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The Evaluation of Endemic Land-Races of Wheat as Genetic Resources for Wheat Breeding Towards Environmental and Biotic Stress Tolerance

A. Blum, C. Y. Sullivan

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Names of Investigators:

Principal Investigator: A. Blum

Cooperating Investigator: C.Y. Sullivan

Name and Address of Affiliated Institutions:

Principal Institution: Agriculture Research Organization, The Volcani Center, POB 6 Bet Dagan,
Israel

Cooperating Institution: USDA, ARS, University of Nebraska, 342 Keim Hall, Lincoln NE
68583 USA

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Signatures:

Principal Investigator

Institution Authorizing Official

A. Blum

M. Hsu

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GENERAL ABSTRACT

A collection of landraces of wheat from the Northern Negev desert of Israel was evaluated as a potential genetic resource for wheat breeding. The collection was subjected to various tests in the field, greenhouse and growth chambers. It was evaluated for yield stability, drought resistance, heat tolerance, disease resistance and grain quality traits.

Large variability was revealed within the collection in drought resistance in terms of grain yield and biomass under drought stress as expressed in the 'drought susceptibility index'. Large variability was found for canopy temperatures under drought stress, which at times were negatively correlated with grain yield under stress. Genetic variation was also revealed for osmotic adjustment and for growth under PEG-induced drought stress, as well as for drought-adaptive whole plant traits such as root growth. Landraces, as compared with modern cultivars, tended to have more root growth under stress and were better capable of supporting kernel growth by stem reserve mobilization under drought stress after anthesis. Landraces varied extensively for heat tolerance as measured by cellular membrane thermostability.

Except for grain protein in the hexaploids, significant variation was revealed among landraces in kernel weight, grain protein, sedimentation, mixograph and carotin content. Among all grain quality traits measured, landraces were superior to modern cultivar only for grain protein content.

Landraces varied in reaction to all three rust diseases and resistance was found mainly for stem rust and stem rust. Resistance to stripe rust was rare among these landraces.

OBJECTIVE OF RESEARCH

Genetic diversity is the cornerstone of plant breeding. The assembly and evaluation of new germplasm is essential for progress in crop plants' improvement. Great progress has been made in wheat improvement but at the same time the genetic basis of currently cultivated wheat is become extremely narrow. New and potentially useful germplasm for wheat breeding is becoming essential for future progress.

Wheat is an ancient crop in the Middle East. It as domesticated in this region and it was continuously cultivated in close contact with native populations of some of its wild progenitors. As such the pre-scientific agriculture wheat landraces grown in this region were deemed as a potentially untapped and useful genetic resource.

Landraces of wheat were grown by the local Bedwin population in the semi-arid Northern Negev in Israel. The mean annual rainfall in this region ranges between *ca.* 150 and 250 mm. In 1976, 1521 spikes were collected from various small fields in the region. The collection was grown at Bet Dagan and was subjected to a thorough systematic survey based on qualitative and quantitative morphological traits. It was found that *Triticum durum* was represented in 84% of the collection and it was clustered into 22 populations. *Triticum aestivum* was represented in 15.6% of the collection and it was clustered into 6 populations. *Triticum compactum* was represented by 8 accessions. Based on variation in discrete plant morphological traits a sub-sample of the collection was constructed, representing all identified populations and holding some 70 accessions.

The purpose of this work was to explore the collection and identify genetic variation for resistance to biotic and environmental stresses of wheat. These included resistance to leaf, stripe and stem rusts, resistance to drought stress and resistance to heat stress. In addition, grain quality traits were also included as an important attribute.

**THE DROUGHT RESPONSE OF LANDRACES OF WHEAT FROM THE
NORTHERN NEGEV DESERT IN ISRAEL**

SUMMARY

Diverse landraces of wheat, collected from the semi-arid (150 to 250 mm of total annual rainfall) Northern Negev desert in Israel were considered as a potential genetic resource of drought resistance for wheat breeding. These materials were therefore evaluated for their responses to drought stress in agronomical and physiological terms. Up to 68 landraces, comprising of *Triticum durum*, *T. aestivum*, and *T. compactum* were tested in two field drought environments, in one favorable field environment, under post-anthesis chemical plant desiccation which revealed the capacity for grain filling from mobilized stem reserves, under a controlled drought stress in a rainout shelter and in the growth chamber under polyethylene glycol (PEG)-induced water stress. Biomass, grain yield and its components, harvest index, plant phenology, canopy temperatures, kernel weight loss by chemical plant desiccation, growth reduction by PEG-induced drought stress and osmotic adjustment were evaluated in the various experiments.

Landraces varied significantly for all parameters of drought response as measured in the different experiments, which was in accordance to their documented large morphological diversity. Variation in grain yield among landraces under an increasing drought stress after tillering was largely affected by spike number per unit area. Kernel weight contributed very little to yield variation among landraces under stress, probably because these tall (average of 131 cm) landraces generally excelled in their capacity to support kernel growth by stem reserve mobilization under stress. Yield under stress was reduced with a longer growth duration of landraces only under early planting but not under late planting. Landraces were generally late flowering but they were still considered well adapted phenologically to their native region where they were always planted late.

Landraces differed significantly in canopy temperature under drought stress. Canopy temperature under stress in the rainout shelter was negatively correlated across landraces with grain yield ($r=-0.67^{**}$) and biomass ($r=-0.64^{**}$) under stress. Canopy temperature under stress in the rainout shelter was also positively correlated across landraces ($r=0.50^{**}$) with canopy temperature in one stress field environment. Osmotic adjustment in PEG-stressed plants was negatively correlated ($r=-0.60^{**}$) with percent growth reduction by PEG-induced water stress. It was not correlated with yield under stress in any of the experiments.

In terms of yield under stress, canopy temperatures and stem reserve utilization for grain filling, the most drought resistant landrace was the 'Juljuli' population of *T. durum*.

INTRODUCTION

Wheat has been traditionally grown by the settled Bedouin population in the Northern Negev desert of Israel, where total annual rainfall range from 150 to 250 mm. A collection had been made in this region in 1967, when 1553 spikes were sampled from numerous small fields. This collection was planted in 1978 at Bet Dagan, Israel and qualitative and quantitative data were collected in each head-row. The collection then was thoroughly classified by a cluster analysis of the data. It was found (Poiarkova and Blum, 1983) that *Triticum durum* represented 84% of the collection. It was clustered into 22 populations, 11 of which were identified as known botanical varieties of *T. durum*. The remaining entries consisted of eight populations of *T. aestivum* and *T. compactum*. Some of the populations were recognized as known landraces of the region and other parts of the Middle East. Phenotypic diversity had been calculated from six plant, spike and kernel attributes, and was found to be very large, even when compared with other larger collections of native wheats (Jain et al., 1975). This collection therefore was considered as a potentially valuable genetic resource for wheat breeding.

Grain quality was previously measured and analyzed in this collection, and its value for improving certain grain quality attributes of wheat had been assessed (Blum et al., 1988). However, the greatest interest in this collection was its potential drought resistance, in view of the aridity of the source region. While various agronomic characters as well as disease and pest tolerance were investigated in collections of landraces of several crops (Fraenkel and Soule, 1981), few evaluations were performed with respect to drought responses. The purpose of this study was to evaluate the extent of variation for drought resistance in this collection and to isolate the most resistant materials in this respect for wheat breeding.

MATERIALS AND METHODS

Twenty two populations of durum wheat (*Triticum durum*) and eight populations of common wheat (*T. aestivum* and *T. compactum*) were studied. Each population was represented by several accessions, the number of which depended on the diversity within each population (Poiarkova and Blum, 1983). Up to 68 accessions were tested in any single experiment. The seed source for any given experiment, common for all entries, was produced under favourable conditions at Bet Dagan.

Field trials, Gilat

Trials were planted in 1986 and 1987 at Gilat Experiment Station in the Northern Negev. This is a relatively dry site, situated about 80 km north-west of the collection site. Total seasonal rainfall was 184 and 268 mm in 1986 and 1987, respectively. Sixty eight entries were planted in a randomized block design with 3 replications. Each plot was 1.7 m wide and 5 m long, planted at 15 cm row spacing at a rate of 13 g m⁻¹. Planting was done at the optimal date (mid-November),

and germination was immediately effected by a light (20 mm) sprinkler irrigation. Weeds were controlled chemically and no diseases developed at this site. Severe water stress developed for about a month during the jointing stage (Feekes stages 7 to 10) in 1986 and for about a month and a half during the jointing-to-flowering stage (Feekes stages 6 to 10.5) in 1987. In both years some growth and yield were recovered by rainfall after anthesis.

As a water stress period developed in each of the two years, canopy temperatures were measured in all plots on clear days at midday with a hand-held infrared thermometer (Blum et al., 1982). Four and five measurements were performed at 4 to 7 day intervals during the drying cycle in 1986 and 1987, respectively. These measurements were averaged over all dates into one value per plot per experiment.

Heading dates were recorded in all plots. Grain yields were determined by combine harvesting the central 1.2 by 4 m area in each plot.

Rainout shelter, Bet Dagan 1987

The shelter consisted of a 500 m² greenhouse structure in the field, covered by a transparent polypropylene roof. All four walls were made of polyethylene curtains that could be rolled up manually to a height of 2 m above ground. When no rains occurred, the curtains were rolled up and the shelter was well-ventilated from all directions. A spray irrigation system was installed inside the shelter by hanging the tubings and the spray heads at 2.1 m above ground. The spray heads were "Naan" type 7102 with optimal water distribution to a distance of 4 m. The system was connected to a fertilization unit and a water metering system which allowed fertilization through the irrigation water. Wheat was planted under this shelter in the previous season (1986) in order to test-run the system. Total available soil moisture at planting, as determined by gravimetric soil samples to a depth of 1.5 m, was 102 mm. Only one irrigation of 80 mm was applied after planting, in order to drought-stress the crop and dry the soil at maturity. Gravimetric soil moisture determinations were made prior to planting of the 1987 experiment. The soil contained no available water to a depth of 120 cm, and had 23 mm of available water at a depth 120-150 cm.

The shelter was divided into an irrigated treatment and a stress treatment. In each part, 68 entries were planted in two replicates. Each experimental unit consisted of 4 rows, 1 m long at 15 cm spacing. The same number of seeds per plot were hand-planted on a late date (January 10, 1987) and germination was effected by an irrigation of 90 mm, which included fertilization at the rate of 10 g N and 12 g P₂O₅ per m². The irrigated treatment received full irrigation throughout the growing cycle, based on pan evaporation, reaching a total of 620 mm of applied water. The stress treatment received only a second irrigation of 100 mm at the beginning of tillering (Feekes stage 2), amounting to a total of 190 mm. As plants grew, they were supported by a stretched polyethylene net, set at heights of 30 and 70 cm above the ground to eliminate lodging.

Canopy temperature measurements in all plots began at the onset of jointing (Feekes stage 4) with an infrared thermometer, on clear days at midday. Six measurements were performed at about weekly intervals. Heading date was recorded in all plots. Upon maturity, each plot was

hand-harvested at the ground surface. Spikes were counted and threshed. Mean kernel weight was determined in a sample of 200 kernels. The remaining stover (including chaff) was weighed after drying for 24 h at 80 C. Biomass was calculated as the total above ground production, while harvest index expressed the fraction of grain in the biomass.

All measurements reported here were subjected to an analysis of variance. Simple correlations were calculated across landraces among all variables.

Field trial, Bet Dagan 1986

Sixty eight entries were planted on December 12, 1986 in a randomized block design with four replications. Plot size was the same as at Gilat, but row spacing was 30 cm. Germination was effected by rainfall immediately after planting. Total annual (seasonal) rainfall was 668 mm. One irrigation (60 mm) was applied just before heading and no plant water stress occurred during the growing season.

When each entry reached 18 days after heading, half of each plot was sprayed to full wetting with a 4% solution of magnesium chlorate. This treatment (Blum et al., 1983a) destroyed the photosynthetic source of the plants (leaves, glumes and awns), while the plant remained alive. Grain filling was then achieved only by mobilized plant reserves. Final kernel weight was recorded in desiccated and control plots. The percent of kernel weight loss under the treatment represented the genotype's ability for grain filling in the absence of photosynthesis, as the case is for a late-season severe drought stress.

Growth chamber

Forty four entries were grown in hydroponic nutrient culture in the growth chamber under 11 h day, at $925 \mu\text{mol m}^{-2} \text{s}^{-1}$ of irradiance and 15C night, 25C day temperatures. A commercial formulation of Hoagland's nutrient solution was used, adjusted to a pH of 6.1 and aerated continuously. Seed were germinated in paper towels and selected homogeneous seedlings were transferred intact to the nutrient culture when the first leaf emerged from the coleoptile. After 14 days in culture, half of the seedlings were transferred to a nutrient solution containing 20% polyethylene glycol (PEG6000), to induce water stress (Blum et al., 1980). Water potential of the PEG-containing solution was -0.59 MPa, as measured psychrometrically. The experimental design was split-plots, with the two solutions as main plots and entries as subplots. Four selected homogeneous plants per solution by entry combination served as replicates. Plants were individually harvested at the crown after 21 and 28 days in culture. Their dry weights were determined individually after drying at 80 C for 24 h. Growth rate was calculated from the two dry weight determinations in each solution. Growth inhibition by PEG-induced water stress was calculated as:

$$\text{Growth Inhibition (\%)} = ((W1 - S1) / W1) * 100,$$

where W1 was growth rate in control and S1 was growth rate in PEG solution.

After 28 days in culture, additional seedlings grown in PEG solution recovered overnight from water stress by replacing the PEG nutrient solution with a pure nutrient solution. The next

morning leaf samples were taken from the topmost expanded and viable leaves, and frozen at -18C. Similar samples were taken from additional control plants. Four samples were taken for each genotype x treatment combination. After thawing for 1 h, samples were placed in a thermocouple psychrometer (Decagon Devices Inc., Pullman Washington) for the measurement of osmotic potential. The difference in osmotic potential at full turgor between recovered and non-stressed plants was taken as an estimate of osmotic adjustment.

RESULTS

Plant production and phenology

Field trials, Gilat. Mean grain yield of all entries at Gilat was 97 and 240 g m⁻², in 1986 and 1987, respectively (Table 1). It varied significantly among landraces from 27 to 233 in 1986 and from 114 to 409 g m⁻² in 1987. The yield difference between the two years corresponded to the difference in total rainfall received in each year. Data on days to heading (Table 1) showed that landraces generally were late flowering, as compared with modern Israeli varieties, which were planted on the same date outside the experiment. For example, while mean days to heading for the landraces was 97 in Gilat-1986, it was 79 to 86 days in different modern cultivars planted at the site. This was confirmed in other experiments planted from 1985 to 1987 at Bet Dagan. A significant genotype x year interaction was not revealed for days to heading. In fact, mean days to heading and its range (Table 1) were very similar in both years, indicating that in this location heading date in these landraces was fairly stable.

Rainout shelter Bet Dagan 1987. Mean grain yield under stress (Table 1) was 227 g m⁻². Significant differences were detected for yield under stress between the landraces which ranged in yield from 50 to 350 g m⁻². Mean grain yield was reduced by water stress to an average of 74% of the irrigated controls (range of 15 to 101%). These data established that landraces differed extensively in their yield response to water stress and that yield of some landraces was not affected at all by the drought stress conditions imposed in the experiment. A general linear model regression of yield under stress on its components revealed that the relative contributions of spikes per m², kernels per spike and kernel weight to yield variations among landraces were 51, 29 and 20%, respectively (model R² was 0.935). Thus, variation in yield under stress among landraces was mostly affected by the number of spikes per unit area and the least affected by kernel weight. This result was obtained in spite of the fact that plant water stress increased with time (see below) and it was greatest during grain filling. Water stress induced earlier heading (Table 1), by an average of 3 days. A significant genotype x treatment interaction was not revealed for days to heading, indicating the relative stability in heading date of these landraces under changing moisture regimes.

Mean total biomass under irrigation was 782 g m⁻². Significant differences were detected for biomass under irrigation between the landraces which ranged in biomass from 824 to 1665 g

m⁻². Mean total biomass was reduced by water stress (Table 1) to an average of 79% of the irrigated controls (range of 21 to 103%). Mean harvest index under irrigation was 0.29 g g⁻¹. It was reduced by water stress to an average of 93% of the irrigated controls (Table 1). However, the effect of water stress on harvest index differed largely with landraces, whereas it was reduced to 57% in the poorest landrace while it increased to 136% in the best landrace, as compared with the irrigated controls.

Since early heading is considered an important attribute under dryland conditions and as all modern Israeli dryland wheat varieties are relatively early flowering, the longer growth duration of landraces from the semi-arid Northern Negev was perplexing. The association between grain yield under stress in Gilat and days to heading across landraces (Fig. 1) showed a trend for yield increase with earlier heading. The association was better in the drier (1986) year, supporting the present contention that earlier flowering ascribes a yield advantage under dryland conditions in this region. Days to heading were generally reduced under the rainout shelter, as compared with Gilat (Table 1), mainly because of the effect of later planting in the rainout shelter. A reduction in days to heading with the delay in planting at Bet Dagan or Gilat has been a very common observation in past experiments. The association between grain yield under stress and days to heading in the rainout shelter (Fig. 2) produced a non-linear positive regression, whereas higher yields were obtained in the medium to late flowering landraces. While the association was not strong, it did not indicate an advantage to early heading under these stress conditions and late planting. The difference in the association between yield under stress and days to heading between early and late planting can perhaps be used to explain why late flowering landraces were found in the semi-arid Northern Negev, as will be discussed below.

Physiological stress indices

Canopy temperatures in the different experiments were not standardized against ambient atmospheric variables such as air temperature, because of instrumentation problems. Still, the data was valuable in exploring the relative responses of the different landraces within an environment. Field trials, Gilat. Landraces differed significantly in mean canopy temperatures during a stress period at Gilat (Table 1). The differences were greater and more significant in the drier (1986) year. LSD's ($p \leq 0.05$) calculated for the 1986 data showed that a mean temperature increase of 0.6°C was sufficient to differentiate among landraces, within a mean temperature range of 20.0 to 25.3°C. In both years, mean canopy temperature was not associated with grain yield across landraces.

Rainout shelter Bet Dagan 1987. Canopy temperatures indicated a clear increase in plant stress with time in the stress plots (Fig. 3), as expressed in the increase in the stress-irrigated temperature differential with time. Some stress was already in evidence at 42 days after emergence (Feekes stage 4), but the greatest stress was experienced at and after heading (Feekes stages 10.2 to 10.5).

Mean canopy temperatures under stress varied significantly among landraces. They were positively associated across landraces with mean canopy temperatures in Gilat-1986 (Fig. 4). The association did not hold for Gilat-1987, most likely because of the wetter conditions and smaller variation in temperature among landraces in that year. 'Maximum' canopy temperatures under stress in the rainout shelter (Table 1) express data recorded on the last date of measurement, when stress was the greatest (Fig. 3). These temperatures were lower than the mean canopy temperature (Table 1) because of the cooler conditions on that day. However, the variation in 'maximum' temperatures was greater than the variation in mean temperatures between landraces (Table 1). Maximum (but not mean) canopy temperatures under stress in the rainout shelter were negatively correlated with grain yield and biomass under stress (Fig. 5). No significant correlations were revealed between canopy temperatures under stress and any of the yield components in the rainout shelter.

Growth chamber. Significant differences were detected among landraces in osmotic adjustment (Table 1). It ranged among landraces from 0.09 to 0.91 MPa. Evidently some landraces were nearly devoid of any osmotic adjustment while others excelled in this respect. Significant differences were detected among landraces in growth reduction by PEG-induced water stress. It ranged across landraces from practically nil to 100%. Growth reduction by PEG-induced water stress was negatively associated with osmotic adjustment (Fig. 6). Landraces of poorer osmotic adjustment tended to suffer a greater growth reduction under stress. Osmotic adjustment or growth reduction by PEG-stress in this experiment were not associated with grain yield in any of the experiments.

Field trial Bet Dagan 1986. Landraces ranged in plant height from 115 to 157 cm (Table 1). They may therefore be classified as tall, when compared with a typical height of 90 to 110 cm in modern semi-dwarf cultivars as measured at Bet Dagan for many years. Kernel weight loss by chemical desiccation (Table 1) averaged 20%. Significant differences were detected among landraces in kernel weight loss, ranging from practically no loss (0.3%) to a loss of 41.1%. Kernel weight loss was not correlated with kernel weight in non-desiccated plants. Neither was it correlated with yield in any of the experiments.

DISCUSSION

Drought resistance in the agronomic terms of yield production under drought stress or yield reduction by stress was found to be highly variable among wheat landraces from the Northern Negev. Large diversity for several physiological attributes of drought resistance also was observed among these landraces, which is in accordance to their documented large phenotypic diversity (Poiarkova and Blum, 1983). The diversity of this landrace population in drought resistance attributes may be associated with its inherent genetic diversity, which may ascribe an advantage under the changing environmental conditions typical to the semi-arid region. It is a common knowledge that the Bedouin farmers in this region maintain this diversity by mixing various wheats

and even wheat with barley as means for stabilizing food production. This diversity may also be explained by the possible traffic of seed into this small region from the more humid Northern areas, especially after drought years (Poiarkova and Blum, 1983).

When water stress developed and intensified after full tillering (in the rainout shelter), the more drought resistant landraces produced more grain because they sustained more spikes per unit area. Since the tillering stage was largely free of water stress, the difference in spike number among landraces under the effect of water stress could be ascribed to differential tiller survival or differences in potential tillering. The importance of tiller survival and spike number in sustaining yield under stress as revealed here is supported by results obtained for barley (Hadjichristodoulou, 1985), where tiller survival and spike numbers were considered as critical for yield under drought stress. Kernel weight was relatively less important than other components in explaining variations in grain yield under stress among landraces, even though stress was maximized during grain filling in the rainout shelter. The relative insensitivity of grain filling to water stress in these materials may possibly be ascribed to stem reserve mobilization. Mean kernel weight loss after chemical desiccation was relatively low (20%) in these landraces, as compared with common values of *ca.* 40% to 50% in modern high yielding semi-dwarf wheats (Blum et al., 1983b). Likely, the taller plant stature which is typical of these landraces (Table 1), is partly responsible for their better ability to support kernel growth under stress by stem reserve mobilization.

Plant phenology appeared to have an important effect on yield under stress, as reflected in the negative association between days to heading and yield under severe stress (Gilat 1986). A general trend for increased dryland wheat yield in early flowering genotypes is a very common observation in Israel and early heading is a major selection criterion for dryland wheat. These landraces were generally late flowering as compared with modern Israeli dryland cultivars. Their longer growth duration appears therefore to be in contrast with expectations of cultivars from the arid region from which they were collected. The negative association between days to heading and yield under stress was not in evidence in the rainout shelter experiment, where growth duration was reduced by late planting. Under late planting, medium to later flowering materials generally were the higher yielding. This is in complete accordance with the difference in planting date practices between the Bedwin farmer and modern growers. Bedouins practice late planting, because they would not plant before some moisture has accumulated after the first seasonal rains (during November-December). They may not realize the full potential of wet years when planting late, but they nearly always gain some production in the driest years. The modern farmer plants into a dry soil before the first rains (November), in order to take advantage of a full season while hoping for a wetter year. If this hope is not realized, his loss is minimized by a crop insurance program against total loss by a severe drought. This interpretation would support a re-evaluation of modern dryland wheat practices, by experimenting with late flowering varieties under late planting over variable moisture regimes.

On the average, harvest index was reduced by water stress by only about 8%. This resulted from the fact that it was significantly reduced in some landraces while it increased in others. Kanemasu (1983) reviewed evidence for changes in harvest index with water stress. While a general trend was seen for a decrease in harvest index under water stress, the results obtained here show that a strong genotypic effect may be expected in this respect. An increase in harvest index under drought stress in some landraces indicates that depending on genotype, vegetative growth may be relatively more sensitive than reproductive growth. No correlation existed between HI and biomass under stress ($r = -0.105$), while a significant correlation existed between HI and grain yield ($r = 0.585$; $p = 0.0001$). It follows that in spite of the large variations among landraces in biomass under stress, HI was largely determined by the effect of stress on grain yield. If harvest index is indeed largely affected by grain yield, there seems to be no apparent advantage (Donald and Hamblin, 1976) in using harvest index as a selection criterion in addition or instead of yield under stress.

Data on canopy temperatures under stress generally supported previous results (Blum et al., 1982) on the utility of infrared canopy temperature sensing for identifying genotypic variations in plant water stress. The increase in plant stress under the rainout shelter was well sensed by infrared thermometry, against a baseline of the irrigated plots. Landraces with lower canopy temperatures apparently were at a better plant water status (Blum et al., 1982). The positive correlation across landraces in canopy temperatures between the rainout shelter and the field environment in Gilat-1986 provides further credibility to the method in selection work. As already found (Blum et al., 1982), it was confirmed here that the method becomes more sensitive and useful as drought stress increases. This was seen in the greater temperature variation among landraces in the drier (1986) as compared with the wetter (1987) year at Gilat. Because of the complex association between plant water deficit and plant production, it was not expected that canopy temperatures would be simply associated with final plant production, across landraces. Still, maximum canopy temperature under stress in the rainout shelter was negatively associated with grain yield and biomass.

Osmotic adjustment has been receiving increased attention lately as a possibly important drought resistance mechanism in wheat (Morgan, 1984). Landraces differed significantly for osmotic adjustment under PEG-induced water stress. Values reaching 0.9 MPa of osmotic adjustment, as measured here, may be considered high in wheat (Blum et al., 1983c; Johnson et al., 1984). Growth reduction by PEG-induced water stress tended to be smaller for landraces with greater osmotic adjustment, showing that drought resistance and growth were associated with the osmotic adjustment of landraces within an experiment. However, osmotic adjustment as measured in the growth chamber experiment was not associated with yield or yield components under stress in the field or in the rainout shelter. Thus, The role of osmotic adjustment in drought resistance of these landraces can not be clearly elucidated. The strong effect of phenology and tiller production and survival on yield of landraces under stress may have masked the contribution of osmotic

adjustment these experiments. This is consistent with work in pearl millet (Bidinger et al., 1987), where phenology and developmental plasticity were found to be important for yield under drought stress, as compared with unique physiological attributes of stress adaptation.

All data acquired in this research were entered into a computerized database. The database was queried for landraces within the best 20% for yield in all stress environments, mean canopy temperatures in Gilat-1986, maximum canopy temperature in the rainout shelter (stress) and percent kernel weight loss by chemical desiccation. Four entries were recovered, all belonging to a *T. durum* population which has previously been identified (Poiarkova and Blum, 1983) as the very well known Mideastern landrace 'Juljuli'. This landrace population may therefore be taken as an important genetic resource for the improvement of drought resistance in wheat.

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Table 1: Means, coefficient of variation among landraces, ranges and statistical significance of differences among landraces for variables observed in 5 experiments.

Variable	Unit	Mean	CV (%)	range		Sig.
				min.	max	
<u>Gilat Dryland 1986</u>						
Days to heading	days	97	7.6	83	116	**
Canopy temperature	C	22.9	5.7	20.0	25.3	**
Grain yield	gr m ⁻²	97	41.9	27	233	**
<u>Gilat Dryland 1987</u>						
Days to heading	days	98	7.3	83	117	**
Canopy temperature	C	22.4	2.2	21.5	23.9	*
Grain yield	gr m ⁻²	240	26.4	114	410	**
<u>Rainout Shelter (stress)</u>						
Days to heading	days	84	7.5	72	98	**
stress/nonstress	%	96	6.1	78	104	*
Mean canopy temperature	C	21.3	3.8	19.8	23.1	*
Max. canopy temperature	C	19.7	7.9	17.2	21.9	**
Spikes per m ²	no.	259	22.0	95	404	**
stress/nonstress	%	91	26.8	29	120	**
Kernels per spike	no.	20.4	18.6	8.8	31.9	**
stress/nonstress	%	82	23.6	13	126	**
Kernel weight	mg	43.5	12.9	30.1	54.2	**
stress/nonstress	%	99	11.2	76	105	*
Total biomass	gr m ⁻²	782	23.3	284	1274	**
stress/nonstress	%	79	30.8	21	103	**
Grain yield	gr m ⁻²	227	25.6	50	350	**
stress/nonstress	%	74	33.5	15	141	**
Harvest index	gr gr ⁻¹	0.29	17.2	0.16	0.41	**
stress/nonstress	%	93	19.4	57	136	**
<u>Growth Chamber</u>						
Growth reduction by PEG	%	43	61.0	0	100	**
Osmotic adjustment	MPa	0.29	55.3	0.09	0.91	**
<u>Bet Dagan 1986</u>						
Plant hight	cm	131	8.6	115	157	
kernel weight loss	%	20.0	46.5	0.3	41.1	**

(*, **) Differences among landraces are significant at p=0.05 and p=0.01, respectively.

Fig. 1. The association across landraces between days to heading and grain yield in Gilat. A-1986 (184 mm of rainfall); B-1987 (268 mm of rainfall).

Fig. 2. The association across landraces between days to heading and grain yield under drought stress in the rainout shelter experiment (late planting).

Fig. 3. Mean canopy temperature differences between stressed and irrigated plots on six dates of measurement in the rainout shelter. (Vertical bars are S.D.; Arrow is mean days to heading under stress).

Fig. 4. The association between mean canopy temperature in Gilat-1986 and mean canopy temperature under stress in the rainout shelter (1987), across the same landraces.

Fig. 5. The association across landraces between maximum canopy temperature (temperature measured at peak water stress, see fig. 3) in the rainout shelter and (A) grain yield and (B) biomass under stress.

Fig. 6. The association across landraces between osmotic adjustment and growth reduction by PEG-induced water stress in the growth chamber.

PUBLICATIONS

- 1. The grain quality of landraces of wheat as compared with modern cultivars. Plant Breeding, 99:226-233, 1987.**
- 2. The drought response of landraces of wheat from the Northern Negev desert in Israel. Euphytica, 1989 (accepted).**
- 3. Yield stability and canopy temperatures of wheat genotypes under drought stress. (submitted)**