Selection for Low Temperature Germination of Pearl Millet (Pennisetum typhoideum Rich.)

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The main problem of pearl millet *(Pennisetum typhoideum* Rich.) for early spring planting is low temperature at seed germination. Objectives of the study were: to study germination response patterns of two pearl millet populations on the levels of temperature, to select seeds germinated in the low temperature (15 °C), and to field-evaluate the selected sub populations. There were significant effects of the low temperature on seed germination. Germination was declined in the low temperature, and increased as increasing of temperature. No different patterns were observed in the germination between populations as varied temperature, and the linear patterns were obtained. Sub population, however, showed no significant difference in grain yield evaluated in the field, but its interaction with plant density was significant. As conclusion, pearl millet may have an ability for repairing the growth and yield in the field after low temperature stress in germination stage and, therefore, selection for early spring planting may be possible.

INTRODUCTION

There are many advantages in early planting of the crops. Depending on the case, it allows safe harvesting before the onset of rains or frosts that may decrease seed quality, enables the marketing of an early and competitive produce (Blum, 1988), could increase number of options available for subsequent crops (Kane and Grabav, 1992).

Temperature is often of overriding importance for seedling growth, especially in chilling-sensitive species (Richner et *al.*, 1996). Low temperature at sowing delays both germination and plant emergence, lengthens the crop cycle and increases production costs by demanding greater irrigation time (Otubo et *al.,* 1996). It became one of the main limiting factors for seed germination in the early spring planting. Not only reduces germination, but it also carries an effect on subsequent seedling growth and its field performance. An understanding of the low temperature germination and its field evaluation, thus, would facilitate cultivar development for early spring planting adaptation.

Study had been reported, in a little number, regarding with low temperature germination and/or field performance of pearl millet. Yoshida and Sumida (1996) had studied mass selection for early germination at low temperature, heavy grain weight, and early heading of pearl millet and had estimated their heritability values. They had reported that the population selected for early heading had more ears and higher grain yield than that of original population, but no significant interactions for traits studied between planting density and cycle of selection were detected. Totok and Yoshida (1996) had studied an interrelationship among yield-related characters of pearl millet population evaluated in the field. They had reported that number of productive panicles, panicle

weight, and seed weight were important components to the yield. Bertin et *al.* (1996) had screened rice varieties for chilling tolerance during germination and vegetative growth from 10 ° to 25 "C. Redona and Mackill (1996) studied about genetic variation for seedling vigor traits in rice at 18 ° and 25 ℃. Very limited studies, however, concerned to the pearl millet adapted for early spring planting were available.

Selection for low temperature germination pattern and its field evaluation for yield and yield components in pearl millet, therefore, is important.

Objectives of the study were: to study germination response patterns of two pearl millet populations on several levels of temperature, to select seeds germinated in the low temperature, and to evaluate the selected sub populations for yield and yield components in field.

MATERIALS AND METHODS

Two pearl millet populations, tall and short stature, were used as materials. The former was originated from several breeding materials of early maturing and the latter was originated from open pollinating variety "ICVM83074", both of which were kindly provided by Dr. C. T. Hash of ICRISAT (India), and were later seed-increased by open pollinating in several seasons including May and August sowing.

1. Germination experiment

Experiment was conducted in a factorial pattern of completely random design with 4 replications on from December 4, 1995 to February 10, 1996. Treatments consisted of two, tall and short stature populations, and 4 levels of temperature, i.e. 15°, 20°, 25° and 30 "C. A filter paper in a 7 cm diam. petri dish was used as medium. Amount of 50 seeds of populations were germinated in petri dishes for levels of temperature in a incubator. There were, therefore, 1600 seeds of 32 unit experiments included. One ml of sterilized water was supplied daily on each of petri dish, and percent of germination (%), root length (mm), shoot length (mm), and shoot-root ratio, were measured in 5 days after planting.

Significance of treatment effects was tested using analysis of variance procedure and differences among mean values were tested using protected least significant difference test procedure (Stell and Torrie, 1980). Regression equations of % of germination, root length, shoot length and shoot-root ratio to temperature were measured, and the coefficient of determinations were computed.

2. Field experiment

For materials preparation, on April 18, 1996, amount of 50 seeds were germinated in a filter paper, in a 18cm diam. and 5cm height petri dish at 15°C incubator for 7 days. The germinated seeds were measured for root length and shoot length. The highest 10 % of root length and the highest 10 % of shoot length of the germinated seeds were selected and used as materials. Materials were transplanted to paper pots and grown in a green house for about 2 weeks and later transplanted to the field on May 10.

For field experiment, a factorial pattern with randomized complete block design in 3 replications for each treatment was applied. Treatment combinations consisted of six sub

populations, i. e. the highest 10% root length of short stature sub population (S1), the highest 10% shoot length of short stature sub population (S2), original short stature sub population (S3), the highest 10 % root length of tall stature sub population (S4), the highest 10 % shoot length of tall stature sub population (S5), original tall stature sub population (S6), and two planting densities, i.e. 10 plants m^{-2} (D1) in a 2 m^2 plot and 20 plants m^{-2} (D2) in a 1 m^2 plot. There were, therefore, 36 unit of experiments included. Space planting as 20 x 50 cm (D1) and 10 X 50 cm (D2) within and between rows, and 5 g of N : $P_2O_5 : K_2O$ fertilizer per plant were applied. Plant height (cm) and number of productive panicles were measured after heading. Medium 5 plants were harvested from each plot as samples on August 13, 1996 and panicle length (cm), panicle weight (g), seed weight (g) and seed yield (gm^{-2}) were measured after panicles be dried. Data were subjected for analysis of variance continued by protected least significant difference test procedures.

RESULTS AND DISCUSSIONS

1. Germination

Mean squares of the % of germination, root length, shoot length, and shoot-root ratio values and result of analysis of variance for temperature levels and populations effects on the characters measured were shown in Table 1. Table showed that total treatment had

Table 1. Mean squares of the percent of germination, root length, shoot lengt, and shoot-root ratio of pearl millet in the different temperature conditions

Source	df	% of gemination	root lenght (mm)	shoot length (mm)	shoot-root ratio
Treatment	7	181.82*	4548.3**	1782.27**	432.83**
Pop.	1	34.03	2.4	9.43	0.68
Temp.	3	308.87**	10433.2**	4132.32**	1000.22**
Interaction	3	104.03	178.6	23.17	9.48

*,**, significant at the 0.05 and 0.01 levels, respectively

Table 2. Mean values of the percent of germination, root length, shoot length and shoot-root ratio of pearl millet in the different temperature condition

Factor	% of gemination	root lenght (mm)	shoot length (mm)	shoot-root ratio(arc sin)
Population				
Tall	87.50 a	56.99 a	31.11 a	31.68 a
Short	91.62 a	56.44 a	30.02 a	31.39 a
Temperature				
15	70.10 a	5.37 a	1.43 a	17.65 a
20	94.50 b	57.86 b	24.09 b	27.56 b
25	97.25 b	79.08 c	44.83 c	38.59 c
30	95.50 b	84.55 c	51.91 d	42.34 c
c. v.	18.35	14.67	13.75	11.83

For each factor, means followed by the same letter within a column are not significantly different at the 0.05 level according to protected LSD Test

significant effects to all of four characters. Temperature levels, individually, had significant effect to the characters under study. It means that the temperature effects contributed more substantially than population effects to the total variability in characters under study. Same result was reported by Wilson *et al. (1992)* with *Brassica* conducted in the dark at 10 constant temperature (from $0°$ to 50°C) for percentage germination.

Neither significant effect, however, for populations nor its interaction with temperature levels to the characters under study were shown. It means that both populations have same response pattern to the temperature in germination parameters observed.

Mean values for % of germination, root length, shoot length, and shoot-root ratio in each of treatment and its significance to each others were presented in Table 2. Table showed that in low temperature the four characters were declined in its performance, but the mean values increased as increasing of the temperature. The decline in root growth with reduced temperature involves a reduced capacity for water and mineral uptake, with subsequent, secondary nutritional effects on plant growth (Blum, 1988). These results confirmed with forage cultivars of *Brassica* by Wilson *et al.* (1992). They reported that cultivars differed significantly in percentage germination on both day 4 and 14 at temperature treatments and the best germination for most cultivars occurred between $10°$ to 35 "C. In rice, results had been reported that high temperature increased the values of shoot and root lengths of 27 rice cultivars in growth chamber screening (Redona and Mackill, 1996) and germination slowed down with lowering the temperature in all varieties (Bertin *et al.,* 1995).

Root systems that are more extensive than required under optimal growing conditions show generally a response to environmental stresses in the rooting zone (Richner et *al., 1996).* In the study, declining of root length as a response to lower temperature leads to limitation of water and nutrients supply to the shoot. It causes slowing down of shoot growth. It seems that the low temperature impairment has high impact on the shoot growth. This, therefore, decreases the shoot-root ratio.

No significant difference between 25 ℃ and 30 ℃ treatments, however, were observed, except shoot length, for the characters under study. Coefficient of variation of characters were between 11.83 and 18.35. It means that these characters were not **too** influenced by environmental condition fluctuations.

Varied mean values for % of germination, root length, shoot length, and shoot-root ratio of the populations as response patterns to the levels of temperature are presented in Fig. 1. Regressions of root length and shoot length on temperature for the both of populations were obtained as follow:

Y(tall pop. shoot length) $= -49.34 + 3.58X$ (R$=$0.911)
Y(tall pop. root length) $= -66.37 + 5.48X$ (R$=$0.844)
Y(short pop. shoot length) $= -44.47 + 3.31X$ (R$=$0.933)
Y(short pop. root length) $= -53.08 + 4.87X$ (R$=$0.755)
where, X: temperature, R: coefficient of determination.

These equations may be interpreted as; increasing of one temperature unit could be followed by increasing of germination characters unit proportional to those of regression
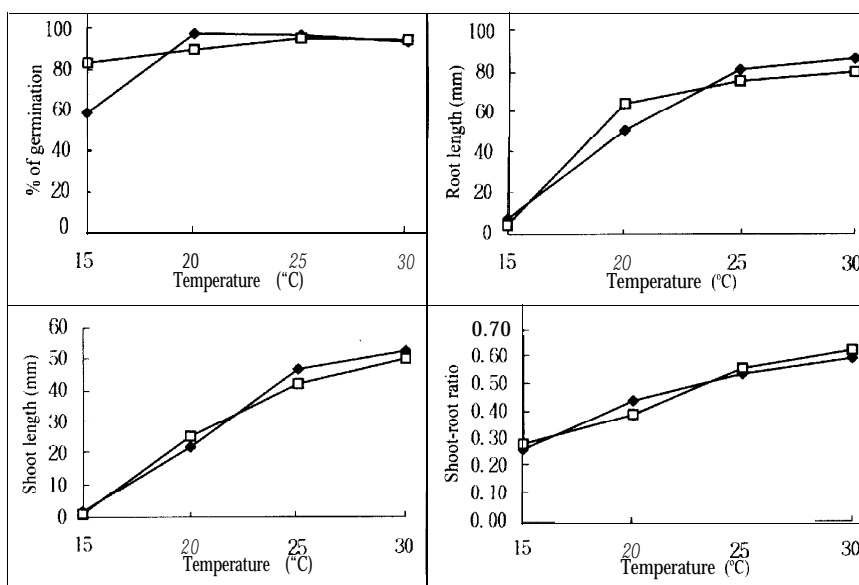
Fig. 1. Germination response of pearl millet populations on levels of temperature for % of germination, root length, shoot length and shoot-root ratio characters, respectively. ——◆—— tall population, ——□—— short population.

coefficient value. From the X values of Y=0, in tall stature population case, seeds need upper than 13.80 ℃ for shoot initiation and upper than 12.09 ℃ for root initiation. In short stature population case, seeds need upper than 13.43 ℃ for shoot initiation and upper than 10.91 ℃ for root initiation. These were confirmed using same materials for 10 ℃ germination checking at September 24 to October 2, 1996 and no seeds germination were observed.

Coefficient of determinations varied between 0.75 and 0.93. It means that 75% ─ 93% of the temperature-germination characters relationship may be explained by those equations.

2. **Field Evaluation**

Mean squares for sub population yield and yield components values in the two planting densities and the result of analysis of variance are shown in Table 3. There were significant effects of total treatment to plant height, panicle length and seed yield. But, no significant effects on the number of productive panicles and seed weight were observed. The significant effects were contributed by individual effect of sub population for plant height and panicle length, and by individual effect of plant density for seed yield. Significant interaction of sub population and plant density was detected only for seed yield and no interaction for the other characters.

Mean yield and yield components of sub population evaluated in the field for low

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Table 3. Mean squares for pearl millet sub population yield and its components in the two planting densities

Source	df	x1	x2	x3	x4	x5	x6
Replication	2	45.79	0.17	8.04	57.11	29.26	7617.25
Treatment	11	2823.08**	2.01	16.98*	62.23	31.21	43944.46**
Sub pop.	5	6122.12**	1.36	29.58**	69.88	31.41	5072.37
Density	1	91.41	3.61	2.13	49.09	15.36	424277.06**
Interaction	5	240.77	2.34	7.29	57.20	34.17	6750.05*

*, ** significant at the 0.05 and 0.01 levels, respectively

xl, x2, x3, x4, x5 and x6, are plant height (cm), number of productive panicles per plant, panicle length (cm), panicle weight (g), seed weight (g) per plant, and seed yield (gm^{-2}), respectively

temperature germination pretreatment are shown in Table 4. Table showed that, in general, sub populations were separated into two groups significantly different between both of them, but not significantly different to each other within a group for plant height and panicle length. Each of the two group were originated from same population. The 10% highest root length of short stature sub population (Sl) and the 10% highest shoot length of short stature sub population (S2) were not significantly different from the original short stature sub population (S3) for yield and yield components (Table 4). It means that both sub populations, Sl and S2, may have compensated their growth of root and shoot in field condition for low temperature germination pretreatment. The same phenomena were also shown in the tall stature sub populations, S4 and S5. Even if chilling stress in roots may be severe enough to cause irreversible damage, the recovery of root growth and function after chilling is possible, depending on the intensity and duration of stress (Blum, 1988).

Table 4. Mean yield and its components of pearl millet sub populations evaluated for low temperature germination

Factor	x1	x2	x3	x4	x5	x6
Sub population						
s.1	116.77 a	2.03	24.41 ab	39.28 a	27.59 a	391.21 a
s.2	130.73 a	1.93	24.29 ab	31.24 a	22.78 a	330.41 a
s.3	124.20 a	2.67	26.49 a	37.23 a	26.36 a	400.41 a
s.4	179.93 b	2.40	22.86 bc	32.01 a	22.91 a	339.83 a
s.5	180.70 b	3.23	20.86 c	31.13 a	21.71 a	350.02 a
S.6	184.17 b	2.63	20.82 c	34.69 a	24.75 a	380.25 a
Planting density						
D.l	154.34 a	2.80 a	23.54 a	35.39 a	25.02 a	256.79 a
D.2	151.15 a	2.17 a	23.05 a	33.09 a	23.70 a	473.92 b
c.v.	10.33	41.90	10.94	16.81	17.34	13.32

For each factor, means followed by the same letter within a column are not significantly different at the 0.05 level according to protected LSD Test. For x1-x6, see Tab. 3

Average of population seed yields was $256.79\,gm^{-2}$ and $473.92\,gm^{-2}$ for $10\,m^{-2}$ and $20\,m^{-2}$ planting densities, respectively. Our results were higher than that of, 1634 and 2386 kg ha^{-1}, resulted by M'Khaitir and Vanderlip (1992) in 1988 and 1989 under dryland conditions, and nearly similar to, 371-451 gm^{-2} and $164-239\,gm^{-2}$, reported by Yoshida and Sumida (1996) under May and August planting, respectively, in Fukuoka. It is, therefore, clear that low temperature (15°C) germination pretreatment studied is still within the stress tolerance limitation, showing that earlier sowing than May sowing may be possible.

Yield and yield components were not significantly different for their performance that was caused by the different plant density, except for the seed yield. The plant height, number of productive panicles, panicle length, panicle weight, and seed weight tended to decrease as increasing of plant density, but seed yield increased as increasing of planting density. These results agree in M'Khaitir and Vanderlip (1992) with sorghum and pearl millet. They had reported that sorghum yield increased as plants density increased. But, they found no yield response for the ranges from 15000 to 135000 plants ha-l for pearl millet under dryland conditions. They also reported that pearl millet panicle number per plant consistently decreased as population increased in both locations, Manhattan and St. John, and in both years, 1988 and 1989, but sorghum showed no significant effect of population on panicle number per plant. However, how far the decreasing tendencies of the yield components, as increasing of planting density mentioned above, still may be counterbalanced by increasing of seed yield in population, is still unfound.

Varied yield and yield performance of sub populations as responses to the plant densities are shown in Fig. 2. Sub population and planting density interaction showed significant effect on seed yield, but no significant effect on the other characters studied. M'Khaitir and Vanderlip (1992) also reported significant interaction of population density and variety for pearl millet grown at Manhattan in 1989. Cox (1996) reported significant interaction of hybrid and plant density for grain yield and dry matter production of maize. Significant interaction of sub population and planting density on seed yield in this study means that yield difference between two planting densities differed among sub populations. Fig. 2 shows that seed yield of the short stature population groups tended to be higher than that of the tall stature population groups in the low planting density. Seed yield of the short stature population groups, however, tended to be lower than that of the tall stature population groups in the high planting density. However, the optimum planting density for maximum seed yield is still not found yet and needed to be studied.

Concluded that lower temperature declined seed germination characters but the values increased as increasing temperature, populations gave same response to temperature levels in the linear pattern, and temperature had more contributed than population on the germination characters variability. Plants in the field may have a reparability after 15 °C temperature germination pretreatment and selection for early spring planting of pearl millet may be possible.
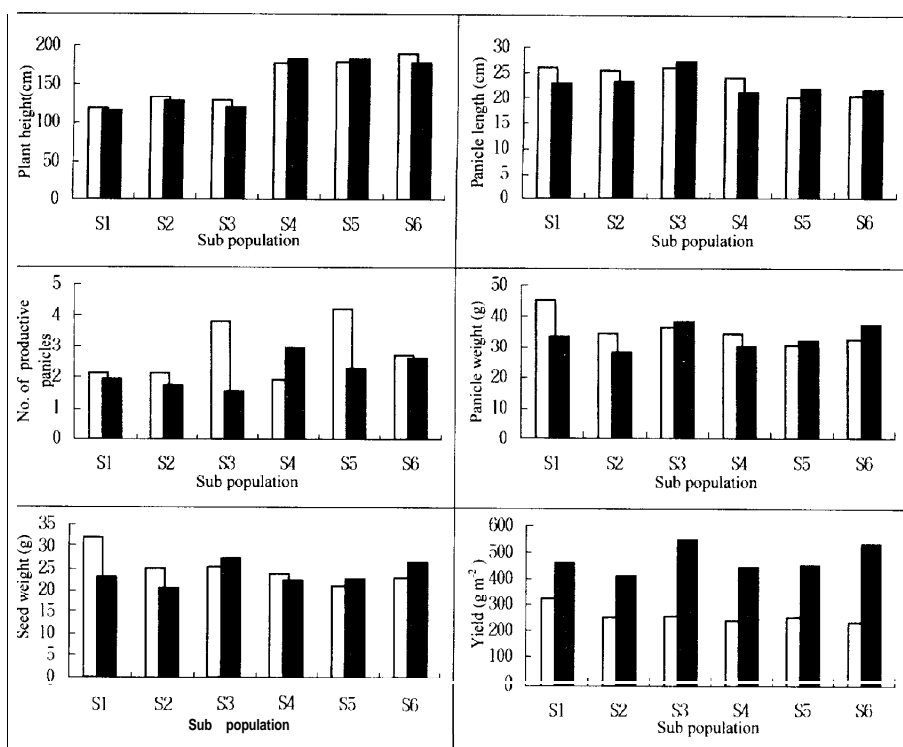
Fig. 2. Sub populations response on two planting densities after low temperature germination pretreatment for plant height, productive panicles, panicle length, panicle weight, seed weight and yield characters, respectively. S1,S2, S3, S4, S5 and S6 are the highest 10% root length of short stature, the highest 10% shoot length of short stature, original short stature, the highest 10 % root length of tall stature, the highest 10 % shoot, length of tall stature, and original tall stature sub populations, respectively.
□ 10 plants m^{-2},   ■ 20 plants m^{-2}.

REFERENCES

Bertin, P., J. M. Kinet and J. Bouharmonth 1995 Evaluation of chilling sensitivity in different rice varieties. Relationship between screening procedures applied during germination and vegetative growth. *Euphytica, 89: 201-210*

Blum, Abraham   1988   *Plant Breeding for Stress Environments.* CRC Press. Inc., Boca Raton, Florida, PP 223

Cox, W. J.   1996 Whole plant physiological and yield responses of maize to plant density. *Agron. J., 88: 489-496*

Kane, L. J. and L. J. Grabau 1992 Early planted, early maturing soybean cropping system: Growth, development, and yield. *Agron. J., 84: 769-773*

M'Khaitir, Y. 0. and R. L. Vanderlip 1992 Grain sorghum and pearl millet response to date and rate of planting. *Agron. J., 84: 579-582*

Otubo, S. T., M. A. P. Ramalho, A. F. B. Abreu, and J. B. dos Santos 1996 Genetic control of low

temperature tolerance in germination of the common bean (*Phaseolus vulgaris* L.). *Euphytica, 89:* 313-317

Redona, E. D. and D. J. Mackill 1996 Genetic variation for seedling vigor traits in rice. *Crop Sci.,* 36: 285-290

Richner, W. A. Soldati, and P. Stamp 1996 Shoot-to-root relations in field-grown maize seedlings. *Agron. J.,* **88**:56-61

Stell, G. W. and J. H. Torrie 1980 *Principles and Procedures of Statistics.* McGraw-Hill Inc., London

Totok Agung Dwi Haryanto and T. Yoshida 1996 Performance and interrelationship among several characters of pearl millet *(Pennisetum typhoideum* Rich.) population. *J. Fac. Agr., Kyushu Univ., 41:* 1-9

Wilson, R. E., E. H. Jensen, and G. C. J. Fernandez 1992 Seed germination response for eleven forage cultivars of brassica to temperature. *Agron. J., 84: 200-202*

Yoshida, T. and K. Sumida 1996 Mass selection and grain yield of improved population in pearl millet *(Pennisetum typhoideum* Rich.). *Japan J. Crop Sci., 65: 58-62*