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Response of Wheat and Triticale Cultivars to Water Stress

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Fifteen cultivars of wheat and three triticale were evaluated for two seasons under three water regimes; dry (40%), moist (60%) and wet (80%), of the field capacity, in a split plot design. Increasing the percent of soil moisture increased yield, plant height, Kernel weight, days to heading, grain filling period and number of days to maturing. Variations among cultivars were significant and interacted with water regimes. Drought susceptibility coefficients calculated for each cultivar varied from year to year. There was no relation between coefficient drought susceptibility and species. It was concluded therefore, that this coefficient was the property of the cultivar rather than the species. The drought susceptibility coefficient was negatively correlated with the grain filling period. This coefficient could be used to identify drought tolerant cultivars, but it should be calculated for more than one season.

Irrigation water is one of the essential inputs affecting wheat grain yield in Saudi Arabia. With the spectacular increase in wheat acreage in the last decade, irrigation water has become the limiting factor for further expansion in wheat production. Therefore, reducing water requirement of wheat without affecting yield would have a priority in studying optimum conditions for wheat production.

Robins and Domingo (1962) obtained yield depressions of 10-35% resulting from severe moisture stress in irrigated spring wheat. Reductions were greater when plants were exposed to water stress during the following heading, or during maturity stages. Day and Intalap (1970) showed that wheat is sensitive to moisture stress at any stage of growth especially during the earlier stages.

Reaction of the different cultivars to moisture stress has been studied by plant breeders and crop physiologists in order to identify and characterize tolerant cultivars to water stress. May and Milthorpe (1962) and Levitt (1972) classified the mechanisms of drought resistance as: escape, avoidance and tolerance. Although several creteria were suggested to measure drought tolerance, Fischer and Maurer (1978) suggested the use of yield depression upon exposure to drought condition as an index to measure drought susceptibility. Drought levels caused by irrigation cut-offs varied from 69 days before anthesis date to only 10 days before. Grain yield under drought showed highly significant interaction between cultivars and drought levels. They demonstrated linear relationship between cultivar yield and drought intensity. Tall wheat cultivars were more resistant to drought followed by barley and dwarf wheat, while durum wheat and triticale were the most susceptible. Fischer and Wood (1979) demonstrated that drought susceptibility was unrelated to plant-water relationship under drought but was related to various non-drought traits. It increased with increased non-drought yield, harvest index, kernels/m^2, kernels/spike and leaf water potential and with decreased plant height and waxiness.

Innes and Blackwell (1981) showed that there was genotypic variation in drought tolerance. They demonstrated that reaction to drought stress would depend on yield structure of wheat plants.

The objectives of the present investigation were: (1) to identify the optimum water regime to grow wheat and to examine the effect of water stress on yield and yield components, (2) to study the interaction between cultivars and water regimes in order to identify the tolerant cultivars to water stress and (3) estimate the correlation between water stress and agronomic characteristics.

Materials and Methods

The present investigation was conducted with 15 wheat and three triticale cultivars under three water regimes at the Agricultural Experimental Station, King Saud University at Deirab during the 1984 and 1985 growing seasons. The soil at the experimental site is highly calcareous, non-saline sandy clay loam.

The wheat cultivars consisted of 12 common wheat (*Triticum aestivum,* L.), three durum wheat (*Triticum turgidum* var *durum*) and three triticale (X *Triticosecale* Wittmak). Among the common wheat, the two recommended cultivars; Yecora Rojo and West Bred were included. Names and source of the 18 cereal cultivars are given in Table (1).

Three water regimes were applied to study the response of the cereal cultivars to water stress. Plants were exposed to these regimes during the whole growing season. The water regimes used were wet, moist and dry. Plots were irrigated

Table (1) Names and sources of the 18 cereal cultivars under study

Cultivar	Species	Source
1. CM 8671	*Triticum aestivum* L.	Mexico
2. CM 15133	" "	"
3. Mexipak 85	" "	"
4. CM 5375	" "	"
5. F10 – line 4	" "	Saudi Arabia
6. Sakha 80	" "	Egypt
7. F10 – line 17	" "	Saudi Arabia
8. Barouk	" "	Mexico
9. QT 4081 Pw Th 13	" "	Australia
10. Sama L.S. 100	" "	Saudi Arabia
11. Yecora Rojo 71	" "	U.S.A.
12. West Bred 911	" "	U.S.A.
13. 9876-29	*T. turgidum* L.	India
14. Cr'sl/pl's/Ato'sL 436-3L	" "	Lebanon
15. CD 10535-D-1-M-1Y-4M-Y	" "	Mexico
16. Drira X 7110	X-*Triticosecale Wittmak*	Australia
17. May-11-ARM	" "	Mexico
18. X 8745-B-1Y-2M	" "	Mexico

when the available soil moisture was depleted to an average of 80% (wet regime), 60% (moist regime) and 40% (dry regime) of the field capacity. Soil moisture was measured by gypsum blocks installed at a depth of 15-20 cm in the soil in each plot and calibrated by a Bouyoucos moisture meter. A 5-cm depth of irrigation water was applied for each scheduled irrigation throughout the growing season.

The layout of the experiment was a split plot with four replications. The water regimes were assigned to the main plots and the 18 cultivars were allocated to the sub-plots within each main plot. Each sub-plot consisted of 10 rows, 5 m long and 20 cm apart. The experiment was sown on the 20th and 30th of Nov. 1984 and 1985, respectively. The seeding rate was 120 kg/ha. Fertilizer rates of 120 kg of N and 35 kg of P were applied.

Data were collected from a representative sample of one m^2 taken from the center of each sub-plot on grain yield (g/m^2), number of days to heading, number of days to maturity, grain filling duration, plant height (cm), 1000-kernel weight (g), and test weight (kg/hl).

Statistical analysis was calculated for each year as given by Steel and Torrie (1980) considering the effects of varieties and water regimes as fixed effects. The variations among the three water regimes were partitioned to linear and quadratic components. According to the significance test, the appropriate response curve of grain yield to water regime was calculated for each cultivar, and for the means of the 18 cultivars. The significant regression coefficients of these curves were used as indicators of drought susceptibility (Fischer and Maurer 1978). Correlation coefficients were calculated between drought susceptibility coefficients and the characteristics of the different cultivars.

Results and Discussion

A summary of the analysis of variance combined over the two years is given in Table 2. Differences due to year effects were significant for grain yield, day to heading, grain filling period, plant height and 100 kernel weight. Growing conditions were more favorable in 1984 for grain yield, kernel weight, plant height and days to heading while they shortened the filling period, in 1984 as compared to 1985 season (Table 3). Both the test weight and days to maturity were not affected by years.

The first order interactions involving year were significant for most of the characters under study. Therefore, the effects of water regimes and cultivars will be separately presented for each year due to the differential effect of years.

Table (2) Significance level from the analysis of variance for different characters as affected by year water regimes and cultivars

S. O. V.	d.f.	Significance Level						
		Grain yield (g/m^2)	Days to heading	Grain filling period	Days to maturity	Plant height (cm)	1000 kernels wight(g)	Test weight (kg/hl)
Years (Y)	1	**	**	**	ns	**	*	ns
Water Regimes (W)	2	ns	ns	ns	ns	**	**	ns
W x Y	2	**	**	**	**	ns	ns	ns
Cultivars (V)	17	**	**	ns	ns	**	**	**
V x Y	17	**	**	**	**	**	ns	*
V x W	34	ns	ns	ns	ns	ns	**	**
V x W x Y	34	**	**	**	ns	ns	ns	ns

ns, * and ** non-significant and significant at 0.05 and 0.01 levels of probability, respectively.

Table (3) Means of the different characters for the two growing seasons averaged over water regimes and cultivars

Season	Grain yield (g/m^2)	1000 kernels wight(g)	Test weight (kg/hl)	Plant height (cm)	Days to heading	Grain filling period	Days to maturity
1984	480.0[a]	35.1[a]	68.7[a]	100.2[a]	93.4[a]	38.4[b]	131.8[a]
1985	314.9[b]	33.7[b]	68.7[a]	94.2[b]	87.7[b]	44.2[a]	131.9[a]
Mean	397.5	34.4	68.7	97.2	90.5	41.3	131.8
C.V. %	21.2	11.2	2.8	13.1	2.4	8.9	2.0

Means followed by different letters (within a column) are significant at the 0.05 level of probability.

Water Regimes

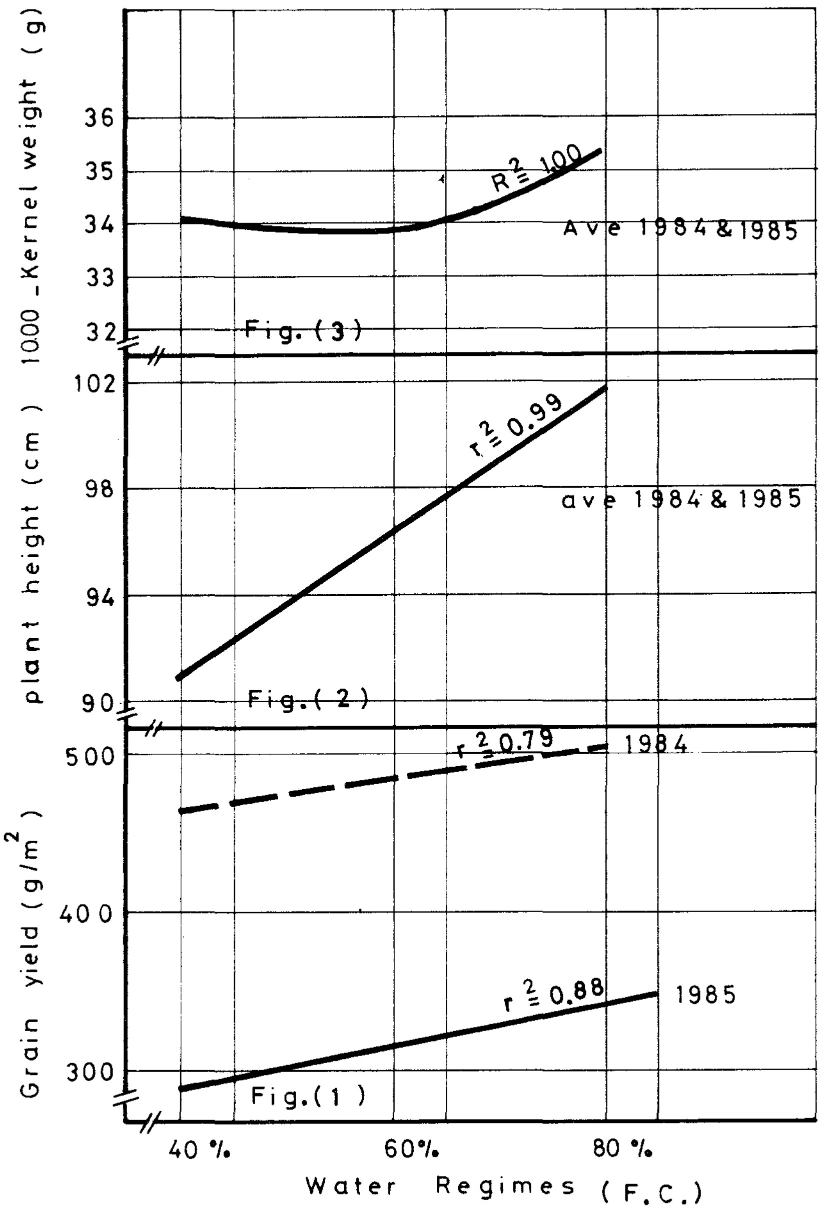
Response of grain yield to water stress was linear and negative, as expected (Fig.1). However, the rate of reduction was slightly higher in 1985. It amounted to .15 g for each 1% reduction in soil moisture content. Increasing the water supply resulted in a linear increase in plant height and a quadratic increase in kernel weight (Figs. 2 and 3). This increase was consistent in the two years.

The reaction of the cereal varieties to water dosage with respect to maturity characters was different in the two growing seasons. In 1984 exposing the plants to water stress shortened the number of days to heading. The effect was linear and almost consistent (Fig. 5). On the other hand, the grain filling period increased with higher soil moisture content in 1984 while it was not affected by the change in water regimes in 1985 (Fig. 4). The effect of water regimes on number of days to maturity was also different for the two seasons. It increased linearly with the increase of soil moisture in 1984 while it showed a curvilinear response in 1985 (Fig. 6). Test weight was not affected by water regimes in both seasons. The present results are in general agreement with those reported by Robins and Domingo (1962) Day and Intalap (1970) and Singh *et al.* (1979) on grain yield and days to heading, Hang and Miller (1983) on plant height of winter wheat.

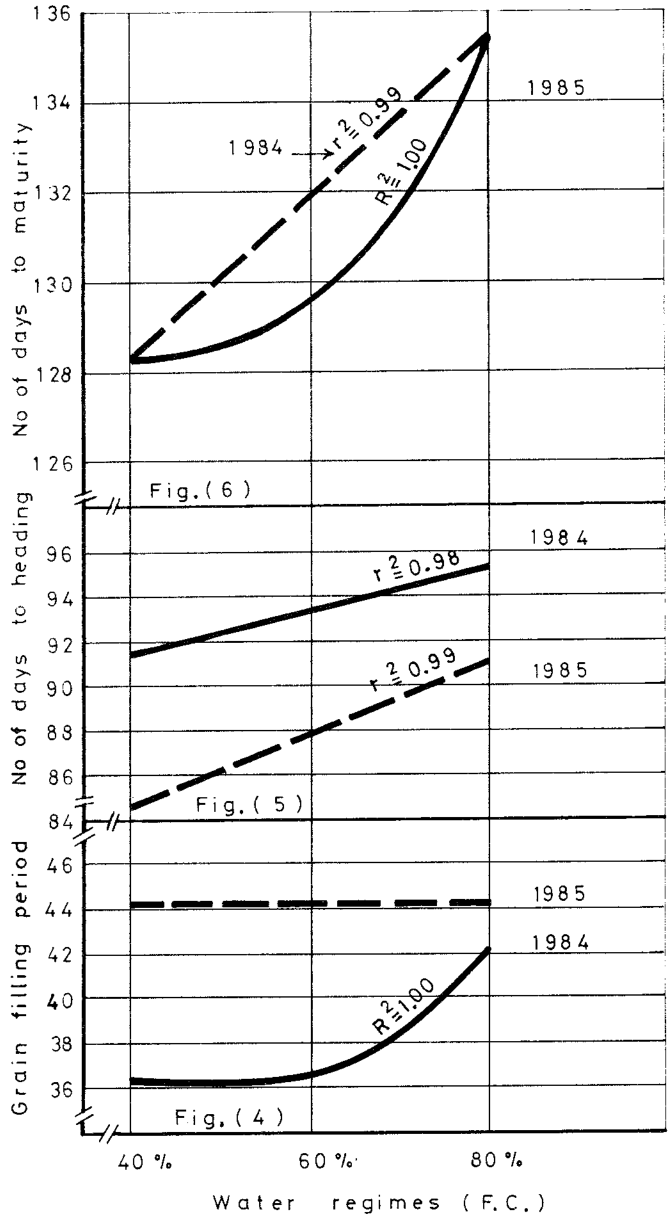
Cultivars

The combined analysis of variance revealed that differences among cultivars were significant for all the studied characters except grain filling period and days to maturity (Table 3). The analysis of variance for each season showed that in 1984, both cultivars and the interaction between cultivars and water regimes were significant for all characters except plant height. On the other hand, in 1985 the differences between cultivars were significant for all characters while their interactions with water regimes were significant for yield and test weight only.

For grain yield, the differences between cultivars were more pronounced in 1984 than in 1985 due to the lower magnitude for error in the former year. Grain yield responses of the 18 cultivars to the three water regimes were expressed in terms of linear and quadratic regression coefficient of yield on the percent of available soil moisture (Table 4). The reactions of the 18 cultivars to the change in moisture percent were split to three groups. The first, susceptible group, included 11 cultivars in 1984 and 4 in 1985 which responded significantly and positively to the increase in water supply. The second, the drought tolerant group consisted of the cultivars that did not significantly respond to the change in water regimes. It included 6 cultivars in 1984 and 13 in 1985. The third group showed a negative response to the excess of soil moisture and contained only one cultivar in both seasons. The reaction of first group to changes in water regime was ex-



Figs. (1 - 3) Average response of 18 cultivars to three water regimes during 1984 and 1985 seasons.



Figs. (4 - 6) Average response of 18 cultivars to three water regimes during 1984 and 1985 seasons.

Table (4) Mean grain yield ($\overline{Y}$) linear (b_1) and quadatic (b_2) responses to increases in available soil moisture for the 18 cultivars in 1984 and 1985 seasons.

Cultivar	1984			1985		
	$\overline{y}$	b_1	b_2	$\overline{y}$	b_1	b_2
1. CM 8671	491	47.8**	41.4**	285	41.3	– 6.9
2. CM 15133	455	33.2**	2.9	277	13.3	–11.9
3. Mexipak 85	500	–31.5**	–23.2**	385[a]	29.8	– 4.6
4. CM 5375	461	10.6	– 3.1	284	41.9	–19.7
5. F 10-4	521	76.4**	–21.1**	329	63.5*	–14.7
6. Sakha 80	468	38.7**	9.6	299	–22.3	2.0
7. F 10-17	494	– 1.5	17.6**	319	– 8.9	– 8.1
8. Barouk	515	9.2	4.3	363[a]	94.7**	1.2
9. Q T 4081	496	36.0**	–12.5**	394[a]	19.1**	2.6
10. Sama L.S 100	412	45.3**	– 6.0	234	24.6	– 9.1
11. Yecora Rojo	556[a]	45.7**	14.1*	342	61.1*	– 0.6
12. West Bred	537[a]	13.6	9.3	393[a]	41.9	–10.6
13. 9876-29	434	12.4	– 4.8	275	97.5**	7.9
14. CRS/PLS	464	5.1	– 4.6	291	33.0	–10.1
15. CD 10535	504	25.3*	– 3.2	293	19.4	0.8
16. Drira x 7110	476	92.0**	–15.7**	288	3.1	– 9.1
17. May-11-ARM	397	58.8**	5.5	297	3.6	–33.9
18. X 8745	460	17.2	–13.1*	321	40.3	1.3
Mean	480	26.8**	2.8	314.9	33.15**	– 7.1

*,** : indicate significant at the 0.05 and 0.01 levels of probability, respectively.

a : high yielding group according to Dunnett procedure.

pected. However, cultivars belonging to the second group will be designated as drought tolerant as their yields were not affected by the change in water regimes from the wet to the stress condition. High yielding cultivars within this groups will be the most desirable. The third group included those cultivars which were sensitive to the excess of soil moisture.

The high yielding cultivars within each season were identified using Dunnett's test (Steel and Torrie 1980). The characteristics of the high yielding varieties for each season are summarized in Table (5) and their reaction to the change in water regime is illustrated in Fig. (7). The two cultivars recommended for the area, Yecora Rojo and West Bred were within the high yielding group in both seasons. Only West Bred cultivar was consistently drought tolerant while Yecora Rojo and line F 10-4 were consistently drought susceptible. On the other hand, Barouk was drought tolerant in 1984 and drought susceptible in 1985. In general, the 1984 season was a favourable season for screening the drought reaction than 1985, since the cultivars x water regimes interaction was more pronounced in 1984.

Average of drought susceptibility coefficients for three cereal species; bread wheat, durum wheat and triticale were 27, 14.2 and 56.0 in 1984, and 33.3, 50 and 16 in 1985, respectively. These values indicate that, the differences among the three species with respect to drought susceptibility coefficients were not consistent and suggest that, the reaction to drought was mainly a characteristic of the cultivar rather than the species. Fischer and Maurer (1978) showed that both durum wheat and triticale were more susceptible to drought than bread wheat. However, they showed considerable variability within these groups. This might support the present findings that susceptibility to drought is characteristic of the cultivar. Innes and Blackwell (1981) reported that the degree of drought response, in terms of reduction in grain yield, depended upon the yield structure of yield components of the different cultivars.

The relationship between the drought susceptibility coefficients and the characteristics of the different cultivars were studied by calculating the correlation coefficients between the linear regression coefficient and the corresponding means of the 18 cultivars for the different characters in 1984 and 1985. Only the correlation coefficient between susceptibility coefficient and the grain filling period in 1984 was significant ($r = -0.57$). This would indicate that cultivars with longer filling period would be more tolerant to drought stress. Other characters were independent from drought susceptibility coefficients. These findings are different from those reported by Fischer and Wood (1979), where their susceptibility index increased with the increase in non-drought yield, harvest index,

Table (5) Means of different characters of the high yielding cultivars averaged over water regimes for 1984 and 1985 seasons

Variety	Grain yield (g/m^2)	No. of days to heading	No. of days to maturity	Grain filling duration (days)	1000 kernels weight (g)	Test weight (kg/hl)	Plant height (cm)	Drought* reaction
				1984				
Yecora Rojo	556	87.7	123.3	35.7	42.2	72.1	71.0	G-1
West Bred	537	98.6	134.7	36.1	38.8	71.2	71.6	G-2
Line F 10-4	521	91.8	128.5	36.8	37.7	70.1	95.9	G-1
Barouk	515	89.2	128.0	38.8	37.3	69.8	92.8	G-2
				1985				
QT 4081	394	80.0	131.4	51.4	36.6	69.5	91.4	G-2
West Bred	394	97.7	132.9	34.4	37.2	70.4	77.4	G-2
Mexipak 65	385	81.5	131.8	50.3	33.0	69.5	82.9	G-2
Barouk	363	77.7	133.0	55.3	35.9	69.5	90.2	G-1
Yecora Rojo	342	71.0	129.9	57.9	37.8	71.5	85.1	G-1
Line F 10-4	329	76.7	130.2	53.6	34.7	69.0	103.9	G-1

* G-1 : Drought susceptible and G-2 = Drought tolerant.

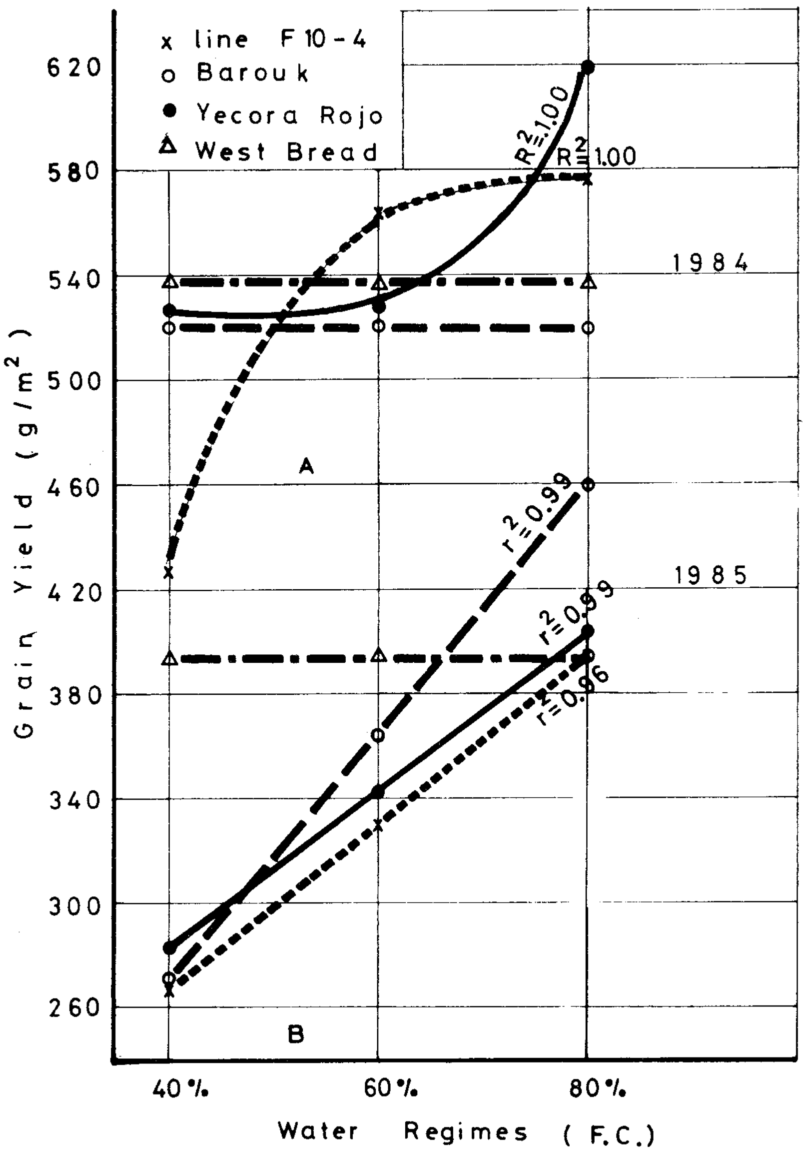


Fig. (7) Grain yield response of the high yielding wheat cultivars to the change in water regimes in 1984 and 1985.

kernels/m^2, kernls/spike, and with decreased plant height. Their estimate of susceptibility index depended on the yield of one cultivar across different water regimes while the susceptibility coefficient in the present investigation was calculated using the average soil water content. The latter coefficient would be more consistent and more reliable from the statistical view point.

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