EFFECTS OF LAYER AND PLANTING DISTANCE ON GROWTH OF FAN PAK CHOY (*BRASSICA RAPA L. SUBSP. CHINENSIS*) ON A MULTILAYER PLANTING SYSTEM

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ABSTRACT

Vertical or multilayer farming is getting popular and more attention in Malaysia due to its effectiveness of space optimization. Planting density also another focus to maximize the production capacity with compromise of growth and yield. However, uneven lighting and shading was an issue on multilayer planting system in a greenhouse. Therefore, a study on the effect of layer and different planting distance on growth of Fan Pak Choy in a multilayer planting system was studied. This study was conducted in greenhouse at the Malaysian Agricultural Research and Development Institute (MARDI) using two factor factorial Randomized Complete Block Design (RCBD). The first factor is layer (L) which consists of 3 levels, namely below (L1), middle (L2) and top (L3). The second factor is planting distance (S) which consists of 3 distances arranged with 13cm (S1), 18cm (S2), 23cm (S3) in a single row. Parameters observed were plant height, number of leaves, leaf area, plant fresh weight, relative chlorophyll content, air temperature, relative humidity, light intensity and air speed. Top and middle layers show better results compared from below layer on plant height, number of leaves, leaf area, plant fresh weight and relative chlorophyll content. Planting distance of 13cm, 18cm and 23cm was not significantly different for all parameters except for plant fresh weight and leaf area which is 18cm (327.06g, 2482.77m²) gives better results followed 13cm (299.46g, 2181.91m²) and 23cm (229.70g, 1875.67m²) respectively. In summary, combination between layer and planting distance was significantly affect on yield of Fan Pak Choy.

Keywords: *Fan Pak Choy, green house, multilayer, planting distance*

INTRODUCTION

Brassica oleracea and *B. rapa* are the main species that dominate the vegetable market. There is a wide range of varieties belonging to *B. rapa* species planted in Malaysia, such as Dwarf Type Pak Choy, Hybrid Shanghai Dwarf Pak Choy, Ma Yee Pak Choy, Curly Dwarf Pak Choy, Curly Wrap Wong King Pak Choy, Pak Choy Purple Red Dwarf, and Fan Pak Choy (CityFarm, 2022a). Generally, these cultivars can be grown in Malaysia, indicating a wide choice for production using vertical farming (Stephen & Gobilik, 2022).

Vertical or multilayer farming is getting popular and more attention in Malaysia due to its effectiveness of space optimization. A multilayer planting system refers to a method of planting crops in layers, one on top of the other, to increase the number of crops that can be grown in a small space. This method is commonly used in urban agriculture and indoor gardening. The logic of vertical farming is simple: produce more food on less land (Touliatos et al., 2016; Muller et al, 2017).

The number of layers in a multilayer planting system has a significant impact on the growth of vegetables. The more layers there are, the more plants can be grown in the same space, which can lead to higher yields (Eigenbrod & Gruda, 2014). However, too

many layers can also lead to reduced light and air circulation, which can hinder plant growth. Therefore, it is important to find the right balance between the number of layers and the amount of light and air each plant needs.

The distance between plants within each layer also affects their growth (Choy & Son, 2005; Wiangsamut & Koolpluksee, 2001). Plants that are too close together may compete for nutrients and light, leading to stunted growth and lower yields. On the other hand, plants that are too far apart may not make full use of the available space and light, which can also result in lower yields. Therefore, it is important to find the optimal planting distance for each type of vegetable. As previously stated, among many vertical designs, the column hydroponic system (CHS) is the most effective in increasing leafy vegetable yield per unit area. However, some CHS-features limit Pak Choy's production in the system, especially factors associated with plant spacing (i.e., related to column spacing) and light intensity (Stephen & Gobilik, 2022). Accordingly, a study on the effect of layer and different planting distance on growth of Fan Pak Choy in a multilayer planting system was studied.

MATERIALS AND METHODS

The study was conducted in greenhouse at the Malaysian Agricultural Research and Development Institute (MARDI) using two factor factorial Randomized Complete Block Design (RCBD). The first factor is layer (L) which consists of 3 levels, namely below (L1), middle (L2) and top (L3). The second factor is planting distance (S) which consists of 3 distances arranged with 13cm (S1), 18cm (S2), 23cm (S3) in a single row.

The recommended planting distance for Pak Choy is based on the plant's growth habit and the space it needs to grow and develop properly. Pak Choy is a leafy vegetable that grows in a compact rosette shape. It has shallow roots and does not grow very tall, usually reaching a height of about 15-20 cm. Spacing the plants about 13-25 cm apart in rows that are 30-45 cm apart provides enough room for each plant to develop a healthy root system and to grow a mature rosette of leaves without being crowded by neighbouring plants.

Parameters observed were plant height, number of leaves, leaf area, plant fresh weight, relative chlorophyll content (SPAD meter), chlorophyll fluorescence (Fluor Pen), total chlorophyll A and B (Spectrophotometer), light intensity (light meter), air temperature and relative humidity (thermometer and a hygrometer). Data was analyzed by analysis of variance (ANOVA) using SAS software version 9.4 and tested for significance using Least Significant Difference (LSD) at $P \leq 0.05$.

Multilayer system

A multilayer system consists of a 6 layer of growing container per rack, which is two layers from bottom is consider as below layer (L1), two layers in middle is consider as middle layer (L2) and two layers at the top is consider as top layer (L3). All container is fulfilled with mixture media such as perlite, vermiculite and peatmoss (1:1:1). Structure and layout of multilayer system showed in Figure 1.

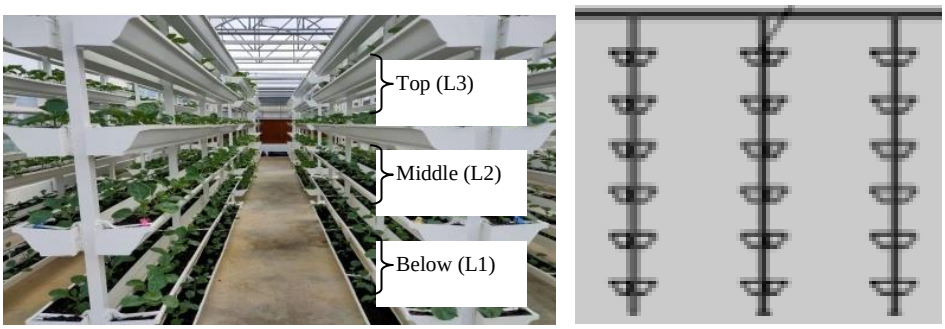
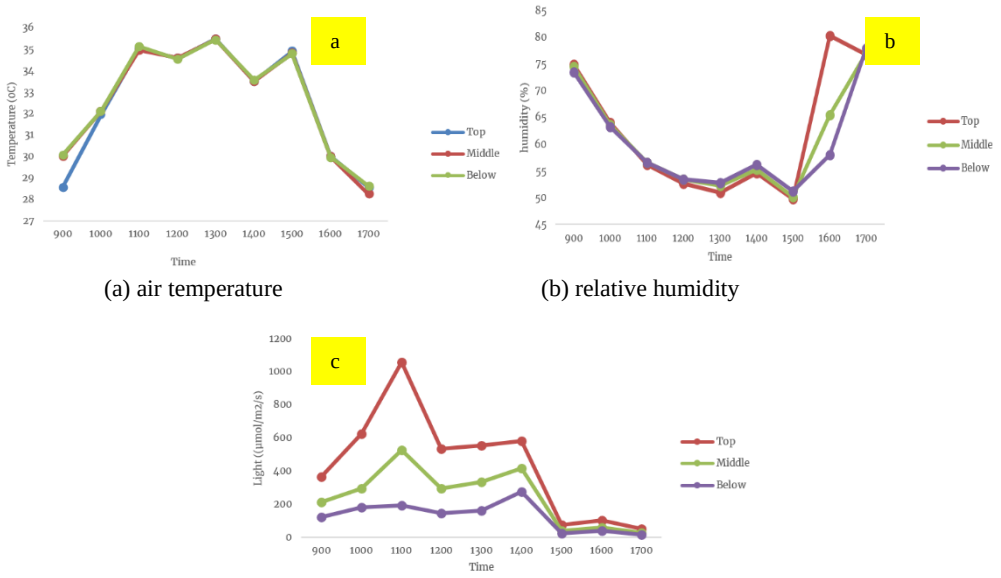


Figure 1. Structure and layout of multilayer which consist of 6 layers of growing container

RESULT AND DISCUSSION

Environment condition

Greenhouses are designed to create a controlled environment that is optimal for plant growth. The air temperature, relative humidity and light intensity are some of the factors that are typically controlled in a greenhouse. By controlling these environmental factors, greenhouse growers can create an ideal growing environment that promotes healthy plant growth and maximizes crop yields. The environment in greenhouse in this study were showed in Figure 2. The temperature during 11:00 am to 3:00 pm for all layer's ranges from 33-35 ˚C. On sunny days, the relative humidity varies between 50-75%, while during rainy days, it increases beyond 75% for all layers. The top layers receive the highest amount of light, followed the middle and while bottom layers experience relatively lower light conditions. For instance, during the period of 10.00 am to 11.00 am, the top layer receives 1100 µmol m^2/s^1, the middle layer receives 500 µmol m^2/s^1, and the bottom layer receives approximately 200 µmol m^2/s^1.



(a) air temperature (b) relative humidity

(c) light intensity

Figure 2: The environment in greenhouse (a) air temperature, (b) relative humidity and

Effect of different layer conditions result

Table 1 showed the layer level of top, middle and below was significantly different for all parameters which is plant height, number of leaves, leaf area, plant fresh weight and relative chlorophyll content of Fan Pak Choy planting on multilayer system in a greenhouse. Top and middle level grew more vigorously than below level. The shortest plant (15.23cm) was found in the below condition which was at par to middle level (16.98 cm). The tallest plant (17.55cm) was recorded under the top level which is the highest-level condition.

Similar result was shown for growth characters of Fan Pak Choy at different layer levels, which is the increase of layer levels (bellow to top) will increase significantly growth for number of leaves, leaf area, plant fresh weight and relative chlorophyll content (Table 1). Top and middle layers showed better results compared from below layer because in greenhouse natural light were limited for below layer. Overall, multilayer systems in greenhouse can offer several benefits for plant growth, including increased productivity, better nutrient absorption, reduced water usage, and pest and disease control. However, the effectiveness of multilayer systems will depend on the specific design, plant species and growing conditions.

Lighting plays a critical role in vertical farming since plants rely on light energy for photosynthesis and their growth and yield depend on the quantity and quality of light they receive (Wang & Folta, 2013). Inadequate lighting can result in slow plant growth and development. Vertical farming systems can face shading issues where plants at the bottom receive less light than those at the top, leading to slow growth and reduced marketability (Touliatos et al., 2016; Gobilik et al., 2021). In a multilayer system, light intensity is suspected to decrease from top to bottom and from outer to inner sides, affecting plant growth and yield (Touliatos et al., 2016; Gobilik et al., 2021). Artificial light is commonly used to supplement natural light in top vertical farming systems, although its cost-effectiveness for small-scale operations remains debatable (Shao et al., 2016). However, relying solely on artificial light increases the initial cost of vertical farming systems, which may be a challenge for smallholder farmers who make up the majority of vegetable farmers in Malaysia.

Table 1: Growth characters of Fan Pak Choy under different levels on multilayer planting system in a greenhouse.

Layer level	Plant height (cm)	Number of leave	Leaf area (m^2)	Plant fresh weight (g)	Relative chlorophyll content
Top (L3)	17.55a	13.59a	2639.56a	353.47a	40.45a
Middle (L2)	16.98ab	13.22a	2560.57a	353.33a	36.81b
Bellow (L1)	15.23b	10.41b	1340.22b	149.42b	30.45b
LSD	1.87	1.21	626.83	95.59	4.36

In a column, the figures having similar later do not differ significantly using Least Significant Difference (LSD) at $P \leq 0.05$.

Effect of different planting distance result

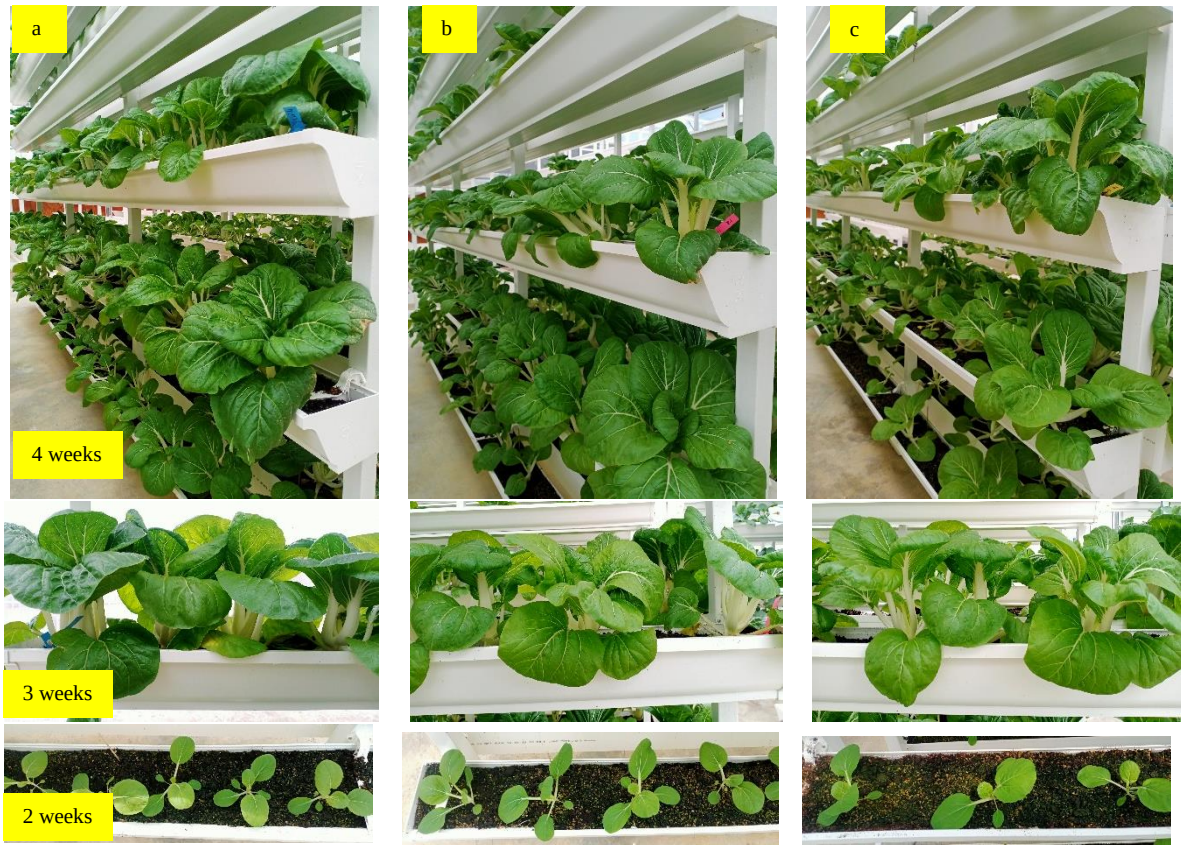
Choosing the right distance for a specific crop is crucial to maximize resource utilization, minimize competition, and minimize the risks of pests, diseases, and weeds. Table 2 showed the results of this study that a planting distance of 13cm, 18cm and 23cm was not significantly different for all parameters except for plant fresh weight and leaf area which is planting distance of 18cm (327.06g, 2582.77m^2) gives the best results followed by 13cm (299.46g, 2181.91m^2) and 23cm (229.7bg, 1875.67m^2) respectively. Figure 3 displays pictures of varying planting distances, including 13cm, 18cm and 23cm at 2, 3 and 4 weeks after transplanting.

There have been several studies on the optimal planting distance for Pak Choy, but the specific recommendations may vary depending on the growing conditions, climate, and variety of Pak Choy. The difference in recommended spacing between these studies may be due to differences in the specific varieties of Pak Choy used, as well as differences in growing conditions and cultural practices. It's also possible that newer varieties or changes in growing practices may have led to different optimal planting distances compared to older studies. Overall, the recommended planting distance for Pak Choy is based on a combination of scientific research, practical experience, and observations of plant growth and development. It's always a good idea to experiment with different planting distances to find what works best in your specific growing conditions.

Table 2: Growth characters of Fan Pak Choy different planting distance on multilayer system in a greenhouse.

Planting distance (cm)	Plant height (cm)	Number of leave	Leaf area (m^2)	Plant fresh weight (g)	Relative chlorophyll content
13cm (S1)	17.35	12.63	2181.91ab	299.46ab	35.99
18cm (S2)	16.25	12.82	2582.77a	327.06a	36.23
23cm S3)	16.16	11.78	1875.67b	229.70b	35.30
LSD	1.87	1.21	626.83	95.59	4.36

In a column, the figures having similar later do not differ significantly using Least Significant Difference (LSD) at $P \leq 0.05$.



(a) 13cm of planting distance (b) 18cm of planting distance (c) 23cm of planting distance

Figure 3. Different planting distances of (a) 13cm, (b) 18cm and (c) 23cm at 2, 3 and 4 weeks after transplanting.

CONCLUSION

For optimal growth of Fan Pak Choy using a multilayer planting system, it is advisable to space them 18cm apart to achieve a higher yield. It is crucial to effectively plan and manage the system, as some vegetables may perform better than others. The combination of the layer and planting distance significantly affects the yield of Fan Pak Choy. However, the study's results were obtained from a single season trial, which may not be sufficient to determine the sustainability of the findings. Therefore, it is suggested to conduct similar experiments in at least one additional season to arrive at a conclusive outcome.

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