SHADING AND VEGETABLE-BREAD-FISH WASTE COMPOST EFFECTS ON GROWTH AND YIELD OF FIELD GROWN *ANDROGRAPHIS PANICULATA*
(KESAN TEDUHAN DAN KOMPOS SISA SAYURAN-ROTI-IKAN TERHADAP PERTUMBUHAN DAN HASIL *ANDROGRAPHIS PANICULATA* DI LADANG)

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ABSTRACT Medicinal herb production has become more challenging nowadays as it is demanded, as far as possible, to avoid chemical fertilizers and other agrochemicals for higher quality of the produce. The present study was a split plot experiment conducted to examine the effect of shading and application of compost derived from dumped brassica vegetable-dumped or expired bread-fish gill and internal organ (3:2:1) wastes towards growth and yield of *Andrographis paniculata* grown in open field as alternative to conventional organic fertilizers in current market. Main plots were plots of full sunlight and 50% relative light intensity (RLI) as achieved by commercial 50% shade netting. Within each main plot, sub plots of treatments at 0 g compost + 5 g nitrophoska (NPK) green/plant, 0, 25, 50, 75 and 100 g compost/plant, respectively, were laid out at random. Fertilization was carried out only once throughout the production period of eight weeks. Each sub plot treatment was replicated four times, each with three plants per replicate. Results indicated that plant grown under full sunlight combined with application of 100 g compost/plant, or 3 tonnes compost/hectare at 30,000 plants/hectare, was the best, especially in production of leaves as its main economic plant part for the herbal industries. Such inorganic fertilizer free plants were better than the recommended inorganic 5 g NPK green /plant or at a rate of 150 kg/hectare fertilization in production of this medicinal plant.

Keywords: medicinal herb; fertilization; height; stem branching; leaf production

ABSTRAK Penghasilan herba perubatan menjadi kian mencabar kini kerana ianya perlu mengelakkan penggunaan baja kimia atau bahan kimia agro sejauh yang mungkin untuk hasil berkualiti lebih tinggi. Kajian ini adalah eksperimen petak pecah yang dijalankan untuk menentukan kesan teduhan dan aplikasi kompos berasal daripada bahan buangan sayuran brassica-roti buangan atau tamat tempoh makan-sisa insang dan organ buangan ikan (3:2:1) terhadap pertumbuhan dan hasil *Andrographis paniculata* di ladang sebagai gantian kepada baja organik yang sedia ada di pasaran. Petak utama adalah petak cahaya penuh dan 50% keamatan cahaya relatif (RLI) yang diperolehi dengan jaring teduhan komersial 50%. Dalam setiap petak utama, sub-petak sebagai rawatan 0 g kompos + 5 g nitrofoska (NPK) hijau/pokok, kompos sebanyak 0, 25, 50, 75 and 100 g/pokok masing-masing adalah dibentang secara rawak. Pembajaan dilakukan hanya sekali sepanjang tempoh pengeluaran selama lapan minggu. Setiap rawatan sub-petak adalah diulangi sebanyak empat kali, setiapnya terdiri daripada tiga pokok. Keputusan menyatakan bahawa tumbuhan bawah cahaya penuh bergabung dengan aplikasi kompos sebanyak 100 g/pokok, atau kompos sebanyak 3 tan/hektar pada kepadatan tanaman 30,000 pokok/hektar, adalah yang terbaik, terutamanya dalam penghasilan daun sebagai bahagian tumbuhan ekonomi utama untuk industri herba. Tumbuhan bebas baja inorganik adalah lebih baik berbanding dengan pembajaan inorganik NPK hijau sebanyak 5 g/pokok atau pada kadar baja 150 kg/hektar dalam penghasilan tumbuhan ubatan ini.

Kata kunci: herba perubatan; pembajaan; ketinggian; pencabangan batang; penghasilan daun

INTRODUCTION

Andrographis paniculata, well known as king of bitter, has been used for decades in traditional health care system (Akbar 2011; Anju et al. 2012; Kumar et al. 2014). It is called with different names in different countries but in Malaysia, it is well known as Hempedu Bumi (Niranjan et al. 2010). This annual herb is effective to treat diseases such as flu, liver disease (Jarukamjorn & Nemoto 2008; Okhuarobo et al. 2014), diabetes, hypertension, fever, diarrhea (Wongnawa et al. 2012), cough, and snake bite (Biffa 2003; Jaganath & Teik 2003; Meenatchisundaram et al. 2008). Over the past twenty years, interest in herbal products as natural medication has grown immensely (Joselin & Jeeva 2014). Constant supply of herbal and medicinal plants becomes challenging.

In addition to continuous production of *A. paniculata*, there is also demand to avoid the use of any inorganic fertilizer and chemical pesticides in the production of this plant for better quality of produce and consumption safety reasons (Bhat Savitha et al. 2012). Organic manure and compost have frequently been preferable as soil amendments and nutrient supplies in medicinal plant cultivation (Uddin et al. 2012; Forge et al. 2016). This practice is not only beneficial in increasing yield, but also to increase the value or quality of the produce (Hue & Silva 2000; Sharafzadeh & Ordookhani 2011). Organic fertilizers also improved soil physical properties (bulk density and macro-porosity) (Carter et al. 2003), soil aggregate stability and soil microbiological properties as compared with inorganic fertilizer in crop production (Wang et al. 2013). Long term application of compost could also enhance soil permeability, porosity and water holding capacity (Vengadaramana & Jashothan 2012), chemical properties, microbial activity and biological functions in soil (Akhtar 2000; Cooperband 2002; Whalen et al. 2003; Taban & Naeini 2006; Diacono & Montemurro 2009; Valarini et al. 2009; Leu et al. 2010). Some types of compost have been reported to sustain essential nutrient availability for plants for many years with reduced leaching as usually found with many inorganic forms of fertilizers (Sullivan et al. 2002). The current study was carried out to enhance organic production of *A. paniculata* using compost derived from some common kitchen and food wastes as alternative to conventional organic fertilizer available in local markets.

MATERIALS AND METHODS

Location of Study

The study was conducted in open field of Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Puncak Alam (N 03°11.84’, E 101°26.93’). Compost, on the other hand, was prepared in the media preparation area near the greenhouse and open field as mentioned at six months prior to experimentation.

Compost Preparation

Dumped brassica vegetables, expired or dumped bread and fresh fish refuse (internal organs and gills) were collected from local wet markets and shops for preparing vegetable-bread-fish waste compost. Such wastes were chosen to provide compost with high nitrogen (N) content for enhancing leaf production of *A. paniculata* as the economic important plant part of this medicinal plant.

Composting of these wastes was carried out using a mini automated composter (IMP Organic Malaysia). An amount of 1 kg of cocopeat was first loaded into the chamber of the composter as the bulking agent of compost. Then, 1.5 kg of vegetable, bread and fish refuse at 3:2:1 in ratio were put into the chamber daily or at alternate days, depending on the degree of degradation of the raw materials. There were three L shape metal bars in the chamber that rotated automatically for 2 min at 30 min intervals to mix the composting materials for enhancing aeration, growth of microorganism populations and composting process.

Loading of the mentioned wastes was stopped when the amount of these composting materials reached the full level of the chamber within a week. Then, the materials were allowed to further decompose for a week until their volume was found reduced to half. Then, 1.5 kg of raw materials of vegetables, bread and fish refuse were loaded into the chamber again at the same ratio daily or at alternate days until full level again within a week. The temperature indicator on the composter showed temperature above 40°C but always below 50°C during waste degradation process carried out by natural microorganisms for about three weeks. Composting temperature of below 60°C is beneficial to keep hormonal and enzymatic compounds intact for benefits of the plants applied with this compost later. There was no enzyme, microbial inoculant or water added throughout the composting procedure.

After loading the wastes into the chamber of composter to reach full level for the second time, these composting materials were left to complete degradation procedure with only regular mixing by the L shape mixing metal bars at half hourly intervals. Mature compost was obtained within the next two to three weeks when the temperature indicator on the composter showed reading of ambient temperature and the volume of compost in the chamber reduced to half again. The compost was then unloaded from the composter and stored in sealed plastic bags to avoid the compost from absorbing moisture from the air until use.

A total of three batches of compost of the same composition of raw materials were prepared. Then, the different batches of compost were mixed evenly using a mini mixer prior to experimentation. Nutrient analysis indicated that the compost had pH of 3.65 and contained 3% nitrogen (N), while phosphorous (P) and potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) were below 1.5% (Table 1).

Table 1. Nutritional composition of compost

Element	Quantity
Carbon (C)	46.58±1.70%
Nitrogen (N)	3.09±0.41%
Phosphorus (P)	0.38±0.05%
Potassium (K)	0.59±0.10%
Calcium (Ca)	1.20±0.09%
Sulphur (S)	0.12±0.02%
Magnesium (Mg)	0.13±0.01%
Boron (B)	n.a.
Iron (Fe)	392±82 mg/kg
Manganese (Mn)	15.59±6.37 mg/kg
Zinc (Zn)	98.53±19.74 mg/kg
Copper (Cu)	n.a.
Molybdenum (Mo)	0.84±0.25 mg/kg

Mean±SD

Test Material

Ripe fruits of *A. paniculata* before dehiscence and cracking open of capsules were collected from a single vigorous mother plant in the open field collection near the greenhouse mentioned above. Capsules were broken open carefully by fingers and the seeds collected from the fruits were sown directly on peatmoss mixed with top soil at 1:1 ratio in perforated plastic germination trays. Seed germination was carried out in a bright place in the greenhouse. Watering was done twice daily for 10 min with automated overhead mist sprinkler in the greenhouse. Seed germination took place after two to three weeks. Then, seedlings of height of 2 to 4 cm with four to six leaves by six weeks after sowing were transferred to beds as test materials in this study.

Experimental Procedure

Field preparation work started at one month prior to transplanting of the seedlings. The experimental plot was first covered with silver plastic mulching sheets for two weeks to kill the weeds. Then, mulching sheets were removed and lining was carried out to mark the beds. Eroded sandy top soil obtained from the bottom of the slope nearby was added onto the beds and ploughed into the beds using a mini ploughing machine. This was done to enhance soil properties and also avoid water logging during rainy days. Such site amendment resulted in sandy loam planting beds with 81% sand, 5% silt and 14% clay based on soil texture analysis. Average pH of the soil was 4.81.

Beds of 6 m in length, 0.75 m in width and 15 cm in height were prepared manually using a hoe. There were eight beds, arranged in four sets of two beds, side by side, in East-West orientation. Commercial 50% shade netting was put up at a height of 2 m across the four beds at one side to create approximately 50% relative light intensity (RLI) while the other four beds on the other side had 100% RLI. AccuPAR PAR/LAI Ceptometer model LP80 (Decagon Devices) was used to make several measurements on photosynthetic active radiation at above and below shade netting and found the netting was acceptable with 45-50% light transmittance. Shade netting was allowed to drop at edges to a point of approximately 20 cm above the soil surface to ensure plants at bed edges also received the desired 50% RLI. Between main plots of 50% RLI and 100% RLI, there were buffer plants taking up space of 0.5 m to ensure all experimental plants received the RLI as designed in this experiment. Within each bed, six treatments of 0 g compost + 5 g nitrophoska (NPK) green (15:15:15)/plant, compost of 0, 25, 50, 75 and 100 g/plant, respectively, were tested in this study. The experiment was, hence, set up as a split plot design with four replicates. Space between beds was approximately 0.25 m at all sides.

After bed preparation, beds were covered with silver mulching sheets followed by planting hole demarcation as six evenly distributed sets of three-planting holes in 30 cm triangular arrangement. This gave approximately 30,000 plants/hectare. Fish netting with holes sized 2x2 cm was fixed to a height of approximately 1 m at the perimeter of experimental plot to prevent damage of the plot and plants by wild boars.

Compost, where applicable, was incorporated one week before transplanting of the seedlings. Plastic mulching sheet was cut at planting points to expose bed with diameter of approximately 10 cm. Compost was applied at a depth of 5 cm in the planting hole. There were six treatments of 0 g compost + 5 g NPK green/plant, compost of 0, 25, 50, 75 and 100 g/plant arranged randomly on each bed as mentioned, each treatment consisted of a set of three adjacent planting holes on the bed. With the plant density of approximately 30,000 plants/hectare, 5 g NPK green/plant gave application rate of 150 kg NPK green/hectare while 100 g compost/plant was equivalent to 3 tonnes compost/hectare. Such application rates were determined based on preliminary studies and general recommendation of compost and NPK green fertilization for herbaceous plant (Cooperband 2002; Tejada & Gonzalez 2006; Valarini et al. 2009; Mahboobeh et al. 2014). The exposed planting points were watered daily when necessary to allow stabilization of compost with moist soil until transplanting of the seedlings. For the treatment of 0 g compost + 5 g NPK green/plant, NPK green was applied to the soil in pocket at depth of 2 cm at one week after planting of seedlings. Compost or NPK green was applied only once and no other additional fertilization procedure was carried out throughout the experimentation of eight weeks.

Transplanting of the seedlings to planting holes was carried out in the evening when the seedlings had four to six leaves at approximately 45 days after sowing. Each planting hole was planted with two seedlings. Culling of one of the two seedlings in each planting hole was performed at 10 days after transplanting. Each plant was then provided with a bamboo stick of approximately 0.5 m in length for support of this herbaceous plant when necessary, especially during heavy rain and strong wind period.

Weekly Growth Measurements

Plant height, number of branches and number of leaves were recorded weekly after planting, for a period of eight weeks. Plant height was measured using a measuring tape from the root collar to the highest point of the apical shoot in its own form. Leaves with length of ≥1 cm were counted for the parameter of number of leaves.

Measurements at Harvest

All plants were harvested at eight weeks when a few plants started flowering. At harvest, each plant was cut at root collar using a pair of secateurs. Then, the stem diameter at root collar was measured using a digital vernier caliper. The 3rd order (first fully mature) leaves of each plant was collected and traced on graph paper for estimation of single leaf area. A total of three 3rd order leaves were selected at random from each plant for this measurement. Then, all the other leaves were separated from the stem and branches, with stem and branches cut into pieces of shorter length using a pair of secateurs. Lastly, the roots were removed carefully from the bed followed by cleaning with tap water. All the leaves, stems and roots of each plant were placed into paper bags accordingly, labelled and dried in a convection oven at 60°C for several days until three unchanged dry weight readings were obtained. All plant parts in their respective paper bags were cooled to room temperature in a desiccator prior to determination of their dry weight using an analytical balance.

Statistical Analysis

Analysis of variance (ANOVA) as a split plot design was carried out with the collected data and treatment means were compared using Tukey's Honestly Significant Difference (HSD) test at 5% level of significance.

RESULTS AND DISCUSSION

The height of *A. paniculata* was significantly affected by RLI by third week after field planting onwards (Table 2). Plant grown under 50% shading was 54.34 cm as compared to plant height of 43.11 cm obtained under full sunlight by eight weeks. Application of compost at rates of 25 g to 100 g/plant in planting hole, or alternatively with 5 g inorganic NPK green/plant, on the other hand, also enhanced plant height growth of this annual medicinal plant (Table 2). This indicated that this herbaceous medicinal plant could be totally produced without any addition of inorganic fertilizer. Control plant with no fertilizer treatment was the shortest plant. There was generally no significant interaction between RLI and compost application rate for this parameter (Table 2).

Table 2. Plant height

	Mean plant height in cm / F-value by period (weeks after planting)								
RLI (%)	0	1	2	3	4	5	6	7	8
100	1.99^{a}	2.89^{a}	4.06^{a}	6.99^{a}	11.73^{a}	18.53^{a}	25.51^{a}	35.06^{a}	43.11^{a}
50	1.98^{a}	2.90^{a}	4.70^{a}	9.08^{b}	15.67^{b}	24.17^{b}	34.14^{b}	45.15^{b}	54.34^{b}

For RLI, means having the same letter within column are not significantly different at 5% level of significance.

Compost application rate (g/plant)									
NPK*	2.00^{a}	3.15^{a}	4.71^{a}	8.96^{a}	14.42^{a}	22.44^{a}	31.13^{a}	41.67^{a}	50.42^{a}
0	1.98^{a}	2.79^{a}	3.96^{a}	6.52^{a}	10.71^{a}	14.73^{b}	21.69^{b}	31.13^{b}	39.08^{b}
25	2.00^{a}	2.88^{a}	4.56^{a}	8.52^{a}	14.42^{a}	22.50^{a}	30.50^{a}	39.83^{a}	49.13^{a}
50	1.94^{a}	2.50^{a}	4.02^{a}	7.79^{a}	13.50^{a}	22.44^{a}	30.88^{a}	40.83^{a}	49.33^{a}
75	2.00^{a}	2.85^{a}	4.40^{a}	7.77^{a}	13.77^{a}	22.27^{a}	31.75^{a}	42.92^{a}	51.15^{a}
100	1.98^{a}	3.19^{a}	4.65^{a}	8.65^{a}	15.38^{a}	23.75^{a}	33.02^{a}	44.25^{a}	53.25^{a}

For compost application rate, NPK* denotes 0 g compost+5 g NPK green/plant; means having the same letter within column are not significantly different at 5% level of significance.

RLI x Compost application rate									
F-value	0.72^{ns}	3.98^{**}	1.50^{ns}	1.47^{ns}	2.27^{ns}	1.57^{ns}	1.40^{ns}	1.18^{ns}	1.52^{ns}

For RLI x Compost application rate, F value followed by ns and ** denotes $P \geq 0.05$ and $P < 0.01$, respectively.

Branching of *A. paniculata* was significantly better from fifth week to the end of experimentation with plants grown under full sunlight (Table 3). Application of compost, especially at 100 g/plant, or 5 g inorganic NPK green/plant, also enhanced branching of this medicinal plant from third week after transplanting onwards and achieved approximately 16 branches, as compared to about 13 branches with control plant at harvest (Table 3). There was, however, no significant interaction between RLI and compost application rate on branching of this plant species (Table 3).

Table 3. Number of branches

	Mean number of branches / F-value by period (weeks after planting)					
RLI (%)	3	4	5	6	7	8
100	1.64 [a]	4.07 [a]	7.78 [a]	10.17 [a]	13.69 [a]	16.53 [a]
50	1.39 [a]	3.82 [a]	6.06 [b]	8.50 [b]	11.99 [b]	14.68 [b]

For RLI, means having the same letter within column are not significantly different at 5% level of significance.

Compost application rate (g/plant)						
NPK**	1.75 [ab]	5.50 [a]	7.75 [a]	10.25 [a]	13.88 [a]	16.58 [a]
0	0.00 [b]	1.29 [b]	2.58 [b]	5.58 [b]	8.58 [b]	12.63 [b]
25	1.33 [ab]	4.00 [ab]	7.13 [a]	9.29 [a]	12.71 [a]	15.54 [ab]
50	2.17 [ab]	3.71 [ab]	8.58 [a]	10.17 [a]	13.21 [a]	16.38 [a]
75	1.54 [ab]	3.92 [ab]	7.04 [a]	9.67 [a]	13.71 [a]	15.75 [ab]
100	2.29 [a]	5.25 [a]	8.42 [a]	11.04 [a]	14.96 [a]	16.75 [a]

For compost application rate, NPK** denotes 0 g compost+5 g NPK green/plant; means having the same letter within column are not significantly different at 5% level of significance.

RLI x Compost application rate						
F-value	1.48[ns]	2.20[ns]	1.69[ns]	1.21[ns]	1.53[ns]	0.91[ns]

For RLI x Compost application rate, F value followed by ns denotes P≥0.05.

Leaf production as the most important marketing attribute of this medicinal plant was significantly correlated to branching behaviour of this medicinal plant (r=0.90, P<0.001). RLI factor did not affect significantly the number of leaves throughout the study period of eight weeks (Table 4). Treatment with compost or inorganic fertilizer of 5 g NPK green/plant again resulted in significantly more leaf production as compared to the control plants in the second and third week after planting (Table 4). In later part of the study from four weeks onwards, interaction of RLI and fertilization treatment generally brought about highest number of leaves with plants grown under full sunlight combined with 100 g compost/plant. Such treatment was better than the NPK green fertilizer rate studied in enhancing leaf development in *A. paniculata*. The control plant grown under 50% shade produced significantly the least number of leaves at only 22-43% of that gained by plants subjected to full sunlight and applied with 100 g compost/plant as above. For the best performing plant at full sunlight with 100 g compost treatment, there was 6.25 fold increment from 36 leaves on the fourth week to 225 leaves on the eighth week while the control under 50% shade had only 4.9 fold increment from 16 to 76 leaves over the same period (Table 4)

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Table 4. Number of leaves

	F-value / Mean number of leaves by period (weeks after planting)							
RLI (%)	1	2	3	4	5	6	7	8
F-value	0.06^{ns}	0.67^{ns}	0.00^{ns}	0.14^{ns}	1.71^{ns}	0.45^{ns}	0.21^{ns}	0.10^{ns}

For RLI, F value followed by ns denotes P≥0.05.

Compost application rate(g/plant)	1	2	3	4	5	6	7	8
NPK*	5.67 a	7.75 a	14.50 ab	27.33 a	50.42 a	77.92 a	122.58 ab	192.00 a
0	5.58 a	6.75 a	9.33 b	15.08 b	17.83 b	32.50 b	52.25 c	83.42 b
25	5.75 a	7.42 a	12.75 ab	22.75 ab	41.38 a	66.67 a	104.50 b	152.33 a
50	5.46 a	7.42 a	15.00 ab	23.58 ab	45.58 a	71.04 a	117.42 ab	170.33 a
75	5.50 a	7.00 a	13.42 ab	23.17 ab	43.67 a	73.00 a	123.46 ab	200.38 a
100	5.00 a	7.83 a	15.58 a	27.92 a	53.04 a	90.75 a	155.33 a	204.96 a

For compost application rate, NPK* denotes 0 g compost+5 g NPK green/plant; means having the same letter within column are not significantly different at 5% level of significance.

RLI (%)	Compost application rate (g/plant)	1	2	3	4	5	6	7	8
100	NPK*	5.67 a	7.83 a	15.33 a	27.50 ab	51.67 ab	76.17 ab	114.33 bc	187.50 ab
	0	5.67 a	6.33 a	9.33 a	14.67 a	19.67 bc	34.17 b	54.50 bc	90.92 cd
	25	5.56 a	7.33 a	11.56 a	20.22 ab	39.44 bc	58.89 b	87.33 bc	122.11 bcd
	50	5.40 a	7.07 a	13.47 a	24.00 ab	47.07 ab	70.33 b	114.93 bc	169.07 abc
	75	5.00 a	6.17 a	11.50 a	19.83 ab	41.50 abc	67.50 b	117.75 bc	186.17 ab
	100	5.33 a	8.50 a	19.17 a	36.00 a	73.00 a	121.67 a	201.67 a	225.00 a
50	NPK*	5.67 a	7.67 a	13.67 a	27.17 ab	49.17 ab	79.67 ab	130.83 ab	196.50 ab
	0	5.50 a	7.17 a	9.33 a	15.50 b	16.00 c	30.83 b	50.00 c	75.92 d
	25	6.00 a	7.50 a	14.33 a	25.67 ab	43.00 abc	72.00 ab	116.00 bc	172.33 abc
	50	5.50 a	7.83 a	15.67 a	21.83 ab	42.50 abc	71.33 ab	118.67 bc	170.08 abc
	75	6.00 a	7.83 a	15.33 a	26.50 ab	45.83 abc	78.50 ab	129.17 abc	214.58 ab
	100	4.67 a	7.17 a	12.00 a	19.83 ab	33.08 bc	59.83 b	109.00 bc	184.92 ab

For RLI x Compost application rate, NPK* denotes 0 g compost+5 g NPK green/plant; means having the same letter within column are not significantly different at 5% level of significance.

At harvest, full sunlight combined with 100 g compost/plant again was found advantageous for growth of stem of *A. paniculata* in terms of stem diameter (Table 5). Stem diameter at root collar was above 6 mm within 2 months, providing sturdy plants that can resist wind damage better as compared to the others with rather similar height but smaller stems.

Table 5. Stem diameter, stem dry weight, root dry weight at harvest (eight weeks after planting)

RLI (%)	Compost application rate (g/plant)	Stem diameter (mm)	Total dry weight (g/plant)	
			Stem	Root
100	NPK*	4.39 ^{bc}	6.0213 ^{bc}	2.6481 ^{bc}
	0	3.21 ^{c}	1.5668 ^{cd}	0.9953 ^{de}
	25	4.34 ^{bc}	3.9029 ^{bcd}	2.4491 ^{bc}
	50	4.64 ^{b}	6.0560 ^{bc}	3.4325 ^{ab}
	75	4.67 ^{b}	5.9615 ^{bc}	2.8500 ^{bc}
	100	6.45 ^{a}	10.7861 ^{a}	4.2546 ^{a}
50	NPK*	4.81 ^{b}	7.1112 ^{ab}	1.6015 ^{cde}
	0	3.20 ^{c}	1.4193 ^{d}	0.5272 ^{e}
	25	5.33 ^{ab}	6.8550 ^{ab}	1.9908 ^{cd}
	50	4.98 ^{b}	5.9343 ^{bcd}	1.6852 ^{cde}
	75	5.47 ^{ab}	8.0350 ^{ab}	1.5937 ^{cde}
	100	5.08 ^{b}	6.6401 ^{ab}	2.1211 ^{cd}

NPK* denotes 0 g compost+5 g NPK green/plant; means having the same letter within column are not significantly different at 5% level of significance.

Leaf attributes in terms of leaf area and dry weight were significantly determined by only compost application rate. Similar trend of highest first mature leaf area was obtained with organic fertilization at compost application rates of 25-100 g/plant, or with inorganic 5 g NPK green/plant (Table 6). Nonetheless, when evaluated in terms of total leaf dry weight, plants subjected to treatment with compost at higher rates of 50-100 g/plant gained significantly higher dry weight, with those applied with 100 g/plant having the highest leaf dry weight. It is encouraging for plant applied with 100 g compost to record 25% more leaf biomass than plant applied with the studied inorganic NPK green. Control plant with no fertilizer treatment gained the least leaf dry weight, attributed to the lowest morphological growth performance in height, branching and number of leaves as above.

Table 6. First mature single leaf area and total leaf dry weight at harvest (eight weeks after planting)

Compost application rate (g/plant)	First mature single leaf area (cm^2/leaf)	Total leaf dry weight (g/plant)
NPK*	14.67 ^{ab}	6.5368 ^{b}
0	13.25 ^{b}	2.1967 ^{c}
25	14.94 ^{ab}	6.5833 ^{b}
50	16.65 ^{ab}	7.5858 ^{ab}
75	17.18 ^{a}	7.9051 ^{ab}
100	16.38 ^{ab}	9.4249 ^{a}

NPK* denotes 0 g compost+5 g NPK green/plant; means having the same letter within column are not significantly different at 5% level of significance.

As for the dry weight of stems and roots, both RLI and compost application rate interacted significantly to result in highest biomass of stem and root gain in plants grown under full sunlight combined with application of 100 g compost/plant (Table 5). This is in accordance to the more robust plants which developed under this combination of RLI and compost application treatment.

Andrographis paniculata preferred full sunlight in the open field for more leaf production as the leaf is the most valuable plant part for medicinal product development. The higher light availability as studied could have been more beneficial for photosynthesis of this medicinal plant contributing to more branching and eventually more leaf development and biomass production. Such practice is advantageous for open field planting as setting up shade netting above open field beds can be troublesome and that also incurs additional cost of production. This result was, however, in contrast with that recorded by Purwanto *et al*. (2011), which indicated that shading gave better growth of *A. paniculata*.

Application of vegetable-bread-fish waste compost in this study demonstrated greater benefit than the conventional inorganic NPK green in enhancing leaf and also overall production of *A. paniculata*. Besides providing essential nutrients needed by plants, compost also offers many vitamins, hormones and organic acids that may help in nutrient availability and uptake by plants, and other plant health benefits in a complex manner. Compost also improves soil physical properties by reducing its bulk density but it increases aeration and water holding capacity, as added advantages to improvement of soil chemical properties. Under better chemical and physical conditions, soil microorganisms would thrive, which offers further bioconversion benefits for plant growth and yield.

With the plant density adopted in this study that brought about 30,000 plants/hectare, lower application rate of 100 g compost/plant, or 3 tonnes compost/hectare, could produce higher plant biomass (245 kg dry weight/tonne compost/8 weeks) as compared to that grown for 10 weeks with 10 tonnes chicken dung/hectare in a previous study on the same medicinal plant as conducted by Zaharah (2005) on BRIS soil in Malaysia (200 kg dry weight/tonne chicken dung/10 weeks). It shows that this kitchen and food waste compost can be a valuable organic fertilizer for this herbaceous medicinal plant. It is also in accordance to many other researchers that also mentioned the benefits of compost in enhancing plant growth (Caballero et al. 2009; Courtney and Mullen 2008; El-Quesni et al. 2013; Liu et al. 2013; Tejada & Gonzalez 2006; Traversa et al. 2010).

CONCLUSION

Full sunlight and application of 100 g vegetable-bread-fish waste compost/plant was effective in organic production of *A. paniculata*, especially in terms of leaf production as the plant part of greatest economic importance within shorter production period of two months. Such treatment of 3 tonnes compost/hectare, based on the studied plant density of 30,000 plants/hectare, allowed higher production achieved by chicken dung but chicken dung was applied at 10 tonnes/hectare in other previous study in Malaysia.

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