Effect of Water Stress and Variety on Phenology of Bread Wheat (*Triticum aestivum* L.) in Sokoto, Sudan Savannah, Nigeria.

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Abstract
The objective of this study was to determine the effect of water stress on phenology and identify drought resistance mechanism in bread wheat and also to find out the most crucial stage of growth with respect to water stress in wheat variety. The experimental materials consisted of and two bread wheat varieties (Star 11 TR 77173/SLM and Kauz/Weaver). Water stress was imposed at three critical growth stages by withholding water at (tillering, flowering, grain filling stages, there was also the control with no water stress treatments. The experiment was laid out in a split plot design with three replications. Water stress was allocated to the main plot, while variety was assigned to the sub plot. The research was conducted during the 2009/10 and 2010/11 dry seasons at the Usmanu Danfodiyo University, teaching and research Fadama farm, Sokoto in the Sudan Savanna ecological zone of Nigeria (latitude $13^0 01^1$N; longitude $5^0 15^1$E and at an altitude of about 350 m above sea level). Water stress at tillering resulted in significant ($P<0.05$) reduction in days to 50% booting, heading and anthesis, Water stress at grain filling resulted to significant reduction in grain filling duration and such limitation caused the canopy to senesce prematurely, The variety Star II TR 77173/ SLM had shorter days to booting, heading and anthesis than Kauz/Weaver. Star II TR 77173/ SLM was better than Kauz/Weaver in its ability to complete its growth period and mature before the drought stress appeared to exert its limiting effect. The phonological stages of booting, heading, flowering and maturity were all influenced by water stress/drought. Star II TR 77173/ SLM is recommended to this area and other areas with similar climate due to its superiority over Kauz/Weaver through its ability to complete its growth period and mature before the drought stress appears to exert its limiting effect.

Key words: *Water stress; variety; bread wheat; phenology; Sudan savannah.*

Introduction

Wheat is a cereals crop that belongs to the tribe *Triticeae* which is one of the largest and most important tribes in the grass *Poaceae* family (Dewey, 1984). Wheat (*Triticum aestivum* L.) is one of the most important staple food crops of the world (Akbar *et al*., 2001). Global average production is around 2.7t ha^{-1} with high variability among countries and regions. The highest average production is obtained in Western Europe, with more than 8 t ha^{-1}, in contrast to less than 1 t ha-[1] in several countries in Central/West Asia and North Africa (Rajaram and Braun, 2006).

Water constitutes over 90% of plants total mass and has important function in photosynthesis, transpiration, turgor pressure (Pressure to inflate cells and hold plant erect), movement of products of photosynthesis throughout the plant, and regulation of stomatal opening and closure. Water also serves as a source of presure to move roots through the soil and medium for biochemical reactions (Colorado Master Gardener (CMG, 2010). Water stress to plants results in reduced growth, vigor, nutrient deficiencies and senescence (Colorado Master Gardener (CMG, 2010). Water stress in wheat changes the pattern of plant growth and development. Depressed water potential suppresses cell division, organ growth, net photosynthesis, protein synthesis and alters hormonal balances of major plant tissues (Gusta and Chen, 1987). Drought at booting and after anthesis reduced mean days from plant emergence to maturity by 5% in wheat (Ehdaie, 1995). Sionit *et al.* (1980) also noted that water stress in wheat hastens senescence by 3 days. Innes and Blackwell (1981) observed that water stressed wheat matures 12 days earlier than fully irrigated plots. Water stress at booting stage greatly affects anthesis and pollen viability (Saini and Aspinal, 1982). Drought at booting and after anthesis reduced mean days from plant emergence to maturity by 5% in wheat (Ehdaie, 1995). Peterman *et al.* (1985) and Spiertz and Vos (1985) reported that grain filling duration can be reduced by drought and such limitation may cause the canopy to senesce prematurely, and grain filling then relies more on the reserves stored in the stems (Blum *et al.,* 1994).

Five terms which have been used to express the plant mechanism for resistance to the drought, are escape from drought (eg pre-maturation), drought avoidance (eg stomata and coticoli resistance), drought tolerance (eg osmotic adjustment and swelling increase), post drought resistance (Izanloo e*t al.,* 2008, Mohammed, 2008). One of the drought resistance mechanisms is the escape from drought which represents the plants capability to complete its growth period and mature before the drought stress appears to exert its limiting effect. The simplest way for a plant to adapt itself to drought conditions, is to escape from drought. In regions which possess the drought at the end of seasons, pre-maturation is an essential way to escape the drought (Skoric, 2009). An amending strategy against the drought is reducing the life cycle of a crop in order to enable it to mature within the time of the precipitation period (Magloire, 2005). Drought may influence the phenology of the plant for instance it may push forward the flowering of wheat. Dodigo *et al.* (2002) observed that the grain yield in the drought conditions is improved by such factors as selecting for early flowering, high temperature resistance and large number of seeds per cluster. Olsovska (2001) reported that the genotypes with high yield in the optimum conditions of water reserve could become the most drought resistance genotype via synchronized selection of drought-resistance factors like pre-maturation.

Wheat is an important cereal crop and serves as a staple food in many countries of the world (Wajid, 2004). Haj *et al.* (2007) observed that higher productivity of wheat in United States was due to more favorable environmental condition which includes temperature and moisture.

The objective of the study is to evaluate the effect of water stress on the penology of two bread wheat cultivars in Sokoto Sudan Savannah Nigeria.

Materials and Methods

The trials were conducted during the 2009/2010 and 2010/2011 dry seasons at the Fadama Teaching and Research Farm, Usmanu Danfodiyo University, Sokoto, (Latitude 13^0 01'N. longitude 15^0 13'E) at Kwalkwalawa village in Sokoto. The farm is located within the Sudan Savanna Zone of Nigeria (Kowal and Knabe, 1972). The area has a long dry season that is characterized by cool dry air during harmattan from November to February and hot dry air during hot season from March to May. Relative humidity ranged from 26-39 % in the dry season. Minimum temperature ranged between 18 ^{0}C to 29 ^{0}C and Maximum temperature ranged from 30^{0}C to 40^{0}C and wind speed ranged between 1.9 M/S to 5 M/S [(Sokoto Energy Resource Center) (SERC, 2011)]. The soil is hydromorphic that is seasonally flooded during rainy season. The area was previously used for the cultivation of vegetables and cereals.

Prior to planting, soil samples were collected from nine randomly selected points within the experimental site at 0-30 cm depth using soil auger, which were bulked to form a composite sample and sub-sampled using coning and quatering, air-dried and sieved. The sub sample was used for physico-chemical analysis.

The treatments consisted of combination of water stress which was imposed by withholding water at (tillering, flowering, grain filling stages and Control (No water stress), Two bread wheat cultivars; Star 11 TR 77173/SLM and Kauz/Weaver. The experimental design was a two factor factorial experiment in a split plot design with three replications.

Water stress was allocated to the main plot, while variety was assigned to the sub plot. The land was cleared, ploughed, harrowed, leveled and followed by construction of basins and water channels. Gross plot size was 3m x 3m (9m^{-2}) while the net plot consists of 11 rows, 2 meter long, spaced at 0.2 meter (4.4m^{-2}). One meter (1m) lee-way was left between blocks and 0.5m between plots. The seeds were treated with Apron star 42 WS (20% w/w thiamethoxam, 20% w/w metalaxyl-M and 2 % w/w difenoconazole) at the rate of 4 kg of seed to 10 g before sowing. The seeds were sown by hand drilling at 20 cm intra row spacing at 2-3 cm depth and at the rate of 120 kg/ha.

Four irrigations were applied to the crop before imposing water stress to allow for proper establishment of sowing. The method of irrigation used was check basin irrigation; water was applied to soil saturation (plots were flooded at the same capacity) at 5 days interval. Weeds were controlled manually with hoe at 3 and 6 Weeks After Planting (WAS) which ensured weed free plots.

Fertilizer was broadcast at the recommended rate of 120, 60 and 60 kg N, P_2O_5 and K_2O per ha^{-1} respectively. Half of nitrogen and full dose of phosphorous and potassium was worked in to the soil during seed bed preparation using NPK 15: 15: 15: while, the second dose of 60 kg N ha^{-1} was applied in form of urea (46% N) prior to tillering.

Birds were controlled by scaring while rodents were controlled by using baits and traps. No diseases out break were recorded.

The crop was manually harvested from the net plot at physiological maturity using sickles when 50% of the peduncles have turned brown. The plants were cut at ground level and sun dried for a period of 4 days.

Data were collected in respect of the following:

Days to 50% booting

The days to 50% booting was recorded when half of plant population within a plot had booted.

Days to 50% heading

A plant is regarded to have headed when the spike was clearly visible. The days to 50% heading was recorded when 50% of the spikes were visible.

Days to 50% anthesis

Days to 50% anthesis was recorded when half of plant population within a plot had extruded anthers from flowers.

Days to physiological maturity

This it is that stage of growth in which the plant has completed all of its development, including seeds which, when planted, can survive on their own. The number of days from planting to physiological maturity of the plants was recorded when at least 50% of the peduncles have turned brown and leaf have senesced using visual observation.

The data collected was subjected to analysis of variance (ANOVA) using SAS (2003).

Results and Discussion

Days to 50% Booting

The effects of water stress and variety on days to 50% booting in 2009/10, 2010/11 dry seasons and combined are presented in Table 1. The result indicated that, water stress at tillering resulted to early booting as compared to water stress at flowering, grain filling or the control (no stress) which were statistically similar with longer days to booting. This may be due to water stress imposed at tillering. This is because water stress retard photosynthesis and translocation of photosynthates and this affects overall plant development which is reflected by overall shortening of days to booting. Water stress may shorten the length of maturation and hasten senescence (Peterman *et al.,* 1985).

On varietal differences, in 2009/10 and combined, Kauz/Weaver differed significantly from Star II TR 77173/SLM with longer days to 50% booting. The two varieties were statistically similar in 2010/11 dry season (Table 1). Star II TR 77173/SLM exhibited mechanisms for drought resistance, which is similar to the findings of Izanloo e*t al.* (2008), who reported that five terms used to express the plant mechanism for resistance to the drought, are escape from drought (eg pre-maturation), drought avoidance (eg stomata and coticoli resistance), drought tolerance (eg osmotic adjustment and swelling increase), post drought resistance.

Days to 50% Heading

The effect of water stress and variety on days to 50% heading of two bread wheat in 2009/10, 2010/11 dry seasons and combined is presented in Table 2. The result showed that in both seasons and combined, water stress at tillering resulted in shorter days to heading than water stress at flowering or grain filling and control (no stress) which were statistically at par with each other with longer days to heading. The early heading of the water stress at tillering may be as a result of water stress imposed at that stage. Because water stress retards photosynthesis and translocation of photosynthates and this affects overall plant development which is reflected by overall shortening of days to heading.

There was significant effect of variety on days to 50% heading in 2009/10 dry differed significantly from Star II TR 77173/SLM with longer days to 50% heading. The two varieties were statistically similar in 2010/11 dry season. The result revealed significant differences in days to booting between the two varieties and this is as a result of genotypic variation (Table 2). The result is similar to that of Bilgi (2006) who reported significant effect of variety on number days to heading.

The interaction between water stress and variety on days to 50% heading in 2009/10 dry seasons was significant (Table 3). The results indicated water stress did not affect days to 50% heading, but irrespective of water stress Kauz/Weaver differed significantly from Star II TR 77173/SLM with longer days to 50% heading in the combined analysis.

Days to 50% Anthesis

The effect of water stress and variety on days to 50% anthesis of two bread wheat varieties in 2009/10 and 2010/11 dry seasons and combined is presented in season and combined. Kauz/Weaver Table 4. The result showed that in 2009/10 dry season and combined, water stress did not affect days to 50% anthesis, but in 2010/11 dry season water stress at tillering resulted in decrease in days to anthesis, while water stress at flowering and grain filling were statistically similar with the control treatment that had no water stress with longer number of days to anthesis.

There was significant effect of variety on days to 50% anthesis in 2009/10 dry season and combined. Kauz/Weaver differed significantly from Star II TR 77173/SLM with longer days to 50% antheisis. The two varieties were statistically similar in 2010/11 dry season. The variation may be genetically controlled. This is similar to the findings of Bilgi (2006), who reported significant effect of variety on days to 50% anthesis.

Table 1: Effect of water stress and variety on days to 50% booting of bread wheat in 2009/10, 2010/2011 dry seasons and combined at sokoto

Treatment	Days to 50% booting		
	2009/10	2010/11	Combined
Water stress			
Tillering	47.58[b]	48.75[b]	48.16[b]
Flowering	49.25[a]	49.25[ab]	49.25[a]
Grain filling	50.08[a]	49.37[ab]	49.72[a]
Control	48.70[ab]	50.04[a]	49.37[a]
Significance	*	*	*
SE±	0.415	0.309	0.250
Variety			
Star II TR77173/SLM	47.56[b]	49.56	48.35[b]
Kauz/ Weaver	50.25[a]	49.14	49.90[a]
Significance	*	Ns	*
SE±	0.345	0.162	0.288
Interaction			
S X V	NS	NS	NS

Means in a column and treatment group followed by same letters are not significantly different using DNMRT at 5% level. NS = Not Significant, * = Significant at 5% level.

Table 2: Effect of water stress and variety on days to 50% heading of bread wheat in 2009/10, 2010/11 dry seasons an combined at Sokoto

Treatment	Days to 50% heading		
	2009/10	2010/11	Combined
Water stress			
Tillering	53.00^{b}	54.45^{b}	53.72^{b}
Flowering	54.41^{ab}	55.79^{a}	55.10^{a}
Grain filling	55.08^{a}	55.75^{ab}	55.41^{a}
Control	54.12^{ab}	56.29^{a}	55.20^{a}
Significance	*	*	*
SE±	0.511	0.383	0.366
Variety			
Star II TR77173/SLM	53.02^{b}	55.58	54.30^{b}
Kauz/ Weaver	55.29^{a}	55.56	55.42^{a}
Significance	*	Ns	*
SE±	0.220	0.119	0.229
Interaction			
S X V	*	NS	NS

Means in a column and treatment group followed by same letters are not significantly different using DNMRT at 5% level. NS = Not Significant, * = Significant at 5% level.

Table 3: Interaction between water stress and variety on days to 50% heading in 2009/10 dryseason at Sokoto

	Variety	
	Star II TR 77173/SLM	**Kauz/ Weaver**
Water stress	**2009/10**	
Tillering	51.58^{d}	54.41^{a-c}
Flowering	53.16^{cd}	55.66^{ab}
Grain filling	54.16^{bc}	56.00^{a}
Control	53.16^{cd}	55.08^{ab}
SE ±	0.502	

Means followed by same letters are not significantly different using DNMRT at 5% level of probability.

Table 4: Effects of water stress variety on days to 50% anthesis of bread wheat in 2009/10, 2010/2011 dry seasons and combined at Sokoto.

Treatment	Days to 50% anthesis		
	2009/10	2010/11	Combined
Water stress			
Tillering	61.50	58.58^{b}	60.04
Flowering	60.50	59.41^{ab}	59.95
Grain filling	60.70	59.75^{a}	60.22
Control	61.75	59.70^{a}	60.72
Significance	Ns	*	Ns
SE±	0.631	0.294	0.374
Variety			
Star II TR77173/SLM	60.06^{b}	59.22	59.64^{b}
Kauz/ Weaver	62.16^{a}	59.50	60.83^{a}
Significance	*	Ns	*
SE±	0.402	0.123	0.280
Interaction			
S X V	NS	NS	NS

Means in a column and treatment group followed by same letters are not significantly different using DNMRT a5 5% level. NS = Not Significant, * = Significant at 5% level.

Days to Physiological Maturity

The effect of water stress and sowing date on days to physiological maturity of two bread wheat varieties in 2009/10 and 2010/11 dry seasons and combined is presented in Table 5. The result showed that in 2009/10 dry season, water stress did not affect days to physiological maturity. In 2010/11 dry season and combined, water stress at grain filling resulted in decreased days to physiological maturity. Control (no water stress) had the longest days to physiological maturity. This early maturity observed at water stress at grain filling was due to stress imposed at that stage. This is similar to the findings of Spiertz and Vos (1985) who stated that grain fill during can be reduced by drought and may cause the canopy to senesce permanently. Similar findings were reported by Peterman *et all*. (1985).

Variety had no significant effect on days to physiological maturity in 2009/10 and 2010/11 dry seasons and combined (Table 5).

Conclusion

Star II TR 77173 SLM exhibited drought resistance mechanisms which enable it to escape from drought through it ability to complete its growth period and mature before the drought stress exert its limiting drought resistance mechanism and this allows it to extent its growth period through the drought period and this may affect grain production in wheat. Booting, heading< anthesis and days to physiological maturity are the most critical phenological stages influenced by water stress in wheat, while variety influenced number of days to booting, heading and anthesis.

Recommendation

Star II TR 77173/ SLM is therefore recommended to this area an other areas with similar climate due to its superiority over Kauz/Weaver through its ability to complete its growth period and mature before the drought stress appears to exert its limiting effect.

Table 5: Effect of water stress and variety on days to physiological maturity of bread wheat in 2009/10, 2010/11 dry seasons and combined at Sokoto.

Treatment	Days to physiological maturity		
	2009/10	2010/11	Combined
Water stress			
Tillering	81.91	87.37^{b}	84.64^{ab}
Flowering	79.25	87.87^{b}	83.56^{bc}
Grain filling	79.79	85.70^{c}	82.75^{c}
Control	79.83	90.91^{a}	85.37^{a}
Significance	NS	*	*
SE±	0.817	0.401	0.501
Variety			
Star II TR77173/SLM	79.93	87.85	83.89
Kauz/ Weaver	80.45	88.08	84.27
Significance	Ns	Ns	Ns
SE±	0.491	0.184	0.362
Interaction			
S X V	NS	NS	NS

Means in a column and treatment group followed by same letters are not significantly different using DNMRT at 5% level. NS = Not significant, * = Significant at 5% level.

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