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Germination of Sorghum Cultivars at Different pH Levels and Moisture Potentials

U.R. Bishnoi, Stephen Garton and Alassane Maiga*
Department of Plant and Soil Science,
Alabama A&M University, Normal, AL 35762, U.S.A.

Abstract: Inadequate germination and field stand establishment causing low yield or crop failure in grain sorghum (*Sorghum bicolor* L. Moench) is common in arid and semi-arid tropical regions having erratic rainfall and variation in soil pH. Therefore, effects of water potential and soil pH on germination of newly introduced U.S. grain sorghum cultivars in comparison to regional cultivars of West Africa were studied. Physiological germination (radicle emergence) of six American (SC283, SC574, SC689, B68181, SC33 and RTam 428) and four West African (Csm63, IS6705c, IS7173c and IS 7419c) sorghum cultivars was conducted at three osmotic potentials (control, -0.4 and -0.8 MPa) and at five points on the pH scale (5.0, 6.0, 7.0, 8.0 and 9.0) in the laboratory. Germination was decreased by 25% and 60% with decreased water potentials of -0.4 and -0.8 MPa, respectively, compared to controls. Alteration of pH from 7.0 significantly reduced germination in some cultivars. The effects on germination due to moisture and pH stress varied among cultivars. Cultivars SC283 and SC689 were most tolerant of, and sensitive to, low water potentials. Cultivar Csm63 was the most sensitive to low pH while B68181 showed similar response to high pH.

Key words: *Sorghum bicolor*, germination, tropical, erratic rainfall, arid climate.

Sorghum (*Sorghum bicolor* L. Moench), the world's fifth important cereal crop, is grown extensively in the arid and semi-arid areas of U.S.A., Asia and tropical Africa. In arid climates, erratic rainfall and excessive evaporation often create abiotic stress conditions of low water potentials and unfavorable soil pH, which cause poor seed germination. Hunter and Erickson (1952) observed that for germination to occur, seeds of each species must attain a specific moisture content. In arid climates, inadequate moisture is a frequent cause of germination failure. Yields of sorghum are very low in low rainfall years even though the plants are considered to be drought-tolerant. The principal cause of this low yield is inadequate plant density (Brar *et al.*, 1992). Hadas and Russo (1984) reported that a poor seed-soil moisture contact reduced the rate of water uptake and thus caused delayed or poor germination. Evans and Stickler (1961) reported that sorghum seed germination was reduced by 16% when the osmotic potential (OP) of imbibition solution was reduced from 0 to -1.0 MPa.

* Department of Agriculture, Bamako, Republic of Mali, West Africa.

Similarly, Smith and Hoveland (1986) observed a 44% reduction in sorghum germination with decreased OP from 0 to -1.0 MPa.

Soil acidity, alkalinity and low moisture content inhibit imbibition and reduce the ability of seeds to germinate. Wiggans and Gardner (1959) demonstrated such differences in several osmotica. Being genetically different, seeds of some sorghum cultivars may be more resistant than others to effects of decreased water potential or pH changes. Such differences in germination and growth have been reported in field beans (Adams and Pearson, 1967) and in sorghum cultivars (Stout *et al.*, 1980). In two separate studies, Gurmu and Naylor (1991) and Saint-Clair (1976) observed the ability of a sample of sorghum cultivars to germinate in polyethylene glycol (PEG) solutions of low water potential and related this to the field drought tolerance of the cultivars. Mali *et al.* (1979) measured water absorption in germinating seeds of 14 sorghum varieties and observed varietal differences in water uptake before germination. The authors suggested that through appropriate selection of variety, it may be possible to minimize the risk of low germination in dry lands.

Polyethylene glycol (PEG), a high molecular weight polymer, is commonly used to create low water potential conditions, which simulate the effects of drought on seed germination (Smith and Hoveland, 1986). Kaufman and Ross (1970) compared the germination of lettuce (*Lactuca sativa* L.) and wheat (*Triticum aestivum* L.) seed by using PEG 6000 solutions in petri dishes versus soil held at specific osmotic potentials. They concluded that total germination was comparable in two systems, but that the rate of germination was increased in the petri dishes. Manohar (1966) concluded that PEG absorption was not important until the radicle came into contact with the solution.

The selection of vegetable cultivars with high salinity tolerance was studied and cultivars with high salt tolerance were selected (Miyamoto *et al.*, 1985). However, information on the relationships of soil acidity or alkalinity on germination of diverse grain sorghum cultivars is not available.

Previous research has provided some insight into the germination of sorghum seed under moisture stress, but a comparative evaluation of newly introduced American hybrid cultivars and of newly developed West African sorghum cultivars are needed. Results of this study may facilitate selection of appropriate cultivars to reduce the risk of germination failure at low water potential or at extreme pH conditions. Therefore, experiments were carried out to evaluate six American and four West African grain sorghum cultivars for germination at five pH and three water potential levels.

Materials and Methods

Seeds of six U.S. (SC283, SC574, SC689, B68181, SC33 and RTam 428) and four West African sorghum cultivars (Csm63, IS6705c, IS7173c and IS7419c) were obtained from the International Sorghum and Millet Cooperative Research Support Program, University of Nebraska, Lincoln, NE, U.S.A., in November 1991, and the germination experiments were conducted in April 1992. To avoid after-ripening effects and to ensure uniform germination, the study on the seeds were conducted after 120 days of their harvest. Before planting, seeds were treated with terra-coat [Uniroyal, Middlebury, CT (penta Chloronitrobenzene 5-ethoxy-trichloromethyl)-1, 2-4-thiadiazole] to reduce decay problems during germination.

The three solutions with osmotic potentials of control (with no solute), -0.4 and -0.8 MPa to simulate different moisture stresses (drought) were prepared by using polyethylene glycol (PEG 6000) as described by Mitchell and Kaufman (1973). The solutions of five different pH values (5, 6, 7, 8 and 9) were prepared by adjusting the pH of distilled water (pH 7) with either a solution of 0.1 N HCl (for pH 5 and 6) or a solution of 0.1 N NaOH (for pH 8 and 9). To plant seeds, two Whatman No. 1 filter papers were placed in 100x15 mm round petri dishes. Five millilitres of solution were added to each petri dish at the beginning of the experiment and then repeated at the time of first count of seedlings after four days of planting. Four dishes for each OP solution were prepared for each cultivar. Fifty seeds per dish of each cultivar, spaced evenly, were then planted. Similarly, a separate experiment was conducted using the five different pH solutions to evaluate germination of each cultivar. Interaction of OP and pH levels was not studied. All sets of petri dishes were then placed in a germinator set at 25°C constant temperature. Starting from the 4th day, germination counts were made at 24 hour intervals with final count made on the 10th day after planting. A seed was considered germinated and counted when the radicle length was 2 mm or more, at which time the germinated seeds were removed from petri dishes. An analysis of variance was

Table 1. Effects of three osmotic potentials (OP) on the per cent germination of grain sorghum cultivars

Cultivars	Osmotic potential (MPa)		
	Control	-0.4	-0.8
U.S. Cvs			
SC 283	97.0a*	79.3a	41.8a
SC 574	97.3a	79.3a	38.0b
SC 689	97.8a	69.3d	24.8f
B 68181	94.0b	65.5e	36.8bc
SC 33	97.0a	78.0ab	38.3b
RTam 428	98.0a	75.8bc	34.3cd
West African Cvs			
Csm 63	94.3b	69.3d	31.3de
IS 5605c	96.5ab	74.5c	33.3d
IS 7173c	97.7a	71.0d	29.0e
IS 7419c	98.0a	76.0bc	28.8e

*Means bearing different letters in the same column differ significanlty ($p < 0.05$).

performed on data of total germination per cent using a randomized complete block design. Significant differences among means were separated by Tukey's test.

Results and Discussion

Effect of low osmotic potential

Sorghum cultivars responded differently ($P < 0.05$) to decreasing OP (Table 1). While all cultivars showed a decrease in germination due to decrease in OP, the cultivar SC283 maintained highest germination (41.8%) and African cultivar IS7419c the lowest (28.8%) when OP decreased from 0 to -0.8 MPa. The analysis of variance showed that the effects of OP and cultivars on total germination percentage were highly significant ($P < 0.01$; Table 2). The interactions reflected changes in the magnitude of the per cent germination and not a change of cultivar rankings. The significance of quadratic and linear components revealed different response by the cultivars to changes in water or osmotic potential. These results were similar to findings of Smith and Hoveland (1986) with a pearl millet and sorghum cultivar, and of Evans and Stickler (1961) in sorghum. The latter reported a 16% reduction in sorghum germination when OP was decreased from 0 to -1.0 MPa. In this study, a decrease of 56-73% in germination with a decrease in OP from 0 to -0.8 MPa was observed. The results also suggest that most of the American cultivars appear to be more tolerant of lower OP than the West African cultivars. This implies that American grain sorghum hybrids have similar or better tolerance to and may germinate under low moisture potentials, which may be advantageous in stand establishment under less than ideal conditions that frequently occur in arid tropics. This may be due to the relatively small size and high tannin content requiring lesser water to start germination in seeds of American cultivars.

Table 2. Mean square and significance for sources of variation of total sorghum germination due to osmotic potential treatments and cultivar

Source of variation	df	Mean squares of germination
Reps	3	1.5
Cultivar	9	155.8**
OP	2	43431.4**
Linear OP	1	84890.5**
Quadratic OP	1	1972.3**
CV x OP	18	117.6**
Error	87	1.6

** Significance ($p < 0.01$).

Effects of pH

Data on germination per cent indicated that pH stress has a significant effect on grain sorghum and that cultivars were more sensitive to a pH lower instead of higher than 7.0 (Table 3). Cultivars IS7173c and IS7419c were most tolerant, whereas, cultivar Csm63 was very sensitive to low pH. Most cultivars were tolerant to pH 6-8, and per cent germination ranged from 88.8 to 98. Total germination decreased for all cultivars at pH 9 except West African cultivar, Csm63. Among the cultivars, all the West Africans (except Csm63) tended to show more tolerance to a pH lower, as well as higher than 7.0. The analysis of variance indicated that the effects of pH on germination percentages were highly significant. The effects of cultivars and the

Table 3. The effects of pH on per cent germination in grain sorghum cultivars

Cultivars	pH				
	5.0	6.0	7.0	8.0	9.0
U.S. Cvs					
SC 283	81.5cd*	95.8ab	97.0a	96.1ab	88.5b
SC 574	85.0bc	97.0a	97.3a	95.0ab	84.8bcd
SC 689	84.3be	96.0a	97.8a	95.9ab	83.0d
B 68181	82.2cd	92.7b	94.0b	93.3b	81.8d
SC 33	85.8b	95.0ab	97.0a	96.5ab	89.0b
RTam 428	81.1cd	96.0a	98.0a	94.2ab	90.3ab
West African Cvs					
Csm 63	79.5d	88.8c	94.3b	94.5ab	92.7a
IS 6705c	82.5bc	95.6ab	96.5ab	96.8a	87.0bc
IS 7173c	93.4a	97.1a	97.7a	97.a	82.0d
IS 7419c	94.3a	98.2a	98.0a	94.0ab	82.8d
CV (%)	1.04	0.79	0.94	0.89	1.13

* Means bearing different letters in the same column differ significantly ($p<0.05$).

effects of interactions of cultivars x pH treatments were also significant (Table 4). The significance of linear and quadratic components revealed that the cultivars responded differently to changes in pH values.

Results from this study suggested that the cultivars SC283 and Csm63 may comparatively reduce the risk of germination failure in low osmotic potentials, and at higher pH, respectively, whereas, cultivars IS7173c and IS7419c would be better selections to minimize stand failure at a pH lower than 5. Since germination counts were made when the radicle length was 2 mm or more, it is of considerable interest to note that cultivars highly tolerant to low water potential and to adverse pH also had discernible differences in the ability of their seeds to produce longer radicles and coleoptiles. This suggests that by means of a relatively rapid laboratory germination test, one can screen early generations of breeding lines for tolerance to soil pH and the water potential conditions prevalent in arid environments.

Table 4. Mean square and significance for sources of variation of sorghum germination due to pH and cultivar

Source of variation	df	Mean squares of germination
Reps	3	0.2
Cultivar (Cv)	9	98.3**
pH	4	974.3**
Linear pH	1	46.9**
Quadratic pH	1	3666.9**
Cv x pH	36	99.6**
Error	147	0.8

**Represent significance ($p < 0.01$).

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