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Potential Productivity of Hydroponically-grown Tomatoes in the Genting Highlands, Malaysia

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ABSTRAK

Lima penanaman percubaan telah dijalankan untuk menguji potensi pengeluaran tomato di dalam sistem hidroponik kultur air dalam di Genting Highlands, Malaysia (1,200 m atas paras laut). Tanaman tomato dibenarkan mempunyai hanya satu batang utama yang dilatih mengikut sistem berlapis atau sistem tegak. Varieti-verieti tak berterusan (determinate) dan berterusan (indeterminate) yang mengeluarkan buah-buah yang besar, sederhana dan kecil digunakan di dalam kajian ini. Tanaman yang ditanam mengikut sistem berlapis tahan selama 9 bulan; tetapi jikalau ia hanya ditanam untuk selama 6 bulan, dua kali penanaman dapat dilakukan setahun dengan memberi potensi hasil sebanyak 252-288 tan metrik/ha/tahun. Sistem tegak yang mengeluarkan ketiga-tiga saiz buah tomato mengeluarkan tiga penanaman setahun dengan anggaran hasil sebanyak 210-248 tan metrik/ha/tahun. Varieti-varieti tak berterusan mengeluarkan hasil-hasil yang berbeza; pengeluaran sebanyak tiga kali setahun akan memberi hasil sebanyak 131-216 tan metrik/ha/tahun. Hasil-hasil yang diperolehi daripada sistem hidroponik ini adalah lima hingga 10 kali ganda lebih tinggi daripada hasil yang dapat diperolehi mengikut cara tanaman tradisional sama ada di tanah tinggi atau di tanah rendah di Malaysia.

ABSTRACT

Five trials were carried out to assess the potential productivity of tomatoes in a deep culture hydroponic system in Genting Highlands (1,200 m a.s.l.), Malaysia. The tomatoes were maintained as single-stemmed plants using the layering and vertical methods of plant training. Determinate and indeterminate varieties producing large, medium and small-sized fruits were investigated in these trials. Under the layering system, the indeterminate plants could last for nine months but if crops were kept for only six months, two crops per year could be produced with a potential yield of 252-288 ton/ha/year. The vertical system could produce three crops per year with a range of 210-248 tonnes/ha/year for the three sizes of fruits. The determinate varieties produced a wide range of yields and, with three crops per year, a yield range of 131-216 ton/ha/ could be expected. The yields obtained in the tested hydroponic system were at least five to ten times higher than those obtained from traditional soil cultivation under highland and lowland conditions in Malaysia.

INTRODUCTION

Tomatoes (*Lycopersicon esculentum* Mill), an important vegetable crop in Malaysia, is traditionally grown in soil, in the Cameron Highlands (1,000 to 1,500 meters above sea level). Tomato cultivation using hydroponics or soilless culture techniques, widely practised in Europe, have not gained acceptance by local commercial growers. One of the reasons for this is the high initial capital costs and the fear of not achieving sufficient productivity to off-set the high initial capital outlay. There is thus the need to assess the potential productivity of tomatoes under a hydroponic system and to monitor potential problems that may affect the productivity of the crop.

The following is a report on some trials carried out to determine the potential productivity of tomato, as a crop, in a hydroponic system (Kyowa Hyponica) using a number of

commercially available tomato varieties. Determinate and indeterminate varieties were grown; the former being allowed to grow until the terminal inflorescence was produced while the latter varieties were trained as single-stemmed plants using the vertical or layering techniques.

MATERIALS AND METHODS

Location

The trials were carried out in a glasshouse using the hydroponic deep culture system at the Hydroponic Unit, Universiti Pertanian Malaysia, Genting Highlands. This unit is situated at 1,200 meters above sea level and has similar climatic conditions to the Cameron Highlands where tomatoes are normally cultivated in Malaysia. The average day and night temperatures in the Genting Highlands are around 22°C and 17°C, respectively. Although temperatures vary very little throughout the year, days are more misty and windy in December and January with wind gusts of around 14-18 m/sec. In the glasshouses, however, air temperature can reach up to 35°C on bright sunny days although day temperatures of 25-30°C can be considered average.

The Hydroponic System

The Kyowa Hyponica deep culture hydroponic system (previously described by Lim and Wan 1984; and Wan and Lim 1984) was the system used in the trials.This system consists of troughs (1 m × 3 m × 10 cm) laid end to end, 11 troughs per row with one meter spacing between each row of troughs. Each glasshouse of 1,000 m^2 held 128 troughs each planted with 14 plants. This gave a planting density of 4.7 plants per m^2 within each trough; but if paths between the rows were included, the overall planting density was 1.8 plants per m^2.

Nutrient Supply

The composition of the nutrient solution to the plants is as shown in Table 1. Nutrient solution was supplied to each trough from an underground tank by a submersible pump and continuously recirculated at the rate of 4 1/min per trough until the plants were two months old. Thereafter the rate of nutrient flow was increased to 6 1/min. These comparatively fast flow rates were considered necessary to maintain a high level of dissolved oxygen within the 45 mm deep solution (for the first two months) and the 25 mm deep solution for the subsequent months.

TABLE 1
Composition of nutrient solution
(From Lim and Wan, 1984)

Major nutrients	mg/l	Minor nutrients	mg/l
Nitrogen	206	Boron	0.54
Phosphorous	62	Zinc	0.05
Potassium	386	Manganese	1.30
Calcium	136	Copper	0.01
Magnesium	49	Molybdenum	0.01
Iron	3.82		

The electrical conductivity (E.C.) and pH of the nutrient solution were monitored daily and maintained between 2.1 to 2.4 mS/sec and 5.5 to 6.5, respectively. There was little fluctuation of E.C and pH of the nutrient solution as the nutrient storage tank contained 15 m^3 of solution in addition to 15 m^3 in the troughs and pipes.

Cultural Techniques

There is very little local experience in the hydroponic cultivation of tomatoes. In order to assess the overall potential production in a hydroponic system, as many available tomato varieties as possible were used in order to give a better picture of the overall potential of the crop within the system. The varieties grown were supplied by various seed companies but it must be noted that the trials were not laid out to compare performance of the varieties.

Seeds were sown directly in 2.5 cm gravel aggregates in perforated pots placed in the troughs and supplied with continuously recirculating nutrient solution for three weeks. Germination occurred within one week. Two weeks after germination, selection was carried out to retain only one normal seedling per pot and these were then transferred to the main cultivation troughs with PVC mulching to prevent light from reaching the root regions. Each trough contained plants of the same variety and the troughs were randomly allocated within each row. A summary of the trials carried out is shown in Table 2.

TABLE 2
A summary of the trials

Trial No	Date of Sowing	Duration of cropping (days)	Training system	No. of varieties	Plants per variety	Size of fruits*
1	5/5/86	134 - 195	Layering	4	70	M
2	16/2/87	50 - 56	Vertical	5	14	S
3	16/2/87	46 - 56	Vertical	12	14	M
4	16/2/87	46 - 50	Vertical	7	14	L
5	16/2/87	44 - 56	Vertical (determinate)	7	14	L,M,S

* Size of fruit : L = Large, M = medium, S = small.

Three methods of plant training were tested. For the indeterminate varieties the plants were trained vertically, into single stemmed plants, using rafia string. This was carried out by manual removal of the side shoots. In Trial No. 1, the plants were maintained at a height of the 1.7 m frame and lowered and layered twice weekly to maintain this constant height (Walls 1977). Pruning of the lower leaves that did not subtend any fruit was regularly carried out when harvesting commenced. This method of plant training allowed the plants to be retained for up to nine months.

The second training technique practised in Trials No. 2, 3 and 4 used the vertical system whereby the indeterminate varieties, also trained as single-stemmed plants, had their growing points removed upon reaching the top of the frame at 1.7 m with around 6 or 7 trusses. Under this system, the plants were removed once all the trusses had been harvested.

In the third system, Trial No. 5, the plants were also trained as single stemmed plants and supported with rafia string until a final determinate inflorescence terminated further growth.

To assist in fruit-set, opened flowers were sprayed with a 0.5 percent solution of sodium-4-chloro-hydroxy phenoxy acetate ("Tomatlane") on alternate days.

RESULTS

Trial No. 1: Production under the Layering System

Under this system, the crop remained in production for seven months for varieties "Firedance" and "Precodor" and around nine months for varieties "Gross Lisse" and "Pink FR26". For the former two varieties, the residual effects of the fruit inducing hormone used could be discovered; the young leaves produced in the later stages were deformed, elongated and leathery with overall reduction in leaf area. As a consequence of this reduced leaf area, the fruits formed in the later trussess were unfilled, possibly indicating an insufficient supply of assimilates.

Management of the crop under this layering system was laborious as the plants had to be lowered twice weekly to maintain a constant height. The lower leaves which no longer subtended the fruit had to be regularly removed. When pruning was delayed, air circulation within the canopy was reduced resulting in increased infestation of powdery mildew (*Erysiphe* sp.). This infestation could, however, be easily controlled by the use of Triforine ("Saprol") at the rate of 0.19 ml a.i./litre of water.

With regard to insect pests, only the occasional caterpillar was observed and was removed by hand. Thus, no insecticide application was necessary for the crop.

The mean yield for the varieties under this system of training (Table 3) was 15.16 kg/plant (S.E. = 0.375) for the longer duration crop (194 days) and 9.51 kg/plant (S.E. = 0.057) for the shorter duration crop (135 days). Average fruit production per day of cropping was between 70-80 g/plant. If the crop had been retained for only six months to overcome some of the management problems i.e. 100 days of cropping after commencing harvest at around

TABLE 3
Production of indeterminate tomato varieties under the layering system

Variety	Seed Company	Last harvest d.a.p.*	Total cropping days	Yield kg/plant	Production g/cropping day	No of fruit/ plant	Weight/fruit (g)
GrosseLisse	T.S	274	195	15.69	80.5	98	160
Pink-FR26	Sakata	274	193	14.63	75.8	84	173
			Average (a)	15.16	78.2	91	166.5
			Std. Error	0.375	2.350	4.9	4.59
Firedance	Sakata	213	136	9.59	70.5	56	172
Precodor	Royal Sluis	211	134	9.43	70.4	68	138
			Average (b)	9.51	70.5	62	155
			Std. Error	0.057	0.04	4.2	12.0

* d.a.p. = days after planting

80 days after sowing, a yield of 7.0 to 8.0 kg/plant would have been expected for each season. Thus, with two crops in a year, an annual yield of 14 to 16.0 kg/plant (252-288 tonnes/ha) could be expected.

Trials No. 2, 3 and 4: Production under the Vertical System (Indeterminate Varieties).

Under the vertical system, the plants produced around six to seven trusses upon reaching the top of the frame when their growing points were removed. This form of management was less laborious than the layering system as the plants were kept for only 120-130 days. However, there was no residual effect of the fruit hormone used nor any build-up of fungal or insect pests. To aid crop aeration the lower leaves subtending ripe fruits were removed once harvest commenced for each truss.

For all the varieties tested, harvest commenced at around 75 days after sowing and lasted around 45 to 55 days. Mean yield for the small fruited varieties (Table 4) was 4.27 kg/plant (S.E = 0.266) i.e. 79.6 tonnes/ha. For varieties with medium-sized fruits (Table 5), the mean yield was 3.90 kg/plant (S.E = 0.158) i.e. 70.2 tonnes/ha. For the large beef-steak varieties, the mean yield (Table 6) was 4.58 kg/plant (S.E = 0.241) i.e. 82.6 tonnes/ha. Thus, the mean yield between the three types of tomatoes producing either small, medium or large fruits did not vary greatly and ranged from 70 to 83 tonnes/ha/season. As there is very little climatic variation throughout the year, three crops could be grown per year enabling a total of around 210 to 248 tonnes/ha/year to be produced under this vertical training system.

TABLE 4
Production of small sized tomatoes from indeterminate varieties under the vertical system

Variety	Seed Company	Yield kg/plant	No of fruit/ plant	Weight/ fruit (g)
85006	T.S	5.05	59	85
Nortona	Bruinsma	4.86	51	96
Virona	Bruinsma	4.01	39	102
Zircon	Royal-Sluis	4.00	35	116
Nadir	Nunhhems	3.45	38	90
	Average	4.27	44.4	97.8
	Std. Error	0.266	4.07	4.80

Trial No. 5. Production from Determinate Varieties

The determinate varieties reached a height of only 0.8 m when the terminal inflorescence was produced. As minimal pruning was carried out, management of the crop was much easier.

TABLE 5
Production of medium sized tomatoes from indeterminate varieties under the vertical system

Variety	Seed Company	Yield kg/plant	No of fruit/ plant	Weight/ fruit (g)
Aratino	Van den Berg	4.73	33	145
Granada	Bruinsma	4.53	37	122
Arletta	Royal-Sluis	4.38	29	155
Senator	Bruinsma	4.29	23	190
Dombitto	Bruinsma	3.99	23	174
Red King	Sakata	3.78	23	168
Parana	Royal Sluis	3.71	29	127
Pink-FR-26	Sakata	3.66	21	175
Turquesa	Royal Sluis	3.61	29	125
Bunter	Hurst	3.33	26	130
Fire-dance	Sakata	2.89	17	168
	Average	3.90	26.4	152.6
	Std. Error	0.158	1.65	6.90

TABLE 6
Production of large sized tomatoes from indeterminate varieties under the vertical system

Variety	Seed Company	Yield kg/plant	No of fruit/ plant	Weight/ fruit (g)
Master No.2	Takii	5.90	27	215
Caruso	Van den Berg	5.22	22	232
Camil	Nunhems	4.70	23	201
Rakata	Van den Berg	4.55	17	262
85007 Grosse	T.S	4.52	21	217
Lisse	Sakata	4.27	17	251
Rampo	Sakata	3.84	15	252
FR-26	Sakata	3.63	13	286
	Average	4.58	19.4	239.5
	Std. Error	0.241	1.54	9.30

Harvest commenced around 80 days after planting and cropping lasted around 45-55 days. Variety "TS 841" was a large beef-steak type with fruits around 300 g in weight. "Invictus" and "Narita" produced medium sized fruits averaging 130 g and the remaining varieties gave small fruits weighting around 70-87 g.

Mean yield per plant (Table 7) which was 3.17 kg/plant (S.E = 0.222) was significantly lower than the indeterminate varieties. Three crops could be grown per year with an expected yield of 171.2 tonnes/ha, with a range of around 131 to 216 ton/ha/year.

TABLE 7
Production of tomatoes from determinate varieties

Variety	Seed Company	Yield kg/plant	No of fruit/ plant	Weight/ fruit (g)
841	T.S.	3.97	13	299
Invictus	Hurst	3.21	23	138
Narita	Royal Sluis	3.08	24	130
Artella	Royal Sluis	4.00	46	87
Freya	Hurst	3.09	35	87
MT 11	MARDI	2.44	34	71
Aragon	Royal Sluis	2.43	32	77
	Average	3.17	29.6	–
	Std. Error	0.222	3.71	–

DISCUSSION AND CONCLUSION

As expected, production per year from indeterminate varieties was much higher under the layering system than with the vertical system as the layering system allowed a longer cropping season/year (an additional 80 days) than the vertical system. Crop management using the layering system was more difficult but became easier with experience. For the determinate varieties, the average yield was lower than with the indeterminate varieties. However, easier crop management may compensate for the reduced yield.

It can be concluded that yields of tomatoes cultivated hydroponically, for any of the training systems investigated, are at least 5-10 times higher than those obtained from the

traditional method of cultivation in the soil. Tomato yields in the Cameron Highlands are only around 20-35 tonnes/ha/season (Nordin *et al.* 1986) whereas those from the lowlands are around 28.5 tonnes/ha (Haron 1987) to 30.8 tonnes/ha (Vimala 1985). These crops, unlike those under the present hydroponic system, are grown without protection and are exposed to the vagaries of weather. They are not sprayed with hormone to assist fruit set and development and are normally affected by fungal pests such *Phytophthora infestans* (Nordin *et al.* 1986).

Under the present investigation a maximum yield of around 280 tonnes/ha could be expected. This is still lower than that typically obtained in the South coast of the United Kingdom which is around 328 tonnes/ha or higher in some cases (van de Vooren *et al.* 1986). With further selection of varieties more suited to the tropics and experience with the crop and nutrient manipulations, higher tomato yields can be anticipated. This may eventually convince the local growers to choose hydroponics as a commercial method for the cultivation of tomatoes.

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