Comparative Evaluation of Drought Hardiness of Some Local and Exotic Wheat Varieties

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Efficiency of some techniques was compared to test the drought tolerance ability of 5 exotic and 11 local varieties. In one experiment, forty-day old wheat seedlings were subjected to atmospheric and soil moisture stress in a drought machine which could regulate varying levels of soil moisture, temperature and relative humidity to create stress conditions. Comparative tolerance of the varieties was adjudged by the number of seedlings survived following the treatment.

In the second experiment, the varieties were exposed to soil moisture stress by withholding irrigation. Drought hardiness of the varieties was scored on the basis of their differential survival rate and ultimate yield performance.

In both the tests Punjab 14, Thatcher and C. 228 appeared to be better drought tolerant whereas C.518 was the worst affected. Yield performance also exhibited a similar trend except for Thatcher which yielded low due to its late maturity. The results indicated that both the techniques can be usefully employed for detecting inherent differences in drought tolerance, the machine test was, however, more efficient in yielding added information on the relative importance of the various elements of drought.

INTRODUCTION

Almost one-third of the total wheat acreage in West Pakistan is located in the semi-arid areas dependent on natural precipitation. The rainfall being meagre and unevenly distributed, the crop is frequently exposed to severe moisture stresses, which results in extremely low yields. Even in the canal-irrigated areas the crop often faces short water supply during its critical period of growth, that causes poorer development of grains.

As there are hardly any chances of providing artificial irrigation to the crops in these rainfed areas, the only alternative to raise the production level is the evolution and introduction of drought tolerant varieties with good yielding ability under conditions of moisture stress. Although drought is one of the most important environmental factors that influence the growth and ultimate yield of crop plants in arid and semi-arid regions, little specific breeding for drought-resistance has been done anywhere in the country. This is probably

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due to the lack of complete understanding of the complex plant reactions to a severe moisture stress as well as lack of information on appropriate testing technique—a pre-requisite for an effective breeding programme for drought resistance. The studies reported in this paper were designed to develop and to test some techniques to screen genetic material for its ability to withstand moisture stress.

REVIEW OF LITERATURE

Shirley (1934) used an apparatus consisting of a revolving table working in a closed chamber to study the atmospheric drought resistance in pine seedlings under controlled conditions of temperature, light and relative humidity. Drought endurance was judged from the number of days taken by the seedlings to die at a temperature of 35° to 40°C. AaModt (1935) employed a tunnel-shaped glass enclosure to create atmospheric drought by blowing hot air at a constant speed. He provided a moving chain in the chamber to ensure uniform treatment to the seedlings. Bayles *et al.* (1937) used similar apparatus for testing comparative drought resistance of wheat seedlings. Temperature was regulated at 92° to 98°F. and the resistance was calculated from the relative amount of the injury in various varieties. Later, McAlister (1944) used a similar chamber to study the comparative hardiness of grass species, in which a current of hot air at a temperature of 80°F. was blown over the seedlings at a constant speed of 5 miles per hour. Results corresponded with the known field performance of the species. Sandhu and Laude (1958) subjected winter wheat seedlings to temperature ranges of 132-134°F. and 96-98°F. for 24-26 hours and 98 hours, respectively, alongwith soil moisture stress. Survival values obtained agreed with the field performance of the varieties tested. Kinbacher (1962) studied the effect of relative humidity on heat resistance of oats using a temperature range of 110°F. at relative humidity levels of 50-75-100 per cent for 8 hours. He found that at low level of humidity the plants endured heat more effectively due to increased transpiration which had a cooling effect.

Asana and Saini (1958) exposed wheat plants of three varieties to intermittent drought and found that in the first four weeks after dehiscense drought hastened the yellowing of leaves and stems and reduced the number of grains. Reduction in leaf and stem surface after earing, however, had no effect on grain development, so long as the ears remained green. Aspinall (1961) found that in cereals, grain yield was halved by late drought but was unaffected by pre-flowering moisture stress. Chinoy (1960) ascribed the greater susceptibility of late maturing types of wheat in India to the ascending temperatures during the ripening phase and not to any hereditary differences. He further observed that growth analysis alone could not determine the relative drought resistance

of varieties having different periods of maturity. Afzal (1962), in his wilt endurance studies on wheat, suggested that leaf water contents during wilting, particularly critical leaf water contents, were of special importance to determine the relative drought hardiness of various varieties.

MATERIAL AND METHODS

The experimental material consisted of 3 sets of wheat varieties. Set 1 comprised 8 commercial types, both old and new, C271, C273, C228, C217, C518, Punjab 14, Type 8A and 9D, which differed in time of maturity and drought tolerance. Set II contained 3 promising new cultures, 30/2, 5660 and 5667, developed locally for the semi-arid regions of West Pakistan. Set III included 5 exotic strains, namely Thatcher, Golden Ball, Hard Federation, Dirk and Norin 53, selected for their drought tolerance and general adaptability. Drought resistance of these varieties was tested at Lyallpur during the years 1961-63.

To assess the impact of various climatic factors on the drought tolerance of the experimental material, a small machine was improvised which made it possible to regulate temperature, relative humidity, wind velocity, soil moisture and nutrition. The machine consisted of a thermo-controlled double walled glass chamber of 50-inch height and 66-inch diameter and was mounted on a wooden table. A revolving platform of 60-inch diameter was installed inside the chamber and was connected to a one-horse power electric motor through a gear system, providing a range of 10, 20 and 30 revolutions per minute. The platform was fitted with roller bearings underneath to avoid tilting and to ensure smooth and light running. Another one-horse power electric motor operated a 12-inch diameter blower at 1600 RPM which delivered preheated air into the chamber through a brasspipe of 1¼-inch diameter. Air was electrically heated and blown into a humidity control cell containing ten 16×12-inch trays in which calcium chloride was used as a desiccant. A filter was provided to prevent entry of clacium chloride particles into the chamber. Two heating plates of 1000 watts each, were suspended inside the chamber and coupled with a thermostat to make up for the heat losses through radiaion. A 16-inch size electric fan was fixed to ceiling to avoid formation of any air or temperature pockets during the treatment. System of air circulation was a closed circuit type, *i.e.*, the air was drawn from the chamber, dried and reblasted inside. The machine was installed in the open to ensure natural light for the material tested. All joints were insulated with rubber padding. (Fig. 1).

The following four different sets of conditions were accomplished in the machine: 1. High temperature (110°F.), low relative humidity (20-25 per cent) and normal soil moisture (15 per cent). 2. High temperature, normal

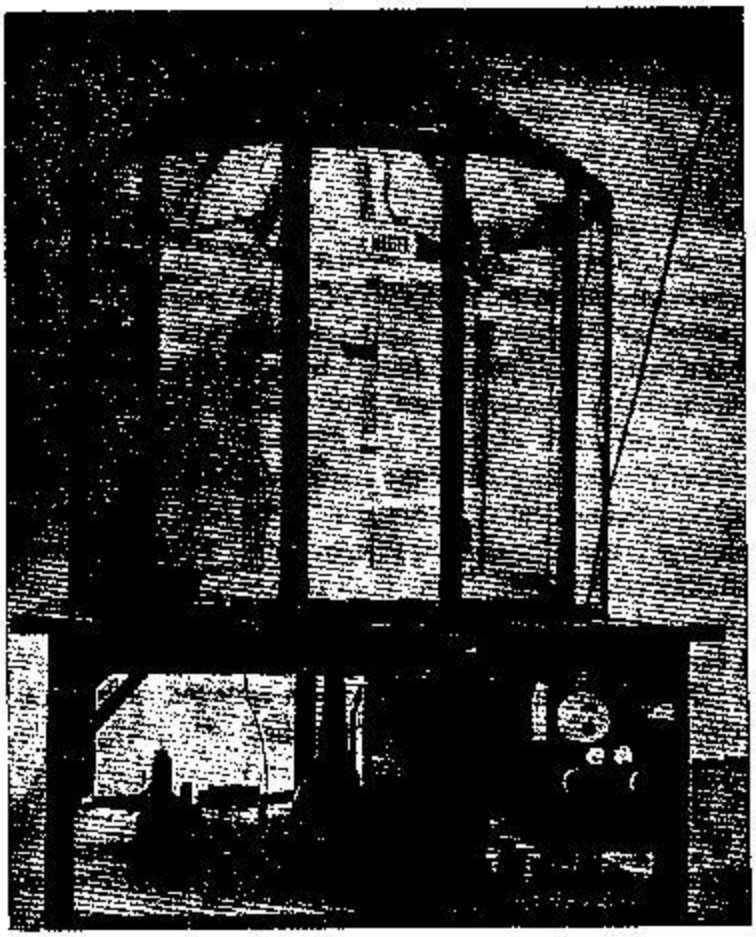

Fig. 1.—Front View of the Drought Machine

relative humidity (60-70 per cent) and normal soil moisture. 3. High temperature, low humidity and low soil moisture (7 per cent) and 4. Normal temperature (90°F.), low relative humidity and normal soil moisture.

The material for machine tests, was grown in small tin pots of one pound capacity. River sand was thoroughly sieved and washed free of salts and nutrients, using distilled water for the final washing. The sand was sun-dried, analysed for moisture contents and the labelled pots were filled at the rate of one pound of sand per pot. Four seeds were dibbled in each pot, and irrigated with Sach's nutrient solution. Twenty potted plants of a variety were used for each treatment. Forty days after planting, ten pots with equally vigorous seedlings were selected from each variety retaining only two seedlings in each pot. Soil moisture was replenished to the desired level by weighing the individual pot and restoring the deficit, if any, by adding nutrient solution,

The pots were wrapped in card-board to avoid excessive heating of the couter surface and plugged by cotton on the top to minimize surface evaporation before they were placed into the machine at random.

In all cases the tratment was started at 6 a.m. and was stopped when 50 per cent mortality was observed except in treatment 4, where it was stopped after 36 hours.

After the treatments, the pots were unpacked and irrigated with nutrient solution regularly for ten days to record survival, on variety basis. Every treatment was repeated twice during each of the two years.

To ascertain the relative drought resistance, the material under study was planted in earthenware pots of 10-inch top size, and administered artificial soil drought shock at the seedling stage. Pots were filled with field soil pulverized to uniform structure, half of which was reserved for next year's experiment. Fifty pots were planted to each of the sixteen varieties with 10 seeds dibbled per pot and later thinned out to seven seedlings per pot. The pots were placed inside a wire cage in the field and were watered daily. The irrigation was stopped on the 40th day after sowing during both the years, and was restarted when about 50 per cent mortality had been obtained. Forty pots of each variety were then sorted out and survival count taken after the 10th day of renewed irrigation. Observation and data on yield were recorded on pot basis for each variety occupying 20 pots carrying 4 plants each.

RESULTS

1. Effect of atmospheric and soil drought

Data on sixteen wheat varieties tested for their reaction to the change in atmospheric temperature, relative humidity and soil moisture levels are reported in Table 1. Varietal differences for survival under stress were statistically significant. In set 1, where high temperature was coupled with low humidity and optimum soil moisture, a maximum survival value of 17.00 seedlings was noted in variety, Punjab 14, followed by Thatcher, C228 and Norin 53 with no significant differences. However, variety C518 gave the lowest value of 7.50 seedlings and significantly differed from all the other varieties.

In set 2, providing high temperature with normal relative humidity and optimum soil moisture, the varietal behaviour was more or less the same. Punjab 14 had the maximum survival of 15.75 seedlings and was not significantly different from C228, C217, 9D, Thatcher and Norin 53, with values ranging between 14.00 and 15.5. Variety C518 was again the worst hit with 8.75 seedlings only.

Under set 3, where low soil moisture was combined with high temperature and low humidity, the varieties exhibited the highest mortality. Variety Thatcher

TABLE 1. *Mean seedling survival in 16 wheat varieties at different levels of temperature, relative humidity and soil moisture.*

Variety	Mean survival	Stat. Sig.*	Variety	Mean survival	Stat. Sig.*
	Set 1			Set 2	
Punjab 14	17.00	a	Punjab 14	15.75	a
Thatcher	16.25	ab	Thatcher	15.50	a
C 228	15.75	ab	Norin 53	14.75	ab
Norin 53	15.25	ab	C 228	14.50	abc
C 217	15.00	bc	C 217	14.00	abcd
H. Federation	14.75	bc	Type 9D	14.00	abcd
Dirk	14.50	bcb	5667	13.25	bcde
Type 8A	13.25	cde	C 273	12.50	cde
C 271	12.75	de	5660	12.50	cde
5667	12.75	de	Type 8A	12.50	cde
Type 9D	12.75	de	Dirk	12.50	cde
C 273	12.22	e	H. Federation	12.25	de
5660	12.22	e	C 271	12.00	de
30/2	12.00	e	30/2	11.25	e
Golden Ball	11.75	e	Golden Ball	11.25	e
C 518	7.50		C 518	8.75	
S. E.	0.58		S. E.	0.64	
	Set 3			Set 4	
Thatcher	14.50	a	Punjab 14	20.00	a
Punjab 14	13.75	ab	5667	20.00	a
Type 9D	12.25	bc	30/2	20.00	a
Type 8A	12.00	bc	C 217	20.00	a
Norin 53	12.00	bc	Type 8A	20.00	a
C 228	11.75	bcd	Type 9D	20.00	a
5660	11.75	bcd	H. Federation	20.00	a
5667	11.75	bcd	Dirk	20.00	a
C 217	11.75	cde	Norin 53	20.00	a
Dirk	11.50	cdef	Thatcher	19.75	ab
H. Federation	11.25	cdef	C 228	19.75	ab
C 273	11.00	cdef	C 273	19.50	ab
Golden Ball	10.75	def	Golden Ball	19.50	ab
C 271	9.75	ef	5660	19.25	ab
30/2	9.50	f	C 271	19.00	b
C 518	9.25		C 518	18.00	
	4.00				
S. E.	0.64		S. E.	0.26	

*Varieties having the same letter do not differ significantly at the 5 per cent level by Duncan's new multiple range test.

was on top with a survival rate of 14.50 seedlings, followed by Punjab 14 with 13.75 seedlings. The two were, however, not significantly different. Variety C518 with only 4.00 seedlings was the poorest survivor and was significantly different from the remaining 15 varieties.

In set 4, where stress was imposed only through low relative humidity, the varieties showed very little mortality. Nine of the varieties including Punjab 14 and C217 gave 100 per cent survival. Lowest average survival of 18.00 seedlings was recorded for C518.

2. Comparative wilt endurance of the varieties under study

(*i*) **Plant survival.** Varietal differences for plant survival were significant during both the years (Table 2). Punjab 14 gave the maximum average survival of 5.40 and 5.50 seedlings per pot in the years 1961-62 and 1962-63, respectively. Varieties, Norin 53 and Thatcher were fairly close to Punjab 14 in 1961-62 with 5.32 and 5.30 seedlings respectively. However, these two varieties, alongwith ten others, having values ranging between 4.82 and 5.25, were not significantly different from Punjab 14. In 1962-63, Punjab 14 was followed by Type 9D, Norin 53, C228, Thatcher, Dirk, C273, Golden Ball and Type 8A, in order of merit. The difference among these varieties, however, were statistically non-significant. Lowest survival was observed in variety C518 during both the years, values being 4.25 and 4.12 plants, respectively. Although varieties 9D, C217 and C271 in the first year and 30/2 and C271 in the second year, had a higher plant survival than C518, the differences were not significant during both the years.

(*ii*) **Yield.** Grain yields for all varieties are shown in Table 3. Significant varietal differences were obtained in both the years. In 1961-62 Punjab 14, with a mean grain yield of 2.69 grams per pot, ranked highest. However, it was not significantly different from all other varieties except C518 and Thatcher. Variety Thatcher gave the lowest yield of 1.76 grams per pot and C518 with 1.96 grams was the second lowest and was significantly different from varieties Punjab 14, C228, 5660 and Dirk. In 1962-63, C228 gave the maximum yield of 3.08 grams per pot followed by Punjab 14 and Norin 53 each with 2.84 grams. Variety C518 gave the lowest yield of 2.06 grams per pot. Varieties Thatcher and Golden Ball performed slightly better than C518, but not significantly. The differences among most of the intermediate varieties, were also non-significant for both the years.

DISCUSSION

Drought in its proper sense is related to soil and sets in when the available soil moisture diminishes to an extent that the plant can no longer take up water from the soil rapidly enough to replace water lost to the air by transpiration.

TABLE 2. *Mean plant survival per pot, in wilt endurance studies at Lyallpur.*

1961-62			1962-63			Mean		
Variety	Mean survival	Stat.* Sig.	Variety	Mean survival	Stat.* Sig.	Variety	Mean survival	Stat.* Sig.
Punjab 14 ..	5.40	a	Punjab 14 ..	5.50	a	Punjab 14 ..	5.45	a
Norin 53 ..	5.32	ab	Type 9D ..	5.15	ab	Norin 58 ..	5.21	ab
Thatcher ..	5.30	ab	Norin 53 ..	5.10	abc	Thatcher ..	5.18	abc
Dirk ..	5.25	ab	C 228 ..	5.10	abc	C 228 ..	5.16	abc
C 228 ..	5.22	ab	Thatcher ..	5.07	abc	Dirk ..	5.15	abc
Type 8A ..	5.20	ab	Dirk ..	5.05	abc	Type 8A ..	5.06	abc
5667 ..	5.07	ab	C 273 ..	5.02	abc	Golden Ball	5.00	bcd
Golden Ball ..	5.02	ab	Golden Ball ..	4.97	abc	Type 9D ..	4.98	bcd
H. Federation ..	5.02	ab	Type 8A ..	4.92	abc	5667 ..	4.98	bcd
5660 ..	4.97	ab	5667 ..	4.90	dc	C 273 ..	4.96	bcd
30/2 ..	4.90	ab	5660 ..	4.87	bc	H. Federation	4.92	bcd
C 273 ..	4.90	ab	H. Federation	4.82	bc	5660 ..	4.92	bcd
Type 9D ..	4.82	abc	C 217 ..	4.82	bc	C 217 ..	4.78	cd
C 217 ..	4.75	bc	30/2 ..	4.62	bcd	30/2 ..	4.76	cd
C 271 ..	4.72	bc	C 271 ..	4.50	cd	C 271 ..	4.61	d
C 518 ..	4.25	c	C 518 ..	4.12	d	C 518 ..	4.18	
S. E. ..	0.19		S. E. ..	0.18		S. E. ..	0.13	

*Varieties having the same letter do not differ significantly at the 5 per cent level by Duncan's new multiple range test.

TABLE 3. *Mean grain yield of sixteen wheat varieties tested in wilt endurance experiment at Lyalpur, their standard errors and statistical significance.*

1961-62			1962-63			Mean		
Veriety	Yield gms/pot.	Stat.* Sig.	Variety	Yield gms/pot	Stat.* Sig.	Variety	Yield gms/pot	Stat.* Sig.
Punjab 14	2.69	a	C 228	3.08	a	C 228	2.86	a
C 228	2.64	a	Punjab 14	2.84	ab	Punjab 14	2.76	ab
5660	2.63	a	Norin 53	2.84	ab	Norin 53	2.68	bc
Dirk	2.58	a	Dirk	2.78	ab	Dirk	2.68	bc
Norin 53	2.53	ab	Type 8A	2.74	ab	5660	2.64	bc
C 273	2.53	ab	5667	2.74	ab	Type 8A	2.62	bc
C 271	2.50	ab	C 217	2.74	ab	5667	2.59	bcd
Type 8A	2.50	ab	C 271	2.69	ab	C 271	2.59	bcd
Type 9D	2.44	ab	5660	2.66	ab	C 273	2.58	cd
5667	2.44	ab	C 273	2.63	b	C 217	2.56	cd
C 217	2.38	ab	Type 9D	2.59	b	Type 9D	2.51	cd
H. Federation	2.35	ab	H. Federation	2.56	bc	H. Federation	2.45	de
30/2	2.23	abc	30/2	2.43	bcd	30/2	2.33	e
Golden Ball	2.10	abc	Golden Ball	2.16	cd	Golden Ball	2.13	f
C 518	1.96	bc	Thatcher	2.14	cd	C 518	2.01	fg
Thatcher	1.76	c	C 518	2.06	d	Thatcher	1.95	g
S. E.	0.19		S. E.	0.14		S. E.	0.06	

*Varieties having the same letter do not differ significantly at the 5 per cent level by Duncan's new multiple range test.

An imbalance, therefore, occurs between the moisture in the soil and the amount transpired. Since transpiration largely depends on the atmospheric temperature and relative humidity, the drought machine used in this study was so improvised as to control these variables of drought. A maximum temperature of 110°F. was used, which is the highest reached during the growth period of wheat under natural field conditions in West Pakistan.

The varieties, Punjab 14 and Thatcher, consistently gave the best survival rate under all conditions tried in this machine, whereas, variety C518 showed the lowest survival rate (Table 1). It is indicated that variation in temperature as well as in soil moisture produced a more significant effect on seedling survival than variation in relative humidity. Variety C518 which is recommended for fertile lands with abundant water supply can also outyield others in normal conditions. The consistent varietal reaction to different drought variables seems to be conditioned genetically as these varieties react differently to the extremes of the drought variables. Correlation of survival rate at the seedling stage with economic characters like yield was, however, not worked.

In the other experiment in which only soil moisture was controlled the survival was almost the same as observed in the drought machine experiment. Varieties, Punjab 14, Thatcher and Norin 53, were the best and C518 again the poorest survivor (Table 2). This would seem to indicate that this less complicated method can be used more conveniently for the selection of drought tolerant material. In similar studies in wheat, Asana (1957) pointed out that to bring into play the inherent capabilities of the various varieties to survive after adverse conditions the material should be repeatedly subjected to drought shocks. One important object in breeding varieties of wheat is the maximum grain yield and, therefore, the drought resistance of a variety has also to be considered from the yield point of view. Punjab 14 which had the highest survival of plants, gave the highest grain yield per pot (Table 3). But, on the other hand, variety, Thatcher, which also had the highest number of plants recovered from drought shock, gave the lowest grain yield due apparently to its late maturity. It may, therefore, be emphasized that the varieties to be tested for relative drought resistance ought to be uniform in ripening. Within the same maturity group, the varieties that gave better survival of plants, as for instance, C228 and Punjab 14, also produced the highest grain yield. It may be pointed out that the drought shock was administered only once at the seedling stage, so the varieties may react differently than they did in this study to moisture stress at any subsequent stage of development, particularly the critical stage. This point needs further investigation. It is evident from the foregoing discussion that if the varieties differ in their maturity range, seedling tests would be more reliable criteria as compared to growth and yield analysis.

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