineralization rate of Ch-3 and Ch-5 is presumably due to the higher content of decomposable organic matter. These organic matter are more effectively attacked by soil microorganisms for their energy or nutrient supply. The N amount of Ch-1 mineralized after 21 days was very low, 5.6% of added N to soil and then became decreased in the second batch of the experiment. This manure compost therefore have a very low N fertilizer effect in soil in the short-term. However, treatment of Ch-3 and Ch-5 showed a high N mineralized and a longer presence in soil during two consecutive experiments. Therefore it considered they have a high N fertilizer effect and displayed a comparable effect with urea (U-2 treatment). Ammonium in soils were generally low. This lack of major NH_4^+-N accumulation indicated that the condition for nitrification was always favourable, even in manured pots.

Yield and Dry-matter of Komatsuna

The applied chicken-manure composts with various nitrogen (N) contents ranged from 2.3% - 6.5% (Table 1). Since the amount of applied N did not differ among the treatments, the results were comparable. Incorporation of chicken-manure composts into the soil resulted in the increase of Komatsuna yield (Fig. 2).

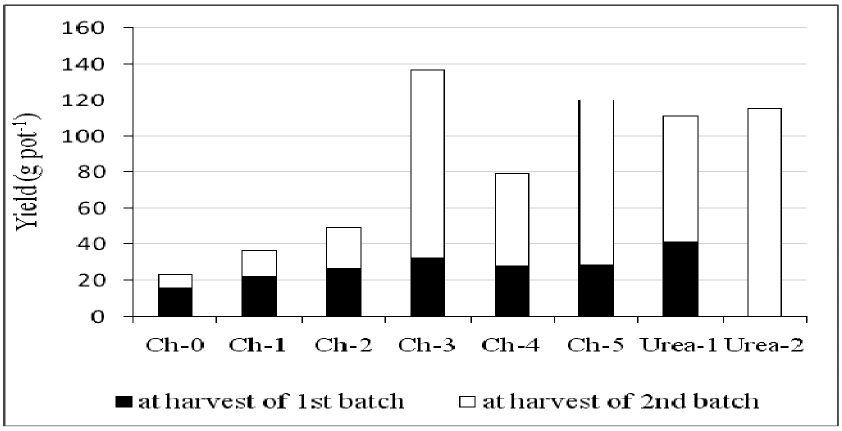

Fig. 2. Yield of komatsuna as affected by chicken-manure composts at harvest of first and second batch (residual effect).

As shown in Fig. 2, in the first batch of the experiment the urea treatment (U-1) displayed the highest yield (41.23 g pot^{-1}) followed by the treatment of Ch-3 (32.03 g pot^{-1}) , Ch-5 (28.50 g pot^{-1}), Ch-4 (27.83 g pot^{-1}), Ch-2 (26.53 g pot^{-1}) and Ch-1 (22.43 g pot^{-1}); while the lowest one was control soil, Ch-0 (15.93 g pot^{-1}) and it showed poor growth of Komatsuna. The low yields harvested from the soil without manure (control treatment) are due to the insufficient supply of plants in nitrogen, leading at first to limitation of carbon assimilation, resulting in reduction of plant productivity (Shangguan et al., 2000; Lawlor, 2002).

The residual chicken-manure composts resulted in higher yield of Komatsuna than those in the first batch, mainly for Ch-3 (105 g pot^{-1}), Ch-5 (91.13 g pot^{-1}), Ch-4 (51.27 g pot^{-1}), and U-1 (69.90 g pot^{-1}). However, they did not increase the yield in other treatments of chicken-manure compost (Fig. 2). Residual effects of Ch-3 and Ch-5 increased the yield of Komatsuna more appreciably than residual urea (U-1 treatment). Komatsuna in soil without manure (Ch-0) demonstrated N deficiency symptoms, such as yellowing leaves and retarded growth of plants

In the first batch, dry-matter yield of Komatsuna was significantly affected by the incorporation of chicken-manure composts when compared with the Ch-0, but there was no significant difference among the treatments and those were also not significantly different with urea (Fig. 3).

Dry-matter yield of Komatsuna was significantly influenced by the residual chicken-manure composts (Fig. 3). The dry-matter content of Komatsuna in treatments of Ch-3 (9.27 g pot^{-1}) and Ch-5 (8.61 g pot^{-1}) were significantly higher than the residual urea of treatment of U-1 (6.55 g pot^{-1}), but it was not significantly different with treatment U-2 (8.72 g pot^{-1}). It is due to a less residual N of treatment U-1 remained in the soil after the first batch of the experiment than that of treatment of Ch-3 and Ch-5 (Table 2), and it correlated with the faster release of N of treatment of U-1 to the soil than that from treatment of Ch-3 and Ch-5. The treatment of Ch-3 and Ch-5 showed a longer presence in soil during two consecutive experiments (Fig. 1) and showed a comparable effect with treatment of U-2. The less residual N in soil at the end of first batch of experiment resulted in insufficient supply of N for plants in the second batch.

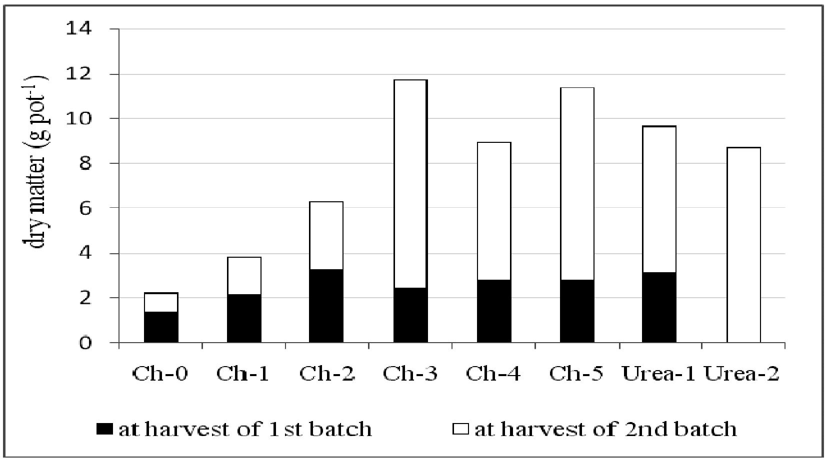

Fig. 3. Dry-matter content of Komatsuna at harvest as affected by chicken-manure composts (first and second batch).

Nitrogen Uptake of Komatsuna

The N uptake of Komatsuna was influenced by the incorporation of various chicken-manure composts (Fig. 4.) The N uptake of Komatsuna in the soil with chicken-manure composts was significantly higher than that of unmanured soil (Ch-0), except for Ch-1.

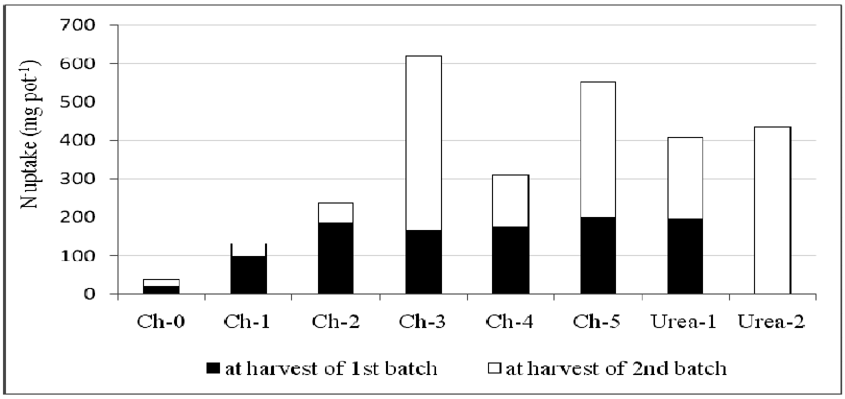

Fig. 4. Nitrogen uptake by Komatsuna at harvest as affected by chicken-manure composts (first and second batch).

Organic materials are subject to considerable changes due to physical, chemical, and biological processes taking place in soil. Rowel and Hadad (2014) stated that animal manures contribute more to the soil than just nitrogen, phosphorus, and potassium. It builds organic matter in soils and improves soil structure. This modification of soil structure helps improve water holding capacity, aeration, friability, and drainage. These conditions are necessary for satisfactory plant growth (Eimhoit et al., 2005; Mbhata, 2008).

The recovery of N by crops are affected by plant species, soil, climatic, and management practices (Allison, 1973). Nitrogen recovery determined by difference method also varied statistically, and its correlation coefficient with the N content of chicken-manure composts was significant. The apparent recovery (R_n) of material-N added to soil by the crop should be related to the level of material-N in a characteristic way. R_n is defined by :

$$R_n = (U_c - U_0)/N_m \quad \text{.......................................} \quad (1)$$

Where, U_c is the uptake of N by the whole plant excluding fibrous roots when an amount N_m of material-N is applied and U_0 is the corresponding uptake when no material or fertilizer is applied.

Nitrogen uptake (Table 2) showed that Ch-3 and Ch-5 were higher than residual urea (treatment of U-1), but these did not show significant difference with treatment U-2. Nitrogen uptake of the other treatments of chicken-manure composts, containing lower N (2.3% - 3.6%) were low, and among them did not indicate significant difference. The amount of residual inorganic nitrogen in soil before the sowing of the second batch (at the end of the first batch of the experiment) ranged from 1.46% (Ch-1 treatment) to 61.70% (Ch-3 and Ch-5 treatment) (Table 2). A higher residual N level from Ch-3 and Ch-5 after the first batch of the experiment correlated with the slower release of N to the soil than that from chemical fertilizer (urea). As would be expected, plant N content was influenced by the application of chicken-manure composts to the soil as the source of N. The effect of different N compounds of chicken-manure composts upon plant composition was also related to the release of N. The higher mineralization rates of them in soil, such as treatment of Ch-3 and Ch-5, tended to give a higher N contents of plant and N uptake of plant than did the slower mineralization rates, such as treatment of Ch-1. According to the yield of Komatsuna as mentioned above, the yield of Komatsuna in the unmanured treatment was very low (15.93 g pot^{-1}) than the other treatments. Thus, it is logical to conclude that N was the most growth limiting factor in this soil.

Table 2. Availability of residual nitrogen of chicken-manure and urea in soil

Treatment	Nitrogen Content	Residual N in soil at harvest of 1st batch mg N pot^{-1}	A (%)	Total N Uptake* (mg N pot^{-1})	N Recovery (%) A
Ch-0	0	-	-	15.43 a	-
Ch-1	2.31	14.60	1.5	31.68 a	1.6
Ch-2	3.43	74.00	7.4	50.21 a	3.5
Ch-3	6.53	617.00	61.7	456.00 b	44.1
Ch-4	3.90	227.00	22.7	137.00 ab	12.2
Ch-5	6.16	617.00	61.7	352.00 b	33.7
U-1	46	396.00	39.6	214.00 ab	19.9
U-2	46	-	-	436.00 b	42.1

A : based on the amount of N applied in the first experiment

* Means followed by the same letters referring to the respective indices are not significantly different.

Quality of Plant Production

Nitrogen content in vegetative parts, such as leafy vegetables, is present in an inorganic or simple organic form (as nitrate, nitrite, free amino, etc.). The accumulation of nitrate in plants is affected by either the availability of nitrate in soil and the plant's ability to convert nitrate by assimilation processes to higher products (Maynard and Barker, 1979 *in* Haynes, 1986). The entire nitrate content, absorbed by plants, was not assimilated in the plant metabolism and was partly accumulated in the vacuola of plant cells (Rufty et al.,1982).

The nitrate content of shoots (Fig. 5) varied greatly among the treatments. It is suggested that nitrate content of shoots was attributed to the differences of N availability of chicken-manure composts and by the N uptake. Generally, higher fresh and dry-yield of Komatsuna plants as in treatments of Ch-3 and Ch-5 were accompanied with increasing nitrate concentration of plant. Nitrate accumulation in plants occurs as a result of nitrate accumulation in the soil due to the activity of soil nitrifying organisms (Hanafy et al., 2000).

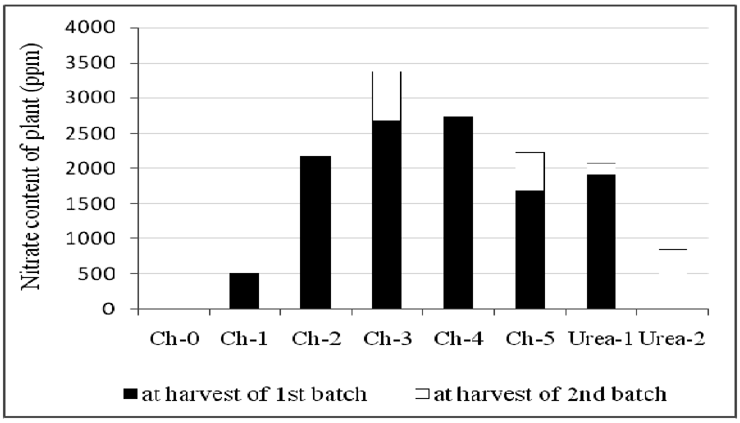

Fig. 5. The effect of chicken-manure composts on nitrate content of Komatsuna (*Brassica rapa L.*) at harvest (first and second batch).

In the second batch of the experiment, the nitrate content of the shoots became lower compared to the first batch, although treatment of Ch-3, Ch-5, and U-1 still showed a high nitrate content than the other treatments. The higher plant nitrate from Ch-3 and Ch-5 treatments might be due to the large residual N and the longer presence of N in soil. This is in accordance with Barker's statement (1975 *in* Haynes, 1986) that much nitrate is accumulated in plants from organic manures as from inorganic fertilizer if adequate time is allowed for mineralization. Organic manures that mineralize slowly lead to less nitrate accumulation in vegetables than materials that mineralize rapidly and therefore release more NO_3^--N in soil. The plant quality depends on the magnitude of nitrate accumulation. The high concentration of nitrate in plant could be toxic for health (European Food Safety Authority, 2008).

The content of glucose and reducing sugar (Fig. 6 and 7) tended to be lower with the increase of nitrate content. The glucose and reducing sugar content of shoots in the first batch of the experiment were 0.08-1.36% and 0.15-0.54%, respectively. By adding urea, the glucose content was the lowest one than the chicken-manure compost treatments. While the lowest reducing sugar content was also achieved with U-1 application, followed by Ch-3.

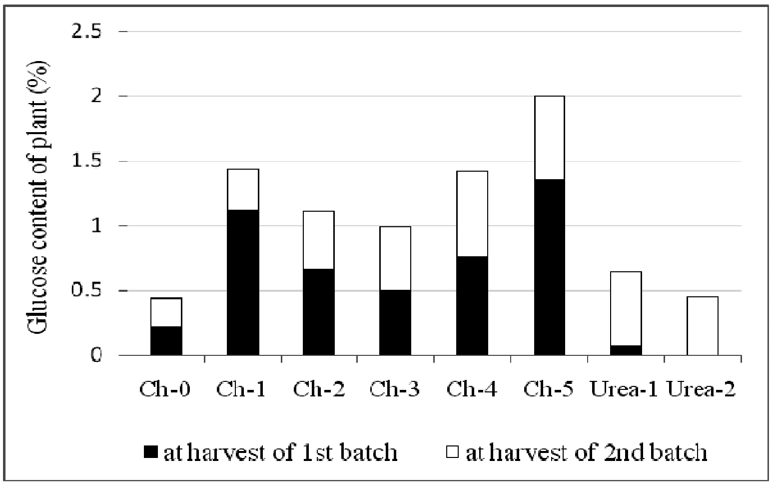

Fig. 6. The effect of chicken-manure composts on glucose content of Komatsuna at harvest (first and second batch)

The higher the nitrate content of the plant, the lower the glucose or reducing sugar content because the assimilation of nitrate in plant metabolism requires energy from the process of carbohydrate formation, the glucose and reducing sugar content would therefore be lower. Buwalda and Warmenhoven (1999) worked on lettuce and mentioned that the concentration of nitrate and the sum of sugars and organic acids in the shoots of lettuce showed a strong negative correlation. These decrease in total sugar concentrations might be explained that plants used most of the carbon in structural growth, but incorporated relatively less carbon in soluble organic compounds. In this way, nitrate accumulation in the vacuoles will increase to compensate for the shortage of sugars to replace the decline in osmotic value (Hanafy et al., 2000). Thus, NO_3 accumulation was inversely related to the accumulation of sugars (Seginer et al., 1998). In addition, plants that contain adequate concentrations of sugars are able to assimilate nitrate at a faster rate than comparable plants containing lower concentrations of sugars (Kirkby, 1981).

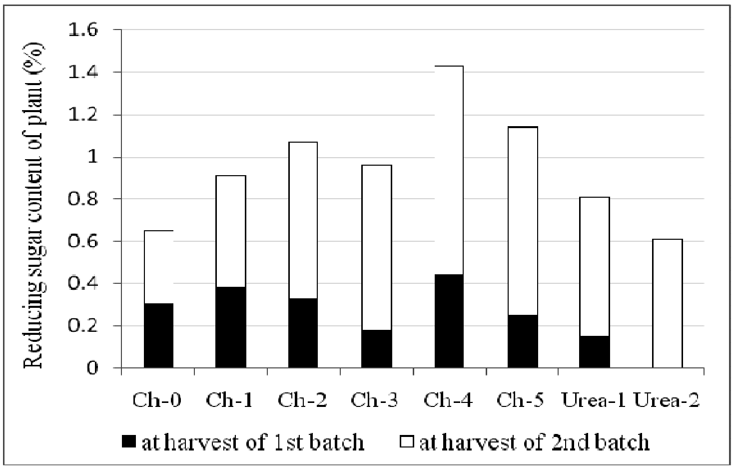

Fig. 7. The effect of chicken-manure composts on reducing sugar content of Komatsuna at harvest (first and second batch).

CONCLUSION

The difference in nitrogen content of chicken-manure composts has an influence on plant yield and quality of product. The high nitrogen content of chicken-manure compost contributed to higher yield of Komatsuna (*Brassica rapa* L.). Chicken-manure compost with high N content (6% N) had a high N fertilizer effect and displayed a comparable effect with urea on crop growth and yield. The higher N uptake and yield tended to increase the content of nitrate in Komatsuna plant and to decrease the glucose and reducing sugar content of Komatsuna. In contrast, chicken-manure compost with low N content (2.3% N) showed a lower effect than urea. The best treatment to give high yield of Komatsuna (*Brassica rapa* L.) and to reduce application of nitrogen chemical fertilizer was chicken-manure with high nitrogen content (Ch-3 and Ch-5).

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