Surprising flowering response to photoperiod: Preliminary characterization of West and Central African pearl millet germplasm

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Introduction

Pearl millet (*Pennisetum glaucum*) is considered to be a short-day species that flowers, or flowers earlier, when day lengths are short. A few studies with two to six planting dates and few selected entries have been conducted in USA (Burton 1965), Senegal (Ramond 1968), and India (Patil et al. 1978, Das 1991). However, there is no known research on the flowering response of pearl millet to photoperiod changes over the entire year. Likewise, knowledge about the photoperiod-sensitivity in West and Central African pearl millets is insufficient.

Materials and methods

Monthly sowings of 12 pearl millet varieties at Samanko, Mali. A set of 12 West African pearl millet varieties from Senegal, Mali, Burkina Faso and Niger, covering a large range of photoperiod-sensitivity, was sown every month at Samanko, Mali (12°32' N, 8°04' W) during 2 years from June 2004 to May 2006. Plantings were on or about the 10th of each month, except for the first two sowings on 26 June and 27 July 2004. Plots of four rows, 0.75 m apart and 5 m long were sown with 10 seeds per hill at 20 cm within rows and thinned to one plant per hill two weeks after emergence. Plots were irrigated twice a week during the dry season. Two plants per plot were sampled weekly and dissected to count the number of leaves initiated at the apex and record the date of panicle initiation. Air temperature at 2 m above ground was recorded and thermal time was calculated on an hourly basis, using 11, 34 and 54°C as base, optimal and maximum temperatures, respectively.

Two sowings of 360 landraces at Sadoré, Niger. Three-hundred sixty pearl millet landraces from all over West and Central Africa were sown in Sadoré, Niger (13°06' N, 2°21' E) on 14 July and 15 August 2006. The July sowing was done using two-row plots, with 0.75 m interrow and 0.8 m intra-row distance and 7 hills per row. The entries were randomized using a-design with 8 plots per incomplete block and 3 replications. The August planting was an unreplicated observation nursery using 1-row plots of 7 hills, with the same spacing as above. The August planting was irrigated once a week with 30 mm from 3 October until 15 November. Plots were thinned to two plants per hill in both sowings. ANOVA of the replicated flowering data from the July sowing was used to estimate the standard error for flowering dates (assumed to be equal also in the August planting) as:

$$t * \sqrt{\frac{\sigma_e^2}{n} + \sigma_e^2}$$

with t = student, σ_e^2 = error variance and n = number of replications.

Results and discussion

Monthly sowings in Samanko, Mali. The 12 varieties showed large variation for the duration of their vegetative phase (*sensu stricto*, from sowing to panicle initiation) in response to the different sowing dates (Fig. 1). This large variation was observed both when measured in days and in thermal time, with quite close agreement between the two measures. The duration of the vegetative phase of GB 8735 did not respond to sowing dates in the first six months of the year and the minimum vegetative phase, lasting 23 days or 277°C.d, occurred when sown in July, while the maximum (40 days or 527°C.d) occurred with the October sowing. The varieties Sanko and Kapelga, in contrast, were highly responsive, and Bandiagara was

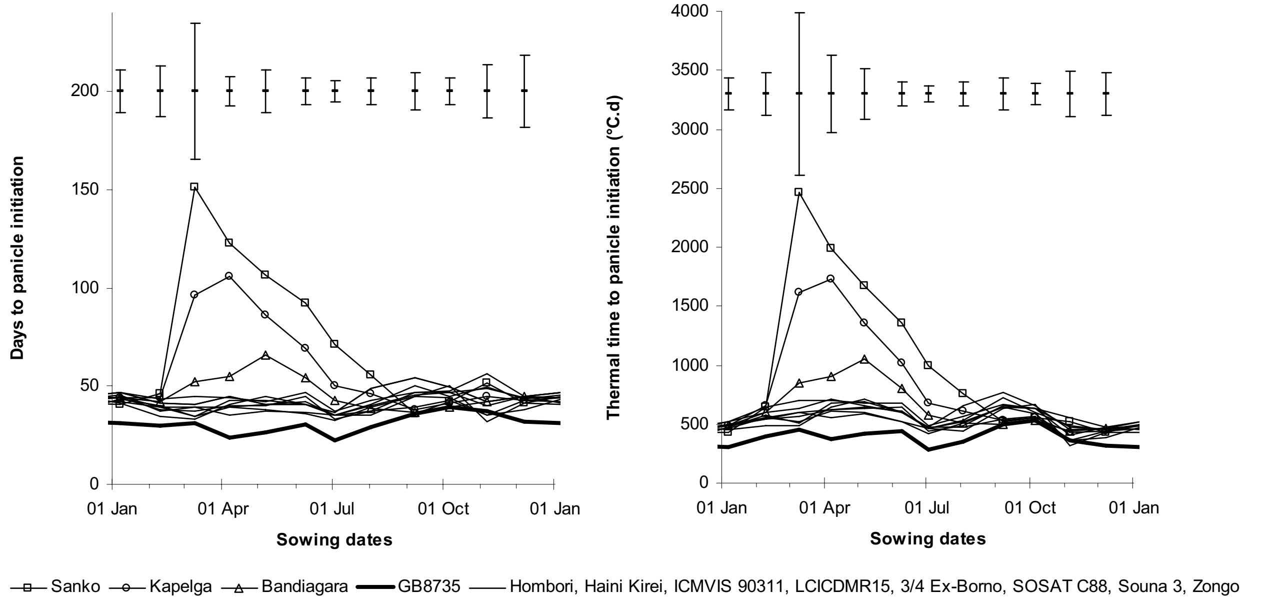

Figure 1. Average duration of the vegetative phase, from sowing to panicle initiation, in days and thermal time, of 12 pearl millet varieties sown monthly at Samako, Mali during the period of June 2004 to May 2006. Bars indicate the confidence interval (*P* = 0.05) of each monthly average.

intermediate. The vegetative phase of Sanko was 151 days or 2462°C.d at its maximum when sown in March, and only 36 days or 424°C.d when sown in September. The remaining 8 varieties had similar and fairly stable duration of their vegetative phase for the first six sowings of the year, which averaged 41 days, suggesting photoperiod-insensitivity. However, they exhibited an unexpected minimal duration of 35 days for the sowings in early July. Durations were a bit more variable for sowings during the last five months of the year. The average durations of the vegetative period for the 8 early varieties (Hombori, Haini Kirei, ICMVIS 90311, LCIC-DMR15, ¾ Ex-Borno, SOSAT C88, Souna 3 and Zongo) plus GB 8735, expressed in thermal time, showed two annual minima, 460°C.d in July and 424°C.d in December, and two annual maxima, 650°C.d in May and 659°C.d in September. These observations indicate that these early-maturing varieties achieved panicle initiation fastest for sowings done both when the day lengths were the longest (late June to early July) and the shortest (December). These observations are surprising and actually raise questions about the classification of pearl millet as a short-day plant.

Two sowing dates of 360 accessions in Sadoré, Niger. The flowering of 360 West and Central African millet accessions occurred between 43 and 109 days after sowing when sown on July 14, with an average of 70.1 days. The range of flowering for the 15 August sowing

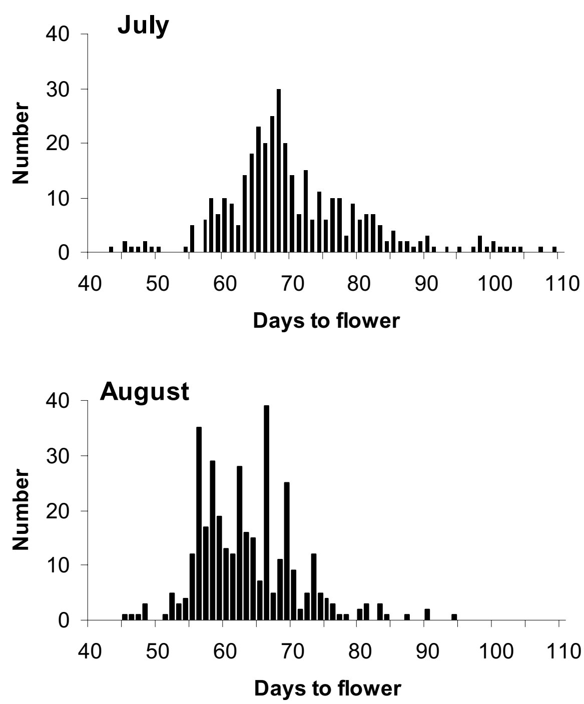

Figure 2. Frequency distributions of the durations from sowing to 50% flowering recorded on 360 West and Central African pearl millet accessions at Sadoré, Niger for sowings done on 14 July and 15 August 2006.

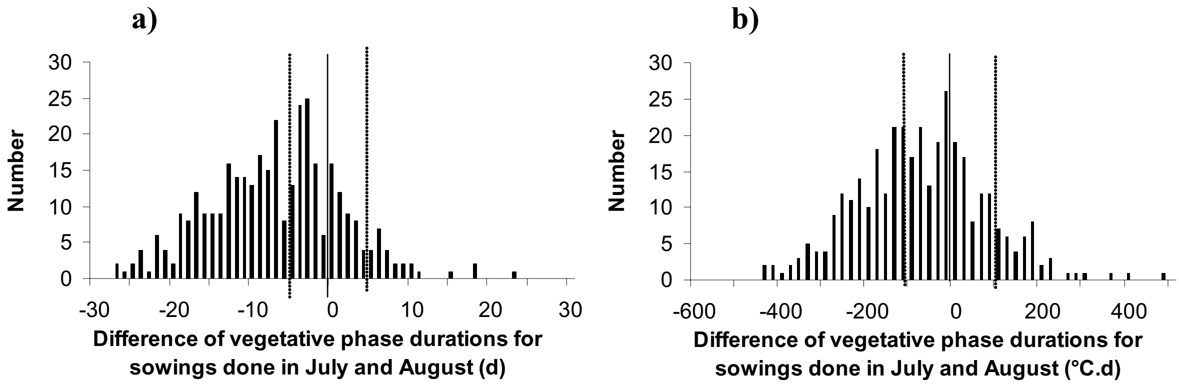

Figure 3. Frequency distribution of the difference of the durations from sowing to flowering in (a) days and (b) thermal time, of 357 pearl millet accessions when sown on 14 July versus 15 August 2006 at Sadoré, Niger.

date was between 45 and 94 days, with an average of 63.2 days (Fig. 2). Thus the vegetative phase (*sensu lato*, from sowing to flowering) was 6.9 days shorter in the August sowing. The varietal differences for duration of their vegetative phase between the July and August sowing dates ranged from −27 (strong shortening of the time to flower in the August planting) to +23 days (prolonged time to flower in the August planting) (Fig. 3a). The confidence interval for comparing the duration of the vegetative phase between sowing dates was 5.6 days (at 5% level of probability). Using this confidence interval, the 197 accessions (55% of the collection) that had significantly shorter vegetative cycles with the later sowing date were classified as photoperiod-sensitive, and the 137 (39%) accessions that had vegetative cycle differences near zero (between −5.6 and +5.6) were classified as insensitive. The 22 varieties (6%) that had a significantly longer vegetative phase for the August sowing were particularly surprising. These varieties flowered between 43 and 77 days in the July sowing; representing the earliest half of the total flowering range observed in the collection. Since September was warmer than July and August (data not shown), the thermal time during 50 days after sowing was also lower for the July sowing (864°C.d) than for the August sowing (902°C.d). Therefore, the number of varieties with a significantly longer vegetative phase in August increased to 34 (9% of the collection) when the duration was expressed in thermal time (Fig. 3b). These preliminary observations require further validation.

Results from the 2006 experiment in Sadoré, Niger confirm that many West and Central African pearl millet varieties are photoperiod-sensitive. Further, they confirm the results from Samanko, Mali that showed a significant number of early varieties of pearl millet which flowered later when sown in August than in July. This unexpected response is not due to a direct effect of the temperature but could be caused by an interaction between photoperiod and temperature. It also could be caused by another signal which is the daily change of the sunrise and sunset hours, as has been already shown for tropical trees (Borchert et al. 2005). The period around 21 June is not only the moment when day lengths are longest but also the moment when the daily variation of the sunset time reaches a minimum. Since long day lengths in July are not expected to induce early flowering dates, the daily change of the sunset time could be the signal that explains this behavior.

The capacity of early pearl millet varieties to reduce their vegetative phase by a week when sown late, ie, in July, may provide significant adaptive advantages in the Sahelian region when later sowing dates correspond with more limited duration of available moisture. This capacity for growth plasticity in materials traditionally considered to be photoperiod-insensitive certainly warrants more detailed examinations.

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