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The effect of organic fertilizers on growth and yield of broccoli (*Brassica oleracea* L. var. *italica* Plenck cv. Top Green)

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Abstract

The research was undertaken to study the effect of application of different rate of organic fertilizers on broccoli. There were five treatments in total consisting of inorganic, organic fertilizers and blank control. The organic treatment included compost applied with three different rates of chicken manure tea (CMT) i.e. (0 ml/week, 100 ml/week and 200 ml/week) and the remaining two treatments were inorganic fertilizer treatment and blank control. The vegetative parameters measured were stem diameter, leaf number, leaf diameter, plant weight and height. In all the vegetative parameters measured, the inorganic fertilizer treatment gave the highest mean value which was statistically significantly different from other treatments except for leaf diameter which was statistically similar to CMT 200 ml and compost treatment. The result showed that the head yield of inorganic fertilizer was statistically highly significant over organic treatments, but there was no significant difference between inorganic fertilizers and 200ml CMT/week and compost treatments. The highest yield was obtained from inorganic fertilizer with the yield of 12.12 t/ha and the least from control with yield of 9.29 t/ha respectively. The positive dose-response pattern of the CMT applications suggests that there is good potential to further optimise this soil amendment. Also, an economic analysis of the costs and benefits of the high performing organic treatments would be valuable.

Keywords: chicken manure tea; yield; broccoli; organic; inorganic.

Introduction

Growing organic vegetable is a rapidly growing industry and the concerns over the pesticides residues in food and the environment has resulted to increase in demand for organic food. Organically grown foods are perceived as better quality, healthier and more nutritious than conventional counterparts (Warman and Havard, 1997). On the other hand, the relatively slow mineralization of the composts and other organic fertilizers limits the effective nitrogen utilization (Hartz *et. al*., 2000). The low availability of nitrogen in organic fertilizers is the main underlying factor contributing to the low yield in organic farming and as per Badgley *et. al.* (2007) 'The principal objections to the proposition that organic agriculture can contribute significantly to the global food supply are low yields and insufficient quantities of organically acceptable fertilizers'.

However, liquid organic fertilizers like poultry manure tea and compost tea have been found to contain nitrogen mainly in inorganic form like ammonia (Price and Duddles, 1984; Gross *et al*., 2007) and can provide nutrients instantly to the plants much like the chemical fertilizers. Not much information is available on fertigation of crops by manure teas.

Broccoli (*Brassica oleracea L*.var. *italica*) belongs to family Brassicaceae. It is a fast growing crop and requires high nitrogen input. It is one of the most important crops as it is highly nutritious vegetable with abundant vitamins and minerals such as vitamin A and C, carotenoids, fiber, calcium, and folic acid (Paradis, *et al*. 1995; Michaud *et. al*., 2002). Broccoli and other brassica vegetables have high content of glucosinolates (Zhao *et al*., 2007) which has cancer-fighting properties. Broccoli buds are rich source of minerals especially K, S, P, Mg and micro-elements (Aboul-Nasr and Ragab, 2000).

The aim of this investigation was to evaluate the productivity of broccoli with organic fertilizers and compare with mineral fertilizing.

Methodology

The study was conducted under field conditions in the research field of the Vegetable Division, Maejo University, Thailand. Before planting, soil samples consisting of approximately ten cores across the diagonal of the soil layers 0–30 cm deep of the experimental field were taken to determine the amount of NPK and other properties.The experiment was laid out in randomized complete block design (RCBD) and the treatments were replicated three times. Broccoli *(Broccoli oleraceae L.* var. *italica*) cultivar 'Top Green' was cultivated as the experiment plant. The broccoli seeds were sown in plastic nursery trays filled with peat as the growing media and raised inside greenhouse. After one month, the seedlings were transplanted in the field at a spacing of 60 cm (row) by 40 cm (plant) on raised beds.

The compost was prepared by Passively Aerated Window Method (FAO, 2003).The C/N ratio of the raw materials was maintained at 1:30. The compost mixture was placed inside heavy duty polythene bag having a dimension of 2 m in height and 0.8 m wide. One perforated plastic pipes, each having four rows of 1.27 cm (FAO, 2003) diameter holes drilled in it, was inserted into the compost bag for aeration. The mouth of the bag was closed and the upper ends of the inserted pipes were exposed to the open air to facilitate aeration in the interior of the compost pile. The composting was carried for one month and then cured for additional one month. The chicken manure tea (CMT) was prepared by "Bucket Method" as described by Ingham (2005). A total of twenty kg fresh poultry manure was collected every week from the Maejo University Dairy Farm. The manure was then put in a burlap sack, tied with string and placed in the bucket without it touching the floor with the help of horizontally placed sticks. Then twenty litres of de-chlorinated water (1:1 W/V) was added into the bucket. As a food source for beneficial microorganisms during fermentation period, one litre of molasses were added. The lid of the bucket was partially closed and stirred twice (once each in the morning and evening) daily and after fifteen days, the tea was steeped and used in the experiment plot.

Treatments

There were five treatments in total,

1. Compost,
2. Compost and chicken manure tea (100 ml/week),
3. Compost and chicken manure tea (200 ml/week),
4. Inorganic fertilizers, and
5. Control (without fertilizers).

The compost at the rate of 100 g/m^2 was mixed with the soil during the bed preparation in all the organic plots. The chicken manure tea was applied on weekly basis starting from the day of transplanting at the rate of 0 ml/m^2, 100 ml/m^2 and 200 ml/ m^2 in treatment no.1, 2 and 3 respectively. The mineral fertilizers were applied at the rate of 42.73 g urea, 31.76 g P_20_5 and 26.96 g K_20 per meter square as per the soil analysis report and the recommendation of the Oregon State University (2004).

Measurements

Vegetative growth characteristics were measured on a random sample of ten plants, taken from each experimental bed and the following data were recorded: plant height, leaf number per plant, stem diameter, leaf diameter and plant weight. All broccoli heads of each plot were harvested at marketable stage and the following variables measured: head yield (t/ha), mean head weight (g/plant), head diameter (cm), and head compactness (head diameter/head weight in grams).

Statistical analysis

The data collected in the experiment were statistically analysed with SAS Version 9.0 statistical software program. Analysis of variance (ANOVA) was done on every measured parameter to determine the significance of differences between means of treatments. Means for each parameter were separated by the least significant difference (LSD) test at $P \leq 0.05$.

Results

1. Nutrient content in composts and chicken manure tea

The Table 1 shows the nutrient composition of compost, chicken manure tea, soil in organic plot and in inorganic plot. Composts were analysed for its nutrient content after 68 days of composting. Chicken manure tea (CMT) was analysed after fermenting for 14 days. It has already been established by Rai (2010) that the 15 days old CMT had the higher nitrogen content over the one that was fermented for 21 days. According to Gross *et al*. (2008), all the uric acid in the chicken manure is degraded to ammonium by this period and it will just result in loss of ammonium through

ammonification. A similar method was used to prepare the tea and only the 14 days old sample were analysed for nutrient content. The CMT had an NPK content of 0.15%, 0.04% and 0.82% respectively, with a pH of 6.96.

Table 1. Nutrient content in composts and chicken manure tea.

Organic fertiliser treatment	pH	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Carbon (%)	C:N ratio
Compost	6.27	0.60	1.43	0.58	7.90	13.93
Chicken manure tea	6.96	0.15	0.04	0.82		
Organic plot	6.11	0.08	0.03	0.007	0.85	10.24
Inorganic plot	6.31	0.09	0.03	0.016	0.91	10.40

2. Vegetative growth

The highest value of all the vegetative parameters that were measured was found in the inorganic treatment (Table 2). The differences in the value were statistically significant over the rest of the treatments (P=0.05). Its mean plant weight was 1329 g. The control gave the least vegetative growth. However, its vegetative growth was statistically similar to treatment no. 1 (compost). Treatment no. 3 showed the highest vegetative growth among the organic treatments. However, the values were statistically similar to treatment no. 2. The treatment no. 2 in turn had all its vegetative growth values statistically similar to treatment no. 1 except for plant weight.

Table 2. Effect of organic fertilizers and mineral fertilizers on vegetative growth.

	Treatments	Stem diameter (cm)	Leaf number per plant	Leaf diameter (cm)	Plant weight (g)	Plant height (cm)
1	Compost	3.60cd	20.73cd	22.38b	1062.18c	51.79cd
2	Compost & CMT (100ml/week)	3.70cb	22.13bc	22.48b	1145.67b	52.62cb
3	Compost & CMT (200ml/week)	3.85b	23.18b	23.22a	1198.71b	54.50b
4	Inorganic fertilizers	4.03a	27.20a	23.76a	1329.23a	61.03a
5	Control	3.42d	19.36d	22.19b	1011.83c	49.98d
	f-test	**	**	**	**	**
	CV%	3.858	6.55	2.1	4.03	3.37

Means within the column with the same letter were not significantly different at P=0.05 by the Least Significant Difference (LSD).

The numbers of leaves per plant were recorded from seven days after transplanting until harvest (Figure 1). The greatest numbers of leaves were recorded in inorganic treatment throughout the growth period. Initially, leaves number per plants from the organic treatments and control were similar but there was gradual increase in difference in new flushes as the recording continued. Treatment no. 3 recorded the highest numbers of leaves from among the organic treatments followed in order by treatment no 2, treatment no. 1. The control had the fewest leaves per plant.

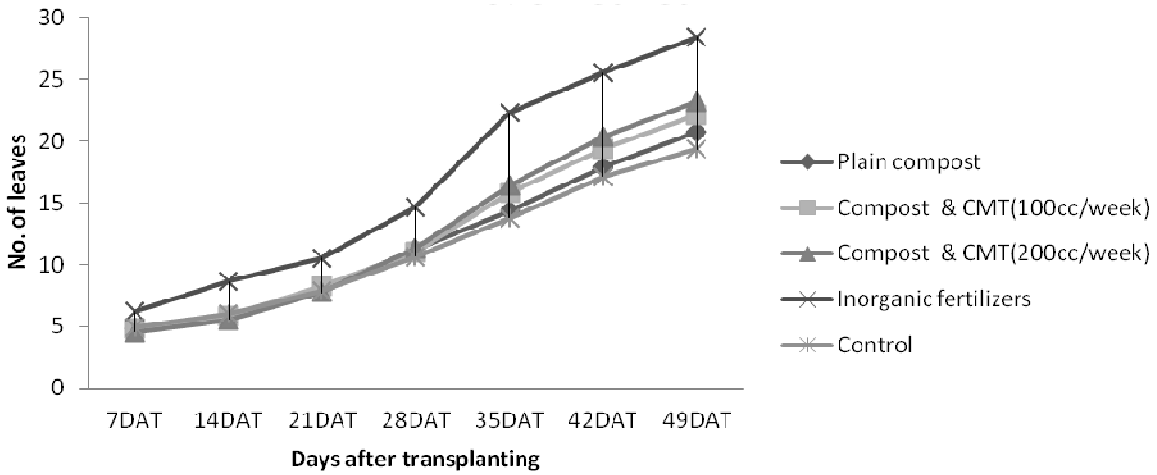

Figure 1. Leaves numbers per week from different treatments.

The plant height measurement also reflected the same trend (Figure 2) where the inorganic treatment had the tallest plants starting from the first week after transplanting. Similarly, the shortest plants were recorded from control, while the treatment no. 3 recorded the tallest plants among organic treatments.

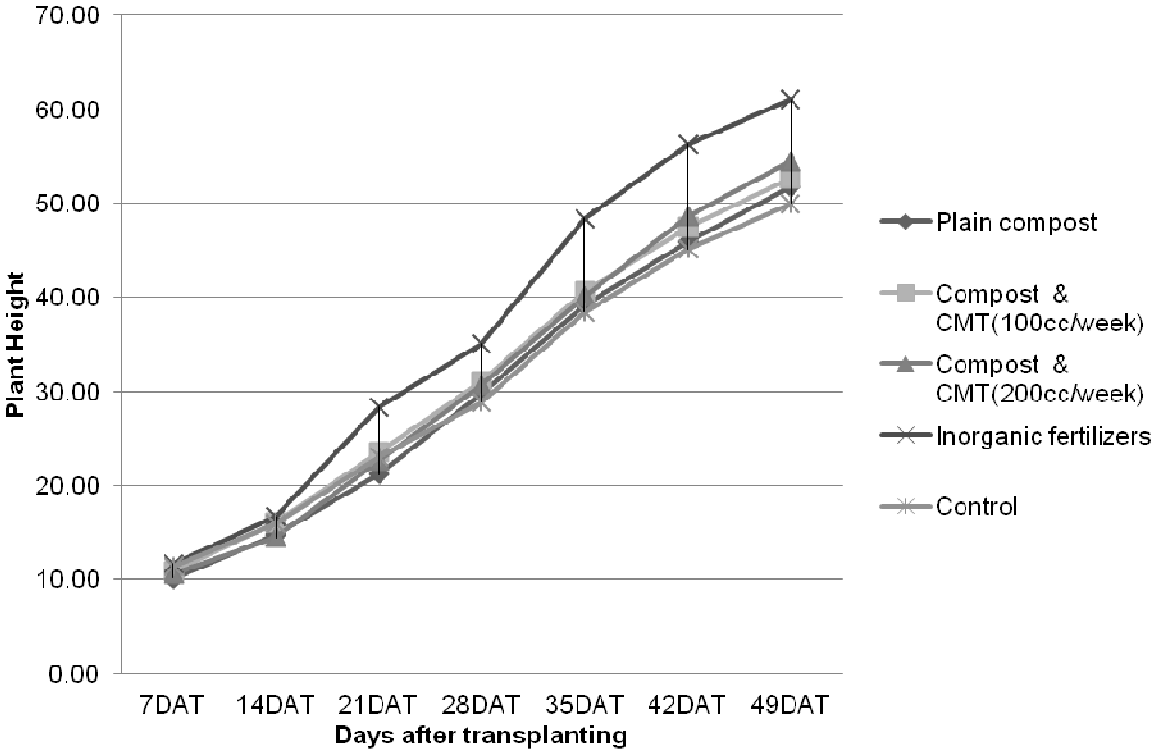

Figure 2. Plant height at weekly interval from different treatments.

3. Head yield

As indicated in Table 3, the highest yield was obtained from inorganic fertilizer treatment with a yield of 12.12 t/ha and the lowest from the control treatment with a yield of 9.27 t/ha. There was no statistical difference in yield between the inorganic treatment and the compost and CMT 200 ml treatment. Among the organic treatment, the highest yield was obtained from CMT 200ml and compost with a yield of 11.59 t/ha followed by CMT 100 ml and compost, and compost with a yield of 10.63 t/ha and 9.59 t/ha respectively. The yield in organic treatment increased with the increase in level of CMT being applied. On the other hand, application of compost alone to the soil did not show noticeable increase in the yield. The difference in yield between different levels of CMT was statistically significant. It can be deduced that chicken manure tea (liquid organic fertilizer) provided adequate nutrients to the plant at the early crop stage.

Table 3. Effect of organic fertilizers and mineral fertilizer yield and compactness coefficient.

	Treatment	Head weight (g)	Head weight (g/m^2)	Head yield (t/ha)	Compactness (g/cm)
1	Compost	239.83c	959.33c	9.59c	17.69c
2	Compost & CMT (100 ml/week)	265.63b	1062.50b	10.63b	19.15b
3	Compost & CMT (200 ml/week)	289.87a	1159.48a	11.59a	20.33a
4	Inorganic fertilizers	302.90a	1211.60a	12.12a	20.46a
5	Control	231.83c	927.32c	9.27c	17.31c
	f-test	**	**	**	**
	CV%	4.445	4.445	4.445	4.722

Means within the column with the same letter were not significantly different at *P*=0.05 by the Least Significant Difference (LSD).

The highest compactness co-efficient value of the broccoli head was shown by inorganic fertilizer with a value of 20.46 g/cm followed by CMT 200 ml and compost, CMT 100 ml and compost, compost and control with value of 20.33 g/cm, 19.15 g/cm,17.69 g/cm and 17.3 1g/cm respectively. The head compactness coefficient increased with the increased in nitrogen availability (Wojciechowska, 2005).

Discussion

In all the vegetative growth parameters measured, inorganic fertilizers showed the highest value and the control had the lowest value. Among the organic fertilizers, the highest value of all the parameters measured in descending order was CMT 200 ml/week + compost, CMT 100 ml/week + compost, compost. The greater vegetative growth of the broccoli plant with inorganic fertilizers treatment may be attributed to its readily available N in high content. The amount of nitrogen and other nutrients applied in inorganic plot is much higher than the organic treatments i.e. by almost twenty times. Soil nitrogen fertilizer application increased the head weight, head diameter, plant weight and plant height of broccoli (Yildirim, 2007).

Likewise, plots fertilized with CMT (both 200 ml and 100 ml/week) also showed good vegetative growth without any indications of nutritional stress. With the increase in dose of CMT, there was increase in vegetative growth. This healthy growth of plants treated with CMT may be attributed to the presence of readily available form of nitrogen (ammonium) which was supplemented every week. A similar trend was observed by Fayed (2010), who found that the CMT significantly increased the vegetative parameters of the Roghini olive trees. Further, El-Tantawy (2009) found that farmyard compost tea increased the height and leaf area of potato plant.

These effects of manure tea on plant growth may be related to the important role of nitrogen, phosphorus and potassium in plant tissues which reflects on its vegetative growth. They play a vital role in photosynthesis, carbohydrate transport, protein formation, control of ionic balance, regulation of plant stomata and water use activation of plant enzymes and other processes (El-Sawy *et al*., 2000; El-Dissoky, 2008). CMT contains all three of these nutrients and was made available to the plants through its application. Gross *et al*. (2008) found that ammonium was the major form of nitrogen present in the extract solutions from all manure types and that the nitrogen released after the 14-day extraction by the different methods from the different manures ranged between 50% and 85%. This result confirms that organic liquid fertilizers like CMT contains instant plant nutrients and is suitable for short duration vegetable crops.

However, the plants in compost treatment showed statistically similar vegetative growth to that of control in terms of stem diameter, head diameter and leaf diameter. It was found that the plants were of shorter size with the plant weight much lower than the other organic treatment's. The total nutrient might not have been adequate due to the low amount of compost applied. For vegetable cultivation, compost application rates of 10-60 t/ha on a dry weight basis, are recommended for vegetable production, although applications as low as 7 t/ ha. have shown positive effects on vegetable yields (Roe, 1998). Other factor for low vegetative growth might be the slow mineralisation properties of nutrients in compost as the nutrients are in organic form (Hue, 1997). The higher C:N ratio for compost only would suggests that slower mineralisation could have occurred. It was found that only 10% to 50% of the total nitrogen in solid manure/compost was available for plant uptake within the season of application and this fraction decreases with the extent of decomposition (Gale *et al*., 2006).

The yield in organic treatment increased with the increase in level of CMT being applied. On the other hand, application of compost alone to the soil did not show noticeable increase in the yield. The difference in yield between different levels of CMT was statistically significant. The increase in the total yield resulting from application of the chicken manure tea may be attributed to the presence of readily available form of nutrient i.e. ammonia and nitrate (Gross *et al*., 2008) and also to its property to enhanced soil aggregation, soil aeration and water holding capacity, offers good environmental conditions for the root system of broccoli plants. This better availability of soil nutrients and favourable soil condition resulted in healthy plants with large vegetative growth, which lead to higher yield and head diameter. The highest yield was obtained in inorganic treatment due to availability of readily available nutrient in high quantity. The lowest yield in control is due to the insufficient supply of plants in nitrogen resulting in reduction of plant productivity (Shangguan *et al*. 2000, Lawlor 2002). The link between head compactness measurement and an increase in nitrogen was observed here, and this has been reported elsewhere (Wojciechowska, 2005).

Conclusion

The treatment with compost and 200 ml CMT/week showed the best result in terms of yield, head compactness co-efficient and vegetative growth characteristics among the organic treatments. Thus it can be concluded that to obtain higher yield, this is the best treatments from among the organic fertilizers combination studied, though it was not as effective as the mineral fertilizer treatment for

some growth variables. The positive dose-response pattern of the CMT applications suggests that there is good potential to further optimise this soil amendment. Also, an economic analysis of the costs and benefits of the high performing organic treatments would be valuable.

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