ISSN: 1394-7990
Malaysian Journal of Soil Science Vol. 16: 71-87 (2012) Malaysian Society of Soil Science

Impact of Different Fertilization Methods on the Soil, Yield and Growth Performance of Black Pepper (*Piper Nigrum* L.)

Yap Chin Ann

Research and Development Division, Malaysian Pepper Board
Kuching, Sarawak, Malaysia

ABSTRACT

Black pepper is a high nutrient demanding crop. Fertilizer use and management is therefore of crucial importance to sustain growth and high yield. This experiment was carried out to study the effect of chemical and organic fertilizers on some physiological characteristics, yield and soil fertility of pepper in the first 30 months of planting. The treatment consisted of T1: chemical fertilizer; T2: organic and foliar (seaweed) fertilizer; T3: organic and chemical fertilizer and T4: no fertilizer. These selected integrated fertilizer treatments out-yielded organic and chemical fertilizer by 75.38% and 16.14%, respectively, with the higher yield being associated with various phenotypical alterations, which are reported here. Significant measureable changes were observed in physiological processes and plant characteristics, such as large leaf area index, more chlorophyll content and high photosynthetic rate coupled with lower transpiration rate in integrated fertilizer treatment compared with other treatments. The high fertility level in organic fertilization reflected the importance of organic fertilizers in improving soil quality. However, the 75.38% reduction in pepper yield should be compensated by premium price of organic pepper. In conclusion, to achieve high growth performance and yield in pepper, organic fertilizer alone is insufficient whilst integrated fertilization gave a significant increase in yield and growth of pepper.

Keywords: Black pepper, organic fertilizer, integrated fertilization, growth performance, yield

INTRODUCTION

Black pepper (*Piper nigrum* L.) is one of the most important commodities in Malaysia and is considered as the king of the spices (Anon 2003). High yield production of pepper is urgently needed to meet the increasing population and growing demand for food. One of the main problems faced by the pepper farmers is the high cost of production due to the increasing trend of using inorganic fertilizers. The problem is complex because black pepper is a high nutrient demanding crop. Based on current culture practice, pepper farmers are required to apply approximately one, two and three tons of compound fertilizer (12%: 12%: 17%: 2% (Mg) + trace elements) per hectare per year for the first, second and third year of planting, respectively. The application of this compound fertilizer will

*Corresponding author : E-mail: *cayap@mpb.gov.my*

finally lead to the occurrence of soil acidification and cause a drop in pH around the pepper root system. Lower pH value can lead to nutrient deficiency e.g. calcium and magnesium which are leached after displacement from soil particles (Naqvi *et al*. 1999). Also, due to lower pH soils and microbe's preference for ammonium as a nitrogen source, the crop suffers greater disease pressure (Fraterrigo *et al.* 2011).

Further, the continued use of chemical fertilizers causes health and environmental hazards such as ground and surface water pollution by nitrate leaching and surface runoff (Pimentel 1996). Therefore, it is important to develop cost effective methods to fulfill the nutrient demand of black pepper and at the same time alleviate the environmental hazards. As organic farming is becoming popular among pepper farmers, one of the options to reduce the use of chemical fertilizers could be recycling of organic wastes. Compost derived from organic wastes can be a valuable and inexpensive fertilizer and source of plant nutrients. Positive effects of organic waste on soil structure, aggregate stability and water-holding capacity have been in reported in several studies (Wells *et al*. 2000; Shen and Shen 2001; Jedidi *et al.* 2004 and Odlare *et al.* 2008). Furthermore, compost has high nutrient contents, especially nitrogen, phosphorus and potassium, while contamination from heavy metals and other toxic substances is very low (Asghar *et al.* 2006). Previous studies have shown that a combination of compost with chemical fertilizers further enhances the biomass and grain yield of crops (Cheuk *et al.* 2003; Sarwar *et al.* 2007; Sarwar *et al*. 2008).

Therefore, as an initial step towards this goal, this study was carried out with the objective of investigating the influence of inorganic (NPK) and organic (compost and foliar fertilizer) fertilizers on the early growth stages of black pepper in term of soil fertility, growth performance and yield.

MATERIALS AND METHODS

The experiment was carried out during the period of 2009 to 2012 at a farmer's land in Melaka on Melaka-Durian-Munchong soil series. The particle size analysis showed that the texture of this brownish yellow soil was clay loam and had a pH of 3.85 (Table 1). Geographical location of the experimental site was 102^{o}09.549 latitude and 02^{o}17.235 E Longitude with average altitude of 23.21 m above sea level with the average temperature ranging between 30°C - 35°C during the day, and 27°C - 29°C at night with the average annual rainfall being about 1500 mm. A completely randomized block design (RCBD) was used. Pepper vines of the variety *Semongok Aman* were planted in rows with spacing of 2.1 m x 2.1 m between and within the rows, with a population of 2,000 plants per hectare. The site was divided into three blocks or replicates. Each block contained four treatments and 100 plants of *Piper nigrum* were planted for each treatment.

The four treatments consisted of (T1): chemical fertilizer. Within this treatment, the pepper vines were randomly selected to receive the NPK fertilizer (12%: 12%: 17%: 2% (Mg) + trace elements) at the rate of one, two and three tons of compound fertilizer per hectare per year for the first, second and third

year of planting, respectively. This rate of fertilization corresponded to 120 kg ha^{-1} of N and P, 170 kg ha^{-1} of K and 20 kg ha^{-1} of Mg in the first year, 240 kg ha^{-1} of N and P, 340 kg ha^{-1} of K and 40 kg ha^{-1} of Mg in the second year and 360 kg ha^{-1} of N and P, 510 kg ha^{-1} of K and 60 kg ha^{-1} of Mg in the third year of planting. NPK compound fertilizer was applied 6 times annually (every 2-month intervals), following Malaysian Pepper Board's recommendation rate based on their expected productivity (Malaysian Pepper Board 2011). In addition, ground magnesium limestone was applied to neutralize the soil acidity.

TABLE 1
Initial chemical characteristics of Sg Udang soil

Chemical properties	Soil depth (0 - 25cm)
pH	3.85
CEC (cmol (+)/ kg)	9.7
Exchangeable K^+ (cmol (+)/ kg)	0.79
Excha ngeable Mg^{2+} (cmol (+)/ kg)	0.72
Exchangeable Ca^{2+} (cmol (+)/ kg)	1.72
Exchangeable Na^+ (cmol (+)/ kg)	0.09
Organic carbon (%)	1.68
C/N ratio	6.61
Total nitrogen (%)	0.25
Available p hosphorus (mg/kg)	10.32
Total p otassium (mg/kg)	28.52

The second treatment was (T2) which involved the application of organic fertilizer + foliar based fertilizer (seaweed). The organic based fertilizers used were compost derived from empty oil palm fruit branches and organic seaweed fertilizer with International Federation of Organic Agriculture Movement (IFOAM) certification (Table 2). Within this organic culture practice, the pepper vines were applied with approximately 0.5 kg of compost and 3 L ha^{-1} of seaweed at 2-month and 1-month intervals, respectively. Treatment T2 which consisted of foliar application was sprayed using motorized sprayer before 10 o'clock in the

TABLE 2
Chemical properties of organic based fertilizers

Chemical properties	Compost	Seaweed
Nitrogen (%)	2.2	1.2
Phosphorus (%)	1.9	0.26
Potassium (%)	1.7	5.20
Calcium (%)	2.72	1.4
Magnesium (%)	1.29	0.94
Trace elements	B, Mn, Pb, Zn	Mn, Fe, Zn, Mob, Cu, B, Co, S, Cl, Vitamin
Hormone	-	Auxin (150.0 cm^3/Litre) Cytokinins (25.0 cm^3/litre)

morning, since stomata are known to be open during this period. The application of foliar fertilizer was carried out on the whole pepper crop, including the leaves, stems, branches, flowers and fruits. For the third treatment (T3), both organic and chemical fertilizers were utilized. Under this treatment, each pepper crop was applied with both organic and compound fertilizers on alternative months. Under this treatment, the application of organic fertilizers was the same as stated in T2 whereas for chemical fertilizers, 30% of the compound fertilizers was reduced. No additional limestone was applied. In the case of (T4), no fertilizer was applied. For treatment T2 and T3, both organic and chemical fertilizers were broadcasted evenly surrounding the mound, about 30-50 cm from the main stem.

The plant was allowed to grow for up to 30 months of age so as to record growth parameters. Destructive whole plant dry matter analysis was performed at 2-month intervals during the first 30 months of planting. Upon completion of the experiment (30 months after planting), the plants were harvested by uprooting at maturity for yield and yield component, root length and root weight measurements and recording. To assess leaf area, ten (10) pepper vines from each replicate were randomly selected and leaf areas were measured using a leaf area meter (CI-202 Laser Area Meter). Leaf area index was determined by using LAI meter (LICOR-2200TC Canopy Analyzer). The pepper plant was then oven dried at 70^0 C for 72 h and dry weight was also recorded. Concentration of photosynthesis pigment (chlorophyll) as well as photosynthesis rate and transpiration were measured in mature leaf samples taken 30 months after planting by using potable photosynthesis system (PPS System, model TPS 200). After the plant samples were taken, the soil samples were collected and analyzed. Standard methods were adopted for pH (McLean 1973), cation exchange capacity (Thomas 1982), organic carbon (Mclean 1973) and the concentration of nitrogen (Bremner and Mulvaney 1982), phosphorus (Olsen and Sommers 1982) and potassium (Knudsen *et al*. 1982). For leaf nutrients content, mature leaves were collected and oven-dried before P, K, Mg and Ca contents were analyzed by using dry ashing method as described by (Gupta 2004) and the Kjeldahl method (De Waard 1969) was used to determine total N. All data obtained were subjected to Analysis of Variance (ANOVA) and Duncan Multiple Ranged Test using Statistical Package for Social Science (SPSS) software.

RESULTS AND DISCUSSION

White Pepper Yield

Pepper is a perennial crop which starts producing berries after 18 months of planting (immature stage). The development of the pepper berries to maturity takes about 8-9 months from flowering to full ripeness. The dry weights of the pepper berries per plot over the years were significantly different among the treatments (Table 3). The yield of dry white pepper berries grown under integrated fertilizer treatment (T3) (6.98 t ha^{-1}) was higher than both those grown under chemical fertilizer treatment (T1) (5.74 t ha^{-1}) and organic fertilizer treatment T2 (3.98 t

ha^{-1}) (Table 3). A number of previously published reports showed enhancement of crop yield through the integrated fertilization regime (Ayoola 2006; Alam *et al*. 2005). This study found integrated fertilization to increase pepper yield by 21.60% compared to chemical fertilization whereas under organic fertilization, the pepper yield was decreased by 75.38% from 6.84 t ha^{-1} to 3.98 t ha^{-1}. The differences in pepper yield between these three methods of cultivation were due principally to difference in nutrients supplied, the average number of fruit spikes per vine (Table 3), LAI value (Table 5) and nutrients uptake (Table 7) by pepper among the four different treatments. This observation agreed with the work reported by Ayoola (2006) which identified low nutrient availability in organic material as the main factor attributed to low crop production in plants applied with organic fertilizers. A similar result was reported by Varughese and Ghawas (1993) which mentioned that the production of pepper/vine was dependent on number of spikes and leaf area index of vine (Table 4). The greater the bushiness of vine, the more the production of pepper berries.

TABLE 3
Effect of fertilizer treatments on yield of pepper (Piper nigrum)

Treatment	Yield (ton/ha^{-1})	Average no. of fruit spikes/vine
T1- Chemical fertilizer	5.74 ± 0.74 b	801 ± 127b
T2 - Organic fertilizer	3.98 ± 0.55c	438 ± 112c
T3 - Chemical and organic fertilizer	6.98 ± 0.32a	987 ± 134a
T4 - Control plot (no fertilizer)	0.86 ± 0.21d	134 ± 26d

Means in column with different letters are significantly different at 0.05 level using Duncan Multiple Range Test.

TABLE 4
Effect of different fertilizer treatments on root after 30 months of planting.

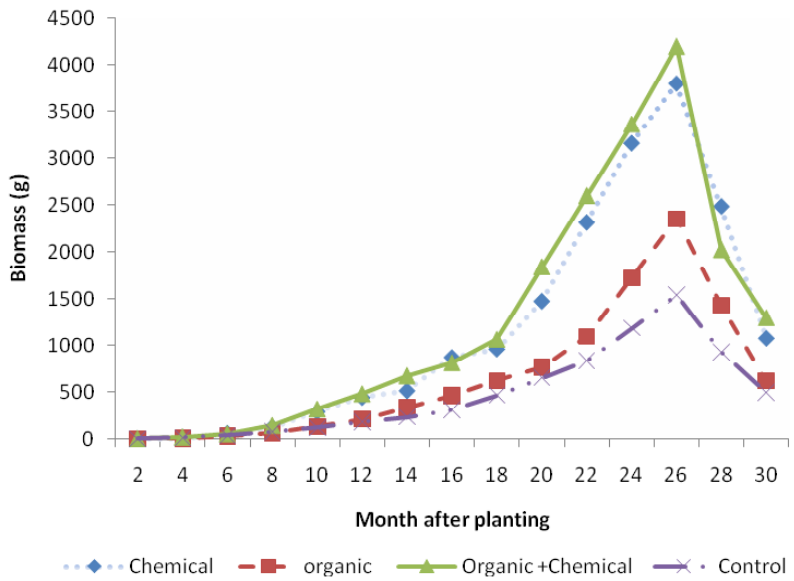
Fertilizer treatments	Root dry weight (g)	Root length (cm)
T1 - Chemical fertilizer	49.8b	89 .6b
T2 - Organic fertilizer	40.6c	75.3c
T3 - Chemical and organic fertilizer	59.8a	95.7a
T4 - Control plot (no fertilizer)	32.9d	51.5d

Means in column with different letters are significantly different at 0.05 level using Duncan Multiple Range Test .

Plant Dry Matter Weight

Total biomass production increased with time irrespective of fertilizer treatment with the maximum plant dry matter weight (DMW) being observed in the T3 treatment (*Fig. 1*). The increase in plant dry weight was mainly due to the increased mass of the above and ground organs. The total dry matter accumulation from 0 to 30 months after planting exhibited a sigmoidal behaviour like other annual crops, characterized by better growth rate in the period of leaf production and fruit formation (flowering to harvest, 18 to 26 months after planting) with

a slow decline towards fruit maturation and harvest (*Fig. 1*). The decline in dry matter weight can be explained by loss of plant parts like leaves and fruits due to harvesting. The analysis also showed that the plots receiving both organic and inorganic fertilizers produced slightly higher ($P<0.05$) plant biomass compared with other treatments. These results are in accordance with Wong *et al.* (1999) and Magnusson (2002) on chinensis cabbages (*B. Chinensis*) and Abddelrazzag (2002) on onion (*Allium cepa*). This variation might be due to improvements in soil water holding capacity with organic fertilizers (Roe and Cornforth 2000). Furthermore, organic fertilizer activates many species of living organisms, which release phytohormones and may stimulate plant growth and absorption of nutrients (Arisha *et al.* 2003). Even though the utilization of organic fertilizers has been reported to sustain crop growth and yield (Makinde *et al.* 2010), sole dependence on organic fertilization resulted in a lower plant biomass compared to chemical fertilization. This could be due to limited nutrients that the soil could supply with the addition of a small quantity of external input. This finding was further confirmed by the research reported by Yap (2012). He reported that pepper crop required approximately 293-46-265 kg of N-P-K per hectare annually in order to sustain high yield and soil nutrient balance.



T1: Chemical fertilizer treatment, T2: Organic fertilizer treatment, T3: Both chemical and organic fertilizer treatments, and T4: control plot (no fertilizer)

Fig. 1. Effect of different fertilizer treatments on plant dry weight of black pepper.

Root Characteristics

Root growth was measured at 30 months after planting which is when vine actively produces flowers for subsequent year production. The average root dry

weight and root length grown under different fertilizer treatments increased with time, reaching a maximum in the T3 treatment (Table 4). The effect of organic and inorganic fertilizers on root growth showed that the treatments significantly increased pepper root length, with the highest root length value recorded with the application of both organic and inorganic fertilizers (95.7 cm), followed by application of the chemical regime (89.6 cm), organic fertilizer (75.3 cm) and the control plot having the lowest root length (51.5 cm). The highest root length value in T3 might probably be due to the application of foliar fertilizer and compost in integrated cultivation systems. This finding is in agreement with the findings reported by Atiyeh *et al.* (2000a). Besides, this finding is also in conformity with that reported by Abdel-Mawgoud *et al.* (2010) as foliar fertilizer (seaweed) contains a growth hormone that can stimulate the growth of pepper roots. In most of the studies, an increased amount of nutrients led to an increase in the rate of assimilation and ultimately to higher root growth (Mir *et al*. 2010). The current study also showed that pepper dry weight growth under integrated fertilization (T3) was nearly twice as heavy as control vine. It is believed that pepper vine with better root growth and higher physiological activity would synthesize large amounts of cytokinin that is responsible for promoting cell division. Similar results were also observed by Thakur *et al*. (2009) who stated that better root growth and higher physiological activity in rice was dependent on the production of a large quantity of cytokinin.

Leaf Characteristics

The leaf canopy architecture of pepper vine is an important growth characteristic for determining vigour and productivity of black pepper. At the individual plant level, the pepper vine planted under different fertilizer treatments affect the leaf characteristics of pepper genotypes. The mean and total leaf area of pepper grown under integrated fertilizer treatment (22.6 cm^2 and 230.7 cm^2, respectively) and sole chemical fertilizer treatment were higher (19.7 cm^2 and 195.5 cm^2, respectively) than those grown using organic fertilizer treatment (15.7 cm^2 and 176.9 cm^2, respectively) and control treatment (13.57 cm^2 and 159.4 cm^2, respectively) (Table 5). Laghari *et al.* (2010) reported that an increase in the leaf area is a common response of leaves that absorb an appropriate amount of nutrients. The finding may be due to the specific leaf area (cm^2/g) increasing with increasing nutrient availability (Table 5), as seen in other crops e.g. wheat (Laghari *et al.*

TABLE 5
Effect of different fertilizer treatment on leaves after 30 months of planting.

Fertilizer treatments	LAI	Mean leaf area (cm^2)	Total leaf area (cm^2)	Specific leaf area (cm^2/g)
T1- Chemical fertilizer	5.03b	19.7a	195.5a	224.3a
T2 - Organic fertilizer	3.81c	15.7b	176.9b	164.3b
T3 - Chemical and organic fertilizer	5.62a	22.6a	230.7a	243.7a
T4 - Control plot (no fertilizer)	2.01d	13.57b	159.4b	139.4c

Means in columns with different letters are significantly different at 0.05 level using Duncan Multiple Range Test.

2010) and rice (Thakur *et al.* 2009). From the data obtained, the mean LAI of pepper grown under both chemical and organic (5.62) and chemical fertilizer (5.03) treatments were higher than those grown under the organic fertilizer regime (3.81) and control treatment (2.01). In general, there was a significant correlation between LAI and yield (r = 0.767) in the regression between LAI and yield ($Y = 0.068X^2 + 0.232x + 3.076$) which showed that an increase in LAI will result in a yield increase (*Fig. 2*). This finding is expected because the production of pepper is based on the number of leaves based on the concept of '1 leaf 1 flower'. The emergence of every new leaf will cause the formation of a new flower on the opposite site (Plate 1). However, this finding could not be applied on pepper vine treated with organic fertilizers. This is because at the flowering stage, not all leaves were accompanied by the development of flowers. This could be attributed to low nutrient availability in organic fertilizers.

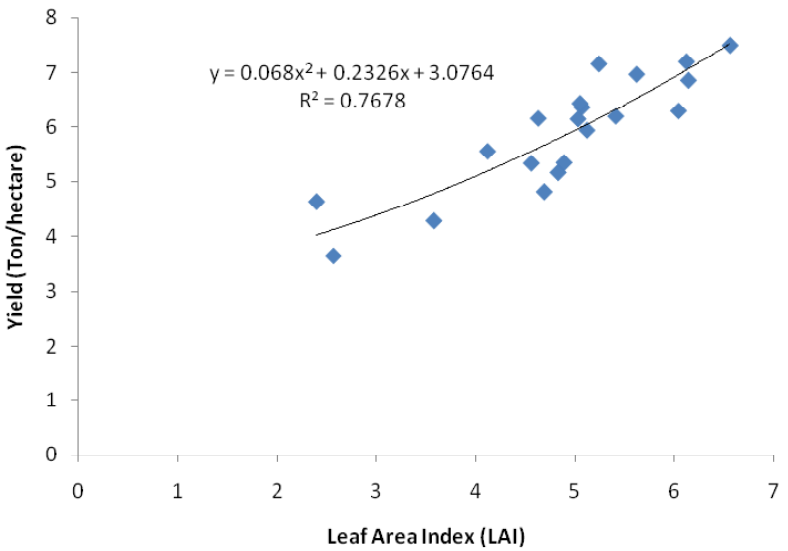


Fig. 2. Relationship between leaf area index and yield of pepper (Piper nigrum). Correlation coefficient: r > 0.66 significant at P = 0.05

Chlorophyll Content and Photosynthesis Rate

It has been reported that availability of nutrients in soil significantly affects the photosynthetic rate (Pn), chlorophyll (Chl) and transpiration in pepper vine (Shangguan *et al*. 2000; Thakur *et al.* 2009). From the analysis, net photosynthetic rate was markedly higher for plant grown under integrated fertilization treatment compared to sole organic fertilization treatment although there were no significant differences between chemical and integrated fertilization method (Table 6). This observation is supported by the findings of Okali and Owusu (1975) who reported that net photosynthetic rate was highest in plants that were maintained at the highest nutrients level. The high photosynthetic rates were mainly due to greater chlorophyll contents as well as the availability of nutrients to plants.

Plate 1. Growth performance of pepper flower as affected by the growth of pepper leaf cause production of pepper based on a production concept of '1 leaf 1 flower'.

Chlorophyll content is of particular significance in precision agriculture as an indicator of photosynthesis activity (Tranavicience *et al.* 2008). There is a strong linear relationship between nutrient availability and chlorophyll content according to Sabo *et al*. (2002) and Bojovic and Stojanovic (2005). It was also observed that the pepper crop grown under treatment T1 and T3 had dark green leaves, higher chlorophyll content and a higher chlorophyll a/b ratio than those under organic fertilization treatment. This indicates that better nutrients supply received by T1 and T3 compared to T2 as chlorophyll is believed to take part in the process of organogenesis (Bojovic and Stojanovic 2005). Previous reports also support our finding that lighter green leaves, unless experiencing allow light condition (shading), have reduced total chlorophyll/mg fresh weight and higher chlorophyll a/b ratio (Murchie and Horton 1997; Harper *et al.* 2004).

Concomitantly, our analysis also showed that organic fertilization treatment has a higher transpiration rate than pepper grown under chemical and integrated fertilization treatment (T3) (Table 6). The ratio of photosynthesis to transpiration (instantaneous water use efficacy) was accordingly higher in integrated fertilization treatment; with the loss of one m mol of water, 3.91 and 1.55 and 4.81 µmol of CO_2 was fixed in pepper vine grown under, chemical, organic and integrated fertilization treatment, respectively. A high photosynthetic rate with lower CO_2 concentration inside the sub-stomata cavity in integrated fertilization treatment suggested a more efficient carboxylation system (Table 6). The instantaneous water use efficacy of the leaf (represented by the ratio of photosynthesis to transpiration) is a measurement of carbon gained through photosynthesis with per unit of water

transpired. A higher photosynthetic rate with lower transpiration in integrated fertilization treatment (T3) indicates that water was used more efficiently than in organic fertilization.

TABLE 6
Comparison of chlorophyll content, transpiration rate, net photosynthesis and internal CO_2 concentration with different fertilizer treatments.

Parameters	Fertilizer treatments			
	T1	T2	T3	T4
Chlorophyll a (mg g^{-1} FW)	2.95a	1.53b	3.05a	0.75c
Chlorophyll b (mg g^{-1} FW)	1.18a	0.82b	1.34a	0.43c
Total Chlorophyll	4.13b	2.35c	4.39a	1.81d
Net photosynthesis rate (μ mol m^{-2} S^{-1})	24.86a	12.28b	26.87a	10.56b
Transpiration (m mol m^{-2} S^{-1})	6.35c	7.92b	5.59d	8.21a
Internal CO_2 concentration (ppm)	295.6b	335.9a	267.8b	345.5a

T1: Chemical fertilizer treatment, T2: organic fertilizer treatment, T3: Both chemical and organic fertilizer treatments, and T4: control plot (no fertilizer)

Means in columns with different letters are significantly different at 0.05 level using Duncan Multiple Range Test.

Effect of Fertilizer Treatment on Foliar Nutrient Contents

The foliar nutrient content of pepper vine under different fertilizer treatments is presented in Table 7. There was a significant increase ($P<0.05$) in the N, P, K, Mg and Ca contents of organic, chemical and integrated fertilization treatment compared to unfertilized control treatment. It was also observed that there were no significant differences between integrated and chemical fertilization treatment.

TABLE 7
Foliar nutrient contents of pepper with different fertilizer treatments.

Treatment	Nutrient concentration (%)				
	N	P	K	Mg	Ca
T1- Chemical fertilizer	3.24a	0.44a	1.97a	0.48a	2.32a
T2 - Organic fertilizer	0.73b	0.15b	0.97b	0.42b	1.43b
T3 - Chemical and organic fertilizer	3.42a	0.41a	2.12a	0.52a	2.21a
T4 - Control plot (no fertilizer)	0.32c	0.03c	0.29c	0.21c	0.34c

Means in column with different letters are significantly different at 0.05 level using Duncan Multiple Range Test.

This indicated that the nutrient applied might be the optimal fertilizer schedule for black pepper. According to the content range defined by Sadanandan *et al.* (2000), pepper nutrition planted under integrated and chemical treatments was in the sufficient range. No case of deficiency was recorded, whereas for pepper planted under organic and control treatment, almost all the pepper vines experienced nutrient deficiency syndrome. This can be seen thought the development of pale and yellowish leaves in the pepper vine. Besides, the nutrients deficiency

symptom can also confirmed by the reduction of flower in pepper vines. This was in conformity with Wahid and Kamalam (1982) who had the same reports for pepper leaf symptoms grown under limited nutrients content.

Effect of Fertilizer Treatments on Soil Fertility

Table 8 shows the influence of different fertilizer treatments on soil chemical properties. The plots applied with only organic fertilizers and a combination of both organic and chemical fertilizer significantly increased the soil pH after cropping except for application of chemical fertilizers. The effect of soil acidification is mainly due to high fertilizer levels. This research finding agreed with work of Ayoola (2006), who reported that application of a high level of chemical fertilizer as the main factor for reducing soil pH in a cassava-based cropping system. These findings were further confirmed by the observation of soil acidity symptoms on pepper leaves (Plate 2).

TABLE 8
Nutrient status in soil after treatments

Treatments	pH	O.C (%)	CEC (cmol(+) kg^{-1})	Tot-N (%)	Av. P (mg/kg)	Total. K (mg kg^{-1})
T1- Chemical fertilizer	4.48d	0.95d	7.4d	0.14b	10.58a	38.56a
T2 - Organic fertilizer	5.28a	1.54a	11.2a	0.20a	9.85b	18.95c
T3 - Chemical and organic fertilizer	5.03b	1.43b	9.0b	0.22a	11.56a	30.65b
T4 - Control plot(no fertilizer)	4.81c	1.04c	8.8c	0.16b	9.21b	16.76d

Means in columns with different letters are significantly different at 0.05 level using Duncan Multiple Range Test.

Plate 2: Soil acidity symptoms

The level of organic C decreased by 9.09%, 17.48%, 76.84% and 61.54% under organic, chemical +organic, chemical fertilizer and no fertilizer, respectively. This showed that incorporation of organic fertilizers into the soil could be an efficient way of maintaining desired soil organic matter level. Table 8 indicates the percent of total nitrogen decrease in the entire plot with a greater decrease in T3. This might probably be due to the more readily available nutrients compared to that from other treatments. The highest reduction in organic C and nitrogen was observed in the plots treated with chemical fertilizers resulting from stimulated decomposition of soil organic matter and crop residue by the applied fertilizer which led to higher mineralization. This could be due to higher N uptake by pepper and /or loss through leaching. The availability of phosphorus was highest in plants with integrated fertilization (11.56) compared to that from chemical sources (10.58) and organic sources (9.85). These results prove that the utilization of both inorganic and organic fertilizers could supply the plants with good amounts of available phosphorus. From the data obtained, the changes in available P were generally low (Adzemi *et al.* 1993). This might be partly because P is relatively immobile and strongly adsorbed by soil particles (Ige *et al.* 2005). The highest CEC value was obtained by organic fertilizer treatment (11.2) followed by integrated fertilizer treatment and control (9.0 and 8.8 $cmol_{(+)} kg^{-1}$, respectively), while the lowest value (7.4) was observed by chemical fertilizer treatment. The highest CEC value observed in organic treatment indicated those nutrients were highly retained compared to those from other treatments. The chemical fertilizer treatment had the highest available total potassium (38.56 mg kg^{-1}) which was significantly higher than in all other treatments (30.65, 18.95 and 16.76 for integrated, organic fertilizer and control treatment (Table 8)). The high availability of potassium in the chemical fertilizer treatment indicated that this element was in excessive amount and has been overused for pepper production. This finding is in accordance with the report published by Yap (2012) which states that the pepper crop only requires 265 kg ha^{-1} of potassium in order to sustain the growth and production of pepper berries.

CONCLUSION

The application of organic fertilizer only has led to poor growth performance of pepper as well as a reduction of 70% of pepper yield annually. Therefore, for sustainable crop production, integrated use of chemical and organic fertilizers is a more viable option. It is characterized by reduced input of chemical fertilizers and the combined use of chemical fertilizers with organic materials such as animal manure, crop residue, green manure and composts. From the results obtained, it can be concluded that the application of inorganic fertilizers supplemented with organic fertilizers could sustain the growth and optimum yield of pepper. Though the application of organic fertilizers plays a significant role in improving soil and crop sustainability, there is, however, a 60-70% reduction in crop yield and this should be compensated by premium pricing of organic produce.

ACKNOWLEDGMENTS

The authors wish to thank the host farmer on whose plots the data was collected. We also thank the Government of Malaysia and the Malaysian Pepper Board for financing and making this research possible. Sang ak Jam and Wan Ambi are also thanked for excellent technical assistance.

REFERENCES

Abddelrazzag, A. 2002. Effect of chicken manure, sheep manure and inorganic fertilizers on yield and nutrient uptake by onion. *Pakistan Journal of Biological Sciences.* 5: 266–8.

Abdel-Mawgoud, A.M.R., A.S. Tantaway, M. Magda and A.M. Habib. 2010. Seaweed extract improves growth, yield and quality of different watermelon hybrids. *Research Journal of Agriculture and Biological Sciences*. 6(2): 161-168.

Adeleye, E.O., L.S. Ayeni, S. O. Ojeniyi. 2010. Effect of poultry manure on soil physioco-chemical properties, leaf nutrient contents and yield of yam (*Dioscorea rotundata*) on Alfisol in Southwestern Nigeria. *Journal of American Science.* 6(10): 871-878.

Adzemi, M.A., J. Hamdan, J.S. Sjahril. 1993. Macro-Nutrient Removal Studies on Black Pepper (*Piper nigrum* L.) in Sarawak. The Pepper Industry (Problems and Prospects), Universiti Pertanian Malaysia, Sarawak, Malaysia, 1993. 80p.

Alam, S.M., S.A. Shah, S. Ali and M.M. Iqbal. 2005. Effect of combined application of organic waste and inorganic fertilizer on growth, P-uptake and yield of wheat Songklanakarin. *Journal of Science and Technology*. 27(3): 449-455.

Anon. 2003. Technical bulletin on Pepper cultivation. Technical Bulleting No: 4. Department of Export Agriculture, 1095, Peradeniya.

Atiyeh, R.M., C.A. Edwards, S. Subler and J.D. Metzger. 2000a. Earthworm processed organic wastes as components of horticultural potting media for growing marigold and vegetable seedlings. *Compost Science and Utilization.* 8: 215-223.

Arisha, H.M.E., A.A. Gad and S.E. Younes. 2003. Response of some pepper cultivars to organic and mineral nitrogen fertilizer under sandy soil conditions. *Zagazig Journal of Agricultural Research.* 30: 1875–99.

Asghar, H.N., M. Ishaq, Z.A. Zahir, M. Khalid and M. Arshad. 2006. Response of radish to integrated use of nitrogen fertilizer and recycled organic waste. *Pakistan Journal of Botany*. 38: 691-700.

Ayoola, O.T. 2006. Effects of fertilizer treatments on soil chemical properties and crop yields in a cassava-based cropping system. *Journal of Applied Science Research.* 2(12): 1112-1116.

Bojovic, B. and J. Stojanovic. 2005. Chlorophyll and caratenoid content in wheat cultivars as a function of mineral nutrition. *Archives of Biological Sciences.* 57: 283-290.

Bremner, J.M. and C.S. Mulvaney, 1982. Nitrogen-total. In: *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties* (2nd ed). Madison, Wisconsin, USA: American Society of Agronomy, Inc.

Cheuk, W., K.V Lo, R.M.R Branion and B. Fraser. 2003. Benefits of sustainable waste management in the vegetable greenhouse industry. *Journal of Environmental Science and Health*. 38: 855-863.

De Waard, P.F.W. 1969. Foliar diagnosis, nutrition and yield stability of black pepper (*Piper nigrum* L.) in Sarawak, Koninklijk Institute Vooe De Tropen, Amsterdam, p. 64.

Fraterrigo, J.M, M.S Strickland, A.D Keiser and M.A Bradford. 2011. Nitrogen uptake and preference in forest understory following invasion by an exotic grass. *Oecologia*. 167(3): 781-791.

Gupta, P. K. 2004. *Soil, Plant, Water and Fertilizer Analysis*, pp. 261 – 263. India: Agrobios.

Harper, A. L., S. E. Gesjen, A. S. Linford, M. P. Peterson, R. S. Faircloth, M. M. Thissen and J. A. Brusslan. 2004. Chlorophyllide a oxygenasem RNA and protein levels correlate with the chlorophyll *a/b* ratio in *Arabidopsis thaliana. Photosynthesis Research.* 79:149–159.

Ige, D.V., J.A. Adepetu and O.A. Obi. 2005. Effect of organic amendment on P release in soils of south western Nigeria. *Ife Journal of Agriculture*. 21: 216-228.

Jedidi N, A, Hassen, O. Van Cleemput and A. M'Hiri. 2004. Microbial biomass in a soil amended with different types of organic wastes. *Waste Management and Research.* 22: 93–99.

Knudsen, D., G.A. Peterson and P.F. Pratt, 1982. Lithium, sodium and potassium. In: *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties* (2nd ed.), ed. R.H. Miller and D.R. Keeney. Madison, Wisconsin, USA: American Society of Agronomy, Inc.

Laghari, G.M., F.C Oad, S.Tunio, A.W. Gandahi, M.H. Siddiqui, A.W. Jarirani and S.M. Oad. 2010. Growth and nutrient uptake of various wheat cultivars under different fertilizer regimes. *Sarhad Journal of Agriculture.* 26(4): 489-497.

Magnusson, M. 2002. Mineral fertilizers and green mulch in Chinese cabbage (Brassica Pekinensis Rupr): Effect on nutrient uptake, yield and internal tipburn. *Soil and Plant Science.* 52: 25–35.

Makinde, E.A., O.K. Oluwa, A.O. Oke and P.O. Duyile. 2010. Effects of organic organominerals and NPK fertilizer treatment on fresh and dry matter yield of Amaranthus cruentus on soil types in Lagos, Nigeria. *New York Science Journal.* 3(4): 12-17.

Malaysian Pepper Board. 2011. Pepper Production Technology in Malaysia, p.56. Malaysia: Malaysian Pepper Board.

McLean, E. O. 1973. *Soil Testing and Plant Analysi*s (rev. ed.), pp. 78-85. Madison, Wisconsin, USA: Soil Science Society and America, Inc.

Mir M. R. , M. Mobin, N.A. Khan, M.A. Bhat, N.A. Lone, K.A. Bhat, S.M. Razvi, S.A. Wani, and W.A. Payne. 2010. Crop responses to interaction between plant growth regulators and nutrients. *Journal of Phytology*. 2(10): 09–19.

Mohammadi, K. 2011. Effect of different fertilization methods on soil biological indexes. *World Academy of Science, Engineering and Technology.* 78: 407-410.

Murchie, E. H. and P. Horton. 1997. Acclimation of photosynthesis to irradiance and spectral quality in British plant species: Chlorophyll content, photosynthetic capacity and habitat preference. *Plant Cell and Environment.* 20:438–448.

Naqvi, S.S.M., S.M. Alam and R. Ansari. 1999. Impact of Coil pH on Nutrient Uptake by Crop Plants. Handbook of Plant and Crop Stress (2nd ed.). Madison, Wisconsin, USA: CRC Press.

Odlare, M., M. Pell and K. Svensson. 2008. Changes in soil chemical and microbiological properties during 4 years of application of various organic residues. *Waste Management*. 28: 1246-1253.

Okali, D.U.U and J.K. Owusu. 1975. Growth analysis and photosynthetic rates of cocoa (*Theobroma cocoa* L.) seedlings in relation to varying shade and nutrient regimes. *Ghana Journal of Agricultural Science*. 8: 51-67.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorus. In: *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties* (2nd ed.), eds. R.H. Miller and D.R. Keeney. Madison, Wisconsin, USA: American Society of Agronomy, Inc.

Pimentel, D. 1996. Green revolution and chemical hazards. S*cience of Total Environment*. 188: 86-98.

Roe, E.N. and C.G. Cornforth. 2000. Effect of dairy lot scraping and composted dairy manure on growth, yield and profit potential of double-cropped vegetables. *Compost Science and Utilization*. 8: 320–327.

Sabo, M., T. Teklic, and I. Vidovic. 2002. Photosynthetic productivity of two winter wheat varieties (*Triticum eastivum* L.). *Rostlinna. Vybrobo.* 48: 80-86.

Sadanandan, A.K., S. Hamza, S, Bhargava, H.B Raghupathi. 2000. Diagnosis and recommendation integrated system (DRIS) norms for black pepper (*Piper nigrum* L.), growing soils of South India, In: *Recent Advances in Plantation Crops Research*, ed. N. Muraleedharan and P. Raj Kumar, pp. 203-205. New Delhi, India: Allied Publishers Ltd.

Sarwar, G., N. Hussain, H. Schmeisky, S. Muhammad. 2007. Use of compost an environment friendly technology for enhancing rice-wheat production in Pakistan. *Pakistan Journal of Botany.* 39(5): 1553-1558.

Sarwar, G., N. Hussain, H. Schmeisky, S. Muhammad, M. Ibrahim and E. Safdar. 2008. Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. P*akistan Journal of Botany.* 40: 275-282.

Shangguan, Z.P., M.A. Shao and J. Dyckmans. 2000. Nitrogen nutrition and water stress effects on leaf photosynthetic gas exchange and water use efficiency in winter wheat. *Environmental and Experimental Botany.* 44: 141–149.

Shen, Q.R and Z.G. Shen. 2001. Effects of pig manure and wheat straw on growth of mung bean seedlings grown in aluminium toxicity soil. *Bioresource Technology*. 76: 235-240.

Singh, N. I. and J.S. Chauhan. 2009. Response of french bean (*Phaseolus vulgaris* L.) to organic manures and inorganic fertilizer on growth & yield parameters under irrigated condition. *Nature and Science.* 7(5): 52-54.

Thakur, A. K., U. Norman and A. Edna. 2009. An assessment of physiological effects of system of rice intensification (SRI) practices compared with recommended rice cultivation practice in India. *Journal of Experimental Agriculture*. 10: 1 -22.

Thomas, G. W. 1982. Exchangeable cations. In: *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties,* eds. A.L. Page, R.H Miller and D.R Keeney (2nd ed.) pp. 159 – 166. Agronomy Monograph No. 9. Madison, WI: American Society of Agronomy.

Tranavicience, T., A. Urbonaviviute, G. Samuoliene, P. Duchovskis, I. Vagusevicience and A. Sliesaravicius. 2008. The effect of differential nitrogen fertilization on photosynthetic pigment and carbohydrate contents in the two winter wheat varieties. *Agronomy Research*. 6(2): 555-561.

Varughese, J. and M.M. Ghawas. 1993. Yield evaluation of selected varieties of pepper (*Piper nigrum* L.) and their compatibility to *erythrina indica* live support system in Johor In: *The Pepper Industry- Problems and Prospects, eds.* M.Y. Ibrahim, C.F.J Bong and I.B. Ipor, pp. 35-43. Sarawak, Malaysia: University Pertanian Malaysia.

Wahid, P.A. and N.V. Kamalam. 1982. Mineral nutritional of slow wilt affected pepper (*Piper nigrum* L.). *Journal of Plantation Crop.* 10: 21-26.

Wong, J.W.C., K.K. Ma, K.M. Fang and C. Cheung. 1999. Utilization of manure compost for organic farming in Hong Kong. *Bioresource Technology.* 67: 43–6.

Wells, A., K. Chan and P. Cornish. 2000. Comparison of conventional and alternative vegetable farming systems on the properties of a yellow earth in New South Wales. *Agriculture, Ecosystems and Environment* .80: 47-60.

Yadav, H. and B. Vijayakumari. 2003. Influence of vermicompost with organic and inorganic manures on biometric and yield parameters of chilli (*Capsicum annuum* (L.) var. Plri). *Crop Research.* 25(2): 236-243.

Yap, C.A. 2012. Determination of nutrient uptake characteristic of black pepper (*Piper nigrum* L.). *Journal of Agricultural Science and Technology* A. 6: 86-89.