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EFFECT OF DROUGHT STRESS ON GROWTH, YIELD AND SEED QUALITY OF TOMATO (*Lycopersicon esculentum* L.)

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Plant growth is seriously affected by abiotic stresses such as drought, salinity or temperature. Drought is one of the most important limiting factors for agricultural crops and vegetable production in particular all around the world. Drought stress during vegetative or early reproductive growth usually reduces yield by reducing the number of seeds, seed size and seed quality. To assess the effect of drought stress on seed yield, seed quality and growth of tomato, the experiment was conducted in green house in plastic pots at Pen-y-Fridd field station, University of Wales, Bangor, U.K. during 2003-2004. Tomato cv. 'Moneymaker' was used as a test crop. There were four treatments i.e. early stress (when first truss has set the fruits), middle stress (when fruits in first truss were fully matured and started changing their colour), late stress (when fruits on first truss were ripened fully), whereas in control no stress was imposed. Analysis of data regarding various attributes (fruit weight and shoot dry weight per plant, number of seeds per fruit, total number of seeds and seed weight per plant and vigour of seed) showed that drought stress had non-significant effect on vigour, quality and yield of tomato seed. Plant height, number of leaves and number of fruits per plant showed significant results toward drought stress signifying drought effects on growth of tomato.
Keywords: Tomato, drought stress, seed yield, seed quality

INTRODUCTION

Worldwide, the aggressive exploitation of natural resources has endangered water resources, biodiversity and soil quality. More than 1.2 billion people in over 110 countries are already affected by the social and environmental effects of the land degradation in dry lands (Schuster, 2003), which leads to declining biological and economic productivity. Pakistan is also one of the countries, which have agriculture system challenged with climate change. Acute shortage of irrigation water is adversely affecting the crop production in general and vegetable production in particular. Water stress during vegetative or early reproductive growth usually reduces yield by reducing the number of seeds in soybean (Brevedan and Egli, 2003) and canola (Sinaki *et al.*, 2007), while water stress during seed filling reduces seed size (De-Souza *et al.*, 1997) and yield can be reduced by short periods of stress during flowering and pod set (Vieira *et al.*, 1992).

The tomato is a major vegetable crop and grown all over the world in outdoor fields, greenhouses and net houses. Aside from being tasty, tomatoes are a very good source of vitamins A and C (Farooq *et al.*, 2005). The principal objectives of the science of seed production and seed technology are to improve the quality of propagation materials and to increase the performance of individual plant derived from them. The second important aspect of seed production is to multiply improved quality seeds in sufficient amounts to satisfy the demands of growers. The characters determining good seed quality are: its genetic purity, strong germination capacity, uniformity of seed size, freedom from seed borne diseases and the absence of weed or other crop seeds (Hartmann and Kester, 1983). Thomson (1979) commended that seed quality is a multiple concept comprising several components. Seed vigour is also an important component that can influence crop plant density and yield (Siddique and Wright, 2004). Vigour of seedlings relates with their ability upon germination to grow rapidly and well. It is suggested that speed and uniformity of emergence are important parameters of seed quality (Copeland and McDonald, 1995). Although many vigour tests have been suggested but only few have been accepted by seed analysts and seed testing organization (Perry, 1987). Hampton and Terkrony (1995) recommended conductivity tests, accelerated ageing and controlled deterioration tests for conducting seed vigour. However, germination test is used to determine seed viability (Hartmann and Kester, 1983). A controlled deterioration test is a seed vigour test that predicts relative field emergence and seed storage potential (Hampton and Tekrony, 1995). It is carried out at a high temperature and higher seed moisture content, therefore, aged seeds deteriorate rapidly in contrast to normal commercial storage.

Seed yield and viability can be reduced by environmental stress. It is reported that drought stress during seed production of soybean usually reduced seed yield. The major portion of this reduction is related to fewer number of seeds being produced (Dornbos *et al.*, 1989 and Heatherly, 1993) but some yield loss is also associated with a reduction in weight per seed (Heatherly, 1993). Vieira *et al.* (1991) reported yield loss of soybean up to 35-41% when drought stress was imposed during seed filling in green house experiment but found no effects on germination. In this research, we studied the effects of drought and shortage of water on tomato yield and quality.

MATERIALS AND METHODS

This experiment was designed to observe the effect of water stress on yield, quality and vigour of tomato seeds, cultivar 'Moneymaker'. For this purpose, 160 tomato seeds were sown in plastic trays and were transplanted with a single seedling in three litre capacity plastic pots filled with John Innes compost No. 1. The experiment was carried out in greenhouse No. 3 at Pen-y-Fridd field station, University of Wales, Bangor, U.K. The minimum day and night temperature was 18^{o}C and 15^{o}C and pots were placed on iron benches. The experiment was laid out according to Randomized Complete Block Design with four replicates. There were four treatments and each replication per treatment comprised ten plants. Lateral branches were continuously removed from all the plants during the course of experiment. Treatments were as follows:

T_1 = Control plants (no stress imposed)
T_2 = Early stress (when first truss has set the fruits)
T_3 = Middle stress (when fruits in first truss were fully mature and started changing their colour)
T_4 = Late stress (when fruits on first truss were ripened fully)

In case of early stress, the stress was imposed by with holding water and plants were re-watered when 50% of the treated plants showed the signs of wilting. The middle stress and late stress were imposed at respective stages. Fruits were harvested, when fully ripened, five times during the course of experiment. Fruits were counted and fresh weight was recorded for each treatment. At the time of harvest, morphological characters like plant height and leaf number per plant were recorded. Roots were not harvested in this experiment. The vegetative parts of the plants were oven dried at 70^{o} C for 72 h and dry weight was recorded.

Seeds were extracted from ten fruits, and then fermented in pulp and juice at ambient temperature for two days. After that seeds were washed, dried on tissue paper and then stored in polyethylene bags at room temperature. The observations made at that time were plant height (cm), leaf number per plant, fruit number per plant, fruit weight per plant (g), seed number per plant, seed weight per plant (g) and main stem dry weight (g).

For measuring the quality and vigour of seeds as influenced by the drought stress, following tests were performed.

Germination test was carried out by placing 25 seeds in each Petri dish on two moist layers of Whatman No. 1 filter paper. The germination of seeds was counted daily for eight days. A seed was considered as germinated when 3-4 cm long radicle was visible outside the seed coat (Fernandez and Johnston 1995). An emergence test was performed in green house at 15-17^{o}C and a day length of 8 h. Fifty seeds of each treatment were planted in the trays. Emergence counts were made daily up to two weeks. The following observations were recorded from the seedlings: emergence percentage, shoot length and dry weight of shoot.

To determine electrical conductivity of seed leachates (Hampton *et al.*, 1994), 50 seeds for each replicate were weighed. An electrical conductivity (EC) meter (Mettler Toledo Analytical AG, Sonnenvergstrasse-74.CH-6803, Schwerzenbach, Switzerland, made in USA) was used to measure EC. The EC of distilled water was measured and then seeds were soaked in the water. The EC was measured again after 24 h by keeping the material at 20^{o}C and expressed as µS $cm^{-1}g^{-1}$ (ISTA, 1988 and Perry, 1977).

For accelerated ageing test, 100 seeds from each replicate of all the treatments were initially exposed over water at a room temperature for a week in plastic container which was covered with a glass plate to increase seed moisture contents by humidification. After humidification, the moisture contents of the seeds ware determined prior to ageing. The seeds were then incubated at 45^{o}C for different time periods with maximum 3 days as required to create different vigour levels. These samples were then subjected to germination test. Statistical analysis was performed using the ANOVA function of the MINITAB Statistical Package version 1.4.

RESULTS

The effects of water stress treatments for various growth and yield components of tomato cultivar Money Maker are presented in Table 1. Imposition of water stress caused a significant reduction in plant height of treated plants as compared to control plants (79.2 cm). Well watered plants produced the taller plants as compared to rest of the treatments. However, late stress had much less effects on plant height and it produced taller plants (77.5 cm) than early and middle stress. The water stress significantly reduced leaf numbers per plant as compared to control. The late stressed plants produced comparatively more leaves (17.2) as compared to early (16.5) and middle stress (16.7), which were at par with each other.

Table 1. Effect of drought stress on growth and yield of tomato cultivar Money Maker

	Plant Height (cm)	Leaf No. per plant	Fruit No. per plant	Fruit wt. per plant (g)	No. of seeds per fruit	No. of seeds per plant	Seed wt. per plant (g)	Shoot dry wt. per plant (g)
Control	79.2 a	18.0 a	14.7 b	700 a	38.2	561.54	1.12	40.3
Early Stress	73.2 c	16.5 c	14.0 b	642 b	29.8	417.2	0.90	34.9
Middle Stress	73.5 c	16.7 c	12.5 c	613 c	43.5	543.75	1.23	34.8
Late Stress	77.5 b	17.2 b	15.2 a	706 a	40.8	620.16	1.13	36.6
L.S.D.	4.468	0.961	0.157	71.74	N.S.	N.S.	N.S.	N.S.

L.S.D. values @ 0.05

There was a mixed trend in production of fruits as a result of stress treatments. Late stress had no effect on fruit production and produced a little higher fruits per plant (15.2) as compared to control (14.7). On the other hand, little effect of stress was noted in case of early and middle stress but plants were more affected from middle stress than early. However, control plants had more fruits than early and middle stress. There was a significant reduction in fruit weight in early (642 g) and middle stressed plants (613 g) as compared to control (700 g). Nevertheless, late stress showed no effect on fruit weight and produced a little heavier fruits.

There were non-significant effects of stress treatments in above mentioned components than control plants. However, control plants had a comparatively higher dry weight per plant (40.3 g) when compared with stress treatments. However, middle and late stress treatments had more seed number and seed weight than control plants. Moreover, early stress treatment declined the seed number per plant greater than untreated control plants.

Results for germination percentage are shown in Table 2. There was no significant effect on germination leachates. In general, stress treatments showed comparatively higher values than non-stressed plants. Among stress treatments, middle stress had lower values against early and late stress (Table 2).

As shown in Table 2, experiment showed non-significant results for emergence percentage, shoot length and leaf number per shoot. However, control plants had greater percentage of seedlings emerged as compared to stress treatments. They also produced little taller seedlings. Nevertheless, all the treatments produced similar number of leaves. Germination percentage after controlled deterioration gave non-significant results (Table 3). However, control plants gave the maximum values for germination with late stress at the bottom. Early and middle stresses were in between control and late stress and had similar germination percentage.

DISCUSSION

Drought stress treatments affected the vegetative growth of plants in most of the cases. The treated plants showed a reduction in biomass production in

Table 2. Effect of drought on emergence of tomato cultivar Money Maker

	Emergence %	Shoot Length (cm)	No. of leaves per shoot	Germination %	E.C. (µS)
Control	91.5	4.5	2.0	99.36	28.66 d
Early Stress	77.5	3.0	2.0	89.66	50.03 b
Middle Stress	78.5	3.0	2.0	91.67	37.86 c
Late Stress	81.0	3.0	2.0	90	56.31 a
L.S.D.	N.S.	N.S.	N.S.	N.S.	3.324

L.S.D. values @ 0.05.

percentage. Water stress did not reduce germination percentage significantly over the control. However, it was higher for control plants (99.36) whereas, early stress was at the bottom and gave the lowest values for germination percentage (89.66) as compared to other stress treatments. Early and middle stresses were at par with each other. There were significant results for electrical conductivity (EC) of seed most of the stress treatments except late stress treatment. This was in association with a reduction of leaf production along with smaller plants as compared to control. Ibrahim (1990) reported similar findings for chickpea where a greater reduction was seen in vegetative parts with decreased branch production and correspondingly the main shoot became a more dominant component of the total shoot biomass.

Table 3. Effect of drought stress on germination of tomato cultivar Money Maker after controlled deterioration

	Germination percentage
Control	86.50
Early Stress	83.00
Middle Stress	79.00
Late Stress	68.00
L.S.D.	N.S.

L.S.D. value @ 0.05.

It is well known that drought stress during seed development reduces seed yield. The stress shortens the seed filling period, which reduced the final seed size. The major influence of water stress by applying at seed production period was to minimize the seed yield. Reproductive growth is very sensitive to water stress. Heatherly (1993) also observed that drought stress during seed production of soybean usually reduced the yield and quality of seeds. However, there is disagreement in the literature on the effects of drought stress on seed germination and vigour. Yield and seed number per plant did not show any severe effects from middle and late stress as compared to control. All of these effects might be due to moisture stress during seed filling (Vieira *et al.*, 1992).

Seed yield of tomatoes remained unaffected in case of middle and late stress. Seed weight of pea plants was significantly affected by stress treatments whereas, in tomato no effect was seen in this respect (Fougereux *et al.*, 1997). If the stress occurred early in seed filling then seed number was reduced but stress could shorten the seed filling period and reduced the yield without affecting seed number (Fougereux *et al.*, 1997). It is difficult to relate the level of stress and the responses obtained in greenhouse pot experiments to stress levels that may occur in the field (Brevedan and Egli, 2003). Re-watering the plants after a relatively short stress period did not completely eliminate the effects of water stress on plants. Drought stressed soybean plants produced fewer pods, followed by fewer seeds per pod and smaller seed mass than well watered plants (Dornbos *et al.*, 1989).

Seed yield and the yield components were reduced significantly by drought imposed during pod filling. Stress reduced seed number per pod and per plant basis, in plants under observation, but mean seed weight remained unaffected in contrast with many observations (Dornbos *et al.*, 1989). A prolonged and severe water stress reduced growth by reducing photosynthetic rate by both stomata closure and effects on photosynthesis metabolism (Hsiao *et al.*, 1985).

Vigour test showed that seeds from field plots where moisture was withheld during pod filling were low in vigour (Dornbos *et al.*, 1989). These results are in contrast with some previous experiments that showed little effect of moisture stress on germination (Yaklich, 1984 and Vieira *et al.*, 1991). However, they are consistent with other reports which showed reduction in germination (Dornbos *et al.*, 1989 and Simiciklas *et al.*, 1989) and vigour (Yaklich, 1984 and Dornbos *et al.*, 1989). Drought stress occurring during seed formation or seed filling resulted in reduced seedling vigour and germination (Simiciklas *et al.*, 1989 and Yaklich, 1984). In the present studies drought stress reduced germination of the harvested seeds.

The effect of water stress on seed quality has been investigated in soybean (Simiciklas *et al.*, 1989) and in peas (Fougereux *et al.*, 1997). They observed that water stress during the seed filling period induced a reduction in seed quality assessed by germination and conductivity results. This reduction was not seen with earlier water stress. Nichols *et al.* (1978), working with potted plants of peas observed no effect of drought stress on seed conductivity or germination.

It can therefore, be concluded that water limitations during whole growing season had no significant effects on seed quality and vigour of tomato seeds but clear significance on the growth of the tomato. These results are in partially agreement with Fougereux *et al.* (1997) for peas and Vieira *et al.* (1992) for soybean, who reported that it seems unlikely that drought stress would have a direct effect on metabolic activity of the seed that would subsequently affect quality but, water stress can considerably reduce yield.

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