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Physiology of Growth and Yield of Bread Wheat (*Triticum aestivum* L.): A Comparison of Indigenous and Exotic Cultivars of Saudi Arabia

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Abstract. Ten cultivars of wheat (3 local and 7 exotic) were evaluated for growth, development, yield and yield components in 1978/1979. The highest grain yield (7.8 tons/ha) was obtained by the semi-dwarf Mexican wheat cultivar, Mexipak. As to the local cultivars, Summa ranked third, while Luggami and Kholani were the lowest. Almost similar amounts of total dry matter were produced by the low and high yielding cultivars in the pre-anthesis stage. In the post-anthesis stage, however, Mexipak accumulated the highest amount of total dry matter that was mainly stored by the developing spikes. The high dry matter accumulation in Mexipak was apparently attributed to a high leaf area index, crop growth rate, relative growth rate, and net assimilation rate maintained at the end of the growing season. Correlation coefficient indicated that weight and number of grains per spike and number of tillers were the most correlated characters with yield. It is therefore, evident that the incorporation of these traits together with other physiomorphological traits of Mexipak in the local cultivars may lead to the release of high yielding cultivars.

Introduction

In recent years, plant breeders have recognized that selection for components of grain yield only may not necessarily be the most efficient means to achieve yield increase. A number of workers has suggested the use of growth analysis to obtain better selection criteria (Stoskopf *et al.* 1963; Donald 1968; Voldeng and Simpson 1967).

Other investigations have shown that dry matter of the stem and leaf often declines during grain filling in wheat (McNeal *et al.*, 1966 Austin *et al.* 1977; Lal *et al.* 1978). Part of this decline can be attributed to both respiration and retranslocation of assimilates to grain (Rawson and Evans 1971).

Numerous interrelationships of yield and its various components have been reported, most of these have suffered from one or more limitations. Several studies were conducted in the greenhouse (Voldeng and Simpson 1967) where conditions differed from those encountered in the field. In many field studies, the material is space-planted (Walton 1969, Hsu and Walton 1971), but in commercial production, solid seeding is the common practice.

The objective of this study was to compared growth analysis and performance of some important and indigenous wheat cultivars and determine the most important characters and developmental stages correlated with yield in solid seeding stands.

Material and Methods

Ten (3 local and 7 exotic) bread wheat cultivars (Table 1) were planted in a randomized complete block design with four replications in 12 m × 7.0 m plots. Cultivars, Summa, Luggami and Kholani are the local cultivars. The experiment was conducted for only one season (1978/1979) at the Experimental Farm, College of Agriculture, King Saud University, Riyadh. The trial was sown in the first week of December at a seed rate of 150 kg/ha and was given 120 kg P_2O_5/ha (prior to planting) and 240 kg N/ha splitted into four equal doses. The crop was kept down from weeds and was irrigated as need arise. Plant samples (1 m^2) were taken randomly at four growth stages; namely, 60 days after planting (DAP), anthesis, 30 days from anthesis and at full maturity. These were used to determine leaf area, culm dry weight, leaf dry weight, spike dry weight (when present) and total dry weight. These characters, in turn, were used to calculate leaf area index (LAI), specific leaf area (SLA), crop growth rate (CGR), relative growth rate (RGR), as given by Radford (1967). Leaf area was measured by photocopying and weighing method. Protein was determined by the use of Kjldehal method. At full maturity, another sample of 1 m^2 was harvested and used to determine grain yield/m^2 and its components.

Results

1. *Total Dry Matter Production*

At the first harvest (60 DAP), significant differences among the cultivars were evident with TDW values ranging from 167 g/m^2 for Luggami (local) to 267 g/m^2 for Najah (Table 1). Maximum TDW was attained in all cultivars at the last last growth stage, where the largest values were observed for Mexipak, Giza 155, Luggami and Najah (Table 1). Moreover, TDW values gradually increased at the successive growth stage for all of the wheat cultivars (Table 1).

All cultivars, except Luggami, Giza 144 and Senator displayed their greatest amount of culm dry weight (CDW) at the third harvest (30 days from anthesis). Lug-

TABLE 1. Accumulation of total dry weight and its components in 10 wheat cultivars.

Parameter	Total dry weight (g / m²)				Culum dry weight (g / m)				Spike weight (g / m²)		
Harvest cultivar	1	2	3	4	1	2	3	4	2	3	4
Summa	254	826	1537	1870	97	432	740	740	112	493	879
Luggami	167	1179	1655	1975	62	625	734	790	119	488	885
Kholani	192	983	1358	1637	72	555	698	671	154	373	764
Mexipak	183	909	1665	2205	75	456	704	647	193	675	1330
Giza 144	244	872	1413	1764	90	479	707	714	129	432	808
Gizza 155	220	842	1605	2146	93	467	833	770	125	473	1159
Najah	267	831	1423	1911	127	397	779	742	226	434	1005
Senator	256	1038	1454	1838	115	570	667	684	154	556	955
Ageeba	213	938	1560	1753	71	483	718	721	135	530	754
Horani 27	177	1176	1429	1579	62	688	787	698	134	313	621
Mean	217	959	1507	1868	86	515	737	718	148	474	916
S. E. +	11	42	34	101	7	29	16	14	11	31	66
C. V.	16	14	7	11	26	18	7	3	24	21	23

1. 60-DAP
2. Anthesis
3. 30 days after anthesis
4. Maturity

gami, Giza 144 and Senator reached maximum values of CDW at the final harvest (144 DAP) at which Luggami exhibited the largest value observed for any cultivar. Spike dry weight (SDW) gradually increased with the growth stage, reaching its maximum, in all cultivars, at the fourth growth stage (Table 1).

Green leaf weight (GLW) was maximum at the second harvest (Table 2), with Luggami, Horani 27, Senator and Ageeba, showing the highest; Najah and Kholani showing the lowest values. Withered leaf dry weight (WLW) generally rapidly increased from 60 DAP where it averaged 3.2 g/m^2 to a maximum mean value of 280.8 g/m^2 at the last date as expected (Table 2). Such trends of partitioning total leaf dry weight (LDW) into GLW and WLW during the growing season indicate that the accumulation of dry matter in leaves of wheat continued to increase and reached its maximum value at the second harvest after which production of new leaves apparently stopped. Following the second stage of growth, increases in TDW were mostly due to the increase in spike weight. Trends in leaf area index (LAI) were similar to those observed for GLW; *i.e.*, they were maximum during the second growth stage and then dropped afterwards (Table 2).

2. *Growth Analysis*

Crop growth rate (CGR) and relative growth rate (RGR) values during the vegetative stage were highest for Luggami and lowest for Summa (Table 3). During anthesis, CGR apparently decreased in Luggami, Kholani, Senator and Horani 27 and increased in the remaining cultivars. However, it generally decreased afterwards in all cultivars. On the other hand, RGR values decreased during and after anthesis in all cultivars.

TABLE 2. Green (GLW) and withered (WLW) leaf weights and leaf area index (LAI) in 10 wheat cultivars.

Parameter	Green leaf weight (g/m^2)				Withered leaf weight (g/m^2)				Leaf area index			
Harvest cultivar	1	2	3	4	1	2	3	4	1	2	3	4
Summa	153	208	196	28	3.9	74	108	224	5.3	4.4	3.4	0.5
Luggami	104	344	303	19	0.9	90	130	281	2.0	8.4	7.1	0.4
Kholani	115	197	179	9	5.1	77	109	195	5.9	4.9	3.1	0.2
Mexipak	107	230	224	51	1.5	30	63	180	2.8	4.7	4.5	1.2
Giza 144	147	207	183	13	7.1	57	91	229	3.2	4.5	4.4	0.3
Giza 155	125	207	182	34	2.3	43	116	184	3.4	4.5	4.0	0.8
Najah	138	180	173	16	2.0	28	39	164	4.1	5.3	5.0	0.6
Senator	138	246	133	30	3.2	68	97	169	3.5	3.6	2.6	0.6
Ageeba	138	242	203	31	4.6	77	108	249	4.9	5.5	4.6	0.7
Horani 27	113	292	235	44	1.4	62	94	217	3.2	6.5	4.7	0.9
Mean	128	235	201	28	3.2	61	96	208	3.8	5.3	4.6	0.6
S. E. +	5	16	14	4	0.6	7	8	11	3.9	4.3	3.9	0.9
C.V.	14	21	22	49	62.3	35	28	17	31.3	26.0	28.6	48.0

1. 60–DAP 2. Anthesis
3. 30 days after anthesis 4. Maturity

TABLE 3. Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) in 10 wheat cultivars.

Parameter	CGR (g/day)			RGR (mg/g/day)			NAR ($g/m^2/day$)		
Harvest cultivar	I	II	II	I	II	III	I	II	III
Summa	15.1	33.9	12.3	31.1	29.6	7.4	3.1	8.6	8.1
Luggami	37.4	22.7	10.7	72.3	16.2	6.0	8.3	2.9	4.4
Kholani	20.8	14.4	9.6	43.0	12.4	6.4	3.9	3.7	9.9
Mexiplak	23.4	32.9	27.0	51.7	26.3	14.1	6.4	7.1	10.8
Giza 144	16.5	25.8	11.7	36.3	23.0	7.4	4.7	5.8	7.6
Gizza 155	21.5	36.3	18.0	46.3	30.7	9.7	5.4	8.6	9.4
Najah	27.1	42.3	12.2	54.8	30.4	7.4	5.8	8.2	5.8
Senator	27.0	19.8	12.8	48.3	16.0	7.8	7.6	6.4	9.4
Ageeba	27.0	29.7	7.4	55.7	24.5	4.5	5.2	5.9	3.6
Horani 27	21.7	12.1	6.5	41.2	9.3	4.3	4.7	2.2	2.98
Mean	23.8	27.0	12.8	48.1	22.6	7.5	5.5	5.9	7.2
S. E. +	3.9	3.1	1.9	3.7	2.9	0.9	0.5	0.7	0.9
C. V.	25.5	36.3	46.2	24.1	40.2	37.5	29.1	39.5	39.4

I, II, III = Growth intervals.

It is also evident from Table 3 that Luggami and Summa had also maintained, respectively, the highest and lowest values of net assimilation rate (NAR) during the vegetative stage. In four cultivars; *viz.*, Mexipak, Giza 144, Giza 155 and Senator, NAR increased steadily throughout the growing season. In Summa and Kholani, NAR values attained during maturity were higher than those observed during the vegetative stage, while in cultivars, Luggami, Ageeba and Horani 27 the reverse was true.

Leaf area ratio (LAR) values indicated that in cultivars Giza 155 and Senator and in contrast to the others proportionally less amounts of assimilates were being involved in leaf production during the vegetative stage (Table 4). For the other cultivars, lower amounts of assimilates were proportioned to leaf production as the plant matured.

TABLE 4. Leaf area ratio (LAR), specific leaf area (SLA) and leaf weight ratio (LWR) in 10 wheat cultivars.

Parameter	LAR cm^2/g			SLA cm^2/g			LWR (g/g)		
Harvest cultivar	I	II	II	I	II	III	I	II	III
Summa	100	34	9	271	194	176	0.369	0.176	0.051
Luggami	87	55	13	225	240	236	0.388	0.230	0.054
Kholani	112	34	7	355	210	173	0.314	0.162	0.038
Mexipak	81	37	13	228	203	214	0.354	0.182	0.061
Giza 144	77	40	10	218	228	240	0.356	0.174	0.048
Giza 155	9	36	10	244	218	217	0.350	0.165	0.048
Najah	94	47	13	295	292	316	0.320	0.160	0.040
Senator	6	25	8	190	168	196	0.334	0.149	0.043
Ageeba	107	42	13	280	227	227	0.381	0.183	0.055
Horani 27	88	43	15	247	212	199	0.358	0.202	0.076
Mean	76	39	11	255	219	219	0.352	0.178	0.051
S. E. +	11	3	1	15	10	13	0.008	0.007	0.004
C. V.	47	21	24	18	15	19	6.870	13.130	21.710

I, II and III = Growth intervals.

It is evident from Table 4 that specific leaf areas (SLA) values attained in all cultivars, during the vegetative stage, were comparatively higher than those attained at later stages. Among all cultivars, Summa and Mexipak, apparently maintained thicker leaves towards the end of the growing season, since they had the highest SLA values.

Leaf weight ratio (LWR) data in Table 4 indicated that lower amounts of assimilates were translocated to the leaves as the plant matured. On the average, about 35, 18 and 5% of the total plant weight was proportioned to the leaves during the vegetative, anthesis and the post–anthesis stages, respectively.

3. Grain Yield, Yield Components and Other Characters

It is evident from Table 5 that highly significant differences existed among the cultivars with respect to grain yield, its components and other characters evaluated in the present study. It is also clear from the data that Mexipak, the top yielding cultivar, gave the highest harvest index (40%) and the highest number (56) and weight (2 g) of seeds per spike and the highest number of grains (21200) per square meter.

TABLE 5. Plant height, yield and yield components of 10 wheat cultivars.

Character/ cultivar	Grain yield (g/m^2)	Harvest index (%)	No. of spike/ m^2	Weight of grains/ spikes (g)	No. of grains/ spike	1000-grains wt (g)	No. of grains/ m^2 ($\times 10^{-3}$)	Days to heading	Filling period (days)	Plant height (cm)	No. of shoots/ m^2	Protein contents (%)
Summa	550	25	559	1.0	19.6	53.1	11.0	95	47	101	609	18.7
Luggami	391	29	438	0.9	19.9	46.7	8.7	94	54	103	701	17.6
Kholani	436	33	447	0.8	27.2	35.8	12.2	95	53	106	635	18.7
Mexipak	768	40	380	2.0	55.8	35.8	21.2	89	54	80	456	17.1
Giza 144	539	27	428	1.3	28.6	44.6	12.2	95	55	107	627	18.7
Giza 155	547	35	416	1.3	31.8	41.4	13.2	89	54	106	618	18.8
Najah	584	39	320	1.8	38.7	47.3	10.2	81	56	111	429	17.7
Senator	492	36	414	1.2	36.3	40.1	15.0	89	53	101	573	18.2
Ageeba	561	30	440	1.1	26.2	40.1	11.5	97	53	90	719	20.0
Horani 27	567	28	360	1.3	30.5	42.6	1.0	105	47	116	500	14.7
Mean	515	32	409	1.3	31.1	43.5	12.3	92	53	103	586	17.9
S.E. +	31	1	21	0.1	3.0	1.7	1.0	2	1	3	49	0.5
C.V.	20	15	17	29.0	32.3	13.0	27.0	7	7	10	17	8.3

Besides, Mexipak showed to be the shortest (80 cm) cultivar with a relatively low number (456) of shoots/m^2.

The simple correlation coefficient (Table 6) indicated that weight and number of grains per spike were highly significantly and positively correlated with grain to yield (P = 0.01), whereas number of shoots/m^2 were negatively (r = – 0.745) correlated with it (P = 0.05). Meanwhile, harvest index tended to be positively (r = 0.556), plant height negatively (r = – 0.551) correlated with grain yield. The remaining characters (Table 6) were not correlated with grain yield, with non-significant, negative r-values.

TABLE 6. Simple correlation coefficient of grain yield (g/m^2) with harvest index, number of spikes and other yield components in 10 local and exotic spring wheat cultivars.

Characters	r
Harvest index	0.556
No. of spikes/m^2	– 0.064
Grain weight/spike	– 0.811**
No. of grains/spike	0.818**
1000 – grains weight	– 0.027
Filling period	– 0.025
Plant height	– 0.551
No. of shoots/m^2	– 0.745*
Protein content	– 0.118

*, **Indicate significance at 0.05 and 0.01 levels of probability, respectively.

Discussion

It is obvious from the data presented in this study that highly significant differences in TDW, CDW, LDW and its components (GLW and WLW), LAI, CGR, RGR, NAR, LAR, SLA and LWR existed among the ten wheat cultivars evaluated. Similar reports in the literature (Evans and Hughes 1962, Milthorpe 1962 and Clark *et al.* 1984) indicated that variations in dry matter, produced by different cultivars might be related to differences in leaf area, leaf area ratio, net assimilation rate and relative growth rate.

Data on grain yield and its components (Table 5) also indicated the existence of highly significant differences among the cultivars in all of the characters evaluated. However, it was evident from the simple correlation analysis that harvest index and number and weight of grains per spike were the most important grain yield contributing characters in the present study. Similarly, high correlations between grain yield and number of grains per spike (Fischer and Khon 1966, Nass 1973), harvest index (Singh and Stoskopf 1971) and grain weight (Nass 1973) were reported in the literature.

On examining the performance of individual cultivars, it is evident that Mexipak, a semi-dwarf Mexican cultivar, produced the highest grain yield (7.8 t/ha). As to the local cultivars, Summa ranked the third (5.5 t/ha), while Kholani (4.4 t/ha) and Luggami (3.9 t/ha) ranked the eight and ninth, respectively. Almost similar amounts of total dry matter were produced by Kholani, Luggami (the low yielding cultivars) and Mexipak (the top yielder) in the pre-anthesis stage. In the post-anthesis stage, however, Mexipak accumulated the highest significant ($P = 0.05$) amount of total dry matter (2205 g/m^2) that was mostly stored by the developing spikes. Such high dry matter accumulation in Mexipak was attributed to the comparatively high leaf area index (1.19), crop growth rate (27 g/day), relative growth rate (14.1 g/day) and net assimilation rate (10.8 g/m^2/day) maintained at the end of the growing season (*i.e.*, at full maturity).

Among the ten cultivars evaluated, Mexipak also gave the highest harvest index (40%), indicating its high efficiency in diverting most of its assimilates (current and stored) to the developing grains. The high harvest index in Mexipak was mostly associated with its large sink capacity, as indicated by its ability in maintaining a relatively large number (56) heavy (2 g) grains per spike. Numerous reports (Syme 1972, Bhatt and Derera 1977, Fischer and Kertesz 1976, Nass 1980, Nass 1983, Khalifa and Al-Saheal 1984) have indicated that selection for harvest indext could be very effective in developing high-yielding cultivars of wheat. In Britain, the high yielding cultivars of barley and spring and winter wheats possess a higher harvest index than traditional cultivars (Walton *et al.* 1958 and Walton *et al.* 1963).

It may thus be concluded that, in view of the present investigation, incorporation of the physiomorphological traits of Mexipak in breeding programmes with the local cultivars may prove to be an efficient approach in future wheat improvement programmes in Saudi Arabia.

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فسيولوجيـــة نمـو ومحصـــول قمـــح الخـــبز : مقارنـة الأصناف المحليـة والأجنبيـــة في المملـــكة العربيـــة السعوديـــة

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المستخلص . تم اختيار عشرة أصناف من القمح (٣ محلية و ٧ أجنبية) لدراسة معامل النمو ومحصول الحبوب ومكوناته في عام ١٩٧٨ - ١٩٧٩م .

وقد تفوق الصنف القصير «مكسيباك» في كمية المحصول (٧,٨ طن / هكتار) أما الصنف المحلي «صما» فقد كان في المرتبة الثالثة بينما الصنفان المحليان «لقيمي» و«خولاني» أعطيا أقل محصول . وقد أنتجت أعلى الأصناف وأقلها نفس الكمية من المادة الجافة في فترة ماقبل الإزهار . أما في فترة النضج فقد جمع الصنف «مكسيباك» أكبر كمية من المادة الجافة التي خزن معظمها في الحبوب . وتعود كفاءة المكسيباك هذه على مايبدو إلى ارتفاع دليل مساحة الأوراق ومعدل نمو المحصول ومعدل النمو النسبي ومعدل الكفاءة الصافية للتمثيل في الفترة المتأخرة من نمو المحصول . وقد أوضح تحليل الارتباط والانحدار أن دليل الحصاد ووزن وعدد الحبوب في السنبلة هي أهم الصفات المحصولية التي شاركت في التأثير على كمية المحصول . وعلى ضوء هذا يتضح أن إدخال هذه الصفات مع الصفات الفسيومورفولوجية الأخرى للمكسيباك في الأصناف المحلية قد يؤدي إلى الحصول على أصناف عالية الإنتاج .