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Determination of harvesting time and quality of kesum (*Persicaria minor*) in different cultivation systems

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Abstract

Various planting techniques and systems have been studied and practised to produce high quality and yield crops. Among the cultivation systems that are widely used in agriculture are open-field planting, fertigation, and hydroponic systems. Harvesting at the optimal maturity stage is a vital approach to obtaining crops with high quality and nutrient content. Kesum (*Persicaria minor*) is an aromatic herb that is very native to Southeast Asian countries and is synonymous with Asian cuisine because of its ability to enhance flavour in dishes and is also used as a traditional medicine. This study was conducted to evaluate the optimal harvesting time and quality of kesum in different cultivation systems, which were open field planting, fertigation, and hydroponic systems (controlled and semi-controlled environment). In an open field and fertigation system, kesum were planted on soil but with different fertilizer rates and applications. While for the hydroponic system, kesum were planted in 156 cm × 63 cm polystyrene boxes filled with water in a controlled and semi-controlled environment (closed and opened rain shelter structure, respectively). Samples were harvested at different maturity stages 8, 12, 16, and 18 weeks after planting. The postharvest quality of the samples was measured at every harvesting time. The plant fresh weight was found to increase at every harvesting week in all cultivation systems, whereas optimal weight was reached at week 16 after planting (296.18 g in controlled hydroponic, 509.45 g in semi-controlled hydroponic, 639.20 g in fertigation and 751.5 g in open field). Meanwhile, the total phenolic content (TPC) was found to increase to optimal content at week 12 for kesum planted in semi-controlled hydroponic (183.47 mg/g), fertigation (333.30 mg/g) and open field (435.32 mg/g) system but at week 16 in controlled hydroponic (207.43 mg/g). Ascorbic acid and water content showed a decreasing trend throughout the harvesting weeks, in contrast to the total soluble solids content, total titratable acidity, and pH value, which increased in all four cultivation systems. Based on the data obtained, the optimal harvesting time for kesum planted in either fertigation, conventional or hydroponic systems is at week 16 after planting for obtaining kesum with high yield and quality.

1. Introduction

Kesum (*Persicaria minor*) is an aromatic herb that is very native to Southeast Asia countries and is synonymous with a food ingredient because of its ability to enhance flavour. It has been used as a traditional medicine to treat dandruff, stomach ingestion, and fungal skin infection (Vimala *et al*., 2012; Musa Ahmed *et al*., 2015) making it potential to be developed into medicinal products. It also has potential as an antiulcer, antimicrobial, anticytotoxicity and anti-genotoxicity (Uyub *et al*., 2010; Wasman *et al*., 2010; Qader *et al*., 2011). In order to produce good quality kesum, its cultivation needs to be paid attention.

Planting systems, plant care and providing nutrients to planted plants are important in producing high-yield and high-quality crops. There are various cultivation techniques and systems that have been practised over time. This cultivation system and technique, apart from giving high and quality yields, also aims for a crop that

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can be harvested early. Among the popular and widely practiced cultivation systems are hydroponics, fertigation, and open fields (conventional). Medicinal plants are usually grown in open fields (conventional), giving different biomass yields every season or year, including metabolite content, which depends on factors such as weather, nutrient content in the soil, planting practices, and insect and disease attacks. Therefore, there is increasing interest and studies for artificial cultivation such as cultivation in greenhouses and hydroponics systems where the environmental factorials can be controlled. The hydroponic cultivation system has been practiced commercially in the cultivation of vegetables such as tomatoes, cucumbers, sweet peppers, melon (Hasan *et al*., 2018), cabbage, broccoli, mustard greens, water spinach (Lenzi *et al*., 2011; Ferguson *et al*., 2014; Parkell *et al*., 2016; and ornamental trees and flowers (Hasan *et al*., 2018). Hydroponics utilises liquid media as a source of nutrients that plants require for growth rather than soil used in conventional systems (Gericke, 1937). Hydroponic cultivation is said to increase yield and phytochemical content as well as speed up optimal harvesting time. Several studies record that hydroponic systems increase biomass production and phytochemical content (Yoshimatsu, 2012; Surendran *et al*., 2017).

Fertigation is one of the most practised crop cultivations in agriculture. Fertigation with drip irrigation technology is a planting technique that has been proven to positively affect crop growth and yield. Fertigation is a combination of two English words namely fertilizer and irrigation. In this fertigation technology, fertilization and irrigation are done simultaneously directly to the plant's root zone (Yaseer *et al*., 2013). Among the crops that are grown commercially using the fertigation system are onions, broccoli, bananas, potatoes, tomatoes, sugar cane, okra, chilies, cucumbers, and so on (Aakash *et al*., 2020). The fertigation technique helps overcome nutrient deficiency in soils, supplying the nutrients directly to the root and the amount and form of nutrient supply can be regulated as per needs saving in the amount of fertilizer usage (Aakash *et al*., 2020).

The maturity stage and optimal harvesting time of a crop should be paid attention to as it would affect the quality, phytochemical and nutritional content of the crops after harvest. Crops must be harvested at optimal maturity in order to obtain yields with high quality and nutrient content (Prasad *et al*., 2018). This present study was to determine the quality of kesum at different growth stages in four types of cultivation systems which were controlled and semi-controlled environment hydroponics, fertigation and an open field (conventional) system.

2. Materials and methods

2.1 Preparation of planting materials

In this study, four different cultivation systems were used to grow kesum, namely a controlled environment hydroponic system, a semi-controlled environment hydroponic system, a fertigation system and an open field as a control. Kesum used in this study was the elite accession MKSM004. Kesum elite accession cuttings were prepared in advance with a length of 15 - 20 cm or 5 - 7 nodes. For fertigation and open field cultivation, the cuttings were grown on peat moss media for 3 weeks until they produced roots, while for hydroponic cultivation, cuttings were grown on germination sponge media. Cuttings that were rooted were then transferred to the study plot.

2.2 Cultivation systems set up

This study was arranged in randomized complete block design at each cultivation system comprising four harvesting stages and replicated thrice.

2.2.1 Hydroponic cultivation

For hydroponic cultivation, a polystyrene box of size 156 cm × 63 cm is used. The cover of the polystyrene box was punched with a hole with a diameter of 1.6 cm with the distance between the holes was 18 cm. The prepared cuttings were clamped with a wet sponge and inserted into the hole. The distance between the plants in the hydroponic box was 18 cm. Water is filled into the polystyrene box until the water level submerges the bottom of the cutting. The hydroponic boxes were then arranged in two types of rain shelter structures, namely the fully closed type (controlled environment) and the partially open type (semi-controlled environment). The fertilizer given was NPK fertilizer with a rate of 230:68:360 ppm every month throughout the experiment timeframe.

2.2.2 Fertigation and open field cultivation

For fertigation and open field cultivation, rooted cuttings were planted on mineral-type soil with a plot area of 1 m × 2 m. Plant spacing between plants was 20 cm and 50 cm between rows. The fertilizer given was NPK fertilizer at a rate of 100:50:70 kg per hectare at 4, 8 and 12 weeks. Irrigation in the fertigation and open fields system was done three times a day in the first two weeks, followed by twice a day after two weeks until harvesting time.

2.3 Postharvest quality measurement

Kesum plants from all four cultivation systems were harvested at different maturity stages which were 8, 12, 16 and 18 weeks after planting. During each harvesting,

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harvested samples were subjected to physical measurements (plant height and weight) and chemical analyses (moisture content, pH value, total titratable acidity (TTA), total soluble solids (TSS), ascorbic acid and total phenolic acid content). Plant height (cm) and weight (g) were measured manually using measuring tape and an analytical balancer (A&D GF-6100). While moisture content (%), pH value and TSS (°Bx) of the leaves sample were obtained using a moisture analyser (A&D MX-50), pH meter (Metler Toledo) and refractometer (ATAGO), respectively. TTA, ascorbic acid and phenolic content were determined according to the method by AOAC (2005), Nielsen (2017) and Mirfat *et al*. (2020), respectively.

2.4 Statistical analyses

All experiments were carried out in triplicates. The data analyses were done using IBM SPSS version 26 (SPSS Inc; Chicago, USA). A mean comparison between treatments was obtained using Duncan's multiple range test at P = 0.05 level.

3. Results and discussion

The growth and quality of the kesum plant in four different cultivation systems are shown in Tables 1 - 4. The physicochemical quality of kesum that were plant height, fresh weight, water content, pH, total titratable acidity (TTA), total soluble solid (TSS), ascorbic acid content and total phenolic content show differences at each maturity stage and between cultivation systems. Criteria for determining crop maturity can be subjective or objective, depending on the variety or type of crop. Among the commonly used methods are observations of physical characteristics, chemical changes, physiological characteristics and the calculation of days or weeks (Hassan, 1999). Plant height increased from week 8 to 16 for kesum plants in the controlled hydroponic, fertigation and open field system and there was no change in size at week 18. While kesum was in the semi-controlled hydroponic system, plant height was found to increase from week 8 to 12 and stable in size afterwards until week 18. Plant fresh weight (yield) also shows an increase at each harvesting whereas it reached optimal fresh weight at week 16 in all four cultivation systems. At week 16, the optimal weight for kesum planted in controlled hydroponic was 296.18 g while a higher weight obtained from semi-controlled hydroponic was 509.45 g at same week. Kesum planted on soil either using fertigation or an open field system produced a higher yield compared to both hydroponic systems which were 639.20 g and 751.50 g at same week 16. Changes in the size of the crop while growing are frequently used to determine the optimum time to harvest (Reid, 2022).

The water content in the leaves and stems of kesum showed a significant decrease from week 8 to 18 for all cultivation systems. A decrease from 81.97% to 75.86% was recorded for controlled hydroponic systems, 77.40 - 70.24% for semi-controlled hydroponics, 82.25 - 60.11% for fertigation and 75.81 - 59.20% for open field systems. The lowest water content was recorded in the fertigation and open field cultivation systems in week 18, which were 60.11% and 59.20% respectively, compared to 75.86% and 70.24% for the controlled and semi-controlled hydroponic systems respectively. The same

Table 1. Postharvest quality of kesum from controlled environment hydroponic cultivation system at different harvesting week.

Week	Plant height (cm)	Plant weight (g)	Water content (%)	pH	Total titratable acidity (mg/g)	Total soluble solid (°Bx)	Ascorbic acid content (mg/100 g)	Total phenolic content (mg/g GAE)
8	42.30^{c}	96.07^{b}	81.97^{a}	5.91^{c}	2.09^{c}	3.14^{b}	6.82^{a}	40.60^{c}
12	70.93^{b}	181.19^{b}	81.37^{a}	6.60^{a}	2.67^{b}	3.20^{b}	4.44^{b}	99.09^{b}
16	92.67^{a}	296.18^{a}	74.40^{b}	6.21^{b}	2.60^{b}	3.44^{b}	4.95^{b}	207.43^{a}
18	88.33^{a}	293.30^{a}	75.86^{b}	5.97^{c}	3.12^{a}	4.78^{a}	5.05^{b}	43.81^{c}

Values are presented as means of triplicates. Values with different superscripts within the same column are statistically significantly different (P<0.05) according to Duncan Multiple's Range Test.

Table 2. Postharvest quality of kesum from semi-controlled environment hydroponic cultivation system at different harvesting week.

Week	Plant height (cm)	Plant weight (g)	Water content (%)	pH	Total titratable acidity (mg/g)	Total soluble solid (°Bx)	Ascorbic acid content (mg/100 g)	Total phenolic content (mg/g GAE)
8	47.15^{b}	154.13^{c}	77.40^{a}	5.77^{b}	2.39^{b}	3.44^{c}	7.00^{a}	44.21^{c}
12	90.44^{a}	283.33^{b}	72.18^{ab}	6.11^{a}	2.87^{a}	4.44^{b}	4.54^{c}	183.47^{a}
16	96.44^{a}	509.45^{a}	72.19^{ab}	6.32^{a}	3.11^{a}	5.08^{b}	4.61^{c}	79.88^{b}
18	92.95^{a}	493.26^{a}	70.24^{b}	6.30^{a}	3.16^{a}	7.49^{a}	5.06^{cb}	54.85^{c}

Values are presented as means of triplicates. Values with different superscripts within the same column are statistically significantly different (P<0.05) according to Duncan Multiple's Range Test.

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Table 3. Postharvest quality of kesum from fertigation cultivation system at different harvesting week.

Week	Plant height (cm)	Plant weight (g)	Water content (%)	pH	Total titratable acidity (mg/g)	Total soluble solid (°Bx)	Ascorbic acid content (mg/100 g)	Total phenolic content (mg/g GAE)
8	33.06[c]	136.80[c]	82.25[a]	5.44[b]	2.86[b]	2.73[d]	6.53[a]	68.56[b]
12	75.22[b]	458.00[b]	68.70[b]	5.39[b]	3.15[b]	3.82[c]	4.91[b]	333.30[a]
16	89.48[a]	639.20[a]	62.19[c]	5.64[ab]	3.21[b]	4.89[b]	5.01[b]	384.72[a]
18	94.55[a]	612.00[a]	60.11[c]	5.55[ab]	3.94[a]	6.11[a]	5.26[b]	64.17[b]

Values are presented as means of triplicates. Values with different superscripts within the same column are statistically significantly different ($P<0.05$) according to Duncan Multiple's Range Test.

Table 4. Postharvest quality of kesum from open field cultivation system at different harvesting week.

Week	Plant height (cm)	Plant weight (g)	Water content (%)	pH	Total titratable acidity (mg/g)	Total soluble solid (°Bx)	Ascorbic acid content (mg/100 g)	Total phenolic content (mg/g GAE)
8	35.28[c]	154.33[c]	75.81[a]	5.27[c]	2.98[c]	3.05[b]	6.02[a]	65.52[b]
12	70.41[b]	516.20[b]	72.10[a]	5.57[ab]	2.80[c]	3.61[b]	5.12[b]	435.32[a]
16	85.67[a]	751.50[a]	66.11[b]	5.34[bc]	3.41[b]	6.12[a]	4.85[b]	391.64[a]
18	88.41[a]	735.30[a]	59.20[c]	5.63[a]	3.87[a]	6.55[a]	4.76[b]	84.70[b]

Values are presented as means of triplicates. Values with different superscripts within the same column are statistically significantly different ($P<0.05$) according to Duncan Multiple's Range Test.

trend was reported in *Centella asiatica* where the young plant (50 days of harvest) contains higher moisture content and then decreases significantly at 60 and 70 days of harvest (Rosalizan *et al*., 2008). During maturation, the leaves will lose water which causes the water content of young leaves to be higher than old leaves (Adhamatika *et al*., 2021). Young leaves tend to have a relatively higher water content compared to older leaves because leaves with older age will experience an increase in metabolism process and genetics (Bielczynski *et al*., 2017). The ascorbic acid content also showed a significant decrease from the highest content at week 8 to significantly lower at week 12 and subsequently, there was no change in content from week 12 up to week 18. This trend was recorded similarity in all cultivation systems. Rosalizan *et al*. (2008) reported the same trend in *Centella asiatica* where vitamin C content was higher in young plants at 50 days and significantly decreased with the advance in maturity. Vitamin C levels in crops depend on the activity of the ascorbate oxidase enzyme which increases in the activity lead to a decrease in vitamin C levels (Kartasapoetra, 1994). The decrease is also probably due to biochemical oxidation as it is easily oxidised by the presence of oxygen (Mapson, 1970). Various factors, including maturity, can influence the content of vitamin C in fruits and vegetables. Changes in pH, TTA and TSS values with an increment trend at each maturity level were measured in all four cultivation systems but there was no change in pH in the fertigation system. TTA and TSS values recorded an increase throughout the maturity stage in all systems. The highest increase in TSS content was seen in kesum in the semi-controlled hydroponic system with an increase of 4.05 from week 8 to 18, while the least increase was in kesum in the controlled hydroponic system (1.64). TSS value refers to the total content of sugar and dissolved minerals in a fruit or vegetable and is a parameter of the quality of fruit and vegetables. TTA along with TSS are often used as an indicator of maturity. As crops grow, total dissolved solids increase as organic acids and polysaccharide compounds are processed into simple dissolved sugars (Mahmood *et al*., 2012). The acidity of almost all fruits and vegetables changes during maturation, decreasing as the crops mature (Prasad *et al*. 2018) but it contradicts this finding probably due to the formation of organic acids during maturation.

In determining the maturity and optimal harvesting time of an herb, the phytochemical content is used as the basis for determining the appropriate maturity stage when the herb is optimally suitable for harvest. The total phenolic content recorded changes throughout the period of kesum growth in all four systems. Overall, the total phenolic content was found to increase from week 8 to week 12 – 16 and decreased afterwards in all four cultivation systems. The total phenolic content in the controlled hydroponic system was the highest at week 16 (207.43 mg/g), while as early as 12 weeks in the semi-controlled hydroponic system (183.47 mg/g). While kesum in fertigation and open field systems recorded the highest phenolic content in weeks 12 - 16 (333.30 – 385.72 mg/g, 435.32 – 391.64 mg/g, respectively) before it was found to decrease significantly in week 18. The maturation of crops is often accompanied by changes in their chemical composition. Many of these changes have been monitored in maturation studies. Phenolic content in crops depends on and is affected by several factors such as genotype, growing condition, maturity stage and

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crop characteristics (Kalt, 2005). Kazim and Onur (2014) reported that total phenolic content in jujube increased until stage 3 of maturity before it dropped in stage 4. Triterpene compounds (madecassic acid, madecassoside and asiaticoside) in *Centella asiatica* showed an increment from day 50 to 60 of harvest but then decreased significantly at day 70 as reported by Rosalizan *et al*. (2008). Data obtained from this study, especially the parameter of plant weight and total phenolic content suggested that the optimal harvesting time for kesum planted in all four cultivation systems was 16 weeks after planting, obtaining high and quality yield.

A comparison of the yield and quality of kesum between the four cultivation systems was analysed (Table 5). At week 16 after planting, which was the optimal harvesting time, it was found that the open field and fertigation system recorded the highest yield of 751.50 g and 639.20 g, respectively, followed by the semi-controlled hydroponics (509.45 g). While the controlled hydroponic system recorded the lowest yield (252.93 g). The open field and fertigation planting also gave significantly higher total phenolic content (391.64 mg/g and 384.72 mg/g, respectively) compared to both hydroponic systems where hydroponic in a controlled environment gave higher total phenolic content (207.43 mg/g) rather than 79.88 mg/g in hydroponic in a semi-controlled environment. Water content in kesum from hydroponic systems showed significantly higher content (74.40% and 72.19% in controlled and semi-controlled hydroponic, respectively) compared to kesum planted in soil (66.11% and 62.19% in open field and fertigation systems, respectively). While TSS content was recorded highest in the open field system (6.12°Bx). There was no significant difference in ascorbic acid content in all four systems.

There are several studies that reported an increase in crop yield from the fertigation system. A report from Aakash *et al*. (2020) recorded an increase in yield for several studied crops such as okra (18% yield increase), onion (16%), broccoli (10%), banana (11%), potato (30%), tomato (33%) and sugarcane as much as 40% increase in crop yield. The same report also notes that planting by fertigation reduces and saves the use of fertilizers by up to 40% for planting crops such as okra, onions, broccoli, potatoes and tomatoes. For sugarcane crops, a 50% saving in fertilizer use was recorded. There are several studies reporting the advantages and disadvantages of hydroponic cultivation systems. A study done by Yoshimatsu (2012) observed an increase in biomass and glycyrrhizin content of Chinese liquorice. While Surendran *et al*. (2017) recorded an increase in yield, organic acid and antioxidant content in spearmint when grown in hydroponic. Both studies compared soil cultivation. However, Souret and Weathers (2000) reported that the fresh weight of the saffron crocus flower was lower in the hydroponic system. Similar to a study by Maggini *et al*. (2012) that found coneflower (*Echinacea angustifolia*) grown in hydroponic has lower echinoside compound content.

4. Conclusion

All types of planting systems have their own advantages and disadvantages. The findings from this study showed that kesum are suitable for harvesting at week 16 after planting either in hydroponic, fertigation or open-field cultivation systems based on the plant yield and phenolic content. It is recommended that fertigation and open field planting systems are the best planting systems in obtaining kesum with high yield and quality.

Conflict of interest

The authors declare no conflict of interest.

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Table 5. Quality comparison of kesum from four different cultivation systems at week 16 after planting.

Cultivation system	Yield (g)	Water content (%)	Total soluble solid (°Brix)	Ascorbic acid content (mg/100g)	Total phenolic content (mg/g GAE)
Controlled environment hydroponic	296.18^{c}	74.40^{a}	3.44^{c}	4.95^{a}	207.43^{b}
Semi-controlled environment hydroponic	509.45^{b}	72.18^{a}	5.08^{b}	4.61^{a}	79.88^{c}
Fertigation	639.20^{a}	62.19^{b}	4.89^{b}	5.01^{a}	384.72^{a}
Open field	751.50^{b}	66.11^{b}	6.12^{a}	4.85^{a}	391.64^{a}

Values are presented as means of triplicates. Values with different superscripts within the same column are statistically significantly different (P<0.05) according to Duncan Multiple's Range Test.

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