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INFLUENCE OF SUPPLEMENTAL LIGHTING ON REDUCING PRE-MATURE FRUIT DROP AND INCREASING FRUIT YIELD OF GREENHOUSE GHERKINS

KARUNARATHNE, C.L.S.M.[1]*, CHAMINDIKA, B.G.L.[2], WEERAKKODY, W.A.P.[3], WEERASINGHE, K.W.L.K.[4] and HETTIARACHCHI, H.A.N.S.[5]

[1,2,3,4] *Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka*
[5] *Sunfrost Limited, Block 61-62, Export Processing Zone, Biyagama, Sri Lanka*

Abstract

The gherkin industry in Sri Lanka has been experiencing a problem of greater pre-mature fruit drop, leading to lower crop production, hence this research was designed to investigate the influence of supplemental lighting on reducing pre-mature fruit drop and increasing fruit yield of greenhouse gherkins. The study was conducted at a commercial scale production greenhouse in the Low Country Wet Zone of Sri Lanka during Yala season (May - July), 2012 (Experiment I) and early Maha season (September - November), 2014 (Experiment II). In Treatment 1 and Treatment 3, supplemental lighting was provided to extend day length from 5.00 a.m. to 7.00 a.m. and 5.00 p.m. to 7.00 p.m. while in treatment 2, supplemental lighting was provided only under rainy/cloudy weather condition from 7.00 a.m. to 5.00 p.m. In Experiment I, a combination of fluorescent lamps and incandescent lamps were used at the ratio of 2:1, while the same source of lights were used at the ratio of 5:1 for treatment 3 and treatment 1. In Experiment II the light source of treatment 1 and treatment 2 were replaced with LED (light emitting diodes) while treatment 3 was kept similar to treatment 3 in Experiment I. The treatments were laid according to Completely Randomized Design (CRD) with three replicates per treatment, assigning 20 plants per each replicate. Results revealed that fruit drop in both experiments (Experiment I and II) with respect to T1 (40; 109 fruits/plant), T2 (38; 105 fruits/plant) and T3 (44; 111 fruits/pant) has significantly reduced through supplemental lighting when compared to that of control (51; 159 fruits/plant); however, no significant difference was observed among the supplemental lighting treatments related to fruit drop. Grade I fruit yield was significantly ($P \leq 0.05$) greater in T2 (392.8; 885.3 g/plant) as a result of increased overall fruit yield (498.6; 993.3 g/plant) and reduced fruit drop, compared to that of T1 (304.5; 747.5 g/plant) and T3 (324.3; 709.4 g/plant). Given T2 was more cost effective than T1 in Experiment II, we conclude that T2 as the most appropriate supplementary lighting solution to reduce the pre-mature fruit drop and to increase fruit yield of greenhouse gherkin in the low country wet zone of Sri Lanka.

Keywords: Fruit drop, gherkin, grade I yield, greenhouse, supplementary lighting.

Introduction

Gherkin (*Cucumis sativus*) is an important vegetable crop cultivated extensively in sub-tropical and tropical countries. It is a popular commercial cash crop, recently introduced to greenhouse vegetable sub sector in Sri Lanka (Jayaweera *et al.*, 2013). Protected culture could be successfully used to overcome environmental limitations in agriculture enhancing high quality, fresh production while maintaining production stability (Weerakkody, 1998). However, semi-intensive scale protected culture is being practiced in most developing countries aiming to minimize cost factors.

Furthermore, gherkin industry in Sri Lanka has been experiencing a problem of greater pre-mature fruit drop, resulting lower yield/crop production. The reasons would be undesirable external environmental conditions that partially/indirectly affect on growth of indoor

Corresponding Author. Email: karunarathneclsm@gmail.com

plants and competition between sources and sinks of gherkin plant. In addition, lower light intensity levels in greenhouse than the open field condition could be another reason since cucurbits are warm season crops which require plenty of light (Dana and Lerner, 2000). Several attempts have been taken on resolving the problem such as use of exogenous plant growth regulators under controlled environmental condition (Dissanayake *et al.*, 2011); different fertilizer formula under controlled environmental condition (Hettiarachchi, 2012; Jayaweera *et al.*, 2013) and testing the effect of pruning, fruit thinning and stimulant application (Subasinghe, 2005) on reducing pre-mature fruit drop of gherkin; however, limited progress have been shown so far.

For an optimum plant production light intensity, light spectrum and photoperiod have to be met with the requirement of the crop while optimizing other growth factors. Therefore this research was designed to investigate the influence of supplemental lighting on reducing pre-mature fruit drop and increasing fruit yield of greenhouse gherkins**.**

Materials and Methods

This study was conducted under greenhouse (40×10 m) conditions at Sunfrost (Pvt.) Limited, Alawwa in Low Country Wet Zone (LCWZ) of Sri Lanka during *Yala* season (May - July), 2012 (Experiment I) and early *Maha* season (September - November), 2014 (Experiment II). The research was laid out according to Completely Randomized Design (CRD) with three replicates per treatment, assigning 20 plants per each replicate. The gherkin variety "Vertina" was planted in drip-fertigated grow bag culture at the spacing of 45 (within a row) × 90 cm (in between rows).

Three supplemental lighting treatments (treatment1, 2 and 3) were applied 4 weeks after sowing (WAS) with natural light as the control treatment (treatment 4). In treatment 1 and treatment 3, supplemental lighting was provided to extend day length during 5.00 a.m. to 7.00a.m. and 5.00 p.m. to 7.00 p.m. In treatment 2, supplemental lighting was provided only under rainy/cloudy weather condition from 7.00 a.m. to 5.00 p.m. In Experiment I, a combination of fluorescent lamps and incandescent lamps at a ratio of 2:1 was used for treatment 3, while the same source of lights at a ratio of 5:1 was used in treatment 1. In Experiment II, the light source of treatment 1 and treatment 2 were replaced with LED (light emitting diodes) while treatment 3 was kept similar to treatment 3 in the Experiment I.

The lighting was provided at the rate of 120 W×3/plot (in case of LEDs) at the canopy height in Experiment II and 120 W×2/plot (in case of fluorescent lamps and incandescent lamps) in Experiment I. Black polythene was used to blackout against the boarder effect between lighting treatments. The improved technologies adopted in the protected culture were also used in this experiment such as containerized transplants, black polythene mulch, fertigation, drip irrigation, pruning and training of vines. After harvesting, fruits were graded according to their diameter. In Experiment II, fruits having diameter between 17-21 mm were categorized to Grade I and beyond 22 mm to a grade called CRS. Nevertheless the harvesting standards followed in Experiment I, were slightly different from Experiment II since 12-14 mm diameter fruits were categorized to Grade I while fruits with diameter >15 mm were categorized to CRS grade in Experiment I. Vegetative parameters (plant height, internodal length, leaf area, number of leaves and number of branches) were measured weekly until vines reached upper horizontal crop support, established 1.75 m from ground level. As reproductive parameters, yield per vine, Grade I fruit yield per vine, number of fruits dropped per vine and crooked fruit yield per vine were measured. Daily light intensity, temperature and relative humidity inside the greenhouse were also measured. Net assimilation rate was measured once using portable photosynthetic machine (Licor 6400) in Experiment II. The results were statistically analyzed using the software, SAS.

Results

Environmental parameters

The variation of the weekly temperature and relative humidity are shown in Figure 1. The mean day temperature in Experiment I was 30.0±0.4 ˚C and it was comparatively similar to the Experiment II, which exhibited 31.0±2 ˚C. The average relative humidity (RH) in Experiment I was also similar (83.0±2.4%) to that in Experiment II (83.0±4.2%). Furthermore, the number of supplemental lighting hours provided at Experiment I (67 hrs) was lower than the Experiment II (120 hrs). In Experiment I, use of supplemental lighting was highest during 9 WAS, while in Experiment II it was during 10 WAS.

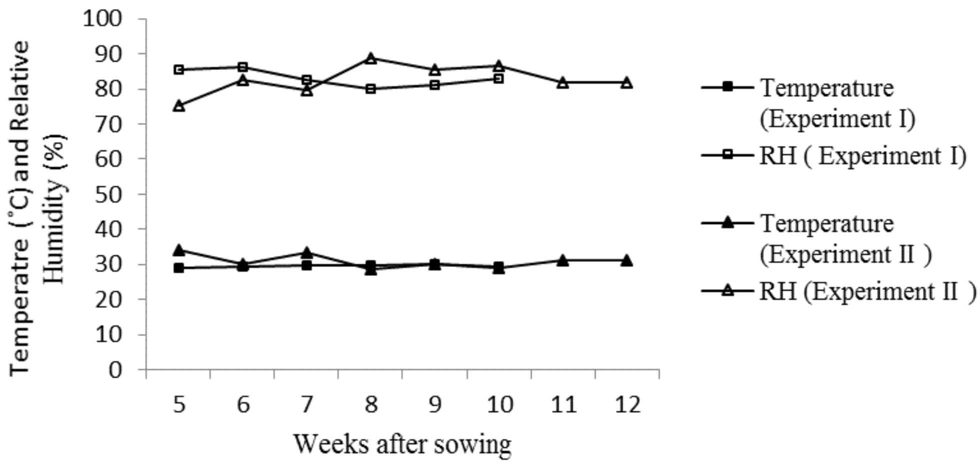

Figure 1*: Variation of weekly temperature (˚C) and Relative Humidity (%)*

Vegetative parameters

There were no significant differences (P≤0.05) among light treatments with respect to any of the vegetative growth parameters (plant height, intermodal length, leaf area, number of leaves and number of branches), except for plant height at 4 WAS and number of branches at 6 WAS in Experiment II. Experiment I reported slightly higher plant height (230±22 cm), but a lower leaf number (24±2.5 per plant), and similar internodal length of (12±0.4 cm), when compared to Experiment II at 6 WAS. In contrast Experiment II reported a mean plant height of 175±13 cm, LAI of 44.5±3.0, number of leaves of 33.5±6.0 per plant and internodal length of 11.4±0.1 at 6 WAP.

Reproductive parameters

Yield per plant

Treatment effects on yield per plant were statistically significant (at P≤0.05) in both Experiment I and Experiment II. Both supplemental lighting during cloudy conditions and supplemental lighting provided to increase day length have significantly increased the total yield per plant when compared to that of control (Figure 2). In both experiments, treatment effect of supplemental lighting under cloudy conditions (treatment 2) has shown a significant effect on yield per plant, compared to other treatments. However, there was no significant difference between two light treatments, used to increase the day length using the same light source at different ratios in Experiment I and by using different light treatments (i.e., LEDs and combination of incandescent and fluorescent lamps at the proportion of 2:1) in Experiment II. The overall yield of Experiment II has increased when compared to the Experiment I, potentially due to slightly different harvesting standards followed in each case.

Treatment effect on Grade I yield per plant was very similar to the treatment effects on the total yield per plant. Grade I yield per plant in control has shown drastic reduction when compared to supplemental lighting treatments at 9th WAS in Experiment I (Figure 3). Furthermore, in Experiment II control exhibited significantly lower yield when compared to remaining 3 treatments (treatment 1, 2 and treatment 3). Though treatment 1 and 3 demonstrated slighter reduction in Grade I yield per plant when compared to treatment 2 at 10 WAS, the difference was statistically non-significant at P≤0.05.

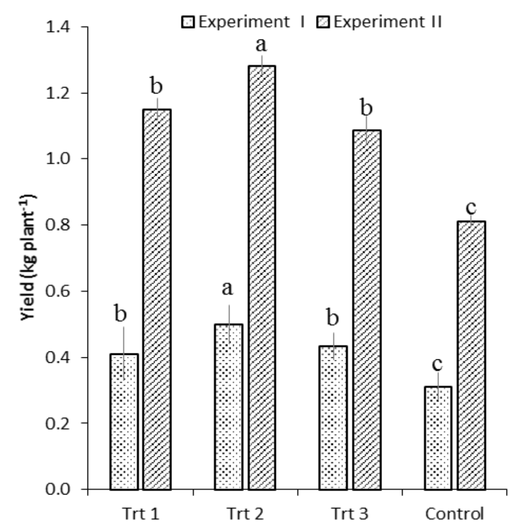

Figure 2*: Effect of supplemental lighting on yield per plant in Experiment I and Experiment II. Different letters indicate a significant difference at (P≤0.05).*

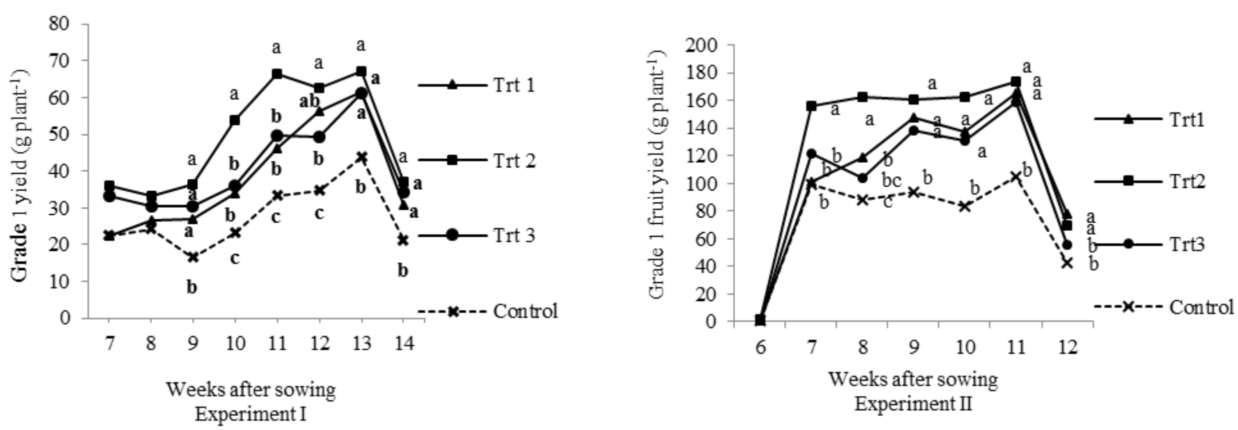

Figure 3*: Variation of weekly Grade I fruit yield per plant under different light treatments in Experiment I and Experiment II. Different letters indicate a significant difference at (P≤0.05).*

Fruit drop

Supplemental lighting treatments (treatment 1, 2 and 3) in both Experiment I and II have shown significantly reduced fruit drop at (P≤0.05) (Figure 4). However, there were no significant differences observed among the treatments on total fruit number in Experiment II. Furthermore, supplemental lighting have significantly increased the total fruit number when compared to the control in Experiment I. However, there was no significant difference observed between Treatment 1 and Treatment 3, where the supplemental lighting was provided in order to increase the day length using same combination of lighting sources at different ratios.

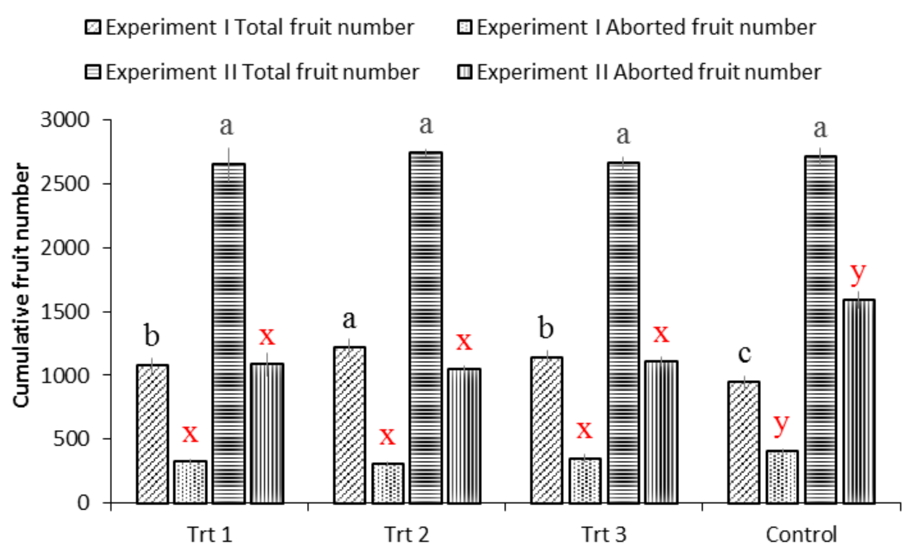

Figure 4: *Effect of supplemental lighting on cumulative fruit number. Different letters indicate a significant difference at (P≤0.05).*

Net assimilation rates (Experiment II)

There was a significant difference (P≤0.05) in net assimilation rates (NAR) between treatment 2 and control under cloudy conditions, indicating that supplemental lighting under cloudy condition increased the NAR, compared to that of control. Further, there was a significant treatment effect on NAR between 5.00 p.m. to 6.00 p.m., in treatment 1 and treatment 3, where day length was increased by different light sources. However, net assimilation rates recorded during 5.00 p.m. to 6.00 p.m. were very lower and positive NAR were not exhibited after 6.00 p.m.

Table 1 Impact of supplemental lighting on net assimilation rate in different treatments

Treatment	Net assimilation rates (µmol CO2 m-2 s-1)
Treatment 2 (under cloudy)	10.6 ± 1.1a
Treatment 4 (under cloudy)	4.9 ± 1.3b
P<	0.0001
CV	18.4
Treatment 1 (between 5.00 p.m.to 6.00 p.m.)	0.9 ± 0.3a
Treatment 3 (between 5.00 p.m.to 6.00 p.m.)	0.6 ± 0.1b
Control (between 5.00 p.m.to 6.00 p.m.)	0.1 ± 0.3c
P<	0.0001
CV	39.1

Discussion

The higher RH and lower sunshine hours at Alawwa, could be the result of continuous rain that existed during the *Maha* season in Experiment II. However, both experiments maintained relatively high temperature during day time (31.0±2.0 ˚C). Light intensity recorded during experiment was relatively 25-35% lower when compared to open field condition. Further different light intensity levels were found at different canopy heights due to mutual shading. Cloudy/rainy conditions demonstrated further reduction in an incident light levels, affecting assimilation rates thereby reducing dry mater partitioning to fruit sink. Therefore these light limitations can be overcome by providing light supplementation wherever necessary.

The influence of supplemental lighting (treatment 1, treatment 2 and treatment 3) in both Experiment I and II for greenhouse gherkin may have caused formation of more fruits leading to higher Grade I yield and lower fruit drop, compared to that of control. Therefore, both supplemental lighting under rainy /cloudy condition and supplemental lighting provided to increase day length have significant effect on increasing fruit yield and reducing fruit drop. However, no significant difference reported between treatment 1 and treatment 3, where supplemental lighting was provided to increase the day length in both Experiment I and II.

Incandescent lamps radiate higher red light intensity than the blue light hence incandescent lamps are not usually effective sources of radiation for supplemental lighting (Anon., 2010). However, fluorescent lamps are cooler, more light efficient than incandescent lamps and radiate higher blue light than red light (Anon., 2010). Therefore, in order to produce fairly balanced spectrum in the photosynthetically active radiation (PAR) zone two ratio combinations of fluorescent lamps and incandescent lamps (5:1 and 2:1) were used in Experiment I.

The plants in Treatment 2 maintained their NAR at a considerable level, even under cloudy conditions, when compared to the control through the supplemental lighting (Table 1). The higher NAR of Treatment 2 under rainy/cloudy weather compared to of the control under rainy/cloudy weather could have contributed to greater yield per plant and lower fruit abortion of Treatment 2 in both experiments. This point has also been very clearly demonstrated by variation of weekly Grade I fruit yield per plant under different light treatments in Experiment I and Experiment II (Figure 3). During 9th and 10th weeks in Experiment I and Experiment II, (when supplemental lighting was highest), Treatment 2 maintained the consistency in Grade I yield even under cloudy conditions, without exhibiting a yield drop. In Experiment II, LEDs were used for supplemental lighting under cloudy conditions

(Treatment 2). With LED lighting, spectral output can be tuned, consequently makes it possible to apply the optimum 'light recipe' at every stage of the crop growth (Berstrand and Schussler, 2012).

There was no significant difference (P≤0.05) among the light treatments on any of the vegetative growth parameters (plant height, intermodal length, leaf area, number of leaves per plant, number of branches per vine and stem thickness) under greenhouse conditions in Experiment I (Chamindika, 2012). The same trend was evident with the results of Experiment II as well.

In order to reach to a sustainable and economically viable production, cost effectiveness of supplemental lighting has to be maximized. For commercial greenhouse production, supplemental lighting is most beneficial in areas that receive less than 4.5 hours of average daily sunshine. But in tropical region, artificial lighting is not cost effective due to high cost of production (Anon., 2010). However, most of gherkin farmers in Sri Lanka are practicing semi-intensive levels of protected culture in order to minimize the cost of production. Therefore supplemental lighting should be cost effective in order to reach economic benefits under Sri Lankan context. The capability of LEDs to provide optimum 'light recipe' at every stage of the crop growth, with its additional advantages on effective heat management, long lifetime, high luminous efficiency and energy efficiency has indicated the potential benefits on greenhouse crop production.

Table 2 *Cost related to supplemental lighting over the season*

Treatment	Investment cost/plant (LKR)	Electricity cost/plant (LKR)	Supplemental cost/plant (LKR)	Additional yield/plant (kg)	Additional income/plant (LKR)	Additional profit/plant (LKR)
Experiment I						
Treatment 1(Fluorescent/ incandescent)	-	-	99.45	0.10	13.85	-85.60
Treatment 2(Incandescent)	-	-	27.06	0.19	24.99	-2.07
Treatment	**Investment cost/plant (LKR)**	**Electricity cost/plant (LKR)**	**Supplemental cost/plant (LKR)**	**Additional yield/plant (kg)**	**Additional income/plant (LKR)**	**Additional profit/plant (LKR)**
Experiment II						
Treatment 1(LEDs)	4.21	5.06	9.27	0.23	24.50	+15.23
Treatment 2(LEDs)	2.95	3.22	6.17	0.34	35.95	+29.78

According to the cost analysis (Table 2), supplemental lighting during rainy/cloudy conditions would be more productive (Anon., 2010). Supplemental lighting in treatment 1, where the day length was increased using LEDs and treatment 2, in which LEDs were used for supplemental lighting under rainy/cloudy in Experiment II were cost effective due to the lower running cost of LEDs. Among the two treatments, treatment 2 was the most cost effective due to the significant yield increase when compared to treatment 1. Given above, we conclude that supplemental lighting under cloudy condition can be a viable option in reducing pre-mature fruit drop and increasing fruit yield of greenhouse gherkins in LCWZ of Sri Lanka.

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References

Anonymous (2010). *Light and lighting control in greenhouse guide.* Argus Control Systems Ltd., 1281 Johnston road, White rock, British Columbia, Canada.

Bergstrand, K.J. and Schussler, H.K. (2012). Growth and photosynthesis of ornamental plants cultivated under different light sources. Acta Horticulture (ISHS), 956: 171-766.

Chamindika, B.G.L. (2012). Influence of supplementary illumination on growth and yield of greenhouse gherkin. B.Sc. Dissertation, Faculty of Agriculture, University of Peradeniya, Peradeniya.

Dana, M.N. and Lerner, B.R. (2000). *Growing Cucumbers, Melons, Squash, Pumpkins and Gourds*. Purdue University Cooperative Extension Service, West Lafayette, IN.

Dissanayake, D.M.D., Rupasinghe, A.P.S. and Weerakkody, W.A.P. (2011). 1-MCP and NAA on fruit retention of gherkin (*Cucumis sativus* var. anguria) under greenhouse conditions. B.Sc. Dissertation, Faculty of Agriculture, University of Rajarata, Anuradhapura.

FAO, (2007). Cucumber Integrated Pest Management. An Ecological guide. Food and Agriculture Organization of the United Nation, Washington, USA.

Ganiev, I.G., Mauzafarov, I.S. and Pchelin, V.M. (2011). Increase of efficiency of horticultural lighting. Acta Hort. (ISHS), 907: 131-135.

Hemming, S. (2011). Use of natural and artificial light in horticulture-interaction of plant and technology. Acta Horticulturae (ISHS), 907: 25-35.

Hettiarachchi, H.A.N.S. (2011). Effects of the size of grow bag and supplementary foliar nutrition on yield and quality of greenhouse gherkin. B.Sc. Dissertation, Faculty of Agriculture, University of Peradeniya, Peradeniya.

Jayaweera, D.R.I.P., Senanayake, W. and Weerakkody, W.A.P. (2013). Fertigation on immature fruit drop and yield of gherkin (*Cucumis anguria* L.). B.Sc. Dissertation, Faculty of Agriculture, University of Rajarata, Anuradhapura.

Masterlerz, J.W. (1977). *The greenhouse environment.* Dover Publication Inc., New York.

Meijer, G. (1958). Influence of light on the elongation of gherkin seedlings. Acta Botanicu Neerlandica, 7:614-620.

Peiris, B.C.N., Karunanada, P.H. and Weerakkody, W.A.P. (1999). Fruit formation, marketable yield and fruit quality of tomato varieties in two agro-ecological zones during the rainy season. Journal of National Science Foundation Sri Lanka, 27(3): 177-186.

Subasinghe, A. (2005). Effect of fruit thinning, pruning and stimulant application on fruit abortion and the marketable yield of gherkin. B.Sc. Dissertation, Faculty of Agriculture, University of Peradeniya, Peradeniya.

Valanzuda, K. and Kandll, T. (1994). Field cucumber production guideline for Hawai, Research extension series 153.

Weerakkody, W.A.P. (1998). *Evaluation and manipulation of the major environmental influences of tomato cultivation during the rainy season*, 159p, PhD Thesis, Postgraduate Institute of Agriculture, Peradeniya.

Weerakkody, W.A.P. (2004). *Protected Culture*. Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya.