

The Effect of Water Limitation in the Field on Sorghum Seed Germination and Vigor

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Abstract: Although drought stress has been shown to reduce sorghum yield, little information has been published regarding its effects on sorghum seed quality. To evaluate the effects of water limitation treatments (full irrigation (Control), irrigation until flowering stage and irrigation until eight-leaf stage) on grain yield, yield components, seed germination and vigor in grain sorghum (*Sorghum bicolor* L. CV. *Kimia*), field and lab experiments were conducted at research farm and laboratory of Agriculture College, University of Tehran, Karaj, Iran in 2005. The experiments were arranged with a Randomized Complete Block Design (RCBD) and split-plot experimental design (water limitation treatments as a main plots and seed harvest stages as a sub-plots) with four replications in farm and laboratory, respectively. The Results showed that water limitation had significant effect on grain yield and yield components ($p < 0.01$). Control plants had more grain yield and yield components than the other irrigation levels due to longer growth season and better use of environmental conditions. Withholding irrigation at eight-leaf stage decreased grain yield and its components. Nevertheless, qualitative attributes i.e. seed germination and vigor index were not significantly affected by irrigation levels. Thus, it doesn't seem that water limitation would have a direct effect on metabolic activity of seed and consequently seed quality.

Key words: Seed germination, Sorghum, Vigor, water limitation

INTRODUCTION

The yield of viable and vigorous seed is an important goal for seed producers. Environmental stress such as water limitation during growth and development plants can affect subsequent seed quality. Although evidence indicates the water limitation decrease yield and yield components in many crops, little information has been published regarding its effects on seed quality (Khodabande and Jalilian, 1997). Understanding how stress affects seed yield, viability and vigor could facilitate the identification of useful traits for increased stress resistance. Stress varies greatly in timing, intensity and duration (Sio-Se Mardeh *et al.*, 2006). Water limitation during seed development usually interrupts development and results in small seed size (Cruz-Aguado *et al.*, 2000). The reduction in seed size is due primarily to a shortening of the filling period rather than an inhibition of seed growth rate (Vieira *et al.*, 1992). Nevertheless, it was reported that small-seeded soybean cultivars produced high quality seeds under drought stress conditions (Vieira *et al.*, 1992). Rassini and Lin (1981), reported reductions in soybean seed vigor as drought stress increased during growth stages R_3 to R_5 . Khodabande and Jalilian (1997), reported a similar decrease in soybean seed vigor, as measured by the accelerated aging test, following drought stress during the seed filling period; however, there was no effect on seedling emergence from sand or soil. Also Dornbos *et al.* (1998) reported that drought stress during the seed filling period in soybean caused significant reductions in germination, axis dry weight and increase in seed conductivity in 1-yr of a 2-yr greenhouse study. In contrast, Meckel *et al.* (1984) reported that drought stress caused earlier seed maturation and reductions in size, but this would not be expected to affect seed germination. Ghassemi *et al.* (1997) observed that although water limitation during whole growing season could reduce sorghum yield, it had no any significant effect on seed quality. Also Viera *et al.* (1992) reported yield reductions of 35 to 41% when drought stress was imposed during seed filling in two greenhouse experiments, but found no effect on germination or vigor. Westgate and Thomson Grant (1989) suggested, the moisture status of the seed during development is not affected by changes in plant water status and rate of accumulation of dry matter by the seed was not affected by drought stress that caused significant reductions in yield. Thus, it doesn't seem that water limitation would have a direct effect on seed quality.

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Sorghum is a warm season crop growing well in tropical and subtropical climates. Thus Sorghum frequently experience drought stress during vegetative and reproductive growth. The effect of drought stress on yield and yield components are well known; however, there is disagreement in the literature on the effects of drought stress on seed germination and vigor. Thus, the objective of this research was to evaluate the effect of drought stress imposed during vegetative and reproductive growth on seed germination and vigor of sorghum.

MATERIALS AND METHODS

Two field and lab experiments were conducted at research farm and laboratory of Agriculture College, University of Tehran, Karaj, Iran in 2005. The soil type of experimental site was clay loam with a clay type of montmorillonite, PH of 7.6 and EC = 0.44 dS m⁻¹. The grain sorghum cultivar, Kimia, with high yielding potential was selected. Seeds were planted on 5 May 2005 at a planting density of 14 seeds m⁻². Plot size was 4 m wide and 3 m long with 75 cm between row spacing. There were four rows in each plot in an E-W direction. To evaluate the effect of water limitation treatments (full irrigation (Control) (IR₀), irrigation until flowering stage (IR₁) and irrigation until eight-leaf stage (IR₂)) on yield and yield components of sorghum, the field experiment was arranged with a Randomized Complete Block Design (RCBD) with four replications in research farm. A split-plot experimental design (water limitation treatments as a main plots and seed harvest stages (the beginning of doughing stage (h₁), 112 days after sowing (between doughing and physiological maturity stages) (h₂) and physiological maturity stage (h₃) as a sub-plots) with four replications in seed research laboratory was used, for the evaluate the effect of water limitation on seed quality during seed filling of sorghum.

Yield was estimated by harvesting 2 m of the two middle rows. Seed mass was determined by counting and weighing subsamples of seed from the yield sample, and the number of seed per unit area was estimated from the weight per seed and yield data. Seed quality was evaluated by standard germination and two vigor tests. For standard germination test, four 50-seed samples from each field plot were placed in petri dishes and transferred into a germinator at a constant 25 °C for 7 d (AOSA, 1988). Two vigor tests, accelerated aging and seedling growth rate were used to measure seed vigor according to the vigor testing Handbook (AOSA, 1988). For seedling growth rate, seeds in petri dishes were germinated at a constant 25 °C after 7 d, the cotyledons of the normal seedlings were removed. The seedling axes were dried in a convection oven for 24 h at 70 °C and weighed.

All data were analyzed with analysis of variance using a Proc GLM procedure of SAS (SAS Institute, 1994). Mean separation was obtained using a Duncan's New Multiple Range Test at the 0.05 probability level.

RESULTS AND DISCUSSION

Results:

The effect of drought stress on yield and yield components is shown in Table 1. Seed yield and yield components were reduced significantly by drought stress imposed during vegetative and reproductive growth stage of sorghum. Control plants had more grain yield and yield components than the other irrigation levels due to longer growth season and better use of environmental conditions. There were large reduction in yield due to withholding irrigation at eight-leaf stage rather than withholding irrigation at flowering stage. Each yield component decreased significantly as drought stress increased. Seed number reduced by 298 grain in per ear with withholding irrigation at eight-leaf stage and by 592 grain in per ear in withholding irrigation at flowering stage treatment. Drought stress during vegetative and reproductive stages interrupted development and resulted in small shriveled (small, misshapen, underdeveloped) seeds. Seed mass, a primary component of yield, is determined by seed growth rate and duration of seed fill. The reproductive period duration (RPD), the time period between the beginning of rapid seed fill and physiological maturity, can be affected by drought stress treatment. Water limitation lowered the level of seed mass in withholding irrigation at eight-leaf stage treatment, while withholding irrigation at flowering stage had no significant effect on seed mass of sorghum when compared with control.

Quantitative effects of drought stress on seed germination and vigor, unlike yield, have received little attention. In this study, increased trend of germination and vigor were observed with delay in harvesting time (Table 2). In general, the highest germination and vigor of sorghum were obtained in the harvested seed in physiological maturity stage. Withholding irrigation at eight-leaf and flowering stages did not reduce germination of sorghum (Table 2). Germination was high for all irrigation treatments in physiological maturity stage. Also seedling growth rate was not significantly affected by irrigation levels. Seed vigor, as measured by accelerated aging, was high for all treatments and showed no effect of water limitation. Thus, it doesn't seem that water limitation would have a direct effect on metabolic activity of seed and consequently seed quality. However, foregoing treatment had negative effects on seed yield.

Table 1: Yield and yield components of sorghum as affected by water limitation treatments

1000- Grain weight	Grain number per ear	Grain yield	water limitation treatmentsa
39.29a	975a	4144a	IR ₀
35.42a	592b	3310ab	IR ₁
18.4b	298.8c	921.3c	IR ₂

Values in columns marked with the same letter are insignificantly different on significance level $\alpha = 0.05$

Table 2: Germination and vigor of normal sorghum seeds harvested in three stages and affected by water limitation treatments

Seed harvest stage	water limitation treatments	standard germination(%)	seedling axis dry growth (g)	Accelerated aging
h ₁	IR ₀	61c	0.0031c	5.53c
	IR ₁	57c	0.0027c	4.48c
	IR ₂	55c	0.0023c	4.75c
h ₂	IR ₀	73b	0.0058a	6.31b
	IR ₁	71b	0.0043b	5.91b
	IR ₂	69b	0.0038b	5.91b
h ₃	IR ₀	97a	0.0086a	7.31a
	IR ₁	95a	0.0066a	6.81a
	IR ₂	89a	0.0061a	6.23a

Values in columns marked with the same letter are insignificantly different on significance level $\alpha = 0.05$

Discussion:

In this study, we evaluated the effect of water limitation on yield and yield components. Also the effect of water limitation on seed quality during seed development was compared. Our results show that Withholding irrigation at eight-leaf stage caused the largest reductions in sorghum yield. Withholding irrigation at flowering stage had little effect on seed yield when compared with control. Yield components (seed number and seed mass) were reduced significantly by drought imposed during vegetative and reproductive growth stages of sorghum. Withholding irrigation at eight-leaf stage reduced seed mass in sorghum, but seed mass had not affected by Withholding irrigation at flowering stage. Concurrent photosynthesis is the predominant source of photoassimilates for seed growth (Sinclair and Jamieson, 2008). When photosynthesis is inhibited during seed filling, reserves in the maternal tissues can be mobilized to maintain assimilate supply to the seed (Cruz-Aguado *et al.*, 2000). Final seed mass is a product of the rate and duration of seed filling. Reduction in seed mass caused by water deficits apparently result from a shorter filling period, while seed growth rate is coserved (Schussler, 1986). Meckel *et al.*, (1984) found the seed filling period was more sensitive to drought than seed growth rate and that the reduction in the duration of seed fill may be one way drought reduced yield.

The data suggest that sorghum plants can be subjected to significant levels of drought stress during seed filling without experiencing any effect on seed germination or vigor. These results are consistent with some previous experiments that showed little effect of drought stress on germination (Vieira *et al.*, 1991; Yaklich, 1984) or vigor (Smiciklas *et al.*, 1989). They are in contrast to other reports which showed reductions in germination and vigor. Dornbos *et al.* (1998) reported only small reductions in quality in 1-yr of 2-yr study, while the germination reduction reported by smiciklas *et al.* (1989) occurred only when stress was applied at one growth stage (R₅) out of several tested.

Sever drought stress during seed filling can result in seeds that are shriveld and misshapen. Delouche *et al.* (1980) reported that stress, severe enough to interrupt seed development, resulted in light, shriveled seeds. We found a small proportion of such seeds in Withholding irrigation at eight-leaf stage treatment and their germination and vigor were reduced. It is interesting to note that normal round seeds that were greatly reduced in size showed high levels of germination and vigor.

Many known characteristics of the growth and development of a sorghum seed suggest that drought stress would not affect seed quality. Morphological development of the seed, as shown by cell division in the cotyledons, is completed early in seed development (Egli *et al.*, 1981) and immature seeds will germinate and produce a normal seedling after drying when they have accumulated < 50% of their maximum dry weight (Vieira *et al.*, 1991). Thus, It is clear that sorghum seeds do not have to complete their normal filling period to produce a germinable seed. Drought stress cause earlier seed maturation (Meckel *et al.*, 1984) and reductions in size, but this would not be expected to affect seed germination. The rate of accumulation of dry matter by the seed was not affected by drought stress that caused significant reduction in yield. Thus, it seems unlikely that drought stress would have a direct effect on metabolic activity of the seed that would subsequently affect quality.

Maintenance of a favorable water status within the seed may be an important prerequisite for conserving seed growth rate under adverse environmental conditions (Westgate and Thomson, 1989). Observations similar to those reported here have been made in maize, wheat, barley and rice. The breadth of these observations suggests that the apparent independence of seed water status from that of the maternal tissues may be a

phenomenon common to all seeds in sorghum, as well as in the other crops, this independence may be due to the lack of direct vascular connections between the maternal and zygotic tissues.

It is well known that drought stress during seed development will reduce yields. The stress shortens the seed filling period, which reduces the final seed size. If the stress is extreme, the seed will be small, shriveled and misshapen. The evidence presented here in combination with a companion greenhouse experiment (Vieira *et al.*, 1991) suggest that, in the absence of shriveled seed, drought stress during seed filling is unlikely to affect seed germination or vigor.

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