R 7574:   FINAL TECHNICAL REPORT

Rapid Generation Advance in Photoperiod Sensitive Sorghums

V.Mahalakshmi
Principal Scientist
Global Theme 1
ICRISAT, P.O.
Patancheru 502 324
Andhra Pradesh, India
E-mail: V.Mahalakshmi@cgiar.org

Executive Summary

Sorghum is grown between latitudes of 42 °N and 42°S. Many of the sorghums grown at low latitudes less than 14 °N and S are highly photoperiod sensitive. Sorghum is a short-day plant and flowering is advanced under short-days. Techniques that can rapidly advance flowering will help breeding programs aimed at improving sorghum for the post-rainy (*rabi*) season, by advancing two generations a year instead of the one that is currently possible. This would double the rates of genetic gain per year. This study was designed to enhance generation advance in photoperiod and post-rainy sorghums under short days. The objectives of this project was to develop 1): techniques to produce rapidly the seeds for generation advance in photoperiod sensitive sorghum and 2): more lines advanced to next generation in a cost effective and adaptable manner in limited time and space.

Experiments were carried out during 2000-2002 under glasshouse conditions at the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India. Short-day treatments (8h day length) were imposed by covering the plants from emergence to 35 days after emergence (DAE) with a manually operated blackout facility of 3m long by 1.7m wide by 1.5m high. To determine the optimum time for short-day treatment, experiments were conducted at various periods during the year. Fifteen genotypes ranging in their photoperiod sensitivity and representing possible photo-period responses of cultivated sorghum were used in this study. Though flowering was induced under short day treatments, growing sorghum plants up to maturity in small pots was not effective. Plants showed both depressed growth and nutritional disorders despite receiving adequate nutrients. Therefore, seedling were grown in small Styrofoam cups (6.5 cm diameter of 150 cc) under short-day treatments up to 35 DAE and then seedlings were transplanted into big pots (33 cm diameter of 13,200 cc) or in field and grown until maturity.

Flowering was advanced by short-day treatment in most genotypes. However, the plantings where the mean temperatures during the panicle development were greater than 28°C was not effective in seed set. In these experiments the daily mean temperatures exceeded the reported optimum temperature for sorghum and resulted in delayed flowering under short day treatment. Further in some genotypes the spike-lets were sterile when the daily mean temperatures during panicle development exceeded the optimum temperature. Therefore, any period (except April and May in this study) where the daily mean temperatures during the year do not exceed 28°C is recommended for short day treatment for inducing flowering in sorghum. To accommodate more plants in the short day treatment, it was decided to grow the seedling in small Styrofoam cups up to 35 DAE under short days and then transplant them into bigger pots or into field. Transplanting by uprooting usually sets back the plant growth and delays flowering in sorghum. However, in these experiments the intact transplanting of plants from the Styrofoam cups showed no such depression.

Recommendations

- Any period (except April and May in this study) where the daily mean temperatures during the year do not exceed 28 °C is suitable for short-day treatment to advance time to flowering in sorghum.

- Short-days (8h day-length) cycles from emergence to 35 DAE are sufficient to induce flowering in most photoperiod sensitive genotypes.
- Short-day treatments can be given to plants grown in small pots (in Styrofoam cups) and transplanted at 35 DAE to either big pots or field.

R 7574 - Rapid Generation Advance in Photoperiod Sensitive Sorghums

Background

Sorghum is an important small-grain cereal grown between latitudes of 40 °N and 40°S of the equator. Many of the sorghums grown at low latitudes of less than 14 °N and S are highly photoperiod sensitive. Sorghum is a short-day plant (SDP) and flowering is advanced under short-days. In Africa this photoperiod sensitivity gives adaptation to the varying rainfall patterns (Curtis, 1968). This photoperiod sensitivity, while giving local adaptation for the crop to match with the water availability patterns limits their adaptation in mid-latitude environments and their utilisation in breeding programs (Curtis, 1968). *Previous studies have shown that, growing sorghum in short day lengths could induce panicle initiation in photo-sensitive sorghums over a range of temperatures (Caddel and Wiebel, 1971 & 1972; Lane, 1963).* Craufurd, 1987; Craufurd et al 1998 & 1999) but under supra optimal temperatures the short day-length effects are reversed (Craufurd et al, 1999). Despite the variation in planting time due to the uncertain onset of rains, the sorghum in Nigeria flower at the same calendar time, which coincides with the more certain end of rains. Post-rainy (*rabi*) sorghums in India are grown over 6 million ha but yield levels has been stagnant over the last 3 decades. Many of the post-rainy sorghums in the germplasm collection at ICRISAT are from low latitudes but highly photoperiod sensitive. Traditionally the use of such germplasm in breeding programs has been through their conversion into photoperiod insensitive types.

Project Purpose

Techniques to rapidly advance generation of photoperiod sensitive material could enhance their utilization in breeding programs. A very simple technique to rapidly advance generation in photoperiod sensitive sorghum using locally available material was developed and tested with a wide range of photo-period sensitive sorghum at different times during the year to determine the optimum conditions. Further this technique will help breeding programs aimed at improving sorghum for the post-rainy (*rabi*) season, to advance two generations a year instead of the one that is currently possible. This would double the rates of genetic gain per year.

Research Activities

Fifteen sorghum germplasm lines varying in their photoperiod sensitivity were used to determine the optimum short-day, and minimum nutrient level to advance their flowering time to produce good quality seeds. The experiments were conducted in glass-house using the facility to impose short-days and controlled environments at ICRISAT. The glass-house experiment was later disseminated to NARS for their use. Unlike other cereals where the deprival of nutrient results in earlier flowering, in case of sorghum, N deficiency leads to delay in flowering. Therefore, alternate approaches such as light competition (high density or packing plants close together) under short days, optimum minimal pot size and potting mixture were determined and standardised.

Experiments were carried out during 2000 and 2002 under glasshouse conditions at the International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India (17 30’

N, 78 16’ E, altitude 545 m). Short-day treatments (8h day length) were imposed by covering the from emergence to 35 days after emergence (DAE) in a manually operated blackout facility of 3m long by 1.7m wide by 1.5m high. To determine the optimum time for short-day treatment, seven experiments were conducted at various planting times during the year (see details in Table 1).

Table 1. Details of the experiments conducted with the dates of emergence and the mean maximum and minimum temperatures during the first 35 days after emergence (DAE).

Experiment	Date of emergence	Maximum temperature °C	Minimum temperature °C	Number of genotypes	Experimental design
Pot size (2), high and low fertility, normal and short day treatment	3rd May 2000	35.8	21.6	10	Split-plot
Normal and short day	7th Aug 2000	28.3	19.3	10	Split-plot
Normal and short day	21st Nov 2000	29.4	11.6	15	Split-plot
Normal and Short day	2nd Apr 2001	37.4	23.0	15	Split-plot
Short day treatment	12th June 2001	32.2	22.2	15	Randomised block design
Short day treatment + transplanting at 35 DAE	18th Sept 2001	29.7	20.5	15	Randomised block design
Normal and short day and transplanting at 35 DAE	7th July 2002	31.7	21.4	15	Split-plot

Ten genotypes ranging in their photoperiod sensitivity were used in the initial two experiments to determine the optimum number of short-day treatments, fertility level and planting density. Once the protocol for short day treatment was determined, fifteen genotypes ranging in their photo-period sensitivity and covering the possible photo-period responses of cultivated sorghum were used in other experiments to determine the optimum pot size and transplanting of seedlings after short day treatment (Table 2). To accommodate maximum number of plants in the short day treatment, two sizes (12.5 cm diameter of 900 cc and 15.0 cm diameter of 1800 cc) of pots were evaluated. Though flowering was induced under short day treatments, growing sorghum plants up to maturity in these pots was not very effective. Plants showed both depressed growth and nutritional disorders despite receiving added nutrients. Therefore, we used small Styrofoam cups (6.5 cm diameter of 150 cc) for growing plants in the short-day treatments up to 35 DAE and then plants were transplanted into big pots (33 cm diameter of 13,200 cc) or in field until maturity.

Table 2. List of genotypes, their origin and photoperiod response (time to flowering in 8h day-length at mean temperatures < 25°C

Genotype	Origin and photoperiod response	Days to flowering at 8h day length
IS 34969	Central African republic, landrace– highly photoperiod sensitive	69.8
IS 33225	Central African republic, landrace – highly photoperiod sensitive	68.0
RS 610	USA, Single cross hybrid – photoperiod insensitive	64.0
M 35-1	India, a selection from Maldandi landrace bulk, postrainy season variety – photoperiod sensitive	81.8
E 36-1	Ethiopia, a selection from landrace bulk - IS 30469, postrainy season variety, highly stay green – photoperiod sensitive	66.7
SPV 1359	India, an improved variety developed by Mahatma Phule, Krishi Vidyapeeth, Rahuri, postrainy season variety	97.7
NTJ 2	India, post-rainy season variety developed from a landrace bulk of IS 30468 from Nandayal by Acharya N G Ranga Agricultural University, Agricultural Research Station photoperiod sensitive	67.8
ICSB 677	ICRISAT, stay-green type maintainer line suitable for *rabi* season hybrids' development	83.0
ICSB 101	ICRISAT developed high yielding maintainer line	81.8
296 B	India, a high yielding maintainer line developed by National Research Center for Sorghum, Hyderabad	85.3
SPV1380*	India, an improved variety developed by University of Agricultural Sciences, Agricultural Research Station, Bijapur, postrainy season variety	93.7
ICSB 440(SFPR) *	ICRISAT developed shoot fly resistant maintainer line for postrainy season	87.7
ICSB 461(SFPR) *	ICRISAT developed shoot fly resistant maintainer line for postrainy season	87.2
ICSB 417(SFR) *	ICRISAT developed shoot fly resistant maintainer line for rainy season	88.5
ICSB 418(SRR) *	ICRISAT developed shoot fly resistant maintainer line for rainy season	82.5

* Additional genotypes in experiments 3 to 7

Short days were effective in advancing flowering in all genotypes and the effect was more apparent in the photoperiod sensitive types where the flowering did not occur till 130 days after emergence (Table 3). Low fertility generally delayed flowering in both normal and short day treatments. Flowering was also generally delayed in smaller pots due to competition. In this experiment plants were sampled to determine the panicle initiation. In short day treatment panicle initiation occurred in all genotypes by 35 DAE. Under normal days the plants were subjected to increasing day lengths (March – June) and increasing temperatures. This joint effect of longer day lengths and high temperatures resulted in delayed panicle initiation in IS 34969 and IS 33225, which are photoperiod sensitive germplasm lines. In the post rainy germplasm lines the effect of short day in advancing flowering time was not that significant and the effect of high temperatures in delaying flowering was more evident. The Indian post rainy germplasm lines seem to be temperature sensitive as well. Though they are less photoperiod sensitive than the central African landraces the effect of short day in advancing flowering was not as effective as in the very photoperiod sensitive lines.

Table 3. Time to flowering in sorghum as affected by pot size, soil fertility and photoperiod (May 2000)

	Normal Day Treatment				Short Day Treatment (8hr)			
	High Fertility		Low Fertility		High Fertility		Low Fertility	
Genotype	**Big pot**	**Small pot**	**Big pot**	**Small pot**	**Big pot**	**Small pot**	**Big pot**	**Small pot**
IS 34969	NF	NF	NF	NF	66.2	65.2	70.5	71.2
IS 33225	NF	NF	NF	NF	67.8	62.5	60.2	63.0
RS 610	49.5	52.7	54.8	58.0	50.0	52.0	57.3	59.3
M 35 -1	70.7	62.8	64.5	68.7	62.5	59.7	66.7	75.2
E 36-1	78.5	84.3	95.3	97.2	59.5	60.8	58.3	61.0
SPV 1359	86.8	87.7	87.0	104.7	80.2	84.0	89.2	116.5
NTJ 2	73.0	78.8	79.7	81.3	57.3	57.8	57.3	59.2
ICSB 677	82.3	82.3	70.7	83.7	64.8	70.3	77.5	82.0
ICSB 101	77.7	79.8	75.0	76.8	58.8	62.8	69.0	77.0
296 B	79.7	69.0	76.5	75.7	66.8	64.5	66.5	67.7

SE_m (genotype x fertility x pot x treatment) = 2.5 (Add one more digit after decimal)

NF not flowered until 130 days; Small pots 900cc and 12.5 cm diameter; Big pots 1800cc and 15 cc diameter.

Unlike the long-day crops (wheat and barley) where low fertility and high competition advanced flowering, in sorghum low fertility and competition delayed flowering. The results from this experiment suggested that short day treatment from emergence to 35 DAE were sufficient to induce early flowering in most sensitive sorghum germplasm lines.

Experiments were conducted under short days at various times during the year to understand the effect of temperature. In the April planting where the mean temperatures were > 28°C, short day treatment was not effective in advancing flowering as the plants remained vegetative till 100 DAE. Even in plants, that had panicles the florets were barren or sterile and this resulted in the growth of ancillary tillers from the lower leaf nodes.

The question of advancing more lines under short day treatment in limited space still remained. Though it is known that sorghum seedlings can be transplanted, it was presumed such transplanting was done prior to panicle initiation. There fore experiments were conducted to evaluate the effect of transplanting of seedling after panicle initiation.

Seedlings were grown in small Styrofoam cups (6.5 cm diameter of 150 cc) under short-day treatments up to 35 DAE and then transplanted into big pots (33 cm diameter of 13,200 cc) or in field and grown until maturity. To avoid any transplanting shock the cups were slit open and the seedlings were planted directly into the soil in pots or in the field. Transplanting after panicle initiation had no effect on flowering (Table 4).

Table 4 . Time to flowering as affected by transplanting of plants grown under natural day lengths and under short day length for 35DAE [experiment 7, 2001]

Genotype	Normal Day	Short Day
	Days to flowering	
IS 34969	148.3	68.8
IS 33225	149.5	68.3
RS 610	58.0	52.0
M 35-1	70.75	66.5
E 36-1	71.0	61.3
SPV 1359	87.5	85.3
NTJ 2	71.0	59.0
ICSB 677	75.7	68.8
ICSB 101	75.0	63.7
296B	73.8	67.3
SPV 1380	81.5	69.7
ICSB 440	76.0	70.2
ICSB 461	69.3	63.3
ICSB 417	72.5	72.2
ICSB 418	76.5	70.7

SE_m (genotype x treatment) = 1.5 (Add one more digit after decimal)

For post rainy sorghums flowering can be advanced during the rainy season by growing seedling in small cups under short day lengths for 35 DAE and then transplanting them in bigger pots. Post rainy sorghum are more sensitive to high temperatures than the other sorghum germplasm used in this study. Care should be taken to avoid period when temperatures are high.

Output 1. Techniques to produce seeds for generation advance in photoperiod sensitive sorghum.

Short day length treatments from emergence to 35 DAE is sufficient to induce flowering in most photoperiod sensitive genotypes. However it is recommended that temperatures during the short day treatment and panicle development should be below 28° C. Indian post rainy season sorghums are especially sensitive to high temperatures.

Output 2. More lines advanced to next generation in limited time and space.

Both low nutrient status and high plant density delayed flowering and not recommended for advancing flowering in sorghum. Growing seedling in small Styrofoam cups for 35 DAE under short days and then transplanting the seedlings into bigger pot or in field can be used to accommodate more lines for advancing to the next generation.

Contribution of Outputs

The technique as such needs no further refinement. However, the interaction of temperature and photoperiod with genotypes seems to be strong in some cases. Post-rainy season material from India is sensitive to high temperatures and short day treatments have limited effect on advancing flowering. This aspect of post-rainy sorghum is often reported as them being photoperiod sensitive which needs detailed studies to understand. Currently a study is under way by the NRCS physiologist.

The facility is in operation and in use at ICRISAT. This technique is already in use at ICRISAT by the sorghum breeders for advancing generation in the stay green backcrossing program for Marker Assisted Selection.

During the field days at ICRISAT we had shown the facility to both breeders from national program and seed industry. We are currently finalizing a flier on this technique, which will be distributed to sorghum breeders (private and public sector).

A short note is being prepared for communication to International Sorghum and millet newsletter for wider dissemination.

Recommendations

- Any period (except April and May in this study) where the daily mean temperatures during the year does not exceed 28 °C is suitable for short-day treatment to advance time to flowering in sorghum.
- Short-days (8h day-length) cycles from emergence to 35 DAE are sufficient to induce flowering in most photoperiod sensitive genotypes.
- Short-day treatments can be given to plants grown in small pots (in Styrofoam cups) and transplanted at 35 DAE to either big pots or field.

This technique is in use at ICRISAT by the plant breeders who are currently advancing lines for stay green trail using marker assisted breeding by incorporating the trait in locally adapted germplasm by backcrossing.

References

Craufurd, P.Q. 1987 Forcing flowering in photoperiod sensitive sorghums using short-day treatments. Sorghum newsletter pp:35

Craufurd, P.Q., V. Mahalakshmi; F.R. Bidinger; S.Z. Mukuru; J. Chantereau; P.A. Omanga; A.Qi; E.H. Roberts; R.H. Ellis; R.J. Summerfield; G.L. Hammer. 1999. Adaptation of sorghum: characterisation of genotypic flowering responses to temperature and photoperiod. Theor Appl Genet 99:900-911

Craufurd, P.Q.; A.Qi; R.,H. Ellis; R.J, Summerfield; E.H. Roberts and V. Mahalakshmi. 1998. Effect of Temperature on Time to Panicle Initiation and Leaf Appearance in Sorghum. Crop Science Vol. 38. No.4

Caddel. J.L. and D.W. Weibel. 1971. Effect of photoperiod and temperature on the development of sorghum. Agronomy Journal 63:799-803.

Caddel, J.L., and D.E. Weibel. 1972. Photoperiodism in sorghum. Agron J. 64:474-476.

Curtis, D.L. 1968. The relation between yield and date of heading of Nigerian sorghum. Experimental Agriculture 4:93-101.

Lane, H.C. 1963. Effect of light quality on maturity in the Milo group of sorghum. Crop Science 3:496-499.

Publications:

1. Half yearly report of the Genetic Resources and Enhancement program- 2001
2. Annual report of the Genetic Resources and Enhancement Program – 2000, 2001

Any Significant Staffing Changes: Nil

Date: 26th May 2003