Influence of Soil Moisture on Yield and Quality of Tomato on a Heavy Clay Soil

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Abstract

The effect of three soil moisture regimes [deficit: 22-26mm H_2O per 100 mm soil depth, field capacity (FC): 34-43 mm and saturation: 44-48 mm] on growth, yield and quality of a tomato (*Lycopersicon esculentum* L. Mill) cultivar 'Improved Apollo' was examined on a heavy clay soil. Leaf area and plant height were reduced in deficit and saturation, whereas stem diameter increased with increasing soil moisture. Fruit yield declined by 31 and 24% in deficit and saturation respectively compared with the FC. Maximum attainable fruit yield would be achieved with 35 mm H_2O per 100 mm soil depth. Total titratable acidity (TTA), ascorbic acid (AA) and firmness decreased and pH increased with increasing soil moisture. Dry matter, total soluble solids (TSS), TSS: TTA and blossom end rot (BER) were highest for deficit, followed by saturation and lowest at FC. Although yield increased and BER decreased at FC, other quality improved with water stress compared to FC.

INTRODUCTION

Tomato is precise in terms of its water requirements (Rudich and Luchinsky, 1986). With moisture in excess of plant requirements, water replaces air in the soil and reduces mobility of oxygen that remains trapped in air pockets or dissolved in the soil water (Meek et al., 1983). By decreasing the supply of soil oxygen to tomato roots, high soil moisture can cause large losses in crop yield and quality (Poysa et al., 1987).

Deficit irrigation enhances fruit quality. However, dry soil constrains growth and development and exacerbates physiological disorders (Guichard et al., 2001). Drought causes only small reductions in yield and quality if imposed after flowering and fruit set (Grierson and Kader, 1986).

Heavy irrigation during the period of fruit development and maturation has adverse effects on quality indices as shown by negative linear correlations between water consumption on one hand and total soluble solids (TSS) and total titratable acidity (TTA) on the other resulting in a negative correlation between crop yield and quality (Rudich and Luchinky, 1986), which is largely variety specific. We examined the effect of irrigation rates on growth, yield and quality of tomato Cv:'Improved Apollo'.

MATERIALS AND METHODS

The crop was sown on 5 May 2003, in black sealed plastic containers (25 cm diameter x 28 cm height) filled with 18.3 kg of black heavy clay (*vertisol)* soil inside the screen house (67% of full sunlight) at Rockhampton, Australia (23^{0}22'S and 150^{0}31' E). The field capacity (FC) and wilting coefficient of the soil was 43 and 22 mm H_2O per 100 mm soil depth respectively. The experiment was laid out in a randomised complete block design. Three irrigation levels (Deficit: 22-26 mm H_2O per 100 mm soil depth (50-60% of FC,); FC: (34-43 mm) and Saturated (43-48 mm)) replicated five times. Each plot consisted of a fully bordered container, spaced at 75 cm x 60 cm, planted with a single plant pruned to a single stem and staked.

Soil moisture was determined by a Microgopher (a time domain refractometry technique from Soil Moisture Technology, Australia) and gravimetric determination by weighing pots twice daily (8 am & 2 pm). Plant height, leaf area and stem diameter were recorded on each plant at 15-day intervals. As fresh fruit were harvested from 134 to 159 days after sowing, fruit samples were dried, and total dry matter (DM) was determined.

Fruit DM, TSS, TTA, pH, firmness, ascorbic acid (AA) and blossom end rot (BER) were assessed on uniformly ripe fruit as described by Grierson and Kader (1986).

Data were subjected to analysis of variance (ANOVA) using generalized linear model of SYSTAT 9 (SPSS Inc, 1999). F-test was significant at $p \leq 0.05$. Regressions from individual plot data were used to determine soil moisture and yield relationship.

RESULTS AND DISCUSSION

Weather, Soil Moisture and Water Use

Soil moisture over the period remained at 22-26, 34-43 and 43-48 mm/100 mm for deficit, FC and saturation respectively. Actual amounts of water applied over the season were 188.4 L, 134.9 L and 100.7 L plant^{-1}, for FC, saturation and deficit treatments, respectively. Mean temperatures ranged between 11 and 24°C with a growing season mean of 18.1°C. Soil and ambient temperatures declined gradually for the first 3 months, followed by a steady increase. Daily solar radiation ranged from 1.2-16.55 MJ m^{-2} with a season average of 10.36 MJ m^{-2} day^{-1} and a growing season total of 1545 MJ m^{-2}. Daily solar radiation declined, as for temperature, gradually for the first three months followed by a steady increase for rest of the crop period (data not presented).

Plant Growth and Development Characteristics

Leaf area was reduced by 35 and 44% in deficit and saturation respectively, compared with that of the FC whereas plants were significantly taller at FC, intermediate in saturation and shortest for the deficit treatment. Li et al. (1999) also observed retardation of tomato growth due to soil moisture stress. Stem diameter at harvest increased significantly with increasing soil moisture content (Table 1).

Fruit Yield, Yield Components and Dry Matter Partitioning

Yield decreased by 31 and 24% respectively in deficit and saturation compared with FC. The highest yield in FC was attributable to heavier fruits (Table 1). An extrapolated highest yield at 35 mm irrigation suggested that the crop could be maintained at less than FC for highest yield (Fig. 1). DM partitioning was proportionately lower to stem (9.8 and 13.5 vs 22.6%), higher to leaf (22.5 and 22.1 vs 20.6%), and fruits (62.8 and 62.9 vs 58.6%) in deficit and saturation compared to FC respectively. However, partitioning to root was higher (1.8 vs 1.03 and 1.1%) for deficit compared to saturation and FC (Fig. 2). The harvest index (HI), measured as dry fruit weight to total dry weight was higher for deficit (0.637) and saturation (0.633) compared with the FC (0.593). This results is in agreement with Martin et al. (2003) work in clover but such an effect was not evident when irrigation was reduced from satisfying full to 66% and 33% of the canopy transpirational demand in maize (Paolo et al., 2001).

Fruit Quality and Blossom End Rot

Fruit DM % was significantly greater in the deficit, followed by saturation and FC. Fruit yield and DM were, therefore, negatively correlated as reported by Renquist and Reid (2001). Fruit firmness and TSS were significantly higher at deficit compared with FC and saturation. The TTA and AA decreased and pH increased with increasing soil moisture (Table 1). However, the ratio of TSS: TTA was highest at deficit, followed by saturation and lowest in FC. That moisture stress increased TSS:TTA ratio was also noted by Elkner and Kaniszewski (1995). BER increased by three fold in deficit and saturation compared with FC (Table 1). Soil moisture stress in association with low air humidity probably reduced the availability of Ca^{2+} in the tomato fruits, resulting in increased BER.

CONCLUSIONS

Soil moisture beyond 35 mm reduced fruit yields suggesting that irrigation below FC maximize yield. Soil moisture stress improved eating quality but increased BER. An intricate relationship between soil water, soil aeration and vapor pressure deficit determines the Ca^{2+} transport, at least in saturated soil, needs further investigation.

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Tables and Figures

(see next page)

Table 1. Plant growth, fruit and biomass yield and fruit properties as influenced by soil moisture.

Soil moisture	Growth parameters Per plant			Fruit and biomass			Fruit quality parameters							
	Height (cm)	Leaf area[1] (m^2)	Stem diameter (mm)	Fruit weight (g $plant^{-1}$)	Mean fruit weight (g)	Biomass (g)	DM (%)	TTA (%)	TSS (^{0}Brix)	pH	TSS: TTA	Firmness (kg)	AA (µg/kg)	BER (%)
Dry	134	0.43	11.5	1985	19.2	337	10.6	0.408	9.6	3.6	23.25	4.2	100.6	23.6
Field capacity	176	0.66	15.4	4476	27.8	563	7.1	0.380	6.5	3.9	17.10	2.7	90.8	7.3
Saturation	147	0.37	18.4	2617	21.0	353	9.2	0.364	7.2	4.0	20.00	2.7	87.6	21.0
P value	0.004	0.05	0.000	0.001	0.007	0.035	0.015	0.051	0.028	0.000	0.007	0.005	0.046	0.009
SED (8 df)	10	0.11	0.98	501	18.06	87.15	1.01	0.61	1.07	0.03	0.09	0.46	2.06	4.68

[1] Leaf area was determined at the crop stage at first harvest.

Figures

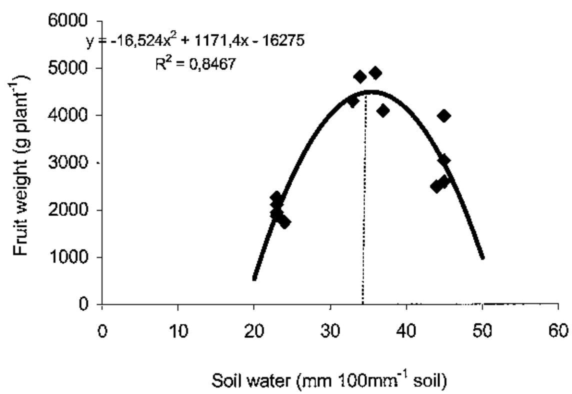

Fig. 1. Fruit yield with respect to soil moisture levels.

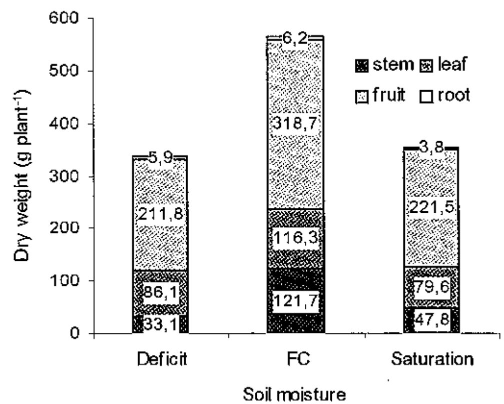

Fig. 2. Dry matter partitioning at different soil moisture regimes.