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Tropical Agricultural Research Vol. 10 1998, 236-245

Plant Growth, Flowering and Fruit Formation of Tomato Grown under Protected Culture

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ABSTRACT. *Protected culture is a remedy for environmental problems of crop cultivation. However, seasonal weather changes adversely affect indoor grown plants. Therefore, this study was conducted to examine the affect of protected (indoor) culture and other improved technologies, often used in protected culture, on tomato (Lycopersicon esculentum L.) grown with irrigation during the Maha season. Two indoor cultures together with improved technology and two outdoor (open-field) cultures with and without improved technology were used as treatments. Vegetative and reproductive growth of tomato were evaluated during the respective growth stages.*

Except at early vegetative growth, dry weather prevailed during the cropping season. Most of the vegetative growth parameters were not significantly different between the indoor and outdoor treatments. However, indoor culture showed significantly higher flowering and fruit formation. The shed house recorded the highest number of fruits per plant. Significantly higher vegetative growth was observed with the use of improved technologies, irrespective of the experimental conditions. Moreover, the improved technologies contributed for greater number of flowers per plant but not for number of fruits. Indoor culture in combination with the improved technology assured greater vegetative growth, flowering and fruit formation of tomato when compared to outdoor culture under low rainy conditions that prevail during the Maha season. Except for fruit formation, comparative advantages of different indoor structures were not evident.

INTRODUCTION

Protected (indoor) culture is predominantly used in temperate regions where seasonal agro-climatic changes restrict the year-around cultivation of

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perishable horticultural crops under open–field conditions. In addition, it protects plants from pest problems and adverse soil conditions, enabling the production of high yields of quality produce continuously (Aoki, 1995). An average annual tomato yield of 388 t ha^{-1} was produced from protected culture in the Netherlands in 1991 (Ikeda, 1995). Due to these advantages, its applicability in the tropical environments especially for cultivating high–value crops during rainy seasons has been identified (Iqbal, 1987).

In Sri Lanka, commercial growers of ornamental plants or vegetable crops use different types of indoor structures which provide protection at different levels. Barrel shaped polythene houses are the commonly used indoor structures for vegetable crop production. Although these houses performs well in high elevations and during rainy seasons, their influence on crop growth and development under relatively dry weather conditions is variable. Low yield of indoor grown tomato during Summer has been reported by Joubert and Poissonier (1991). Weerakkody and Peiris (1996) have shown that the growth and yield differences of tomato under simulated rainfall is due to micro–climatic changes that occur under different weather conditions. Therefore, this study was conducted to examine the effect of protected culture, comparative performances of different indoor structures and applicability of new improved technologies on irrigated tomato during the *Maha* season.

MATERIALS AND METHODS

The experiment was conducted at Peradeniya (the soil type: Alluvial) during *Maha* season (longer rainy season; October to January, 1996/97). The 4 treatments and 4 replicates were arranged in an incomplete block design. The plot size was 3 m × 3 m. Tomato (*Lycopersicon esculentum* L.) *var.* T–245 was selected based on the recommendations of the Department of Agriculture, Sri Lanka (Anon., 1990). The treatments were shed house (partially covered) with improved technology (T1), polythene house (fully covered) with improved technology (T2), open–field culture with improved technology (T3) and open–field culture with recommended technology (control–T4).

The improved technologies used in the case of first three treatments were soil fumigation using Basamid (*a.i.* Dazomet), containerized transplants, polythene mulch (black), frequent irrigation to maintain soil moisture at field capacity (manually, twice a day) and split–application of fertilizer. Thin plastic containers with the size of 90 ml filled with N, P and K fertilizer amended coirdust and paddy husk were used for containerized transplant production (Weerakkody *et al.*, 1997). The top dressing (125 g of Urea and 75 g of KCl) was applied in two splits, at 3 and 6 weeks after planting (WAP). The recommendations of the Department of Agriculture were followed for the alternative practices in T4 (Anon., 1990).

The shed house was covered from the top with fiberglass roofing sheets while the polythene house was covered from the top as well as from two sides by 500 gauge polythene. Structure of the houses were composed of galvanized iron and polyvinyl chloride (PVC) pipes (Weerakkody, 1998). The side covers of T2 (fully covered polythene house) were kept stretched (closed) during 0–3 WAP to protect from rain and during 8–11 WAP to protect from pest and disease infections. During other periods the sides were kept open in order to facilitate passive ventilation.

Nursery management was initiated on 30th October in 1996, and transplanting was done 21 days later at 40 cm × 60 cm spacing. A basal dressing was applied at the rate of 225 kg of urea, 275 kg of super phosphate and 125 KCl ha^{-1}. The control (T4) was irrigated at 2–3 day intervals, only when rainfall was inadequate. Weeding was practiced, manually, only in the control plots at 3 and 6 WAP. Chemical control of pest and diseases were done by application of Atabron (*a.i.* chlorfluazuron) and Vondozeb (*a.i.* mancozeb) at 4, 6 and 8 WAP. In addition, pegging at 4 WAP, application of top dressing (Urea - 125 kg ha^{-1}) at 3 and 6 WAP and regular observation were done.

The transplant success (survival rate) was estimated by the percentage of plants that showed successful establishment at 3 WAP. Plant dry weight, leaf area index (LAI), leaf number and plant height were measured at weekly intervals up to 6 WAP. Time of flowering (days to attain 50% or 100% flowering), flower production (number of flowers per week), and fruit set (number of fruits per week) were recorded to study the flowering behavior and fruit production under different treatments. Because of the insufficiency of fruit samples in T4, the final yield could not be determined. The climatological data were also recorded during the cropping season. Statistical analysis of results was done using the GLM procedure. The contrasts between indoor and outdoor cultures, polythene and shed houses, and improved and recommended technologies were tested (SAS, 1990).

RESULTS AND DISCUSSION

Weather

The average weekly rainfall during crop growth (16.68 mm) was extremely lower than the usual rainfall in the *Maha* season (45 mm week^{-1}) at Peradeniya Sri Lanka. Only the early vegetative phase (up to 3 WAP) received a considerable amount of rainfall (Figure 1). The maximum (day) temperature under open–field conditions was almost constant (30.2±1°C) during the season while minimum (night) temperature showed a slight variation (17.0±1.5°C), especially at the latter part of the season. The mean day temperature in the shed house (28.7°C) was slightly lower than the ambient value. A relatively higher mean day temperature (29.8°C) was observed in the polythene house than the shed house during the cropping season, and it increased further to 31°C when the side covers were closed. The mean night temperature of both indoor structures (23.7°C) showed a slight increase (1.5°C) than the outside.

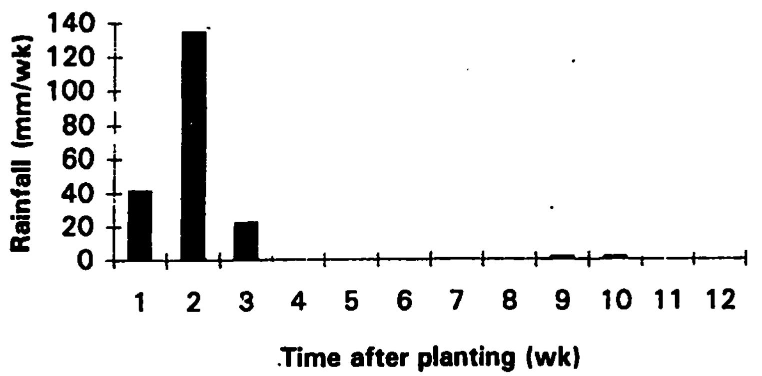

Figure 1. Rainfall distribution during growth period during *Maha*, 1996/97.

The mean light intensities of open–field condition that prevailed under sunny and rainy conditions during mid day were 3900 and 2980 lx, respectively. The reduction in mean light intensities in the shed house and the polythene house were 28.5 and 12.8%, respectively. The mean day time RH (71.54±9.5%) showed a considerable reduction at the end of the season.

However, treatment difference and diurnal difference in RH were not prominent due to dry weather that prevailed during this *Maha* season.

Transplant success and shoot growth

Significantly higher transplant success (Table 1), dry weight (Figure 2) and height (Table 1) of plants grown in field conditions with improved technologies (T3) than those in the control indicated the positive effect of improved technology on vegetative growth. Results of the previous studies on advantages of the use of containerized transplants (Weerakkody *et al.*, 1997) and polythene mulch (Wein *et al.*, 1993) on the vegetative growth of tomato support this observation. The highest transplant success (84%) was reported in indoor culture. Moreover, indoor culture showed a higher plant dry weight and plant height than the open–field cultivation during the early vegetative growth. The highest amount of dry matter accumulation in plants was observed in the polythene house. The protection from rainy weather could be considered as the main reason for the relatively higher shoot growth reported in indoor culture and the polythene house during the early vegetative growth period (Weerakkody, 1998). Low day temperature (21–25^{0}C) for high rate of dry matter accumulation (Dorely, 1976) and dry foliage for low disease spread (Elmstone and Maynard, 1992) could be the main advantages of indoor culture when compared to rainy outdoor conditions.

Leaf growth

The effect of improved technology on leaf number (Table 1) and LAI (Figure 3) were significant throughout the vegetative phase. Significantly higher LAI (during early vegetative growth) and leaf number (throughout the vegetative growth) were seen in indoor culture than the open–field cultivation. The polythene house showed the highest LAI (Figure 3). Differences in weather between early and late vegetative growth phases (Figure 1) reveal that the effect of improved technologies on leaf growth was evident under variable weather conditions. The results also indicate that the negative impacts of rainy weather in the field conditions could be overcome by indoor culture. Furthermore, suppression of leaf growth of tomato due to dry weather (Weerakkody and Peiris, 1996) appeared to be reduced by both improved technologies and indoor culture.

Table 1. Plant height and leaf number of tomato.

Treatment	Transplant Success (%)	Plant Height (cm)		Leaf Number (per plant)	
	3 WAP	3 WAP	6 WAP	3 WAP	6 WAP
T1	75.5[a]	17.29[a]	37.14[ab]	9[a]	34[ab]
T2	87.7[a]	18.69[a]	56.83[a]	10[a]	31[ab]
T3	84.4[a]	13.15[a]	44.63[a]	7[b]	27[b]
T4	61.1[a]	10.57[b]	21.42[b]	5[c]	12[c]
Mean	77.2	14.93	40.21	8	26
LSD (p=0.05)	14.2	3.55	23.34	13	5.6

T1 - partially covered shed house + improved technology; T2 - fully covered polythene house + improved technology; T3 - open-field culture + improved technology; T4 - open-field culture + recommended technology (control); LSD - Least Significant Difference.

Flowering

Early flowering was observed in the treatments with improved technology confirming the results of previous experiments conducted in the wet season (Weerakkody, 1998). The indoor grown plants attained 50% and 100% flowering earlier (at 22 and 32 days, respectively) than the field grown plants (at 34 and 42 days, respectively). Early flowering in the treatments with improved technology and indoor culture can be considered the result of the vigorous vegetative growth as described by Weerakkody and Peiris (1996).

The use of improved technology induced a greater number of flowers throughout the flowering phase (Figure 4). A greater number of flowers were found in indoor culture than in the open-field during the early flowering stage (4-5 WAP). In addition, the maximum number of flowers (during 7-8 WAP)

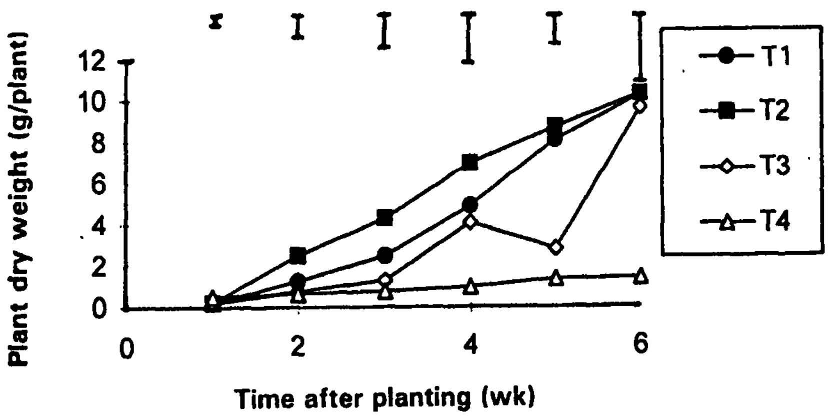

Figure 2. **Variation in plant dry weight of tomato.**
[Note: The vertical bars indicate the Least Significant Difference at p=0.05]

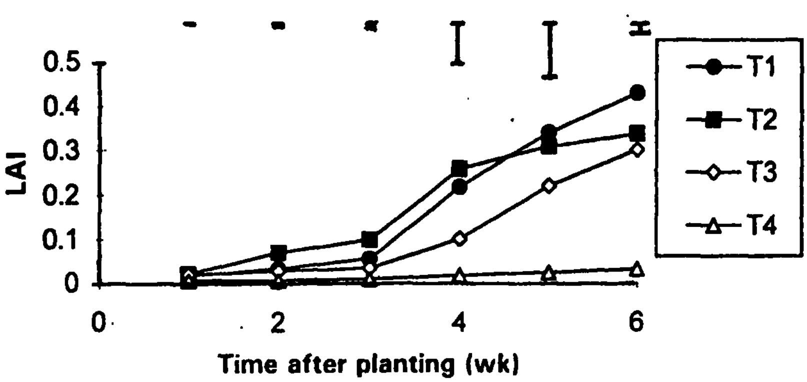

Figure 3. **Variation in leaf area index (LAI) of tomato.**
[Note: The vertical bars indicate the Least Significant Difference at p=0.05]

were higher in the indoor grown plants than the outdoor grown plants (Figure 4). As described by Koning (1991) mild temperature (23-29°C)that prevailed in indoor culture under similar experimental conditions could be a reason for the difference between flower number between indoor and outdoor cultures. In addition, marginal changes of other environmental factors such as relative humidity, soil moisture, soil temperature, plant nutrients and pest and disease incidence may have contributed to this difference.

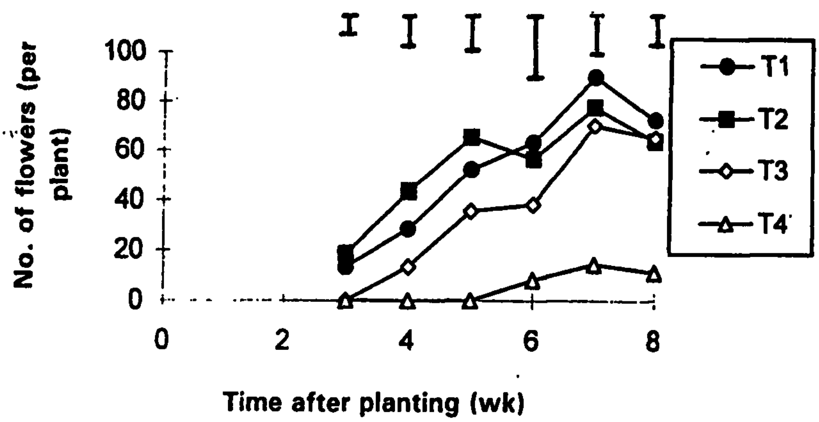

Figure 4. **Variation in number of flowers of tomato.**
[Note: The vertical bars indicate the Least Significant Difference at p=0.05]

Fruit development

Adoption of improved technology produced a significantly higher number of fruits over the recommended technology at peak fruit set (Figure 5). The absence of the effect of the improved technology on fruit formation

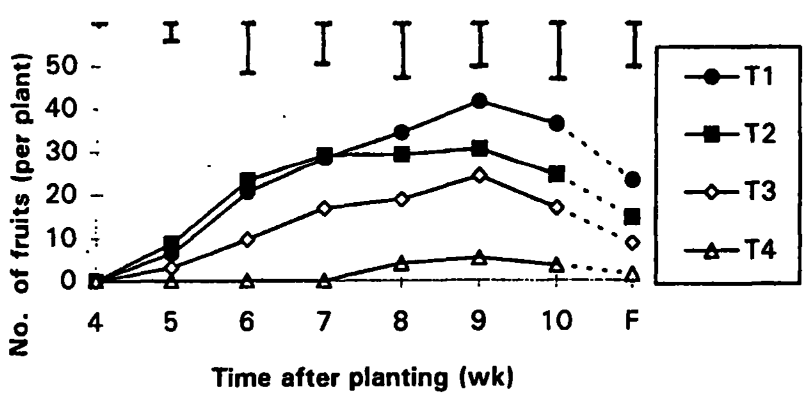

Figure 5. **Variation in number of fruits of tomato.**
[Note: F: at harvesting; the vertical bars indicate the Least Significant Difference at p=0.05]

during the latter part of the fruit development stage indicates the less importance of the improved technology for the fruit growth, under dry conditions that prevailed in the *Maha* season, 1996/97.

Number of fruits was higher in indoor culture when compared to field condition assuring the importance of indoor culture for this purpose (Figure 5). Profuse flowering and low day temperature and the other possible environmental factors could have contributed for higher fruit number. In contrast to the results of previous experiment conducted during wet season (Weerakkody, 1998), the shed house gave the highest number of fruits during the late fruiting stage. This reverse trend could be due to the influence of relatively high day temperature or humidity (when side covers were closed) on the initiation or retention of fruits in the polythene house. However, low light intensity in the shed house could have an negative impact on fruit set (Baever, 1990; Nasiruddin *et al.*, 1995).

CONCLUSIONS

The growth of indoor cultured irrigated tomato was more prominent in flowering and fruit formation than the vegetative growth under low rainy conditions that prevailed during this *Maha* season. Plants in the polythene house did not show a superior vegetative growth and flowering of tomato over those in the shed house. Instead, the plants in shed house dominated in terms of fruit formation over those in the polythene house. In general, the vegetative growth of tomato was higher with the use of improved technology irrespective of the experimental conditions. The improved technology increased flowering but did not influence the fruit formation.

Indoor culture together with improved cultural practices can be suggested as a technology which provides favourable environmental conditions for the growth and development of irrigated tomato even during seasons with low rainfall. However, further studies are needed to identify the most appropriate housing structure for distinct weather conditions.

ACKNOWLEDGEMENTS

The authors wish to thank the National Science Foundation (NSF), Sri Lanka for the financial assistance provided to conduct this research.

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