BARLEY GROWN UNDER LIMITING WATER CONDITIONS[1]

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ABSTRACT - Three barley (*Hordeum vulgare* L.) cultivars were grown with a preplanting irrigation plus rainfall at the University of Arizona Marana Agricultural Center to study the relationship of growth and physiological characteristics to yield under limiting moisture conditions. Grain yield of barley cultivars were ranked in the order Bold = 4-21-13 > 309-1. The cultivar that had the highest ear growth rates at late stages of growth, had the highest yield, but they did not have earlier maturity dates under dryland conditions.

Index terms: *Hordeum vulgare*, water stress, physiological studies.

CEVADA CULTIVADA EM CONDIÇÃO DE ESTRESSE HÍDRICO

RESUMO - Três cultivares de cevada (*Hordeum vulgare* L.) foram cultivadas com uma irrigação de pré-plantio e precipitação adicional na Universidade do Arizona, com o objetivo de estudar a relação existente entre o crescimento, fisiologia e produtividade. A produtividade da cultivar Bold foi semelhante à da cultivar 4-21-13, e esta obteve produtividade superior à da cultivar 309-1. A cultivar que obteve a maior taxa de crescimento da espiga no final do período reprodutivo obteve alta produtividade. As cultivares mais produtivas não apresentaram ponto de maturação precoce.

Termos para indexação: *Hordeum vulgare*, estresse hídrico, estudos fisiológicos.

INTRODUCTION

Improvements in yields can be obtained by increasing the duration of the reproductive period and the investment of assimilates toward reproductive growth (Evans, 1975). In this regard, Gebeyehou et al. (1982) reported a positive correlation between the length of the grain filling period and grain yield in wheat. Woodruff & Tonks (1983) noted that wheat cultivars which have long grain filling periods yielded better than those with short grain filling periods. The suggestion that yield of cereal crops can be increased by increasing the duration of grain filling has been questioned by a number of reports; Nass & Reiser (1975), Sayed & Gadallah (1983) and Bruckner & Frohberg (1987) concluded that the rate of grain filling and not the duration of grain filling, in barley and wheat, was a more important yield determinant under temperature and stress conditions. Although there are significant differences among genotypes for grain fill duration (Rasmusson et al., 1979) and rate of grain fill (Bruckner & Frohberg, 1987), there is no agreement if plant breeders should attempt to increase yield by increasing grain filling duration or rate. Ramage (1987) pointed out that increasing grain filling duration or rate will not cause an increase in grain yield because under different environmental conditions these two processes (grain filling duration or rate) can adjust to reach the same seed size. He suggested that increasing seed size would be a more profitable approach to increase yield.

Despite the effort plant physiologists have made to understand the plant mechanisms that control yield under limited water conditions, the relationship of growth and physiological characteristics to yield under limiting water conditions deserves more attention.

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The objectives of this field work were to study the relationship of vegetative growth, to barley yield, under limiting water conditions, and explore the relationship existing between anthesis and maturation dates and head growth duration, to yield of field grown barleys.

MATERIAL AND METHODS

A field experiment was carried out at the University of Arizona Marana Agricultural Center. Three different barley (Bold, 309-1, and 4-21-13) cultivars were studied. Seeds were planted on Dec. 10, 1985 and harvested on May 16, 1986. The experiment was conducted on a Pina Clay Loam, which has a pH of about 7.7, low organic matter content, and a plow layer at about 25 to 48 cm. The soil was fertilized with 75 kg/ha of N as NH_4NO_3 and 100 kg/ha of P_2O_5, and irrigated with 150 mm of water, seven days before planting. An additional 105 mm of rainfall occurred during field study.

The experimental design was a completely randomized block with three treatments (cultivars) and four replications. Plots contained four rows 3 m long spaced 40 cm apart. Adjacent plots were 1 m apart. Plots were mechanically seeded at the rate of 100 seeds per row.

A soil moisture release curve (Fig. 1) was constructed by measuring, at different depths, soil water content, gravimetrically, and soil water potential, with a Decagon SC-1C sample chamber and a NI-3 nanovoltmeter (Decagon Devices Inc: Fullmen, WO).

After emergence, frequent checks were made on the developmental stages of each cultivar as described by Castro Neto (1988).

For water potential measurements, plants were sampled before dawn once a week. Five to six leaf discs 0.5 cm in diameter were taken from the lower portion of the youngest leaf blade and placed in single junction psychrometer chambers (Merrill 75-13C psychrometer, Merril Specialty Equipament, Logan, Utah). Psychrometers were placed in an insulated box in the field and transferred into the laboratory and placed on a water bath at 25°C. Water potentials were determined with a Kenthley Wescor MJ-55 microvoltmeter (Wescor Inc., Logan, Utah) after a four-hour equilibration. For leaf osmotic potential determinations, the psychrometers were frozen in liquid nitrogen for approximately ten seconds, allowed to thaw, and, equilibrated in the bath for two or more hours before measurements were recorded.

RESULTS AND DISCUSSION

Comparing yield and yield components of barley

Yields obtained from the three barley cultivars are similar to those obtained earlier for barley plants grown with limiting water (Day & Thompson, 1975), and they reinforce earlier findings of Ottman et al. (1986), Sarmadnia (1981) and Adjei (1982) that good yield of small grains can be obtained with a total of about 250 mm water.

Grain yields of 309-1 were significantly lower than those of Bold or 4-21-13 (Table 1). Because maturity dates for 4-21-13 and 309-1 were the same (4/14) and 9 days earlier than those of Bold, the results do not agree with the suggestion derived from earlier studies that higher yielding cultivars should have earliest maturity dates. Additionally, since the head growth periods of Bold, 4-21-13, and 309-1 were 28, 26, and 26 days, respectively, difference in yield was not due to the duration of grain filling. Rather, data on Table 1 suggests that lower yields obtained for 309-1 may

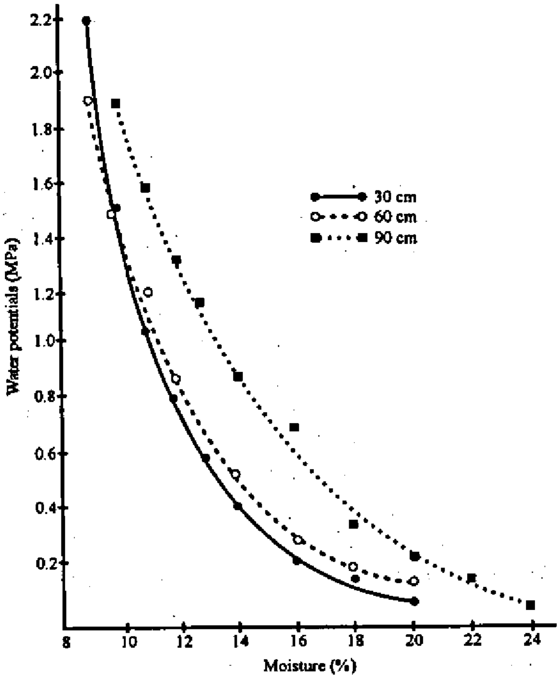

FIG. 1. The relation of water potential to moisture percentage at three depths of a Pima Clay Loam soil.

have been due to its significantly smaller seed size, or a combination of lower seed size and reduced tiller numbers. The correlation studies (Table 2) showed that for all three cultivars, yield was positively correlated with tiller numbers and 1000 seed weight, and negatively correlated with grains/spike.

Leaf area index (LAI)

LAI are alike during early growth (Table 3), but by 2/20 and thereafter 4-21-13 had lower LAI than either Bold or 309-1. These data suggest that in the three barley, there is no relation between yield and LAI at late stages of growth.

Above ground dry weight

This study does not show any correlation between yield and total above ground dry weight. Also, no association between yield and dry weight at anthesis was seen in this study (Table 4).

Plant height was measured only from the ground to the tip of the last floret (Fig. 2). All barley cultivars showed an increase in plant height after anthesis, but the lowest yielder, 309-1, was the tallest whereas the highest yielder, Bold, was the shortest. These data indicate that cultivars which may have invested photoassimilates in plant height rather than in grain growth after anthesis, obtained lower yield. This is in agreement with Evans (1975) and Gardner et al. (1985).

Root depth

When replenishment of soil moisture does not occur, the soil zone supplying water for growth can be inferred by determining soil water potential changes that occur over a time course. Among the barley cultivars, Bold appears to extract water from lower soil depth than either 309-1 or 4-21-13 at late stages of growth (Table 5).

Water status changes in flag leaves during development of barley

Among the barley cultivars, leaf water potential for Bold and 309-1 were alike and higher than that of 4-21-13 at late stage of growth (Fig. 3). Because yields of 4-21-13 were greater than 309-1 (Table 1), yields

TABLE 1. Yield and yield components of barley cultivars[1].

Barley cultivars	Anthesis date	Maturity date	Yield (kg/ha)	Wt. 1000 seeds (g)	Grains/ spike	Tiller/m²
Bold	3/25	4/23	4830.6 a	45.0 a	42.2 a	178.12 a
4-21-13	3/18	4/14	4388.1 a	44.7 a	51.0 a	128.75 a
309-1	3/18	4/14	3286.6 b	40.8 b	48.0 a	124.38 a

[1] Values with the same letter within a column are not significantly different at the 0.05 level according to the Student Newman Kuel test.

TABLE 2. Pearson correlation coefficients calculated by SAS (1985).

Variables	Yield	Tiller/m²	Grains/spike
Wt. 1000 seeds	0.6607*	0.1975	-0.2557
Yield		0.715*	-0.1195*
Tiller/m²			-0.3269

* Values are significantly different from zero, at the 5% level.

TABLE 3. Leaf area indexes for barley cultivars[1].

Cultivars	Date							
	2/6	2/20	2/27	2/30	3/20	3/26	4/2	4/15
Bold	0.50 a	1.16 b	2.90 a	2.70 a	2.50 a	2.40 a	2.30 a	2.20 a
4-21-13	0.50 a	0.95 b	2.20 b	2.00 b	1.90 b	1.85 b	1.80 b	1.70 b
309-1	0.50 a	1.90 a	2.70 a	2.80 a	2.40 a	2.35 a	2.30 a	1.90 b

[1] Values with the same letter within a column are not significantly different at the 0.05 level according to the Student Newman Kuel test.

TABLE 4. Total above ground dry weight of barley cultivars[1].

Cultivars	Date						
	2/6	2/20	2/27	2/30	3/20	4/2	4/15
	(g/pl)						
Bold	0.30 a	1.76 a	1.78 a	4.86 a	5.10 a	8.00 a	9.15 a
4-21-13	0.27 a	0.53 a	1.26 c	4.10 c	4.50 c	7.60 a	8.97 a
309-1	0.30 a	0.84 a	1.75 a	4.34 a	5.00 a	7.30 a	9.10 a

[1] Values with the same letter within a column are not significantly different at the 0.05 level according to the Student Newman Kuel test.

did not correlate with leaf water potential. In this study, the high yielder Bold had higher leaf turgor at late stage of growth. This may have been an effect of deeper roots extracting water from lower soil depths. An analysis of the water status of the cultivar 4-21-13 (Fig. 3) suggests that osmotic adjustment may be the primary factor responsible for increasing turgor. The characteristic could be taken into account in a breeding program for increasing barley water stress resistance.

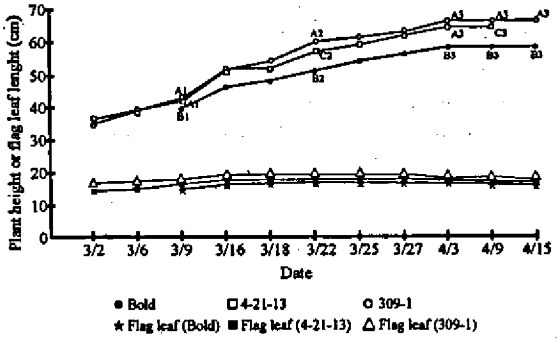

FIG. 2. Plant heights and flag leaf lengths of barley cultivars. Plant heights were measured from the ground to the tip of the last floret. Values are means of 4 or 5 measurements. Values with different letters are for comparisons within date whereas values with different numbers are for comparisons among dates and are significantly different at the 0.05 level.

TABLE 5. Mid to late-season soil water potential. Soil moisture contents were determined gravimetrically and soil water potentials were obtained using the graph in Fig. 1. Values represent single determinations.

Depths (cm)	Soil water potential			
	Date			
	3/6	3/21	4/10	4/26
	(MPa)			
	Bold			
30	-0.5	-0.6	-1.3	-2.1
60	-0.3	-0.8	-1.0	-1.4
90	-0.2	-0.2	-0.5	-0.7
	309-1			
30	-0.5	-0.6	-1.3	-2.0
60	-0.3	-0.8	-1.0	-1.4
90	-0.2	-0.2	-0.4	-0.6
	4-21-13			
30	-0.4	-0.7	-1.5	-2.4
60	-0.3	-0.8	-1.2	-1.2
90	-0.2	-0.2	-0.4	-0.5

Head development studies

Head growth of the two barley cultivars 4-21-13 and 309-1 were alike, but Bold, which had the lowest head dry weight from 3/29 to 4/14, obtained higher head dry weight than the other two cultivars at late stage of growth (Fig. 4). Yield was proportional to head growth rates at later stages of growth (Fig. 5). The high rate of Bold could be due to its higher water potential and turgor pressure that may have kept its higher photosynthesizing leaf area (higher LAI) functional at later growth stage. Cultivar 4-21-13 had lower LAI and lower leaf water potential than

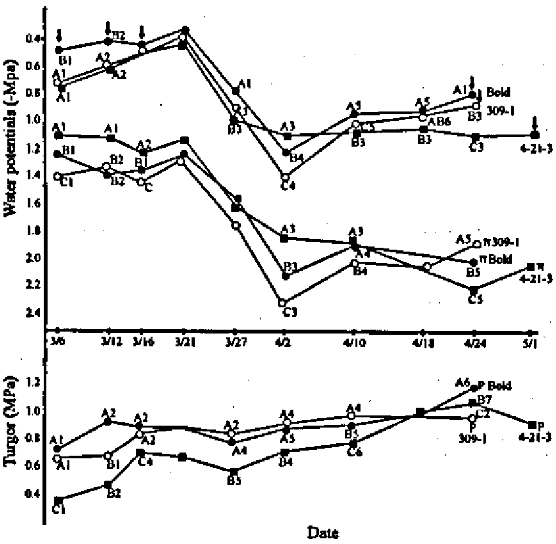

FIG. 3. Time course changes in water status of Bold, 309-1 and 4-21-13. Values are means of 3 or 4 measurements. Values with different letters are for comparisons within date whereas values with different numbers are for comparisons among dates and are significantly different at the 0.05 level. Small arrows refer to the occurrence of rainfall.

309-1 at later growth stage, but 4-21-13 may have presented better partitioning of fotoassimilates. The head growth rate (Fig. 5) data suggest that there was variation for head growth of all three barley cultivars, but it was much less for Bold than for the other two cultivars. The peak showed by 4-21-13 (from 3/27 to 3/29 and from 4/6 to 4/9) and by 309-1 (on 3/30 and 4/5) could be caused by additional translocation of assimilates to head growth or by partitioning of assimilates between head growth and growth or storage of other plant parts.

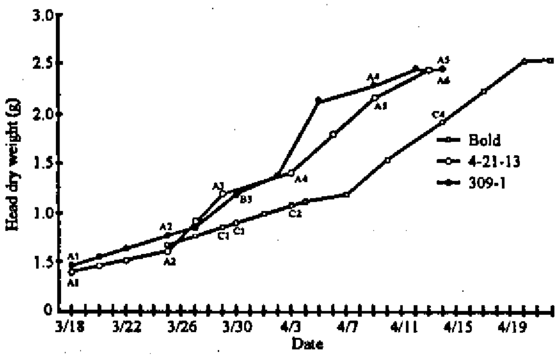

FIG. 4. Head growth of Bold, 4-21-13 and 309-1. Values with different letters are for comparisons within date, whereas values with different numbers are for comparisons among dates and are significantly different at the 0.05 level.

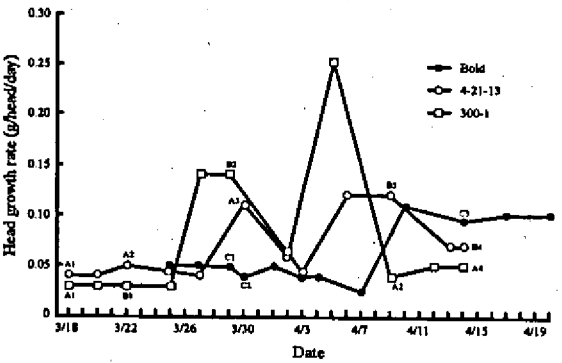

FIG. 5. Head growth rate of Bold, 4-21-13 and 309-1. Values with different letters are for comparisons within date whereas values with different numbers are for comparisons among dates and are significantly different at the 0.05 level.

CONCLUSIONS

1. High yielding barley cultivars do not have earlier maturity dates under dryland conditions.
2. Higher yielding cultivars have higher head growth rates at late stages of growth.

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