Plant Training and Spatial Arrangement for Yield Improvements in Greenhouse Cucumber (*Cucumis sativus* L.) Varieties

M.G.S. Premalatha[1], K.B. Wahundeniya[2], W.A.P. Weerakkody[1]
and C.K. Wicramathunga[2]

Postgraduate Institute of Agriculture
University of Peradeniya
Peradeniya, Sri Lanka

ABSTRACT. *Greenhouse cucumber (*Cucumis sativus* L.) varieties are very sensitive and respond differently to training and pruning methods because of their high degrees of perishability and differences in branching and flowering behaviors. Several salad-type cucumber varieties that are popularly grown using protected crop technologies in Sri Lanka and which yielded well in a previous screening trial, were grown under average greenhouse conditions in drip fertigated grow-bag culture using three training/pruning treatments with spatial arrangements. The three training treatments were the Umbrella system at 60 cm × 60 cm spacing, V-system at 60 cm × 60 cm spacing and coiling of stem base around the growing bag (New system) at a 45 cm × 60 cm spacing. Cucumber varieties were Thunder, Sakura and Efdal.*

Vegetative growth, reproductive growth, yield and quality parameters were affected by both treatments, but not by the interaction. The newly introduced system of lowering and coiling of the main stem around the grow-bag after pruning the lower leaves was better than the two conventional pruning systems in terms of leaf growth, total yield and marketable yield. Meanwhile, the variety, Sakura performed better than varieties, Thunder and Efdal, in terms of total and marketable yields mainly due to the comparative success in flowering, fruit set and final fruit number. The fruits of Sakura were more attractive due to their medium size, cylindrical shape and smooth skin texture. In spite of less attractive fruit qualities in Thunder and formation of more abnormal fruits in Efdal, they also demonstrated a significant yield potential and in some cases, resistance to powdery mildew.

INTRODUCTION

Protected culture of greenhouse vegetables is an emerging sub-sector in the Sri Lankan horticulture sector. It has been identified as a perfect solution for many problems faced by the sector in recent times. However, the sub-sector suffers from many basic technical and institutional problems, hindering further expansions and losing economic prospects for the growers (Gunasena, 2000; Weerakkody *et al*., 2001; Niranjan *et al*., 2005). Among the most widely grown greenhouse vegetable crops, salad cucumber (*Cucumis sativus* L), which is also referred to as green or slicing cucumber, leads in production and marketing statistics in Sri Lanka in recent years (PAEA, 2005) and generally in major cucumber producing countries (Wittwer and Honma, 1979). However, greenhouse

---

[1] Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

[2] Horticultural Crop Research and Development Institute, Gannoruwa, Peradeniya, Sri Lanka.

cucumber farmers often encounter many problems regarding the agronomy of the crop because of the existing gaps in the local knowledge base. Some of the key controversial issues in this concern are the selection of varieties and appropriate systems of plant manipulation to match with variety specific branching habits.

In greenhouse vegetable production, profits are greatly dependent on the quantity and quality of the yield. Pruning of leaves and side shoots contribute to the ultimate yield in various ways. Training maximizes the plant's ability to obtain the sunlight needed for growth (Guo *et al.,* 1991). It is also important to maintain adequate air movement around the plant to reduce risk of fungus and insect problems (http://www.hydro-gardens.com). A dense canopy of leaves shades the fruits, causing them to be pale (Hebert, 1990). Relatively high perishability has made cucumber plants to be more vulnerable to intensive crop management and unfavorable environmental conditions. Excessive pruning of leaves sometimes causes the plants to cease producing flowers. Therefore, it is important to maintain sufficient foliage on the plant for adequate rates of photosynthesis. Manipulation of canopy architecture through pruning and training together with appropriate spatial arrangements has been identified as key management practices for getting maximum marketable yields from greenhouse crops (Cebula, 1995; Guo *et al.*, 1991; Lorenzo and Castilla, 1995).

Several F1 hybrids of cucumber, namely Thunder, Sakura Efdal and Zena have been proven as promising cucumber hybrids through a screening trial under the same environmental conditions (Chandima *et al.*, 2006). The most vegetable growers practice the "umbrella system" to prune and train greenhouse cucumber. There are some drawbacks of this system such as slow growth of two laterals that are required to form the umbrella shape after decapitating the main stem. Hochmuth *et al*. (1996) also reported that pinching the growing point resulted in a delay in new growth. The umbrella system appears not to be suitable for some greenhouse cucumber varieties such as Thunder, which bear more female flowers on lateral branches than on the main stem (Chandima, *et al*., 2006; PAEA, 2005). Comments of Florescu and Molea (1989) on the need of different plant densities and training and pruning systems for different varieties confirm this phenomenon. Furthermore, wider space requirement of this system is a negative point in relation to crop productivity and high cost of protected culture.

Based on these facts, the research project was conducted to examine alternative training and pruning systems with their specific spatial arrangements to rearrange the plant density for a higher plant growth and yield for selected promising cucumber varieties.

MATERIALS AND METHODS

The experiment was conducted in a top-vent type film plastic greenhouse (having a floor area of 110 m^2) at the Horticultural Crop Research and Development Institute, Gannoruwa during January - July 2005. It was designed as a two factor factorial experiment and laid-out as a Complete Randomized Design (CRD) with three replicates. Three training and pruning systems named Umbrella system, V-system and the New system, having system-specific plant spacing, were tested for three F1 hybrids (varieties) of salad cucumber, namely Thunder, Sakura and Efdal (nine treatment combinations). The plot size was 2.4 m × 1.2 m, consisting of 8 plants in the first two systems and 10 plants in the New system.

Plants were arranged in a double row system. Descriptions of the pruning systems are as follows.

Umbrella system: The main stem was allowed to grow vertically along the supporting string up to the overhead wire (2 m above the ground level). The growing point was removed after producing two leaves above the overhead wire. Two healthy and vigorous lateral branches at the top of the vine was allowed to grow along the wire for about 15 cm and trained to grow downwards. All other laterals were removed (Fig. 1). Plants were arranged in a 60 cm × 60 cm spacing.

"V" system: The main stem was allowed to grow along the supporting string and the growing point was removed at the 6th leaf stage. The two emerging lateral branches were trained into a "V-shape" onto the overhead wire (Fig. 1). Other practices were similar to the Umbrella system.

New training system: The main stem was allowed to grow vertically along the supporting string towards the overhead wire as in the case of the Umbrella system. All lateral branches were removed up to a height of 45 cm. When the plant reached the overhead wire, the supporting string was untied at the top and the whole vein was lowered by coiling the basal part of the stem around the grow bag and this practice was repeated periodically. Healthy and vigorous side branches above 45 cm from the base of main stem were allowed to produce one leaf and one fruit before pinching. All unhealthy or less vigorous branches were removed (Fig. 1). Plants were arranged in a spacing of 45 cm × 60 cm.

In all three training systems; tendrils, over-matured leaves, all male flowers, all female flowers up to 45 cm height of the main stem and excess flowers of flower clusters were pruned frequently.

Partially burnt paddy husk and clean, but old coir dust were mixed in a 1:1 ratio to prepare the planting medium. It was filled into and 21.2 l (35 cm height and 30 cm width) containers (grow-bags) made of 300 gauge black polythene. Grow-bags were treated with l g/l solution of fungicide, Homai (Thiophanate methile 50% + Thiram 30%) solution and kept for 3 days. Direct seeding was done (one seed per grow bag) followed by adequate watering. Seeds started to germinate within 3 days. After emergence of the first true leaves, Albert's fertilizer of Chemical Industries Colombo Ltd. (CIC) was applied and continued according to the dosages given in Table 1. Dissolved fertilizer was supplied through a drip system, following the application time based control of fertilizer dosage and discharge volume. In addition, a concentrated calcium nitrate solution (10 g/l) was sprayed to foliage weekly during the reproductive stage.

Table 1.   **Dosage of fertilizer and discharge volume of irrigation water.**

Growing stage	Concentration of the nutrient solution (g/l)	Volume (ml/plant/day)
Seedling stage	2	100
Vegetative stage	2	200
Flowering stage	3	200
Fruit bearing stage	4	250

Due to high temperature, all the plants at reproductive stage were severely infected with red mites. Nissorun (Active Ingredient (AI) hexythiazox 10% WP) and Selecron (AI Profenofos 500 g/l EC) were sprayed alternatively to control mites' population. Daconil (AI Chlorothalonil 500 g/l SC) was sprayed to control powdery mildew from the flowering stage onwards at two-week intervals.

Plants located in the middle of each plot were sampled. Plant physiology was assessed in terms of rate of photosynthesis (through air-exchange rate) and rate of sap flow (transpiration rate) at three distinct times during the crop growth using a LI-COR LI-6400 Portable Photosynthesis System. The environmental conditions were recorded in terms of temperature and RH continuously throughout crop growth, and light intensity periodically. Vegetative growth was assessed in terms of the Leaf Area Index (LAI) while reproductive growth was assessed using the rate of flower (male and female) initiation (earliness of flowering), total flower number, percentage success in flowering and fruit set (with respect to number of nodes). Yield at the early stage, fruit weight and number of fruits were measured while abnormal fruits were used to estimate the marketable yield. The fruit quality was assessed in terms of fruit weight, fruit size (circumference and length) external and internal color (using RHC charts), brix value and juice pH (Chandima *et al.*, 2006). Pest and disease incidence were also assessed to evaluate the treatment effects. Statistical analyses were done through ANOVA and mean separation procedures using appropriate SAS procedures (SAS, 1999).
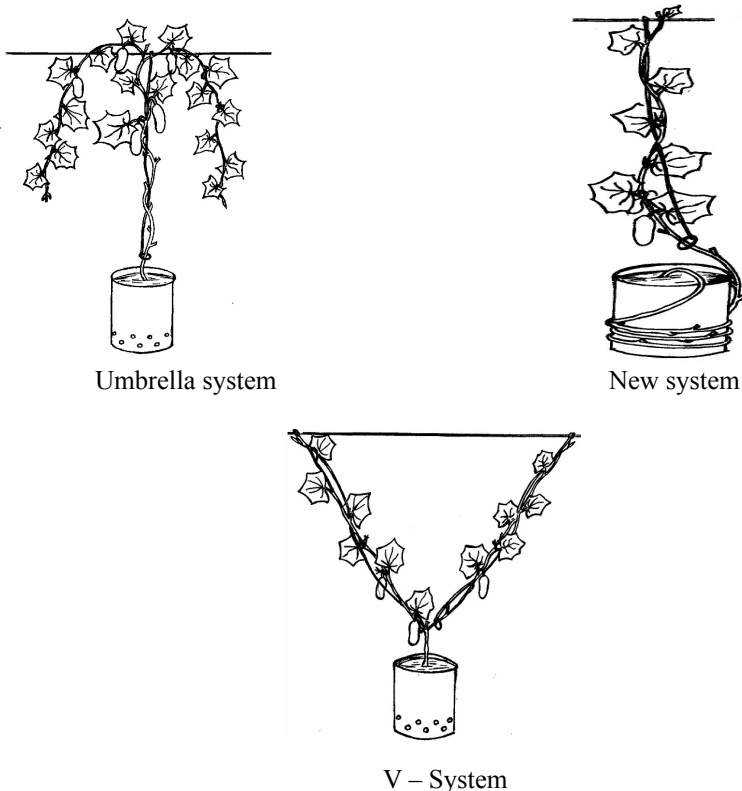

Umbrella system   New system

V – System

Fig. 1. **Training and pruning treatments.**

RESULTS AND DISCUSSION

Micro climatic conditions

The mean day temperature inside the protected house was 32.7 ± 2.8^0C during the growing period while minimum and maximum temperatures were 22.1 ± 0.8^0C and 38.3 ± 1.5^0C, respectively. The light level was 2.72 ± 0.73 klux in the morning, 5.17 ± 2.86 klux at midday and 3.92 ± 2.13 klux in the evening. However, these mean temperatures and light intensities fall out of the favorable range for salad cucumber ($24\text{-}27^0$C and 5.5 klux) as specified by Johnson and Hickmun (1984) and http://www.hawardresh.com. The daily mean relative humidity was $59.4\pm12.7\%$ inside the protected house during the daytime.

Vegetative growth

LAI, determined just before flowering (4 Weeks After Planting, WAP) was significantly different in the training systems. The highest LAI (1.6) was found in the New system (Fig. 2). The LAI of varieties and the interaction effects were not statistically significantly different.
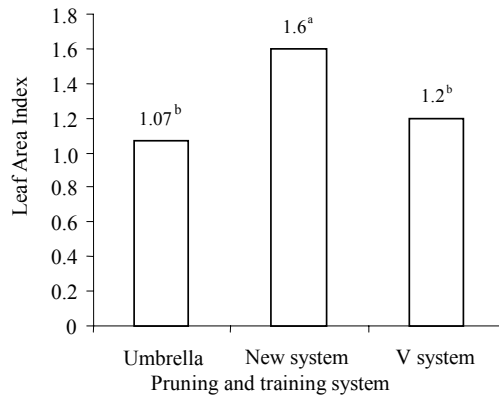

Fig. 2.   Variation of LAI with pruning and training system at 4 WAP.
Note: The same letters in superscripts are not significantly different.

Flowering and fruit set

The rate of flower initiation was not significantly different among treatments or the interactions between treatments. The mean number of days to 50% flowering was 33.4 ± 0.9 days. Only one variety, Thunder formed flowers at the rate of 0.28 male to female ratio. In this variety, the majority of male flowers (88.4%) was formed during early flowering.

Meanwhile, ratios of "fruits to flowers" and "fertile nodes to total nodes" were significantly different among varieties and also among training systems. Sakura was the most successful variety, having a 0.5 ratio of fruits to flowers and 0.4 ratio of fertile nodes to total nodes while others ranged between 0.3-0.4 for fruit to flowers and 0.27-0.33 for fertile nodes to total nodes. Therefore, it was clear that Sakura was able to form more flowers and

then convert them to fruits more efficiently than the other two varieties. Excessive flower drop due to the high temperature that prevailed during the growth period could be one of the main reasons for lower fruits to flower ratio at the early stage.

The Umbrella system had a significantly higher fruits to flower ratio (0.50) than the others (0.33) while both Umbrella system and V-system formed higher ratio of fertile nodes to total nodes (0.40) compared to the New system (0.25).

Yields and yield components

There were significant differences among varieties in all recorded yield parameters. Sakura produced the highest total yield per plant as well as per square meter. This yield advance seems to be caused by higher number of fruits per plant (Table 2).

Early yields (up to 4th week of harvesting) of all three varieties were comparatively higher than at mid and late harvesting stages (Fig. 3). The total harvesting period was more or less similar in all the varieties (73±2 days).

Variety, Thunder also produced higher yields at the late harvesting stage. Sakura provided a higher yield at the early harvesting stage, which decreased gradually (Fig. 3). The lowest abnormal fruit percentage was found in Sakura and Thunder (12.5-15.5%). The highest total yield (9.7 kg/m^2) and marketable yield (9.2 kg/m^2) per unit area were obtained from the training New system (Table 2). However, it was lower than that of the Umbrella system in terms of per plant yield. Comparative results and earlier reports on some spacing trials (Cebula, 1995; Gaye *et al*., 1991; Stoffella and Bryan 1988) showed that higher yield per unit area in the New system can be considered as a result of dense planting.

Table 2.   Variations in yield and yield components with varieties and training systems.

Treatments	Total yield		Marketable yield		Number of fruits/plant		Early yield to total yield	Abnor-mal fruit (%)
	kg/plant	kg/m^2	kg/plant	kg/m^2	Total	Marketable		
Varieties:								
Thunder	2.32[b]	7.22[b]	2.18[b]	6.72[b]	10.82[b]	9.14[b]	0.40[b]	15.60[b]
Sakura	3.32[a]	10.17[a]	3.07[a]	9.63[a]	18.84[a]	15.97[a]	0.45[b]	12.58[b]
Efdal	2.44[b]	7.52[b]	2.30[b]	7.05[b]	11.31[b]	8.86[b]	0.56[a]	21.81[a]
Training system:								
Umbrella system	2.82[a]	7.86[b]	2.67[a]	7.35[b]	13.64[a]	11.58[a]	0.46[a]	16.35[a]
New system	2.60[b]	9.70[a]	2.51[a]	9.21[a]	12.37[a]	10.50[a]	0.51[a]	16.27[a]
V system	2.65[b]	7.34[b]	2.30[a]	6.84[b]	14.30[a]	11.89[a]	0.44[a]	17.38[a]
CV%	20.76	19.19	21.35	20.15	19.40	25.03	17.03	18.40

Note: The means having the same letter as superscripts are not significantly different at p=0.05.

The positive effect of the decapitation of main stem on the yield of cucumber suggested by Dobrzanska (1998) could be applied to comparatively high per plant yield in the Umbrella system. The opposite results have been observed by Hochmuth *et al*. (1996) where higher yields and better quality in most instances were obtained from training

cucumber vine without removing growing point. Figure 4 shows the yield variation in different training systems over time. Hong (2000) reported that early yield depends significantly on the training system and spacing. The New system produced higher yields both in early and late harvesting stages and a lower yield at mid harvesting stage when compared to other two systems. The yield of V-system was higher at the early stage, but fluctuated afterwards. In Umbrella system, the weekly yield was comparatively stable.
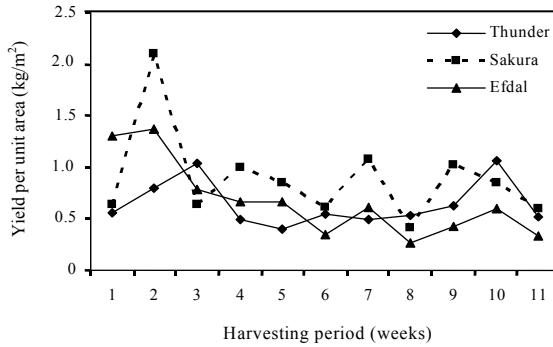

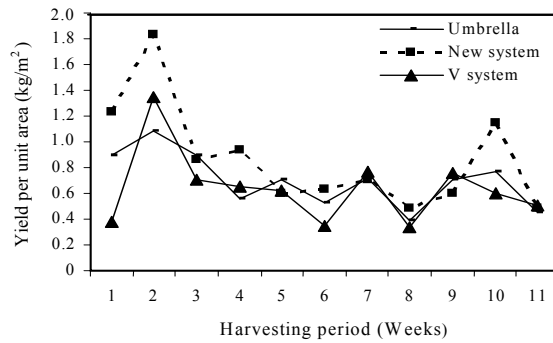**Fig. 3.   Yield variation of varieties during the harvesting period.**

Fig.4.   Yield variation of different training systems during the harvesting period.

Fruit quality

Fruit quality did not change due to interactions between variety and training systems. External quality parameters (Table 3) were significantly different among varieties. Due to a greater length and breadth (circumference), fruits of varieties, Thunder and Efdal were the heaviest and largest. Fruits of Sakura were comparatively short, but wide (stout) while varieties, Efdal and Thunder formed rather slender fruits. Meanwhile, the fruits of Efdal were less uniform in size and shape, leading to form more abnormal fruits. The lowest fruit weight (198 g/fruit) was found in Sakura.

Table 3. **Variation of weight, length and circumference of cucumber fruits with the variety and training system.**

Treatments	Fruit weight (g/fruit)	Fruit circumference (cm)	Fruit length (cm)
Varieties			
Thunder	239.22[a]	15.01[a]	19.64[a]
Sakura	198.22[b]	13.96[c]	17.52[b]
Efdal	262.70[a]	14.34[b]	19.86[a]
Training system			
Umbrella system	240.30[ab]	14.60[a]	18.51[a]
New system	245.89[a]	14.65[a]	19.10[a]
V system	214.00[b]	14.06[b]	19.42[a]
CV%	11.58	2.21	4.75

Note: The means having the same letter as superscripts are not significantly different at $p = 0.05$.

There was no significant difference in fruit length among training systems. However, lower breadth of fruits caused the formation of smaller fruits in the V-system. Cebula (1995) observed reduction in fruit weight of the early harvested cucumber under higher plant densities. However, it was not observed in this experiment. Therefore, the spacing assigned for the new system appeared to be acceptable. This is also confirmed by the results of some earlier experiments where 0.45-0.63 m^2 (5-7 ft^2) of greenhouse space has been recommended for cucumber under adequate sunlight conditions (Hochmuth *et al*., 1996). Either reduction of size of plant frame or overlapping of vines, which are considered as the underlying reasons for the negative influence of close plant densities on the yield and fruit size (Lower and Edwords, 1986), could not be observed in the New system. Fruit breadth appears to be more controlled by environmental factors while fruit length appeared to be a varietal character of some fruit-vegetables such as cucumber and bell pepper (Chandima *et al*., 2006; Qunchu, 1995). Since fruit breath is affected by dry matter partitioning, drastic changes done in the canopy architecture in the V-system by dividing into two stems at a relatively younger stage appeared to be unfavorable for dry matter partitioning to fruits sink. At the same time, higher LAI could have favorably affected the same phenomenon in the New system, despite the negative impact of close spacing. There were no significant main effects or interaction effects of treatments on most of the internal quality parameters (Table 4).

Plant physiology

Rate of photosynthesis was measured just before flowering, at early harvesting and late harvesting. Rate of photosynthesis did not significantly vary with varieties or training systems, except in upper leaves during the late harvesting stage. The mean rate of photosynthesis just before flowering was 22.3±8.5 μmols of $CO_2/m^2/s$. It was 15.8±6.0 μmols of $CO_2/m^2/s$ in the upper canopy and 5.0±3.0 μmols of $CO_2/m^2/s$ in the lower canopy at early harvesting. At late harvesting, the highest rate of photosynthesis was found in variety, Sakura justifying for its comparatively higher yield at late stages of harvesting.

Table 4. **Fruit quality of cucumber varieties.**

Varieties	Fruit shape	Peel color (RHS charts)	Ex. app.[*]	Spines	Taste
Thunder	Tapering to end	Green group 137 B-C	Dull	More and rough	Watery, bitter in some case
Sakura	Cylindrical	Green group 137 B-C	Shiny	Less and smooth	Watery not bitter
Efdal	Cylindrical but vary	Green group 137 C-D	Shiny	Less and smooth	Watery not bitter

Note: [*] External appearance.

Transpiration rate in the upper part of the canopy during the early harvesting stage and lower part of the canopy during the late harvesting stage were significantly different among varieties. In both stages, the lowest transpiration rate was found in Thunder (4.91 mmol of $H_2O/m^2/s$) whereas the mean transpiration rate was 6.85 ± 0.49 mmol of $H_2O/m^2/s$.

At the late harvesting stage, transpiration rate was significantly different among training systems in both upper and lower parts of the canopy. This could mainly be due to changes in the density of foliage under different plant training systems and spacing which seriously change the ventilation and humidity in and around the canopy (Robinson, 1999). The highest transpiration rate was recorded in the New system of training, testifying once again for a better yield of the New system. The lowest value in the upper canopy was found in the V-system while the Umbrella system produced the lowest value in the lower canopy. Hence, manipulation of the canopy architecture through different training and pruning systems appeared to have exerted a significant influence on plant physiology through the changes in rate of sap flow within the plant. These observations closely match the comments of (Robinson and Walters, 1999) on the effects of ventilation and humidity under variable plant density on the rate of transpiration and CO_2 exchange rate of plants.

Pests and disease incidence

All the cucumber vines were attacked by red mites (*Tetranychus* spp.) irrespective of treatment effects since the early harvesting stage. Plants were infected with powdery mildew (*Sphaerotheca fuligenea*) during the mid harvesting stage. During the early stage of infection, both Sakura and Efdal were severely infected, compared to Thunder. However, it was not significantly different in the training systems. At later stages, all the plots were infected with the disease. As stated by Staff (2003) on the close relationship of high humidity and spreading powdery mildew and downy mildew (reducing the photosynthetic area of the leaf and exerting a disease stress on the plant), the humidity that prevailed especially during night (80-90%) could have been highly conducive for the proliferation of powdery mildew.

CONCLUSIONS

Compared to conventional training and pruning systems, the New system (coiling of main stem around the grow-bag) with its close spacing, resulted in a higher total and marketable yield per unit area. Higher yields recorded during early and late harvesting stages were mainly due to vigorous vegetative growth and comparatively low percentage of unmarketable fruits. However, lower percentage of flowering and fruiting nodes have exerted a negative impact on the yield potential in this system. Lower fruit breadth could be identified as a limiting factor in the yield components of the V-system. Meanwhile, external and internal fruit quality parameters were barely affected by the training system.

The variety Sakura produced the highest total and marketable yields and was mainly due to the comparatively higher flowering, fruit set and final fruit numbers. Although the fruits were smaller and lighter, Sakura had an acceptable fruit size and shape. In addition, shiny smooth and less spiny skin made it more attractive. Meanwhile, tapering fruit shape, spiny and rough skin, and occasional bitterness in Thunder and formation of more abnormal fruits in Efdal made them comparatively less preferable even though there is a considerable yield potential. In addition, Thunder seems to be more resistant to powdery mildew.

ACKNOWLEDGEMENTS

REFERENCES

Available on, http://www.ipi.arizona.edu.

Available on, http://www.howardresh.com.

Available on, http://www.hydro-gardens.com.

Cebula, S. (1995). Optimization of plant and shoot spacing in greenhouse production of sweet pepper. Acta Hort. 412: 321-328.

Chandima, T.M., Weerakkody, W.A.P., Weerasinghe, K.W.L.K. and Wahundeniya, K.B. (2006). Growth and yield performances of salad (Green) cucumber (*Cucumis sativus*). Pp. 18. *In*: Somasundara, S. (Ed). Proceedings of the International Symposium. 4-8th July, 2006, Sabaragamuwa University, Belihuloya.

Dobrzanska, J. (1998). Effects of plant training system and plant density on earliness of greenhouse cumber. Available on CD Rom, CAB Abstracts.

Florescu, E. and Molea, I. (1989) Contribution to determine some technical factors affecting glasshouse cucumber growing. Lucrai Stiintifice, Institutal Agronomic 'Nicolae Balcescu', Bucuresti, Seria-B, 32: 31-47.

Gaye, M.M., Jolliffe, P.A., and Maurer, A.R. (1991). Row cower and population density effects on yield of bell peppers in south coastal British Columbia. Can. J. Plant Sci. 72: 901-909.

Gunasena, H.P.M. (2000). Protected agriculture innovative approach towards food security. Daily news. 12th June 2000, Lake House, Colombo, Sri Lanka.

Guo, F.C., Fujime, Y., Hirose, T. and Kato, T. (1991). Effects of the number of training shoots, raising period of seedlings and planting density in growth, fruiting and yields of sweet pepper. J. Japan. Soc. Hort. Sci. 59: 763-770.

Hebert, M. (1998). Greenhouse cucumber production. http://www.uaf.edu

Hochmuth, R.C., Leon, L.L. and Hochmuth, G.J. (1996). Evaluation of twelve greenhouse cucumber cultivars and two training systems over two seasons in Florida. Proc. Fla. State. Hort. Soc. 109: 174-177.

Hong, H. (2000). Effect of pruning and spacing on yield and quality of cucumber. http://www.arc-avrdc.org.

Johnson, H. and Hickman, G. (1984). Greenhouse cucumber production. http://aggie.horticulture.tamu.edu.

Lorenzo, P. and Castilla, N. (1995). Bell pepper yield response to plant density and radiation in unheated plastic greenhouse. Acta Hort. 32: 149-158.

Lower, R.L. and Edwards, M.D. (1986). Cucumber breeding. pp. 173-203. *In*: Breeding Vegetable Crops, AVI Publ. Co., Westport, Connecticut, USA.

Niranjan, F., Gunasena, H.P.M. and Sakalasooriya, M.B. (2005). Survey on controlled environment agriculture in Sri Lanka. Sri Lanka Council for Agricultural Research Policy (CARP), 280/7 Wijerama Mawatha, Colombo.

PAEA (2005). Unpublished Report, Protected Agriculture Entrepreneurs Association (PAEA), 134, Uda Irriyagama, Peradeniya, (Sri Lanka).

Qunchu, Z. (1995). Studies on genetic parameters of main characters of hot pepper and application to breeding. Acta Hort. 402: 293-298.

Robinson, R.W. and Walters, D.S.D. (1999). Cucurbits, University Press, Cambridge, U.K. pp. 125-129.

SAS (1999). SAS Software/release 8, SAS institute Inc, Cary, NC, USA.

Staff, O. (2003). Growing greenhouse vegetables. Publication 371, Ministry of Agriculture, Food and Rural Affairs, Ontario.

Stoffella, P.J. and Bryan, H.H. (1988). Plant population influences growth and yields of bell pepper. J. Amer. Soc. Hort. Sci. 113: 835-839.

Weerakkody, W.A.P., Gunarathne, L.H.P. and Peiris, B.C.N. (2001). Final Report: Controlled Environmental Agriculture in the Uva Province in Sri Lanka. Department of Crop Science, P.O. Box. 37, Peradeniya Sri Lanka. Pp. 120.

Wittwer, S.H. and Honma, S. (1979) Greenhouse Tomato, Lettuce, and Cucumbers. http://www.ipi.arizona.edu.