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Effects of Manure nitrogen on vegetables' yield and nitrogen efficiency in Tanzania

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Abstract

Due to an increasing demand of leaf vegetables, and hence their economic importance in the tropics, it is very common that excessive fertilizer N rates are applied to vegetable gardens and fields to attain high yield. This calls for more information on their nutrient requirements. In this study, we designed experiments to explore the effect of organic N levels on the yield and agronomic N use efficiency (ANE) by chinese cabbage (*Brassica rapa*) and amaranthus (*Amaranthus cruentus*). The experimental design was a randomized complete block design consisting of chinese cabbage (CC) and amaranthus (AM) with three replicates. Chicken manure (CHM) and cattle manure (CAM) were the source of N. The treatments were 0, 200, 300 kg N ha^{-1} and 0, 170, 250 kg N ha^{-1} for CC and AM, respectively. Chicken manure resulted in increased fresh and dry matter yield of CC and AM compared to CAM. All treatments at first harvest induced higher marketable yield of vegetables than controls except with low levels of CAM N. At second harvest, only 300 kg CHM N ha^{-1} resulted in significantly ($P<0.05$) higher marketable yield of CC compared to control, while no significant difference observed in AM by 170 kg CAM N ha^{-1}. Agronomic N use efficiency was decreasing with increasing N levels. Nitrogen levels can be reduced to 200 and 170 kg N ha^{-1} for CC and AM without significantly affecting the yield.

Keywords: Manures; Chinese cabbage; Amaranthus; Yield; N efficiency.

Introduction

Vegetable production in urban areas has become economically important in many African countries, including Tanzania. In Tanzania, chinese cabbage (CC) and amaranthus (AM) are among the important vegetable crops. Amaranthus for instance, has received considerable attention because of its high nutritive value. Its leaves contain 17.5-38.3% dry matter as protein of which 5% is lysine (Oliveira and De Carvallo, 1975), 100 g of the vegetable material cooked without oil contributes about 45% of vitamin A requirement (FAO, 2004), and vitamin C is present in significant levels.

Among other factors, vegetable production in Tanzania is limited by low soil fertility, which is common in many tropical cropping systems where low or no agricultural residues are returned to the soil (Wakene et al., 2001). Further, the cost of inorganic fertilizers in Tanzania has been increasing from 1980 s due to removal of fertilizer subsidies by the government (Kimbi et al., 1996), limiting their use by poor farmers. Thus, to maintain soil fertility and subsequently enhance vegetable production by these poor farmers, cheaper options like application of organic manures, are indispensable. These manures replenish nutrients lost from the soil and thereby play a direct role in plant growth via supplying all necessary macro and micronutrients in available forms during mineralization and improving the physical and biological properties of soils (Suthar, 2009). However, they cannot meet crop nutrient demand over large areas because of limited quantities available, low nutrient content for most of the materials, and high labor demands for processing and application (Fening, 2005).

Animal manures have been a potential source of nutrients in the study area due to their availability to small-scale farmers. This is because of intensive/semi-intensive grazing system caused by limited agricultural land in urban areas. In Morogoro municipality, Tanzania, about 30% of farmers apply manures on land (Kimbi et al., 2001). Cattle and chickens are the dominant type of livestock kept in Tanzania by individual farmers and companies. Manures from these animals are considered a waste and create a disposal problem leading to abundance of manures available to small scale farmers for use in crop production at a relatively low cost per ton. There is a need for better incorporation of these manures in cropping system to maximize nutrient recycling and minimize losses.

In developing countries, it is common that excessive fertilizer N rates are applied to vegetable gardens and fields to attain high yield (Moeskops et al., 2010). In addition, the utilization and amount of manure to be applied are negatively correlated with farm size (Mkhabela and Materechera, 2003). High application rates of fertilizers in urban areas are thought to be economically reasonable due to limited agricultural land and low cost of organic fertilizer inputs as compared to the value of the marketable product. However, proper N balance is required for optimum growth and development of vegetables since excessive N increases their susceptibility to fungal diseases and deterioration of keeping quality (Collingwood et al., 1988). This suggests that nitrogenous sources should be appropriately applied to provide optimum amount of N to vegetables. However, the application is complicated by variations in response of the vegetables to N levels under different soils and agro-climatic conditions. It is therefore pertinent to properly understand the relationship between N levels in various soils and the optimal vegetable yields. This necessitates thorough studies to establish the appropriate rates of N sources to be applied in specific situations. In this study, we designed experiments aimed at exploring the effect of animal manures on the yield and agronomic N use efficiency by CC and AM.

Material and Methods

Study Area

The study was conducted in Morogoro municipality, Tanzania, located between 37°-39° E and 6°-5° S at an altitude of 500-600 m above sea level. Its temperature ranges between

27.0 °C to 33.7 °C in the dry/warm season and 14.2 °C to 21.7 °C in the cold/wet season. Morogoro municipality experiences a sub-humid tropical climate with a 5-month dry season separating a short rains (October to December) and a long rains (March to May) season. The mean annual rainfall is about 870 mm. Experiments were conducted on a typical vegetable field at the horticultural unit of Sokoine University of Agriculture. The soil was sandy clay loam, classified as Umbric Fluvisol (Epidystric) (WRB, 2006).

Materials and growing conditions

Both CC and AM were used in the experiment as they are the most commonly grown and consumed vegetables in Tanzania. The experimental design was a randomized complete block design with three replicates. To investigate soil fertility management practices of vegetable growing fields in the study area, a survey was conducted. Results revealed that chicken and cattle manures are readily available and most used by farmers, hence chosen as the source of N in this experiment (data not shown). The amount of N used by farmers per cultivation season for CC and AM was 172-517 and 50-289 kg N ha^{-1}, respectively. Majority of farmers apply about 300 and 250 kg N ha^{-1} for CC and AM, respectively. Based on these data, two treatments of manure N levels with a control (no manure) were adopted per vegetable: 0, 200, 300 kg N ha^{-1} and 0, 170, 250 kg N ha^{-1} for CC and AM, respectively.

Plot size for each treatment was 4 m^2, separated by 0.7 m within blocks and 0.9 m between blocks. Incorporation of manure into soil was done once, one day before sowing. In CC plots five seeds were sown per point on 1st July 2008 (dry season). Two weeks after sowing, thinning to one plant per point was done resulting in a plant density of 6 plants m^{-2}. Plant to plant distance within rows and between rows was 30 and 50 cm, respectively.

To obtain uniform stand, AM seeds were mixed with sand at a ratio of 1g seed to 100 g sand and broadcasted at a rate of 1g seed m^{-2} (Palada and Chang, 2003) on 18th July 2008 (dry season). Irrigation was practiced once a day (5 litres m^{-2}) to maintain adequate soil moisture. Twenty one days after sowing, the CC plants were sprayed with a synthetic pyrethroid pesticide, Mo-Karatep 5 Ec containing Lambda-cyhalothrin 5g L^{-1} (Agchem Access LTD, Norwich Norfolk, UK) following attack by cabbage aphid (*Brevicoryne brassicae*) in respective plots. However, there were no noted changes on CC production due to aphid attack.

Plant sampling and analysis

Sampling began when vegetables had grown to commercial size. In CC plots destructive sampling were done 30 and 44 days after sowing, while in AM plots this was done 28 and 38 days after sowing. Sampling was carried out between 8 and 10 h in the morning. Three CC plants were uprooted from each plot, while AM plants were uprooted from 3 locations (0.3×0.3 m per location) of each plot; the root length was measured and afterwards separated from the aboveground parts. Each sample containing the aboveground parts was put in a marked plastic bag and then placed in a refrigerating box. In the laboratory, samples were cleaned with a wet towel. All sample material per plot was cut, homogenised into one composite sample, and weighed to obtain fresh yield. Each composite sample was further randomly subdivided into two sub samples for nitrate and dry yield determination.

Sub-samples for dry yield were partially air-dried at room temperature and then dried in oven at 65 °C to constant weight. The dried samples were ground to pass through 0.1 mm sieve using a Tector 1093 Cyclotec sample mill prior to analysis. The total N-concentration was determined by a salicylic acid-sodium thiosulphate modification of the regular Kjeldahl method (to include NO_2^-N and NO_3^--N) (Bremner and Mulvaney, 1982). The results were expressed on a dry weight basis.

Agronomic N use efficiency (ANE) (Budhar et al., 1994) was computed as follows:

$$ANE = (Y_N - Y_0) / N_r$$

Where N_r is the amount of manure N applied (kg N ha^{-1}), Y_N is the dry yield with applied manure N, and Y_0 is the dry yield without manure N applied. To further explore the response to applied manure N, the NR was calculated using the following equation (Cassman et al., 1996b).

$$\%RE = (U_N - U_0) / N_r \times 100$$

Where N_r is the amount of manure N applied (kg N ha^{-1}), U_N is the plant total N content (kg N ha^{-1}) in manure amended soil, and U_0 is the plant total N content (kg N ha^{-1}) without manure applied.

Statistical analysis

Data were statistically analyzed by multifactor analysis of variance (ANOVA) for a randomized complete block design using MSTAT-C package (Freed, 1992). To determine the statistical significance of mean differences between treatments, we carried out the least significant difference (LSD) tests based on Duncan's multiple range tests. A probability level of $P \leq 0.05$ was considered significant. Linear correlations analysis was used to determine the relationships between vegetable yield and N concentration in the shoots.

Results and Discussion

Effect of N source and levels on yields of CC and AM

Plant yields, N uptake, agronomic efficiency and N recovery increased with increasing plant age, with or without N applications through CHM and CAM (Tables 2 and 3). The organic manures significantly increased both fresh and dry matter yields ($P<0.05$) of CC and AM over the control (Tables 2 and 3). The highest fresh yield as well as dry matter of CC was obtained by the application of CHM, however, the difference between CHM and CAM treatments was not statistically significant ($P=0.05$). All fertilized treatments except with 200 kg CAM N ha^{-1}, resulted in significantly higher ($P<0.05$) CC marketable fresh matter yields at 30 days after sowing (DAS) as compared to control. Table 1 demonstrates further that although all treatments at 44 DAS induced higher marketable yield, only CHM applied at 300 kg N ha^{-1} resulted in significantly ($P<0.05$) higher yields than controls. The differences in marketable yield and dry matter between 200 and 300 kg N ha^{-1} with respect to N source were not significant, implying that N levels applied at 300 kg N ha^{-1} to CC are not profitable over 200 N kg ha^{-1}.

Table 1. Mean values of some physical and chemical characteristics of the experimental soil.

Soil properties	Values
pH (2:2.5 soil: water)	7.3
Total N (%)	0.21
Available N (mg kg^{-1})	41.9
Available P (mg kg^{-1})	130.8
Available K (mg kg^{-1})	216
OC (%)	2.4
Sand (%)	69
Silt (%)	11
Clay (%)	20
Texture class	Sandy clay loam
Soil (FAO classification)	Umbric Fluvisol (Epidystric)

Table 2. Chinese cabbage yield (ton/ha), total N uptake (kg/ha), agronomic N efficiency (ANE) (kg dry matter/ kg N) and apparent N recovery (NR) (%).

Days after planting	Fresh matter		Dry matter		Total N uptake		ANE		NR	
	30	44	30	44	30	44	30	44	30	44
Control 0 N kg/ha	5.35^{b}	30.4^{b}	0.32^{b}	1.34^{b}	19.03^{b}	48.53^{b}	-	-	-	-
CHM 200 N kg/ha	10.23^{a}	50.8^{ab}	0.55^{a}	2.5^{a}	29.31^{ab}	83.01^{a}	1.70 ±0.08	5.80 ±0.53	5.14 ±1.52	17.24 ±1.84
CHM 300 N kg/ha	10.85^{a}	62.6^{a}	0.61^{a}	2.88^{a}	32.59^{a}	84.56^{a}	0.97 ±0.06	5.13 ±1.04	4.52 ±1.57	12.01 ±1.97
CAM 200 N kg/ha	8.8^{ab}	48.0^{ab}	0.5^{a}	2.18^{ab}	25.66^{ab}	66.18^{ab}	0.91 ±0.35	4.20 ±0.59	3.31 ±1.66	8.82 ±1.95
CAM 300 N kg/ha	9.95^{a}	48.8^{ab}	0.55^{a}	2.24^{ab}	31.07^{a}	62.47^{ab}	0.77 ±0.18	3.00 ±1.67	3.01 ±1.06	4.64 ±2.60

Means with the same letter in columns are not significant different by Duncan's Multiple Range Test comparison (DMRT) α=0.05. CHM, chicken manure; CAM, cattle manure.

Table 3. Amaranthus yield (ton/ha), total N uptake (kg/ha), agronomic N efficiency (kg dry matter/kg N) and apparent N recovery (NR) (%).

Days after planting	Fresh matter		Dry matter		Total N uptake		ANE		NR	
	28	38	28	38	28	38	28	38	28	38
Control 0 N kg/ha	7.48^{d}	14.11^{b}	0.53^{b}	1.66^{b}	14.97^{b}	28.86^{c}	-	-	-	-
CHM 170 N kg/ha	17.87^{ab}	23.23^{a}	1.06^{a}	2.52^{ab}	28.32^{a}	45.73^{ab}	3.10 ±1.11	5.08 ±3.32	7.85 ±2.40	9.92 ±3.57
CHM 250 N kg/ha	18.69^{a}	25.50^{a}	1.06^{a}	2.90^{a}	33.66^{a}	53.85^{a}	2.09 ±0.30	4.96 ±0.38	7.47 ±1.27	10.0 ±0.85
CAM 170 N kg/ha	11.31^{cd}	21.53^{ab}	0.75^{ab}	2.38^{ab}	20.14^{b}	42.71^{b}	1.29 ±0.35	4.27 ±1.24	3.04 ±1.82	8.15 ±1.91
CAM 250 N kg/ha	13.35^{bc}	25.82^{a}	0.76^{ab}	2.67^{a}	28.39^{a}	50.79^{ab}	0.89 ±0.46	4.06 ±0.97	5.37 ±1.30	8.77 ±0.18

Means with the same letter in columns are not significant different by Duncan's Multiple Range Test comparison (DMRT) α=0.05. CHM, chicken manure; CAM, cattle manure.

Similar to CC, the fresh and dry yields of AM were positively affected by both the N sources and levels (Table 3). CHM yielded more fresh and dry matter of AM than CAM and the difference in fresh yield was significant at 28 DAS ($P<0.05$), while at 38 DAS the effect of CHM was not significantly different from that of CAM. These results are in harmony with those by Abou El- Magd et al. (2006) and Huieh-Ching Fong et al. (1996) who reported high yield of vegetables with CHM as compared to CAM. CHM is rich in its nitrogen and other plant nutrients as a result it favours the growth and development of root system which reflects better vegetative growth, photosynthetic activity and dry matter accumulation (Abou El- Magd et al., 2006).

All treatments with organic manures had significant higher marketable yield of AM ($P<0.05$) than control at both 28 and 38 DAS, except fertilization with 170 kg CAM N ha^{-1}. The increase on the dry matter yield over control at 28 DAS was significant only with CHM treatments while at 38 DAS the significant difference were observed with the application of CHM and CAM at a rate of 250 kg N ha^{-1}. As in CC experiments, there was no significant difference in marketable and dry matter yield between the application of 170 and 250 kg N ha^{-1} with respect to N source. Therefore, fertilization levels can be reduced to 170 kg N ha^{-1}without significantly affecting the yield.

Effect of harvesting time on yield

The vegetable crop may be raised successfully but if not harvested at appropriate stage may lead to reduced vegetable yield and quality. Results from the survey showed that reaping and regrowth system of harvesting has been practiced for CC. This method of harvesting leads to higher total yields as compared to the whole plant harvest. However, larger plant size at harvest start results in higher total yield due to more reserves of carbohydrate present in the remaining part of the plant to stimulate regeneration of new leaves (Fu, 2008). Farmers who do seeding direct in the fields started reaping 4-6 weeks after sowing depending on the demand, while those who practised transplanting started reaping 5 week after. For amaranths, harvesting by uprooting the whole plant was done 4-5 weeks after sowing. However, for some varieties harvesting was done even 3 weeks after sowing. Therefore important to assess how these premature harvest practices can affect yield and N uptake.

In general, the growth rate of CC and AM in the first month after sowing was very low with respect to 14 and 10 days later, respectively. This was reflected in the marketable yield and dry matter accumulation (Table 4), two more weeks in the field resulted in a CC yield increase of 391-477% and 307.3-372.1% for marketable yield and dry matter, respectively. These results indicate that the overall CC weight mainly depends on the duration of the harvesting period. Similar results were found from the AM experiment where 30-93.4 and 137.7-251% for marketable yield and dry matter, respectively, increased within 10 days. These data are in agreement with previous studies conducted in leeks and wheat shoot by Sørensen et al. (1995) and Roshani and Narayanasamy (2010), respectively, where the increment of dry and fresh yield was observed to be due to delayed harvesting time. Also Salomez (2004) reported that total head weight of lettuce depends on cultivation period.

Table 4. Percentage yield increase within 14 and 10 days for Chinese cabbage and Amaranths, respectively.

Manure type	Chinese cabbage			Amaranths		
	Applied N kg/ha	Fresh yield (%)	Dry Yield (%)	Applied N kg/ha	Fresh yield (%)	Dry yield (%)
	0	468	319	0	89	213
CHM	200	396	355	170	30	138
	300	477	372	250	36	174
CAM	200	445	336	170	94	217
	300	391	307	250	93	251

Root development

To deplete the soil inorganic N, a crop needs to have a sufficiently high N-uptake capacity as well as a root system that is well distributed in the soil which brings the crop into contact with as much soil N as possible. This study showed that irrespective of the manure type, the rooting depths of CC and AM increased with increasing N level of manure application. Results in Figure 1 show that the highest rooting depths of CC and AM were recorded in plants supplied with 300 and 250 kg N ha,$^{-1}$ from CHM and CAM at 44 and 38 DAS, respectively. Figure 1A indicates that at 30 DAS the difference between unfertilized and fertilized CC was significant with the application of 200 and 300 kg N ha^{-1} of CHM as well as 300 kg N ha^{-1} of CAM. At 44 DAS the difference was significant with the application of 300 kg N ha^{-1} of CHM. Results for AM indicate that only application of CAM at 250 kg N ha^{-1} led to significantly higher ($P=0.05$) root length than unfertilized plants (Figure 1B). Figure 1A shows further that there were no significant difference ($P \leq 0.05$) in rooting depth between CC fertilized with 200 and 300 kg N ha^{-1} irrespective of manure type. Similar results were observed with AM where the application of 170 and 250 kg N ha^{-1} did not cause significant difference in rooting depth.

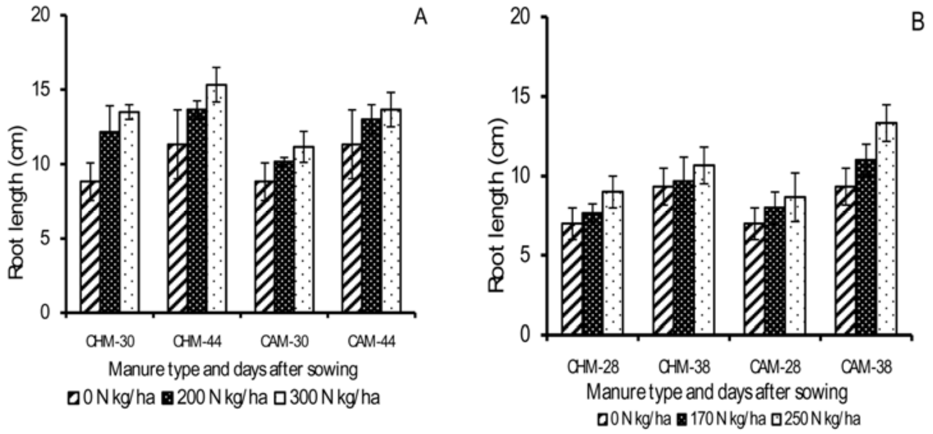

Figure 1. Effect of N source, N levels and harvesting time on root development of Chinese cabbage (A) and amaranths (B).

Root development of both CC and AM was influenced by the interaction of the type of manure and growing period. Regardless of N rates, application of CAM in CC and AM plots resulted into significantly higher ($P=0.05$) rooting depth at 44 and 38 DAS as compared to that harvested at 30 and 28 DAS, respectively (Figure 1). However, with CHM the significant difference in rooting depth due to harvesting date was observed only at the rate of 300 kg N ha^{-1} applied to CC. A maximum of 13.5 and 9 cm at 30 and 28 DAS, and 15.3 and 13.3 cm at 44 and 38 DAS for CC and AM, respectively, were recorded. A shorter root length (5.38 cm) of AM fertilized with nitrogen fertilizers at a rate of 250 kg N ha^{-1} and harvested at 25 DAS was reported by Chakhatrakan (2003). The superiority of AM's root length we observed over that by Chakhatrakan (2003) is probably due to the reason reported by Abou El- Magd et al. (2005) that CAM and CHM improve the soil structure and aeration which support root development. This knowledge on rooting depths in specific situations is important when one wants to apply e.g. models of N dynamics in the soil-plant system, where rooting depth is a crucially important parameter.

The short season and shallow rooted vegetables normally leave more mineral N in the soil at harvest than do deep rooted crops, even though much of this N can be lost by leaching during the following rain season (Thorup-Kristensen, 2001). Therefore, crop rotation with deep-rooted species following CC and AM season must be adapted as strategies for increasing nitrogen use efficiency and avoiding environmental pollution. This means that the capacity of crops to take up N at depth should be based primarily on the inherent rooting depth of species.

N-uptake

Comparing the ability of the crops to take up N and deplete the soil at different N rate supply is of crucial importance as it gives their contribution to the amount of N left in the soil at harvest and is the basis for formulating an N fertilizer advice (Shah et al., 2009). Applied manure N increased vegetable N uptake when compared to non fertilized control (Tables 2 and 3). At 30 DAS, the highest concentrations of manures (i.e. 300 kg N ha^{-1}) induced significantly higher ($P<0.05$) N uptake by CC over controls (Table 2). At 44 DAS, CC fertilized with CHM accumulated significantly higher ($P<0.05$) N than those fertilized with CAM. Analysis using Duncan's multiple range tests indicated that there was no significant difference in N uptake between CC treated with 200 and 300 kg N ha^{-1} regardless of N source (LSD=12) for both 30 and 44 DAS (Table 2). This could be the reason as to why there was no significant difference in marketable yield and dry matter between 200 and 300 kg N ha^{-1}. Therefore it would be an advantage to reduce manure applications to the most economical rate of N and consequently reduce the amount of N left in the soil at harvest.

Application of manure significantly improved N uptake of AM, except the application of 170 kg CAM N ha^{-1} which did not show a significant difference compared to control at 28 DAS, and thus correlated with the order of fresh yield after the same growing period (Table 3). Although N uptake by AM was higher in CHM than CAM treatments, the difference was significant only at N rate of 170 kg N ha^{-1} at 28 DAS.

Figure 2 represents a simple correlation between fresh yield and N uptake. There was a positive and significant ($P<0.05$) relationship between N uptake and above ground fresh matter yield. The plants in treatments that took up most N generally produced higher fresh matter yields of the CC and AM. The relatively low N uptake of CC compared to that documented by other authors (Erley et al., 2009) is probably due to observed shallow rooting depth. The efficient N uptake is related to the large and evenly distributed root system and a high ability of the roots to absorb N in all soil layers (Kristensen and Thorup-Kristensen, 2004). In addition, Erley et al. (2009) reported that total shoot-N uptake differed between cultivars according to their maturity times.

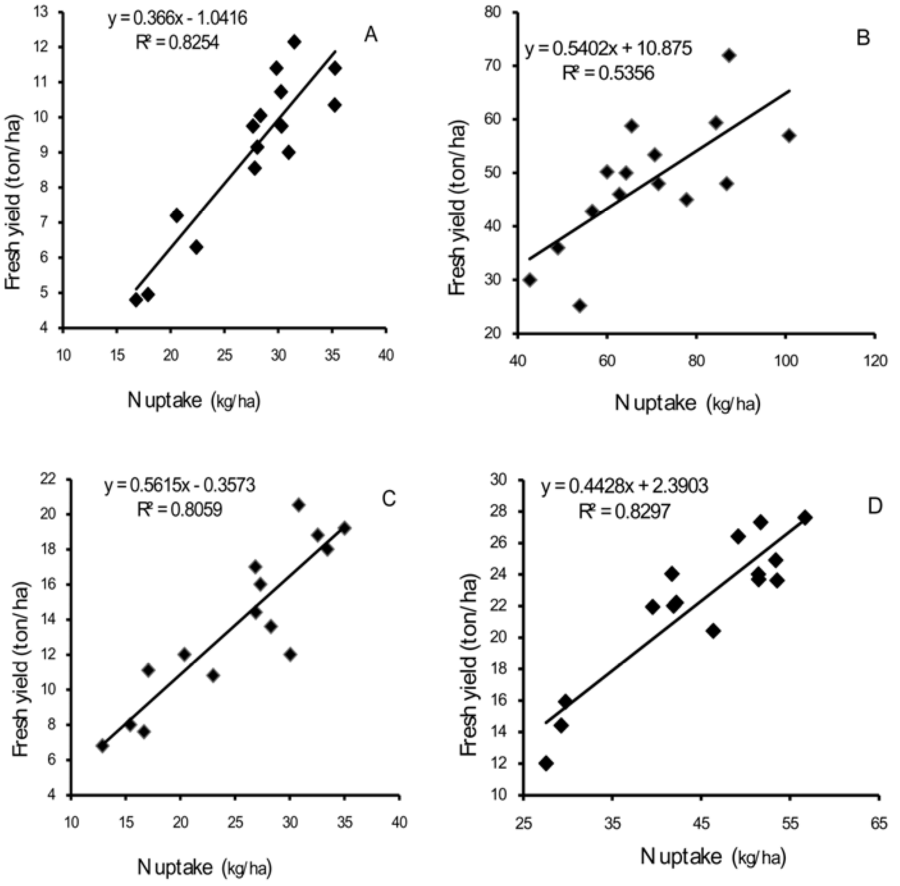

Figure 2. Simple correlation between N uptake and fresh yield of A) CC at 30 DAS, B) CC at 44 DAS, C) AM at 28 DAS and D) AM at 38 DAS.

Various studies have indicated that the N-concentration in the field crops decreases during the vegetative growth cycle. It has been related to the biomass according to the following equations (Greenwood and Neeteson, 1986; Greenwood et al., 1990; Colnenne et al., 1997):

$N_{DM} = a$ for W≤1.0 tonnes dry weight ha^{-1}

$N_{DM} = a \times W^{-b}$ for W>1.0 tonnes dry weight ha^{-1}

Whereby: N_{DM} = N-concentration as a percentage of dry matter

a,b = positive constant

W = total shoot biomass (tonnes dry weight ha^{-1})

The results from all treatments and two harvesting times were used to derive the 'dilution law' defined by the equation above which is presented in figure 3 by the following relationship:

For Chinese cabbage: $N_{DM} = 4.2$ for W ≤ 1.0 tonnes dry weight ha^{-1}

$N_{DM} = 4.2 \times W^{-0.38}$ for W > 1.0 tonnes dry weight ha^{-1}

For amaranthus: $N_{DM} = 2.7$ for W ≤ 1.0 tonnes dry weight ha^{-1}

$N_{DM} = 2.7 \times W^{-0.42}$ for W > 1.0 tonnes dry weight ha^{-1}

Also the reference curve for C_3 crops having no storage organs, i.e. N_{DM} =[4.8×$W^{-0.32}$ (Greenwood et al., 1990) is given in figure 3. The results of figure 3 are in accordance with Greenwood et al. (1986), that points below W=3.5 tonnes ha^{-1} can significantly deviate from the equation (also from the reference equation). The difference between Chinese cabbage and amaranthus indicate that it is necessary to define the specific values of the N dilution curve coefficients for each species according to the different histological plant characteristics. The derivation of these equations is of vital importance when one intends to apply computer simulation models of N dynamics in soil and crop, since many of these models implement the N dilution concept in the model calculations.

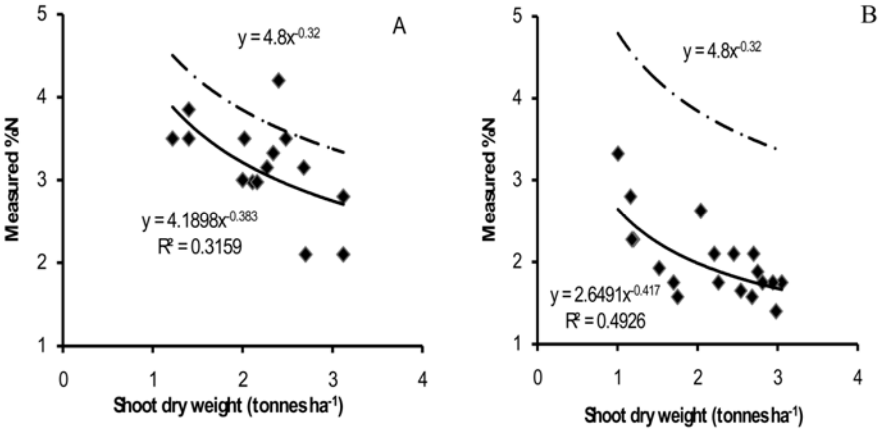

Figure 3. Relationship between N concentration in the shoot and shoot dry weight during growing period of A) CC and B) AM;

Critical N dilution curve ———

Reference curve --------- (Greenwood, et al., 1990).

Agronomical N efficiency and apparent N recovery

The ANE of CC was significantly higher ($P<0.05$) with CHM than CAM fertilization (Table 1). Similar results of ANE were found in AM at 28 DAS but not at 38 DAS (Table 2). Agronomic N use efficiency was decreasing with increasing N levels. The higher ANE at lower fertilization level stretches the possibility for reducing organic inputs in vegetable fields (Zanen and Koopmans, 2008). However, we must be cautious that improvements in efficiency do not come at the expense of the farmers' economic viability.

The NR differed significantly ($P<0.05$) between N sources where CHM led to higher NR than CAM. In CC it decreased with increasing N rate and the difference between the two N levels was significant ($P=0.05$) at 44 DAS. With AM the trend was different from that of CC as NR increased with increasing N rate except for the application CHM at 28 DAS where there was an indication of a decline in NR with increasing N rate. The trends observed in AM are probably due to lower N levels applied to AM as compared to those for CC (Hossain et al., 2005). The low NR values observed harmonise with results of other previous studies (Rodrigues et al., 2001). However, these data contrast the results observed by Azz et al. (2008) who reported high (31.3-54.8%) composts derived N recovery by chingensai leaf (*Brassica campestris* L.) fertilized with 250 to 300 kg N ha^{-1}. The low NR of applied N in the above-ground biomass suggests that N may pose an environmental risk. One explanation for the low NR is also the large N mineralization potential of these soils, which results in significant N uptake in the unfertilized plants. Part of the manure N not taken up directly will be mineralized and be available to a subsequent crop. Moreover, manure N applied, but not taken up by the crop, are vulnerable to losses from leaching, erosion, and denitrification or volatilization, or it could be temporarily immobilized in soil organic matter to be released at a later time (Robert, 2008).

Conclusion

CHM could be a very appropriate fertilizer alternative for CC and AM under specific field conditions. An increase of N dose from 200 to 300 kg N ha^{-1} and 170 to 250 kg N ha^{-1} caused a slight but not significant increase of the commercial yield or dry matter yield of CC and AM, respectively. Thus, fertilization levels can be reduced without significantly affecting the yield. Moreover, the high N levels resulted into low ANE of CC and AM. Delaying the harvesting date associated with considerable increment of vegetable yield. Results of this study should however, be confirmed under different field conditions.

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