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Effects of organic fertilizers on performance of cauliflower (*Brassica oleracea* var. *botrytis*) grown under protected structure

(Kesan baja organik terhadap prestasi kubis bunga (*Brassica oleracea var. botrytis*) ditanam di bawah struktur pelindung)

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Keywords: compost, vermicompost, empty fruit bunches, chrysanthemum residue, soybean waste, curds

Abstract

A study on the effects of vermicomposts and composts on the nutrient status, growth and yield of cauliflower (*Brassica oleracea var. botrytis*) was conducted to assess the potential of these organic fertilizers in replacing the chemical fertilizer for cauliflower production under protected structure. Three composts and two vermicomposts used were oil palm empty fruit bunches compost (EFBC), chrysanthemum residue compost (CRC), soybean waste compost (SWC), green waste vermicompost (GWV) and vegetable waste vermicompost (VWV). A chemical fertilizer ($N:P_2O_5:K_2O$; 12:12:17) was used as control. The amount of fertilizer applied was calculated based on 180 kg/ha of N. It was observed that VWV and EFBC were comparable to the chemical fertilizer based on their effects on the growth and yield performance of cauliflower. VWV and EFBC showed promising results and can be used to replace chemical fertilizers in fulfilling the nutrient requirements of cauliflower. The yield and curd size of VWV and EFBC treated cauliflower were similar to chemically fertilized plants. Furthermore, curds of VWV treated plants can be harvested 7 days earlier than chemically fertilized plants. The use of compost and vermicompost have positive effects on the growth and crop yield of cauliflower, and have great potential to improve vegetable production in Malaysia.

Introduction

Large quantities of crop wastes are produced from agricultural activities. These organic wastes, after being converted into compost, whether through conventional composting or vermicomposting, can be profitably used for fertilizing crops, particularly for food crop production. For vegetable cultivation, particularly under protected rain shelter, organic fertilizer is an important alternative to minimize the impact of salt accumulation from intensive and continuous use of chemical fertilizers. Accumulation of salt in soils under rain shelter is a common phenomenon (Chang and Liao 1989). Continuous cropping and repeated use of chemical fertilizers contributed to enhancement of soil acidity,

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nutrient leaching and degradation of soil physical and organic matter status (Obi and Ebo 1995; Ojeniyi 2000 and Nottidge et al. 2005). In consideration of these impacts, alternative sources of maintaining soil fertility need to be looked into.

Organic fertilizer has far served as a formidable alternative. Many research works have shown that many organic wastes produced in the tropics have the ability to provide nutrients and enhance soil quality. Utilization of organic matter has been well documented to improve physical, chemical and biological properties of soil (Whalen et al. 2000; Tejada and Gonzalez 2003). Cook et al. (1994) showed that the addition of compost to soil generally improves tilth, soil structure, infiltration, drainage and water-holding capacity.

The use of compost and vermicompost has also been observed to improve plant growth and quality. Numerous studies on vermicompost and compost from various sources have been found to promote root formation (Arancon et al. 2005), increase fruit setting and yield (Atiyeh et al. 2002; Arancon et al. 2004) and also increase plant dry mass (Edwards 1995; Subler et al. 1998). It has also been reported that the increase in yield, chlorophyll production and fruit quality of tomatoes was due to improvement of uptake of N, P and K from vermicompost (Tejada et al. 2007). In addition, vermicompost and manure were reported to affect the chemical composition and quality of the marketable produce (Lazcano et al. 2011).

Premuzic et al. (1998) found that tomatoes grown in vermicompost contained significantly more calcium and vitamin C but less iron compared with those grown in a hydroponic medium with chemical fertilizers. Some authors have found that fruit and horticultural organic crops contain more minerals and vitamins than conventional crops (Bourn and Prescott 2002; Magkos et al. 2003). Furthermore, higher levels of vitamin C, iron, magnesium and phosphorus and less nitrates and lower amounts of some heavy metals were found in organically produced vegetables (Worthington 2001).

The benefits of organic production on food quality and safety have created high global demand for organic products. Utilization of organic wastes from agriculture as organic fertilizer for growing crops commercially is very much dependent on the availability of organic wastes and comparability with chemical fertilizers in plant growth and yield performance. Often organic fertilizers are associated with lower yield compared to chemical fertilizers. Hence, an experiment was undertaken to assess the potential usage of locally produced composts and vermicomposts that could replace chemical fertilizers for cauliflower production under protected structure.

Materials and methods

The study was conducted at MARDI Serdang under protected structure with insect proof side netting and plastic roofing (40 m x 10 m) with an average temperature of 34 – 40 °C during the day. The soil of the experimental site was classified as Serdang soil series with sandy clay loam soil texture. The initial characterization and chemical analysis were recorded at 2.08% C, 0.12% N, 0.23 mg/kg P, 0.26 cmol(+)/kg K, 0.01 cmol(+)/kg Ca, 0.03 cmol(+)/kg Mg with pH 7.63.

Hybrid seeds of cauliflower variety White Shot were used in this study. The sources of fertilizers used were locally available organic fertilizers, namely, compost from empty oil palm fruit bunches (EFBC), chrysanthemum residue compost (CRC) from chrysanthemum stalk and unmarketable chrysanthemum flowers, soybean waste compost (SWC) from waste of soybean beverage factory, green waste vermicompost (GWV) from earthworm fed with biodegradable wastes of pruning and unmarketable starfruit and wax apple and vegetable waste vermicompost (VWV) from earthworm fed with biodegradable vegetable waste. All organic wastes were composted with cattle manure. Compound fertilizer containing nitrogen (12%), phosphorus (12% P_2O_5) and potassium (17% K_2O) was used as the control. All organic fertilizers were analyzed for determination of their chemical properties (*Table 1*).

The amount of fertilizer was calculated to be equivalent to applying 180 kg/ha of nitrogen. Rates of EFBC, CRC, SWC, GWV and VWV applied were 12.3, 14.3, 5.1, 8.7 and 7.8 t/ha respectively. Composts and vermicomposts were mixed thoroughly into the top 10 cm soil layer of raised-beds two weeks prior to transplanting while the chemical fertilizer was equally applied at 2 and 5 weeks after transplanting. Three weeks old uniform cauliflower seedlings were transplanted onto raised-beds of 1.2 m wide, 9 m long and 20 cm height in two rows with plants within the rows separated by 0.5 m. Plants were drip irrigated as required. The treatments were arranged in completely randomized block design (CRBD) with 3 replications. Plots were hand-weeded and plants were treated with *Bacillus thuringiensis* based biopesticides to control pests, particularly diamondback moth (*Plutella xylostella*), one of the important pest of crucifers.

Soil samples were collected from the first 10 cm of the soil layer, air-dried and then sieved passing at 2 mm. Soil and compost pH were measured in saturation extract (1:2.5 and 1:5, w/v, suspension of solid in water respectively). Soil and compost organic carbon were determined by the Walkley-Black method (Nelson and Sommers 1996) and total nitrogen (N) content by the Kjeldahl procedure (Bremner 1996). Total analysis of macronutrients and micronutrients in compost was determined using the aqua-regia method (Kluczka 1999; Gulmini et al. 1997). The extraction solution was made using HCl and HNO_3 solution (3:1). Soil exchangeable K, Ca and Mg were determined by shaking method (Schollenberg and Simon 1945; Dynoodt and Sharifuddin 1981), soil available Cu, Fe, Mn and Zn using double acid method – Mehlich No. 1 (Soil and Plant Analysis Council 2000) and soil P by Bray and Kurtz No. II extraction method (Olsen and Sommers 1982). The results are presented in *Table 1*.

Harvesting was done when the curds had fully developed (8 – 9 weeks after transplanting approximately). After harvest, the youngest of fully expanded leaves and curds were collected and dried at 70 °C

Table 1. Main chemical properties of the composts and vermicomposts used

Chemical properties	EFBC	CRC	SWC	GWV	VWV
pH	7.93	7.18	8.91	6.64	5.1
Total N (%)	1.46	1.26	3.52	2.07	2.32
Total C (%)	12.81	18.1	21.52	23.37	22.02
P (%)	1.47	0.84	1.09	0.99	1.54
K (%)	2.58	0.92	5.78	2.02	1.06
Ca (%)	1.69	0.17	2.57	0.55	0.44
Mg (%)	0.24	0.02	0.74	0.13	0.11
Cu (ppm)	89.2	66.6	85.6	31.7	47.2
Fe (ppm)	11,800	9,194	1,3190	4,036	4,790
Mn (ppm)	432.2	96.9	2,078	610.3	506.1
Zn (ppm)	249.3	150.3	256.4	489.9	727.3

EFBC = Empty fruit bunches compost; CRC = Chrysanthemum residues compost; SWC = Soybean wastes compost; GWV = Green wastes vermicompost; VWV = Vegetable wastes vermicompost for 72 h until constant weight and ground. Samples were digested in sulphuric acid and hydrogen peroxide (Lowther 1980) and analyzed using an atomic absorption spectrophotometer (Perkin Elmer AAS-5100) to determine K, Ca, Mg, Fe and Zn. Total N and P were determined using an automated ion analyzer (Lachat Instrument, Wisconsin, USA).

The plant growth performance was observed and evaluated at weekly intervals. Total leaf area was measured using an automatic leaf area meter (LI-3100). Shoot dry mass was measured by cutting plants at soil level and weighing after drying at 70 °C for 72 h. Chlorophyll content was determined by the method of Coombs et al. (1987) at vegetative (4 WAT) and maturity stages (8 WAT). Yield measures included the curd size (diameter), days to harvesting and curd weight.

Data were subjected to an analysis of variance (ANOVA) where a significant F value (p <0.05) was obtained (SAS Institute 2011, Cary, N.C.). Means and standard errors were calculated and Least Significant Difference (LSD) was used for means separation.

Results and discussion

Vegetative growth

The data presented in *Figures 1* and *2* revealed that the vegetative parameters of cauliflower were significantly influenced by the different fertilizer sources. At maturity, total leaf area of VWV treated plants had significant (p <0.05) positive effect compared to other fertilizer sources including the plants that received chemical fertilizers. The total leaf area of VWV treated plants was 33% higher than those fertilized with chemical fertilizers (4,597.9 cm^2). However, there was no significant difference in total leaf area between chemical fertilized plants and the other organic fertilizer sources except for SWC (*Figure 1*). Plants treated with SWC had the lowest total leaf area (3,247.7 cm^2). The positive effect of VWV on total leaf

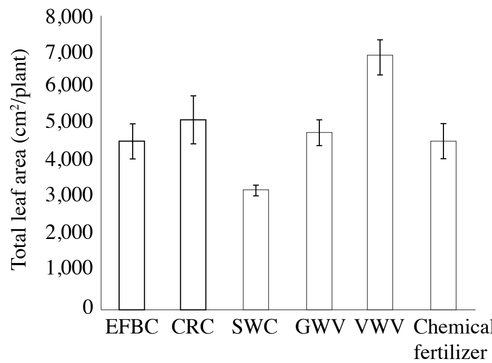

Figure 1. Total leaf area (mean ± standard error) of cauliflower at maturity

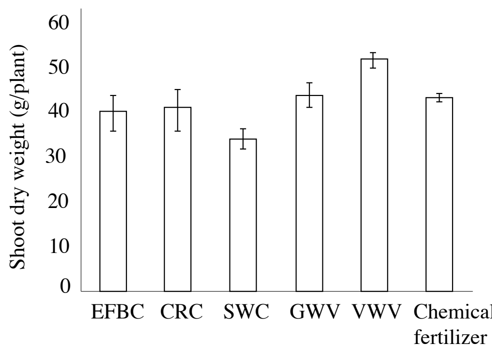

Figure 2. Shoot dry weight (mean ± standard error) of cauliflower at maturity

area was translated into shoot growth. Hence, the highest shoot dry weight (51.19 g/plant) was also obtained by application of VWV (*Figure 2*). However, shoot dry weight of plants which received vermicomposts (VWV and GWV) and chemical fertilizers did not differ significantly.

Similarly, vermicompost application increased leaf number, leaf area and leaf dry weight in tomato seedlings (Atiyeh et al. 2002), cucumbers (Azarmi et al. 2009), strawberries (Arancon et al. 2004), turnips (Classen et al. 2007) and spinach (Peyvast et al. 2008). Plants treated with conventional composts however, had slightly lower shoot dry weight. The lowest value was found from plants treated with SWC (33.85 g/plant).

Different organic fertilizer sources caused various effects on plant growth. This is probably due to the composting process, the state of biological activity, physical state or degree of mineralization of the organic matter. Poor growth development in plants treated with SWC could be due to the physical state of the compost itself. High surface areas contribute to more rapid mineralization of organic N (Montagu and Goh 1990). However, SWC was coarser compared to the other organic fertilizers. The decline in plant growth upon application of SWC could also possibly be related to the stability or maturity of this compost. Values of composts pH close to neutrality indicate biological stabilization of the material (Finstein and Morris 1975; Cardenas and Wang 1980).

However, the pH value of SWC (8.9) was the highest among all composts (*Table 1*). Unstable or immature compost is often odorous and phytotoxic and interfered with plant growth particularly with seed germination due to the elevated concentration of NH_3, salt content and/or organic acids (Kuo et al. 2004). According to Saviozzi et al. (1988), in order to be compatible in horticultural and agricultural uses and to avoid adverse effects on plant growth, organic wastes should be transformed into a humus-like material and be sufficiently stabilized.

From our observation, vermicomposts exhibit better growth performance compared to the composts, with the exception of empty fruit bunches compost (EFBC). Goh and Haynes (1977) reported that plant growth is generally optimized when the pH is between 5.0 and 6.5. The VWV and GWV had a pH of 5.1 and 6.6 respectively, whereas all the composts used had an alkaline pH (between 7.1 and 8.9) (*Table 1*). It is possible that the high pH of these materials have raised the pH of the soil to a degree proportional to the amount of vermicompost or compost incorporated (Gallardo-Lara and Nogales 1987), resulting in a reduced plant growth. Dash and Petra (1979) indicated that increase in plant growth was mostly related to improvements in physical or chemical structure of the growth media.

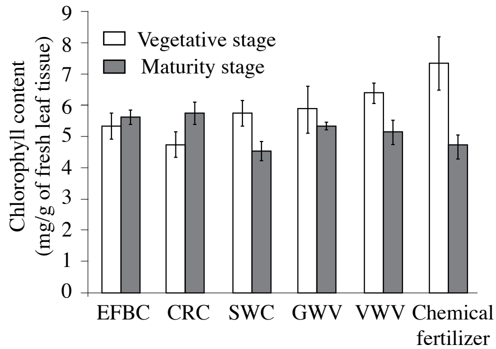

Figure 3. Chlorophyll content (mean ± standard error) of cauliflower at vegetative and maturity stages

Chlorophyll content

Total chlorophyll content was studied as photosynthetic pigments. *Figure 3* shows the amount of chlorophyll in different treatments. At vegetative stage (4 WAT), the plants treated with chemical fertilizer and vermicomposts had slightly higher chlorophyll content than those treated with conventional composts. However, at maturity stage (8 WAT), most organically fertilized plants had slightly higher chlorophyll content compared to chemically fertilized plants with the exception of SWC. This might be associated with the supply of essential nutrients to the plants. Since chlorophyll synthesis in the plants is directly related to the availability of the physiologically active Fe and Mg in plants available form (*Table 2*). Hence, the availability of these nutrients helped in the formation of chlorophyll in the leaves. Studies by Zarrouk et al. (2005) and Hashemimajd and Somarin (2011) revealed that there were positive and significant correlation between P, Fe, and Zn concentration and chlorophyll content of peach leaves. The positive effect of vermicompost on chlorophyll content was also found in pistachio seedlings (Golchin et al. 2006), beans (Fernandez et al. 2010), perennial ryegrass seedlings (Cheng et al. 2007) and lettuce (Fokion et al. 2012).

Table 2. Nutrient content in cauliflower leaf and curd tissues as affected by fertilizer sources

Nutrient concentration	EFBC	CRC	SWC	GWV	VWV	Chemical fertilizer	LSD at 5%
Leaf tissues							
N (%)	2.41b	2.68b	3.38a	2.19b	2.33b	3.42a	0.49
P (%)	0.27a	0.24a	0.22a	0.21a	0.25a	0.25a	0.08
K (%)	4.00a	3.40abc	3.78ab	3.06bc	2.60c	4.10a	0.91
Ca (%)	3.86b	3.67b	5.39a	4.21ab	3.85b	3.39b	1.29
Mg (%)	0.58ab	0.49ab	0.62a	0.55ab	0.44ab	0.40b	0.19
Zn (mg/kg)	60.40a	54.53ab	53.60ab	53.73ab	54.33ab	51.20b	8.70
Fe (mg/kg)	567.33a	543.33ab	557.33ab	530.00ab	545.33ab	511.33b	49.59
Curd tissues							
N (%)	3.91a	3.05b	4.03a	3.64ab	3.39ab	3.67ab	0.74
P (%)	0.55a	0.51a	0.51a	0.48a	0.52a	0.50a	0.08
K (%)	2.60a	2.38a	2.37a	2.49a	2.40a	2.52a	0.27
Ca (%)	0.12a	0.13a	0.13a	0.12a	0.14a	0.11a	0.04
Mg (%)	0.20a	0.19a	0.18ab	0.18ab	0.18ab	0.17b	0.02
Zn (mg/kg)	69.53a	62.73ab	59.67b	60.73b	62.87ab	58.27b	8.67
Fe (mg/kg)	385.33a	233.33b	283.33b	248.67b	248.00b	233.67b	67.66

EFBC = Empty fruit bunches compost;
CRC = Chrysanthemum residues compost;
SWC = Soybean wastes compost;
GWV = Green wastes vermicompost;
VWV = Vegetable wastes vermicompost.
Values in a row with the same letter are not significantly different at $p < 0.05$ according to the LSD

Leaf and curd mineral composition

The source of fertilizers affected the nutrient content in leaves and curds (*Table 2*) of cauliflower. Leaf tissue analysis revealed that total extractable N and K were higher in plants treated with chemical fertilizer and composts and slightly lower in vermicompost treated plants. Leaf P contents were not significantly affected by different fertilizer sources. Leaf tissues of organic plants were slightly higher in Ca, Mg, Zn and Fe concentrations compared to chemically fertilized plants. The Ca and Mg contents of cauliflower leaves were highest in SWC treated plants, while Fe and Zn were highest in plants treated with EFBC. The lowest leaf contents of Ca, Mg, Fe and Zn were observed in chemically fertilized plants. This response could have been due to the fact that there was higher availability of these elements in organic fertilizers particularly in EFBC and SWC as shown in *Table 1*.

Increase in Fe uptake could be due to organic carbon that acts as a source of energy for soil microorganism, which upon mineralization releases organic acids that decreased soil pH and improves availability of Fe (Adediran et al. 2004; Bokhtiar and Sakurai 2005). Zn availability was affected by total Zn content, pH, organic matter, adsorption sites and microbial activity of the soil (Jordao et al. 2006).

The N contents in the cauliflower curds were slightly higher in SWC and EFBC treated plants but did not differ significantly with chemically fertilized and vermicomposts treated plants (*Table 2*). The lowest N content was found in curds in CRC treated plants. The concentrations of P, K and Ca were not significantly different among the treatments. The contents of Mg and Zn were slightly higher in organics compared to chemically fertilized plants with curds from EFBC treated plants having the highest values. The highest value of

Table 3. Maturity, diameter and mean weight of cauliflower curds in response to various sources of fertilizers

Fertilizer sources	Curd weight (g/plant)	Curd diameter (cm)	Curd maturity (DAT)
EFBC	433.33ab	15.25ab	70.50a
CRC	347.00c	14.33b	73.00a
SWC	341.67c	15.63ab	70.00a
GWV	375.09bc	15.79ab	74.83a
VWV	484.43a	16.75a	63.17b
Chemical fertilizer	471.83a	16.67a	71.17a
LSD at 5%	77.49	2.23	5.04

EFBC = Empty fruit bunches compost;
CRC = Chrysanthemum residues compost;
SWC = Soybean wastes compost;
GWV = Green wastes vermicompost;
VWV = Vegetable wastes vermicompost;
DAT = Days after transplanting.
Values in a column with the same letter are not significantly different at $p < 0.05$ according to the LSD

Fe was also found in EFBC treatment. In general, addition of organics in the soil increased the availability of micronutrients to plant (Prabha et al. 2007).

Yield and its component

Yield of cauliflower curd was significantly affected by the fertilizer sources (*Table 3*). Application of VWV produced slightly higher curd weight (484.43 g/plant) but not statistically different from curd weight produced from chemically fertilized plants and EFBC treatment. Regardless of organic fertilizer, all curds diameter (cm) were not significantly different, except with CRC treated plants. Adding organic matter enhanced the soil structure conditions, creates conducive conditions for good root development (Arisha et al. 2003; Togun and Akanbi 2003) and mineralization by microorganisms. Hence, plants are able to get nutrients for higher yield (Radwan et al. 1993; El-Mansi et al. 1999; Wong et al. 1999; Abdelrazzag 2002; Al-Nasir 2002; Togun and Akanbi 2003) upon application of organic fertilizers.

The vigorous growth of curds from VWV treated plants was translated to early maturity. The curd can be harvested at 63.2 days after transplanting, 7 days earlier than chemically fertilized plants (*Table 3*). Other organics were not significantly different from the chemically fertilized plants.

Conclusion

The growth and yield of cauliflower fertilized with vegetable waste vermicompost (VWV) and empty fruit bunches compost (EFBC) were as good as those receiving chemical fertilizers, indicating that they can be an alternative to chemical fertilization. These organic fertilizers could be recommended for cauliflower production under protected structure without affecting plant growth and yield. The nutritional status of the plants demonstrated that the nutrients were adequate and met the requirements for plant growth and curd development. The curd size and weight of cauliflower fertilized with VWV and EFBC were similar to chemically fertilized plants. Furthermore, curds from VWV treated plants can be harvested earlier compared to chemical fertilizer treatment.

It was observed that composts or vermicomposts may produce similar crop growth and yields to chemical fertilizers when the same amount of N was supplied to the plants. However, the effects of compost and vermicompost on plant growth and yield might vary depending on the sources of wastes and production process and the physical state or degree of mineralization of the organic matter. The results obtained provide a better understanding of the effects of composts and vermicomposts on plant growth and proof of the viability of sustainable cultural practices. Furthermore, organic products are expected to be healthy and safe for the environment.

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References

Abdelrazzag, A. (2002). Effect of chicken manure, sheep manure and inorganic fertilizers on yield and nutrient uptake by onion. *Pakistan J. Biol. Sci.* 5: 266 – 268

Adediran, A.J., Taiwo, B.L., Akande, O.M., Sobule, A.R. and Idowu, J.O. (2004). Application of organic and inorganic fertilizer for sustainable maize and cowpea yields in Nigeria. *J. Plant Nutr.* 27: 1163 – 1181

Al-Nasir, F. (2002). Effect of organic fertilizers on yield and nutrients concentration of cauliflower plant. *Arch. Acker-Pfl. Boden.* 48: 37 – 47

Arancon, N.Q., Edwards, C.A., Bierman, P., Metzger J.D. and Lucht, C. (2005). Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. *Pedobiologia.* 49(4): 297 – 306

Arancon, N.Q., Edwards, C.A., Bierman, P., Welch, C. and Metzger, J.D. (2004). The influence of vermicompost applications to strawberries: Part 1. Effects on growth and yield. *Biores. Technol.* 93: 145 – 153

Arisha, H.M.E., Gad, A.A. and Younes, S.E. (2003). Response of some pepper cultivars to organic and mineral nitrogen fertilizer under sandy soil conditions. *Zagazig J. Agric. Res.* 30: 1875 – 1899

Atiyeh, R.M, Lee, S., Edward, C.A., Arancon, N.Q. and Metzger, J.D. (2002). The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Biores. Technol.* 84(1): 7 – 14

Azarmi, R., Giglou, M.T. and Hajieghari, B. (2009). The effect of sheep manure vermicompost on quantitative and qualitative properties of cucumber grown in the greenhouse. *Afr. J. Biotechnol.* 8(19): 4935 – 4957

Bokhtiar, S.M. and Sakurai, K. (2005). Integrated use of organic manure and chemical fertilizer on growth, yield and quality of sugarcanes in High Ganges River floodplain soils of Bangladesh. *Soil Sci. Plant Analysis.* 36: 1823 – 1837

Bourn, D. and Prescott, J. (2002). A comparison of the nutritional value, sensory qualities aspects and food safety of organic and conventionally produced foods. *Crit. Rev. Food Sci. Nutr.* 42(1): 1 – 34

Bremner, M.J. (1996). Nitrogen total. In: *Methods of soil analysis*, Part 3, Chemical methods. (Sparks, D.L., Bartels, J.M. and Bigham, J.M., eds.), p. 1085 – 1121. Madison, Wisconsin: SSSA book series 5, SSSA and ASA

Cardenas, R.R. and Wang, L.K. (1980). Composting process. In: *Handbook of Environmental Engineering*, Vol. II. p. 269 – 327. New York: The Human Press

Chang, S.K. and Liao, F.S. (1989). *Problems in the continuous cultivation of vegetables in plastic houses. Extension Bulletin* No. 300. Food and fertilizer technology centre for the ASPAC region, Taipei, Taiwan R.O.C.

Cheng, H.F., Xu, W.P., Liu, J.L., Zhao, Q.J., He, Y.Q. and Chen, G. (2007). Application of composted sewage sludge (CSS) as a soil amendment for turfgrass growth. *Ecol. Eng.* 29: 96 – 104

Classen, J.J., Rice, J.M. and Sherman, R. (2007). The effects of vermicompost on field turnips and rainfall runoff. *Compost Sci. Utilisation* 15(1): 34 – 39

Cook, B.D., Halbach, T.R., Rosen, C.J. and Monerief, J.R. (1994). Effects of stream component on the agronomic properties of municipal solid waste compost. *Sei. Util.* 2(2): 75 – 87

Coombs, J., Hall, D.O., Long, S.P. and Scurlock, J.M.O. (1987). Analytical techniques. In: *Techniques in bioproductivity and photosynthesis*, (Coombs, J., Hall, D.O. Long, S.P. and Scurlock, J.M.O., eds.), p. 219 – 220. Pergamon Oxford: Scurlock

Dash, M.C. and Petra, U.C. (1979). Wormcast production and nitrogen contribution to soil by tropical earthworm population from a grassland site in Orissa, India. *Rev. Ecol. Biol. Sol*. 16: 79 – 83

Dynoodt, R.F.P. and Sharifuddin, A.A. (1981). Basic guide to soil and plant analyses. Soil Science Department, Technical Bulletin Faculty of Agriculture, UPM. p. 55

Edwards, C.A. (1995). Commercial and environmental potential of vermicomposting: A historical overview. *BioCycle* 36(6): 56 – 58

El-Mansi, A.A.A., Bardisi, A., Arisha, H.M.E. and Nour, E.M. (1999). Studies on some factors affecting growth and yield of pea under sandy soil conditions using drip irrigation system: 2. Effect of farmyard manure and irrigation water quality. *Zagazig J. Agric. Res*. 26(5): 1409 – 1428

Fernandez-Luqueno, F., Reyes-Varela, V., Martinez-Suarez, C., Solomon-Hernandez, G., Yanez-Meneses, J., Ceballos-Ramirez, J.M. and Dendooven, L. (2010). Effect of different nitrogen sources on plant characteristics and yield of common bean *(Phaseolus vulgaris* L.*) Bioresour. Technol*. 101: 396 – 403

Finstein, M.S. and Morris, M.L. (1975). Microbiology of municipal solid waste composting. *Adv. Appl. Microbiol*. 19: 113 – 151

Fokion, P., Ioannis, P., Ioannis, T. and Efstathios, T. (2012). Vermicompost as a soil supplement to improve growth, yield and quality of lettuce (*Lactuca sativa* L.). *Journal of Food, Agriculture and Environment* 10 (2): 677 – 682

Gallardo-Lara, F. and Nogales, R. (1987). Effect of the application of town refuse compost on the soil-plant system: A review. *Biological Wastes* 19: 35 – 62

Goh, K.M. and Haynes, R.J. (1977). Evaluation of potting media for commercial nursery production of container grown plants. *New Zealand Journal of Agricultural Research*. 20: 363 – 370

Golchin, A., Nadi, M. and Mozaffari, V. (2006). The effects of vermicompost produced from various organic solid wastes on growth of pistachio seedlings. *Acta Hort*. 726: 301 – 306

Gulmini, M., Zelano, V. and Ostacoli, G. (1997). A comparison of acid dissolution procedures for the determination of Hg and As in sediments by cold vapour hydride generation A.A.S. *Ann. Chim. (Rome)* 87: 457 – 467

Hashemimajd, K. and Somarin, S.H. (2011). Investigating the effect of iron and zinc enriched vermicompost on growth and nutritional status of peach trees. *Scientific Research and Essays* 6(23): 5004 – 5007

Jordao, C.P., Nascentes, C.C., Cecon, P.R., Fontes, R.L.F. and Pereira, J.L. (2006). Heavy metal availability in soil amended with composted urban solid wastes. *Environ. Monit. Assess*. 112: 309 – 326

Kluczka, J. (1999). Deactivation of metallic mercury in functional material and industrial waste. PhD Thesis, Gliwice (in Polish)

Kuo, S., Ortiz-Escobar, M.E., Hue, N.V., Hummel, R.L. and Pandalai, S.G. (2004). Composting and compost utilization for agronomic and container crops. In: *Recent research developments in environmental biology,* Vol. 1, Part II. p. 451 – 513. Trivandrum, India: Research Signpost

Lazcano, C., Revilla, P., Malvar, A. and Dom´inguez J. (2011). Yield and fruit quality of four sweet corn hybrids (*Zea mays*) under conventional and integrated fertilization with vermicompost. *Journal Sci Food Agric*. 91: 1244 – 1253

Lowther, J.R. (1980). Use of single sulphuric acid hydrogen peroxide digest for the analysis of *Pinus radiata* needles. *Commun. Soil Sci. Plant Anal*. 11: 175 – 188

Magkos, F., Arvaniti, F. and Zampelas, A. (2003). Organic food: nutritious food or food for thought? A review of the evidence. *Int. J. FoodSci. Nutr*. 54(5): 357 – 371

Montagu, K.D. and Goh, K.M. (1990). Effects of forms and rates of organic and inorganic nitrogen fertilizers on the yield and some quality indices of tomatoes (*Lycopersicon esculentum* Miller). *NZ J. Crop Hortic. Sci*. 18: 31 – 37

Nelson, D.W. and Sommers, L.E. (1996). Total carbon, organic carbon and organic matter. In: *Methods of soil analysis* (Sparks, D.L., ed.), Part 3. Second ed. SSSA Book Series No. 5, p. 961 – 1010. Madison, WI: USA

Nottidge, D.O., Ojeniyi, S.O. and Asawalam, D.O. (2005). Comparative effects of plant residues and NPK fertilizer on soil properties in a humid Ultisol. *Nigerian Journal of Soil Science*. 15: 9 – 13

Obi, M.E and Ebo, P.O. (1995). The effect of organic and inorganic amendments on soil physical properties and maize production in a severely degraded sandy soil in southern Nigeria. *Bioresource Technology* 51: 117 – 123

Ojeniyi, S.O. (2000). Effect of goat manure on soil nutrient and okra yield in a rainforest area of Nigeria. *Applied Tropical Agriculture* 5: 20 – 23

Olsen, S.R. and Sommers, L.E. (1982). Phosphorus. In: *Methods of soil analysis, Part 2: Chemical and Microbiological Properties*. (Page, A.L., Miller, R.H. and Keeney, D.R., eds.), Madison: Wisconsin

Peyvast, G., Olfati, J.A., Madeni, S. and Forghani, A. (2008). Effect of vermicompost on the growth of spinach. *J. Food Agric. Environ.* 6(1): 110 – 113

Prabha, M.L., Jayaraaj, I.A., Jeyaraaj, R. and Rao, S. (2007). Comparative studies on the digestive enzymes in the gut of earthworms, *Eudrilus eugeniae* and *Eisenia fetida*. *Indian J. Biotechnol.* 6: 567 – 569

Premuzic, Z., Bargiela, M., Garcia, A., Rendina, A. and Iorio, A. (1998). Calcium, iron, potassium, phosphorus and vitamin C content of organic and hydroponic tomatoes. *Hortscience* 33: 255 – 257

Radwan, S.A., Aboel-fadl, M. and Abo-Hussien, E.A. (1993). Effect of salinity and organic material (farmyard manure) addition on growth and mineral contents of tomato in sandy calcareous soil of Egypt. *Menofiya J. Agric. Res.* 18: 1929 – 1946

SAS Institute (2011). *SAS Procedures Guide*, Version 9.3, Second edition. Cary: SAS Institute

Saviozzi, A., Levi-Minzi, R. and Riffaldi, R. (1988). Maturity evaluation of organic wastes. *BioCycle* 29: 54 – 56

Schollenberger, C.J. and Simon, R.H. (1945). Determination of exchange capacity and exchangeable bases in soils-ammonium acetate method. *Soil Sci.* 59: 13 – 24

Soil and Plant Analysis Council (2000). Chapter 8. Micronutrients (boron, copper, iron, manganese, and zinc). In: *Soil analysis handbook of reference methods*, p. 117 – 135. Boca Raton, FL: CRC Press

Subler, S., Edwards, C.A. and Metzger, J.D. (1998). Comparing vermicomposts and composts. *BioCycle*, 39 (7): 63 – 66

Tejada, M. and Gonzalez, J.L. (2003). Effects of the application of a compost originating from crushed cotton gin residues on wheat yield under dry land conditions. *Eur. J. Agron.* 19: 357 – 368

Tejada, M., Gonzalez, J.L., Hernandez, M. and Garcia, C. (2007). Agricultural use of leachates obtained from two different vermicomposting processes. *Bioresour. Technol.* 99(14): 6228 – 6232

Togun, A.O. and Akanbi, W.B. (2003). Comparative effectiveness of organic-based fertilizers to mineral fertilizers on tomato growth and fruit yield. *Compost Sci. and Utilization.* 11: 337 – 342

Whalen, J.K., Chang, C., Clayton, G.W. and Carefoot, J.P. (2000). Cattle manure amendments can increase the pH of acid soils. *Soil Sci. Soc. Am. J.* 64: 962 – 966

Wong, J.W.C., Ma, K.K., Fang, K.M. and Cheung, C. (1999). Utilization of manure compost for organic farming in Hong Kong. *Bio-resource Technol.* 67: 43 – 46

Worthington, V. (2001). Nutritional quality of organic versus conventional fruits, vegetables and grains. *The Journal of Alternative and Complementary Medicine* 7(2): 161 – 173

Zarrouk, O., Gogorcena, Y., Gomez-Aparisi, J., Betran, J.A. and Moreno M.A. (2005). Influence of almond peach hybrids root stocks on flower and leaf mineral concentration, yield, vigor of two peach cultivars. *Sci. Hort.* 106(4): 502 – 514

Abstrak

Kajian kesan vermikompos dan kompos sebagai baja organik terhadap status nutrien, pertumbuhan dan hasil kubis bunga (*Brassica oleracea var. botrytis*) dijalankan untuk menilai potensi penggunaannya bagi menggantikan baja kimia untuk pengeluaran kubis bunga di bawah struktur pelindung. Baja organik yang digunakan ialah kompos tandan kelapa sawit kosong (EFBC), kompos sisa kekwa (CRC), kompos sisa soya (SWC), vermikompos sisa hijau (GWV) dan vermikompos sisa sayuran (VWV). Baja kimia ($N:P_2O_5:K_2O$; 12:12:17) digunakan sebagai kawalan. Jumlah baja dikira berdasarkan 180 kg/ha N. Pemerhatian terhadap prestasi pertumbuhan dan hasil kubis bunga mendapati VWV dan EFBC setanding dengan baja kimia. VWV dan EFBC menunjukkan keputusan yang mengalakkan sebagai pengganti baja kimia dalam memenuhi keperluan nutrien kubis bunga. Hasil dan saiz kubis bunga yang dibaja dengan VWV dan EFBC menyamai hasil kubis bunga yang menggunakan baja kimia. Tambahan pula, kubis bunga menggunakan VWV boleh dituai 7 hari lebih awal daripada yang menggunakan baja kimia. Penggunaan kompos dan vermikompos memberi kesan positif pada pertumbuhan dan hasil kubis bunga, dan berpotensi untuk meningkatkan pengeluaran sayur-sayuran di Malaysia.

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