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RESPONSE OF CHICKPEA (CICER ARIETINUM L.) TO GYPSUM AND PHOSPHORUS APPLICATION IN SODIC SOIL

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ABSTRACT

In a pot experiment on a ameliorated sodic loamy sand soil, the response of chickpea was observed as a function of levels of phosphorus (0, 20, 40 and 60 kg P_2O_5/ha). The soil ameliorated with gypsum upto 50% G.R. of soil showed increase in grain yield and other growth parameters (germination and nodulation) significantly and decrease in the pH and ESP to 8.1 and 12 (below critical level) from 9.6 and 42 of control, respectively. Phosphorus application only upto 40 kg P_2O_5/ha increased the grain yield significantly.

INTRODUCTION

In arid and semi arid areas of northern India, the underground waters, mostly brackish, are being exploited on large scale for irrigation. An appreciable proportion of these waters is having high residual sodium carbonate (RSC). The continuous use of such waters has been reported to build up high levels of sodium in the root zone. Gypsum application has been frequently recommended for reclamation of these soils. Bhumbla (1972) reported that gypsum application at one fourth of the gypsum requirement was adequate for shallow rooted crops in highly alkali soils of Indo-Gangetic plain. Deo and Kothari (1989) obtained highest yield of wheat with the addition of gypsum at 50% G.R. of soil. This study was undertaken to know the feasibility performance of chickpea, in reclaimed sodic soil.

MATERIAL AND METHODS

An experiment was initiated in October 1985 in cement pots (30 x 30 x 40 cm) fixed in the field at the Haryana Agricultural University, Regional Research Station, Bawal. Bawal loamy sand soil (pH 1:2=9.6, EC 1:2=0.23 dS m^{-1}, ESP=42 and CEC=9.1 me/100 g soil) irrigated with sodic water (RSC=12 meL^{-1}, SAR=26.6 and EC 1.934 dS m^{-1}) for 10 years was treated with five levels of gypsum i.e. 0, 25, 50, 75 and 100% gypsum requirement (G.R.) of the soil in 2 x 5 m. plots. The plots were watered and incubated in situ for one month. Upper 15 cm of treated soil

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was collected from each plot, mixed, sieved and 19 kg of air dried soil was filled in pots. Four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5/ha) through KH_2PO_4 at each gypsum levels were replicated thrice in a randomised block design. Each pot was also supplied with 10,5 and 5 ppm of N, Zn and Fe, respectively. After thorough mixing the soil was packed to a uniform density of 1.5 g cm^{-3}. In each pot ten seeds of chickpea (*Cicer arietinum* L.) CV H-208 were sown on 21st October 1985 and after completion of germination, two plants were allowed to grow in each pot. Recommended cultural practices were followed throughout the growth season. The crop was given six irrigations of two litres each per pot with tap water (RSC=3.5 meL^{-1}, SAR =24.2 and EC=2.0 dS m^{-1}). The crop was harvested after maturity. The nodules were collected at flowering stage (117 days after sowing) from each pot, washed and soaked with filter paper and weighed. For dry matter yield, the plants were washed, dried in an oven at 70°C and weighed. The soil samples from each pot, both at the time of sowing and after harvest of the crop, were taken and analysed for pH (1:2), EC (1:2) and ESP by using the procedure outlined in USDA Handbook No. 60 (Richards 1954).

RESULTS AND DISCUSSION

Soil Characteristics

With increasing levels of gypsum application, pH and ESP of soil decreased while EC increased before sowing and after harvest of the crop (Table 1). Gypsum application @ 50% GR of soil decreased the pH (from 9.6 to 8.1) and ESP (from 42 to 12) below the critical limit and the increase in the values of EC (0.23 to 0.50 dSm^{-1}) were also below the critical limit.

Table 1. Effect of gypsum application on soil characteristics

Gypsum (% GR of soil)	pH (1 : 2)		EC (1 : 2) dSm^{-1}		ESP	
	B.S.*	A.H.**	B.S.	A.H.	B.S.	A.H.
0	9.58	9.59	0.23	0.31	42.0	44.5
25	8.88	8.90	0.34	0.34	25.0	27.0
50	8.10	8.30	0.50	0.61	12.0	12.5
75	7.93	8.00	0.84	0.98	10.0	10.5
100	7.78	7.90	1.04	1.20	9.0	9.0

*Before sowing **After harvest

Germination

Per cent germination increased with the gypsum application upto 50% GR and decreased there after over control. Phosphorus application did not affect the germination upto 40 kg P_2O_5/ha (Table 2). Maximum germination (96%) was recorded when gypsum and phosphorus were added @ 50% GR of soil and 40 kg P_2O_5/ha, respectively.

Table 2. Effect of gypsum and phosphorus application on growth attributes of chickpea

Gypsum (% GR of soil)	Levels of Phosphorus (Kg P_2O_5/ha) 0	20	40	60	Mean
	Per cent germination				
0	66	63	66	54	62.0
25	76	79	88	68	77.8
50	93	93	96	78	90.0
75	80	85	82	66	78.3
100	77	80	78	55	72.0
Mean	78.4	80.0	81.6	64.0	
	Nodule fresh weight (g/pot)				
0	5.5	8.5	8.5	8.0	7.6
25	7.5	14.7	14.5	14.7	12.8
50	17.2	18.5	19.5	18.5	18.4
75	22.0	24.5	28.5	29.0	26.0
100	17.0	19.2	18.0	19.5	18.3
Mean	13.8	17.0	17.8	17.9	
	Grain yield (g/pot)				
0	6.3	9.2	10.2	10.2	8.9
25	8.4	9.8	10.6	10.8	9.9
50	9.3	10.9	11.6	11.8	10.8
75	9.6	10.9	11.7	12.2	11.1
100	8.2	9.3	10.9	12.0	10.1
Mean	8.4	10.0	11.0	11.4	

CD 5%	Per cent germination	Nodule weight	Grain yield
Gypsum	12.0	5.2	0.8
Phosphorus	9.0	3.1	0.6

Nodulation

The nodule fresh weight increased significantly with gypsum application upto 75% and decreased at 100% GR of soil (Table 2). Phosphorus application at and above 20 kg P_2O_5/ha increased the nodule fresh weight significantly. Maximum weight of nodules was recorded in the pots in which gypsum and phosphorus were applied @ 75% GR of soil and 40 kg P_2O_5/ha.

Grain yield

Significant increase in grain yield due to gypsum application upto 50% GR of soil was observed (Table 2). Grain yield at 50 and 75% GR of soil are statistically at par and decreased at 100% GR of soil. Highest yield of chickpea was recorded in pot in which gypsum and phosphorus were applied @ 75% GR of soil and 60 kg P_2O_5/ha, respectively. However, at lower levels of gypsum application chickpea responded upto 20 kg P_2O_5/ha.

to growing at latitudes in India. Recently early pearl millet hybrids that mature in 60-65 days have been produced in India. These hybrids e.g., HHB 67 have both good agronomic traits, and rapid growth rates, and could be used to exploit the more marginal environments for pearl millet where temperatures are high, and rainfall is inadquate and variable.

Evidence from a single pearl millet hybrid, BK 560, has shown that within a seed population there are large variations in the rate of germination, and that seeds which germinate earlier are less sensitive to high (45-50°C) temperatures (Garcia-Huidobro et al. 1982). The large variation in germination rates among pearl millet landraces has been demonstrated by Mohamed (1984) but he did not explore the relationship between high germination rate and tolerance to supra-optimal temperatures. A combination of both traits would confer considerable advantage to early pearl millet hybrids in their utilization for contingent cropping.

The objective of this investigation is to determine the response of two pearl millet hybrids with contrasting germination rates to supra-optimal temperatures.

MATERIAL AND METHODS

Experiment 1

Four pearl millet hybrids BJ 104, ICMH 88951, HHB 67, and ICMH 87913 were used. Relevant information about the hybrids is given in Table 1. Genotypes of different durations were chosen to determine whether the rate of germination is correlated with time to maturity. ICMH 88951 and HHB 67 are short-duration hybrids with the same male-sterile parent. BJ 104, formerly grown extensively in India, has a 80-85 d duration, and was used as a control. ICMH 87913 is a medium-duration hybrid that matures in 85-90 d. All seeds were produced during the rainy season and stored at room temperature (20 to 25°C) for 6 months prior to the germination studies.

Table 1. Origin, average seed weight (mg/seed) and moisture content (dry weight basis) of four pearl millet cultivars

Cultiver	Male Sterile	Pollinator	Crop Duration (d)	Dry weight (mg/seed)	Moisture content (%)
BJ 104	5141A	J 104	80-85	5.7	5%
ICMH 88951	843A	BSEC top cross pollinator	60-65	10.0	9%
HHB 67	843A	883-2	60-65	13.3	10%
ICMH 87913	862A	(843BxB282x 314EXB-30-2-1-1) -13-B-2	85-90	9.0	11%

Seeds, selected for uniformity in size, were germinated in petri-dishes lined with moist filter paper (Whatman No. 1). Each petri-dish containing 10 seeds was placed on a large (180 cm x 120 cm) temperature gradient plate, which consisted of twelve compartments, 6 on each side. The plate was an improved version of that described by Garcia-Huidobro et al. (1982) and Mohamed (1984). The gradient plate was controlled by a CR21x data logger (Campbell Scientific Inc. USA) with an AM 32 multiplexer, that was also used to monitor the temperatures inside the petri-dishes. Copper constantum thermocouples (30 SWG) were used to measure temperature. Internal dimensions of individual plate compartments were 53.5 x 24.2 cm and a measurable difference in temperature between the two sides of each compartment (3-7°C) allowed the use of two temperature treatments within the same compartment. The lowest plate temperature was set at 5°C and the highest at 52°C.

Two hybrids were germinated at a time over a range of 12 constant temperature ranging from low (7-8°C) to very high (49°C). For each temperature treatment, four replications were used in a randomised design. Germination counts were made four times a day. Germination started 18 h after soaking, and was considered successful when the radicle was 10 mm long according to the criterion described by Mohamed (1984).

Experiment 2

Two hybrids, HHB 67 (short) and BJ 104 (medium) and three temperature regimes; 30°C, 40°C and 45°C were used for 3 different durations (1-6 h). An initial imbibition period of 2, 4, or 6 h at 30°C was followed by a period (Stage A) for 1, 2, 3 or 4 hours at 40°C before being moved to 45°C at 1 or 3 h (Stage B), and finally to 30°C until the end of the germination period. The treatments were designed to provide a range of conditions that might be experienced in the natural environment. Six treatments bypassed Stage A and were moved directly to Stage B (i.e., 3 x 2=6 treatments). Three control treatments i.e., without Stages A and B were imopsed at constant 30°C, 40°C and 45°C. Each treatment was replicated four times within each incubator, and each replication consisted of 10 seeds germinated in a petri-dish. Each hybrid was subjected to a total of 33 treatments. The incubators used had temperatures controlled to ± 1°C of the mean temperature. The procedure for germination counts and addition of weter was similar to that for Experiment 1.

RESULTS AND DISCUSSION

Experiment 1

Figure 1 shows the time course of germination of cultivar HHB 67 over a range of 11-38°C. There was no germination between 7-8°C and 41-49°C. At 45°C the radicle died after protuberance, and HHB 67 was the only cultivar with 5% germination at 11°C on day 8 from the beginning of the test.

Fractional germination (Gm), and rate of germination to 50% germination (1/t) against temperature for the four cultivars are shown in Figures 2 and 3 respectively. Cultivar HHB 67 has the highest fractional germination below 22°C and above 38°C

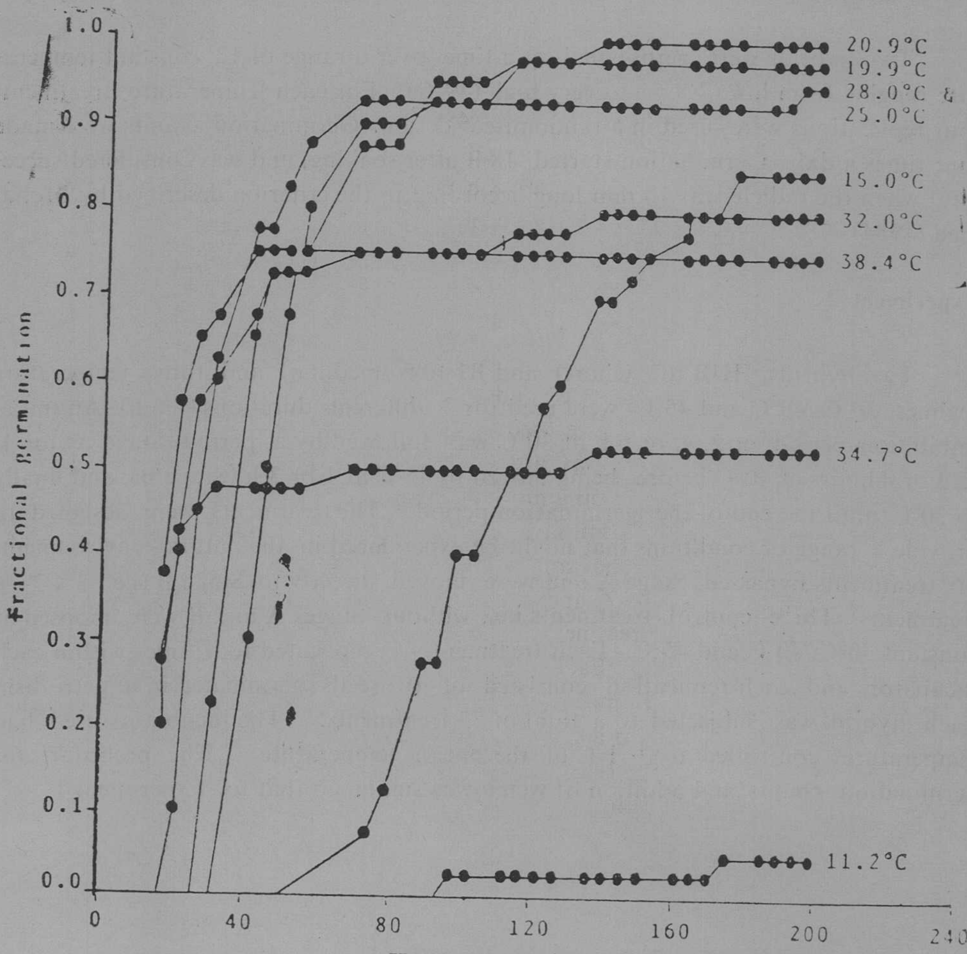

Fig. 1. The time course of fractional germination of pearl millet cultivar HHB 67 at constant temperatures

(Fig. 3). The remaining three hybrids are relatively similar in their percentage germination. The rate of germination of all four cultivars increased linearly with increase in temperature from a base temperature (T_t) to an optimum value (T_o). Above T_o, rate of germination decreased linearly to zero at a maximum temperature (T_m) of 46-48°C depending on the genotype. The relationship between the rate of germination and temperature below T_o is best fitted by the equation,

$$1/t = (T - T_b)\ \theta_1$$

and above To,

$$1/t = (T_m - T)\ \theta_2$$

Where θ_1 is the thermal time for germination below and above the optimum temperature θ_2 and T is mean temperature. Table 2 shows considerable variation between cultivars in cardinal temperatures, thermal times (θ_1 and θ_1) and the ratio of θ_1 to θ_2 which describes the relative sensitivity to temperature on both sides of T_o. The highest rate of germination was recorded for both HHB 67 and ICMH 88951, but BJ 104 had only half the optimum germination rate of the other hybrids and the greatest difference betwcen them was above 33°C. The response of ICHM 87913 was intermediate between the short duration hydribs and BJ 104 (Table 2). HHB 67 had the lowest base temperature (T_b) of 8°C.

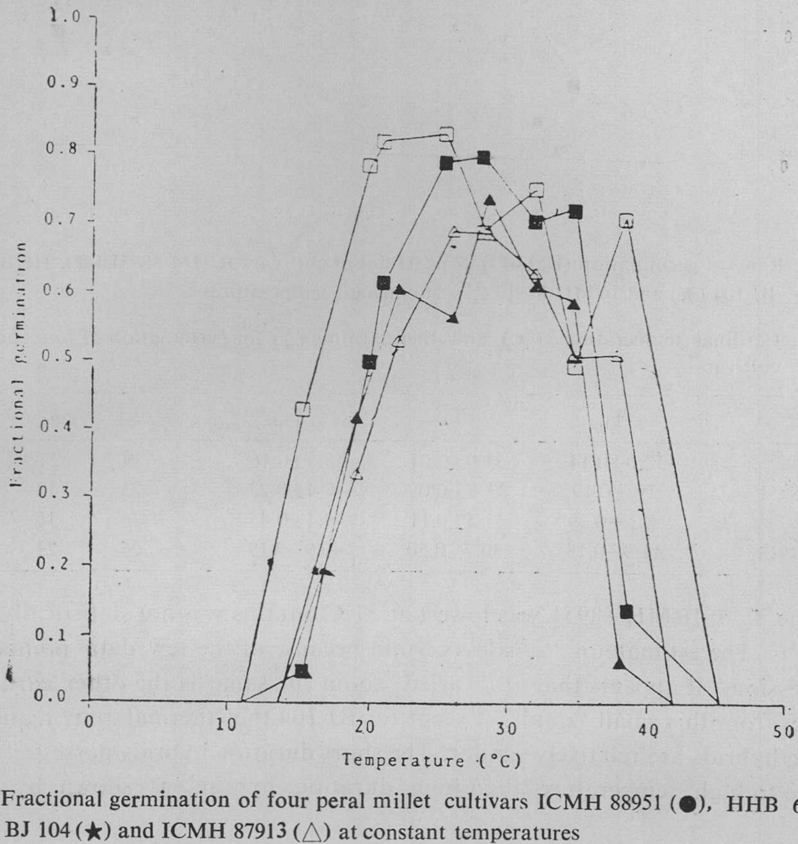

Fig. 2. Fractional germination of four peral millet cultivars ICMH 88951 (●), HHB 67 (□) BJ 104 (★) and ICMH 87913 (△) at constant temperatures

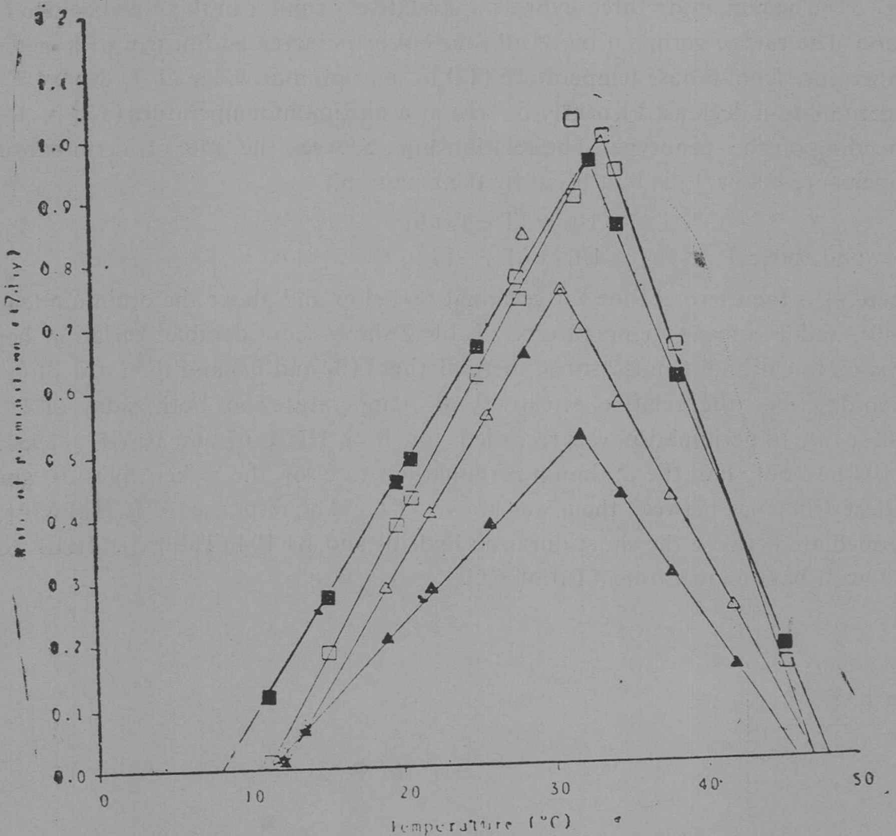

Fig. 3. Rates of germination (Rg) of four pearl millet cultivars ICHM 88951 (●), HHB 67 (□), BJ 104 (★) and ICMH 87913 (△) at constant temperatures

Table 2. Cardinal temperatures (°C) and thermal time (θ) for germination of four pearl millet cultivars

Variety	T_b	T_o	T_m	θ_1	θ_2	θ_1/θ_2
BJ 104	12.0±0.14	31.0±0.05	45.5±0.16	39	27	1.44
ICMH 88951	9 6±0.19	33.5±0.08	47.4±0.22	23	13	1.76
HHB 67	8.1±0.39	31.5±0.11	49.4±0.45	26	16	1.65
ICHM 87913	11.9±0.15	30.7±0.50	46.9±0.19	26	23	1.13

The T_o of ICMH 88951 was lowest at 31°C but this was not statistically different from 32°C. The estimate of T_m is less certain because of the few data points used in the regression. It appears that T_m varied about the same as the other cardinal temperatures from this small sample. Except for BJ 104 the thermal time requirements, θ_1 of the hybrids are relatively similar. The short duration hybrids possessed a greater tolerance to high temperature than long duration hybrids as shown by the lower value of θ_2.

The rates of germination as a function of temperature for the four pearl millet hybrids increased linearly with increasing temperature to a optimum value T_o of 31-34°C depending on the genotype, and declined sharply to zero at T_m. This response of rate of germination to temperature is consistent with that described by Garcia-Huidobro et al. (1982) for pearl millet, Mohamed (1984) for both pearl millet and groundnut and by Covell et al. (1986) for chickpea, lentil, and faba beans. Genotypic variations in rates of germination of pearl millet hybrids in this study confirmed earlier findings by Mohamed (1984) on pearl millet landraces. The high germination rate of both ICMH 88951 and HHB 67 is probably associated with the earliness of the total crop duration but a larger sample of genotypes representing the complete range of pearl millets is necessary for a generalisation of whether high germination rate is related to earliness.

The optimum rates of germination of these early hybrids are about 40% lower than those reported by Mohamed (1984) for the "Oasis" landrace from Niger which displayed the same cardinal temperatures as the early hybrids in this study. Seed size is related to germination rate in this study (Table 1) but conditions during seed storage, or under which seeds are produced can not be ruled out. The similarities of the germination responses of HHB 67 and ICMH 88951 suggest that this trait may be genetically controlled because they share a common parental line. HHB 67 is well adapted to western Rajasthan conditions, and it is not surprising that it is gaining popularity with farmers there. Measurements of soil temperature in western Rajasthan by Gupta (1983) indicated that during the onset of the rainy season it is not uncommon for mid-day soil temperatures to reach 45-55°C. Soil management by mulching with weed residue is effective in reducing soil temperature by 10-12°C (Gupta 1983).

Experiment 2

Germination of HHB 67 was delayed when seeds were subjected to short periods (1-4 h) of supra-optimal temperatures of 40°C and 45°C (Table 3). A reduction of 25%-100% in germination was observed for HHB 67 during the first 22 h following sowing in the heat treatments compared to the controls that were at constant 30°C. The control gave 50% germination whereas the highest and lowest germination percentages in the supra-optimal temperature treatments ranged form 0% to 37.5%. Germination was initiated at a constant temperature of 40°C during the first 22 h, whereas at 45°C no germination was observed. In none of the heat treatments BJ 104 germinated during the first 22 h after imbibition and even the constant 30°C treatment registered only 5% germination reflecting genotypic differences in germination rate.

Mean final germination percentage of both hybrids were unaffected by the initial period of imbibition (2-6 h) at 30°C or by duration of exposure to supra-optimal temperatures (Table 4). In HHB 67, there appeared to be no major effect of supra-optimal temperature treatments on the final percentage germination compared to the constant 30°C treatments. With BJ 104 the final percentage germination was reduced from 85% to 63% with 2-4 h of imbibition at 30°C. These results indicated that the faster germination rate of HHB 67 might have permitted it to escape the damaging effect of supra-optimal temperatures, although this was initially delayed by these temperatures (Fig. 4). Thus, there was no evidence that heat treatment had any beneficial effect on the germination of either hybrid.

Table 3. Effect of imbibition duration for 2, 4 and 6 h at 30°C and different heat durations at 40°C and 45°C on germination (%) of two pearl millet cultivars 22 h after sowing

Duration (h) at supra-optimal temperatures		Imbibition duration (h) at 30°C					
		HHB 67			BJ 104		
40°C	45°C	2	4	6	2	4	6
0	1	22	30	37	0	0	0
0	3	12	17	32	0	0	0
1	1	20	37	2	0	0	0
1	3	7	15	15	0	0	0
2	1	12	20	15	0	0	0
2	3	2	5	7	0	0	0
3	1	20	20	15	0	0	0
3	8	5	2	15	0	0	0
4	1	7	12	25	0	0	0
4	3	0	2	10	0	0	0
Mean		11	16	17			
SE ±		2.3	3.3	3.3			
Constant 30°C		50	53	50	5	5	5

Table 4. Effect of imbibition durations for 2, 4 and 6 h at 30°C and different heat durations at 40°C and 45°C on maximum germination (%) of two pearl millet cultivars, 166 h after sowing

Duration (h) at supra-optimal temperatures		Imbibition duration (h) at 30°C					
		HHB 67			BJ 104		
40°C	45°C	2	4	6	2	4	6
0	1	67	70	77	82	55	82
0	3	67	75	80	57	72	70
1	1	92	72	67	60	57	75
1	3	87	80	73	52	47	62
2	1	80	80	87	82	67	77
2	3	87	75	67	50	72	75
3	1	82	80	67	65	67	65
3	3	72	67	85	62	62	85
4	1	72	80	72	55	60	67
4	3	75	75	70	62	65	70
Mean		78	75	74	63	62	75
SE ±		2.6	1.3	2.1	3.4	2.3	2.5
Constant 30°C		82	82	82	85	85	85

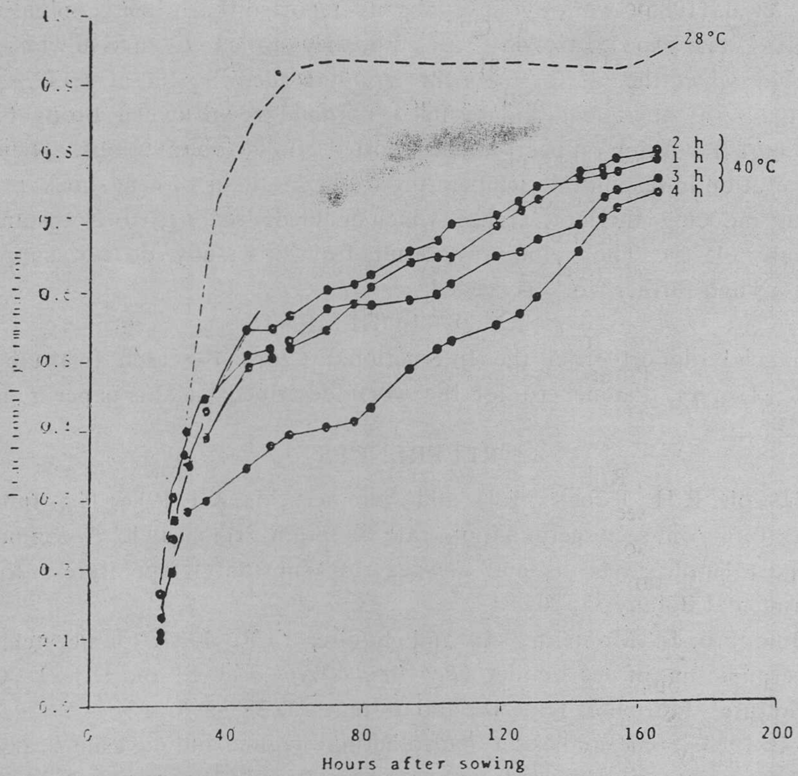

Fig. 4. The time course of mean fractional germination (G) for 1 h, 2 h, 3 h, and 4 h at 40°C of pearl millet cultivar HHB 67. Data for constant temperature treatments 28°C is included for comparison

The response of these two pearl millet hybrids was different from that reported by Garcia-Huidobro et al. (1982) in that they found that the rate of germination was more sensitive to exposure to high heat during imbibition than afterwards, and that the ultimate proportion of seeds which germinated was not affected by exposure to 45°C. In the present study, HHB 67 was more similar than BJ 104 to the BK 560 used in their studies. In sharp contrast the final percentage germination of BJ 104 was greatly reduced by exposure to supra-optimal temperatures during imbibition of 2-4 h. The similarity between HHB 67 and BK 560 was associated with their higher maximum germination rates which were twice that of BJ 104. This observation of the different genotypes is consistent with the evidence from seed populations i.e., seeds which are slow to germinate are more sensitive to high temperature. Further evidence by Garcia-Huidobro et al. (1982) indicated that both the germination rate and final percentage germination are greatly affected when seeds are exposed to 50°C for 1-5 h, reaching only a quarter of the values at constant 28°C.

Key et al. (1985), working on soyabeans reported that when germinating seedlings at 30°C were exposed to 45°C for 2 h, they failed to survive when brought to 30°C, but when the 45°C treatment was preceded by 2 h at 40°C, seedlings endured the 45°C treatment and resumed normal growth when brought to 30°C. Howarth (1987) working on pearl millet reported similar observations. They attributed the variation in response to temperature to the synthesis of heat shock proteins at 40°C, thus inducing thermotolerance which enabled seedlings to withstand higher temperatures (45°C). The preliminray results from this study do not support their observations and further work is needed.

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