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Effects of rates of organic fertiliser on growth, yield and nutrient content of cabbage (*Brassica oleracea* var. capitata) grown under shelter

(Kesan kadar baja organik terhadap pertumbuhan, hasil dan kandungan nutrien kubis (*Brassica oleracea* var. capitata) di bawah lindungan)

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Key words: cabbage, organic, poultry manure, nutrient and nitrate contents, soil improvement

Abstract

This study investigated the effects of various rates of an organic fertiliser (processed poultry manure) on the growth, yield and nutrient content of cabbage grown under shelter on a clay soil, in the lowlands. Treatments consisted of varying rates (0, 15, 30, 45 and 60 t/ha) of processed poultry manure (PPM). The control treatment was an inorganic fertiliser ($N:P_2O_5:K_2O$: MgO = 12:12:17:2) applied at 2 t/ha.

Canopy diameter increased significantly from 32.0–59.5 cm when PPM was increased from 0 –15 t/ha, while the corresponding values for head diameter were from 13.8–15.2 cm. A quadratic yield response to rates of organic fertiliser, represented by the equation $Y= 9.832 + 0.636x - 0.008x^2$, where Y = yield in t/ha and x = organic fertiliser in t/ha, was obtained. The optimum rate of organic fertiliser was 39.75 t/ha. Yield obtained at this rate was 22.47 t/ha.

Organic fertiliser rates had significant effects on P and K contents in the outer leaves and, K and Ca contents in the head. Nitrate contents did not differ significantly. Organic fertiliser improved soil chemical properties compared to the inorganic fertiliser. It is concluded that about 40 t/ha of processed poultry manure as the sole source of nutrient, can be used as a guide for organic cultivation of lowland cabbage grown on clay soils under shelter.

Introduction

Temperate vegetables have been successfully grown under shelter in the lowlands with the application of both organic and inorganic fertilisers (Illias and Ramli 1994; Vimala et al. 1997). Recent studies on cabbage under shelter on peat soils showed good yields of cabbage, with unprocessed poultry manure (PM) as the sole nutrient source (Illias and Vimala 2003). Other studies too, have shown the potential of raw poultry manure as an organic nutrient source for vegetable cultivation (Vimala, Mah, Roff, Ong et al. 2000; Vimala, Mah, Roff, Wan Rubiah et al. 2000; Vimala et al. 2001). Organic growers, however, do not favour raw poultry manure, because of its foul odour, the fly menace and the associated health risks, though restricted use of PM is allowed in organic farming under Malaysian Organic Certification Standards (Anon. 2001).

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With the expanding demand for organic vegetables in the country and elsewhere, there is potential for increased organic production of cabbage and other *Brassica* species under shelter because of better insect control under protected structures. This study evaluated the efficacy of processed poultry manure, an acceptable and readily available organic source, for organic cultivation of cabbage under shelter in the lowlands.

Materials and methods

Field details

The experiment was conducted on a clay soil (45% clay, 19% sand and 34% silt), under a tunnel-shaped structure with plastic roof and netted sides, at MARDI headquarters in Serdang. *Table 1* gives the soil properties. Treatments consisted of varying rates (0, 15, 30, 45 and 60 t/ha) of processed poultry manure (PPM). Half the fertiliser rate for each treatment was broadcast on the plots and rotovated in as basal, one week before planting. The remaining half of the PPM was applied in between the planting rows one month after transplanting. Nutrient content of PPM is presented in *Table 2*.

The control treatment was an inorganic fertiliser ($N:P_2O_5:K_2O:MgO$ = 12:12:17:2) at 2 t/ha, applied around each plant at two weeks and five weeks after transplanting. Plot size used was 14 m x 1.5 m. One-month-old cabbage seedlings (KK cross) were transplanted on raised beds at 60 cm x 60 cm triangular planting, to give 46 plants/plot. The treatments were arranged in a randomised complete block design (RCBD) with three replicates. Canopy diameter and head diameter of 10 randomly selected plants from each treatment were measured one day before harvest. Harvesting started at 10 weeks after transplanting, and was spread over one week.

Table 1. Soil chemical properties

Soil properties	Values
N (%)	0.14
Sol. P (ppm)	20.90
CEC (cmol(+)/kg)	8.52
Total carbon	1.93
Ex. Ca (meq/100 g)	3.82
Ex. Mg (meq/100 g)	2.13
B (ppm)	3.7
Fe (ppm)	7,191
Mn (ppm)	47.9

Plant and soil sampling and analysis

Two plants per treatment were sampled for analysis of macro and micronutrients and nitrate contents one day prior to harvest. Plant samples were oven dried at 65 °C to constant weight and ground for nutrient

Table 2. Nutrients in processed poultry manure (PPM) and inorganic fertiliser

Nutrient	Composition	Nutrients in 40 t/ha PPM (kg/ha)	Nutrients in 2 t/ha inorganic fertiliser (kg/ha)
Macronutrient (%)			
N	3.2	1,280	240
P	2.9	1,160	105
K	4.2	1,680	282
Ca	14.3	5,720	–
Mg	1.1	440	24
Organic C	22.3	–	–
pH	7.1	–	–
Micronutrient content (ppm)			
Mn	581	23.3	
Fe	946	37.8	
Zn	667	26.7	

analysis. All chemical analyses were done at the Analytical and Quality Assurance Laboratory at MARDI headquarters using in-house methods. Plant nitrogen was extracted using the micro-Kjeldahl method and determined using an autoanalyser. The nutrients P, K, Ca, Mg, B, Fe and Mn were determined using the ICP optical emission spectrometer (ICPOES). Nitrate content was determined by dissolving the dried samples in water and using the Flow Injection Autoanalyser (FIA).

Soil samples (0–20 cm) were collected after harvest, by bulking five sub-samples from each treatment plot. Organic C was extracted using the Walkley and Black method and determined with the CHNS analyser. Available P was extracted using the Bray 11 (molybdate blue) method and determined using the FIA. The cation exchange capacity (CEC), exchangeable K, Ca and Mg were extracted with 1 M NH_4OAc and determined using the ICPOES.

Data analysis

Data obtained were subjected to statistical analysis using analysis of variance procedures to test the significant effect of all the variables investigated. Means were separated by the least significant difference (LSD) method using the statistical package of SAS Institute Inc. U.S.A.

Results and discussion

Canopy diameter and head diameter

Canopy diameter and head diameter showed significant effects of organic treatments *(Table 3)*. Mean canopy diameter obtained was 52.6 cm and mean head diameter obtained was 14.8 cm. At zero PPM, canopy diameter was only 32.0 cm. This increased significantly to 59.5 cm at 15 t/ha PPM. Canopy diameter contributes positively to yield through increased leaf area for photosynthetic activity. Head diameter increased significantly from 13.8 cm to 15.2 cm when PPM was increased from zero to 15 t/ha. Higher levels of organic fertiliser did not increase canopy and head diameter significantly, indicating that higher yields obtained at higher rates is probably due to more compact heads rather than larger heads.

Table 3. Mean canopy and head diameters

Organic fertiliser (t/ha)	Canopy diameter (cm)	Head diameter (cm)
0	32.0c	13.8b
15	59.5a	15.2a
30	59.8a	14.7ab
45	59.5a	15.4a
60	60.1a	15.3a
Inorganic fertiliser	44.9b	14.7ab
Mean	52.6	14.8
Significance	**	*
CV (%)	6.55	3.71

Means with the same letter are not significantly different
*Significant at 5%; **Significant at 1%

Yield

Yield response to increasing rates of organic fertiliser was quadratic, represented by the equation $Y = 9.832 + 0.636x – 0.008x^2$, where Y= yield in t/ha and x = rate of organic fertiliser in t/ha *(Figure 1)*. The optimum rate of organic fertiliser was 39.75 t/ha or 40 t/ha. Yield at this rate was 22.47 t/ha. The yield obtained is lower than cabbage yields with chrysanthemum compost (29.1 t/ha) and with raw poultry manure (31.4 t) in the highlands (Vimala et al. 2004), but comparable to yields obtained in an earlier study on cabbage grown on peat under shelter (Illias and Vimala 2003).

The optimum organic fertiliser rate obtained i.e. 40 t/ha PPM for organic cabbage cultivation would theoretically provide 1,280 kg/ha N, 1,160 kg/ha P, 1,680 kg/ha K, 5,720 kg/ha Ca and 440 kg/ha of Mg *(Table 2)*. Though these quantities of nutrients were far in excess of crop requirement (Vimala and Joseph 1977), there were no symptoms of crop damage (leaf burn and leaf fall) usually associated with high nutrient levels from high rates of applied inorganic fertilisers. The reason that

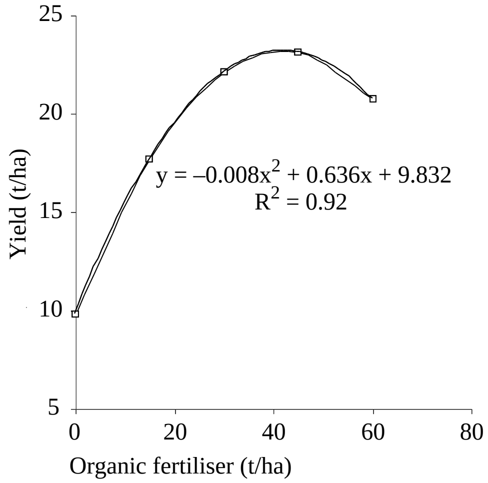

Figure 1. Yield of cabbage at various rates or organic fertiliser

the high rates of nutrients from the organic fertiliser were not detrimental to the crop, but, is in fact necessary in organic cultivation, can be attributed to the low availability of nutrients from organic sources. Generally, only 30% N, 20% P and 30–50% K are available from composts (Dierolf et al. 2001). Based on these availability figures, the organic nutrient source in this study would provide the cabbage crop with 384 kg N, 232 kg P and 504 kg K/ha (assuming 30% K availability).

As no deficiency symptoms (due to nutrient imbalances) were observed, in spite of the high K, it is probable that the availability of K from PPM could be lower than the 30–50% reported by Dierolf et al. (2001). The availability of Ca may possibly be much less, as even 10% availability would provide 572 kg Ca/ha, when requirement for cabbage is less than 100 kg Ca/ha (Vimala and Joseph 1977). Published fertiliser recommendations for cabbage vary widely, ranging from 45–500 kg/ha for N, 46–353 kg/ha for P and 86–300 kg/ha for K. (MacGillivary 1961; Ware and McCollum 1980; Greenwood et al. 1989; Sanchez et al. 1994). This variability can be attributed to various factors such as varieties, yields, soils, soil – nutrient source interactions, irrigation method, time of fertiliser application and weather.

The availability of nutrients from locally available organic sources need to be investigated for a better understanding of organic fertiliser and soil interactions under local conditions. Long-term studies on residual effects of organic fertilisers applied for successive crops are also required for information, on salt build-up and on the possibility of reducing the rates of organic fertiliser for subsequent crops.

The micronutrients Mn, Fe and Zn present in the optimum rate of 40 t/ha PPM i.e. 23 kg/ha Mn, 38 kg/ha Fe and 27 kg/ha Zn *(Table 2)* would have provided a steady supply of these essential nutrients to the cabbage crop, as no micronutrient deficiency symptoms were evident.

Plant major nutrient content

Nitrogen content of the outer leaves (3.33–3.81%) and the N content of the cabbage head (3.37–3.69%), did not differ significantly with treatments *(Tables 4* and *5)*. These values are comparable to the N content obtained in a previous study (Illias and Vimala 2003). Scaife and Turner (1983) reported 3.5% N for healthy young cabbage and 1.9% for deficient plants.

Phosphorus content of outer leaves increased significantly from 0.34–0.58% when PPM was increased from 0–15 t/ha *(Table 4)*. Although the P content increased further to 0.64% at 60 t/ha PPM, it was not significant. The P content of the head ranged from 0.44–0.62 and did not differ significantly with treatments *(Table 5)*. The P content of all treatments, except at 0 fertiliser, was above the critical leaf concentration of 0.35% cited by Scaife and Turner (1983).

Potassium contents of the outer leaves *(Table 4)* were higher than its contents in the head *(Table 5)* and increased significantly from 4.39–9.29% when PPM was increased from 0–30 t/ha. The K content of the head increased significantly from 4.01–5.15% when PPM was increased from 0–30 t/ha.

Table 4. Major nutrient content of cabbage outer leaves

Organic fertiliser (t/ha)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
0	3.38	0.34c	4.39d	3.46	0.57
15	3.37	0.58ab	7.20bc	3.26	0.61
30	3.54	0.57ab	9.29a	3.60	0.74
45	3.33	0.59a	9.29a	3.13b	0.71
60	3.52	0.64a	8.71ab	4.03	0.67
Inorganic fertiliser	3.81	0.44bc	5.82cd	2.43	0.70
Mean	3.49	0.53	7.45	3.35	0.47
Significance	ns	**	**	ns	ns
CV (%)	6.47	14.78	11.62	14.06	11.65

Means with the same letter are not significantly different
*Significant at 5%; **Significant at 1%; ns = not significant

Table 5. Major nutrient content of cabbage head

Organic fertiliser (t/ha)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
0	3.51	0.46	4.01c	0.91a	0.28
15	3.49	0.49	4.35bg	0.65b	0.25
30	3.67	0.57	5.15ab	0.66b	0.28
45	3.37	0.55	5.03ab	0.64b	0.27
60	3.69	0.62	5.49a	0.64b	0.29
Inorganic fertiliser	3.68	0.44	4.57abc	0.84a	0.29
Mean	3.57	0.53	4.76	0.72	0.28
Significance	ns	ns	*	*	ns
CV (%)	8.62	11.54	10.52	13.06	12.46

Means with the same letter are not significantly different
*Significant at 5%; **Significant at 1%; ns = not significant

For all treatments, the K contents were above the critical leaf concentration of 2.0% (Scaife and Turner 1983). The high K content is probably indicative of some degree of luxury consumption, though generally high K contents have been reported for vegetable crops (Adams 1985; Roberts and Smith 1988). Potassium accumulation in vegetable crops, attributed to organic and inorganic nutrient sources have been reported by other workers.

Calcium content of outer leaves did not differ significantly with treatments, and had a mean of 3.35% *(Table 4)*. The calcium content in the head (mean of 0.72%) was much lower than the Ca content in the outer leaves and was significantly higher with the inorganic fertiliser and at the zero fertiliser rate, compared to the other treatments *(Table 5)*. The reason for this is not clear. Critical leaf concentrations for Ca have been reported to be very variable (Scaife and Turner 1983).

Like K and Ca, the Mg contents of the outer leaves *(Table 4)* were higher than in the head *(Table 5)* but both were not significant with increasing rates of organic fertiliser application. Magnesium content of the outer leaf ranged from 0.57–0.74% while the Mg content of the head ranged from 0.25–0.29%. Scaife and Turner (1983) and Maynard (1979) cited 0.2% Mg as critical leaf concentration for vegetables in general.

Plant micronutrient content

Micronutrient contents in the head and in the outer leaves are presented in *Table 6*. Boron contents were slightly higher in the outer leaves (mean = 38 ppm) compared to

Table 6. Micronutrient composition (ppm) of cabbage

Organic fertiliser (t/ha)	B	Fe	Mn
Head			
0	24	109	35
15	31	118	26
30	36	148	24
45	35	139	27
60	37	125	31
Inorganic fertiliser	32	159	32
Mean	33	133	29
Significance	ns	ns	ns
CV (%)	14.1	24.3	16.6
Outer leaves			
0	22c	322	56
15	40ab	366	50
30	41ab	392	46
45	47a	304	57
60	51a	306	62
Inorganic fertiliser	28bc	310	60
Mean	38	333	55
Significance	*	ns	ns
CV (%)	20.9	34.2	23.8

Means with the same letter are not significantly different
*Significant at 5%; ns = not significant

the head (mean = 33 ppm) and differed significantly with treatments for only the outer leaves. The B concentrations obtained were comparable to B concentrations obtained for cabbage and other vegetables in previous studies (Vimala, Yeong et al. 1997; Vimala et al. 1999) and are deemed to be in the sufficient range. According to Gupta and Cutcliffe (1984) B concentration up to 132 ppm was not toxic and deficiency symptoms were not evident at 16 ppm for cabbage.

Like boron, Fe contents too were higher in the outer leaves (mean = 333 ppm) compared to the head (mean = 133 ppm) and was not influenced by increasing rates of organic fertiliser. High levels of Fe in the leaves compared to other plant parts were obtained in previous studies on vegetables in Malaysia (Vimala et al. 1999). The Fe contents obtained in this study are higher than the 50 ppm critical leaf concentration reported by Scaife and Turner (1983) for vegetables and the 100 ppm reported by Maynard (1979) as sufficient for the growth of vegetables. Purvis and Carolus (1964) reported Fe concentration to vary between 25 and 500 ppm depending on plant part and species. Wide variability in the Fe content of vegetables has also been reported by other workers more recently (Lorek et al. 1994; Rangarajan et al. 1997).

As obtained for B and Fe, mean Mn content too was higher in the outer leaves (55 ppm) than in the head (29 ppm) and was not influenced by rates of organic fertiliser. Manganese contents obtained in this study were above the critical leaf concentration of 20 ppm for vegetables reported by Scaife and Turner (1983) and comparable to that obtained in previous studies on cabbage (Vimala et al. 1999). As no Mn deficiency symptoms were observed, the concentrations obtained are deemed to be sufficient. Askew and Smith (1995) reported adequate Mn for cabbage as being between 15 and 100 ppm.

Nitrate content

The nitrate contents of the head and the outer leaves were not significantly influenced by the increasing rates of organic fertiliser applied *(Table 7)*. Nitrate content of the outer leaves was generally double or more than that of the edible head. This, however, is inconsequential as the outer leaves are not consumed. The nitrate contents in the edible head were below the maximum tolerated nitrate concentrations of vegetables (MAFF UK 1999). Thus at the

Table 7. Nitrate content (mg/kg dry wt.)

Organic fertiliser (t/ha)	Outer leaf	Head
0	6,045	3,226
15	5,883	3,153
30	8,258	3,351
45	7,673	3,358
60	8,232	3,686
Inorganic fertiliser	9,907	3,112
Mean	7,666	3,314
Significance	ns	ns
CV (%)	27.4	21.2

ns = not significant

Table 8. Soil chemical properties after harvest

Organic fertiliser (t/ha)	N (%)	Soluble P (ppm)	Ca [cmol(+)/kg]	Organic C (%)	CEC [cmol(+)/kg]
0	0.143cb	21c	3.82b	1.9c	8.5b
15	0.163ab	323b	3.88b	2.3a	9.8a
30	0.170a	236b	4.36ab	2.1ab	9.5ab
45	0.167ab	273b	4.22ab	2.1ab	9.6ab
60	0.180a	550a	5.03a	2.2ab	9.9a
Inorganic fertiliser	0.133c	36c	3.72b	1.8c	8.5b
Mean	0.159	224.9	4.17	2.07	9.32
Significance	*	*	*	*	*
CV (%)	8.07	42.28	12.51	8.36	6.39

Means with the same letter are not significantly different
*Significant at 5%

optimum rate of 40 t/ha PPM, the quality of cabbage is acceptable. Previous studies have reported that organically grown vegetables have lower nitrate contents than those grown conventionally (Stopes et al. 1989; Leclerc et al. 1991; Vimala et al. 2004) giving further strength and reason, to expand organic production in the country and elsewhere.

Soil chemical properties

All the organic treatments improved soil chemical properties significantly compared to the inorganic treatment *(Table 8)*. Soil N increased significantly from 0.14% at 0 t/ha organic fertiliser to 0.17% at 30 t/ha organic fertiliser. Soil carbon content increased significantly from 1.9–2.3% when organic fertiliser increased from 0–15 t/ha. Phosphorus content increased significantly from 21–550 ppm and the Ca content from 3.8–5.0 meq/100 g. The CEC increased significantly from 8.5 cmol(+)/kg at 0 t/ha organic fertiliser to 9.9 cmol(+)/kg at 60 t/ha organic fertiliser.

These soil improvements with one crop season are encouraging, as successive organic nutrient application will probably lead to further soil improvements, which in turn can be translated to lower and sustainable rates of organic fertiliser requirement, hopefully within a couple of years of organic cultivation. Long-term studies on soil improvement in organic cultivation need to be implemented and documented. Soils under the inorganic fertiliser treatment did not differ significantly from the zero fertiliser treatment.

Conclusion

A significant quadratic yield response of cabbage to increasing rates of organic fertiliser was obtained. Processed poultry manure at 40 t/ha was optimum for lowland cabbage cultivation on clay soils under shelter. The effects of increasing rates of organic fertiliser on the nutrient content of the head and outer leaves were variable. There was no significant effect of increasing rate of organic fertiliser on the nitrate content of both the head and the outer leaves. Application of organic fertiliser resulted in an improvement of soil chemical properties while the inorganic fertilizer did not improve the soil.

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Abstrak

Kajian ini menilai keberkesanan kadar baja organik terhadap pertumbuhan, hasil dan kandungan nutrien kubis yang ditanam di bawah lindungan di tanah liat di tanah rendah. Tahi ayam proses (PPM) telah diuji pada kadar 0, 15, 30, 45 dan 60 t/ha. Baja tak organik ($N:P_2O_5:K_2O$: MgO = 12:12:17:2) diguna pada kadar 2 t/ha sebagai rawatan kawalan.

Garis pusat kanopi kubis bertambah dengan signifikan daripada 32.0–59.5 cm apabila PPM bertambah daripada 0–15 t/ha manakala garis pusat kepala kubis bertambah dengan signifikan daripada 13.8–15.2 cm. Perhubungan antara hasil kubis dengan kadar baja organik adalah kuadratik, $Y = 9.832 + 0.636x - 0.00x^2$ dengan Y = hasil dalam t/ha dan x = baja organik dalam t/ha. Kadar baja organik optimum ialah 39.75 t/ha. Hasil pada kadar ini ialah 22.47 t/ha.

Kadar baja organik menunjukkan kesan yang signifikan untuk kandungan P dan K di daun luar kubis dan untuk K and Ca di kepala kubis. Kadar baja organik tidak ada kesan signifikan terhadap kandungan nitrat. Baja organik didapati menambah baik ciri-ciri kimia tanah. Sebagai kesimpulan, 40 t/ha PPM boleh disyorkan untuk menanam kubis secara organik di bawah lindungan di tanah liat di tanah rendah.

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