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https://doi.org/10.5109/24220

出版情報：九州大学大学院農学研究院紀要. 42 (3/4), pp.325-335, 1998-03. Kyushu University
バージョン：

J. Fac. Agr., Kyushu Univ., **43** (3·4), 325-335 (1998)

Responses to Early Spring Planting in Several Genotypes of Pearl Millet (*Pennisetum typhoideum* Rich)

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(*Received November 13, 1997 and accepted December 3, 1997*)

Seven genotypes (G), namely G1,G2,G3,G4,G5,G6 and G7 which were selected for yield, seed weight, number of productive panicles, panicle weight, shoot and root length, and the original population were planted in a field at different planting date (D), namely April 29; May 6, May 13 and May 20. Growth responses for leaf area, dry weight of leaf, stem and root were measured at 2, 3, 5, and 6 weeks after transplanting. Early planting inhibited growth of all genotypes in early stage but not differed in the late stage. Significant growth response of genotypes was caused mainly by the difference of planting date. Significant yield and yield components response was caused by the difference of genotypes. No significant G×D interaction for growth, yield and yield components, except for leaves area was observed. Genotypes selected for yield, number of productive panicles and panicle weight were relatively stable in different planting date and might be consider to be adapted for early spring planting. Photoperiod sensitivity was evidenced and pearl millet might be consider as a facultative short-day plant.

INTRODUCTION

To develop genotypes for early spring planting of pearl millet, information concerning germination at a low temperature is important. It is because low temperature at germination is one of the main problems of pearl millet for early spring planting (Totok *et al.*, 1997) and low temperature is the most common environmental stress during germination and an advantage is often ascribed to early planting (Blum, 1988).

Some studies have reported on germination of pearl millet at a low temperature and the field evaluation. Yoshida and Sumida (1996) applied mass selection for germination at a low temperature, heavy grain weight and early heading in a pearl millet population and estimated the heritability of these characters. Our previous reports in pearl millet suggested that, 1. pearl millet might have capability to recover the growth and yield in the field after exposure to low temperature stress at the germination stage and lead to possibility of selection for early spring planting (Totok *et al.*, 1997), 2. genetic gain and heritability of seedling character such as shoot length and root length at a low temperature in two genetic populations and the correlation to yield components were obtained and concluded that shoot and root lengths were heritable characters, correlated to yield components in the field and may be useful as selection criteria at low temperatures (Totok *et al.*, 1998a), 3. genotype × sowing season interaction was not significant for grain yield and pearl millet might be consider as an early spring and fall season sowing grain crop (Totok *et al.*, In preparation), 4. selection for yield components may be effective for improving grain yield and several promising high grain yield genotypes were obtained (Totok *et al.*, 1988b). However, the performance and grain yield of the genotypes sown at early spring has still not be evaluated yet.

As different planting dates might result in different photoperiod and temperature regimes, which affect both growth and yield or yield components, the potential of selected genotypes could be affected by their responses to the planting date. M'khaitir and Vanderlip (1992) reported that pearl millet showed no significant response to different planting date of May, June and July at Manhattan and St. John, KS, in 1988 and 1989. However, the date-by-variety interaction at Manhattan 1989 was significant for the yield. An understanding the response of genotypes to different planting date might facilitate developing pearl millet adapted for early spring.

In this research, growth and grain yield response of seven genotypes on different planting date was studied in relation to obtain high grain yield genotypes for early spring planting. The photoperiod sensitivity of a genotype was also observed.

MATERIALS AND METHODS

1. Response to planting date

Six selected genotypes (G) from previous studies (Totok *et al.*, 1988a) namely: genotype selected for yield (G1), seed weight (G2), number of productive panicles (G3), panicle weight (G4), shoot length (G5), and root length (G6), and the original open pollinated short population "ICMV89074" from ICRISAT, India (G7) were subjected as materials. Planting date of April 29; May 6; May 13 and May 20, as date of transplanting of 3 weeks old seedling from green house to the field, were arranged as treatment. To prepare the seedlings, seeds were germinated in filter paper for 3 days and then sown in ziffy paper pots, with 2 plant each, in green house for 3 weeks. Each genotype was planted in a plot consists of three rows, with 10 plants each, at 10 and 40 cm interval within and between rows respectively, and 0.8 g N, 0.8 g P_2O_5, and 0.8 g K_2O were applied per plot. Growth responses were consisted of leaf area, dry weight of leaves, stem, and root at 2,3,5 and 6 weeks after transplanting. For growth response observation, the plants in the center row were subjected as samples. For yield and yield components response observation; as plant height, number of productive panicles, panicle weight, panicle length and grain yield per plant; 3 plants were sampled from each rows. Heading and harvesting date from each genotype also were observed. Data obtained were subjected to analysis of variance continued by protected LSD test (Stell and Torrie, 1980).

2. Photoperiod sensitivity

Two kinds of seedling, 3 and 4 weeks old, of a genotype, G1, were subjected to observe photoperiod sensitivity. Seeds were sown in ziffy paper pots filled with fertile soil at June 6 and 16 and placed in the green house to prepare 3 and 4 weeks old seedlings. At July 9, the seedlings were transplanted to plastic pots filled with about 4 kg sifted soil, 0.8 g N, 0.8 g P_2O_5 and 0.8 g K_2O per pot and placed in the three different adjustable photoperiod chambers, namely: Chamber 1, 2 and 3 with 8, 12 and 16 hours photoperiod, respectively. Each seedlings group was planted in three pots and each pot consists of three plants. Since time of maturity is associated primarily with the response of genotypes to photoperiod and temperature (Fehr, 1997a), the heading date as days from germination to 50% heading, the maturity as harvesting date, and the plant height were observed.

RESULTS

Daily mean air temperature along planting period fluctuated from the minimum as 13.1°C and maximum as 31.3°C with 22.78°C in average. Daily mean precipitation fluctuated from the minimum as 0 mm and maximum as 117.0 mm with 8.9 mm in average. The fluctuation in mean air temperature and precipitation in every ten days along planting periods was shown in Fig. 1. Table 1 shows the analysis of variance for growth responses on different genotypes and planting date. Table 2 and 3 shows the mean values

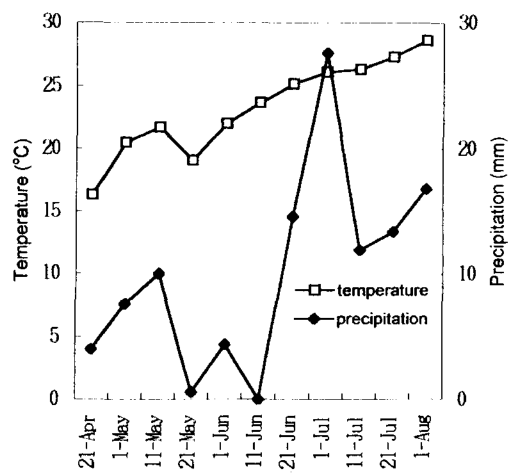

Fig. 1. Fluctuation in mean air temperature and mean precipitation in every ten days from April to August 1997 in Fukuoka (Source: Fukuoka District Meteorological Observatory)

Table 1. Mean squares by ANOVA for leaf area (LA), dry weight of leaves (LDW), stem (SDW) and root (RDW) as response to different planting date

Source	df	LA ($100 cm^2$)	LDW (g)	SDW (g)	RDW (g)
Treatment	27	95.0**	20.5**	184.2**	3.6**
Genotype (G)	6	59.0	5.6	178.5*	2.2
Planting date (D)	3	339.0**	98.6**	755.8**	17.4**
G×D	18	66.0**	12.5	90.8	1.8

*, **, significant at 5% and 1% level, respectively.

Table 2. Mean values for leaf area (LA) and leaves dry weight (LDW) of genotypes in different planting date

Genotypes	LA (100 cm² plant⁻¹)				LDW (g plant⁻¹)			
	Apr. 29	May 6	May 13	May 20	Apr. 29	May 6	May 13	May 20
G1	1.5b	2.1a	1.7abc	1.2a	5.3a	8.0ab	6.7ab	4.0a
G2	1.0b	1.7a	1.1bcd	1.0a	5.0a	10.0ab	3.0bc	4.0a
G3	3.1a	2.0a	1.1bcd	1.0a	7.3a	8.7ab	4.3abc	4.7a
G4	1.1b	2.0a	2.0ab	1.0a	3.0a	11.7a	7.7ab	3.7a
G5	1.9b	2.1a	1.0cd	0.9a	5.0a	8.7ab	3.3bc	3.7a
G6	1.6b	1.7a	2.2a	0.9a	4.3a	5.0b	9.0a	3.7a
G7	1.5b	1.7a	0.7d	0.8a	5.0a	9.3ab	1.0c	2.7a

G1: sel. for yield; G2: sel. for seed wt. panicle⁻¹; G3: sel. for no. of prod. panicles; G4: sel. for mean panicle wt; G5: sel. for shoot length; G6: sel. for root length; G7: original pop. Means followed by a common letter in a column are not significantly different at 5% level.

Table 3. Mean values for stem (SDW) and root (RDW) dry weight of genotypes in different planting date

Genotypes	SDW (g plant⁻¹)				RDW (g plant⁻¹)			
	Apr. 29	May 6	May 13	May 20	Apr. 29	May 6	May 13	May 20
G1	16.3a	16.7bc	7.3a	4.0a	2.0a	2.0a	3.0ab	1.3a
G2	6.7a	21.7abc	2.0a	5.7a	1.3a	2.7ab	2.0bc	1.3a
G3	12.7a	35.3a	7.3a	10.0a	2.0a	3.3ab	1.7bc	1.7a
G4	5.3a	27.7ab	13.3a	5.0a	0.7a	4.0ab	4.7a	1.0a
G5	8.7a	7.0c	4.3a	4.3a	1.7a	2.7ab	1.7bc	1.0a
G6	12.3a	12.3c	10.3a	3.0a	1.0a	4.0a	3.0ab	1.0a
G7	9.0a	8.0c	1.3a	2.3a	1.0a	2.7ab	1.0c	0.3a

Means followed by a common letter in a column are not significantly different at 5% level.

Table 4. Mean values across genotypes for leaf area (LA), dry weight of leaves (LDW), stem (SDW) and root (RDW) as response to different planting date

Planting date	LA (1000 cm²)	LDW (g)	SDW (g)	RDW (g)
Apr. 29	1.7 ab	5.1 b	10.1 b	1.4 c
May 6	1.9 a	8.8 a	18.4 a	3.0 b
May 13	1.4 b	5.0 b	6.6 bc	2.4 b
May 20	1.0 c	3.8 b	4.9 c	1.1 c

Means followed by a common letter in a column are not significantly different at 5% level.

of genotypes for growth characters in different planting date and Table 4 shows the mean values for growth characters across genotypes.

1. Growth responses

Effect of planting date was significant for all growth characters. However, no significant effect of genotypes was observed except for stem dry weight (Table 1). Genotype interaction effect with planting date was detected only for leaf area and no interaction was observed for other characters.

Across genotypes, leaf area (LA) and total dry weight (leaf, stem and root dry weight) in April 29 was lower than in May 6 until 5 week after transplanting (WAT). However, the mean value of LA, dry weight of leaves (LDW), stem (SDW) and root (RDW) between April 29 and May 6 were not significantly different at 6 WAT (Fig. 2; 3 and Table 4). The genotypes showed similar pattern in the growth at each of planting date and the selected genotypes, as G1～ G6, performed relatively higher than the original, as G7, in their mean values for LA, LDW, SDW and RDW (Table 2 and 3).

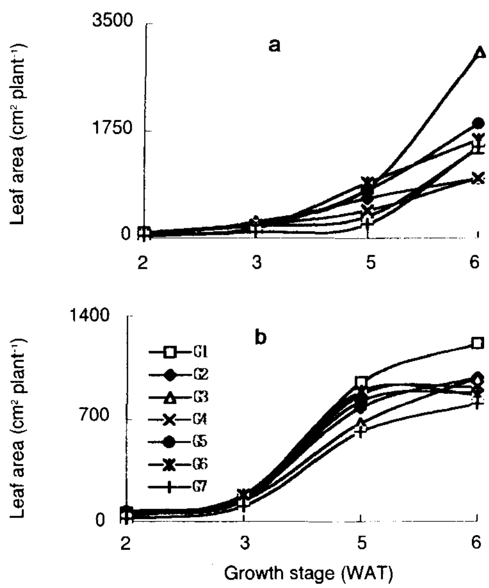

Fig. 2. Differences for leaf area growth of genotypes between planting date of Apr. 29 (a) and May 6 (b).
WAT: week after transplanting

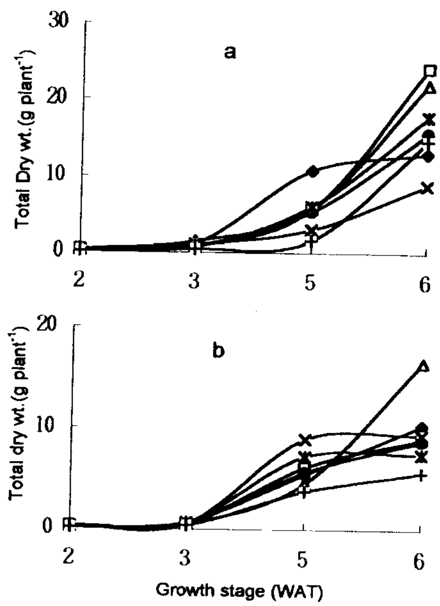

Fig. 3. Differences for total dry weight production of genotypes between planting date of Apr. 29 (a) and May 6 (b).
WAT: week after transplanting

2. Yield and yield components responses

Analysis of variance for yield and yield components was shown in Table 5. Effect of genotypes was significant for number of productive panicles (PP), panicle length (PL), panicle weight (PW), and yield per plant (Y), but not significant for plant height (PH). No significant effect of planting date for panicle weight and yield was observed and no significant genotype×planting date interaction was detected for all characters. The similar results were reported by M'Khaitir and Vanderlip (1992), who observed no significant effect of planting date, as May, June and July, on yield and yield components in pearl millet.

Table 5. Mean square by ANOVA for yield and its components as response to different planting date

Source	df	PH (100 cm)	PP	PL (cm)	PW (100 g plant^{-1})	Y (10 g plant^{-1})
Treatment	27	1.5*	0.5**	11.2**	3.0*	18.9**
Genotype (G)	6	1.2	1.3**	31.2**	10.0**	55.0**
Planting date (D)	3	6.4**	0.5**	12.1*	3.1	12.6
G×D	18	0.9	0.2	4.4	0.6	7.9

PH: plant height; PP: no. of prod. panicles; PL: panicle length; PW: panicle wt; Y: grain yield plant^{-1}.
*, **, significant at 5% and 1% level, respectively.

The mean values for yield and yield components at different planting date were shown in Table 6 and Table 7. The mean values of G1, G3 and G4 were relatively higher than the values of other genotypes for yield and yield components. Especially for grain yield at April 29, G3 showed superior, followed by G1 and G4 (Table 7).

Across genotypes, the mean values for yield and yield components were comparable at different planting date (Table 8). In almost all cases, the mean value for yield and yield components were not significantly different to each others.

Table 6. Mean values for no . of prod. panicles (PP) and panicle length (PL) of genotypes in deifferent planting date

Genotypes	PP				PL (cm)			
	Apr. 29	May. 6	May. 13	May. 20	Apr. 29	May. 6	May. 13	May. 20
G1	2.7 ab	2.0 a	1.9 b	2.4 ab	22.5 abc	21.9 ab	22.0 ab	23.5 ab
G2	2.0 c	1.9 a	2.0 b	2.2 b	23.0 abc	20.6 ab	20.1 bc	21.2 abc
G3	3.4 a	2.2 a	3.2 a	3.0 a	25.6 a	21.7 ab	25.5 a	21.4 abc
G4	2.3 bc	1.7 a	2.2 b	2.3 b	22.7 abc	23.7 a	23.3 ab	24.3 a
G5	1.8 c	2.0 a	1.9 b	1.7 b	19.1 c	18.0 b	17.8 c	20.5 abc
G6	1.8 c	1.7 a	2.4 b	1.7 b	21.2 bc	17.9 b	17.4 c	18.8 c
G7	1.8 c	1.5 a	2.2 b	1.7 b	24.4 ab	21.1 ab	18.1 c	19.7 bc

Means followed by a common letter in a column are not significantly different at 5% level.

Table 7. Mean values for panicle weight (PW) and yield (Y) of genotypes in different planting date

Genotypes	PW (g plant^{-1})				Y (g plant^{-1})			
	Apr. 29	May 6	May 13	May 20	Apr. 29	May 6	May 13	May 20
G1	36.9 ab	36.1 a	39.0 ab	38.7 a	23.5 b	15.6 a	16.1 a	24.0 b
G2	39.7 ab	46.5 a	51.5 ab	29.4 a	15.6 bc	18.8 a	23.3 a	18.7 b
G3	59.9 a	43.5 a	63.2 a	44.2 a	50.5 a	18.6 a	22.1 a	41.1 a
G4	57.3 ab	39.3 a	48.5 ab	45.6 a	16.5 bc	13.9 a	19.3 a	25.4 b
G5	27.3 b	33.8 a	30.0 b	18.2 a	9.2 bc	10.8 a	11.1 a	10.7 b
G6	26.9 b	22.9 a	25.7 b	19.5 a	12.8 bc	8.7 a	9.2 a	12.8 b
G7	29.3 ab	29.7 a	30.3 b	18.9 a	5.2 c	10.5 a	10.4 a	10.9 b

Means followed by a common letter in a column are not significantly different at 5% level.

Table 8. Mean values for yield and its components across genotypes in different planting date

Planting date	PH (cm)	PP	PL (cm)	PW (g plant^{-1})	PY (g plant^{-1})
Apr. 29	106.3 a	2.24 a	22.6 a	39.6 a	19.0 ab
May 6	101.8 a	1.87 b	20.7 b	35.9 a	13.8 b
May 13	117.8 b	2.23 a	20.6 b	41.2 a	15.9 ab
May 20	108.2 a	2.12 a	21.3 b	30.6 a	20.5 a

PH: plant height; PP: no. of prod. panicles; PL: panicle lenght; PW: panicle wt. Y: grain yield plant^{-1}. Means followed by a common letter in a column are not significantly defferent at 5% level.

Table 9. Changes in the heading date and plant height as response to different photoperiods in pearl millet

Seedlings age	Heading date	Harvesting date	Plant height
	8 hours photoperiods		
3 Weeks	63 ab	87 a	109.0 bc
4 Weeks	62 a	92 a	120.7 c
	12 hours photoperiods		
3 Weeks	68 b	101 b	79.3 a
4 Weeks	67 ab	98 b	90.3 ab
	16 hours photoperiods		
3 Weeks	80 c	120 c	93.3 ab
4 Weeks	76 c	118 c	111.3 b

Means followed by a common letter in a column are not significantly different at 5% level.

3. Photoperiod sensitivity

Changes in the heading and planting date and plant height as response to different regimes of photoperiod in the plants from different seedling old were shown in Table 9. No significant difference between 3 and 4 weeks seedling for heading date, harvesting date and plant height was observed in 8 hours photoperiod. The same results also were observed in both 12 and 16 hours photoperiod. Across different seedling old plants, there was no significant difference for plant height in different photoperiod. However, earlier heading and harvesting date in 8 hours photoperiod than both in 12 and 16 hours photoperiods was observed. The earlier heading and harvesting date in 12 hours than in 16 hours photoperiod also was observed.

DISCUSSION

In Pearl millet, low temperature effects on the germination characters (Totok *et al.*, 1997) and relationship between the germination characters and yield components in the field (Totok *et al.*, 1998a) have been reported. In this study, effect of planting date was significant for all characters, but effect of genotypes was significant only for stem dry weight. This revealed that the magnitude of effect by planting date was higher than effect by genotypes for the growth characters.

Mean temperature in the last ten days of April planting date (D1) was as low as 16.3 °C. This condition resulted in the inhibiting of the growth especially in the early stages until 5 week after transplanting (Fig. 2a; 3a) for all genotypes. However, sharp growth rate in the later stages resulted to the insignificant difference between the mean values of growth characters in April 29 and the values in later planting dates at 6 WAT (Table 4; Fig. 2; 3; 4). On the other hand, the genotypes showed similar growth in each of planting date and only stem dry weight differed among genotypes. It appears that the difference in the growth characters as response to the different planting date was predominantly more significant than as response to the different genotypes.

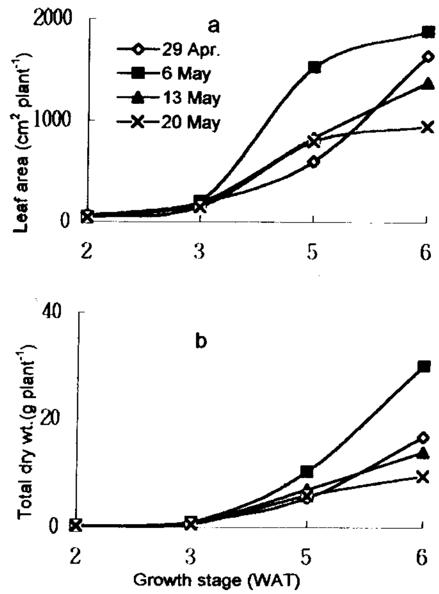

Fig. 4. Differences for leaf area (a) and total dry weight (b) across genotypes in different planting date. WAT: week after transplanting

The higher mean value of leaf area of G3 in April 29 but not significant in another planting date and higher mean value of G4 in May 13 contribute to the genotype × planting date interaction. However, no significant G × D interaction for almost all characters revealed that, in this study, there were no changes in magnitude of the growth response of genotypes to the different planting date. An understanding of the environmental stability of genotypes helps in determination of their suitability for the fluctuations in growing conditions that are likely to be encountered (Fehr, 1987). Results of this study suggested the growth stability of genotypes in the different planting date.

The significant effect of genotypes for all yield and yield components, except plant height, and not significant effect of planting date for panicle weight and yield in this study revealed that yield and yield components were less influenced by planting date. Furthermore, differences among genotypes suggested the effective selection conducted previously (Totok *et al.* 1997; 1998b).

The non significant G × D interaction for all yield and yield components revealed that there were no changes in the magnitude of the response in genotypes by different planting date. This leads to suggestion of yield and yield components stability in genotypes and adaptation for early spring planting.

The higher mean value of G1, G3 and G4 than other genotypes for yield components revealed the more stable and higher grain yield potential of these genotypes for early spring planting. Superiority of G3 at April 29 for grain yield suggested that the selection for number of productive panicles might increase the grain yield and adaptability of pearl millet for early spring planting.

Photoperiod sensitivity in pearl millet is a well recognized trait (Anand Kumar and Andrews, 1993). Depending on genotypes, pearl millet can be classified as: 1). relatively day-neutral and can flower irrespectively of day length; 2). short day, head only when the days are short (less or same as 12 hours) and fail to flower when day lengths are more than 12 hours; and 3). facultative short-day, flowering under long-days but much earlier under short days (summarized from Anand Kumar and Andrews, 1993).

No significant difference between 3 and 4 weeks old seedlings for the heading and harvesting date, and plant height in each 8, 12 and 16 hours photoperiods revealed that the effect of photoperiod was similar to 3 or 4 week old seedlings.

As the plants showed earlier for heading and harvesting date if exposured to the shorter photoperiods, the photoperiod sensitivity of the genotype used in this study was suggested. The photoperiod sensitivity in this study was considered as facultative short-day which was expressed as the acceleration of the growth resulted in the earlier of heading and harvesting time when exposed in the short photoperiod and the prolongation of the growth periods resulted in the postponement of heading and harvesting time when exposed in the long photoperiods if compared with exposured in the 12 hours photoperiods. This result agreed Begg and Burton (1971) which reported that the five genotypes studied behaved as facultative short-day plants: i.e., they were capable of flowering under long days, but flowered much earlier under short days.

In conclusion, early spring planting inhibited growth of genotypes at early stage, but not significant at the later stage. Significant growth response of genotypes was caused mainly by the difference of planting date. Significant yield and yield components response was caused by the difference of genotypes. No significant G×D interaction for growth, yield and yield components, except for leaf area was observed. Genotypes selected for yield (G1), number of productive panicles (G3) and panicle weight (G4) were relatively stable in different planting date and might be consider as genotypes adapted for early spring planting. Photoperiod sensitivity of pearl millet was evidenced. Since pearl millet in this study could flowering even in long-days, as 16 hours photoperiod, and flowered much earlier in short- days, as 8 hours photoperiods, it might be consider as a facultative short-day plant.

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