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Study on morphological traits of bread wheat genotypes and their relation with grain yield, under the condition of drought stress after anthesis and normal irrigation

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ABSTRACT: In this investigation 12 bread wheat genotypes were examined for grain yield and some morphological traits in fragmented plots design in the form of complete randomized blocks with three times of recurring, in Ardabil climate, where the factor included two levels of irrigation regime, normal irrigation and drought stress after anthesis stage, whereas the sub factor was wheat genotypes. Results from statistic analysis indicated that there was significant variation among genotypes in terms of all traits other than biological yield and straw yield. Generally, all the study traits showed a negative response to drought stress and the mean of each trait declined at stressed condition while that of traits such as harvest index, 1000 grain weight, internodes number, awn length and phonological traits were increased under the condition of drought stress after anthesis. Most of the damages resulted from drought stress after anthesis, have been made on the grain yield which results from the dramatic decrease of grain weight due to drought occurring during grain formation period. Results from phenotypic correlations, step by step regression and path analysis showed that among the components of yield, in terms of priority awn length and grain filling period should be increased in order to increase the grain yield under the condition of drought stress after anthesis stage,. In addition, among the components of grain yield, in terms of priority harvest index, biological yield and straw yield should be increased in order to increase grain yield under the condition of normal irrigation. Also, due to water supply restrictions, straw yield should be decreased at the expense of grain yield in order to increase the harvest index.

***Keywords*:** Morpho-physiological, wheat, yield, drought stress after anthesis stage

INTRODUCTION

Plants' growth is always subject to environment. Factors such as humidity, temperature, radiation, nutrients and gases, depending on their amount, can either increase or decrease plant growth. The undesirable amount or concentration of these factors leads to development of stress in the plant or in its parts. The potential damages for plant may be either temporary or reversible, or permanent. In tolerant plants, however, these stresses are often reversible (Sarmadnia and Kojaki, 1989). In the arid and semiarid regions such as Iran, mean precipitation rate is low and the distribution of precipitation varies from one year to another, thus it is very hard to predict its rate and distribution. Under such conditions, the grain yield does also show lots of fluctuations over the consecutive years.

Thus, it is difficult to increase the yield of wheat grain in such a region through breeding and producing varieties adaptable and tolerant for drought. Because there are so many plant traits and environmental factors involved and these traits and factors interact with each other. Most of the investigations conducted on wheat have focused only on grain yield itself, and other traits potentially effective on increasing grain yield have gone unnoticed (Ehdaei, 1993).

Therefore, physiologists specialized on crop plants should identify those important physiological indices which have led to increased yield in the past and in the future could make contribution in improvement of breeding aimed at increasing the quality and quantity of crop.

These traits can be categorized as follow: 1- production efficiency of dry materials, 2-components of economic yield, 3- water consumption efficiency and 4- nitrogen consumption efficiency (Lopez and Richards, 1994).

Principally, lengthiness of plant growth period and that of each phonological stage can affect the yield through either more resource consumption or decreased environmental stresses and shortening of each period. (Davidson et al., 1985) in an investigation on Australian wheat genotypes reported that throughout the history of breeding, no fundamental change has taken place during the time of greening till spike appearance. (Waddington et al., 1986) also didn't observe any characteristic trend in relation to length of greening period till anthesis for wheat varieties in Mexico. (Nevertheless Austine, 1999) in an investigation on English wheat genotypes reported that productive bread wheat varieties reach anthesis stage 1 week earlier than non-productive crops. (Derera et al., 1969) realized that in ordinary wheat there is a negative correlation between grain yield and number of days until heading under the condition of humidity stress.

(Rashidi et al., 1998) showed through analyzing correlation coefficients that the fertile tillers number and 1000 grain weight are the basic components of grain yield, the fertile tillers number and plant height are the main components of straw yield, and grain yield and straw yield in turn are the basic components for harvest index. Therefore, in order to increase each mentioned dependent traits, its effective and associated components can be used.

Existence of awns is among the desirable features in crops exposed to drought condition, and awns are considered as xeromorphic organs. Existence of long awns represents the adaptation of crop to drought. And it is also one of the factors which can increase the water consumption efficiency after anthesis (Blum, 1989). The main superiority of Diem wheat in Australian semiarid regions over ordinary wheat is due to their ability of producing longer spikes, heavier spike at the time of flowering, more grain formation and the higher ratio of grain weight to leaf area after flowering (Syme, 1969). (Gharib Eshghi et al., 1998) after conducting path analysis on the components of bread wheat yield showed that total tiller number and height can be an appropriate criterion for selection of high yield.

A number of investigators have reported that a significant increase has been observed in biological yield of wheat varieties during the years of investigations (Waddington et al. 1986 and Austine et al., 1989). Other investigators also claimed that there have been no dramatic changes in biological yield of wheat throughout the history of its breeding (Austine, 1999 and Slafer and Andrade, 1993). It also has been demonstrated through lots of investigations that there is a positively significant correlation between grain yield and harvest index (Slafer and Andrade, 1993; Reynolds and Rajram, 1999 and Sayre et al., 1997). It seems that both these features (biological yield and harvest index) have played a role on increasing the grain yield of wheat varieties during their genetic improvement.

As with the relation between grain yield and harvest index, Shims (1963) believes that in Australia the yield improvement in Yulaf varieties compared to older varieties has been associated with the increased harvest index without any increase in the amount of their straw yield or in total amount of their dry materials. (Syme, 1969) after conducting an investigation on 49 vernal genotypes claimed that 72% of fluctuation associated with yield on farm can be estimated using harvest index. In the case of wheat, (Austin ,1980) believes that with selection on harvest index one can increase yield by up to 20% and further claimed that it is possible to increase harvest index by up to 60%.

(Pirouznia et al., 1999) by conducting path analysis on wheat grain yield and its components showed that traits such as biological yield, grain number per unit length of ear, harvest index and 1000 grain weight are effective on grain yield. (Hasanpanah et al., 1999) by analyzing the genotypic correlation of wheat varieties showed that harvest index has had the most important effect on grain yield, especially in favorable conditions. Also, in a favorable condition both total tiller number and fertile tillers number per square meter have been highly important for explaining grain yield. In an effort to determine the traits relating to tolerance against thermal stress in wheat varieties, after examining the components of genotypic correlation (Mohammadi, 1999) showed that grain number per ear and after that the biological yield have positively direct effects on these traits.

This investigation aimed at determining appropriate criteria for selection of bread wheat with high grain yield under the conditions of drought stress after anthesis stage and normal irrigation.

MATERIALS AND METHODS

This experiment was conducted at experimental farm of Islamic Azad University, Ardabil Branch, situated in the farming land of Hasan Barugh village (5 km west of Ardabil), the longitude and latitude being 48.2 western and 38.15 northern, respectively; elevation being 1350 m above sea level, on 2008-09 farming year. 12 genotypes (Table 1) planted in a fragmented plot design in the form of complete randomized blocks recurring 3 times, were compared and evaluated. Factor included 2 levels of irrigation regime, normal irrigation and drought stress after anthesis stage and sub factor included 12 bread wheat genotypes. Each experimental plot included 3 rows measuring 3 m long each, and recurring in a 20cm distance from each other. Two autumnal and three vernal irrigations were done throughout the experiment. Precipitation rate and its distribution as well as the mean temperature throughout the farming year have been given in Table 2. In general, notes were taken for following traits:

Grain yield and biological yield (sum of grain and straw yields) in terms of ton/ha and harvest index (%): Harvest index = (grain yield / biological yield) × 100

Grain weight per spike, 1000 grain weight, main spike weight, grain number per spike, weight of internodes, number of internodes, Peduncle's length, spike length, awn length, final plant height, date of heading, date of anthesis, date of physiological maturity, grain formation period and straw yield (difference of biological yield and grain yield).

Table 1 . List of study genotypes in this investigation

Number	Genotypes	Number	Genotypes	Number	Genotypes
1	Gascogne	5	Gobustan	9	4061
2	Sabalan	6	Saratovskaya-29	10	4041
3	4057	7	MV17/Zrn	11	Sissons
4	Ruzi-84	8	Sardari	12	Tous

Table 2 . Meteorological statistic for Ardabil in 2008-09 farming year

Months	Mean heat degree		Mean humidity	Precipitation rate (mm)
	Max	Min		
Mehr 2008	19.9	6.7	73	24.9
Azar	12.3	3.2	82	49.8
Dei	8.1	-3.2	75	8.6
Bahman	6.3	-2.5	76	11.4
Esfand 2009	7.8	-1.5	72	18.5
Farvardin	12.2	0.4	70	24.3
Ordibehesht	15.7	2.4	68	27
Khordad	19.7	5.5	71	30
Teir	22.2	8.3	73	18.6
Mordad	25	11.9	71	3.4
Shahrivar	25.01	12.5	71	1.4

The drought stress intensity (SI) has been estimated based on Fisher Formula (13) (Nomand Mobad)

$SI = 1 – (Y_s/Y_p)$

Y_s = mean yield of genotypes under stressed condition

Y_p = mean yield of genotypes under non-stressed condition

Step by step regression was used separately for stressed and non-stressed conditions in order to avoid the impact of traits with little or no effect on the changes of harvest index and grain yield, and path analysis based on phonotypic correlation was used to explain the causal relations in both stressed and non-stressed conditions and also to determine the effectiveness of traits selected by step by step regression on harvest index and grain yield. In statistical computations MSTAT-C, SPSS-16 and "Path analysis" software were used for variance analysis, step by step regression and path analysis, respectively.

RESULTS AND DISCUSSION

Variance analysis and effect of drought stress after anthesis on traits

Results from variance analysis for each study traits under the conditions of drought stress after anthesis stage and without normal irrigation (Table 3) showed that there is a significant difference between study genotypes in terms of all traits other than biological and straw yields at 1% and 5% probability level which this fact represents the variation of genotypes based on these traits and allow the selection of genotypes based on them.

A significant difference is observed between two irrigation regimes (drought stress after anthesis stage and normal irrigation) in terms of traits such as grain yield, biological yield, harvest index, grain number per spike and the number of internodes between the levels of irrigation regime, at 1% and 5% probability levels. The insignificance difference of traits such as awn length between two irrigation regimes has been due to high inheritability of this trait which is less affected by environment. The interaction of "genotype × irrigation regime" was significant for trait of Peduncle's length, only.

(Sandhu and Hortpn, 1977) declared that a decreased plant height under the condition of drought stress may be due to low humidity reserve within the soil. Fischer and Murer in 1978 declared that old and tall varieties are less sensitive to drought than new short ones. (Hadjichristodoulou, 1987) concluded that tall varieties give higher yield than short ones in water deficient regions.

According to (Elhafid et al., 1998) drought leads to decreased fertility in flowers and this has an important effect on the number of produced grain. (Fischer and Wood, 1979) believe that humidity stress leads to decreased grain number. Decreased grain number resulted from drought is due to decreased spikelet number and grain number per spikelet. (Austin ,1987) also obtained similar results for wheat varieties. Calderini et al., (1990) believed that the increased grain yield was mainly due to increased grain number per spike and this component of yield has been of more importance than grain weight. (Richards et al., 2001; Senjeri, 1999; Blum and et al., 1994; Bidingar et al., 1997 and Hasanpanah, 1997) showed that drought stress leads to decreased grain number and grain weight per spike.

Results from this investigation were consistent with the findings by (Sinha, 1987; Takami et al., 1990); (Wardella and Willenbrink, 1994 and Ritchie and Neguen, 1990). They reported that drought stress decreases 1000 grain weight, whereas irrigation increases 1000 grain weight. In fact, irrigation at the time of grain filling leads to increased photosynthetic materials and their mobilization into the grain and so that grain weight increases. In contrast, lack of sufficient humidity in this sensitive period cause a significant decrease in 1000 grain weight.

(Plaut Butow et al., 2004) also concluded that water inefficiency during flowering stage, decrease grain formation and its fertility significantly, and if happened during grain filling stage it can significantly decrease the mobilization capacity of photosynthetic materials into the grain and leads to shrinking of grain and decreased 1000 grain weight. The increase in biological yield of a wheat variety can happen through increased light absorption and increased light consumption efficiency or both.

Most of the bred old local varieties are of high biological yield. However, they have low harvest index. This is a reason for low economic yield of these varieties compared to new ones which have higher harvest index. In most of the researches on physiological basics of increasing yield through genetic improvement, it has been concluded that throughout the history of the breeding there has been not a remarkable changes in wheat (Rahimian and Banayan, 1997). Therefore, this trait has not played a fundamental role in yield increase.

There have been yet a few investigations in which the significant increase has been seen in biological yield over the investigation years (Perry and Antuono, 1989 and Siddique et al., 1989). Also, it has been shown that less than 20% of increased grain yield has been due to increased biological yield (Perry and Antuono, 1989). The only exception is the single report by (Hucl and Baker, 1987) presented in Canada. They not only achieved a positively significant increase for biological yield throughout the investigation years, but also claimed that the bulk of the increased grain yield was due to increased biological yield (Plaut Butow et al., 2004).

It's worth mentioning that stress intensity (SI) was estimated as much as 19% based on Fischer formula.

Step by step regression

According to Table 4, under the condition of drought stress after anthesis stage when harvest index was considered as dependent variable, four traits namely date of heading, date of maturity, grain number per spike and straw yield were introduced to the model. Values for description factor of the model and the residual effect of other traits were 0.98 and 0.108 respectively. When the grain yield was considered as dependent variable, three traits namely awn length, filling period and straw yield were introduced to the calculation, where the values of description factor of the model and residual effect of other traits were 0.881 and 0.296 respectively.

Under the condition of normal irrigation when harvest index was considered as dependent variable, two traits namely straw yield and awn length were introduced to the calculation. The values for description factor for the model and residual effect of other traits were 0.875 and 0.318, respectively. And finally when grain yield was considered as dependent variable, three traits namely harvest index, biological yield and straw yield were introduced to the model, where the values for description factor of the model and residual effect of other traits were 0.996 and 0.045, respectively.

Path analysis based on phenotypic correlations

Drought stress condition after anthesis stage: in path analysis on harvest index (Table 5), highest positively direct effect belonged to date of maturity (0.63) with total correlation of r= - 0225 and date of heading had a negative effect (-1.185) with total correlation of r = -0728. Their indirect effect through other traits on harvest index is trivial. Direct effect of straw yield was negative (-0.212), whereas the direct effect of grain number per spike on harvest index was positive (0.417).

In path analysis on grain yield (Table 6) it can be seen that the direct effects of all three traits on grain yield have been positive which the highest values belong to awn length (0.848) with total correlation of r = 0.717 and grain filling period (0.548) with total correlation of r = 0.202 and the lowest value belongs to straw yield (0.288) with total correlation of r = 0.663. Indirect effects of grain filling period on grain yield through awn length, and those of awn length on grain yield through grain filling period were negative. In addition, indirect effect of awn length on grain yield through straw yield was positive.

Normal irrigation condition: in path analysis on harvest index (Table 7), the highest positively direct effect belongs to awn length (0.475) with total correlation r = 0.834. Indirect effect of straw yield on harvest index through awn length was positive. Direct effect of straw yield on harvest index is negative and high (-0.979). Negative indirect effect of straw yield through awn length (-0.3) actually has led to increased negative correlation between awn length and harvest index r = - 0.834.

In path analysis on grain yield (Table 8), it can be seen that the highest value for direct effect belongs to biological yield (2.256) with total correlation of r = 0.192, whereas the highest negatively direct effect belongs to straw yield (-2.307) with total correlation of r = -0.253. The indirect effect of straw yield on grain yield through harvest index was positive and high, whereas the indirect effects of straw yield on grain yield through biological yield and those of biological yield on grain yield through harvest index were negative and high.

By justifying the results we can say that the traits such as awn length and grain filling must be increased in terms of priority in order to increase the grain yield under drought stress condition after anthesis stage. And based on the fact that excessive vegetation growth under such condition as water deficiency is not favorable and cause the soil stored water to go wasted, thus in order to increase harvest index the straw yield should be decreased at the expense of grain yield increase, but this decrease should be so much as it won't cause the reduction of plant photosynthesis and in order to meet this object varieties with intermediate height should be selected in breeding programs.

On the other hand, in terms of priority traits such as harvest index, biological yield and straw yield must be increased in order to increase grain yield under normal condition. And since there is no water deficiency under normal irrigation condition and due to the effect of biological yield on grain yield, aerial biomass should be increased by selecting late maturing varieties and extending the growth period, because this is effective on grain filling and nourishing and finally on increasing grain yield. Worth mentioning that regarding the negatively direct effect of straw yield on harvest index, the aerial biomass should be increased to the level in which the plant height and subsequently straw yield are of reasonable quantity and not cause the crops to lodge and finally the ratio of grain yield to biological yield to be high.

Table 3 . Analysis of variance of grain yield and biological and other properties depend onthe conditions of drought stress after pollination stage and normal irrigation

Source	df	Mean of Squares								
		Grain yield	Biological yield	Harvest index	Grain weight per spike	1000 grain yield	spike weight	Seed number per spike	weight of internodes	internodes number
Replication	2	1.492*	14.336	64.62*	13.66**	13	0.394**	43.361*	0.001	2.949**
Irrigation levels	1	9.746**	51.901*	71.184*	5.611	0.257	0.058	22.33*	0.004	0.98*
Error (a)	2	0.165	5.852	7.515	3.635	51.106	0.066	8.24	0.026	0.613
Genotypes	11	0.737*	2.819	54.567*	18.104**	272.503**	0.314**	1427.09**	0.025**	0.311**
Genotypes × irrigation levels	11	0.208	1.308	23.081	3.131	20.579	0.071	171.47	0.001	0.087
Error (b)	44	0.295	1.909	22.472	2.352	17.883	0.045	100.54	0.001	0.074
C. V %			15.89	18.68	10.10	9.92	7.59	13.12	11.20	10.77

* and ** Significantly at p < 0.05 and < 0.01, respectively

Table 3. continued

Source	df	Mean of Squares								
		Peduncle length	Spike length	awn length	Plant height	Days to heading	Days to flowering	Days to maturity	grain formation period	Straw yield
Replication	2	105.69	3.115**	0.143	119.98	2.097	12.792	10.792	8.597	7.339
Irrigation levels	1	216.84	0.091	0.001	392.934	0.014	16.06	13.347	12.5	16.685
Error (a)	2	306.372	1.501	0118	563.62	7.097	25.181	21.847	8.597	7.339
Genotypes	11	99.59**	0.868**	47.38**	476.344**	7.89*	31**	31.125**	11.04*	1.474
Genotypes × irrigation levels	11	10.524*	0.217	0.537	20.773	1.681	1.359	1.468	3.924	1.014
Error (b)	44	4.065	0.177	0.320	21.078	3.931	1.729	1.835	4.335	1.554
C. V %		7.18	5.49	9.63	6.47	1.03	0.65	0.56	4.24	31.36

* and ** Significantly at p < 0.05 and < 0.01, respectively

Table 5 . Path analysis for harvest index in drought conditions after the pollination stage, based on phenotypic correlation

Traits	Direct effect	Indirect effect through				Total correlation
		Days to heading	Days to maturity	Seed number per spike	Straw yield	
Days to heading	-1.184	-	0.487	0.007	-0.04	-0.728**
Days to maturity	0.63	-0.916	-	0.095	-0.036	-0.225
Seed number per spike	0.417	-0.023	0.144	-	-0.033	0.507
Straw yield	-0.212	-0.222	0.104	0.063	-	-0.265

Residual effect = 0.108

Table 6 - path analysis for yield in drought conditions after the pollination stage, based on phenotypic correlation

Traits	Direct effect	Indirect effect through			Total correlation
		awn length	grain formation period	Straw yield	
awn length	0.848	-	-0.241	0.11	0.717**
grain formation period	0.548	-0.373	-	0.026	0.202
Straw yield	0.288	0.324	0.05	-	0.663*

Residual effect = 0.296

Table 7 . Path analysis for harvest index in normal irrigation conditions on phenotypic correlation

Traits	Direct effect	Indirect effect through		
		Straw yield	awn length	Total correlation
Straw yield	-0.979	-	0.145	-0.834**
awn length	0.475	-0.3	-	0.176

Residual effect = 0.318

Table 8 . path analysis for yield in terms of normal irrigation based on phenotypic correlation

Traits	Direct effect	Indirect effect through			Total correlation
		Harvest index	Biological yield	Straw yield	
Harvest index	-0.025	-	-1.257	1.921	0.639*
Biological yield	2.256	0.013	-	-2.078	0.192
Straw yield	-2.307	0.02	2.033	-	-0.253

Residual effect = 0.034

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