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Full Length Research Paper

Seed priming, genotype and sowing date effects on emergence, growth and yield of wheat in a tropical low altitude area of Zimbabwe

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Low wheat yields in low altitude tropical areas result from short winter seasons, late planting and poor stand establishment. Field experiments were carried out over two winter seasons (2005 and 2006) in the south-eastern lowveld of Zimbabwe to investigate effects of seed treatment (non-primed and primed seed), sowing date (2 May, 16 May, 1 June and 16 June) and variety (Dande, Insiza, Kana and S95063) on wheat. In the first season, seed treatment significantly affected final emergence with 84.7 and 78.3% emergence for non-primed and primed seeds respectively. However, in the second season seed treatment had no effect on final emergence. Priming reduced time to 50% emergence by 7 and 14 h in 2005 and 2006 respectively. From the first sowing date to the last, wheat yields were reduced by a mean of 2387 kg ha^{-1} in both seasons. At the last sowing date, Insiza significantly yielded higher than other varieties in the first season while, seed treatment had no effect on yield in both seasons. It was concluded that wheat planting after 16 May reduced yields. Insiza may optimise yields for late sown wheat while seed priming does not improve yield of late sown wheat.

Key words: Seed priming, sowing date, varieties, wheat, yield components.

INTRODUCTION

Low wheat (*Triticum aestivum*) yields experienced by resource limited small-scale farmers in tropical low altitude (< 500 m.a.s.l) areas of Zimbabwe are the result of short winter seasons, late planting, lack of inputs and poor stands. The short winter season in low altitude areas results in early onset of high temperatures, leading to premature senescence thus depressing yields. The yield potential of irrigated wheat in Zimbabwe is highly dependant on temperature as affected by altitude (Mashiringwani, 1989). Yields are often 50 - 60% of those experienced in the cooler high altitude (>1200 m.a.s.l) areas. The cool, dry season lasts from mid-May to mid-August. Mean temperatures on the highveld vary from 12-13°C in winter to 24°C in summer while in the lowveld the temperatures are usually 6°C higher (Hussein, 1987). Typical responses to high temperature include faster phenological development and shorter durations to maturity (Sadras and Monzon, 2006; Ugarte et al., 2007).

Sowing dates have been manipulated to avoid high temperature limitations on wheat yields. To maximise yields in the lowveld, the crop is grown during the time of the year when temperatures are lowest (Nyamudeza and Mutema, 2002). However, for a variety of reasons, which include late availability of seed, late maturity of the summer cotton crop, shortage of labour and lack of

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implements delay the planting of wheat during the recommended period (Havazvidi, 2006). For late planted wheat, early onset of high temperatures reduces the grain filling period and predisposes the wheat crop to pre-harvest sprouting damage caused by early spring rains (Havazvidi, 2006).

While sowing date is a critical part of wheat production in low altitude areas, varietal selections made by farmers also contribute to yield differences between farmers. Nyamudeza and Mutema (2002) reported significant interaction between sowing dates and variety on wheat yields. Studies elsewhere have reported different varietal responses to high temperature (Wardlaw and Moncur, 1995; Stone and Nicolars, 1995). This implies that breeding for high temperature tolerant varieties and use of these varieties by farmers may be a viable option of improving wheat yields in tropical low altitude areas. On-farm seed priming (soaking in water before planting) is relatively unknown in wheat production in Zimbabwe. Some small-scale farmers practise flood irrigation that leaves a crust on the surface which germinating seedlings find hard to break resulting in poor stands. Harris et al. (1999; 2001a) reported that priming led to better crop emergence and growth, earlier flowering and greater yields for summer grown maize (*Zea mays* L.). This has been explained by improved crop stand and from advancement of germination and emergence without any physiological effects after emergence (Murungu et al., 2004a). In another study, primed maize matured 10 days earlier in the winter season, while there was no difference in time to maturity in the summer season (Murungu et al., 2004b). On farm studies elsewhere, for example, in India with seed priming in rice and chickpea, farmers reported earlier flowering (7-10d) and maturity (8-10d) (Harris et al., 1999).

Advancing germination and emergence in wheat through on-farm seed priming might have advantages for both early and late planted wheat in low altitude areas. It was hypothesised that faster emergence may result in better resource utilisation and allows more time for optimal growth and grain filling resulting in higher yields in wheat. The overall objective of the study was to optimise wheat yields in tropical low altitude areas through appropriate sowing dates, cultivar selection and seed priming.

MATERIALS AND METHODS

Location

The study was carried out at Save Valley Experiment Station in Chipinge district, in the south-eastern lowveld of Zimbabwe. The Station is 444 m above sea level and is at latitude 20°21' S and longitude 32°20' E. The soil is classified in the US Taxonomy as an Entic Eutrochrept and in the FAO system as a Chromic Cambisol (Nyamapfene, 1991). The soil is 100 to 150 m deep and is a medium-grained sand loam. Mean annual rainfall is 482 mm, with a monomodal distribution.

Treatments and experimental design

Four wheat varieties were (Dande, Insiza, Kana and S95063) planted at four sowing dates which were 2 May (SD 1), 16 May (SD 2), 1 June (SD 3) and 16 June (SD 4) in 2005. In 2006 the sowing dates were; 2 May (SD 1), 16 May (SD 2), 30 May (SD 3), and 13 June (SD 4). Primed seed was soaked for 12 h overnight, surface dried by blotting on a cloth and then planted. The experimental design was a 4 x 4 x 2 factorial laid out in a split-split plot design with three replications. Sowing date was the main-plot, variety the sub-plot and seed priming the sub-sub-plot. Small trenches 25 cm apart were opened using hand hoes. Wheat seed was applied at a rate of 90 kg ha^{-1}. Compound D (8% N, 14% P, 7% K) was applied to the plots at a rate of 200 kg ha^{-1}. Ammonium nitrate (34.5% N) was applied at a rate of 90 kg ha^{-1} at 21 days after sowing (DAS). The gross plot size was 3 x 10 m (12 rows) and net plot size was 1.5 x 6 m (6 middle rows). Weeding was done just before application of ammonium nitrate using hand hoes and the Class-A evaporation pan was used for irrigation scheduling. Standard germination tests done on the seeds before planting using rolled paper towels revealed a mean germination percent of 94% across all varieties.

Measurements

Emergence counts were recorded daily up to 14 DAS; from two middle rows in each plot at 0900 h. Seeds were considered to have emerged if they were visible at the soil surface. Tiller numbers were determined per meter length at three positions at 14 DAS and at 28 DAS. Two samples per treatment were selected at random from three rows on either side of the six middle rows of the plot and leaf area (cm^2) and dry weight (g) was measured at fortnightly intervals. Leaf area was determined using a leaf area meter (Delta-T Devices Ltd, Burwell, Cambridge, UK).

Days to anthesis was taken as the number of days from sowing up to the time anther dehiscence was complete in 50% of the plants in the net plot. Time to maturity was the time from sowing to when the peduncles turned ripe yellow. Grain filling duration, GFD (in days), was taken as the time from anthesis to maturity. Yield (kg ha^{-1}) and yield components (1000 seed weights, grains per head) were determined from the net plot.

Data analyses

Time to 50% emergence (t0.5) of the emerged seedlings was calculated by drawing a graph with percent-emergence (Y) against days (X), for each plot. A reading was taken from the point at which 50% of final emergence would have occurred and the corresponding time or day was recorded (Mabika, 1994). The final percentage emergence was calculated by simply counting the final number of seedlings emerged and making them a percent of the total seeds sown. Leaf area measurements were used to determine the leaf area index (LAI) which was then used to calculate the leaf area duration (LAD) using the following formula (Boyd et al., 2002):

$$LAD = \sum[(LAI_{n-1} + LAI_n)/2][t_n - t_{n-1}] \quad (1)$$

Where LAIn-1 is the LAI the sampling date prior to LAIn and tn is the Julian date that the sampling took place. LAD was determined up to 70 DAS. The measured variables; t0.5, final emergence percent, LAD, dry weight, time to anthesis, time to maturity, grain

Table 1. Sowing date, variety and seed treatment and effects on t0.5 (days) in the 2005 and 2006 seasons.

	Season					S.E.D (95 d.f.)
Sowing date		**SD 1**	**SD 2**	**SD 3**	**SD 4**	
	2005	4.3	4.0	5.3	5.6	0.09
	2006	7.0	6.0	5.1	5.0	0.28
Variety		**Dande**	**Insiza**	**Kana**	**SC95063**	
	2005	4.7	4.8	4.7	4.9	0.08
	2006	5.6	5.8	6.0	5.8	0.13
Seed treatment		**Non-primed**	**Primed**			
	2005	4.9	4.6			0.06
	2006	6.1	5.4			0.09

Table 2. Variety and sowing date effects on number of tillers m-2 at 14 DAS in the 2005 winter season.

	Dande	Insiza	Kana	SC95063
Sowing date				
SD 1	300.0	380.7	364.9	430.0
SD 2	159.3	185.3	196.9	253.8
SD 3	219.6	218.9	213.8	231.6
SD 4	195.8	194.0	167.1	248.2
S.E.D (95 d.f.)				28.7

filling period, yield and yield components data were subjected to analysis of variance. Correlation analysis was also done between LAD, GFD and parameters such as 1000 seed weights and yield. Means and standard errors of the difference of means (s.e.d.) are shown, with appropriate degrees of freedom (d.f.). Unless otherwise stated, differences referred to in the text are significant at $P < 0.05$.

RESULTS

Temperature

The mean monthly temperatures for May, June, July, August and September were 22.5, 14.2, 15.1, 16.8, and 19.4°C in 2005 respectively. Temperatures for the same months were: 23.1, 17.8, 16.3, 17.4 and 20.7°C in 2006 respectively. The 2006 winter season was relatively warmer than the 2005 season. There was no significant rainfall during this period and approximately 280 mm of water was applied through irrigation in both seasons.

Final emergence and t0.5

2005 season: Sowing date and variety did not significantly affect final emergence percent while seed treatment significantly affected final emergence percent. There were no significant interactions. Non-primed and primed seed had final emergence percentages of 84.7 and 78.3 respectively (S.E.D = 2.7; d.f. = 95). Sowing date and seed treatment significantly affected t0.5 while variety had no significant effect on t0.5. No significant interactions were observed with respect to t0.5. Seed priming and planting on the second sowing date resulted in the shortest t0.5 (Table 1).

2006 season: Sowing date, variety and seed treatment did not significantly affect final emergence percent. Sowing date, variety and seed treatment significantly ($P < 0.01$, $P< 0.05$, $P< 0.05$ respectively) affected t0.5, while no significant interactions were observed on t0.5. Delaying sowing reduced t0.5, Dande had the lowest t0.5 while priming seed reduced t0.5 (Table 1).

Tillering, leaf area duration and dry weight

In the first season there was a significant sowing date × variety interaction on number of tillers at 14 DAS. Generally more tillers were produced with early planting while S95063 produced more tillers at each sowing date (Table 2). At 28 DAS sowing date, variety and priming

Table 3. Sowing date, variety and seed treatment and effects on number of tillers m-2 at 28 DAS in the 2005 season.

Sowing date	SD 1	SD 2	SD 3	SD 4	S.E.D (95 d.f.)
	541.7	455.2	368.7	176.3	20.1
Variety	**Dande**	**Insiza**	**Kana**	**SC95063**	
	333.4	380.4	391.2	436.8	21.0
Seed treatment	**Non-primed**	**Primed**			
	366.7	404.3			15.4

Table 4. Variety and sowing date effects on number of tillers m-2 at 28 DAS in the 2006 season.

Sowing date	Dande	Insiza	Kana	SC95063
SD 1	299.3	329.3	313.3	310.0
SD 2	235.3	338.7	319.3	314.7
SD 3	325.3	345.3	341.3	356.7
SD 4	268.0	242.0	267.3	291.3
S.E.D (95 d.f.)		21.9		

significantly affected ($P < 0.01$, $P < 0.01$, $P < 0.05$ respectively) number of tillers per square meter with no significant interactions being observed.

Delaying sowing reduced tiller numbers while, S95063 produced more tillers than any other variety and primed seed produced more tillers (Table 3). In the second season, sowing date, variety and seed treatment did not significantly affect number of tillers per square metre at 14 days after sowing. The sowing date × variety interaction was the only significant interaction affecting tiller numbers at 28 DAS. For each variety, the last sowing date had the lowest number of tillers; however, Dande at SD 2 had the lowest tiller numbers (Table 4). In both seasons, sowing date and variety significantly affected LAD while seed treatment had no significant effect. Delayed sowing reduced LAD at 70 DAS while varieties did not show any consistent trends between the two seasons (Table 5). In both seasons, sowing date was the only factor to significantly influence dry weight. The last sowing date resulted in the lowest dry weights per tiller (Figure 1).

Days to anthesis, maturity and grain filling duration

In the first season, sowing date × seed treatment and variety × seed treatment interactions were significant with respect to days to anthesis. Seed priming significantly reduced time to anthesis at all sowing dates except the second sowing date (Figure 2a) while, seed treatment significantly reduced time to anthesis for all varieties except for Dande (Figure 2b). In the second season, there were no significant interactions, the second sowing date significantly delayed time to anthesis compared to the other sowing dates while seed priming had no effect. In both seasons, Kana flowered much earlier than the other varieties (Figure 2b, Table 5).

With respect to days to maturity, sowing date and variety significantly ($P < 0.01$) affected time to maturity with no significant interactions being observed in both seasons. Delaying sowing reduced the time taken to maturity and S95063 matured much later than the other varieties. While seed priming significantly reduced the time to maturity in the first season, there were no significant seed treatment effects in the second season (Table 5).

In the first season the sowing date × seed treatment interaction was significant ($P < 0.01$) with respect to the grain filling duration. Late planting and seed priming tended to reduce the grain filling duration. However, the difference in the grain filling duration between non-primed and primed seed was smaller for the first sowing date compared to the other sowing dates (Figure 3). In the second season, seed treatment had no effect on grain filling duration while the last sowing date resulted in a significantly shorter grain filling duration (Table 5). While varietal effects were not significant in the first season, in the second season Insiza and S95063 had significantly longer grain filling durations than Kana and Insiza (Table 5).

Table 5. Sowing date, variety and seed treatement effects on time to anthesis, maturity and the grain filling period in the 2005 and 2006 season.

	LAD (LAI days) 2005	LAD (LAI days) 2006	Days to anthesis 2006	Days to maturity 2005	Days to maturity 2006	Grain filling duration (days) 2006
Sowing date						
SD 1	163.6	170.3	63.6	100.4	101.2	34.0
SD 2	147.3	170.5	86.7	99.5	103.8	36.9
SD 3	137.7	163.6	65.2	96.5	102.1	34.1
SD 4	102.0	138.0	67.0	92.3	97.5	17.2
S.E.D (95 d.f)	3.34	6.24	0.29	0.8	0.39	0.39
Variety						
Dande	118.6	149.6	72.4	98.8	103.0	30.5
Insiza	146.5	149.0	70.8	95.2	95.3	28.8
Kana	128.8	173.5	66.5	88.7	101.9	31.1
S95063	156.6	170.2	72.7	106.0	104.4	31.8
S.E.D (95 d.f)	8.19	5.30	0.31	1.83	0.60	0.61
Seed treatment						
Non- Primed	142.6	160.2	70.5	100.6	101.3	30.6
Primed	138.4	161.0	70.7	93.7	101.0	30.5
S.E.D (95 d.f)	3.92	3.13	0.26	0.41	0.42	0.4

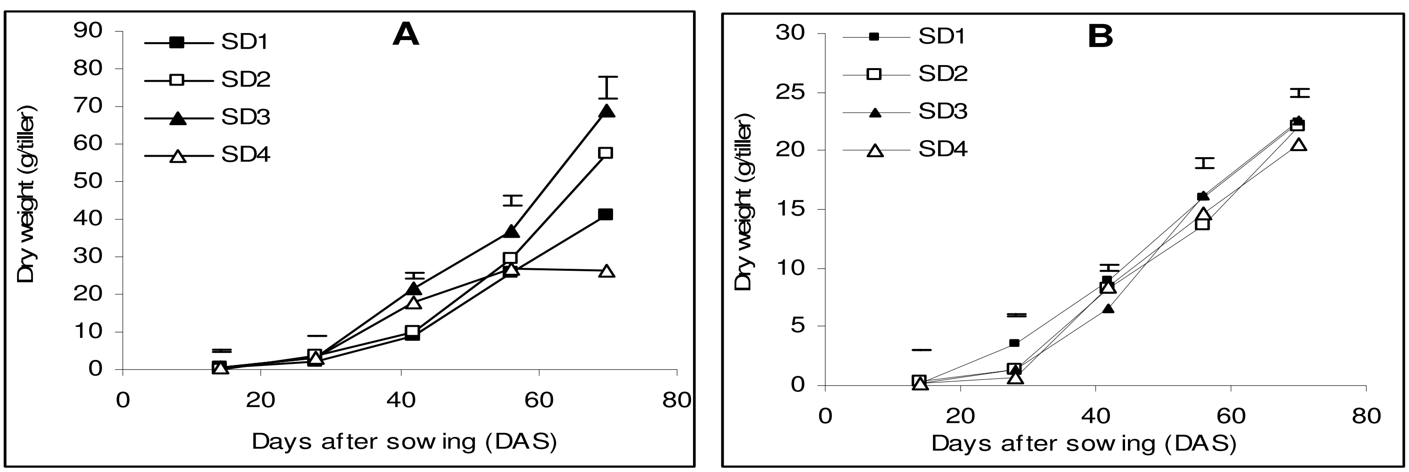

Figure 1. Sowing date effects on dry weight in 2005 (A) and 2006 (B). Error bars represent the S.E.D (95 d.f).

One-thousand seed weight, grains/head and yield (kg/ha)

Sowing date and variety significantly (P < 0.01) affected 1000-seed weight, while seed treatment did not significantly affect 1000-seed-weight in both seasons. No significant interactions were observed with respect to 1000-seed weight. Delaying sowing reduced 1000-seed-weights while, Kana produced the heaviest grains (Table 6).

In the first season, there was a significant (P < 0.01) sowing date × variety interaction on number of grains per head. The last sowing date tended to reduce the number of grains/head however, for Insiza; the last sowing date did not significantly reduce number of grains per head compared with the first sowing date (Figure 4). In the second season, sowing date and variety significantly (P < 0.01) affected number of grains/head with no significant interactions. The last sowing date had the lowest number

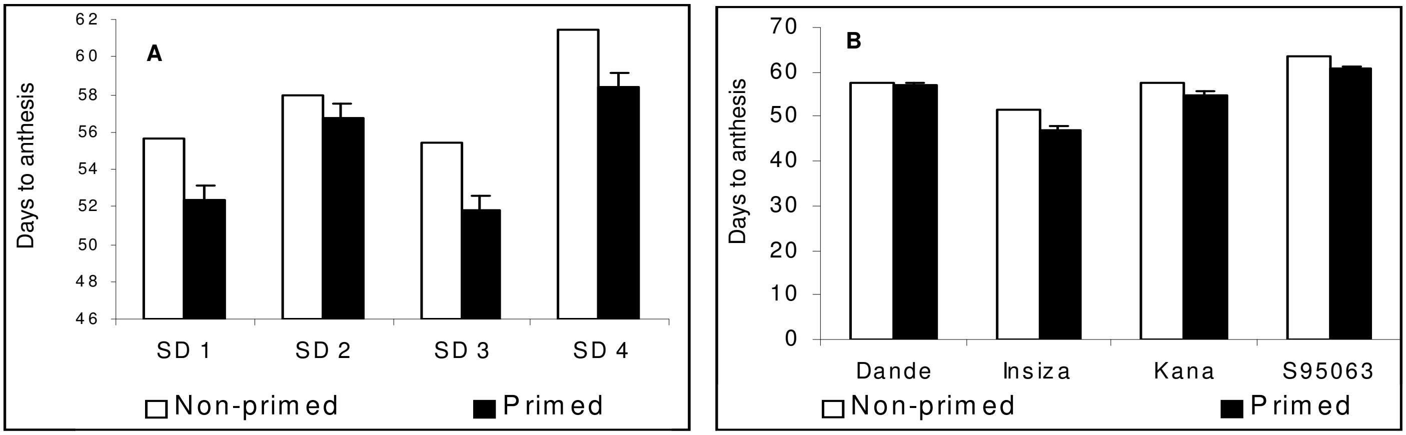

Figure 2. A: Seed priming and sowing date effects on days to anthesis. B: Seed priming and variety effects on days to anthesis in the 2005 season. Error bars represent the S.E.D (95 d.f).

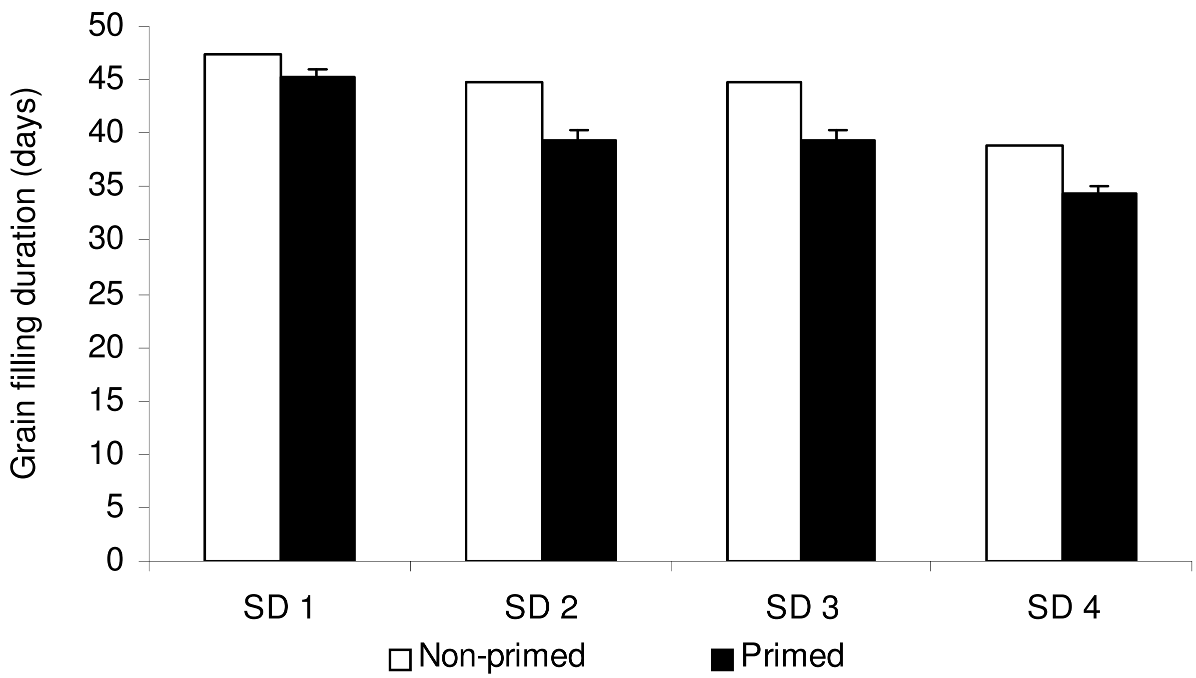

Figure 3. Sowing date and seed treatment effects on grain filling duration in the winter season of 2005. Error bars represent S.E.D (95 d.f).

Table 6. Sowing date, variety and seed treatment and effects on 1000-seed-weights (g) in the 2005 and 2006 seasons.

Sowing date	Season	SD 1	SD 2	SD 3	SD 4	S.E.D (95 d.f)
	2005	45.9	37.0	25.5	23.4	1.01
	2006	42.6	42.2	40.1	34.4	0.83
Variety		**Dande**	**Insiza**	**Kana**	**SC95063**	
	2005	34.1	31.6	35.0	31.0	0.96
	2006	38.1	41.2	41.5	38.5	0.55

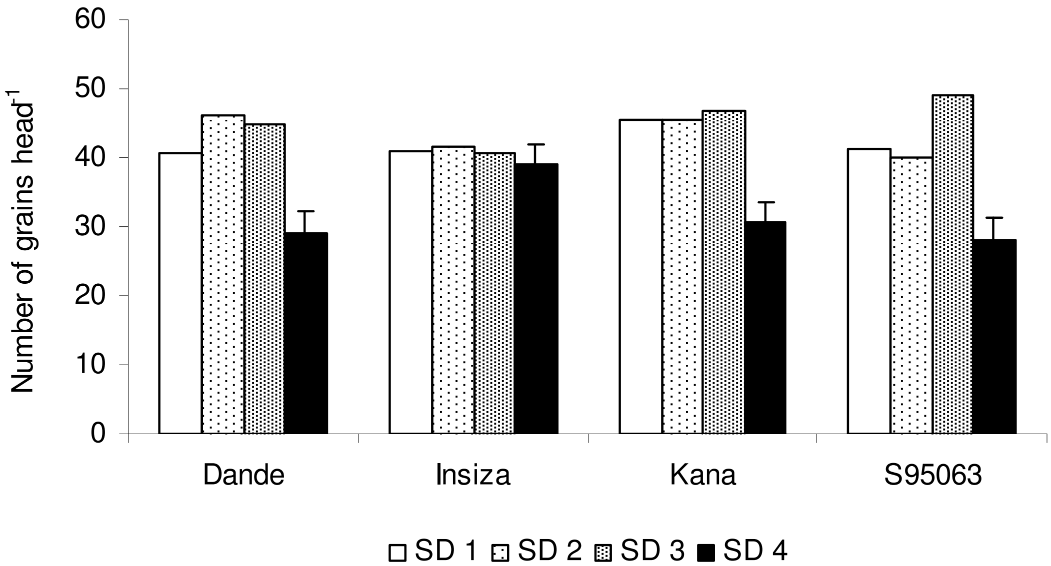

Figure 4. Sowing date and variety effects on number of grains/head in the winter season of 2005. Error bars represent S.E.D (95 d.f).

Table 7. Sowing date, variety and seed treatment and effects on number of grains head-1 in the 2006 season.

Sowing date	SD 1	SD 2	SD 3	SD 4	S.E.D (95 d.f)
	52.0	52.0	57.1	46.7	1.11
Variety	Dande	Insiza	Kana	S95063	
	52.0	57.0	48.3	50.5	1.07

Table 8. Correlations of LAD, GFD and yield components, LAD was taken only up to 70 DAS.

		Grains/ear	Yield	LAD	GFD
1000 seed weight	2005		0.82**	0.44**	0.42**
	2006		0.45**	0.13	0.50**
Yield	2005	0.54**		0.19	0.23
	2006	0.18		0.17	0.19

**Significant at the 1% level.

of grains/head and Kana also had the lowest number of grains/head (Table 7). Seed treatment had no significant effect on number of grains/head in both seasons.

In the first season, the sowing date × variety interaction was significant ($P < 0.01$) with respect to yield. Late planting generally reduced yields. For wheat sown on SD 1, Kana and S95063 produced the highest yields while Insiza produced the highest yield at SD 2 and SD 4 (Figure 5). In the second season, sowing date was the only factor that significantly affected yield. There were no significant interactions. As sowing date was delayed, there was a general decrease in yields. Yields for SD 1, SD 2, SD 3 and SD 4 were 4654 kg ha^{-1}, 4685 kg ha^{-1}, 3973 kg ha^{-1} and 3325 kg ha^{-1} respectively (S.E.D = 378.3; 95 d.f).

Correlation analyses

The GFD was significantly ($P < 0.01$) correlated with 1000 seed weights in both seasons while there was no significant correlation between GFD and grain yield in both seasons (Table 8). Generally, longer grain filling durations resulted in heavier grains. Yield and 1000 seed weights were significantly correlated in the two seasons while the correlation between yield and number of grains/ear was inconsistent between the two seasons. The correlation between LAD and 1000 seed weights was inconsistent between the two seasons while LAD at 70 DAS was not correlated to grain yield (Table 8).

DISCUSSION

Seed priming had a negative effect on final emergence in the first season while in the season it had no effect on emergence. In this study overhead irrigation was used and the lack of soil moisture deficits during the emergence period may explain the lack of differences between primed and non-primed wheat seed. The negative effect of seed priming in wheat in the first season agrees with results elsewhere (Clark et al., 2003) while other studies found no differences in final emergence between primed and non-primed seed (Harris and Mottram, 2005; Giri and Schillinger, 2003; Rashid et al., 2002). The observed lower emergence for primed seed in the first season may be explained by one or more factors, which may include higher soil temperatures during the emergence period or hypoxia. Finch-Savage et al. (2004) reported that the variable response of maize to seed priming may be explained by the different cultivars used, hypoxia during seed soaking which may be amplified by wet conditions in poorly draining soils and high temperatures at sowing.

Primed wheat seed had lower t0.5 than non-primed seed, agreeing with other findings on wheat priming (Harris and Mottram, 2005; Clark et al., 2003; Rashid et al., 2002; Harris et al., 2001b). When planted, non-primed seeds must firstly imbibe water before the germination process can start. On the other hand, primed seed will require little further imbibition before the germination process starts, thus less time is required for the seed to germinate. In soils with a crusting problem, this may be a useful attribute, which may result in better emergence for primed seed, were seed emergence before crust formation. In the present study moisture was not limiting during the emergence period and there was no crusting. Rashid et al. (2006) while working on saline soils reported the response to priming was better in low potential environments than under better conditions in barley. In maize and cotton pot experiments, it has been shown that seed priming can partly compensate for low soil moisture in the seedbed (Murungu et al., 2003).

Tiller numbers varied with sowing date, variety and seed treatment in 2005. A number of factors are known to affect tillering and these include: genotype, planting date, seeding rates, soil fertility, soil and air temperatures as well as soil fertility (Frederick and Bauer, 1999). It has been postulated that tillering ceases at higher population densities due to reduced photosynthetically active radiation (PAR) intensity at the base of the crop canopy (Simon and Lemaire, 1987). This may suggest that at optimal growing conditions wheat plants are able to compensate for lower stand counts (Otteson et al., 2007; Simon and Lemaire, 1987). This may explain the observation in the 2005 season, were seed priming reduced final emergence, but wheat growing in primed plots had significantly more tillers than non-primed plots. The lower tiller numbers from the late sowing dates may partly explain the reduction in yield as sowing was delayed.

Seed priming had no significant effect on parameters such as leaf area duration and dry weights. Harris et al. (2008) observed that water priming did not increase dry weight of wheat during early growth. This is contrary to findings from other studies were seed priming improved dry weights and stem length (Basra et al., 2003; Bhati and Rathore, 1986). However, Clark et al. (2003) observed that the effect of priming on early growth in a wheat variety (Nduna) was greater on seedlings growing in a drier soil. Murungu et al. (2003) also observed that seed priming improved early growth of maize and cotton in drying soils. Differences in soil conditions from the different studies may explain the deferent response to priming from the different studies.

The response to seed priming on time to anthesis, maturity and grain filling duration was inconsistent between the two seasons. Generally, as sowing date was delayed, the time to maturity decreased resulting in a much lower grain filling period for the last sowing date. Early onset of higher spring temperatures may be responsible for the hastened maturity on wheat sown on the last sowing date. The reduced grain filling period for the last sowing date explains the much lighter grains for the late planting. This suggests that assimilate supply was stopped before grain storage had achieved its full potential. The lack of significant correlations between LAD and yield was probably because the measured LAD was only up to 70 DAS and not up to physiological maturity. Some studies have shown that the flag leaf area duration is more closely associated with yield than the total LAD for the whole plant (Verma et al., 2004). There was no correlation between grain filling duration and yield.

This may be explained by the fact that wheat yield is a complex trait determined by number of grains per unit area and grain weight (Brdar et al., 2004). Grain weight itself is a function of grain filling rate and duration of grain filling. It had been hypothesised that faster emergence from seed priming would result in better resource utilisation and allow more time for optimal growth and grain filling resulting in higher yields in wheat. However, this was not the case. Seed priming reduced the grain filling period in the 2005 season while it had no effect on grain filling duration in the 2006 season.

Conclusions

Seed priming reduced the time to 50% emergence however, seed priming did not improve final emergence percent in both seasons. There was no effect of seed priming on leaf area duration or dry weight accumulation, while seed-priming effects on time to anthesis was inconsistent in the two seasons of study. It was concluded that seed priming has little potential for improving yields in low altitudes areas were soil moisture is not limiting. Early sowing (up to 16 May) maximises wheat yields while Insiza may be an appropriate cultivar selection to optimise yields for late sown wheat in low altitude areas.

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