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COMBINING ABILITY AND CORRELATION STUDIES FOR EARLINESS AND PHOTOPERIOD RESPONSE IN PEARL MILLET*

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ABSTRACT

Seven pearl millet parents with good specific combining ability for grain yield (ICMP 423, ICMP 451, ICMP 501, ICMP 84913, ICMP 84122, ICMP 83506 and ICMP 83401) and their 21 F_1 (diallel) were evaluated for time to 50% flowering under normal and extended day lengths. For ICMP 83401 and ICMP 451, general combining ability (GCA) effects were significant and negative under both summer normal day length (SNDL) and summer extended day length (SEDL). The GCA estimates for photoperiod sensitivity for these two parents were also significant and negative. The results indicate that these parents may be particularly useful in generating early flowering photoperiod insensitive progenies. There was a strong positive correlation for time to 50% flowering of the hybrid and parents in the SEDL nursery and at Hisar in the rainy season, indicating that preliminary discrimination among lines on photoperiod sensitivity can be done using the SEDL nursery at Patancheru.

INDEX WORDS : *Pennisetum glaucum*, pearl millet, photoperiod insensitivity, general combining ability, early flowering.

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the most widely grown cereal under short growing season conditions in the semi-arid regions of India. Early flowering is a desirable trait in this crop as it provides an opportunity for escape from terminal drought in normal sowing in northern India or in late sowing in the sorghum-millet transition zones in peninsular India. Relative insensitivity to photoperiod is also likely to contribute to wider adaptation across pearl millet production areas in peninsular and northern India. Early flowering, photoperiod-sensitive genotypes are suitable in northern India, but they perform poorly in the peninsular zone as the shorter day lengths in the region result in a very short vegetative period. It is hypothesized that mid-early pearl millets with a relatively low photoperiod sensitivity may be suitable for both northern and peninsular Indian conditions. While the yield potential of such genotypes could be lower than that of later flowering material in the peninsular region, this may be compensated by more frequent realization of yield potential due to wider adaptation and reduced exposure to terminal drought stress.

Carberry and Campbell (1985) found that as photoperiod increased from 13.5 h to 15.5 h, time taken to panicle initiation increased from 16 to 34 days in a pearl millet hybrid. Pearl millet male-sterile line 23 A flowered much earlier (under short day length) in Puerto Rico than under long day length in the USA (Barnes and Burton, 1966). Bidinger and Rai (1989) observed that both parental lines should be

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insensitive in order to develop photoperiod-insensitive pearl millet hybrids. The parents should also have good combining ability for grain yield.

Early flowering under field conditions does not necessarily indicate photoperiod insensitivity - it can equally well result from the hastening effects of high temperature or an inherently short vegetative growth period. Photoperiod insensitivity must be assessed by comparison of time to flowering in different day lengths. Therefore, the objectives of the present investigation were to (i) identify pollinators with good combining ability for early flowering and photoperiod insensitivity and (ii) determine whether the summer (March-May) extended day length nursery at Patancheru is effective in identifying materials that exhibit delayed flowering in northern India due to photoperiod sensitivity.

MATERIAL AND METHODS

Seven pollinators with good specific combining ability for yield (ICMP 423, ICMP 451, ICMP 501, ICMP 84913, ICMP 84122, ICMP 83506 and ICMP 83401) were crossed in a diallel mating design. The 21 crosses (F_1 hybrids) and 7 parents were grown under four different environments at ICRISAT Center, Patancheru. These were : (1) summer normal day length 1990 (SNDL, day length = 12.5 h), (2) summer extended day length 1990 (SEDL, 14.7 h), (3) *kharif* normal day length 1990 (KNDL, 13.5 h) and (4) *rabi* normal day length 1990/91 (RNDL, 11.6 h). They were also evaluated at Hisar (14.2 h) during the rainy season, 1990.

Time to 50% flowering was recorded as number of days taken from sowing until 50% of the plants produced stigmas on their main panicles. Photoperiod sensitivity was calculated as % delay in 50% flowering under SEDL compared to the time to 50% flowering in the SNDL control.

Combining ability analysis was conducted for time to 50% flowering and photoperiod sensitivity using the fixed effect Model-I method-2 of Griffing (1956) and Mather and Jinks (1982), using data from each of the Patancheru environments. Correlations of performance at Hisar and in the four Patancheru environments were calculated according to standard procedures (Steel and Torrie, 1960).

The ability of three individual normal day length (NDL) test environments at Patancheru to predict time to 50% flowering in north India (Hisar) was compared by : (1) simple correlations of time to flower in the NDL with time to flower at Hisar, and (2) multiple correlations of time to flower in the NDL plus photoperiod sensitivity with time to flower at Hisar.

RESULTS AND DISCUSSION

Parental lines differed in time to 50% flowering by 16 days, and in delay in 50% flowering under extended day length by 15 days (Table 1). ICMP 83401 was the earliest to flower and the least photoperiod-sensitive. Two other less sensitive parents, ICMP 501 and ICMP 84122, were relatively late to flower. ICMP 451 was medium in time to 50% flowering and insensitivity, while ICMP 423, ICMP 84913 and ICMP 83506 were mid-late in time to 50% flowering and the most sensitive to extended day lengths. Burton (1965) reported photoperiodism in certain pearl millet introductions from Nigeria and Upper Volta. The pollinators used in the present study have West African lines in their parentage. It is, therefore, probable that the

TABLE 1. Mean and combining ability effects for time to 50% flowering and photoperiod sensitivity at Patancheru in summer 1990

Pollinator	Time to 50% flowering (days)		GCA effects (time to 50% flowering)				
	Mean (SNDL)	Mean delay (SEDL)	SNDL	SEDL	KNDL	RNDL	Photoperiod sensitivity
ICMP 423	57	19	-1.00*	+0.29	+1.51**	-0.68*	+2.83*
ICMP 451	55	16	-1.51**	-3.45**	-0.83**	-0.88**	-3.33**
ICMP 501	66	10	+2.93**	+1.07*	+2.66**	-0.49	-4.26**
ICMP 84913	58	23	+0.56	+2.66**	-0.46*	+1.25**	+3.72**
ICMP 84122	63	10	+2.78**	+1.00*	+0.06	+1.92**	-4.12**
ICMP 83506	58	21	+0.75	+5.22**	-0.75**	-1.42**	+8.10**
ICMP 83401	50	8	-4.51**	-6.78**	-2.20**	-1.46**	-2.94*
SE ±	1.4	4.2	0.43	0.44	0.22	0.30	1.31

* $P \leq 0.05$; ** $P \leq 0.01$.
SNDL = Summer Normal Day length (12.5 h)
SEDL = Summer Extended Day length (14.7 h)
KNDL = *Kharif* Normal Day length (13.5 h)
RNDL = *Rabi* Normal Day length (11.6 h)
GCA = General Combining Ability

photoperiod sensitivity of these lines is of West African origin.

ICMP 83401 and ICMP 451 had significant and negative GCA effect estimates for time to 50% flowering and for photoperiod sensitivity in all the four environments (Table 1), reflecting their relative earliness in flowering and insensitivity to artifically increased day lengths. Of the parents evaluated, they were potentially the most useful for breeding early flowering progenies with low photoperiod sensitivity ICMP 501 and ICMP 84122 had positive GCA effects ($P < 0.001$) for time to 50% flowering in three of the four environments, and negative GCA effects ($P < 0.001$) for sensitivity, indicating that later flowering material with low photoperiod sensitivity can also be developed. This may be of value in peninsular India.

The correlations between time to 50% flowering at Hisar and in each of the four trials grown at Patancheru were lower for the F_1 hybrids than for the combined F_1 hybrids plus parents (Table 2). This reflected the more extreme responses of the parents. There was a strong positive association of phenology between Hisar and the Patancheru SEDL nursery for both the progeny and the progenies plus parent populations. This may be due to interaction of light and temperature to determine growth and development process (Ong and Monteith, 1985). These results indicate that use of the Patancheru SEDL nursery test environment permits reasonably effective discrimination in preliminary evaluation of breeding materials for early-medium flowering and low photoperiod sensitivity. In comparison, selection among the progenies in the *kharif* (KNDL) or summer (SNDL) normal day length nurseries at Patancheru permitted only limited discrimination. Evaluation at Patancheru in the *rabi* season (RNDL) was, as expected, completely ineffective in identifying differences in phenology at Hisar.

TABLE 2. Correlation coefficients for time to 50% flowering in parents and their F_1 hybrids at Hisar (14.2 h) with time to 50% flowering at Patancheru, with and without an estimate of photoperiod sensitivity

Patancheru time to 50% flowering	F_1 hybrids (21)	F_1 hybrids + parents (28)
KNDL	+0.38	+0.59**
KNDL+PP	+0.83***	+0.84***
RNDL	-0.16	+0.25
RNDL+PP	+0.73**	+0.47*
SNDL	+0.34	+0.61**
SNDL+PP	+0.84***	+0.77***
SEDL	+0.81***	+0.78***

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.
SNDL = Summer Normal Day length (12.5 h),
SEDLN = Summer Extended Day length (14.7 h),
KNDL = *Kharif* Normal Day length (13.5 h), and
RNDL = *Rabi* Normal Day length (11.6 h).
PP = Photoperiod sensitivity

$$= \frac{\text{[Time to flowering in SEDL-Time to flowering in SNDL]}}{\text{Time to flowering in SNDL}} \times 100$$

The ability of the individual NDL environments at Patancheru to predict time to flower at Hisar (Table 2) was poor in the set of F_1 hybrids ($-0.16 < r < 0.38$ NS) and only slightly better in the set of F_1 plus parents ($0.25 < r < 0.61$**). Combining flowering in the NDL and photoperiod sensitivity from the summer environments greatly improved the predictability of time to flowering at Hisar for both the hybrids ($0.73^{**} < r < 0.84^{***}$) and the hybrids plus parents ($0.47^{*} < r < 0.84^{***}$). However, the summer extended day length environment alone is as effective in predicting flowering at Hisar, for both sets of materials ($r = 0.81^{***}$ for the hybrids, and $r=0.78^{***}$ for the hybrids plus parents).

Therefore, while flowering in the longer day lengths of north India can be effectively predicted from flowering in the shorter day lengths of peninsular India combined with an estimate of photoperiod sensitivity, the simpler alternative of directly simulating both the longer day lengths (by artificial day length extension) and the higher temperatures of the north (by sowing in the hot summer season) is equally effective, and considerably less expensive, as it requires only one test environment.

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