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Screening of Greek wheat landraces for their yield responses under arid conditions

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Abstract

The present study was a part of a long time screening experiment that included a high number of wheat landraces (*Triticum aestivum* L.) cultivated in Greece, and focused on the agronomic point of view and the drought adaptation for some of these landraces. One of the most acceptable ways for the assessment of drought resistance is the examination of yield and yield components in different water regimes. Therefore, in our two-years experiments parameters of plants water relations and yield components such as grain yield, total biomass, number of kernels per spike and mean grain weight were recorded for the several cultivars. The data obtained during the two experimental seasons clearly pointed out the differential behavior of wheat landraces under water stress conditions. The populations that exhibited the greater adaptability (low b_N) were Grinias Zakinthou (biomass, grain yield) and Skilopetra Ptolemaidas (harvest index, kernels per spike) and they could be used in breeding programs in Greece and other arid regions.

Keywords: Wheat landraces; Water stress; Drought resistance; Relative adaptability.

Introduction

Wheat is one of the most popular crops in whole world, mainly because of its relatively moderate requirements in influxes for pesticides and fertilizers in combination with its high productivity (Bishaw et al., 2011; Travlos, 2012). The crop is usually cultivated in regions that are characterized either from low annual precipitation or from unequal distribution of rainfalls within a year.

This fact is responsible for water deficits in crops and it is recognized as a primary reason for the reduced expression of yield potential of wheat. Greece belongs mainly in the case of this unequal distribution of rainfalls and given that water resources are continually limited, the farmers are obligated to cultivate anyone crop in a stressor environment (Karamanos and Travlos, 2012). Elaborated this frame, many scientists in the past have suggested a lot of ways to confront the problem of drought in agriculture. Briefly, the efforts are focused: a) in tillage management for better exploitation of soil moisture and b) in the direction of cultivation of drought adaptive species and cultivars (Blum et al., 1999; Travlos et al., 2007; Karamanos and Travlos, 2012). In the first case the possibilities to improve the techniques are limited and strongly associated with the available soil water; therefore the interesting was turned to plant breeding. The driving forces for plant evolution were primarily natural and artificial selection with the well-known consequences in our days. The uninterrupted research for genes that would provide the increase of yield led the rustics to abandon primitive or traditional crop varieties (landraces) and turn in ameliorate cultivars. Many workers tried to definite landraces and Harlan (1975) described them as a mixture of genotypes with enhanced adaptability in the environment that were grown. Earlier, Von Rumner (1908) reported that cereals landraces are varieties that cultivated from the beginning in an individual region and they were named from it. A preview for landraces leads to the common conclusion that they enclose an incredible amount of phenotypic, physiological and agronomic variation derived from their big genetic diversity. Specifically in wheat, there have been cited numerous considerable differences that concern above mentioned attributes namely ear type, glum color, plant height, straw quality, length of biological cycle, demands for vernalization etc. (Kuckuck, 1956; Chaves et al., 2002).

Until now, the magnitude of landraces was limited in the countries that agriculture has not evolved in the rate of developed countries. The causes for this indifference of west world, specifically, must be ascribed in politic, social and financial reasons. The constantly exhaustion of genetic sources, the uniformity of cultivars and the changes of climate, inevitably will conduct the plant breeders to look for new genetic material enable to adapt in new conditions.

Water stress was the subject of many works in the past but the complexity of this phenomenon and the difficulty for quantification or the identification of the stressor environment created serious problems (e.g. interaction with other stresses such as heat stress). The researchers attempted to overcome these impediments devising indices that in their majority relied on the changes of grain yield among separate water regimes or across locations (Blum et al., 1999; Shamsil et al., 2011). Another index based in canopy temperature that proposed by Idso et al. (1981a) seems to be effectiveness only in medium degrees of water stress (Idso et al., 1981b) while there were cases that water potential was directly correlated with a specific trait (Karamanos, 1984; Gupta et al., 2001). Although, the most of these parameters were proved sufficient to describe a possible ability for drought resistance it is unclear whether the impacts in yield is the result of water scarcity or come from a complex influence. Karamanos and Papatheohari (1999) suggested water potential index (WPI) that utilizes the integral of water potential in a given duration. WPI is considered to be an objective indicator for plants that experienced a drought period since it takes into account a well establishment parameter, the leaf water potential. On this way it is easy to correlate any agronomic trait with WPI and to understand the proportion of impact from the water status of a plant.

The present study was a part of a long time experiment that included a high number of wheat landraces cultivated in Greece, as well as observations taken. Here we have focused on the agronomic point of view for some of these landraces, while the physiological and morphological responses of genotypes in drought are going to be presented in a future study. The target is the screening of landraces that are drought resistant and will be used in breeding programs in Greece and other arid regions.

Materials and Methods

Experimental design

The experiment was carried out in two seasons (2002-03 and 2003-04) at one of the research farms of the Agricultural University of Athens (AUA), Greece (latitude 37^{o} 58′ N; longitude 23^{o} 32′ E). The soil was clay loam (CL 0-25 cm; 34.6% clay, 27.7% silt and 37.7% sand), calcareous (13.3% $CaCO_3$), with a pH value of 7.17 and relatively moderate organic matter (determined according to Wakley and Black, 1934) and nitrogen content (1.87 and 13.5%, respectively), with sufficient levels of nitrate and available phosphorus, rich in available potassium and sodium (94.3, 17.95, 600 and 110 ppm, respectively) and with high levels of cation exchange capacity (4990 ppm).

Thirty Greek durum and bread wheat landraces were sown in an area of 320 m^2. In our study we focused on five of these bread wheat landraces, named Hasiko Kritis, Atheras Kerkiras, Zoulitsa Arkadias, Grinias Zakinthou and Skilopetra Ptolemaidas. We were supplied the genetic material from the bank of genetics resources of NAGREF (National Agronomic Research Foundation) in Salonica. The experimental design was a split-plot design with three replications, thirty main plots (landraces) and four subplots (irrigation treatments), all arranged randomly. Every main plot had an area of 1.8 m^2 (1.5×1.2 m) while each subplot was 0.45 m^2 (1.2×0.375 m). The soil moisture levels were differentiated in proportion to the distance of plants from the irrigation line. The wettest treatment (WT_1) was the nearest, while the driest treatment (WT_4) was the most distant from irrigation line.

Cultivation procedures

The soil tillage was conducted in 26/11/2002 and 18/11/2003 for the first and the second season, respectively. The sown took place in 17/01/03 and 19/12/03, respectively. In both years a day after the sown we proceeded in chemical weeding using the herbicide Glean (chlorsulfuron, 5%) in an amount of 1 g per acre.

Technical details

In the stage of shoot elongation, the field was covered by a rain shelter in order to avoid the undesirable rainfall and to control the water volume that was received by each subplot.

Observations and measurements

The determination of plant water status was conducted by means of recording leaf water potential. The sample collection was taking place twice a week at 12.00 a.m. that leaf water potential takes the minimum daily value. From each plant we were cutting the fully youngest expanded leaf and putting into small polyethylene sealed bags with purpose to minimize the water losses by transpiration. Afterwards, the bags were placed in dark and humid containers until the determination time. The number of leaves that their water status was evaluated was three per subplot (treatment) and the method that was followed was by pressure chamber as described by Schollander et al. (1964).

The values of Water Potential Index (WPI) were resulted from the integral of time course of leaf water potential dividing it with the duration of the period that were taking place the measurements. On this way the WPI values are comparable among species that have a different length of biological cycle or between measurements that differ in the duration. (Karamanos and Papatheohari, 1999).

The yield components were determined after the harvest of the crop. Therefore, biomass was dried under natural conditions and since it was weighted the collected data was converted in ton / acre. Grain yield was calculated by weighting the seeds, that were contained 8% moisture and converting the results in $kg.acre^{-1}$. From the quotient grain yield / biomass the harvest index was also calculated. The weight of a hundred grains divided by the number of kernels (100) expresses the mean grain weight, while the number of kernels per spike was obtained from three spikes for each subplot.

Statistical analyses

Homogeneity of variance was evaluated before data analysis. The data were subjected to ANOVA using the Statgraphics statistical software package (v.5.0, Statistical Graphics Corporation, Englewood Cliffs, NJ, USA). Mean comparison was performed using Fisher's least significant difference (LSD) method ($P<0.05$). In the cases that F value was higher than critical F value we proceeded in multiple range tests that were based on Duncan's method.

Results

The rate of decline of water potential was ranged about 0.01-0.05 MPa day^{-1}. For each landrace and for all the water treatments and years, the values of water potential are shown in Table 1. Differences between the landraces and the treatments were significant and the lowest water potential (LWP) showed a rapid decrease with increasing degrees of water stress, at statistically significant level. However, the significant differences among the landraces were evident in WT_1 and WT_4 in the experiment of the second year. Particularly, the cultivar Grinias Zakinthou had the highest rate of decline in both seasons and all treatments, while the lowest values gave Hasiko Kritis, except for the third treatment where Atheras Kerkiras had the lowest rate. It has also to be noted that the general time course of LWP of all wheat landraces in both years showed a progressively falling during water stress. Moreover, from the phenological point of view the landraces have been greatly affected by water stress from the anthesis stage up to the latest stages of growth.

Table 1. The rate of decline of leaf water potential for five bread wheat landraces in two seasons. Means followed by different case letters in columns are significantly different according to Fischer's LSD test (P=0.05).

	Water Potential Index (MPa)							
	2002/03				2003/04			
Landraces	WT_1	WT_2	WT_3	WT_4	WT_1	WT_2	WT_3	WT_4
Hasiko Kritis	0.03^a	0.038^a	0.043^a	0.039^a	0.01^b	0.01^b	0.014^b	0.016^c
Atheras Kerkiras	0.033^a	0.037^a	0.04^a	0.045^a	0.012^b	0.012^b	0.013^b	0.019^{bc}
Zoulitsa Arkadias	0.031^a	0.035^a	0.039^a	0.035^a	0.017^{ab}	0.02^a	0.025^a	0.033^a
Grinias Zakinthou	0.036^a	0.038^a	0.041^a	0.046^a	0.022^a	0.024^a	0.026^a	0.029^a
Skilopetra Ptolemaidas	0.033^a	0.04^a	0.041^a	0.046^a	0.019^a	0.02^a	0.022^a	0.023^b

Taking into account the integral of LWP course for each genotype in both seasons and dividing it by the length of the period of the study WPI values were obtained, according to Karamanos and Papatheohari (1999). The values of these values are shown in Table 2. The WPI values differed between drought levels indicating a gradual decrease as the soil moisture decreased. Furthermore, the WPI values among genotypes were statistically differentiated in each experimental season illustrated also clearly the differences between genotypes across years. Descriptively, from all genotypes studied, Grinias Zakinthou despite its higher rate of decline, showed to be less affected by water stress (-1.71 to -2.06 MPa). Inversely, the WPI range of values (-1.76 to -2.1 MPa) in the genotype Zoulitsa Arkadias was indicative of a higher stressed wheat landrace in both seasons. The data obtained during the two experimental seasons pointed out the differential behavior of wheat landraces under water stress conditions. In particular, in the first season the increased water stress treatment caused an increase in WPI for the cultivar Skilopetra Ptolemaidas, while Hasiko Kritis was affected less than the other genotypes. In the second period due to the differences in climatic conditions, Zoulitsa Arkadias and Hasiko Kritis had the lowest and highest values, respectively.

The drought treatments effects were highly significant for the grain yield in the majority of genotypes in both years (Table 3). In the first period, the grain yield was reduced less by drought in Zoulitsa Arkadias, while in the case of Hasiko Kritis there was observed a loss of about 50% between WT_1 and WT_4. Similarly, in the second year the grain yield of Hasiko Kritis in WT_4 was reduced by 54% related on the wet treatment, a decline that was the highest among all the corresponding values. On the contrary, Skilopetra Ptolemaidas exhibited the smallest change of the trait between WT_1 and WT_4 (39%) but still the statistical differences were significant.

Table 2. The values of WPI across the wheat landraces examined and irrigation treatments in the two seasons. Means followed by different case letters in columns are significantly different according to Fischer's LSD test (P=0.05).

	Water Potential Index (MPa)							
	2002/03				2003/04			
Landraces	WT_1	WT_2	WT_3	WT_4	WT_1	WT_2	WT_3	WT_4
Hasiko Kritis	-1.83^a	-1.89^a	-1.96^a	-2.05^a	-1.65^b	-1.69^b	-1.74^b	-1.85^b
Atheras Kerkiras	-1.71^a	-1.8^a	-1.87^a	-2^a	-1.8^a	-1.85^a	-1.9^a	-1.99^a
Zoulitsa Arkadias	-1.76^a	-1.87^a	-1.96^a	-2.03^a	-1.8^a	-1.86^a	-1.92^a	-2.1^a
Grinias Zakinthou	-1.73^a	-1.83^a	-1.93^a	-2.06^a	-1.71^{ab}	-1.77^{ab}	-1.82^{ab}	-1.93^{ab}
Skilopetra Ptolemaidas	-1.76^a	-1.87^a	-2.03^a	-2.11^a	-1.74^{ab}	-1.82^a	-1.88^a	-1.97^a

Table 3. The grain yield across the wheat landraces examined and irrigation treatments in the two seasons. Means followed by different case letters in columns are significantly different according to Fischer's LSD test (P=0.05).

	Grain Yield (tn ha^{-1})							
	2002/03				2003/04			
Landraces	WT_1	WT_2	WT_3	WT_4	WT_1	WT_2	WT_3	WT_4
Hasiko Kritis	308.3^a	210.1^b	173.16^b	154.6^b	156.8^a	102.04^b	85.92^b	71.18^b
Atheras Kerkiras	275.66^b	247.18^{ab}	208.76^{ab}	180.78^a	135.39^a	101.61^b	96.66^b	81.79^b
Zoulitsa Arkadias	315.03^a	272.96^{ab}	257.25^b	242.56^b	181.91^a	155.8^{ab}	124.07^{bc}	94.57^c
Grinias Zakinthou	299.78^a	210.51^b	226.73^b	182.35^b	171.56^a	147.91^a	87.84^b	79.89^b
Skilopetra Ptolemaidas	338.9^a	231.71^b	195.55^{bc}	174.26^c	153.35^a	126.37^b	98.95^c	92.72^c

From the data in Table 4 is perceptible that biomass was highly significant affected by low moisture level. Indeed, in the first year Grinias Zakinthou reached the highest yield among all treatments except for WT_4 (in that case Zoulitsa Arkadias was the most productive population). In contrast, Skilopetra Ptolemaidas resulted to the lowest total biomass production in WT_1 and WT_4. In WT_4 the difference was significant for Hasiko Kritis, Atheras Kerkiras and Zoulitsa Arkadias. In the intermediate treatments Hasiko Kritis reached the lowest yield. In WT_2 the difference between Hasiko Kritis and the other landraces was not significant, while in

WT_3, the difference was significant for Grinias Zakinthou and Skilopetra Ptlolemaidas. A similar response was observed in the second year, while the steadily highly productive wheat landrace, in all irrigation treatments, was Zoulitsa Arkadias. The cultivars Atheras Kerkiras in two first treatments and Grinias Zakinthou in the latter treatments resulted to the lowest biomass production, even if the analysis of variance demonstrated that there weren't significant differences between populations.

Table 4. The biomass yield across the wheat landraces examined and irrigation treatments in the two seasons. Means followed by different case letters in columns are significantly different according to Fischer's LSD test (P=0.05).

	Biomass Yield (tn ha^{-1})							
	2002/03				2003/04			
Landraces	WT_1	WT_2	WT_3	WT_4	WT_1	WT_2	WT_3	WT_4
Hasiko Kritis	1.95^a	1.5^a	1.38^a	1.42^a	1.42^a	0.97^b	0.92^b	0.86^b
Atheras Kerkiras	1.85^a	1.57^{ab}	1.6^{ab}	1.35^b	1.25^a	0.97^b	0.95^b	0.81^b
Zoulitsa Arkadias	1.87^a	1.66^{ab}	1.67^{ab}	1.54^b	1.91^a	1.7^{ab}	1.55^{ab}	1.32^b
Grinias Zakinthou	1.95^a	1.81^{ab}	1.71^b	1.48^c	1.34^a	1.23^a	0.85^b	0.79^b
Skilopetra Ptolemaidas	1.84^a	1.63^{ab}	1.45^{bc}	1.25^c	1.6^a	1.49^a	1.22^b	1.18^b

In general, the number of kernels per spike was reduced with the increase of soil drought level (Table 5). Based on the percentage changes of the kernel number per spike, between treatments, it is concluded that Hasiko Kritis limited its production from WT_1 to WT_4 by 28%, in first experiment, while and in the same position found Grinias Zakinthou in the second season, reducing the trait by 31.5%. Comparing the values between populations it is demonstrated that Hasiko Kritis preponderated in number of kernels both years while in contrast Grinias Zakinthou was the less productive local variety.

Table 5. The number of kernels per spike across the wheat landraces examined and irrigation treatments in the two seasons. Means followed by different case letters in columns are significantly different according to Fischer's LSD test (P=0.05).

	Kernels per spike							
	2002/03				2003/04			
Landraces	WT_1	WT_2	WT_3	WT_4	WT_1	WT_2	WT_3	WT_4
Hasiko Kritis	37.36^a	29.77^b	30.44^b	26.76^b	37.66^a	35.33^a	27.66^b	29^b
Atheras Kerkiras	34.09^a	30.55^b	30.48^b	24.73^b	32.66^a	26.5^b	25.16^b	26.66^b
Zoulitsa Arkadias	36.18^a	32.25^b	28.77^b	30.14^b	30.66^a	28.33^a	26.66^a	27.33^a
Grinias Zakinthou	29.48^a	26.01^b	24.17^b	23.21^b	36.5^a	26.16^b	22^b	25^b
Skilopetra Ptolemaidas	35.07^a	30.92^b	26.66^c	27.22^b	28.16^a	25.33^{ab}	24.66^{ab}	21.16^b

No significant differences in the mean grain weight were observed across irrigation treatments in first year while in the second experiment it appeared that some genotypes (Hasiko Kritis, Skilopetra Ptolemaidas) were more sensitive in drought in relation to this trait (Table 6). Other researches have reported that water deficit reduced the duration of grain filling and the function of photosynthesis with a consequence the produce of a great number of shrinkage seeds (Fischer and Kohn, 1966).

In Table 7 the harvest index values across the wheat landraces examined and irrigation treatments in the two seasons are also shown with some significant differences among the several landraces.

Table 6. The mean grain weight across the wheat landraces examined and irrigation treatments in the two seasons. Means followed by different case letters in columns are significantly different according to Fischer's LSD test (P=0.05).

	Mean grain weight (g per seed)							
	2002/03				2003/04			
Landraces	WT_1	WT_2	WT_3	WT_4	WT_1	WT_2	WT_3	WT_4
Hasiko Kritis	0.035^{a}	0.034^{a}	0.033^{a}	0.032^{a}	0.046^{a}	0.043^{ab}	0.039^{ab}	0.034^{b}
Atheras Kerkiras	0.034^{a}	0.033^{a}	0.034^{a}	0.033^{a}	0.0426^{a}	0.04^{a}	0.0416^{a}	0.04^{a}
Zoulitsa Arkadias	0.036^{a}	0.037^{a}	0.035^{a}	0.034^{a}	0.043^{a}	0.044^{a}	0.038^{a}	0.04^{a}
Grinias Zakinthou	0.033^{a}	0.033^{a}	0.031^{a}	0.03^{a}	0.48^{a}	0.0476^{a}	0.048^{a}	0.0502^{a}
Skilopetra Ptolemaidas	0.036^{a}	0.032^{a}	0.034^{a}	0.031^{a}	0.0507^{a}	0.048^{ab}	0.045^{bc}	0.043^{c}

Table 7. The harvest index values across the wheat landraces examined and irrigation treatments in the two seasons. Means followed by different case letters in columns are significantly different according to Fischer's LSD test (P=0.05).

	Mean grain weight (g per seed)							
	2002/03				2003/04			
Landraces	WT_1	WT_2	WT_3	WT_4	WT_1	WT_2	WT_3	WT_4
Hasiko Kritis	0.159^{a}	0.139^{a}	0.136^{a}	0.109^{a}	0.11^{a}	0.105^{a}	0.093^{a}	0.082^{a}
Atheras Kerkiras	0.149^{a}	0.158^{a}	0.13^{a}	0.133^{a}	0.108^{a}	0.104^{a}	0.101^{a}	0.1^{a}
Zoulitsa Arkadias	0.167^{a}	0.165^{a}	0.154^{a}	0.158^{a}	0.095^{a}	0.091^{a}	0.08^{a}	0.071^{a}
Grinias Zakinthou	0.154^{a}	0.117^{a}	0.123^{a}	0.123^{a}	0.128^{a}	0.12^{a}	0.103^{a}	0.101^{a}
Skilopetra Ptolemaidas	0.184^{a}	0.142^{b}	0.135^{b}	0.139^{b}	0.102^{a}	0.09^{a}	0.081^{a}	0.078^{a}

Discussion

Concerning the fall of water potential and the variability of LWP between the several cultivars, it seems that the demands of genotype for water were related on the growth stage and the available water in the soil (Salter and Goode, 1967; Angus and Moncur, 1977) but simultaneously, presumably implies the genetic heterogeneity of wheat local varieties. Additionally, it is clear that in the second season the rates were lower than the first period and this could be attributed to the higher level of relative humidity in the second year (data not shown).

However, it is difficult to take out a conclusion about the drought resistance of a plant using only WPI. Therefore, parameters such as grain yield, total biomass, number of kernels per spike and mean grain weight were used to obtain more information related to the physiological effect of water stress on agronomic traits. Besides, other authors reported that the most acceptable way for the assessment of drought resistance is the examination of yield and yield components in different water regimes (Fischer and Maurer, 1978; Karamanos and Papatheohari, 1999; Blum, 2005).

In the first season, Skilopetra Ptolemaidas resulted to the highest grain yield in fully irrigated treatment, while the less productive landrace was Atheras Kerkiras. Under severe drought stress the yield performance was significantly higher in Zoulitsa Arkadias than Hasiko Kritis and their disparity was 0.88 tn ha^{-1}. The respective differences that were observed in the second year involved Zoulitsa Arkadias and Atheras Kerkiras (0.46 tn ha^{-1}), whereas Zoulitsa Arkadias and Hasiko Kritis resulted to the maximum amplitude in the drier subplot (0.23 tn ha^{-1}).

It is well known that water shortage, especially during the differentiation of spike affects productivity because of inhibition in meiosis. Besides, dry conditions increase the percentage of male sterility (Bingham, 1966). Secondly, water deficit in tillering influence the formation of fertile tillers (Salter and Goode, 1967) and this phenomenon was clearly observed in the second season of the experiment (unpublished data). The variability of values among years could be probably attributed to the several wheat genotypes that are characterized by an unstable yield across years, but we cannot ignore the variety in climatic conditions during the experiments, too (Travlos, 2012).

The observed divergences across treatments suggested that the physiological mechanisms, which control the vegetative growth, were influenced from water limitation. Substantially, the physiological function that is involved is photosynthesis by means of the accumulated photosynthetic products, mainly in leaves and other parts of plant. When photosynthesis is inhibited from medium water stress the stomatal resistance is increased, but in high intensity of water shortage, perhaps, the electron transport chain is also restricted (Nilsen and Orcutt, 1996). In addition, water deficit reduces cell turgor and therefore the growth of cells and this has an impact on reduction of the leaf area and the ability for photosynthesis.

The reduced number of kernels sown in Table 5 is also a common reaction of water shortage. The most critical period for water supply is considered to be 5-15 days before heading and a water deficiency in this stage it is possible to provoke a reducing in number of kernels per spike as a result from incomplete differentiation of spikelets (Fischer, 1973). Although, it is considered that the effect of drought in grain filling isn't so dramatic in relation with the impact from high air temperature and warm winds, while Asana and Man (1955) reported that the decrease of grain weight determinates yield in a lower degree in comparison with the number of kernels.

The evaluation of drought resistance in previous studies was attainable by the change of yield across time and location using an environmental index (Fischer and Maurer, 1978; Eberhart et al., 1966). In this study we correlated each parameter against WPI (Tables 8, 9) that is a reliable quantitative index for water stress. The most sensitive trait from water stress was the number of kernels per spike and this result confirms the assumption that the water deficit in the critical stages of heading and flowering decreases the production of seeds per spike. Furthermore, the parameter that remained almost uninfluenced was harvest index with only one exception for Atheras Kerkiras.

Table 8. The correlation coefficients from the linear regressions of six traits against WPI.

Landraces	Biomass Production	Grain Yield	Harvest Index	Number of Kernels/spike	Mean Grain Weight
Hasiko Kritis	ns	ns	ns	0.501**	0.758***
Atheras Kerkiras	0.59***	0.557***	0.405**	0.62***	ns
Zoulitsa Arkadias	0.682***	0.455**	ns	0.519***	ns
Grinias Zakinthou	ns	ns	ns	0.626***	ns
Skilopetra Ptolemaidas	0.486**	ns	ns	ns	0.524***

*, **, *** indicate significance at $P<0.05$, 0.01 and 0.001, respectively; ns=not significant.

Table 9. The parameters of the fitted linear regressions (a: Y-intercept, b: regression coefficient) of six traits against WPI for five bread wheat landraces.

Landraces	Biomass Production		Grain Yield		Harvest Index		Number of Kernels/spike		Mean Grain Weight	
	a	b	a	b	a	b	a	b	a	b
Hasiko Kritis	0.3071	-0.545	-15.875	-92.19	0.047	-0.0386	70.679	21.297	0.0992	0.0339
Atheras Kerkiras	5.5559	2.2831	961.29	426.83	0.3349	0.1132	84.638	29.882	0.0288	-0.0046
Zoulitsa Arkadias	4.7963	1.644	848.97	336.63	0.3027	0.0939	66.034	18.828	0.0576	0.0099
Grinias Zakinthou	2.2219	0.448	418.38	131.32	0.2088	0.0479	74.621	26.014	0.0976	0.0311
Skilopetra Ptolemaidas	3.3089	0.991	487.07	163.86	0.1315	0.0058	54.179	14.121	0.1039	0.0336

The intercept value (a) represents the potential of plant that is associated with the given parameter while the slope value (b) represents the adaptability of genotype in drought. (Karamanos and Papatheohari, 1999). It is well established that high potential yield is often accompanied with low adaptability and vice versa. However, it is no surprise the opposite case where a satisfactory production in favorable water conditions isn't limitative factor for the achievement of high adaptability. In our experiments we observed all the above indicated categories, but the results weren't permanent for both years, so we distinguished: (i) those which had the higher values of a and b for both years (Atheras Kerkiras) and (ii) those which had the lowest values of a and b permanently (Grinias Zakinthou, Skilopetra Ptolemaidas). These cases aren't unusual, taking into account that other workers have reported that a high potential yield is usually conjugated with a low drought adaptability (Karamanos and Papatheohari, 1999), while it is not surprising the second instance, too (Karamanos and Papatheohari, 1999).

Nevertheless, the evaluation of a genotype's adaptability could not be conducted only by the examination of the slope value (Keim and Kronstad, 1979), as well as a combination of intercept and slope value is hard to lead us in a conclusion about the adaptability of genotypes. For this reason Karamanos and Papatheohari (1999) suggested the "relative adaptability" to drought b_N that is the quotient b/a, therefore low values of b_N mean that a given genotype is characterized from higher adaptability related with other genotypes. In Table 10 the values of b_N for the five wheat landraces and the six examined traits are also shown. Conclusively, the populations that exhibited the greater adaptability (low b_N) were Grinias Zakinthou (biomass, grain yield) and Skilopetra Ptolemaidas (harvest index, kernels per spike) while Atheras Kerkiras 184 had, permanently, in all parameters the higher values of b_N. An unusual performance exhibited Hasiko Kritis who gave negative values of yield potential (a), adaptability (b) and relative adaptability (b_N) in some traits as well as Atheras Kerkiras in average seed weight. The above-mentioned results could be further extended, accompanied by the physiological and morphological responses of the several landraces in drought, in order to use some of these local cultivars in extremely arid environments.

Table 10. The values b_N (relative adaptability to drought) for the six examined traits and the five bread wheat landraces.

Landraces	Biomass Production	Grain Yield	Harvest Index	Number of Kernels/spike	Mean Grain Weight
Hasiko Kritis	-1.77	5.81	-0.82	0.30	0.34
Atheras Kerkiras	0.41	0.44	0.34	0.35	-0.16
Zoulitsa Arkadias	0.34	0.40	0.31	0.29	0.17
Grinias Zakinthou	0.20	0.31	0.23	0.35	0.32
Skilopetra Ptolemaidas	0.30	0.34	0.04	0.26	0.32

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