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Evaluation of bread wheat genotypes for yield and other characteristics in Botswana

Geleta L. Fite
Crops Division, Department of Agricultural Research, Private Bag 0033, Gaborone, Botswana;
E-mail: gfite@gov.bw

ABSTRACT

A few farmers produce a limited quantity of wheat in Botswana using cultivars that have not been recommended for production in the country. A trial comprising 50 bread wheat genotypes was conducted at Sebele Agricultural Research Station during the winter season of 2006 to select adaptable and better performing genotypes for further studies to develop a suitable variety. High variability among genotypes was observed for all measured characteristics. Grain yield ranged from 2.2 to 5.8 t ha^{-1}, heading date from 83 to 105 days after planting, and thousand-kernel weight from 25.0 to 50.0 g. Grain yield had significant positive correlation with agronomic score but negative with protein content. Significant correlation coefficient was also observed among other characteristics. On the basis of yielding ability, earliness and other agronomic characteristics 14 genotypes, namely 14SAWYT342, 14SAWYT303, 14SAWYT306, 14SAWYT308, 14SAWYT310, 14SAWYT313, 14SAWYT314, 14SAWYT317, 14SAWYT318, 14SAWYT319, 14SAWYT324, 14SAWYT326, 14SAWYT339, and 14SAWYT341 were selected for an advanced yield trial.

Key words: Adaptation, bread wheat, correlation, early maturing, grain yield

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the world's most important crop. It is a widely grown crop in the world and is produced under a wide range of environments (Hanson *et al.*, 1982). Although wheat is best adapted to cool or temperate growing conditions, it is grown in many areas of the world where heat stress is a major yield-limiting factor, especially at the end of the season (Lillemo *et al.*, 2005).

Environmental delineation for wheat production is largely conditioned by temperature and water availability through rainfall and/or irrigation. The International Maize and Wheat Improvement Center (CIMMYT) has defined different mega-environments that are derived from combinations of available water conditions (irrigated, high-rainfall or low-rainfall available water contrasts), prevailing temperatures (temperate, hot or cold extremes) and prevalent biotic and abiotic stresses (Rajaram and van Ginkel, 1996).

In Botswana, wheat is grown in a small scale at Talana Farm, Pandamatenga, Ramatlabama and few other areas using unknown varieties whose adaptability has not been tested in the country. According to FAO estimate (FAO, 2008) Botswana produced 600 tons with a mean yield of 1.5 t ha^{-1}. The limited wheat production in Botswana is mainly due to short growing season, low rainfall and unavailability of irrigation water. However, if early maturing (to escape high temperatures or to fit into intensive cropping system), drought tolerant and high yielding varieties are locally developed domestic wheat production can be possible.

Earlier, wheat yield trials using materials obtained from the Southern African Regional Wheat Evaluation and Improvement Nursery (SARWEIN) and Zimbabwe were conducted in different parts of Botswana including Sebele, Talana Farm, Pandamatenga, Kasane, Maun, Goodhope.

and Etsha (DAR, 1982). Nevertheless, there is no recommended wheat cultivar for production in the country. On the other hand, more and more farmers are developing interest to grow wheat and have requested for a locally recommended variety. The aim of this study was to select good performing wheat genotypes for advancement with a view of developing a suitable cultivar for production under Botswana environmental conditions.

MATERIALS AND METHODS

Fifty wheat genotypes were used in this study (Table 2). Forty-nine of them were introduced from the International Maize and Wheat Improvement Center (CIMMYT), Mexico, and a check cultivar, Baviaans, was provided by PANNAR, South Africa. The CIMMYT materials were developed for the semi-arid regions of the world.

The trial site was Sebele Agricultural Research Station located at 24° 34' S latitude, 25° 57' E longitude, and 994 m above sea level. The soil at the experimental site is characterized as sandy loam. Weather data during the growing season is presented in Table 1.

A non-replicated observational trail consisting of 10 sub-blocks was planted on May 23, 2006. The aim of sub-blocking was to reduce soil variability among the plots. Each plot contained 5 rows of 3 m long with a space of 1 m between adjacent plots. Furrows of about 3 cm deep were made at a spacing of 20 cm using hoes. Seed was drilled by hand thinly into each furrow using a seeding rate of about 120 kg ha^{-1} and covered with soil.

A 2:3:2 (22) compound fertilizer containing 63 g kg^{-1} N, 94 g kg^{-1} P and 63 g kg^{-1} K was applied at the rate of 200 kg ha^{-1} at planting. Nitrogen was supplemented by side-dressing limestone ammonium nitrate 28% (LAN 28%) at the rate of 150 kg ha^{-1} at jointing. Weeds were controlled by hand weeding. The crop was irrigated at field capacity at intervals of 15 - 21 days using a sprinkler irrigation system until maturity.

Data on heading date (HD), plant height (PH), agronomic score (AS), test-weight (TW), thousand kernel weight (TKW), grain yield (GY), and grain protein content (GPC) were collected from the three middle rows of each plot. Heading date was taken from date of sowing until 50% of the plants in a plot started heading (spikes fully exerted). Mean plant height was taken from ground level to the tip of the terminal spikelet of three randomly selected plants in each plot at crop physiological maturity. Agronomic score on the basis of visual rating was recorded on a scale of 1-5 (1=poor, 2=below average, 3=average, 4=good, 5=very good) at maturity. Three middle rows of each plot were harvested on October 25, 2006 and grain yield was recorded after drying and threshing. The thousand kernel weight expressed in grams per 1000 kernels was taken at approximately 13% grain moisture content. To determine the grain test weight, a volume of grain was measured in a 1 liter volume cylindrical cup. The weight of the grains in the 1 liter-measure was determined using a pan scale. Grain protein content was determined by near infrared reflectance analyser.

Descriptive statistics and the Pearson correlation coefficients for studied characteristics were computed using the SAS Software (SAS Institute, 2003) program. Selection of superior genotypes for advancement involved visual assessment and comparison of agronomic performance of new genotypes with the check variety.

RESULTS AND DISCUSSION

Agronomic performance

Results for grain yield and other characteristics of 50 wheat genotypes are presented in Table 2. Grain yields ranging from 2.2 – 5.8 t ha^{-1} with an average yield of 4.2 t ha^{-1} were observed. Higher yields were recorded with 14SAWYT306 (5.8 t ha^{-1}), 14SAWYT308 (5.5 t ha^{-1}), 14SAWYT324 (5.3 t ha^{-1}), 14SAWYT303 (5.2 t ha^{-1}), 14SAWYT319 (5.2 t ha^{-1}), and 14SAWYT339 (5.2 t ha^{-1}). In general several genotypes gave better yields compared with the check variety, Baviaans, which gave a grain yield of 3.3 t ha^{-1} demonstrating their better performance.

Heading date ranged from 83 to 105 days after planting. The earliest genotype was Baviaans (check) followed by 14SAWYT307 and 14SAWYT311, in both cases the heads emerged 88 days after planting. In wheat, earliness is an important factor for adaptation to heat-stress environments since early maturing varieties escape late-occurring heat stress (He and Rajaram, 1994; Lillemo *et al.*, 2005).

Test-weight ranging from 67.5 to 83.8 kg hl^{-1} was recorded. High test-weights were found in 14SAWYT350 (83.8 kg hl^{-1}), 14SAWYT345 (81.1 kg hl^{-1}) and 14SAWYT310 (80.5 kg hl^{-1}). The test-weight values for sound wheat normally varies from 70 to 80 kg hl^{-1}, but can be higher or lower due to several factors for instance growing environment and insect damage (Troccoli and Di Fonzo, 1999). The highest grain protein content of 15.8% was recorded with 14SAWYT334, 14SAWYT336, and 14SAWYT349. This could be a varietal or an environmental effect and needs further investigation. For bread-making purpose, a protein level of the flour of at least 13% on dry matter basis is required (Belderok *et al.*, 2000). Generally, a number of genotypes showed very good agronomic performance (Fig. 1).

Relationships between yield and other characteristics

Table 3 shows correlation coefficients among studied characteristics. Grain yield had highly significant positive correlation coefficient with agronomic score (0.454) but significant negative correlation coefficient with protein content (-0.344) suggesting that higher yielding genotypes had lower protein content. The negative correlation between grain yield and grain protein content is a well known phenomenon. Fossati *et al.* (1993) also found an inverse relationship between grain yield and grain nitrogen concentration. The two characters are related to genetic incompatibility (linkage, pleiotropy), partitioning efficiency, and competition for photosynthetic energy between nitrogen and carbon (Feil, 1997).

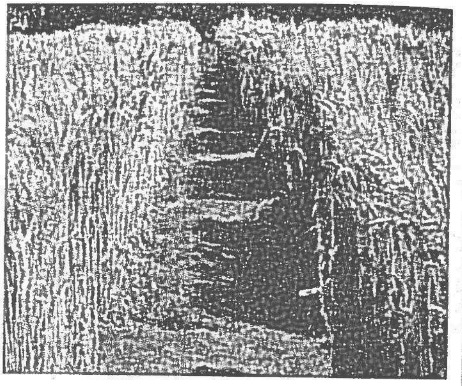

Figure 1: Bread wheat performance at Sebele Agricultural Research Station.

Association between other characteristic was also statistically significant in most cases. Heading date had significant positive correlations with plant height, agronomic score and protein content. Doltacil *et al.* (2003) also reported similar results in respect to the relationship between heading date and plant height. However, Talbert *et al.* (2001) and Doltacil *et al.* (2003) reported inconsistent relationship between heading date and protein content. In late genotypes, grain protein contents were perhaps increased by higher temperatures occurred late in the season. Balla and Veisz (2007) reported protein content of grains exposed to heat stress after anthesis rose significantly in response to the stress. The rise in the relative protein content when high temperature was applied during the grain filling phase could be explained by reductions in the thousand-kernel weight (28–37%), the grain mass (22–29%) and the grain diameter (16–23%) and not associated with an improvement in grain quality (Balla *et al.*, 2009).

Table 1: Temperatures, rainfall and relative humidity during the growing season, May to October 2006

Month	Average temperature (C)		Rainfall (mm)	Relative humidity (%)
	Minimum	Maximum		
May	3.9	23.3	20.2	38
June	2.4	22.7	0.0	34
July	3.5	24.6	0.0	31
August	5.3	24.6	5.5	24
September	8.1	29.2	0.0	23
October	16.2	33.4	2.8	27

Heading date showed inverse relationships with test-weight (r = -0.550**) and thousand-kernel weight (r = -0.443**). Similarly, Talbert *et al.* (2001) reported a negative relationship between heading date and test-weight. The negative association between heading date and kernel weight observed in the present study is also in agreement with previous findings (Doltacil *et al.*, 2003; Munir *et al.*, 2007). The observed high negative association of heading date with test-weight and thousand-kernel weight could be probably due to late genotypes had short grain filling period and affected by high temperatures which rose as high as 33.4/16.2°C late in the growing season (Table 1). Conversely, early genotypes had very plump seeds as they could mature earlier indicating early cultivar could be suitable for Botswana environment. Wardlaw *et al.* (1989) reported that temperatures as high as 30/25°C decreased kernel weight by as much as 38%, and greater increase in temperature from 20/16 to 36/31°C from 7 days after anthesis until ripeness decreased kernel weight up to 85% (Tashiro and Wardlaw, 1989). Gibson and Paulsen (1999) also reported kernel weight was reduced by 29% at 35/20°C compared with 20/20°C. High temperature stress has a greater influence on starch accumulation in the middle phase of grain filling than in the early phase (Yan *et al.*, 2008).

Plant height showed significant positive associations with agronomic score and protein content but had significant negative influence on thousand-kernel weight and test-weight. Within the genotypes studied, taller plants were generally late maturing and as explained above these genotypes had shorter grain filling period to produce seeds of high kernel weight and test-weight.

Kernel weight had highly significant positive correlation with test-weight (r = 0.663**) but negative with protein content (r = -0.341*). In the previous studies Qzturk and Aydin (2004) observed a significant positive correlation between thousand-kernel weight and test-weight while Mahmood *et al.* (2006) reported a negative correlation between thousand-kernel weight and protein content. Genotypes with high test-weight had also decreased grain protein content (r = -0.448**). The present findings indicate that rising temperatures from September can reduce wheat grain quality; hence there is a need to develop early maturing and heat stress tolerant cultivars for production in Botswana.

Table 2: Designation, pedigree, and agronomic performance of 50 wheat genotypes evaluated at Sebele Agricultural Research Station during the winter season of 2006

Designation/Name	Pedigree	GY[1] (t ha^{-1})	HD (day)	PH (cm)	AS (scale)	TW (kg hl^{-1})	TKW (g)	GPC (%)
14SAWYT302	CM85836-4Y-0M-0Y-8M-0Y-0IND	3.93	97	90	2	78.0	36	13.8
14SAWYT303	CM40096-8M-7Y-0M-0AP-0LBN	5.16	93	94	2	75.3	26	14.4
14SAWYT304	KLB103.71-20Y-5M-1100YK-0ARG	3.86	91	108	2	79.1	33	14.7
14SAWYT305	-0DZA	2.22	91	92	2	77.0	39	14.2
14SAWYT306	-0IND	5.76	91	104	5	78.4	37	14.1
14SAWYT307	CMSS98Y04325S-0100M-040Y-020M-040SY-13M-0Y-0SY	3.85	88	106	2	78.4	41	14.2
14SAWYT308	CMSS98Y04325S-0100M-040Y-020M-040SY-28M-0Y-0SY	5.51	97	100	2	76.6	35	13.4
14SAWYT309	CMSS98Y03487F-040M-0100M-040Y-020M-040SY-13M-0Y-0SY	3.61	99	94	2	75.4	34	14.2
14SAWYT310	CMSS98Y04351S-0100M-040Y-020M-040SY-24M-0Y-0SY	3.97	91	94	2	80.5	36	13.9
14SAWYT311	CMSS98Y04622S-0100M-040Y-020M-040SY-18M-0Y-0SY	3.98	88	92	2	79.1	40	13.0
14SAWYT312	CMSS98Y03165T-040M-0100M-040Y-020M-040SY-11M-0Y-0SY	3.96	101	108	3	77.7	36	13.4
14SAWYT313	CMSS98Y03270M-040M-0100M-040Y-020M-040SY-27M-0Y-0SY	5.09	99	110	2	75.5	34	14.9
14SAWYT314	CMSS98Y03413T-040M-0100M-040Y-020M-040SY-22M-0Y-0SY	4.47	97	104	4	79.6	35	12.7
14SAWYT315	CMSS98Y03432T-040M-0100M-040Y-020M-040SY-23M-0Y-0SY	3.42	97	100	4	72.2	32	14.7
14SAWYT316	CMSS98Y03433T-040M-0100M-040Y-020M-040SY-1M-0Y-0SY	3.94	99	100	3	72.7	34	13.0
14SAWYT317	CMSS98Y03433T-040M-0100M-040Y-020M-040SY-12M-0Y-0SY	4.30	101	112	4	74.4	36	15.1
14SAWYT318	CMSS98Y03433T-040M-0100M-040Y-020M-040SY-30M-0Y-0SY	4.91	101	112	4	71.2	35	13.0
14SAWYT319	CMSS98Y03450T-040M-0100M-040Y-020M-040SY-8M-0Y-0SY	5.25	99	108	3	77.6	33	13.0
14SAWYT320	CMSS98Y03450T-040M-0100M-040Y-020M-040SY-13M-0Y-0SY	3.96	105	100	3	74.7	30	14.7
14SAWYT321	CMSS98Y03455T-040M-0100M-040Y-020M-040SY-18M-0Y-0SY	4.37	97	96	4	75.1	39	14.0
14SAWYT322	CMSS98Y03455T-040M-0100M-040Y-020M-040SY-21M-0Y-0SY	4.48	99	100	3	74.1	31	14.8
14SAWYT323	CMSS98Y03489F-040M-0100M-040Y-020M-040SY-21M-0Y-0SY	4.43	105	114	4	69.0	30	15.0
14SAWYT324	CMSS98Y03489F-040M-0100M-040Y-020M-040SY-28M-0Y-0SY	5.32	102	116	3	75.6	39	14.2
14SAWYT325	CMSS98M00137S-0100M-040Y-020M-040SY-9M-0Y-0SY	4.77	101	94	5	74.2	33	14.0
14SAWYT326	CMSS98M00769T-040Y-0100M-040Y-020M-040SY-26M-0Y-0SY	4.69	105	110	4	78.5	38	14.3
14SAWYT327	CMSS98M00790M-040Y-0100M-040Y-020M-040SY-2M-0Y-0SY	4.10	99	116	4	78.8	33	13.2
14SAWYT328	CMSS98M00790M-040Y-0100M-040Y-020M-040SY-15M-0Y-0SY	4.38	99	112	4	71.5	28	14.4
14SAWYT329	CMSS98M00790M-040Y-0100M-040Y-020M-040SY-24M-0Y-0SY	4.49	101	114	4	70.0	27	14.9
14SAWYT330	CMSS98M00790M-040Y-0100M-040Y-020M-040SY-26M-0Y-0SY	4.71	97	110	2	71.0	27	14.3
14SAWYT331	CMSS98M00811T-040Y-0100M-040Y-020M-040SY-8M-0Y-0SY	4.06	99	130	4	70.0	31	15.1
14SAWYT332	CMSS98M00811T-040Y-0100M-040Y-020M-040SY-25M-0Y-0SY	3.97	101	124	4	71.5	32	15.1
14SAWYT333	CMSS98Y00581S-0100M-040Y-020M-040SY-29M-0Y-0SY	3.20	101	126	5	69.0	25	15.7
14SAWYT334	CMSS98Y00582S-0100M-040Y-020M-040SY-9M-0Y-0SY	3.53	101	110	4	67.5	27	15.8
14SAWYT335	CMSS99Y05560T-2M-1Y-010M-010SY-3M-0Y-0SY	3.10	101	110	5	74.8	30	15.1
14SAWYT336	CMSS99Y05560T-2M-1Y-010M-010SY-6M-0Y-0SY	2.69	103	106	4	76.3	31	15.8
14SAWYT337	CMSS99Y05568T-5M-9Y-010M-010SY-20M-0Y-0SY	4.75	103	94	4	74.5	29	15.0
14SAWYT338	CMSS98GH00023S-0100M-040Y-020M-040SY-22M-0Y-0SY	4.48	101	116	4	72.8	28	15.5
14SAWYT339	CMSS97M02966M-040Y-020Y-030M-040SY-020M-29Y-010M-0Y-0SY	5.16	101	112	4	76.9	31	14.2
14SAWYT340	CMSS98Y03454T-040M-020Y-030M-040SY-020M-15Y-010M-0Y-0SY	4.13	103	114	3	74.8	30	14.5
14SAWYT341	CMSS98Y04442S-020Y-030M-040SY-020M-9Y-010M-0Y-0SY	5.03	97	110	3	74.6	33	14.0
14SAWYT342	CMSS98Y04442S-020Y-030M-040SY-020M-13Y-010M-0Y-0SY	4.88	99	114	3	74.8	34	14.3
14SAWYT343	CMSS98Y04442S-020Y-030M-040SY-020M-14Y-010M-0Y-0SY	4.23	103	120	4	74.8	31	15.0
14SAWYT344	CMSS97M02941T-040Y-020Y-030M-040Y-020M-1Y-010M-0Y-0SY	4.12	99	110	5	74.4	37	15.5
14SAWYT345	CMSS97M02941T-040Y-020Y-030M-040Y-020M-12Y-010M-0Y-0SY	3.77	99	100	5	81.1	41	15.0
14SAWYT346	CMSS97M02939T-040Y-020Y-030M-040SY-020M-16Y-010M-0Y-0SY	2.58	93	100	4	78.9	50	15.2
14SAWYT347	CMSS97M02939T-040Y-020Y-030M-040SY-020M-19Y-010M-0Y-0SY	3.91	93	110	4	78.8	40	14.4
14SAWYT348	CMSS97M03158T-040Y-020Y-030M-040SY-020M-24Y-010M-0Y-0SY	4.20	103	112	3	72.4	29	15.6
14SAWYT349	CMSS97M03203T-040Y-020Y-030M-040SY-020M-17Y-010M-0Y-0SY	4.22	103	116	4	69.9	27	15.8
14SAWYT350	CMSS97M00814S-030M-040SY-010M-010SY-8Y-010M-0Y-0SY	4.07	93	110	3	83.8	37	14.2
Baviaans	-	3.29	83	80	2	79.5	33	14.3
Minimum		2.2	83	80.0	2	67.5	25.0	12.7
Maximum		5.8	105	130.0	5	83.8	50.0	15.8
Range		3.6	22	50.0	3	16.3	25.0	3.1
Mean		4.20	98.2	106.7	4.1	75.2	33.5	14.6

[1] GY = grain yield, HD = heading date, PH = plant height, AS = agronomic score, TW = test weight, TKW = thousand-kernel weight, GPC = grain protein content

Table 3: Phenotypic correlation coefficients (n = 50) among various characteristics of studied materials

	Heading date	Plant height	Agronomic score	Thousand-kernel weight	Test weight	Protein content
Grain yield	0.172	0.134	0.454**	-0.146	-0.022	-0.344*
Heading date		0.526**	0.665**	-0.443**	-0.550**	0.331*
Plant height			0.589**	-0.325*	-0.466**	0.354*
Agronomic score				-0.550**	-0.622**	0.073
Thousand-kernel weight					0.663**	-0.341*
Test-weight						-0.448**

*, ** significant at the 0.05 and 0.01 probability levels respectively

CONCLUSION

On the basis of yielding ability, earliness and other agronomic characteristics 14 genotypes, namely 14SAWYT342, 14SAWYT303, 14SAWYT306, 14SAWYT308, 14SAWYT310, 14SAWYT313, 14SAWYT314, 14SAWYT317, 14SAWYT318, 14SAWYT319, 14SAWYT324, 14SAWYT326, 14SAWYT339, and 14SAWYT341 were selected for an advanced yield trial.

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