Water deficit during the reproductive period reduced yields of tomato varieties

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Introduction

In Timor-Leste, demand for tomato (*Lycopersicon esculentum* L.) product increases and is consistent with the improvement of country's economy and family income since the country decided to separate from Indonesia in 1999 and gained independence in 2002. Tomato production in Timor-Leste varies according to data sources. Total tomato production, according to the Food and Agricultural Organization (FAO), increased consistently from 241 tons in 2001 to 600 tons in 2011 (http://faostat.fao.org). Although the production for 2012 has not been recorded yet, based on the available data in previous years, one can expect that the production will be more than 600 tons. On the other hand, a much less tomato production of approximately 2 tons was observed in a recent survey in 2012 conducted by USAID, Timor-Leste (USAID 2013, 7). Further, this study showed production distributions across the country. Five major tomato production districts were Baucau (approx. 1 tons), Maliana (approx. 0.4 tons), Dili (approx. 0.3 tons), Aileu (approx. 0.2 tons) and Liquica (approx. 0.1 tons). Irrespective of the differences in the production of tomato in Timor-Leste between sources, it is clear that the production is not sufficient for consumption and hence its importing requirement is needed to fulfill the consumers' demand. Available data indicated that tomato product imported to Timor-Leste was 24 tons in 2010 (RDTL 2011, 126). High imported tomato product in Timor-Leste is related to its low production which is associated with climate constraints and limited irrigation.

Farmers usually grow tomato towards the end of the rain season. They recognize that by growing tomato early in the rainy season, for example in November or December, production is likely to fail due to disease and pests attack on plants and fruits during heavy raining in February and March. To avoid this, farmers traditionally recognize that a better quality of tomato fruits can be obtained when they grow late in the rain season and/or during dry season. Despite this, irrigation support is lacking and hence production is limited. Water deficit herewith refers as drought increases when plant enters to their reproduction e.g. in May in the northern and central parts of the country when the drought season begins. As tomato plants are semi or indeterminate plants, drought would reduce growth and production of flower and fruit and consequently reduce fruit yield. The extent of tomato yield reduction under drought and whether there was a better adapted variety among varieties tested were not well-understood. This study aimed to quantify and compare yield reduction between tomato varieties under drought and to identify a drought resistant variety.

Methods and materials

Study location and experimental details

This study was conducted in a Field Trial of the Faculty of Agriculture, National University of East Timor (or Universidade Nacional Timor Lorosa'e – UNTL), in Hera from May to September 2012. Three tomato varieties of Apple (VA), Potato (VP) and Local (VL) were used in this study. The VA and VP were considered as improved varieties from Indonesia and seeds were obtained from a local agricultural market in Dili, Timor-Leste. The VL used in this study was the variety that has had been grown locally for years. Seeds of VL were obtained from a local market in Dili, Timor-Leste.

A pre-germinated plant of each variety was grown in a pot containing 7 kg of a 6 : 1 mixture of a sieved air-dried and sand collected from experimental site and nearby river, respectively. Plants in pots

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were arranged in a completely randomized design with 5 replications in a temporary established greenhouse and were well-watered at 70% of field capacity (FC) from sowing until 50% of flowering when drought treatments initiated. The drought treatment was applied by reducing pot water content from 70% FC to 55% FC (for moderate drought) and 40% FC (for severe drought) and these levels of water content were maintained until harvest. The control plants were watered and maintained at 70% FC until harvest. The amount of water used in each watering was calculated by weighing pots in every 2 – 3 days interval.

Plant water use

The amount of water applied in each watering from sowing to harvest was recorded and was summing up for the cumulative plant water use. Total plant water use was used to determine plant water use efficiency (see section plant water use efficiency below for details).

Growth and development

Numbers of plant leaves, branches and plant height were determined at harvest. Plant leaves were determined by counting all plant leaves. The number of branches was determined by counting the number of branches developed. Plant height was determined by measuring its height from the soil surface to the top of highest stem e.g. main stem. Plant materials (except fruits) were oven dried at 70^{o}C for 48 hours and reweighed for dry matter determination.

Flower and fruit production and their abortions

The number of flowers developed including those successfully formed fruits and aborted flowers were counted. In addition, the numbers of fruits as well as aborted fruits were also recorded.

Plant water use efficiency

Water use efficiency for dry matter and fresh fruits were determined by dividing the weight of plant dry matter and fresh fruit to the total plant water use.

Statistical analysis

The package GenStat Discovery Edition 4 (Oxford UK) was used for statistical analysis of the data. The data was analysed using a two-way analysis of variance.

Results and discussion

Plant water use

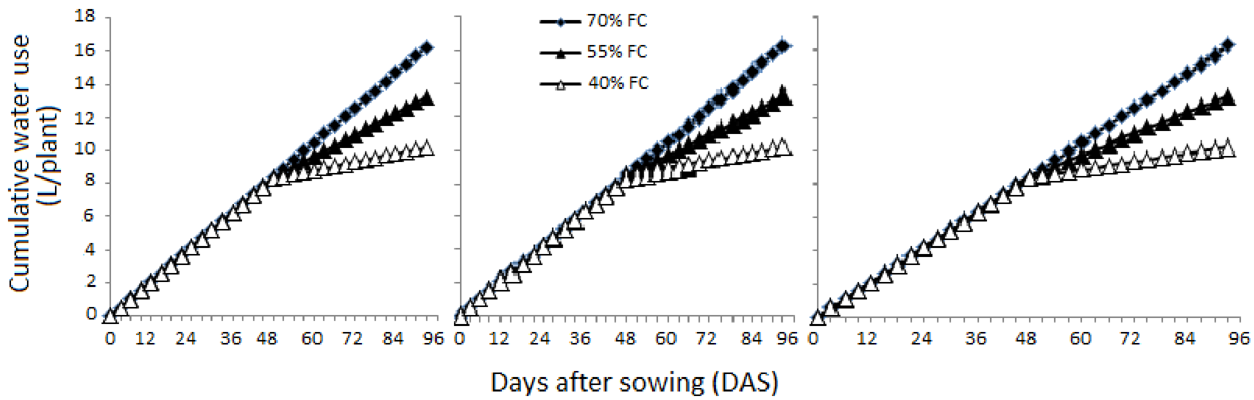

Figure 1 - Cumulative water use for VA (a), VP (b) and VL (c) with control plants (70% FC), moderate drought (55% FC) and severe drought (40%). Data are means ± SE (n = 5).

Plant water use from sowing to 50% flowering at the time when water treatment initiated was approximately 8 L per plant in all three tomato varieties. Drought reduced plant water use by 19% for plants received a moderate drought (55 % FC) and by 38 % for plants received a severe drought (40% FC) in all varieties, compared with their control plants (70% FC). Overall, the reduction of plants' water use affected their physiological activities and thus led to reduce growth, development and yield of tomato varieties.

Growth and development

Drought significantly reduced number of plant leaves ($P<0.001$), branches ($P<0.001$) and plant height ($P<0.01$), despite there was no significant difference between tomato varieties ($P>0.05$) leading to no interaction between treatments and varieties. Under the moderate drought, number of plant leaves was reduced by 19, 17 and 12 leaves in VA, VP and VL, respectively, compared with their controls (Table 1). In a severe drought, plant leaves number were decreased further by 33, 30 and 28 in VA, VP and VL, respectively, compared with their controls. Reduction in plant leaves was due to the reduction in number of branches and nodes. Severe drought reduced plant branch number by 21, 38, and 25% for VA, VP, and VL, respectively and plant height by 17, 12 and 10% for VA, VP and VL, respectively, compared with their controls. These results consistent with studies on an indeterminate growth habit grass pea (*Lathyrus sativus* cv. Ceora) that growth and development were reduced when plants imposed to either moderate or severe drought (Gusmao 2010, 41, 65; Gusmao et al. 2012, 5). Reduction of plant leaves led to reduce green leaf area and thus photosynthesis which led to reduce plant dry matter production as well as flower and fruit production (Table 2).

Table 1. Number of plant leaves, branches and plant height (cm) of the tomato varieties. Data are means ± SE (n = 5).

Water treatment	Tomato variety		
	VA	VP	VL
	Number of plant leaves		
70 % FC	16.0 ± 0.3	15.4 ± 0.7	14.8 ± 0.4
55 % FC	13.0 ± 0.8	12.8 + 0.6	13.0 ± 0.3
40 % FC	10.8 ± 0.8	10.8 ± 0.7	10.6 ± 0.5
	Number of plant branches		
70 % FC	2.8 ± 0.2	2.6 ± 0.2	2.4 ± 0.2
55 % FC	2.4 ± 0.2	2.2 ± 0.2	2.0 ± 0.3
40 % FC	2.2 ± 0.2	1.6 ± 0.2	1.8 ± 0.2
	Plant height		
70 % FC	78.2 ± 2.7	73.0 ± 2.0	71.2 ± 5.5
55 % FC	68.0 ± 7.5	67.8 ± 1.2	67.6 ± 0.9
40 % FC	64.8 ± 5.9	64.2 ± 2.0	64.0 ± 0.8

Dry matter production, fruit number, fresh fruit weight, aborted flower and fruit

There were interaction between treatment and variety in dry matter production ($P<0.001$) (Table 2). The highest dry matter production was VA in control plants, while dry matter production was comparable in all varieties when plants imposed to moderate and severe droughts. Under moderate drought, dry matter production of VA was reduced by almost half (46%) compared with control. A slight further reduction occurred when water application reduced further to a severe drought. Potato variety, however, did not differ between treatments on dry matter production. On the other hand, VL showed a steady reduction of 19 and 34% in moderate and severe droughts, respectively, compared with control. A field study observed that a 75-day irrigation cutoff reduced plant dry matter by 26% compared with control (Mitchell and Shennan 1991, 4) which was in between moderate and severe drought of the VL variety. Reduction of plant dry matter is a consequence of the reduction of photosynthesis when water supplement decreases (Morison et al. 2008, 642) that it reduces plant water status (Gusmao et al. 2012, 5).

Table 2 - Dry matter production, fruit number, fresh fruit weight, aborted flower and fruit per plant. Data are means ± SE (n = 5) at LSD, P<0.05.

Water treatment	Tomato variety														
	VA	VP	VL	VA	VP	VL	VA	VP	VL	VA	VP	VL	VA	VP	VL
	Dry matter production (g/plant)			Fruit number per plant			Weight of fresh fruit (g/plant)			Aborted flower per plant			Aborted fruit per plant		
70% FC	46.7±3.4	28.1±2.3	29.6±2.3	15.4±1.3	11.0±0.7	10.6±0.8	80.2±7.7	44.3±4.9	32.7±2.8	1.4±0.4	1.0±0.5	1.8±0.5	1.2±0.4	2.0±0.6	2.0±0.3
55% FC	25.2±1.5	24.6±1.7	24.0±1.3	11.2±1.2	10.6±0.5	10.2±0.6	43.6±4.2	32.4±2.0	30.9±3.4	5.0±0.5	6.0±0.5	6.8±0.8	1.8±0.2	2.4±0.7	3.0±0.6
40% FC	22.4±1.3	21.4±3.0	19.5±0.7	8.8±0.5	7.8±0.4	8.2±0.4	30.4±1.7	23.9±2.1	21.1±2.2	7.0±0.3	7.8±0.4	12.2±0.6	4.2±0.5	3.4±0.5	4.8±0.4
LSD-Treatment		3.49***			1.27***			2.26***			na			na	
LSD-Variety		3.49***			1.27**			2.26***			na			na	
LSD-Interaction		6.04***			2.20*			3.91***			na			na	

***significant at P≤0.001, **significant at P≤0.01, *significant at P≤0.05, na not aplicable

Table 3 - Water use efficiency for dry mass (WUE_{dm}) and for fresh fruit (WUE_{ff}) of the tomato varieties. Data are means ± SE (n = 5).

Water treatment	Tomato varieties		
	VA	VP	VL
		WUE_{dm}	
70 % FC	2.9	1.8	1.9
55 % FC	1.9	1.9	1.8
40 % FC	2.2	2.1	1.9
		WUE_{ff}	
70 % FC	5.0	2.8	2.0
55 % FC	3.4	2.5	2.4
40 % FC	3.0	2.4	2.1

Fruit production per plant was significantly interacted between water treatments and tomato varieties ($P<0.001$) (Table 2). Under well-watered conditions, the highest fruit production per plant was VA which was 15.4 fruits and this was consistent with the highest dry matter production compared with other varieties (described in the previous paragraph). Fruit productions were similar in VP and VL which were 11 and 10.6 fruits, respectively. Moderate drought did not reduce fruits number in VP and VL compared with their controls, but there was a dramatic reduction in fruit number in VA variety which was 27% less than its control. Severe drought significantly reduced fruit number in all varieties which were 43, 29 and 23% for VA, VP and VL, respectively, compared with their controls. Number of fruits produced was similar in all varieties under severe drought.

The weight of fruits per plant reflected well the fruit number produced described above, except VP and VL where different trends were observed (Table 2). Moderate drought significantly reduced fruits weight by 46 and 27% in VA and VP, respectively, but it did not reduce weight of fruits in VL (6%) compared with their controls. Severe drought significantly reduced fruit weight per plant by 62, 46 and 36% in VA, VP and VL, respectively, compared with their controls. In a field study, it was observed that a 75-day irrigation cutoff reduced tomato fruit yield by 29% compared with control (Mitchell and Shennan 1991, 5). This result can be comparable with the moderate drought in current study as in the field condition, there may be more soil moisture available deeper in the soil profile that support growth and fruit yield of tomato. In the current study, results suggest that VA and VP were more sensitive in response to drought compared with the VL. The reduction of fruit number and weight were due to the increase in flower and fruit abortions (Table 2).

Moderate drought increased flower abortions by triple (compared with controls) in all varieties. When plants imposed to severe drought, there was a moderate increase in flower abortion in VA and VP, but it was almost double in VL, compare with their moderate drought. Fruit abortion under moderate drought did not differ to control plants and they were comparable, except VL where it was higher than the VA (Table 2). However, under severe drought, the highest aborted fruit was VL and this was comparable with VA. High flower and fruit abortion in VL was probably an adaptive strategy of the plant to maintain size of the remaining fruits and this is consistent with other study on indeterminate growth habit grass pea (Gusmao et al. 2012, 5).

Water use efficiency for dry matter mass and fresh fruit

In VA, drought reduced water use efficiency for dry matter production (WUE_{dm}) by 34 and 23% for moderate and severe drought, respectively, compared with control (Table 3). In VL, moderate drought slightly reduced WUE_{dm} (by 0.4%) compared with control, but this was increased again and reached to control value in a severe drought. In VP, drought improved WUE_{dm} by 8 and 22% in moderate and severe drought, respectively, compared with control. Despite this, in VP, drought reduced water use efficiency for fresh fruit (WUE_{ff}) by 10 and 14% in moderate and severe drought, respectively, compared with control. Similarly, in VA, drought reduced WUE_{ff} by 33 and 39% in moderate and severe drought, respectively, compared with control. On the other hand, in VL, drought improved WUE_{ff} by 16 and 3% in moderate and severe drought, respectively, compared with control.

Conclusion

Drought reduced growth and development, but increased flower and fruit abortion of all tomato varieties which led to reduced dry matter production and fruit yields. Within the varieties, the VA was the most sensitive to drought compare to the other two varieties. Variety Local was less affected and showed an improvement in water use efficiency for fresh fruit under drought compared to the other two improved varieties.

Acknowledgement

This paper is part of Mr. Henrique's final project in fulfillment of the requirements for the degree of Bachelor of Science in Agronomy.

Bibliography

Gusmao, M. 2010, *Grass pea (Lathyrus sativus cv. Ceora) – adaptation to water deficit and benefit in crop rotation* (Ph.D. thesis), The University of Western Australia, Perth, Australia.

Gusmao, M., Siddique, K.H.M., Flower, K., Nesbitt, H., Veneklaas, E. J. 'Water deficit during reproductive period of grass pea (*Lathyrus sativus* L.) reduced grain yield but maintained seed size', *Journal of Agronomy and Crop Sciences*, 198 (6): 430 – 441.

Mitchell, J.P., Shennan, C. 1991, 'Tomato fruit yields and quality under water deficit and salinity', *Journal of the American Society for Horticultural Science*, 116 (2): 215 – 221.

Morison, J. I. L., Baker, N. R., Mullineaux, P. M., Davies, W. J. 2008, 'Improving water use in crop production', *Philosophical Transactions of of the Royal Society*, 363: 639 – 658, doi: 10.1098/rstb.2007.2175.

RDTL (Republica Democratica de Timor-Leste) 2011, *Timor-Leste strategic development plan 2011 – 2030*, (http://timor-leste.gov.tl/wp-content/uploads/2011/07/Timor-Leste-Strategic-Plan-2011-20301.pdf).

USAID (United Nations Agency for International Development) 2013, *Fresh vegetables in Timor-Leste*, Published by USAID, Dili, Timor-Leste.