ISSN: 2278-5213

RESEARCH ARTICLE

Photoperiod sensitivity studies in sweet sorghum

M.S. Shinde, B.R. Mutkule, A.R. Gaikwad*, U.S. Dalvi and S.R. Gadakh
All India coordinated Sorghum Improvement Project, MPKV, Rahuri-413722 District, Ahmednagar, Maharashtra, India
atul_sorghum@rediffmail.com*; +91 9404980436

Abstract

The experiment was conducted with 18 sweet sorghum genotypes during *kharif* and *rabi* 2009-10. The photoperiod sensitivity studies revealed that the sweet sorghum genotypes RSSV-167, RSSV-138, RSSV-104, RSSV-96, RSSV-99 and RSSV-157 displayed lower magnitude of photoperiod sensitivity (<9.420%) among the genotypes studied indicating their photoperiod insensitivity for *rabi* season. The genotypes RSSV-259, RSSV-260 and RSSV-261 displayed higher magnitude of photoperiod sensitivity (>24.804%) indicating their photoperiod sensitivity for *rabi* season. Among these genotypes, the photo-insensitivity genotypes RSSV-167, RSSV-138, and RSSV-104 were identified coupled with less reduction in green cane yield during *rabi* season which could be exploited for biomass production during *rabi* season. The studies also suggest that these genotypes could be utilized in hybridization programme from photoperiod insensitivity point of view.

Keywords: Sweet sorghum, genotypes, *kharif*, *rabi*, photoperiod sensitivity, green cane yield, biomass.

Introduction

The term 'photoperiodism' was introduced by Garner and Allard (1920) to designate the response of plants to relative length of light and dark period. The observations of Garner and Allard (1923), McClelland (1928) and Robert (1938) showed that there were significant differences in phenology, growth and development of various agricultural and horticultural crops under different photoperiods. Photoperiod has been implicated as the dominant environmental factor which influence the reproductive period (Coleman and Belcher, 1952). Miller *et al.* (1968) studied the effects of tropical photoperiods on the growth of sorghum when grown in 12 monthly planting and it appeared that sorghum varieties might respond to differences in length of photo period as little as few minutes.

Kozhemyakin and Yashin (1986) studied photoperiod sensitivity of 33 sorghum forms in the Povolzh'e and reported that most marked reaction to day length was seen 5-15 d after emergence. Weakly sensitive or day neutral forms were identified, but no such forms were found among the sweet sorghum types. The duration from emergence to PI (GS_1) was controlled by both photoperiod and temperature while the duration of PI to anthesis (GS_2) and anthesis to PM (GS_3) were controlled by temperature alone in sorghum (Huda *et al.*, 1984; Huda, 1987; Ritchie and Alagarswamy, 1988; Hammer *et al.*, 1989; Major *et al.* 1990). When short day plants was kept in photoperiod longer than the critical photoperiod, the days required for panicle initiation and flowering increased in sorghum as observed by Mayers *et al.* (1989). Planting late maturing sweet sorghum cultivars in areas with long day length increased yield (Miller and McBee, 1993).

Photoperiod is one of the most important factors which control the basic vegetative phase (BVP) of crops. The plants were found to be insensitive to photoperiod in early growth period i.e. up to 14-21 d after emergence. This was identified as juvenile stage of sorghum (Karande *et al.*, 1996). Ellis *et al.* (1997) studied the effect of photoperiod, temperature and asynchrony between thermoperiod and photoperiod on development and panicle initiation in sorghum and it appeared to be an initial photoperiod insensitive but temperature sensitive phase (the juvenile phase), followed by a photoperiod sensitive but temperature insensitive phase and then a final phase insensitive to both photoperiod and temperature. Craufurd and Aiming (2001) concluded that cultivar SK 5912 sown by Kassam and Andrews was acutely sensitive to photoperiod and the thermal duration of the inductive phase was increased by 2115 growing degree days GDD/h photoperiod when mean photoperiod was >13 h, in sweet sorghum.

Sorghum is a quantitative short day plant. For short day plants, basic vegetative phase consist of two stages viz., Juvenile stage (temperature dependent) and inductive stage (photoperiod dependent). The thermal requirement of a genotype must be met before it responds to photoperiod. Flowering of tropical varieties was delayed by longer than 11.1-12.6 h and when day length becomes short ($\leq$12 h), the sorghum plant differentiates from vegetative to reproductive stage (Anonymous, 2003). Folliard *et al.* (2004) reported that the time from emergence to PI decreased from 54 to 22 d for a 2 min variation in day length and evaluated time to panicle initiation (PI) in highly photoperiod sensitive Guinea sorghum variety CSM-388.

Kouressy *et al.* (2008) reported that photoperiod sensitive V_1 and V_2 showed variable crop duration among date's years, whereas V_3 had nearly constant duration in sweet sorghum. Sweet sorghum sensitive response of flowering to photoperiod was essential for more humid environments having a long wet season, resulting in appropriate seasonal timing of flowering and greater flexibility of crop calendars (Kouressy *et al.,* 2008). Sweet sorghum can be grown in the day length ranged from 10 to 14 h (Anonymous, 2009). The light and temperature are the two principle environmental factors which decide the season boundedness of the genotypes which are referred to as photo-thermo-sensitive. The post rainy season (*rabi*) group crops recorded 30-35% less stalk yield with reduced sugar content than rainy (*kharif* season) because of short day length, low night temperature and radiation. In order to meet the industrial demand for raw materials especially after crushing of sugarcane crop, there is a need to develop sweet sorghum cultivars that are photo and thermo insensitive adapted to both rainy and post rainy season with high stalk and sugar yield. However, for commercial exploitation, the barrier of 'season specific genotypes' needs to be broken through physiological screening for photo and thermo insensitive genotypes so as to exploit them in the both seasons. Proper planning of sowing dates for insensitive genotypes in the catchments area of the distillery would help to achieve more commercial stalk sugar/ethanol. Season is one of the most important factor that influences the growth and developments of crop species which is related to photoperiod and temperature. The photoperiod response of genotypes determine the time of flowering and conjunction with the temperature. The photoperiod has been implicated as the dominant environmental influence reproductive period exhibiting varying response to photoperiod (day length). Therefore, identification of non-sensitive sweet sorghum genotypes to meet the industrial demand for raw materials during *rabi* season is needed. The knowledge of photoperiodism is essential to a crop breeder to breed the photoperiod sensitive/insensitive genotypes, low degree of photoperiod sensitivity is desirable to obtain potential biomass yield by adjusting optimal photoperiod with natural day length. As global climate is so gradually changing to higher temperature and sweet sorghum is bound to grow in new areas, photo insensitive genotypes needs to be developed or identified through hybridization or physiological screening for photo sensitivity. In view of the above facts, this study was undertaken to identify different sweet sorghum genotypes for photoperiod sensitivity during *kharif* and *rabi* season.

Materials and methods

Study location: The photoperiod sensitivity studies in sweet sorghum were conducted during *kharif* and *rabi* (2009-10) at All India Coordinated Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri District, Ahmednagar (Maharashtra).

Photoperiod sensitivity: The photoperiod sensitivity was computed as percent early/delay in flowering under specific environment compared to the time of flowering in the normal environment with the help of formula suggested by Talukdar *et al.* (1993).

Photoperiod sensitivity (%) = Days to flowering in specific environment–Days to flowering in normal environment/ Days to flowering in normal environment × 100.

a. Genotypes that differed by lower magnitude of photoperiod sensitivity percentage were considered as insensitive.
b. Genotypes that differed by higher magnitude of photoperiod sensitivity percentage were considered as sensitive.

Green cane yield: The green cane yield at physiological maturity was recorded after stripping the leaves, sheath and panicle in kg per net plot with the help of electronic balance and cane yield per hectare was calculated with hectare factor. The percent reduction over kharif was computed by the following formula.

Percentage reduction in *rabi* season = Green cane yield (t/ha) during *kharif* season–Green cane yield (t/ha) during *rabi* season/Green cane yield (t/ha) during *kharif* season × 100.

Statistical analysis: The randomized block design was used for analysis of days to 50% flowering, photoperiod sensitivity, green cane yield and % reduction as per the procedure given by Panse and Sukhatme (1985).

Results and discussion

The photoperiod has been implicated as the dominant environmental influence reproductive period exhibiting varying response to photoperiod (day length). Photoperiod sensitive reaction in plants is responsive to variation in natural hours of darkness in the field. This response is expressed as variation in the flowering; photoperiod sensitivity in sweet sorghum severely limits the successful biomass production in terms of green cane yield. Therefore, identification of non-sensitive sweet sorghum genotypes to meet the industrial demand for raw materials during *rabi* season.

The knowledge of photoperiodism is essential to a crop breeder to breed the photoperiod sensitive/insensitive genotypes, low degree of photoperiod sensitivity is desirable to obtain potential biomass yield by adjusting optimal photoperiod with natural day length. The photoperiod sensitivity was calculated as the percent early in flowering under specific environment day length (*rabi*) compared with the normal environment (*kharif*) season. From this study, sweet sorghum genotypes showed differential photoperiod sensitivity. Table 1 reveals that sweet sorghum genotypes showed differential photoperiod sensitivity.

Table 1. Photoperiod sensitivity (%) of sweet sorghum genotypes.

S. No	Genotypes	Days to flowering *(Kharif)*	Days to flowering *(Rabi)*	Photoperiod sensitivity (%)
1.	RSSV-82	82.1	74.0	9.867
2.	RSSV-96	82.8	75.0	9.420
3.	RSSV-99	80.3	74.6	7.098
4.	RSSV-104	80.4	75.0	6.716
5.	RSSV-106	90.5	73.9	18.343
6.	RSSV-120	83.4	73.4	11.990
7.	RSSV-138	81.5	75.6	7.239
8.	RSSV-157	80.5	73.0	9.317
9.	RSSV-166	83.7	73.9	11.708
10.	RSSV-167	80.5	75.1	6.708
11.	RSSV-191	92.6	75.3	18.682
12.	RSSV-192	90.1	74.3	17.536
13.	RSSV-259	106.0	79.0	25.472
14.	RSSV-260	105.0	78.0	25.714
15.	RSSV-261	102.0	76.6	24.804
16.	RSSV-262	92.0	79.3	13.804
17.	SSV-84	94.2	76.0	19.321
18.	CSV-19SS	85.0	73.0	14.118
Mean		88.5	75.3	14.325
SE±		0.51	0.68	0.92
CD at 5%		1.52	2.04	2.76

Table 2. Mean green cane yield (t/ha) and % reduction in green cane yield during *rabi* season.

S. No	Genotypes	*Kharif*	*Rabi*	Reduction (%)
1.	RSSV-82	48.4	31.5	34.9
2.	RSSV-96	47.6	26.7	43.9
3.	RSSV-99	48.7	32.0	34.3
4.	RSSV-104	50.3	35.0	30.4
5.	RSSV-106	54.9	34.5	59.1
6.	RSSV-120	41.5	23.5	76.6
7.	RSSV-138	53.4	38.0	28.8
8.	RSSV-157	32.4	16.4	49.4
9.	RSSV-166	35.0	15.0	57.1
10.	RSSV-167	54.7	39.0	28.7
11.	RSSV-191	29.5	19.0	35.6
12.	RSSV-192	53.9	38.5	28.6
13.	RSSV-259	38.3	20.4	46.7
14.	RSSV-260	41.2	25.0	39.3
15.	RSSV-261	31.0	19.0	38.7
16.	RSSV-262	47.2	24.2	48.7
17.	SSV-84	39.4	18.4	53.3
18.	CSV-19SS	43.3	28.0	35.3
Mean		43.9	26.8	42.8
SE±		2.0	4.9	15.3
CD at 5%		6.1	8.9	46.0

The sweet sorghum genotypes RSSV-167 (6.708%), RSSV-104 (6.716%), RSSV-99 (7.098%), RSSV-138 (7.239%), RSSV-157 (9.317%) and RSSV-96 (9.420%) displayed lower magnitude of photoperiod sensitivity among the genotypes, indicates photoperiod insensitive sweet sorghum genotypes for *rabi* season. The genotypes RSSV-260 (25.714%), RSSV-259 (25.472%) and RSSV-261 (24.804%) displayed higher magnitude of photoperiod sensitivity among the genotypes. These sweet sorghum genotypes were found to be photoperiod sensitive for *rabi* season. Shinde (2003) also suggested that a low degree of photoperiod sensitivity is a requirement for broad adaptation in sorghum and that corroborate with results obtained in the present investigation. Table 2 reveals that sweet sorghum grown in *rabi* season produced 28.6 to 76.6% less green cane yield over *kharif* season. In the present investigation, sweet sorghum genotypes viz., RSSV-192 (28.6%), RSSV-167 (28.7%), RSSV-138 (28.8%) and RSSV-104 (30.4%) recorded significantly less reduction in green cane yield during *rabi* season over the *kharif* season. In this study on photoperiod sensitivity indicated that the photoperiod insensitive genotypes viz., RSSV-167, RSSV-138 and RSSV-104 were identified coupled with less reduction percentage in green cane yield which could be exploited commercially for biomass production in terms of green cane yield in *rabi* season.

Conclusion

The photo-insensitive sweet sorghum genotypes viz., RSSV-167, RSSV-138 and RSSV-104 were identified and could be exploited commercially for biomass production in terms of green cane yield in both *kharif* and *rabi* seasons. Simultaneously, these findings could be utilized in breeding programme from the photoperiod insensitive point of view.

Acknowledgements

Authors are thankful to All India Coordinated Sorghum Improvement Project, MPKV, Rahuri (MS) for conducting the trial during *kharif* and *rabi* season 2009-10.

References

1. Anonymous. 2003. Sweet sorghum stalk: A suitable raw material for fuel alcohol production. NATP (NRCS) Book, Series No. 1, 2. Director of Sorghum Research, Rajendranagar, Hyderabad (India). p.2.
2. Craufurd, P.Q. and Aiming, Q.U. 2001. Photothermal adaptation of sorghum (*Sorghum bicolor*) in Nigeria. *Agric. Forest meteorol*. 108(3): 199-211.
3. Ellis, R.H., Guaufurd, G.A., Summerfield, R.J. and Robert, E.H. 1997. Effect of photoperiod, temperature and asynchrony between thermoperiod and photoperiod on development to panicle initiation in sorghum. *Ann. Bot*. 79(2): 169-178.
4. Folliard, A., Traore, P.C.S., Vaksmann, M. and Kouressay, M. 2004. Modeling of sorghum response to photoperiod: A threshold-hyperbolic approach. *Field Crop Res.* 89(1): 59-70.
5. Garner, W.W. and Allard, H.A. 1920. Effect of relative length of day and night and other factors of the environment on growth and reproduction in Plant. *J. agric. Res*. 18: 553-606.
6. Garner, W.W. and Allard, H.A. 1923. Further studies in photoperiodism, the response of the plant to relative length of day and night. *J. agric. Res*. 23: 871-920.
7. Hammer, G.L., Vanderlip, R.L., Gibson, G., Wade, L.T., Henzell, R.G., Younger, D.R., Warren, J. and Dale, A.B. 1989. Genotype by environment interaction in grain sorghum. II effect of temperature and photoperiod on ontogeny. *Crop Sci*. 29(2): 376-384.
8. Huda, A.K.S. 1987. Simulating yields of sorghum and pearl millet in the semi-arid tropics. *Field Crop Res*. 15: 309-325.
9. Huda, A.K.S., Sivakumar, M.V.K., Virmani, S.M., Seetharama, N., Singh, S. and Sekaran, J.G. 1984. Modeling the effect of environment factors on sorghum growth and development in S.W. Virmani and M.V.K. Sivakumar (edn.). Agrometeorology of sorghum and millet in the semi-arid tropics. ICRISAT, Patancheru, India. pp. 277-287.
10. Karande, B.I., Varshneya, M.C. and Naidu, T.R. 1996. Photoperiodically sensitive time interval for panicle initiation of sorghum. *Ind. J. Plant Physiol*. 1(4): 258-261.
11. Kouressy, M., Dingkuhn, M., Vaksman, M., Clement Vital, A. and Chantereau, J. 2008. Potential contribution of Dwarf and leaf longevity traits to yield improvement in photoperiod sensitive sorghum. *E. J. Agronomy.* 28(3): 195-209.
12. Kozhemyakin, V.V. and Yashin, A.G. 1986. Photoperiod sensitivity of sorghum forms in the Povolzh'e. *Selektsiya Semenovodstvo Zernovykh Kulture*. 80-84.
13. Major, D.J., Rood, S.B. and Miller, F.R. 1990. Temperature and photoperiod effects medicated by the sorghum maturity genes. *Crop Sci*. 30: 305-310.
14. Mayers, R.J.M., Foale, M.A. and Keefer, G.D. 1989. Growth and development range of grain sorghum in three tropical and sub-tropical environments. *Field Crop Res*. 22: 267-287.
15. McClelland, T.B. 1928. Studies of photoperiodism of some economic plants. *J. agric. Res*. 37: 603-628.
16. Miller, F.R. and McBee, G.G. 1993. Genetics and management of physiologic system of sorghum for biomass production. *Bioenergy*. 5: 41-49.
17. Miller, F.R., Barnes, D.K. and Cruzado, H.J. 1968. Effect of tropical photoperiods on the growth of sorghum when grown in 12 monthly plantings. *Crop Sci*. 8: 499-502.
18. Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for agricultural workers. ICAR Publication, New Delhi.
19. Ritchie, J.T. and Alagarswamy, S. 1988. Documentation of CERES-sorghum model, growth and development. Simulation modeling workshop, ICRISAT, Patencheru, A.P. (India), Oct. 12-21. pp.1-23.
20. Robert, R.H. 1938. The effects of temperature and other environmental factors upon the photoperiod response of some higher plants. *J. Agric. Res*. 56: 633-663.
21. Shinde, M.S. 2003. Physiological studies of *rabi* sorghum parental lines in relation to phenology as influence by temperature and photoperiod. Ph. D. Thesis MPKV, Rahuri (India).
22. Talukdar, B.S., Babu, P.P.P. and Bidinger, F.R. 1993. Combining ability and correlation studies for earliness and photoperiod response in pearl millet. *Crop Improv*. 20(1): 31-35.