

The Use of Trellis and Mulch Increased Fruit Production of Spaghetti Squash (*Cucurbita pepo* L.)

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Abstract

Spaghetti squash is squash of American origin that has spaghetti-like characteristic of fruit flesh, unlike any other squash varieties. This study aims to investigate the use of trellis and mulch to increase the spaghetti squash production. The experiment was conducted at the Experimental Station of Centre of Tropical Horticulture, Bogor from April to November 2016. The experiment used a completely randomized block design with four replicates. Two factors were tested, i.e. the use of trellis and mulch as the main plots, and accessions of the spaghetti squash as a sub-plot. The treatments were the use of trellis and mulch, mulch without the trellis, the trellis without mulch, and without the trellis and mulch. The spaghetti squash accessions used in this experiment were accessions from Taiwan (F1) and from America. Each experimental unit consists of five plants with a total a total of 160 plants. The results of this experiment showed that the growing squash using mulch and trellis had the greatest number of fruits per plant, more marketable fruits and had the largest fruit weight as compared with the other treatments. Taiwan accession had more fruits per plant and total marketable fruits, the largest fruit weight, the longest and widest fruits with large fruit diameter. Taiwan accession produced fruits at lower nodes of the plants, and fruits can be harvested earlier than the American accession. Correlation analysis indicated that the more fruits per plant, the more number of fruits that are marketable, the greater fruit weight and more fruits can be harvested from the higher nodes of the plants. From agronomical point of view, Taiwan spaghetti squash would be preferable to obtain the high fruit production provided the crops were mulched and grown with trellis.

Keywords: Cucurbitacea, trellis, mulch, plant culture

Introduction

Spaghetti squash, *Cucurbita pepo* L, belongs to the Cucurbitaceae family and has been widely cultivated in various parts of the world such as America, Japan and Taiwan with a variety of cultivation techniques, from traditional to hydroponics (NPGS, 2006). Cucurbitacea consists of around 800 species including cucumbers, melons, watermelons, and pumpkins. Twenty genera are used for culinary purposes, which usually includes consumption of the mature fruit flesh, whole immature fruits, and/or seeds. Three genera, Cucumis (cucumbers, melons), Cucurbita (pumpkins, squash), and Citrullus (watermelons), rank among the top ten in economic importance among the vegetable crops of the world (Schaffer and Paris, 2003). Cucurbitaceae are herbaceous, tendril-bearing vines that are adapted to warm climates; the leaves are large palmate shape, roots are fibrous with large prominent fruits. Under favorable conditions, the plants grow and spread quickly, as stems can elongate 30 cm or more within 24 h (Schaffer and Paris, 2003).

Spaghetti squash has a unique characteristic which differentiates from the other cucurbits; the fruit flesh splits apart like spaghetti when boiled, steamed, or roasted. This happens due to the breakdowns of pectic compounds that are present in the fruit flesh when cooked. As the pectic chains break up the pumpkin flesh started to look like spaghetti (Ishii, 2015). Pectic or pectin is one of the polysaccharide inside plant cell walls that function in complex physiological processes such as growth and differentiation of cells, as well as the development and stiffness of plant tissues (Voragen et al., 2009).

Pumpkins and squash rank high overall in nutritional value, most familiarly in the carotenoid content of the fruit flesh (Schaffer and Paris, 2003). The spaghetti squash has essential vitamins and minerals required for human body metabolism such as vitamins A, C, and E as well as minerals sodium and potassium. The pulps of the squash can potentially substitute

spaghetti made from wheat, in addition it contains low fat. One serving of spaghetti squash contains 42 calories while one serving of wheat pasta contains 221 calories (Self Nutrition Data, 2014). The uniqueness and benefits of spaghetti squash can add variety of highly nutritious horticultural produces in Indonesia.

Spaghetti squash is not a native to Indonesia and not widely known by Indonesian growers. Very limited information is available on squash culture. Therefore in order to introduce squash as a new horticultural crop a standard of production guidelines should be prepared to the crop can grow and produce fruits in the tropics. The current study was conducted to examine whether or not the use of trellis and mulch can increase fruit production of two accessions of spaghetti squash. The use of trellis for Cucurbitaceae have advantages, including keeping the plant leaves dry and avoid fungal diseases, the fruits are easier to harvest, cleaner and uniform in colour compared to when fruits rested on the ground. In addition mulching keep soil humidity and inhibit weed growth (Hinds et al., 2015). The use of trellis improved the yield and quality of Cucumber; improved photosynthetic efficiency has also been correlated to the increased yield (Solangi et al., 2009; Hanna. et al., 1987). The use of organic mulch provides valuable nutrients as the mulch breaks down, and improves soil physical properties (Hinds et al., 2015).

Materials and Methods

This experiment was conducted at the Tropical Horticulture Experimental Research Center, Tajur, Bogor, from June to November 2016. This experiment used split plot design with trellis and mulch as the main plot, and squash accessions as sub plot. The main plots consist of the use trellis and mulch, trellis without mulch, without trellis with mulch, and without trellis and without mulch. Plastic mulch was used, and two accessions, from Taiwan (F1) and from American, were tested in the study. Each experimental unit consists of five plants with a total of 160 plants.

Squash seeds were sown until the seedlings had grown at least two true leaves prior to planting prior to transplanting into raised beds with plant spacing of 1.2 m between rows and 1.4 m within rows. The type of trellis used was *para-para* or bamboo stakes (7 x 1.2 x 1.7 m). Bamboo trellis was used to support the growth of the climbing plants, by tying the branches to the trellis using ropes to direct the plant growth upwards. NPK fertilizer at 10 g.L⁻¹ was applied weekly. Fruits were harvested when ripened and skin has hardened to avoid cut and bruises during handling. Ripened fruits are uniformly yellowish in

colour. According to squash harvesting guideline by The USA Department of Agriculture, Forestry and Fisheries (2011) squash fruits can be harvested at ± 100 days after planting (DAP), or 30-40 days after the pollination of the female flowers.

Scoring was conducted on the total number of fruits per plant, marketable and non-marketable fruits per plant, the smallest and largest fruit weight (g), fruit length and diameter, skin thickness and fruit thickness (cm) using a digital caliper, lowest and highest harvesting nodes, total soluble solids (TSS) using hand refractometer, and time to harvest (weeks after planting, WAP).

Results and Discussion

Fruits had to be harvested early at 6 weeks after planting (WAP) as most of the plants were infected by fruit rot disease *Erwinia*. The infection had caused the plants to set flower early, i.e. at 3 WAP. Squash usually flower at 8 WAP, or 30 to 40 days after pollination, and fruits can be harvested at 13 WAP or about 100 days (Department of Agriculture, Forestry and Fisheries, 2011). The *Erwinia* disease might have spread from the cabbage crops grown adjacent to the squash block. According to Maynard (2007), Cucurbita fruits take about two to three weeks to reach its maximum size and take more than three weeks to reach maturity before the fruits are ready for harvest. Earlier harvest made the fruits had not physiologically matured and not as sweet as the mature fruits, although the fruits have reached their maximum size. In addition, the fruit pulps do not completely break when cooked.

Fruit skin thickness, fruit TSS content and fruit weight were significantly affected by squash accessions and growing methods (Table 1).

Total Fruit Production and Marketable Fruits

Table 2 shows that the number of fruit per plant and marketable fruits were significantly different between accessions. Taiwan accession produced about 30% more fruits per plant than the American accession (Table 2). Differences in the number of fruits harvested might have been caused by the types of seed used in this study. The seeds of Taiwan accession are F1 produced by Known You Seed, whereas the seeds of the American accession come from independent seed producer in America.

There was a significant difference in the fruit production and marketable fruits per plant with the use of mulch and strellis (Table 2). Corn and peanut grown using mulch as ground cover reduced nutrient

Table 1. Recapitulation of the quantitative characteristics of the spaghetti squash fruits

Variable	Pr>F			CV (%)
	Accession	Use of trellis and mulch	Interaction	
Number of fruits	0.00**	0.04*	0.97 ^{ns}	26.45 ^{a)}
Number of rotten fruit	0.19 ^{ns}	0.71 ^{ns}	0.93 ^{ns}	25.46 ^{b)}
Σ Marketable fruits	0.02*	0.04*	0.99 ^{ns}	23.42 ^{b)}
Smallest fruit weight	0.00**	0.47 ^{ns}	0.00**	15.46
Largest fruit weight	0.00**	0.01*	0.62 ^{ns}	9.09
Fruit length	0.00**	0.11 ^{ns}	0.71 ^{ns}	8.88
Fruit diameter	0.00**	0.23 ^{ns}	0.66 ^{ns}	5.83
Fruit flesh thickness	0.33 ^{ns}	0.73 ^{ns}	0.58 ^{ns}	12.96
Skin thickness	0.09 ^{ns}	0.61 ^{ns}	0.05*	11.26
Low node harvest	0.00**	0.76 ^{ns}	0.08 ^{ns}	14.55
High node harvest	0.81 ^{ns}	0.12 ^{ns}	0.89 ^{ns}	21.28
Total soluble solids	0.43 ^{ns}	0.72 ^{ns}	0.04*	11.02
Earliest time to harvest	0.00**	0.47 ^{ns}	0.53 ^{ns}	4.22
Final harvest time	0.01*	0.88 ^{ns}	0.12 ^{ns}	5.18

Note : CV: coefficient of variation; Pr = probability; ns = not significantly different ($\alpha=5\%$). * = significantly different ($\alpha=5\%$). and ** = very significantly different ($\alpha=1\%$). Transformation: ^{a)} \sqrt{X} . ^{b)} $\sqrt{X+0.5}$.

erosion by up to 75% compared with those grown without mulch (Wahjunie and Listyarini, 1998). Shetty et al. (1998) showed that cucumber plants (*Cucumis sativus*) grown using trellis resulted in better quality and quantity of fruits than those grown without trellis. In this study, crops that were grown without trellis produced fewer numbers of marketable fruits compared with plants that were grown with trellis. Agu (2004) reported that growing squash (*Cucurbita maxima*) using trellis resulted in more fruits than that without trellis. This is in line with our results showing a higher number of fruits when plants were grown with both mulch and trellis.

The plants grown with mulch and trellis had more total and marketable fruits compared to those grown with mulch only. The use of mulch can prevent soil and nutrient erosion, whereas the use of trellis potentially increases the rate of photosynthesis as the trained plants had more exposure to sunlight. Chukwudi and Agbo (2014) reported in their studies that pumpkin bells with 90 cm trellis height had the best vegetative growth, flowering and crop productivity compared to other treatments in the study.

The use of mulch, however, can not avoid some fruits to rot even though the fruits had not been in contact directly with the soil. The fruits got rotten when they grow on the ground and exposed to the water puddles retained by the mulch. Fruits that were off the ground can also rot during wet and heavy rain, which had occurred during this research.

Fruit Weight per Plant

The American spaghetti squash produced smaller fruit size than the Taiwanese accession. Beany et al. (2002) reported that the weight of spaghetti squash of American accession "Hasta la Pasta and Vegetable" ranged from 1.1-1.4 kg per fruit. The weight of spaghetti squash fruit from the America in this study ranged from 621.9-1021.3 g per fruit, and the smallest spaghetti squashfruit was only a half of the weight of the spaghetti squash reported in Beany et al. (2002). The largest squash fruit weight of the Taiwan accessions was 360 grams greater than the weight of the spaghetti squash reported in Beany et al. (2002) study, but smaller than the standard squash weight of 2.5 kg per fruit (Known You Seed, 2016).

Table 3 shows the crop growing methods significantly influenced all variables of fruit weight. The use of mulch and trellis resulted in the highest fruit weight compared to other growing methods, and this might be related to less nutrient erosion due to mulch treatment (Wahjunie and Listyarini, 1998). The use of trellis without mulch resulted in smaller fruit weight compared to without trellis and without mulch, possibly because without trellis and without mulch the plants grow horizontally on the ground and each node can produce roots and allowing the plants to absorb more nutrients than the crops that grow vertically with trellis.

Table 2. Effects of trellis and mulch on fruit production of two accessions of spaghetti squash

Treatment	Number of fruits per plant	Number of rotten fruits per plant	Number of marketable fruits per plant
Accession			
Taiwan	3.2a	0.5	2.7a
America	2.0b	0.8	1.6b
Use of trellis and mulch			
Mulch and trellis	3.7a	0.6	3.1a
Mulch without trellis	3.4a	0.6	2.8a
Trellis without mulch	1.9b	0.9	1.2b
Without trellis and mulch	1.6b	0.5	1.6ab

Note : Values followed by the same letters within the same column are not significantly different according to DMRT at $\alpha = 5\%$.

Table 3. Effects of trellis and mulch on fresh weight of spaghetti squash fruits

Treatment	Smallest fruit weight (g)	Largest fruit weight (g)
Accession		
Taiwan	1,024.6a	1,760.2a
America	621.9b	1,021.3b
Use of trellis and mulch		
Mulch and trellis	845.8b	1,620.1a
Mulch without trellis	764.5b	1,555.1a
Trellis without mulch	794.4b	1,124.5c
Without trellis and mulch	1,005.7a	1,361.3b

Note : Values followed by the same letters within the same column are not significantly different according to DMRT at $\alpha = 5\%$.

Fruit Length, Fruit Diameter, Fruit Flesh and Epicarp Thickness

The squash accession and the use of trellis and mulch resulted in different fruit length and diameter (Table 4). The Taiwan accession had a larger fruit length of 21.6 cm compared to the American spaghetti squash of 18.0 cm. The fruit length of Taiwan accession in this study is similar to the description by the seed manufacturer, which is about 23 cm (Known You Seed, 2016). The fruit diameter of the American accession was smaller than that of Taiwan accession, as no fruit thinning was conducted, resulting in non-uniform size (length and diameter) of the fruits. Limiting the number of fruits per plant can affect the length and diameter of the fruit; the fewer the amount of fruit left on the plant, the greater the size of the fruits (Anna, 2009).

Table 4 shows that crops with mulch and trellis produced fruits of similar size compared to other cultural techniques. This suggests that the squash crop could produce fruits of a similar size although they were grown with a different cultivation system.

Spaghetti squash with trellis and without mulch were able to produce fruit sizes similar to the fruits produced with mulch and without trellis. These results demonstrated that spaghetti squash could be cultivated at a lower cost, without the use of trellis or mulch, to produce acceptable fruit sizes.

Fruit Formation and Stem Node Number

Fruit formation was evaluated by recording the node number along the main stem at which the fruit developed. The Taiwan squash were harvested from lower nodes than those in American accession, i.e. in the node 10th and 13th nodes whereas fruits from the American accession were harvested from the 17th and 19th nodes. Crops of Taiwan accession had better vegetative growth than American accession. Good plant growth results in the fruit to set in the lower nodes of the plants. Both accessions had similar fruits formed on the higher nodes.

The use of trellis and mulch (Table 5) had a significant effect on the number of fruits formed on the high nodes. Crops grown with trellis and mulch had fruits

Table 4. Effects of trellis and mulch on fruit characteristics of two spaghetti squash accessions

Treatment	Length of fruit (cm)	Diameter of fruit (cm)	Thickness of flesh (mm)	Thickness of epicarp (mm)
Accession				
Taiwan	21.6a	12.6a	22	2
America	18.0b	11.0b	19	2
Using of trellis and mulch				
Mulch and trellis	20.5	12.2	21	2
Mulch without trellis	20.1	11.8	21	2
Trellis without mulch	20.6	12.2	21	2
Without trellis and mulch	19.4	11.7	21	2

Note : Values followed by the same letters within the same column are not significantly different according to DMRT at $\alpha = 5\%$.

harvested from the 24th node whereas those cultivated without trellis and without mulch had fruits harvested from 17th node. The number of fruits harvested from the lower nodes of the crops grown with trellis and with mulch was similar.

TSS (Total Soluble Solid) Content and Fruit Harvest Time

Squash fruits of Taiwan accession had a higher TSS than fruits of American accession (Table 6). The TSS of both accessions was between 4.1 to 4.6 °Brix (Table 6). The use of trellis and mulch resulted in a significant difference in the fruit TSS. According to Harril (1994) TSS of 6 is considered “poor”, whereas the good TSS value is around 14°Brix. The fruit TSS of both accessions grown with trellis and mulch were all <6, indicating that the harvested spaghetti squash fruits in this study were not sweet.

The use of trellis and mulch affected time to harvest in which the Taiwan accession had an earlier harvest than the American accession. Taiwan fruits were harvested earlier at 6 WAP whereas America

accession fruits were harvested at 9 WAP. Spaghetti squash is usually harvested at 13 WAP (100 days) or 30-40 days after the pollination of female flowers (Department of Agriculture, Forestry and Fisheries, 2011) but in this study the fruits had to be harvested earlier at 42 days to avoid loss due to rotting fruit. The female and male flowers appeared at 3 WAP, whereas based on the Department of Agriculture, Forestry and Fisheries (2011) flowers appear after one to two months after planting. According to Maynard (2007), cucurbita fruits take about two to three weeks to reach its maximum size and takes about three weeks or more to reach maturity until final harvest. The recommended optimum temperature of the Taiwan accession squash based on information from Known You Seed is 15°C – 25°C. Based on this information early harvest will likely result in fruits with reduced sweetness.

Correlation Analysis

Table 8 shows the linear correlation analysis between the quantitative characters recorded in this study. The number of fruits per plant was positively correlated

Table 5. Effects of trellis and mulch on the number of squash fruits harvested from different nodes

Treatment	The lowest node	The highest node
Accession		
Taiwan	10.8a	20.6
America	17.6b	21.9
Use of trellis and mulch		
Mulch and trellis	14.6	24.0a
Mulch without trellis	13.7	22.4ab
Trellis without mulch	14.7	18.5ab
Without trellis and mulch	13.8	17.6b

Note : Values followed by the same letters within the same column are not significantly different according to DMRT at $\alpha = 5\%$.

Table 6. Effects of trellis and mulch on total soluble solids (TSS) and time to harvest of two accessions of spaghetti squash

Treatment	TSS (°Brix)	Early harvest time (WAP)	Final harvest time (WAP)
Accession			
Taiwan	4.6a	6.9b	8.3a
America	4.1b	9.4a	9.6b
Use of trellis and mulch			
Mulch and trellis	4.5a	7.5	9.2
Mulch without trellis	4.5a	7.8	8.8
Trellis without mulch	3.7b	7.8	8.8
Without trellis and mulch	4.6a	7.9	8.5

Note : Values followed by the same letters within the same column are not significantly different according to DMRT at $\alpha = 5\%$.

Table 7. The linear correlation between the quantitative characters of the spaghetti squash

	Σ FPP	Σ RF	Σ MF	LHN	HHN	SFW	LFW	FL	FD	TSS	FT	ST	FHT	EHT
Σ RF	-0.11													
Σ FFS	0.93**	-0.46**												
LHN	-0.44**	0.36*	-0.52**											
HHN	0.74**	0.07	0.63**	0.11										
SFW	-0.03	-0.52**	0.16	0.58**	-0.29									
BFW	0.65**	-0.33	0.70**	-0.75**	0.33	0.61**								
L	0.20	0.05	0.17	-0.59**	-0.05	0.58**	0.82**							
D	0.23	0.07	0.19	-0.56**	-0.02	0.55**	0.78**	0.91**						
TSS	0.22	-0.26	0.30	-0.38*	0.09	0.21	0.54**	0.41*	0.37					
FT	0.08	-0.15	0.13	-0.46*	-0.14	0.37	0.53**	0.73**	0.79**	0.35				
ST	-0.13	-0.06	-0.11	0.14	-0.19	-0.14	-0.17	0.05	0.12	0.03	0.33			
FHT	-0.50**	0.38*	-0.58**	0.85**	-0.08	-0.62**	-0.79**	-0.61**	-0.58**	-0.44*	-0.39*	0.26		
EHT	-0.52**	0.32	-0.58**	0.81**	-0.16	-0.52**	-0.76**	-0.59**	-0.58**	-0.47*	0.34	0.31	0.96**	
FHT	0.41*	-0.37*	-0.37*	0.73**	0.17	-0.54**	-0.52**	-0.36	-0.29	-0.36	-0.20	0.12	0.78**	0.73**

Note : **very significantly different ($\alpha=1\%$); * significantly different ($\alpha=5\%$); Σ FPP = number of fruits per plant; Σ RF = the number of rotten fruit; Σ MF = the number of marketable fruits; LHN = the lowest harvest node; HHN = the highest harvest node; SFW = the smallest fruit weight; LFW = the largest fruit weight; FL = fruit length; FD = fruit diameter; TSS = total soluble solid; FT = flesh thickness; ST = skin thickness; FHT = fruit harvest time; EHT = early harvest time; FHT = final harvest time

with the number of marketable fruits, the highest harvest node and the largest fruit weight. This means that the more fruits harvested, the higher the number of marketable fruits, the many fruits are harvested in high node and the heavily harvested fruit weights. According to Sultana *et al.* (2015) fruit weight correlated positively with the number of fruit per plant and can be used as one of the useful selection criteria for determining fruit yield per plant of *Cucurbita moschata* L.

The number of rotten fruits (Table 7) positively correlated to the lowest harvesting node and the final harvest time. This indicates that many rotten fruits

were harvested from low nodes and harvested in the final week of harvest. Figure 6 shows the rotting fruit that contacts the soil surface as it appears on the low node. The number of rotten fruits was also not correlated to the number of marketable fruits and to the smallest fruit weight. This means, the more rotten fruits harvested, the less the marketable yields which resulted from smaller fruit weights that were harvested. The number of marketable fruits was positively correlated with the highest harvest node and the largest fruit weight. This means that more and more harvestable fruits are harvested, so too many fruit weights are of great weight. Lee (2004) reported that on the Hamigua melon fruits harvested

on the branches of the 8th node on the main stem produced 2.8 kg per fruit, resulting in a higher productivity of 43.4 ton.ha⁻¹ compared to those with fruits harvested from lower nodes (nodes 5th, 6th, and 7th) the marketable fruits were negatively correlated with harvest nodes and early harvest. This means more harvestable fruits are harvested, the fewer fruits harvested from the lowest crop node and few being harvested in the early weeks of the plant harvest.

The fruits harvested from the low nodes of the plants were smaller in length and diameter. The largest fruit weight was positively correlated with fruit length, fruit diameter, and thickness of flesh; this means the heavier squash fruit, the longer and wider the size of the fruit and the thickness of the flesh. The greatest fruit weight was negatively correlated with the time to harvest; this shows that longer growing period resulted in larger and heavier fruits. Fruit diameter was positively correlated with thickness of flesh; meaning the greater the diameter of the fruit the thicker the flesh of squash.

Conclusion

Growing spaghetti squash with trellis and mulch produced more total and marketable fruits per plant and heavier fruits compared with the other cultural methods. The Taiwanese accession had more fruits per plant, more marketable fruits, heavier and larger fruit weight than the American accession, and the fruits can be harvested earlier from the low nodes of the plant. The correlation analysis showed that the more the number of fruits per plant, the more the number of marketable fruits, the greater fruit weight, and the fruits can be harvested from the higher nodes of the plant. Fruits from Taiwanese accession had the largest fruits with mulch, with or without trellis.

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