Bul. Agr. vol. XII (2) : 6-10 (1981)

RESPONSE OF HEIGHT GENOTYPES OF SORGHUM (SORGHUM BICOLOR (L) MOENCH) TO DIFFERENT DAY LENGTHS[1]

Soleh Solahuddin and P.N. Drolsom[2]

Abstract : The response of height genotype of sorghum to different day lengths was studied in the University of Wisconsin Biotron.Two day length chambers were used to represent a tropical climate and a temperate climate, which had 12-hour day length and 15-hour day length, respectively. Eight genotypes of sorghum were used in this study. The heights of sorghum genotypes were significantly affected by photoperiod at 30 days after planting. There also were differnces in plant height at the flowering date due to the effect of genotypes and day length. The highly significant difference in day length reponse of plant height showed that with increased day length there was a corresponding increase in plant height. At the longer day (15 hours), more vegetative growth occured.The heights of 1 – dwarf, 2 – dwarf, and 3 – dwarf hybrid milos were taller than the average of their parents in both day length chambers. There were differences in days to flower ascribed to genotypes and day lengths. There was a corresponding increase in days to flower and in plant height with increased day length. At both day lengths all milo hybrids (1–dwf, 2–dwf, 3–dwf) flowered earlier than their respective parents. In addition to the biotron study, the field trial was conducted at the Arlington Experimental Farm using 24 sorghum genotypes. The field trial revealed that by using one parent of the 4–dwf class, the plant height can be reduced. The yield of 24 sorghum genotypes varied widely from 2 144 kg to 5 672 kg per hectare for C–43 y^+ and NK 233, respectifely. All genotypes, except SM 100, grown in the controlled environment chamber flowered in less time than those grown in the field. One - dwarf and 3 - dwarf milo hybrids took significantly longer to flower than their respective parents, which was in contrast with that observed in the Biotron.

INTRODUCTION

Early photoperiod studies by Garner and Allard in 1923 indicated that sorghum (Sorghum bicolor (L.) Moench) is a short day plant (5). Although sorghum is of tropical origin, many present day sorghum varieties are well adapted to temperate regions.

Photoperiod and temperature are among the factors which strongly influence the pattern of development and eventual crop yield. The modification of length of day usually results in alteration of floral response and morphology. Various experiments have been done to explain adaptation of plants as influenced by photoperiod and temperature. Many workers have evaluated plant height with regard to crop yields of short and tall plants.

Quinby and Karper (11) made the most comprehensive study of the inheritance of height in sorghum. They concluded that four inherited genes, plus a modifying complex, influenced height, with the alleles for tallness being partially dominant. The recessive alleles of each of the 4 genes had essentially the same effect in reducing height. The genes were designated Dw_1, Dw_2, Dw_3, and Dw_4.

Quinby and Karper (12) suggested the use of 1-dwarf, 2-dwarf, 3-dwarf, and 4-dwarf to designate, respectively, the genotypes that were recessive for 1 gene, 2 genes, 3 genes, and 4 genes.

The objectives of this experiment were to study :

(1) The effect of photoperiodic response on height genotypes of sorghum;
(2) the effect of photoperiodic response on plant maturity and
(3) the yield of different height genotypes of sorghum as measured in a field experiment.

Two experiment were conducted, one in the Biotron and the other at the Arlington Experimental Farm of the University of Wisconsin.

MATERIALS AND METHODS

Biotron.

The response of height genotypes of sorghum to different day length was studied in the Biotron. Eight genotypes of sorghum were used in this study and they are as follows : CKA 4–dwf (female), SM100 milo, WSM100 milo, SA1170 milo, CKA 4–dwf x SM100 (3–dwf milo) CKA 4–dwf x WSM100 (2–dwf milo), CKA 4–dwf x SA1170 (1–dwf milo) and P894 (commercial hybrid). Those genotypes were obtained from J. Roy Quinby of Pioneer Hi-Bred International, Inc.

Two day chambers were used to represent a tropical climate and a temperate climate, which has 12-hours and 15-hours day lengths, respectively. The light intensity was 36,584 lux and consisted of flurescent and incandescent light. The temperature of both chambers varied from 24 to 30°C.

Plants were grown in pots containing vermiculite and peat moss with Hoagland nutrient solution. The latter was applied each day, with up to 2 520 mls added in one day. The solution contained 2 100 mls of mineral nutrient and 420 mls of water. The genotypes were seeded at the rate of six seeds to a pot, and after seven days, each pot was thinned to two plants per pot. There were 48 experimental units and two plants per pot for each of the two day length chambers.

1 Research conducted by senior author in partial fulfilment of the requirements for the M.Sc. degree at the University of Wisconsin – Madison, 1977.

2 Former graduate student and Professor of Plant Breeding, respectively, Univ. of Wisconsin – Madison, WI 53706. Present address of senior author is Dept. of Agronomy, Bogor Agricultural University (IPB), Bogor, Indonesia.

The experiment was conducted in a split-plot design with day length as the main plot and genotypes as the sub-plot, with six replicates.

Observations concerning growth behaviour were made, namely :

1) plant height at 30 days and at the flowering date. Height was measured from the surface of the soil to the extreme tip of the least, fully developed leaf;

2) heading date;

3) flowering date, time of flowering was considered to be the time when each head was 50% in bloom.

Field Trial.

The field trial was conducted in a randomized complete block design with three replications.

Seeds of the following sorghum genotypes were obtained from J. Roy Quinby of Pioneer Hi-Bred International, Inc.: 894, 8901, 84311, 54001, CKA 4-dwf female, SM100 milo, WSM100 milo, SA1170, CKA 4-dwf x SM100, CKA 4-dwf x WSM100, CKA 4-dwf x SA1170. De Kalb hybrids BR-44, B-35, C-42s^{+}, C-42y^{+}, C-43y^{+}, B-39y, F-69y, BR-64 and D-60 were supplied by A. Bruce Maunder of DeKalb AgResearch, Inc. Paul Menge of Northrup, King & Co. provided seeds of NK180, NK233, NK266, and NK Brand 1580. There were a total of 24 genotypes. The seeds in this experiment were hand planted at 10 cm within the row and 75 cm between the rows. Each row was 5 m long. Planting depth approximated 5 cm in a fine seedbed. Fifteen days after emergence, the plots were thinned to make a final population of 133,000 plants per hectare. The plots were hand weeded at 15 days, 30 days, 45 days, 60 days, and 75 days after emergence.

The field was irrigated five times due to severe drought during the early part of the growing season.

Observations were made concerning :

(1) plant height at 30 days after planting and at flowering date;
(2) heading date and flowering date;
(3) grain yield.

Genotypes were harvested by hand, according to time of ripening.

RESULTS AND DISCUSSION

A Duncan's new multiple range test was conducted to compare the differences in plant height among genotypes at 30 days after planting and at flowering for the two day lengths, respectively (Tables 1 and 2); and a least significant difference (LSD) was used to compare the difference in plant height between the same genotype at 30 days after planting and at flowering for the two day lengths, respectively (Tables 1 and 2). These differences showed, that with increased day length, there was a corresponding increase in plant height.

Two sorghum genotypes used in this experiment, namely, CKA 4-dwf (female) and P894 (commercial hybrid), had not flowered when the experiment was terminated at 80 days. Those two genotypes were assumed to flower after 80 days and were excluded in the analyses of variance, Duncan's new multiple range test, and the least significant difference (LSD) calculations.

Table 1 shows that under 12-hour day length, plant height at 30 days after planting increased in the order of P894, CKA 4-dwf, CKA 4-dwf x SM100 (3-dwf), SM100, WSM100, CKA 4-dwf x WSM100 (2-def), SA1170, and CKA 4-dwf x SA1170 (1-dwf). SA1170 was not significantly different from CKA 4-dwf x SA1170, neither was SM100 from CKA 4-dwf x SM100. WSM100 was significantly different from CKA 4-dwf x WSM100.

Table 1. Height of eight sorghum genotypes at 30 days after planting when grown at 12-hour or 15-hour day lengths, and the significance of their differences.

Genotype	Ht (cm) day length [1]		Height [2] difference
	12 hrs.	15 hrs	
CKA 4-dwf x SA1170	96.9a	126.5a	29.6**
SA1170	94.0a	120.1a	26.1**
CKA 4-dwf x WSM100	87.3b	102.1b	14.8**
WSM100	77.9c	98.6b	20.7**
SM100	71.9c	76.8d	4.9ns
CKA 4-dwt x SM100	70.3cd	87.2c	16.9**
CKA 4-dwf	66.8d	72.1de	5.5ns
P894	58.8e	68.8e	10.0**

1) Values in a column followed by the same letter are not significantly different (.05 level) using Duncan's new multiple range test. sx = 2.177; df = 70.

2) LSD (.05) = 6.8; LSD (.01) = 9.4.

** Significant at .01 level.

ns Not Significant.

All genotypes, except CKA 4-dwf x SM100, were significantly different from CKA 4-dfw (female). Under 15-hour day length, the order of plant height was the same with that under 12-hour day length, except that CKA 4-dwf x SM100 grew significantly taller than SM100 (Table 1). The day length interactions showed that both at 12-hour and day lengths, CKA 4-dwf x SA1170 grew the tallest, 96.9 cm and 126.5 cm, respectively, while the shortes were 58.8 cm and 68.8 cm for P894 (Table 1).

Table 2. Heights of six sorghum genotypes at flowering when grown at 12-hour day lengths, and the significance of their differences.

Genotype	Ht (cm) at day lenght of[1] 12 hrs.	15 hrs.	Height difference[2]
SA1170	232.6a	247.2a	14.6**
CKA 4-dwf x SA1170	230.7a	233.9b	3.2ns
WSM100	221.2b	226.8bc	5.6ns
CKA 4-dwf x WSM100	212.0c	223.6c	11.6*
CKA 4-dwf x SM100	122.2d	190.6d	68.4**
SM100	115.9d	138.1e	22.2**

1) Value in a column followed by the same letter are not significantly different (.05 level) using Duncan's new multiple range test. Sx = 3.099; df = 50.

2) LSD (.05) = 9.73; LSD (.01) = 13.05

** Significant at .01 level.

* Significant at .05 level.

ns Not Significant.

Table 3. Analysis of variance for days to flower for six sorghum genotypes grown at two day lengths.

Source of variation	df	Sum of Squares	Mean square	F[1]
Day lengths (D)	1	1922.00	1922.00	698.91**
Reps	5	15.94	3.19	1.16ns
Error (a)	5	13.74	2.75	
Genotypes (G)	5	409.85	81.97	42.25**
D x G	5	99.91	19.98	10.30**
Error (b)	50	97.01	1.94	
Total	71	2558.45		

1) ** Indicates significance at the 1% probability level.

ns Indicates not significant.

Table 2 shows that under 12-hour day length, plant height at the flowering date increased in the order of SM100 milo, CKA 4-dfw x SM100 (3-dwf milo), CKA 4-dwf x WSM100 (2-dwf milo), WSM100 milo, CKA 4 dwf x SA1170 (1-dwf milo), and SA1170 milo. Genotype SM100 was not significantly different from CKA 4-dwf x SMa00, neither was CKA 4-dwf x SA1170 from SA1170, whereas the other genotypes were significantly different.

Quinby (9) found that grain hybrids are usually taller than the average of their parents, as are forage hybrids (Chavda and Drolsom, 2). Therefore, tallness has been reported to be a manifestation of hybrid vigor. The results of this experiment conformed with those findings. Plant height consists of the number and length of the interenodes that make up the stem, the length of the peduncle and the length of the head. The same trend of plant height among genotypes also occured under the 15-hour day length, except that CKA 4-dwf x WSM100 was not significantly different from WSM100, whereas the other genotypes were significantly different (Table 2). With regard to height differences between 12- and 15-hour day lengths, CKA 4-dwf x SM100 had the most, followed by SM100, SA1170, CKA 4-dwf x SM100 had the most, followed by SM100, SA1170, CKA 4-dwf x WSM100, WSM100, and CKA 4-dwf x SA1170 (Table 2).

Table 3 shows the analysis of variance for number of days to flower. Differences among sorghum genotypes, day lengths, and the genotype x day length interaction were highly significant. Differences among replications were differences in flowering date due to the effect of genotypes and day lengths, and that genotypes did not respond similarly to the two day lengths.

A Duncan's new multiple range test was conducted to compare the differences for days to flower at the same day length and a least significant difference (LSD) was used to compare the differences in number of days for each genotype (Table 4) The highly significant differences associated with day length, there was a corresponding increase in flowering date and plant height (Tables 1, 2 and 4), The effect just discussed was in general agreement with that observed by Qinby (9) that maturity genes also control size, irrespective of gorwth rate, because the longer a plant grows, the larger it becomes.

Table 4 indicates that under the 12-hour day length all hybrid genotypes (1-dwf, 3-dwf) flowered in less time their parents. This was true also under the 15-hour day length (Table 4). Under 12 and 15-hour day lengths, CKA 4-dwf x SM100 (3-dwf milo) and CKA 4-dwf x WSM100 (2-dwf milo) were significantly different in days to flower compared with their parents, while the difference between CKA 4-dwf x SA1170 (1-dwf milo) and its parent was not significant. Under the 15-hour day length, the difference between 3-dwf milo and 2-dwf milo was significant. SM100 milo took considerably longer to Flower under the 15-hour day length (Table 4). The results of this experiment were in agreement whith those observed by Quinby and Liang (10), who reported that the hybrids flowered earlier than their parents. They found out that the earljerness of sorghum hybrids resulted from more rapid development of the meristem prior to floral initiation and from more rapid development of the panicle. The results of this experiment were also in agreement with those reported by Doggett (4), and Lane (6) that a photoperiod longer than 11–12 hours stimulated vegetative growth but delayed flowering.

Table 4. Number of days to flower for six sorghum genotypes grown in 12-hour or 15-hour day lenghts, and the magnitude of the difference between the number of days for a genotype.

Genotype	Days to flower [1] 12 hrs.	15 hrs.	Difference [2]
WSM 100	54.8a	64.5b	9.7**
SA1170	54.8a	64.2b	9.4**
SM100	54.5b	69.8a	15.3**
CKA 4-dwf x SA1170	53.8a	63.2b	9.4**
CKA 4-dwf x WSM100	51.2b	59.1d	7.9**
CKA 4-dwf x SM100	50.4b	61.2c	10.8**

1) Values in a column followed by the same letter are not significantly different (.05 level) using Duncan's new multiple range test. Sx = 0.568; df = 50.

2) LSD (.05) = 1.83; LSD (.01) = 5.45.

** Significant at .01 level.

Table 5. Duncan's new multiple range test comparing means of days to flower among 24 sorghum genotypes.

Genotypes	Days to flower [1]
P84311	60.0 a
P894	61.0 ab
P54001	62.0 b
P8901	62.0 b
SM100	66.0 c
NK1580	68.0 d
NK 180	68.7 de
CKA 4-dwf x SM100	68.7 de
CKA 4-dwf x WSM100	70.0 ef
NK233	70.0 ef
B-35	70.3 ef
WSM100	71.3 fg
NK266	73.0 g
BR-44	76.0 h
C-42a$^+$	76.0 h
SA1170	76.3 h
B-39y	77.3 hi
CKA 4-dwf x SA1170	79.0 ij
C-42y$^+$	79.7 jk
C-43y$^+$	81.0 kl
CKA 4-dwf	82.3 l
BR-64	94.3 m
D-60	95.0 m
F-69y	95.0 m

1) Values followed by the same letter are not significantly different (.05 level). Sx = 0.6; df = 46.

Field Trial.

The analysis of variance for plant height at 30 days after planting showed a highly significant difference for genotypes and blocks (data not shown). The difference in the block component could be due to uneven irrigation in the early growing season when the plants suffered from drought. The 24 sorghum genotypes tested in this strain trial varied considerably in plant height (data not shown). Commercial hybrids such as P894, P8901, NK233, and NK266, were dwarf sorghums.

With regard to plant height, the breder will continue to be uncertain as to the height of sorghum desired by the grower (7). For example, in sillages under optimum conditions, the 2-dwarf types of perhaps 2 meters in height can stand better under hight population levels than would a 1-dwarf of perhaps 3 meters. To the contrary, with drought the tall type has a better chance for an average performance, whereas the 2-dwarf will likely remain at the grain sorghum or 3-dwarf height, with maturity obviously playing a big part in this response. With grain sorghum, by using one parent of the 4-dwarf class, the height could remain at or below an average condition, which seems desirable with certain forms of sprikler irrigation.

The days to flower varied 60.0 to 95.0 days for P8411 and F-69y genotypes, respectively, because of different response of height and maturity ganes of each sorghum genotype. Commercial hybrids such as P894, P8902, NK1580, NK180, NK233, and NK266 had a relaively earlier flowering date. Relative to flowering date, D-60 and F-69y could be classified as full season, BR-64 as medium late, C-43y$^+$ as medium, C-42y$^+$, B-39y, C-42a$^+$, BR44 as medium early and B-35 as early (Table 5).

Comparing flowering dates of sorghum genotypes grown in a controlled environment chamber under 15-hour day length with the strain trial in the field, it turned out that sorghum grown in the controlled environment chamber environment chamber flowered sooner, except SM100. It is obvious that the changing climatic factors, especially temperature, moisture, and the light in the field, from planting to flowering contributed to a longer growth period.

Table 5 shows that 1- and 3-dwarf milo took significantly longer to flower than their respective parents. These results were in contrast with that observed by Quinby and Liang (10), who reported that the hybrids flowered earlier than their parents. These results were also inconsistent with those observed at the Biotron (Table 4). On the other hand, Pauli et al. (8) checked the influence of planting date on bloom and length of grain filling period for a number of lines and two hybrids. They found that there was a slight tendency for hybrids to use more days in expanding the panicle than the parents, which is contrary to the results of Quinby and Liang (10).

Yields varied widely from 2144 kg to 5672 kg per hectare for C-43y$^+$ and NK233, respectively (Table 6). Commercial hybrids and dwarf milo produced relatively higher yields. Among the experimental hybrids from Pioneer, P84311 produced significantly more dry matter than P54001

The results of this experiment showed that in general the tall plants yielded better than the short types, which agrees with findings of some other workers (1, 3, 13).

Table 6. Duncan's new multiple range test compraring means of dry matter yields of grain for 20 sorghum genotypes grown at Arlington in 1976.

Genotypes	Kg/ha [1)]
C-43y^{+}	2144a
SM100	2421ab
WSM100	2509ab
P54001	2859abc
CKA 4-dwf	2872abcd
SA1170	3171bcde
B-35	3256cdef
C-42y^{+}	3440defg
BR-44	3741efgh
C-42a^{+}	3752efgh
NK266	3765efgh
P894	3813efgh
P84311	3816efgh
CKA 4-dwf x SM100	3987efgh
P8901	4064fgh
CKA 4-dwf x SA1170	4200ghi
NK 1580	4317hi
NK180	4539hi
CKA 4-dwf x WSM100	4968ij
NK233	5672j

1) Values followed by the same letter are not significantly different (.05 level). Sx = 256.9; df = 38.

LITERATURE CITED

1. Casady,, A. J. 1965. Effect of a single height (DW) gene of sorghum on grain yield, grain yield components and test weight. Crop Sci. 5(5) : 385-388.

2. Chavda, D. H., and P. N. Drolsom. 1970. Heterosis among crosses of eight selected parental strains in sorghum. Indian J. Agric. Sci. 40:967-973.

3. Clegg, M. D. 1972. Light and yield related aspects of sorghum varieties. In Sorghum in Seventies. Rao, N.G.P., and Leland R. House (eds.), Oxford & IBH Publishing Co., pp. 279-301.

4. Doggett, Hugh. 1970. Sorghum, Longmans. London (403p).

5. Garner, W.W., and H.A. Allard, 1923. Further studies in photoperiodism. The response of the plant to relative length of day and night. J. Agric. Res. 23: 871-920.

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

7 Maunder, A.B. 1972. Objectives and approaches to grain and forage sorghum improvement in the Americas. In Sorghum in Seventies. Rao., N.G.P. and Leland R. House (eds.), Oxford & IBH Publishing Co., pp. 60-100.

8. Pauli, A.W., F.C. Stickler, and J.R. Lawless. 1964. Developmental phases of grain sorghum (Sorghum vulgare, Pers.) as influenced by variety, location, and planting date. Crop Sci. 4:10-13.

9. Quinby, J.R. 1967. The maturity genes of sorghum. In Advances in Agronomy. Norman, A.G. (ed)., Academic Press, New York and London, 19:267-305.

10. ———, and G.H. Liang. 1969. Leaf number and duration to floral initiation and flowering of sorghum parents and hybrids. Can. J. Gen Cytol. 11:275-280.

11. ———, and R.E. Karper. 1945. Inheritance of height in sorghum. Agron. J. 46:211-216.

12. ———, and R.E. Karper. 1961. Inheritance of duration of growth in the milo group of sorghum. Crop Sci. 1:8-10.

13. Stickler, F.C. and M.A. Younis. 1966. Plant height as a factor affecting responses of sorghum to row width and stand density. Agron. J. 58:370-373.