Field Crops Research 125 (2012) 139–150

Contents lists available at SciVerse ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Why tropical sorghum sown in winter months has delayed flowering and modified morphogenesis in spite of prevailing short days

B. Clerget[a,b,c,*], H.F.W. Rattunde[b], E. Weltzien[b]

[a] CIRAD, UMR AGAP, F-34398 Montpellier, France
[b] ICRISAT, BP 320, Bamako, Mali
[c] IRRI, DAPO Box 7777, Metro Manila, Philippines

ARTICLE INFO

Article history:
Received 4 May 2011
Received in revised form
16 September 2011
Accepted 16 September 2011

Keywords:
Sorghum bicolor
Phenology
Photoperiod
Flowering
Low temperature
UV radiation

ABSTRACT

Sowing certain late photoperiod-sensitive tropical sorghum varieties under short-day conditions in November–January in the northern hemisphere can result in a pronounced delay in flowering and prostrate, high-tillering forms similar to the rosettes in winter small-grain cereals. The cause of this phenomenon in sorghum has long been questioned and is often attributed to the effects of low night temperatures during this period. Monthly sowings, from December to March, in greenhouse compartments with two contrasting night temperatures and under field conditions with contrasting soil conditions were conducted over two years near Bamako, Mali, with three contrasting sorghum varieties. Dates of panicle initiation, rates of leaf primordia initiation at the stem apex, and rates of leaf appearance were observed. In the greenhouse, colder night temperatures were found to have no effect on prolonging vegetative-phase duration when measured in thermal time and on plant development. Although a prolonged vegetative phase and prostrate forms were observed under field conditions, these were not observed in the greenhouse experiments despite having similar temperature conditions. Although the higher soil fertility of the potting soil increased the development rates slightly, and reduced the vegetative phase relative to natural soil conditions in the field, this difference between greenhouse and field growth remained when a comparison was made between plants grown in pots. Thus, it appears that the greenhouse glass had masked the UV component of sunlight, which would mediate the cue responsible for the delayed flowering and modified morphogenesis. This cue, which has strongly contrasting effects between October and November sowings, could be the daily changes in the sunrise and sunset hour that have negative values from November to July.

1. Introduction

Major delays in flowering of photoperiod-sensitive sorghum can be observed in tropical northern-hemisphere sowings during the November to January period relative to September–October or March sowings (Bezot, 1963; Miller et al., 1968; Vaksmann et al., 1997; Clerget et al., 2004; Dingkuhn et al., 2008). This lengthening of the vegetative phase for sowings done during short daylengths was not a simple effect of slower growth due to cooler ambient temperatures of this period, as flowering delays were still apparent when measured in thermal time (Vaksmann et al., 1997; Clerget et al., 2004; Dingkuhn et al., 2008). As short daylengths occur during this period, rapid progress to flowering, in thermal time, would normally be expected with this short-day species.

The prolonged vegetative period of these cool-season sown sorghum varieties is accompanied by a prostrate growth with high tillering (Bezot, 1963). All stems grow nearly horizontally in divergent orientations, constituting a rosette similar to that of small-grain winter cereals. Leaves of some varieties take on a red colour that can be very pronounced. Low night temperatures can drop below the minimum growth temperatures (10–11 °C) for sorghum during these months (Vaksmann et al., 1997; Clerget et al., 2004; Dingkuhn et al., 2008). Consequently, low night temperature has been envisaged as the reason for the delayed flowering of tropical sorghum sown in the field during November to January (Bezot, 1963; Miller et al., 1968; Vaksmann et al., 1997). However, temperatures never fall below 15 °C in Mayaguez, Puerto Rico, where Miller et al. (1968) had carried out their experiment and nevertheless found a large lengthening of the vegetative phase for winter sowings in spite of the very stable daily mean temperature year-round in the Caribbean islands. On the other hand, the prostrate rosette form had also been observed in growth chambers when a photoperiod-sensitive guinea variety from Burkina Faso, named

* Corresponding author at: Crop and Environmental Sciences Division, IRRI, DAPO Box 7777, Metro Manila, Philippines. Tel.: +63 2 580 5600; fax: +63 2 580 5699.
E-mail address: benoit.clerget@cirad.fr (B. Clerget).

0378-4290/$ – see front matter
doi:10.1016/j.fcr.2011.09.010

Table 1
List of the treatments used each sowing month, with their sowing date.

Sowings		Field			Greenhouse	
Month and year	Day	Field soil	Buried pots	Potting soil	Warm	Cold
Dec 2001	10	•			•	
Jan 2002	11	•			•	•
Feb 2002	11	•				
	21		•			
Mar 2002	12	•				•
Dec 2002	2				•	•
	10	•	•			
Jan 2003	6				•	•
	10	•	•			
Feb 2003	10	•	•	•	•	•
Dec 2006	11	•	•	•		
Jan 2007	10	•	•	•		
Feb 2007	9	•	•	•		

Nazongala, had been grown under a 12/12 h light/dark and 27/23 °C alternation, and had not reached panicle initiation after 90 days because of the insufficiency of red radiation in the light spectrum (Clerget, 2004).

Photoperiod sensitivity and temperature interaction have been frequently examined in controlled environments in various day/night temperature combinations (Caddel and Weibel, 1971; Quinby et al., 1973; Ellis et al., 1997; Craufurd et al., 1998). All these authors have found that panicle initiation occurred earlier under short photoperiod of 10–12 h and an optimal mean temperature of 26–27 °C and was delayed by longer photoperiods and cooler or warmer temperatures. Based on similar results in pea, bean, and sorghum, Yan and Wallace (1996) proposed to model the duration of the vegetative phase through a U-shape function, product of the quadratic effects of both temperature and photoperiod. Additionally, in a study carried out on rice, Yin (2008) used 6 combinations of day/night temperatures under a unique photoperiod of 12 h on 3 rice varieties and showed that the temperature regime was able to nearly double the duration of the vegetative phase from 80 to 150 days. However, a weakness of all these studies was that the duration of the vegetative phase has never been expressed in thermal time, which is considered as the physiological time of plants, and their conclusions about the photoperiod × temperature interaction on the duration of the vegetative phase consequently remained debatable.

In the same studies, Quinby et al. (1973) and Craufurd et al. (1998) found that plants had produced a stable number of leaves under mean temperature from 18 to 31 °C, and more leaves at lower or higher mean temperatures. They also found that the plastochron, the number of days between the initiations of 2 consecutive leaves, had been stable between 18 and 31 °C mean temperature, but much longer at 14 °C or 33 °C. Although sorghum is traditionally sown during May–July in the northern hemisphere, its behaviour during November to January sowings was hypothesized to be one aspect of its photoperiod sensitivity, whose study could bring a more complete understanding of flowering responses. This study was thus initially conceived to assess the influence of low night temperatures on flowering and growing behaviour of sorghum varieties of contrasting photoperiod sensitivities and extended later to check the validity of the contrasting results between greenhouse and field environments.

2. Materials and methods

Three contrasting sorghum varieties were used in this study: CSM 335, a tall, traditional *guinea* landrace from Mali known to be highly photoperiod-sensitive; Sariaso 10, a less photoperiod-sensitive variety bred in Burkina Faso from a *guinea* × *caudatum* cross; and IRAT 174, a dwarf photoperiod-sensitive line bred in Burkina Faso from a *kafir* × *durra* cross. Seed of CSM 335 was provided by the ICRISAT-Samanko Sorghum Program, whereas seed of the other varieties came from the CIRAD Genetic Resources Unit in Montpellier, France.

Simultaneous or nearly simultaneous sowings were done in two adjacent compartments of a greenhouse and a field at the ICRISAT research station of Samanko, 15 km to the SW of Bamako, Mali (12°34′N, 8°04′W, 330 m a.s.l.), on 10 December 2001; 11 January, 11 and 21 February, 12 March, 2 and 10 December 2002; and 6 and 10 January and 10 February 2003 (Table 1).

2.1. Greenhouse experiments

The greenhouse (Cambridge Glasshouse Company, Comberton, Cambridge, UK) was glass covered and divided into compartments with glass walls. The light transmittance of the glass was measured under direct sunlight at 2 angles of incidence, 0 and 45°, with a radiospectrometer (FieldSpec® 3 JR (350–2500 nm), ASD Inc., Boulder, CO, USA) (Fig. 1). Canvas sheets were vertically installed against the northwestern walls of 2 compartments to mask possible contaminating sources of light from the offices and from a red light at the top of an antenna's mast. The "cold" compartment was cooled day and night, using an evaporative air cooler (RW4500, AdobeAir Inc., Phoenix, AZ, USA). The "warm" compartment was cooled from 0800 to 1800 with an identical air cooler and warmed during nights with an oil heater (KAI 20, Kongskilde Industries, Sorø, DK) to maintain the temperature above 23 °C. Each sowing date used 60 plastic 10-l pots filled with 8 kg of a mixture of 9 parts soil from the surface of a well-drained plot from the station (fine, loamy,

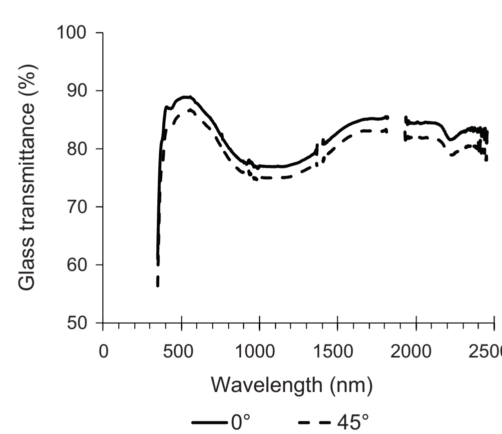

Fig. 1. Transmittance spectrum of greenhouse glass under 2 angles of light incidence, 0 and 45°.