PLANT DENSITY AND PLANTER LEVEL OF LEAFY VEGETABLES AFFECTED YIELD AND PLANT COMPONENTS IN VERTIPLANTER, SELF-WATERING VERTICAL FOR URBAN GARDENING

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ABSTRACT

Majority of amaranth production is still carried out in open field cultivation. However, soilless cultivation of vegetables has gained interest and popularity among urban dwellers due to limited areas for their food garden whereby the green spaces have been covered with concrete due to urbanization. MARDI has been established the Vertiplanter, a self-watering living wall system which requires much less space for growing plants rather than planting horizontally. A study was conducted to evaluate the effect of plant density and planter level on amaranth grown in the Vertiplanter system. Plants were subjected to four plant densities, i.e., i. D1: 25 plants/m2, ii. D2: 50 plants/m2, iii. D3: 75 plants/m2 and iv. D4: 100 plants/m2 (25, 50, 75 and 100 plants/m2, with three planter level, i.e., upper, middle and lower level. The experimental layout was a split-plot design with three replicates. At plant density D4, amaranth planting at lower planter level gave the highest leaf area (1921 cm2/plant) followed by planting at middle planter level (1897 cm2/plant) and the lowest was recorded from amaranth planting at upper planter level (1269 cm2/plant). Moreover, amaranth planting in Vertiplanter system at plant density D4 gave significantly higher in yield per meter square (7261 g/m2), shoot biomass (734 g/m2), root biomass (155 g/m2) and total biomass (889 g/m2) as compared to plant density D1, D2 and D3. Plant harvested at an upper, middle and lower level at a plant population of both 75 and 100 plants/m2 produced significantly higher leaf area compared to the other treatments. However, yield per plant decreased with an increase in plant density. Meanwhile, plant population of 100 plants/m2 significantly higher in yield per meter square, shoot and root biomass and total biomass as compared to plant population 25, 50 and 75 plants/m2. Therefore, plant population of 100 plants/m2 at an upper, middle or lower level of Vertiplanter system increased production of amaranth, as result of increased in yield and leaf area.

Key words: *Amarhantus*, plant density, planter level, soilless, self-watering vertical planter

INTRODUCTION

Spinach (*Amaranthus spp),* is Malaysia's third most common vegetable for its nutritional properties. These warm-season and annual leafy vegetable are rich in vitamin A, vitamin B, vitamin C and minerals such as iron (Fe), phosphorous (P), potassium (K), manganese (Mn) and zinc (Zn). Amaranth leaves have been shown to be excellent protein sources, with their highest accumulation during the blooming period (Kadoshnikov et al., 2005). Amaranth leaves, stems and whole plants can be consumed as a vegetable side dish with a staple food after being shredded and cooked.

In Malaysia, majority of amaranth production is still carried out in open field cultivation. However, soilless cultivation of vegetables has gained interest and popularity among urban dwellers due to limited areas for their food garden whereby the green spaces have been covered with concrete due to urbanization. The innovative, effortless and highly productive approach for production is green wall, without the need for rooting space in the ground (Martensson et al., 2016). Green wall systems consist of continuous screens or compact trays, containers, tiles for plants or flexible bags containing the growing medium and plants (Manso and Castro-Gomes 2015). MARDI has been established the Vertiplanter, a self-watering living wall system which requires much less space for growing plants rather than planting horizontally. It is an alternative vertical greenery system that capable to absorb more rainwater without compromise on the plant performance. It is using a self-watering mechanism whereby the plant roots absorb the water based on their requirement through the capillary action (Rosniza K., 2018).

Ideal plant density can lead to optimum yields, whereas too high or too low plant densities can result in relatively lower yields and quality. Less spacing of the plants or greater plant density decreases individual plant growth but produces more dry matter tightly and less weed competition (Schippers, 2000). El-Badawy and Mehasen, 2012 observed that the closest spacing gave the tallest plant due to a greater competition for space and light, and therefore forced the plants to grow taller Maboko and Du Plooy (2012) revealed that growth and yield of amaranth grown in soilless condition increased 37% when harvested by cutting at higher planting density. Lack of information on the production of amaranth in soilless condition is major concern for urban gardener. An understanding of plant response to plant density and planter level is critical in developing cultural practices for improved vertical yields. Hence, a study was conducted to evaluate the effect of plant density and planter level on amaranth grown in the Vertiplanter system, self-watering vertical system.

MATERIALS AND METHODS

Planting material

A trial was conducted in a rain shelter structure at Horticulture Research Centre, MARDI. Amaranth seeds (*Amaranthus L.*) were sown in 200 plug tray filled with a commercial tray substrate, AG (Agroniche Sdn Bhd, Malaysia). Seedlings were transplanted 14 days after sowing into pot of Vertiplanter system.

Vertiplanter system

The Vertiplanter (Figure 1) system consists of a set of a reservoir and 4 units of specially designed pots. The planting system using self-watering mechanism whereby the plant roots absorbs the water based on their requirement through the capillary action. The components inside the pot consist of LECA ball and growing soilless medium like peat moss, perlite and vermiculite. The pH of media was measured using a pH meter and maintained within a range of 5.5 to 6.5. The fertilizer used for amaranth were Nitrophoska® Green comprising of Nitrogen, Phosphorus and Potassium (15:15:15) for basal. The foliar applications were applied on a weekly basis.

Figure 1. Vertiplanter system planted with amaranth

Experimental design and treatments

Twelve treatment combinations were used, i.e., four plant densities viz. i. D_1: 25 plants/m^2, ii. D_2: 50 plants/m^2, iii. D_3: 75 plants/m^2 and iv. D_4: 100 plants/m^2 combined with three planter level viz. i. Upper, ii. Middle and iii. Lower. A split plot design with three replications was used in this experiment. During harvesting at 30 days after sowing, the parameters measured including leaf fresh mass, leaf and root dry mass, leaf area and number, plant height, plant canopy, stem diameter and chlorophyll content. The leaf area (cm^2) was measured using a leaf area meter (LI-3100 area meter, USA). The chlorophyll content was measured using chlorophyll meter (SPAD-502, Japan). Leaves and roots were dried in an oven at 70°C for 48 hours for leaf dry mass determination.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the SAS software version 9.1. Data were processed by two-way analysis of variance and mean separations were performed through the least significant difference (LSD) test at the 5% level of significance. Correlations were performed between all the examined variables.

RESULTS AND DISCUSSION

Effect of plant density

Plant density produced significantly different yield parameters of amaranth (Table 1) and plant components (Table 2) across different treatments. Yield, shoot biomass, root biomass and total biomass increased with an increase in plant densities. Generally, yield per unit area increased due to increased in plant density, while yield per plant decreased with increasing in plant density. Fresh mass of leaves (per plant and per area), dry mass of shoot and root and total dry mass were significantly influenced by plant density (Table 1). Plant density D_1 gave the maximum (37.82 g/plant) fresh weight of leaves per plant while the minimum (18.22 and 18.16 g) was recorded from plant density D_3 and D_4, respectively. Meanwhile, the maximum (7261.90 g/m^2) fresh mass of leaves per area was recorded from plant density D_4, which was closely followed by D_3 (3786.75 g/m^2) and D_2 (2503.90 g/m^2). For the shoot dry mass, the maximum weight of shoot (734.40 g/m^2) was recorded from D_4, while the lowest (84.70 g/m^2) from plant density D_1. The variations in fresh weight of leaves per area among the plant density treatments were prominent. Similar trend of results was also reported by Moboko and Du Plooy (2012) whereby higher plant population increased production of Amaranth due to the ability of the plants to bear lateral shoots and occupy open spaces. The highest root dry mass was recorded by D_4 (155.11 g/m^2) as compared to D1 (11.78 g/m^2). As for the total dry mass, the highest was recorded from D_4 (889.60 g/m^2) and the minimum was found from D_1 (96.50 g/m^2) followed by D_2 (243.30 g/m^2) and D_3 (328.80 g/m^2). Number of leaves per plant was significantly affected by different plant density (Table 2). Plant density D_4 gave the maximum (32) number of leaves per plant followed by D_3 (30) and the minimum number of leaves per plant was recorded from D_1 (21). However, there was no significant difference in terms of plant height, plant canopy, stem diameter and chlorophyll content index with an increase in plant density.

Effect of planter level

Meanwhile, for the effect of planter level, leaf area and chlorophyll content index were significantly affected by planter level (Table 2). Middle and lower planter level gave the maximum total leaf area (1133.53 and 1046.30 cm^2/plant), respectively and minimum total leaf area was recorded from upper level (933.21 cm^2/plant). The lower level gave the highest chlorophyll content (34.59 µmol/m) as compared to upper level (32.07 µmol/m). however, there was no significant difference in terms of fresh and dry mass of plant, leaf number, plant height, plant canopy and stem diameter at different planter level. Utami et al., (2012) reported that fresh and dry biomass of Chinese cabbage has no significant difference among the level of raise beds of vertical system. This is due to the development of biomass is driven primarily by photosynthesis, while photosynthesis largely depends on light detection, which also varies with the canopy's leaf range (Dorais, 2003).

Table 1. Mean values of total leaf fresh mass, shoot dry mass, root dry mass and total dry mass as affected by density and planter level

Treatment	Total leaf fresh mass per plant (g)	Total leaf fresh mass (g/m^2)	Dry mass (g/m^2)		Total dry mass (g/m^2)
			Shoot	Root	
Density (D)					
25	37.82a	945.50c	84.70b	11.78b	96.50b
50	25.04b	2503.90b	203.20b	40.11ab	243.30b
75	18.22b	3786.75b	266.20b	62.53ab	328.80b
100	18.16b	7261.90a	734.40a	155.11a	889.60a
Planter Level (L)					
Upper	23.35a	3450.70a	345.10a	58.13a	403.23a
Middle	23.34a	3651.80a	325.56a	71.85a	397.42a
Lower	27.74a	3771.20a	295.75a	72.17a	367.92a
Significant level					
D	***	***	***	***	***
L	ns	ns	ns	ns	ns
D X L	ns	ns	ns	ns	ns

Within each column. ns=no statistically significant difference; means followed by different letters are significantly different according to the LSD test at *p≤0.05, **p≤0.01 and ***p≤0.001

Table 2. Mean values of growth parameters of amaranth as affected by density and planter level

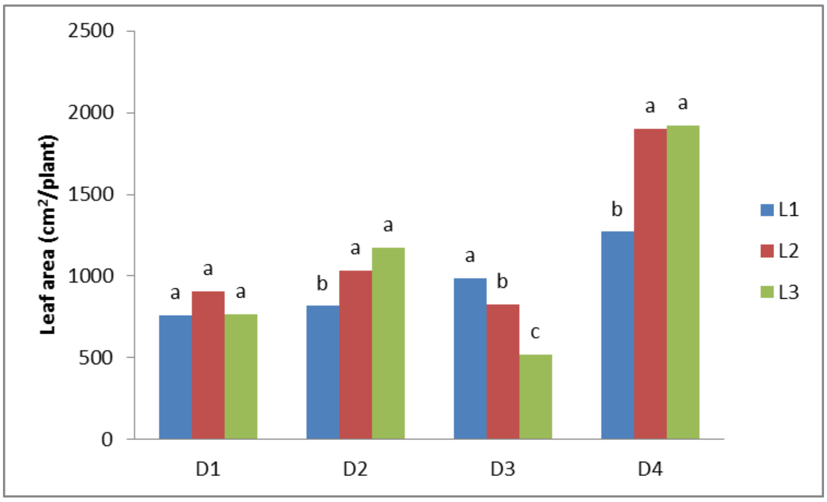
Treatment	Total leaf area (cm^2/plant)	Leaf number	Plant height (cm)	Plant Canopy (cm)	Stem diameter (cm)	Chlorophyll content (µmol/m)
Density (D)						
25	777.35c	21b	28.79a	25.83a	0.92a	33.18a
50	701.37c	24ab	29.81a	25.63a	0.98a	34.42a
75	997.88b	30a	29.77a	24.11a	0.76a	32.84a
100	1674.13a	32a	29.41a	23.86a	1.07a	32.29a
Planter Level (L)						
Upper	933.21b	27a	29.49a	25.77a	1.03a	32.07b
Middle	1133.53a	25a	29.34a	25.27a	0.85a	32.88ab
Lower	1046.30a	27a	29.51a	23.53a	0.93a	34.59a
Significant level						
D	***	***	ns	ns	ns	ns
L	***	ns	ns	ns	ns	*
D X L	***	ns	ns	ns	ns	ns

Within each column. ns=no statistically significant difference; means followed by different letters are significantly different according to the LSD test at $^*p \leq 0.05$, $^{**}p \leq 0.01$ and $^{***}p \leq 0.001$

Combined effect of plant density and planter level

For the combined effect of plant density and planter level, the interaction effect of plant density and planter level on the leaf area of amaranth is presented in Figure 1. At plant density D_1, the leaf area had no significant different at different planter level. Meanwhile at plant density D_2, the highest leaf area was observed at lower level (1174 cm^2/plant) which was statistically identical to middle planter level (1035 cm^2/plant) and the lowest leaf area at upper planter level (816 cm^2/plant). For the amaranth planting at plant density D_3, the highest leaf area was observed at upper planter level (986 cm^2/plant) followed by middle planter level (1828 cm^2/plant) and lower planter level (522 cm^2/plant). As for plant density D_4, amaranth planting at lower planter level gave the highest leaf area (1921 cm^2/plant) followed by planting at middle planter level (1897 cm^2/plant) and the lowest was recorded from amaranth planting at upper planter level (1269 cm^2/plant).

Figure 1. Interaction effect of plant density (D_1, D_2, D_3 and D_4) and planter level (upper, middle, lower) on leaf area. Means followed by different letters are significantly different according to the LSD test at $p \leq 0.05$.



CONCLUSION

The results demonstrate the potential of increased growth and yield of amaranth harvested at plant density D_4 (100 plants/m^2) at middle and lower planter level in Vertiplanter system. It should be noted that the trial was conducted in a self-watering vertical system and plant might perform differently in other cultivation system, such as soil cultivation.

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