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Yield and Quality of Tomato as Affected by Rainfall During Different Growth Stages

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ABSTRACT. *Cultivation of tomato (Lycopersicon esculentum) is severely affected during the peak rainy periods in Sri Lanka, which leads to a seasonality in production and fluctuation of prices. To study the nature of rain damage and to identify the critical growth stages prone to rain damage, staggered planting of tomato was practiced in the Mid Country Intermediate Zone during the Maha season. The rain damage was evaluated in terms of yield components, yield and fruit quality.*

During the vegetative growth and early flowering, rainfall was positively correlated with yield components and fruit quality. However, rainfall received during the late flowering phase reduced the weight and final number of fruits. During fruit growth, rainfall was positively correlated with fruit cracking and juice pH. A negative correlation existed with other fruit defects. Hence, positive effects of rainfall during vegetative growth and negative effects of rainfall during reproductive growth were evident. Late flowering and fruit ripening stages were identified as critical for yield components while fruit growth and fruit ripening stages were identified as critical for fruit quality.

INTRODUCTION

Tomato is one of the major fruit vegetables in the world. In Sri Lanka, it is annually cultivated in more than 2200 ha, producing approximately 34000 metric tons (Perera, 1989). However, the average productivity of tomato in Sri Lanka (11 metric tons/ha) is much lower than the world average (24 metric tons/ha) (Hurelbrink *et al.*, 1993; Ikeda, 1996). In the meantime, a shortage in the months of peak rainfall (May and November) and a production glut in the

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months of harvesting (March to May and September to October) lead to a dichotomy in the distribution of annual tomato production (Samarathunga *et al.*, 1996).

With regard to the effect of rainfall and its associated factors on the yield of tomato, reduction in number of flowers due to flower drop can be considered as a major effect (Weerakkody and Peiris, 1997). In addition, diseases such as damping off, blight, leaf mould and blossom end rot that proliferate under high humidity, mild temperature and insufficient drainage would cause yield and quality losses (Hessayon, 1985). Furthermore, fruit cracking has been identified as a result of fluctuations in temperature, light or soil moisture during fruit growth (Peet, 1992).

Effect of rainfall may differ depending on the rainfall characteristics (drop size, intensity and duration) and the crop growth stage exposed to rain. The identification of the critical growth stages with respect to rain damage would be basically important for further studies on the nature of damage and on possible remedies to overcome this problem. Staggered planting has been considered as a relatively easy but a useful procedure to test the effect of variable environmental factors on crop growth. Therefore, this research was conducted to identify the relatively critical growth stages of tomato susceptible to rain damage by means of staggered planting during the rainy season.

MATERIALS AND METHODS

The experiment was conducted at the University Experimental Station, Dodangolla, Kundasale. Sri Lanka in the *Maha* season (Oct. 95 – Jan. 96) using a Randomized Completely Block Design. Different times of planting with different levels of rainfall were considered as treatments. Tomato variety T–146, was selected because of its suitability to the Mid Country Intermediate zone. The nursery seedlings were raised in the plant house at the Department of Crop Science, University of Peradeniya, Sri Lanka. Seeds were planted in plastic trays, filled with a mixture of top soil and river sand in 4:1 ratio. Basamid and Captan were applied during the 1st week to protect plants from damping–off and sucking insects, respectively. Regular watering was done, and observations were recorded until the time of transplanting (18–21 days after seeding).

In the four treatments; Early (T1), Early–mid (T2), Late–mid (T3) and Late (T4), transplanting was done at 2 week intervals beginning from 27th September. Blocking was done in the East–West direction along a contour strip. Plots were 3.6 m × 1.8 m, and the seedlings were planted at a 60 cm × 40 cm spacing. Shade was provided during the 1st week after transplanting (WAP). Watering was done only when rainfall was inadequate to keep the soil at its field capacity. Application of fertilizer, control of pest and diseases, staking for support and the harvesting were done according to the recommendations of the Department of Agriculture (Anon., 1990).

Fruit counts were taken weekly, beginning from the fruit set. The yield and yield components were determined by the number of fruits and fruit weight. Several quality parameters of fruits were measured. These were fruit size (volume), freedom from defects, fruit colour (Montagu and Goh, 1990) fruit shape (the ratio between height and width), titratable acidity, juice pH, total soluble solids (Brix value) and percentage locular material. Fruit defects were categorized into fruit cracks, fruit spots and others which included misshapened, bruised and rotten fruits. The treatment effect, contrasts between treatments and correlations between rainfall and yield and quality parameters were statistically tested by using SAS package (SAS, 1985).

RESULTS AND DISCUSSION

Climatic conditions

Rainfall distribution during the different growth stages is shown in Figure 1. The highest variation in rainfall was observed during vegetative growth, and was followed by the flowering and fruit development stages. Although a high diurnal temperature difference prevailed during the fruit growth and ripening phases, it was not considerably different among planting times. The mean day and night temperatures during the experimental period was 29.95±1.01°C and 19.65±1.35°C, respectively. The mean RH measured at 10:00 a.m. and 3:00 p.m. was 77.14±8.71%. Daily hours of bright sunshine showed a slight increase along with the season. As a result, daily sunshine hours, received by treatments 1– 4 in different growth phases slightly increased in the ascending order. The mean daily sunshine period was 6.16±0.55 h.

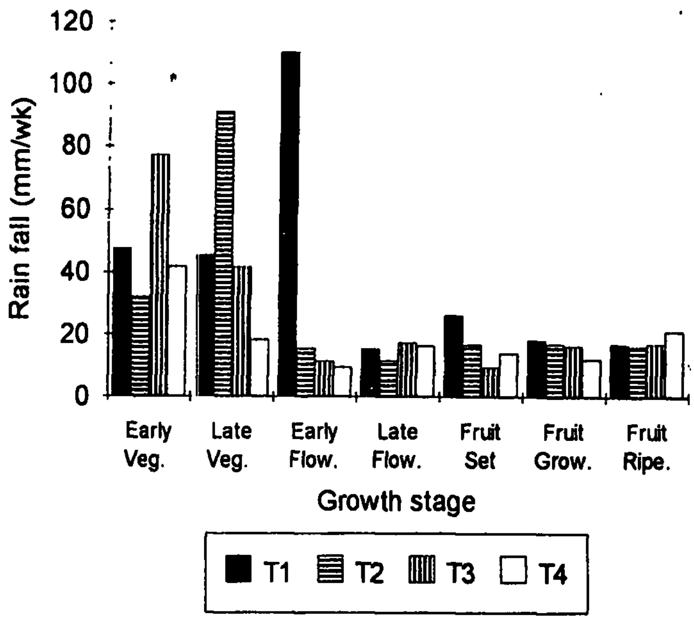

Figure 1. Rainfall received during different growth stages.

Fruit number

Highly significant variations in fruit number were observed from 7 WAP to the time of harvesting. Late–mid and early planting gave the highest fruit number during the entire fruit development. Late and early–mid planting had relatively low fruit numbers during the fruit set and fruit ripening stages, respectively (Figure 2).

Fruit numbers at early stages of development were positively correlated with rainfal received during flowering, indicating the need of rainfall for fruit set. This could be an effect of rain enhancing spore dissemination (Parker *et al.*, 1995). However, fruit number at the late stages of fruit development and the maximum number of fruits during 10–12 WAP were negatively correlated with rainfall during the late flowering and fruit ripening periods (Table 1). The negative relationship with rainfall during late flowering agrees with the observations of Weerakkody and Peiris (1997). Furthermore, the negative relationship with rainfall during fruit ripening is probably due to rain enhancing fruit drop during the ripening phase.

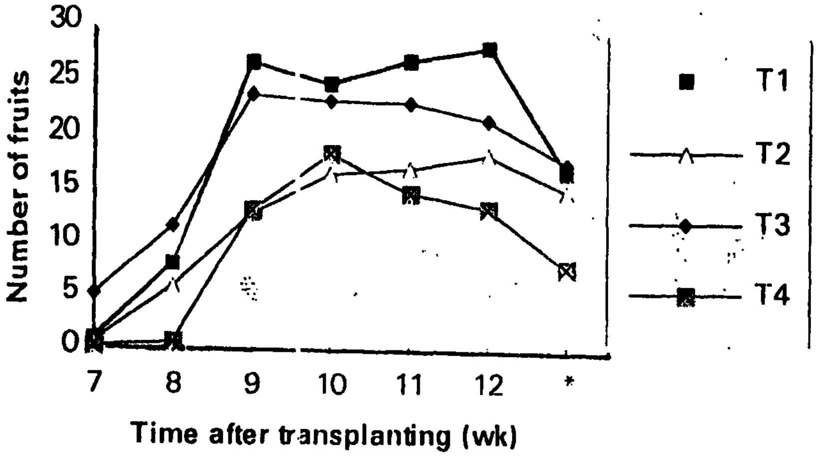

Figure 2. **Variation in fruit number with time in different treatments.**
[Note: * - At harvesting].

Fruit weight and fruit size

Both fruit weight and size significantly varied with the time of planting. Fruits of the early and early–mid planting were heavier than in other treatments. Late planting produced the smallest fruits (Figure 3).

Fruit weight was positively correlated with rainfall received during the stages of vegetative growth and fruit set, suggesting the importance of proper vegetative growth and rainy weather during fruit development. However, fruit weight was negatively correlated with rainfall received during late flowering and fruit ripening stages (Table 1).

Table 1. Correlations between yield components and rainfall at different growth stages.

Rainy Period (Total rainfall)	Fruit Number		Fruit Weight	Yield
	During fruit growth	Maximum		
Vegetative growth (1 – 6 WAP)	NS	NS	0.805	0.773
Early flowering (6 – 8 WAP)	0.469[1]	NS	NS	0.403
Late flowering (8 – 10 WAP)	0.507[2]	-0.402	-0.654	-0.417
Fruit growth (10 – 13 WAP)	0.467[3]	0.460	0.692	0.745
Fruit ripening (12 – 15 WAP)	-0.692[4]	-0.407	-0.688	-0.702
Total growth (1 – 15 WAP)	NS	NS	0.667	0.744

NS = Not significant 1 - 8 WAP; 2 - 9 WAP; 3 - 11 WAP; 4 - at harvesting

Economic yield

Economic yield, the product between the marketable fruit number (more than 25 g in fruit weight) and average fruit weight, was affected by rainfall in a similar way to that of yield components (Figure 3 and Table 1).

Correlation between yield and rainfall closely followed that between fruit weight and rainfall signifying the relative importance of fruit weight as a yield component. However, the relationship between number of marketable fruits and rainfall (not determined) should also be considered in confirming the above statement. According to studies on the effect of irrigation on fruit growth and yield of tomato by Borin (1990) and Vivutongana *et al.* (1991), the positive response of yield to rainfall appeared to be mainly influenced by the soil moisture status.

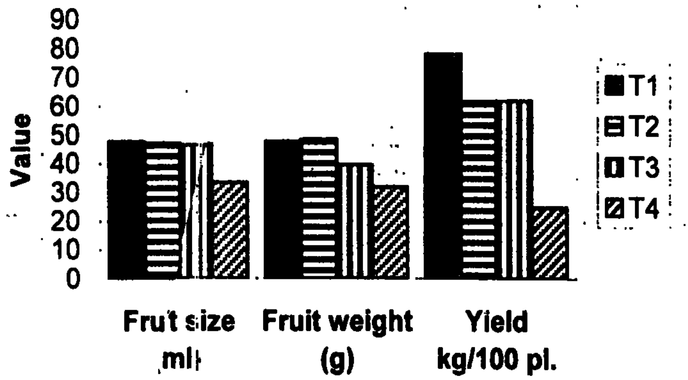

Figure 3. **Variation in yield components with time of planting.**

Fruit shape

Fruit shape showed a significant variation with time of planting. Fruits of the late–mid planting were more round in shape than those of early or late–planting (Figure 4). The significant positive correlation between fruit shape and rainfall (Table 2) during the vegetative growth suggests the need for rainfall during the vegetative growth to produce round shaped fruits of tomato.

Fruit cracking

Concentric fruit cracks were observed in all treatments. It was significantly higher ($p = 0.10$) in early and late-mid planting than in the other planting dates (Figure 4). Although rainfall during fruit growth was positively correlated with fruit cracking, rainfall during fruit ripening showed a negative correlation with rainfall. Therefore, fruit growth appeared to be more susceptible to rainfall than fruit ripening with respect to fruit cracking. Although diurnal temperature difference and RH also influence fruit cracking (Peet, 1992), none of those varied considerably during the fruit development. Therefore, fluctuations in soil moisture could be the primary reason for differences in fruit cracking.

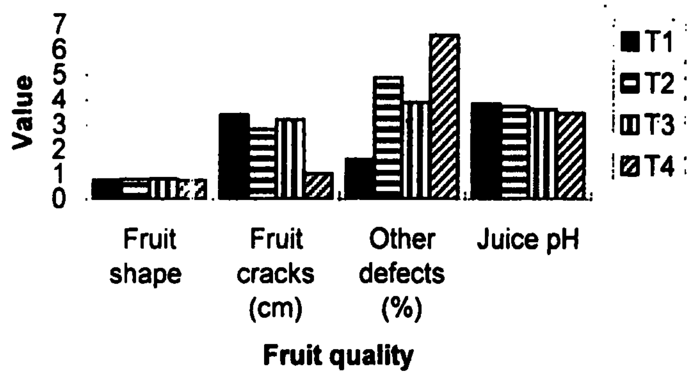

Figure 4. **Variations in fruit quality with time of planting.**

Other fruit defects

The difference in other defects such as misshapened fruits, bruising and rot was significant between early and late planting (Figure 4). Significant negative correlation between other fruit defects and rainfall received during fruit growth phase indicate the favourability of rainfall at this stage to produce good quality tomatoes (Table 2). In contrast, rainfall received during fruit ripening was positively correlated with other fruit defects. Rainy conditions and high diurnal temperature differences leading to high disease incidence such as fruit rot and spots could be considered as the main cause for greater fruit defects during fruit ripening. Moreover, fruit defects were positively correlated with diurnal temperature difference ($r = 0.536$) and daily sunshine hours ($r = 0.478$) during fruit ripening.

Fruit acidity

Although both pH and titratable acidity of fruit juice showed significant treatment effects, the contrasts between treatments were marginally

Table 2. Correlation between rainfall at different growth stages and fruit quality.

Rainy period	Fruit shape	Fruit cracks	Other defects	Juice pH
Vegetative growth	0.54	0.723	-0.531	NS
Fruit growth	NS	0.603	-0.552	0.741
Fruit ripening	NS	-0.597	NS	-0.696

NS = Not significant

variable (P= 0.1). Fruit juice pH was positively correlated with rainfall received during fruit growth and negatively correlated with rainfall received during fruit ripening. In addition, fruit juice pH showed a significant negative correlation with daily sun shine hours during fruit ripening (r = -0.625). Thus, a rainy period during fruit growth and a dry period during the fruit ripening appeared to improve the fruit acidity of tomatoes.

CONCLUSIONS

Time of planting which created a variation in the rainfall distribution during different growth phases affected yield components and fruit quality of tomato. The variation in yield, fruit number, fruit size and fruit weight emphasized the need for rain almost up to the stage of fruit maturity. Late flowering and fruit ripening could be identified as critical growth stages in terms of rain damage affecting the yield and yield components. Rainfall during vegetative growth appeared to be favourable for fruit shape. The fruit growth and fruit ripening phases could be identified as critical considering the effect of rainfall on fruit quality. However, the effect of rainfall during the above growth stages on the quality parameters were contradictory. Rainfall received during the fruit growth stage increased fruit cracking and fruit juice pH but decreased other fruit defects whereas rainfall received during fruit ripening reduced fruit cracking and juice pH but increased other fruit defects.

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