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Grain Yield and its Stability of Some Selected Wheat Varieties in Saudi Arabia

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Abstract. Field experiments were conducted for five seasons, 1980/81 through 1984/85, to evaluate the performance and yielding stability of four high-yielding varieties of wheat. Two durum (Crane' S and Bittern' S) and two bread wheat (HD 2172 and CM 8237) varieties were grown at Deirab, near Riyadh where high temperatures prevailing at the end of the growing season had very critical effects on the wheat plant. The recommended *Yecora rojo* was also included as a check variety. Grain yield, yield attributes filling period and filling rate were investigated.

Results indicated that seasons significantly affected all traits and the interaction between seasons and varieties was also significant. Grain yield and other traits in the 1982/83 season were superior to other seasons and this might be attributed to the cooler temperatures.

Regression analysis showed that varieties No. 1, 2 and 3 were stable, whereas varieties No. 4 and 5 were unstable, with regard to grain yield production across seasons. The high grain yield was associated with long grain filling period and high rate of grain filling and high kernel weight.

Introduction

Wheat is the major crop grown in Saudi Arabia with a total annual area of about 630,000 ha yielding about 2.5 million tons [1]. The recommended cultivars are *Yecora rojo* and Westbred – 911, with the former cultivar occupying about 90% of the total wheat area. This monocultivar system is very dangerous with regard to plant disease infection and development. Growing a single cultivar or few closely related cultivars leaves the farmer without protection against any disease breakout. Incidents similar to this have been reported many times in the literature with regard to wheat and other agricultural crops which caused great loss on the agricultural production [2, pp. 17–31].

Yecora rojo is a 2-gene dwarf high-yielding cultivar but is very sensitive to any change in the environmental factors such as temperature, especially during the critical period of grain filling towards the end of the growing season. The increase in temperature during this period causes the plant to speed up its life cycle and shorten the time for grain filling and, thus, the kernel weight is reduced and consequently so is grain yield. Grain yield ability fluctuates from one season to another and from one location to another depending on the environmental factors that prevail.

Therefore, it is the responsibility of the plant breeders in Saudi Arabia and in cooperation with crop physiologists to evaluate and select different wheat cultivars that could tolerate and produce stable yields over a wide range of environments.

The importance of testing crop genotypes to examine their yield potential over a range of environments has been recognized by plant breeders for a long time [3, pp. 164–169]. The decision to release a high yielding strain is usually made on the basis whether the performance of the strain is superior to that of the standard cultivars over several years in order to sample the different unpredictable climatic factors. Therefore, yield stability should be a major selection criterion [4] in addition to higher yield in a national wheat breeding program.

Finaly and Wilkinson [5] and Eberhart and Russell [6] developed a method for measuring crop yield stability, based on regression technique, and described a stable cultivar as one with a mean regression coefficient of unity and a small deviation from regression.

The objective of the present investigation was to evaluate the performance of four new high-yielding wheat varieties for a period of five growing seasons to measure their stability over seasons. The interrelationship between yield and yield attributes was also under study.

Materials and Methods

The trials were conducted for five growing seasons from 1980/81 to 1984/85, at the College of Agriculture, King Saud University, Experimental Research Station, at Deirab near Riyadh (24° N, 46° E). The material consisted of 4 high-yielding varieties, (Table 1), two durum wheat (varieties 1 and 2) and two bread wheat (varieties 3 and 4). These varieties were selected from the variety evaluation trials grown at the

Experiment Station. The recommended cultivar, *Yecora rojo* (variety 5), was included as a check cultivar starting from the second season (1981/82). The materials were grown in a randomized complete block experiment with four replications. Plot size was 2 × 2.5, 10 × 2.5, 12 × 5, 11 × 2.5, and 11 × 2.5 m for the consecutive seasons. The seeding rate was 120 kg/ha for the first season and was increased to 140 kg/ha for the other seasons. Seeds were drilled in rows 20 cm apart during the second half of November. Fertilizer was applied at the rate of 120 N, 75 P_2O_5, 10 K_2O kg/ha. The source of irrigation was well water for the first two seasons and municipal sewage-treated water for the other seasons. Flood irrigation was applied once every week before anthesis and it was shortened to 3–5 day interval thereafter in order to avoid exposing the wheat plants to moisture stress.

Table 1. Names and origins of varieties under study

Variety	Name	Origoin	Species
1	Crane's–USA–SO 2229	Mexico	*T. turgidum*
2	Bittern's	Mexico	*T. turgidum*
3	HD–2172	India	*T. aestivum*
4	CM 8237–G–1M–3Y–2M	Mexico	*T. aestivum*
5	Yecora Rojo (check)	U.S.A.	T. aestivum

Data were recorded for days to heading (DH) and maturity (DM), plant height (PH), grain yield (GY), and kernel weight (KW). Filling period (FP) and filling rate (FR) were calculated. Days to heading was defined as the number of days when 50% of the spikes reached flowering; and days to maturity as the number of days when 75% of the spikes turned yellow. Plant height was measured as the distance from the soil surface to the tip of the main tiller's spike. Grain yield was estimated as the weight of clean grain from 1 m^2 taken at random from the center of each plot. Kernel weight was determined from 1000 kernels of the clean grain. Filling period was calculated by substracting the number of days to heading from the number of days to maturity and filling rate was calculated by dividing the grain yield/plot by the filling period assuming that the rate of GF was linear over the entire period.

Data from each year were statistically analyzed and then combined over the five seasons as outlined by Steel and Torrie [7]. Variety means for the five seasons were subjected to stability index analysis as given by Eberhart and Russell [6]. Correlation coefficients between the different characters were estimated as given by Steel and Torrie [7].

Results and Discussion

Seasonal variations significantly affected all traits (Table 2). The interaction between seasons and varieties was also significant for all traits under study (Table 2), indicating that the differences between varieties were affected by the growing season.

Table 2. Summary of the analyses of variance for the effect of season and variety on yield and agronomic traits

SOV	GY	KW	DH	DM	FP	FR	PH
Years (Y)	**	**	**	**	**	**	**
Cultivar (C)	**	**	**	**	**	**	**
Y × C	**	**	**	**	**	**	**
Error	5315	12.1	16.8	8.5	19.8	4.4	38.3
Mean	434	41.0	87.7	131.6	43.9	10.2	80.7
C.V. (%)	16.8	8.5	4.7	2.2	10.1	20.4	7.7

** indicate significance at the 0.01 level of probability.
GY = grain yield (g/m^2); KW = 1000 kernel weight (g); PH = plant height (cm); DH = days to 50% heading; DM = days to 75% maturity; FP = filling period (days); FR = filling rate (g/m^2/day).

Growing season

Means of the five seasons averaged over the five varieties for all the traits under study are presented in Table 3. All traits varied considerably among seasons with yields and other characters in the 1982/83 season being superior to the other seasons. This superiority could have been due to low temperature which prevailed during the 1982/83 season as compared to the other seasons (Fig. 1). The period from February to the end of April in 1983 was characterized by moderate temperatures and was the coolest season especially during the critical stage of grain filling. This was reflected on all the characters except PH.

The differences between seasons in GY were mainly due to reduction in KW, FP and FR and these characters are temperature–dependent which means that cool season will extend the periods of vegetative growth and grain filling and consequently would be expected to give high grain yield. The 1982/83 season was the longest for both DH and FP and these were reflected on the higher means of KW and GY for this season. These results are in agreement with those found by Spiertz [8], Sofield *et al.* [9], Chowdhurry and Wardlaw [10] and Wiegand and Cuellar [11]. They showed that an increase in daily average temperature over 15°C during the grain filling period had resulted in reduction in kernel weight and grain yield. The reduction in GY and other associated characters in the other seasons could have been due to higher temperature in March through May. This was brought about by shorter periods of DH, DM and FP as a result of higher temperatures.

Table 3. Seasonal means for the different agronomic traits averaged over varieties

Season	GY	KW	DH	DM	FP	FR	PH
1980/81*	411[c]	35.9[e]	84.8[d]	130.6[c]	45.1[a]	8.93[b]	81.8[bc]
1981/82	386[c]	39.6[c]	90.2[b]	133.3[b]	43.1[b]	8.97[b]	87.0[a]
1982/83	549[a]	49.9[a]	99.6[a]	148.1[a]	48.6[a]	11.57[a]	83.0[b]
1983/84	435[b]	41.9[b]	87.4[c]	124.1[c]	36.7[c]	12.49[a]	75.7[d]
1984/85	382[c]	36.7[d]	76.2[e]	121.9[d]	45.8[a]	8.90[b]	76.5[cd]
LSD.05	47	2.2	2.6	1.9	2.9	1.3	3.9

* Means followed by the same letter are not significantly different according to LSD at .05 level of probability.

GY = grain yield (g/m^2); KW = 1000 kernel weight (g); PH = plant height (cm); DH = days to 50% heading; DM = days to 75% maturity; FP = filling period (days); FR = filling rate (g/m^2/day).

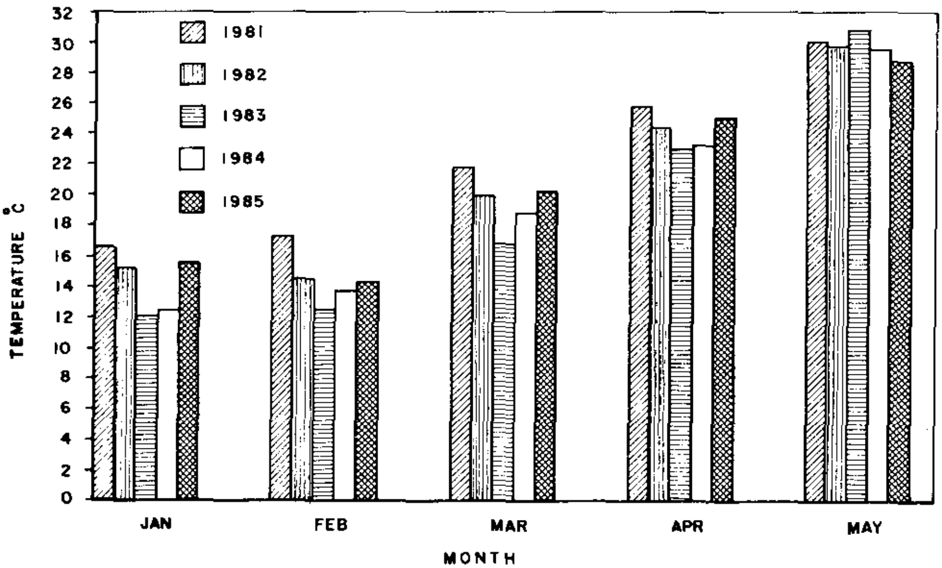

Fig. 1. Average monthly temperature for the five growing seasons

Varieties

The differences among the five varieties were highly significant for all seven traits (Table 2). Aso, highly significant interactions between seasons and varieties were found indicating that some varieties ranked differently during years of testing for the seven traits.

Reaction of the five varieties to seasonal variation with regard to grain yield and other traits is summarized in Tables 4 and 5. Variety 1 had consistently high yield while varieties 2 and 3 were intermediate. Both variety 4 and variety 5 (*Yecora rojo*) were inconsistent in their rank. Therefore, stability index was calculated for each variety as given by Eberhart and Russell [6]. Classification of the varieties according to their stability which incudes the means and responses across years, i.e., the regression coefficient of individual variety yield upon the mean yield of all varieties and the deviation from regression is presented in Table 4. The regression coefficients were significant for varieties 2, 3 and 4 which indicated that they were highly responsive to the change in the average productivity of the growing season. However, variety 4 showed significant deviation from the regression line indicating its instability. This variety was the highest yielding variety only in the 1982/83 season where the temperatures were cooler during February-April period while its yield was poor in the other seasons (Fig. 2). Therefore, this variety would be recommended for further testing. The other two responsive varieties 2 and 3 were also stable as their deviation from the regression line was not significant (Table 4). Their average yield was high and, therefore, they would be recommended as promising varieties and need further testing in the Central Region of Saudi Arabia.

Table 4. Mean grain yield for five varieties under four and five growing seasons and their stability statistics

Variety	Seasonal mean					Overall mean		Stability statistics	
	81	82	83	84	85	4 year	5 year	b	S^2d
1	478^a	499^a	544^b	428^b	399^a	468^a	469^a	0.56^{ns}	1.83^{ns}
2	475^a	352^b	569^b	489^a	364^a	444^a	449^a	1.18*	1.69^{ns}
3	370^b	354^b	599^b	436^b	427^a	454^a	437^a	1.31*	1.29^{ns}
4	321^c	349^b	762^a	369^c	406^a	472^a	441^a	2.44*	5.05**
5	***	375^b	273^c	456^b	316^b	355^b		-0.45^{ns}	5.68**

Means followed by the same letter are not significantly different according to LSD .05. ns, * and ** indicate nonsignificance and significance at the 0.05 and 0.01 levels of probability, respectively.
****Yecora rojo* was not included.

Table 5. Means for agronomic traits for five varieties averaged over the five seasons

Variety	GY	KW	DH	DM	FP	FR	PH
1	469[a]	45.6[a]	84.6[b]	129.9[c]	45.5[a]	10.6[ab]	77.9[b]
2	449[a]	44.7[a]	89.1[a]	135.9[a]	46.8[a]	9.7[bc]	85.8[a]
3	437[a]	36.9[c]	90.9[a]	131.6[bc]	40.8[b]	10.9[a]	82.7[a]
4	441[a]	39.2[b]	90.2[a]	132.3[b]	42.1[b]	11.1[a]	84.7[a]
5*	335[b]	38.2[c]	82.9[c]	127.6[d]	44.7[b]	8.7[c]	70.7[c]
Mean	430	41.0	87.7	131.6	43.9	10.2	80.7

Means followed by the same letter are not significantly different according to LSD at .05 level of probability.
GY = grain yield (g/m^2); KW = 1000 kernel weight (g); PH = plant height (cm); DH = days to 50% heading; DM = days to 75% maturity; FP = filling period (days); FR = filling rate (g/m^2/day).
* means of four seasons only.

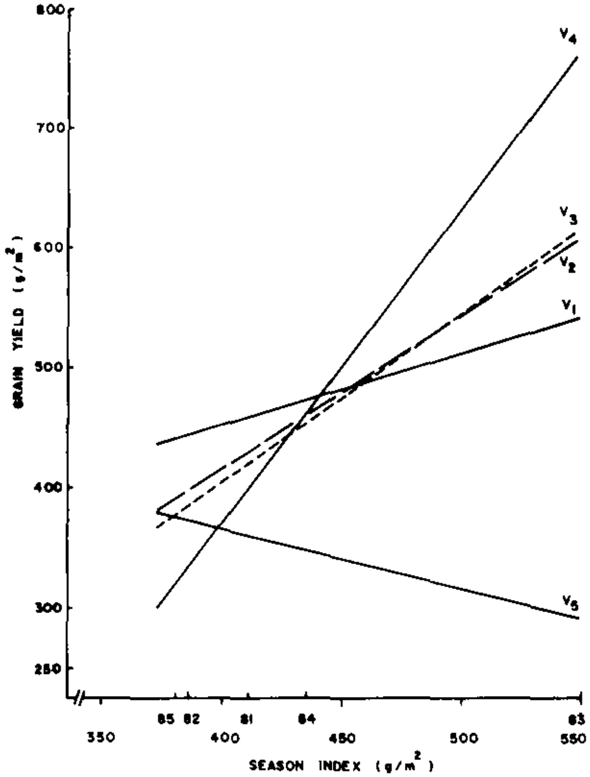

Fig. 2. Regression lines of variety grain yield on environmental productivity index

Although variety 1 was responsive to the environmental conditions in three seasons, it did not respond to the more favourable growing season (1982/83). Therefore, this variety might possess the genes for high yield but it is lacking the genes for stability. Therefore, it is recommended for breeding programs where genes for stability would be incorporated in this high yielding variety [12, pp. 55–88].

Variety 5 is the recommended variety for Saudi Arabia. However, it was not responsive to the change in the productivity level and significantly deviated from regression line (Table 4). As an average of the five seasons, it was the lowest yielding variety and was also unstable. This variety was the earliest among the tested varieties and it might shorten the vegetative growth period and consequently reduce the FR (Table 5).

Comparing the differences among varieties in the five seasons, it might be concluded that the differences were small under stress conditions (1985 season) and increased with the increase in productivity level (1983 season; Fig. 2). Although the evaluation of the varieties would be easier under a more favourable environment (1983 season), conducting the evaluation under less favourable environment is essential to detect the variety stability. Rosielle and Hamblin [13] showed that selection for high stability would generally decrease both mean productivity and yield of the non-stress environments as in the case of varieties 2 and 3 in the present study.

Means for agronomic traits for the five varieties are presented in Table 5. The high grain yield of the two durum varieties (1 and 2) were associated with high kernel weight, long grain filling period as reported for wheat by Spiertz *et al.* [14] and Gebeyebou *et al.* [15-16] and for maize by Ottaviano and Camussi [17]; and to some extent to the high rate of grain filling (Table 5). The two durum varieties were higher in KW and FP than the common wheat varieties. The check cultivar *"Yecora rojo"* had the lowest grain filing rate and that is probably the main reason for its low GY.

The relationships between grain yield and other agronomic traits for the five seasons were expressed in terms of pooled phenotypic correlation coefficients (Table 6). A highly significant correlation was found for GY and KW ($r = 0.44$), DH ($r = 0.43$), DM ($r = 0.54$), and FR ($r = 0.72$). Also, a significant correlation was found with PH ($r = 0.21$) and FP ($r = 0.26$).

Moreover, kernel weight was correlated with FR ($r = 0.36$) and FP ($r = 0.22$) which indicated the importance of FR rather than FP in determining grain size and grain yield potential. On the other hand, FP was negatively correlated with FP ($r = 0.48$) indicating that these two characters are competitive and that FR is limited by

Table 6. **Phenotypic correlation coefficients among grain yield (GY) and related traits of wheat varieties grown in five seasons.**

Traits	KW	PH	DH	DM	FP	FR
GY	0.44**	0.21*	0.43**	0.54**	0.26*	0.72**
KW		0.02	0.49**	0.59**	0.22*	0.46**
PH			0.487**	0.427**	0.00	0.17
DH				0.70**	−0.24*	0.52**
DM					0.53**	0.10
FP						−0.48**

* and ** indicate significance at .05 and .01 levels of probability, respectively.
KW = 1000 kernel weight (g); PH = plant height (cm); DH = days to 50% heading; DM = days to 75% maturity; FP = filling period (days); FR = filling rate ($g/m^2/day$).

the physiological capacity while FP is mainly determined by temperature during the growing season.

In conclusion, the present results would recommend that in Saudi Arabia, which is characterized by a short cool winter followed by a warm and dry period towards the end of the growing season, plant breeders should place more emphasis on selecting a stable high yielding variety with high filling rate to compensate for the short FP.

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المحصول وثباته لمجموعة من أصناف القمح المختارة في المملكة العربية السعودية

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ملخص البحث . أجريت هذه التجارب على مدى خمسة مواسم زراعية، ابتداء من عام ١٩٨١/٨٠م إلى عام ١٩٨٥/٨٤م لتقويم القدرة المحصولية لأربعة من أصناف القمح ذات الإنتاجية العالية، إثنان منهما من نوع أقماح المكرونة Bittern's and Crane's والإثنان الآخران من نوع أقماح الخبز (HD 2172 and CM 8237).

كما زرع الصنف الموصى بزراعته من قبل وزارة الزراعة والمياه وهو (*يوكورا روجا*) كصنف للمقارنة. وقد تم زراعة هذه الأصناف بمحطة التجارب الزراعية بديراب (قرب مدينة الرياض) والتي تتميز بارتفاع درجـات الحرارة خلال نهاية موسم النمو والتي لها تأثيرًا سيئاً على نباتات القمح . وقد درست الصفات التالية : كمية المحصول، مكونات المحصول وفترة امتلاء ومعدل امتلاء الحبوب.

وأوضحت التجارب أن الموسم الزراعي له تأثير معنوي على جميع الصفات التي درست، وكذلك كان التفـاعل بين الموسم الزراعي والأصناف معنويًا أيضًا، وكانت كمية المحصول والصفات الأخرى أفضل في موسم ١٩٨٣/٨٢م عما كانت عليه في المواسم الأخرى، وربما يعود سبب ذلك إلى انخفاض درجات الحرارة في هذا الموسم عنه في المواسم الأخرى، وقد أظهر معامل الارتداد أن الأصناف رقم ١، ٢، ٣ أكثر ثباتًا في كمية المحصول عما هو عليه في الصنفين ٤، ٥ كذلك دلت النتائج على أن هناك ارتباطًا وثيقًا بين كمية المحصول وطول الفترة ومعدل امتلاء الحبوب وكذلك مع وزن الحبوب.