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Full Length Research Paper

Effects of drought stress condition on the yield of spring wheat (*Triticum aestivum*) lines

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Water deficit is one of the most important factors limiting crop yield, and the monitoring of crop water status is important for reasonable irrigation and water saving cultivation. Drought stress tolerance is seen in almost all plants but its extent varies from species to species and even within species. In this study, seven agronomical traits (grain yield, 1000 grain weight, biomass, harvest index, plant height, main spike length and awn length) of 17 spring wheat lines with variable responses to drought stress, obtained from the agriculture research centre of Zanjan province, Iran, were investigated under three different levels: (a) normal irrigation (b) after anthesis drought stress condition, and (c) no irrigation, in a split block design in a randomized complete block design with three replications in Zanjan, Iran, from March to September 2006.This study was conducted to extract the probable correlation between different traits and stress tolerance index (STI) of wheat lines. It was also conducted to estimate the direct and indirect effects of traits on STI and heritability of these traits to provide plant breeders useful information regarding drought resistance in wheat breeding. Analysis of variance indicated that there were significant differences among the genotypes for all studied traits. For biomass, 1000 grain weight, grain yield and harvest index, there was no significant interaction between genotypes and levels of stress. The Zarrin line produced the highest amount of grain yield, biomass, and harvest index. Moreover, under normal irrigation and no irrigation conditions, the harvest index (75 and 70%) had the highest broad sense heritability. Under normal conditions, a positive and significant correlation between STI with grain yield, biomass, and harvest index was observed. Additionally, in stress conditions there was a positive and significant correlation between STI and awn length, spike length and plant height. Under normal conditions, the correlation between biomass and STI was bigger than the stress condition. In path analysis, in all three different conditions, the biggest direct effect on STI was related to grain yield resulting in a positive and significant correlation between grain yield and STI.

Key words: Agronomical traits, correlation, drought stress, path analysis, wheat, yield.

INTRODUCTION

Plants are frequently exposed to many stresses such as drought, salt, flooding, heat, low temperature, oxidative stress and heavy metal toxicity during their growth period. Drought is a meteorological term that occurs when the accessible water in the soil is reduced and atmospheric conditions cause plant to lose water by transpiration or evaporation. Generally, drought stress tolerance varies from species to species and even within species. Water deficit and salt stresses are global problems that affect the survival of agricultural crops and sustainable food production (Jaleel et al., 2007a, b, c, d, e). In plants, a better understanding of the morpho-anatomical and physio-biochemical characteristics of changes in drought resistance could be used to select or create new varieties of crops to obtain a better productivity under water stress conditions (Nam et al., 2001; Martinez et al., 2007).

High yield potential under drought stress is the target of crop breeding (Blum, 1996). Iran, has an average annual rainfall of about 220 mm, however, because of its

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geographical situation and topographical features, about 80% of its total area experience an arid or semiarid climate and in most areas of the country wheat crops encounter serious drought stress, especially after anthesis (Ehdaie, 1995). Drought stress can reduce grain yield. Edmeades et al. (1994) estimated an average yield loss of 17 to 70% in grain yield due to drought stress. Morphological characters, such as root length, tiller, number of spike per m^2, grain per spike number, fertile tillers per plant, 1000 grain weight, peduncle length, spike weight, stem weight, awn length, grain weight per spike, grain yield, biomass, harvest index, plant height, and main spike length etc., affect the wheat tolerance to the water shortage in the soil (Blum, 2005; Boyer, 1996; Johnson et al., 1988; Kramer, 1983; Lazar et al., 1995; Levitt, 1980; Moustafa et al., 1996; Passioura, 1977; Plaut et al., 2004). Improving the genetic potential of wheat to drought stress and identification of tolerant genotypes are the main objectives of regional breeding programmes. It has been found that under the water deficit conditions, those genotypes that show the highest harvest index and highest yield stability are drought tolerant (Rathore, 2005). In Iran, water shortage is very common in the late season after the anthesis, even in the irrigated lands. Therefore, the availability of wheat cultivars tolerant to the water shortage in the late season is essential to the sustainable production of this important food crop (Nouri-Ganbalani et al., 2009).

Sukhorukov (1989) reported reduction in grains per ear and 100-grain weight revealed low yield in wheat under drought conditions. Deswal et al. (1996) reported in wheat that grain yield per spike showed a direct association with total biomass, grains per spike and 100-grain weight. Singh et al. (2002) also reported that grain yield exhibited positive correlation with grains per spike, spike length and 1000-grain weight, while grain weight per spike was positively correlated with 1000-grain weight and harvest index. Yield is reduced mostly when drought stress occurs during the heading or flowering and soft dough stages. Drought stress during maturity resulted in about 10% decrease in yield, while, moderate stress during the early vegetative period has essentially no effect on yield (Bauder, 2001). An important source of carbon for grain filling under stress conditions is stem reserve and, under mild conditions, current assimilates may be limited for normal grain filling. According to Plaut et al. (2004), the rate of dry matter accumulate ion by kernels was considerably decreased by water deficit in wheat cultivars. Shafazadeh et al. (2004) in their study on 20 wheat genotypes under post-anthesis drought stress conditions, reported significant differences for genotypic and irrigation effects, and also for irrigation × year, genotype × irrigation and genotype × year interaction effects, when grain yield was considered. It was also reported that membranes of cells and organelles are primary sites for desiccation injury (Tan and Blake, 1993; Fan and Blake, 1994).

The objectives of this study were: (i) to verify the reliability of some agronomical traits for screening wheat lines under water stress; and (ii) to determine the probable correlation between different agronomical traits and stress tolerance index (STI).

MATERIALS AND METHODS

A field experiment was conducted in the Department of Plant Breeding, Faculty of Agriculture, Zanjan University, Iran, about 48° 27' E longitude, 36° 41' N latitude, and 1620 m a.s.l from March to September, 2006. Seventeen wheat lines with variable responses to drought stress were evaluated under two different levels: (a) normal irrigation, where the plots were irrigated with approximately 10 day intervals throughout the growing season, (b) after anthesis drought stress condition, where the irrigation was cut off after the heading of the wheat (moderate stress), and (c) no irrigation, where the irrigation was cut off after germination (intensive stress). The experiment was conducted in a split block in randomized complete block design with three replications. The levels of irrigation were the main plots and the wheat lines were the sub plots. Each sub plot consisted of six rows of 5 m long and 25 cm apart. The seventeen wheat lines with variable responses to drought stress were from the Agriculture Research Centre of Zanjan province. These lines included Alvand, Ghods, Shahriar, Pishtaz, C-80-20, C-80-10, and Zarin, which were irrigated lines and Sardari, Son-64, 18 Yeknavakht-82, B1-3, B3-2, B3-3, B3-1, A2-3 and NikNejd, which were dryland lines.

Stress tolerance index (STI)

STI is the drought tolerance criteria based on grain yield. In this study, three STI were calculated based on different stress levels. It was calculated using this formula:

$$STI_{N,M}= (Y_N)\ (Y_M)/(\overline{Y}_N)^2 \quad STI_{N,S}= (Y_N)(Y_S)/\ (\overline{Y}_N)^2 \quad STI_{M,S}= (Y_M)(Y_S)/(\overline{Y}_M)^2$$

Where, Y_N, Y_M, and Y_S are the genotypes yield in normal, moderate stress and intensive stress conditions, respectively and Y_N, Y_M, and Y_S with bars represent genotypes mean yield in the three different conditions (Fernandez, 1992).

Agronomical traits

The following traits were determined:

Grain yield: The harvested grains of each experimental unit were weighed and converted to kg ha^{-1}.

1000 grain weight: For the measurement of 1000 grain weight, some seeds were selected randomly from each experimental unit and after counting by seed they were counter machine (CONTADOR) weighted by balance.

Biomass: After harvesting of the lines from the lowest part of the stem in each experimental unit, the total aboveground part was weighed and converted to kg ha^{-1}.

Harvest index: was calculated from the ratio of grain yield on biomass in each experimental unit.

Plant height (cm): Three plants were randomly chosen in each experimental unit and their plant height was obtained from soil surface until spike tip in the main stem without considering awns.

Table 1. Analysis of variance of split block of agronomical traits in normal, moderate, and intensive stress.

S.O.V	MS							
	DF	Grain yield	1000 grain yield	Biomass	Plant height	Spike length	Awn length	Harvest index
Replication	2	254244	0.68	1019532	121.88	1.91	0.23	17.72
Stress level	2	2762426**	1023.85**	293266750**	414.52**	3.92**	5.40**	338.09**
Exp. Error (a)	4	516586	156.61	178564821	64.99	0.54	0.74	20.70
Line	16	2847802*	715/75**	166567734**	2287.85**	7.50*	43.34**	463.08*
Exp. Error (b)	32	333763	5.32	7957583	98.61	0.67	0.10	56.29
Line × stress level	32	147441	206.05	51372514	58.03**	0.71*	0.51**	171451
Exp. Error (ab)	64	111997	289.82	73175020	22.28	0.43	0.27	13.72
CV%		33.98	8.45	21.49	8.04	6.37	7.35	19.9

CV, Coefficient variation; *,** Significant at the 5 and 1% probability level, respectively.

Main spike length (cm): Three plants were randomly chosen from each experimental unit and the length of the main spike was measured from the collar to spike tip without considering awns.

Awn length (cm): This was measured from the mean length of one awn in each of the three chosen plants in each experimental unit.

Data analysis

Statistical computing of this research was done by MSTATC and SPSS software. Analysis of variance (ANOVA) of a split block design based on randomized complete block design (RCBD) was also done by MSTATC and treatments compared by least significant difference (LSD) at the 5% probability level. In addition, a matrix of simple correlation coefficients between STI and relative water traits were computed by *SPSS*. Broad sense heritability of studied agronomical traits was obtained using E(MS) in the tables of analysis of variance (RCBD).

Path analyses

Path analysis is an extension of the regression model, and is used to test the fit of the correlation matrix against two or more causal models that are being compared by the researcher. To investigate the direct and indirect effects of traits on STI, path analysis was calculated for agronomical traits. For this purpose, a simple coefficient correlation was obtained between all traits and the partial coefficient regression (direct effects) of traits was calculated by SPSS. The indirect effects were calculated by multiplying the direct effects in simple coefficient correlation.

RESULTS AND DISCUSSION

Analysis of variance

The results of the analysis of variance based on the split block are shown in Table 1. In all agronomical investigated traits, there was a significant difference between wheat lines and stress levels showing genetic diversity between selected lines. For biomass, 1000 grain weight, grain yield, and harvest index, there was no significant interaction between lines and stress levels. However, for spike length, awn length and plant height, this interaction was significant. Zarrin and Alvand had the highest amount of grain yield and 1000 grain weight. The highest biomass was observed in the Zarrin and Ghods lines. Lines with a high amount of biomass also had a high amount of grain yield. An increase in biomass means an increase in the aboveground parts of the plant photo-synthetic organs, stem and yield components which lead to higher yield. Additionally, more biomass help maintain snow on the field surface, increasing the soil moisture, decreasing cold injury, increasing organic material, and, finally, increasing the yield.

In this study, 18-Yeknavakht 82 and Son-64 (in normal condition) and Son-64 and B1-3 (in moderate stress) and Zarrin lines (in intensive stress) showed the highest plant height. Therefore, because of the earlier maturity and greater plant height, the Zarrin line is protected from intensive drought stress conditions. Blum and Pnuel (1990) reported that water limitation during the terminal spikelets to booting stage affected the yield and yield components. Water deficit at this stage considerably decreased the number of spikelets per spike. The spike length reportedly showed stability under different conditions. However, the findings of Iqbal et al. (1999) on durum wheat indicated that the highest reduction in spike length under water deficit conditions was at the flowering stage. In respect of the mean comparison B3-2 and B3-3 (in normal condition), B1-3 (in mediate stress) and Zarrin lines (in intensive stress) had the highest spike length, which might be the cause of more grain yield of Zarrin in dryland conditions.

Awns are the last organs that form and they are tolerant against water deficit. Resistant lines have longer awns. In this research, Pishtaz and Alvand lines had the highest awn length for all three stress levels. The harvest index shows the percentage of transferring produced organic matter from source to sink, and the lines with a high harvest index, which are able to transfer more carbohydrates to green organs, lead to an increased yield (Austin, 1980). Ghods and Zarrin lines also had the

Table 2. Broadsense heritability of agronomical traits in stress and non-stress conditions.

Estimate	Stress level	Grain yield	1000 grain weight	Biomass	Plant height	Spike length	Awn length	Harvest index
	N	60	69	50	61	55	70	75
$h^2B\%$	M	45	70	17	48	50	60	65
	S	65	60	47	65	46	46	70

N, Normal; S, intensive stress; M, moderate stress; h^2B, broad sense heritability.

highest amount of harvest index. Passioura (1977), Richards (1983), and Siddique et al. (1990) demonstrated that in water deficit conditions, the amount of harvest index depends on the amount of available water for the plant during the pollination period. However, photosynthesis is limited during grain filling under drought tress. Transferring stem stores to grains plays an important role in grain filling. The existence of a high amount of stems stores or their high ability to transfer to grains result in more harvest index after the pollination period. Sanjari Pireivatlou and Yazdansepas (2008) showed 24 wheat genotypes produced significantly less grain yield under pre-anthesis drought stress condition than non-stress and post-anthesis drought stress conditions. These findings are however, not in agreement with the results of Calhoun et al. (1994) and Van Ginkel et al. (1998) who reported a higher grain yield under early drought than late drought stress conditions.

Broadsense heritability

Broad sense heritability of traits was calculated based on the genotype mean using the ANOVA table for the different levels of stress in RCBD and its result is shown in Table 2. The yield and its component traits are controlled by polygene and are strongly influenced by the environment (Ahmed and Khaliq, 2007). Heritability measures the proportion of genotypic variance to phenotypic variance and plays an important role in selective breeding (Songsri et al., 2008). It also provides an estimate of the genetic advance a breeder can expect from selection applied to a population under different environments. The higher the heritability estimates, the simpler are the selection procedures (Khan et al., 2008). Saba et al. (2001) reported a low and moderate broadsense heritability of grain yield in stress and normal conditions, respectively. In this research, a moderate heritability was obtained for grain yield in all three conditions. An almost high heritability for 1000 grain weight was also observed, which is compatible with the findings of Saba et al. (2001), Kettana et al. (1976) and Zhao et al. (1995). Some researchers reported a low heritability (Pandit and Islam, 1988), moderate heritability (Rebetzke and Richards, 1999; Siddique and Whan, 1994) and high heritability (Loss and Siddique, 1989; Shah, 1989; Shoran, 1995; Krishnawat and Sharma, 1998) for biomass or biological yield.

Furthermore, the heritability of the biomass was moderate in normal and intensive stress but low in moderate stress conditions. Previous research showed that plant height had moderate heritability (Aydeme, 1981; Baric, 1996; Mather et al., 1981) or high heritability (Awaad, 1996). Saba et al. (2001) obtained a moderate and high heritability in stress and normal conditions, respectively. However, in this research, a moderate heritability for plant height and spike length in all three conditions was found. Previous studies reported a high heritability for awn length (Ghosheh, 1989; Khan et al., 1972). More also, awn length had a high heritability in normal conditions and a moderate heritability in moderate and intensive conditions. This study obtained high broad sense heritability for harvest index in all three conditions, while Saba et al. (2001) reported a moderate heritability for harvest index in both stress and normal conditions. Saba et al. (2001) found moderate narrow-sense heritability for STI. In this research, moderate heritability for STI_{NM}, STI_{NS}, and STI_{MS} was also found. As a whole, high estimates of broad sense heritability coupled with high genetic advance indicate additive genetic effects, which provide sufficient scope for the selection of most of the characters.

Simple correlation coefficients STI_{NS} with traits in normal and intensive stress conditions

Because of the raining after anthesis, there was no significant difference in normal and moderate conditions. Therefore, STI_{NM} was not used in the calculations.

The simple correlation coefficient between different traits with STI_{NS} in normal and intensive conditions is shown in Table 3. There is a positive and highly significant correlation between STI_{NS} with grain yield, awn length, spike length, plant height, biomass, and harvest index in intensive stress conditions. However, in normal conditions a positive and significant correlation between STI_{NS} with grain yield, biomass, and harvest index is observed. The results of the experiments by Debake et al. (1996) demonstrate that imposing stress, especially after the anthesis stage entail a significant decrease in harvest index. Gupta et al. (2001) declared there was a direct positive relation between biological yield and grain yield. However, 1000 grain weight had a negative and

Table 3. Simple correlation coefficient of STI_{NS} with agronomical traits in normal and intensive stress conditions

	1000 grain weight	Harvest index	Biomass	Plant height	Spike length	Awn length	Yield
Harvest index	0.049 -0.396**						
Biomass	0.117 -0.206	0.647** 0.395**					
Plant height	0.336* -0.077	-0.164 0.266	0.261 0.539**				
Spike length	-0.088 -0.241	-0.153 0.093	-0.133 0.280*	0.130 0.501**			
Awn length	-0.110 -0.464**	0.319* 0.522**	0.145 0.416**	0.26 0.288*	0.100 0.196		
Yield	0.086 0.338*	0.876** 0.804**	0.909** 0.846**	0.100 0.507**	0.079 0.250	0.244 0.537**	
STI_{NS}	-0.020 -0.256	0.734** 0.673**	0.737** 0.738**	0.003 0.460**	0.002 0.315*	0.250 0.431**	0.845** 0.891

Upper and lower numbers are related to normal and intensive stress condition respectively. *,**: Significant at the 5 and 1% probability level, respectively.

non-significant correlation with STI_{NS} in both conditions. Royo et al. (2000) reported that flowering-to-maturing drought stress, especially accompanied by high temperature, shortened the grain filling period for Triticale, thereby reducing the 1000 grain weight. Mohammedi (1998) reported that correlation between dryland wheat grain yield and 1000 grain weight, plant height, tiller no, length of last internodes, seed no per spike and harvest index are significant and positive. In this research, there was a positive and significant correlation between the grain yield and harvest index, biomass, spike length, and awn length in intensive stress conditions. However, the correlations for biomass and harvest index were much more than the correlation of grain yield with other traits for normal (r_{HI}=0.876**, $r_{Biomass}$=0.909**) and intensive stress (r_{HI} = 0.804**, $r_{Biomass}$ = 0.846**), thus, with increasing grain yield, other traits also increased but not the harvest index and biomass. Richards et al. (2001) declared that during the flowering stage, drought stress disrupted the flowing photo-synthesis and transfer of stored substances into grains, which can be the cause of the reduction of the number and weight of grains.

In addition to the source power in producing photosynthesis materials, the ability of absorption, metabolism, and storing assimilates (sink power) are important factors in transferring photosynthesis products for determining the yield potential of wheat (Wardlow, 1990). In this study, a positive correlation between yield and spike length was observed. The importance of spikes of wheat in grain filling because of suitable light conditions for spike photosynthesis and being near to grains has been confirmed by many researchers. Different research has identified the portion of spikes in the final grain yield from 10 to 76% depending on the lines and environmental conditions (Evans, 1972; Papahosta and Gagianas, 1991). Demotes and Jeuffroy (2001) supposed that wheat lines with longer and bigger spikes in comparison to lines with smaller and shorter spikes have more power in transferring photosynthesis products to grains. Subhani and Chowdhry (2000) also found a direct relationship of grain yield with flag leaf area, plant height, spike length, grains per spike, 1000-grain weight, biomass per plant and harvest index. Plant height plays an important role in photosynthesis. Malik and Hassan (2002) and Khanzada et al. (2001) reported that shoot length wheat genotypes were significantly reduced under water stress. Similarly, Inamullah et al. (1999) also observed that water stress reduced plant height in wheat varieties when compared with irrigated. In this research a positive correlation between plant height and yield in normal (r = 0.1) and intensive stress (r = 0.507**) conditions was observed.

Simple correlation coefficients STI_{MS} and traits in moderate and intensive stress conditions

The simple correlation coefficient between different traits with STI_{MS} is shown in Table 4. In induction drought stress after anthesis, there was a positive and significant correlation between STI and grain yield, awn length, biomass, and harvest index. In addition, in intensive stress a positive and significant correlation between all studied traits and STI was observed. In contrast, there was a negative correlation between 1000 grain weight with STI (r= -0.148, r=-0.314*) and grain yield (r=-0.091, r=- 0.338*) in both stress conditions. Whereas awn length

Table 4. Simple correlation coefficient of STI_{MS} with agronomical traits in moderate and intensive stress conditions.

	1000 grain weight	Harvest index	Biomass	Plant height	Spike length	Awn length	Yield
Harvest index	-0.166 -0.396**						
Biomass	-0.042 -0.206	0.481** 0.395**					
Plant height	0.325* -0.077	0.079 0.266	0.391** 0.539**				
Spike length	-0.041 -0.241	-0.096 0.093	0.113 0.280*	0.292* 0.501**			
Awn length	-0.333 -0.464**	0.342* 0.522**	0.105 0.416**	-0.276* 0.288*	-0.014 0.196		
Yield	-0.091 -0.338*	0.823** 0.804**	0.864** 0.846**	0.252 0.507**	0.041 0.250	0.245 0.537**	
STI_{MS}	-0.148 -0.314*	0.683** 0.673**	0.724** 0.821**	0.128 0.518*	0.026 0.327*	0.306* 0.453**	0.864** 0.936**

Upper and lower numbers are related to moderate and intensive stress respectively. *,**: Significant at the 5 and 1% probability level, respectively.

showed a positive and significant correlation with STI_{MS} in both moderate (r =0.306*) and intensive (r=0.453**) stress conditions; it can be more suitable criteria in comparison with plant height and spike length. Awn in comparison with spikes has more portions in the total photosynthesis of the spike. Awns are the last organs that form in plants and have less respiration area, which means that their photosynthesis is less affected by drought stress. It is reported that the portion of awn in producing dry matter is about 12%. Brogevic (1990) found that wheat with awns in comparison to without awns produces more products under drought stress conditions.

Plant height showed a positive and non-significant correlation with STI_{MS} and STI_{NS}, however, in intensive stress there was a positive and significant correlation with both STIs. Richard (1992) found that in the final drought season long genotypes yield more in comparison with short ones. Richard (1992) also reported that lines with short stems and with less stem length in comparison with long stem plants were more efficient in the distribution of stem stores to spike. Biomass, harvest index, and grain yield also showed a positive and significant correlation with STI in all conditions. The high correlation between biomass and yield (0.864**, 0.846**) shows the effect of the aboveground part, (photosynthetic part) of the plant on yield. Therefore, more aboveground part results in higher photosynthetic rate, which leads to an increase in the ability of the plant for grain filling and also for forming more grains.

Path analysis

In path analysis, standard regression coefficients are used, which are the amount of standard change in the Y variable for one standard unit change in the X variable, when the other X variables are fixed.

Path analysis of STI_{NS} with agronomical traits in normal and intensive stress conditions

The result of path analysis of STI_{NS} and agronomical traits in normal and intensive conditions are shown in Table 5 and Figure 1. In both conditions, the biggestdirect effect is grain yield. The significant correlation between yield and STI is explained by its direct effect. The significant correlation between biomass and awn length with STI was explained by the indirect effect of them on STI by yield. Lines with the highest amount of biomass had the highest amount of grain yield, thereby showing a good relationship between biomass and grain yield. Therefore, among the studied traits in respect of moderate heritability of grain yield and biomass and also high heritability of awn length, these traits are suitable for drought tolerant selection in normal conditions.

Path analysis of STI_{MS} with agronomical traits in moderate and intensive stress conditions

The result of path analysis of STI and agronomical traits in intensive stress conditions is shown in Table 6 and Figure 2. In both conditions, the biggest direct effect was related to grain yield. In addition, the positive and significant correlation between yield biomass, plant height, spike length, and awn length with STI was due to their indirect effect on yield. Wheat lines with long awns in warm and dry regions lead to more water use efficiency

Table 5. Path analysis of STI_{NS} with agronomical traits in normal and intensive stress conditions.

Parameter	Grain yield	1000 grain yield	Biomass	Plant height	Spike length	Awn length	Correlation with STI_{NS}
Grain yield	0.941 1.017	-0.006 -0.025	-0.081 -0.081	-0.005 -0.028	-0.005 0.036	0.001 -0.029	0.0845 0.891
1000grain yield	0.018 -0.344	-0.067 0.073	-0.010 0.020	-0.018 0.004	-0.006 -0.034	-0.001 0.025	-0.020 -0.256
Biomass	0.855 0.860	-0.008 -0.015	-0.089 -0.096	-0.014 -0.030	-0.009 0.040	0.001 -0.022	0.737 0.738
Plant height	0.0941 0.516	-0.023 -0.006	-0.023 -0.052	-0.053 -0.055	0.008 0.072	-0.001 -0.015	0.003 0.460
Spike length	0.074 0.254	-0.006 0.017	0.012 -0.027	-0.007 -0.027	0.065 0.143	0.001 -0.010	0.002 0.315
Awn length	0.230 0.546	0.007 -0.034	-0.013 -0.40	0.014 -0.016	0.007 0.028	0.006 -0.053	0.250 0.431

Upper and lower numbers are related to moderate and intensive conditions, respectively.

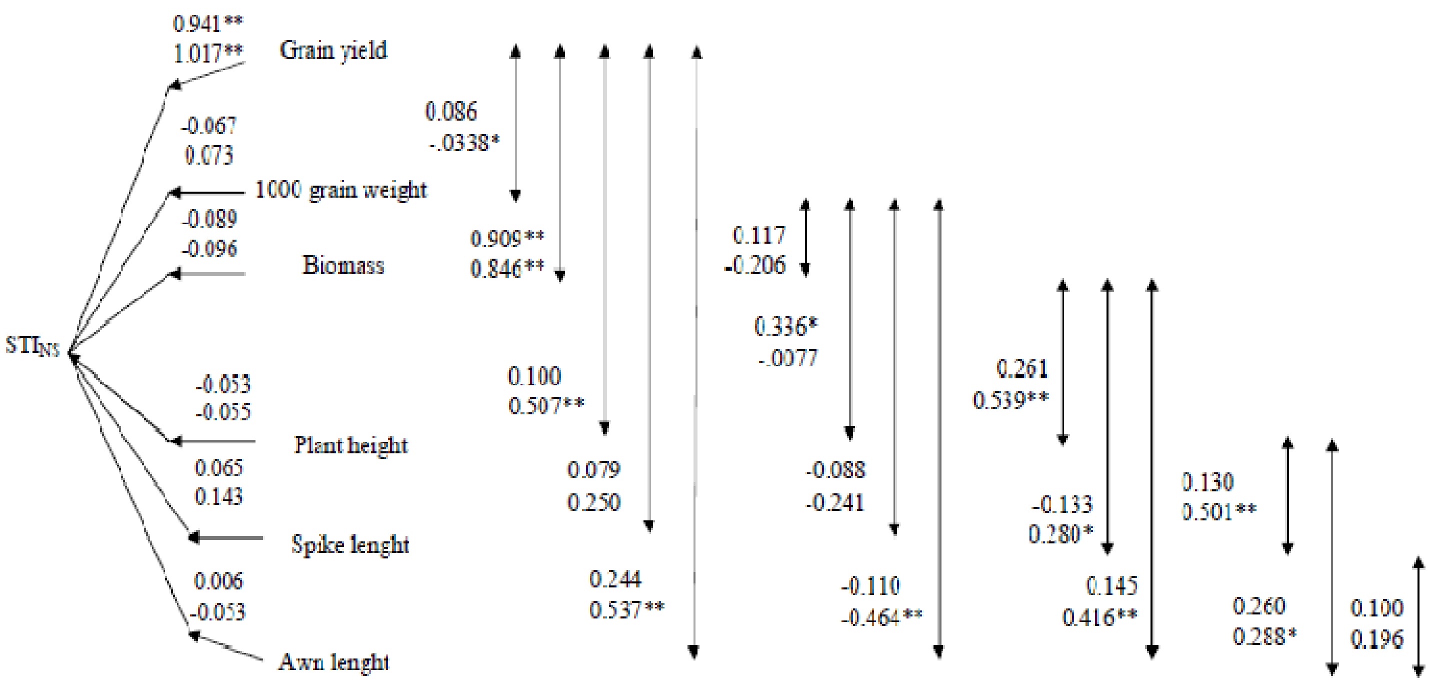

Figure 1. Diagram of path analysis of STI_{NS} and agronomical traits in normal and intensive conditions. Upper and down numbers are related to normal and intensive stress respectively. *,**: Significant in 5 and 1% level of probability.

after anthesis. Awns do photosynthesis and increase the amount of photosynthesis after anthesis 20 to 30% (Austin, 1982). Because of the high heritability of awn length and moderate heritability of plant height and spike length, we can expect drought resistance by direct or indirect selection of grain yield by biomass, spike length, and awn length. The 1000 grain weight had a negative and non-significant correlation with STI_{MS} in moderate

Table 6. Path analysis of STI_{MS} with agronomical traits in moderate and intensive stress conditions

Parameter	Grain yield	1000 grain yield	Biomass	Plant height	Spike length	Awn length	Correlation with STI_{MS}
Grain yield	0.873 0.889	0.002 0.004	-0.013 0.059	-0.016 0.001	0.004 0.024	0.017 -0.042	0.864 0.936
1000grain yield	-0.079 -0.300	-0.026 -0.012	0.001 -0.014	-0.020 -0.001	-0.0004 -0.023	-0.023 0.036	-0.148 0.314
Biomass	0.754 0.752	0.001 0.002	-0.015 0.07	-0.024 0.001	0.001 0.027	0.007 -0.032	0.724 0.821
Plant height	0.220 0.451	-0.008 0.001	-0.006 0.038	-0.062 0.002	0.003 0.049	-0.019 -0.022	0.128 0.518
Spike length	0.036 0.222	0.001 0.003	-0.002 0.020	-0.018 0.001	0.010 0.097	-0.001 -0.015	0.026 0.327
Awn length	0.214 0.477	0.009 0.005	-0.001 0.029	0.017 0.001	-0.0001 0.019	0.069 -0.078	0.306 0.453

Upper and lower numbers are related to normal and intensive conditions respectively.

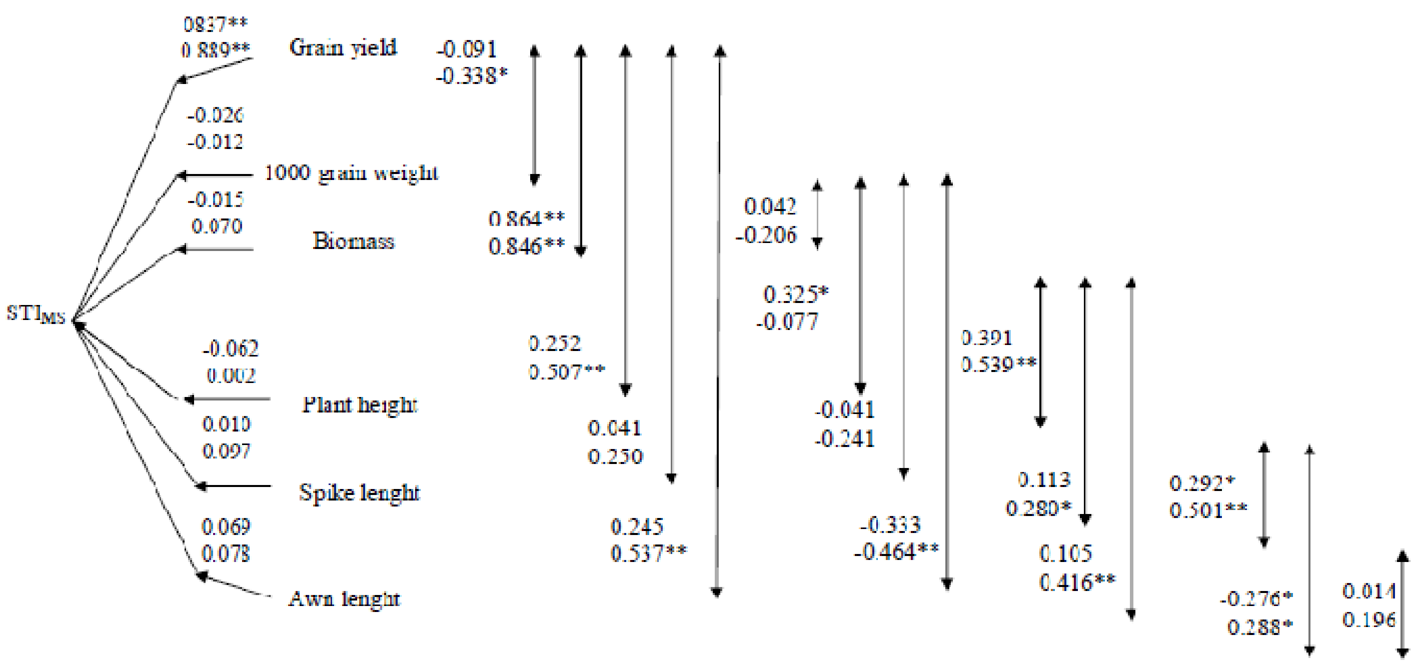

Figure 2. Diagram of path analysis of STI_{MS} and agronomical traits in moderate and intensive conditions. Upper and lower numbers are related to moderate and intensive stress, respectively. *,**: Significant at the 5 and 1% level of probability.

stress but in intensive stress this correlation was negative and significant. Stress conditions and a lack of photosynthesis materials leads to less balance between the sink and the source. However, because of raining during the pollination and anthesis stages, there was a suitable condition for forming more grain in spike in intensive stress resulting less plant capacity for filling grains and less 1000 grain weight.

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