OPEN ACCESS
Haya: The Saudi Journal of Life Sciences
Abbreviated Key Title: Haya Saudi J Life Sci
ISSN 2415-623X (Print) |ISSN 2415-6221 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://scholarsmepub.com/haya/

Original Research Article

Sugarcane Flowering At Sugarcane Breeding Sub Station (SBSS), Murree

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DOI:10.21276/haya.2019.4.6.1 | **Received:** 02.07.2019 | **Accepted:** 09.07.2019 | **Published:** 23.07.2019

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Abstract

Sugarcane flowering is a blessing in subtropical and temperate areas. It is intricate process subjected to a complex interaction of physiological and environmental facets chiefly plant maturity, photoperiod and temperature. Though at Murree, later two (environmental) parameters vary to bit extent from optimum, even then flowering does occur among good number of lines. Almost 41% of the lines grown during this study period flowered to different degree at 400m altitude. Lines were categorized as early (early November to July, 20 lines), intermediate (March to July, 45 lines) and late flowering (May to July, 21lines). Late flowering lines have relatively defined flowering period of 6 to 8 weeks. For sugarcane to flower, minimum physiological maturity is observed to be achieved when plant is about 75 days old or has developed 3 to 4 naked internodes. Shortening day length from 12h 30min to 12h was achieved in second week of September at 120 second per day. Average minimum temperature of (12.2^{o}C) prevailed during flower initiation which was much below optimum requirement of 22^{o}C. Low temperature resulted in variation in flowering among genotypes and was also responsible for reduced fuzz viability. Present study was conducted to ascertain factors responsible for sugarcane flowering at particular site. It will also help to plan future hybridization program in sugarcane.
Keywords: Sugarcane, Flowering, Breeding, Pakistan.

INTRODUCTION

For improvement of any crop through genetic makeup, proper functioning of its reproductive parts is prerequisite. From breeding view point, sugarcane is complicated plant due to higher heterozygosity and its complex nature of genetic make (polyploidy). Another factor proving this plant difficult for breeding is the challenge of flowering induction and synchronization. Sugarcane breeding started with discovery of sexual reproduction in this plant in late 1880's [1, 2]. Hybridization remained the principal way following which sugarcane breeders create genetic variation for selection [3]. Any hybridization program involves the fully functional floral organs and flowering in sugarcane is principally controlled by photoperiod. In sugarcane flowering is a composite mechanism comprising a number of developmental stages (initiation, flagging, emergence and pollen shedding, Paliatse and Chilton [4] and Araldi *et al.*, [5] with each of the stage having particular sets of physiological and environmental requirements [6-8]. Under severe divergence from optimum prerequisites, flowering is inhibited.

In addition to photoperiod and temperature, other major ecological determinants that predominantly control flowering [9, 10] include soil moisture and nutritional status, plant physiological maturity, light quality and quantity that influence the floral initiation and development [1, 9, 11, 7, 12]. Later components can mask or enhance the effects of temperature and day-length resulting in reduced or high flowering. Conditions determining different flowering processes are not always similar [4]. Fluctuations in flowering intensity in the field occur due to the deviation in minimum temperature, rainfall, light hours particularly in the inductive period [13].

Temperature controls the crop growth and development while photoperiod can modify this growth and development [10]. Each flowering development stage is strictly dependent on prevailing temperature [14, 8]. For flowering to occur smoothly without any barrier for any of its development stage, a temperature between 21 to 30°C is required. Frequent fluctuations above or below this temperature range will result in delay to flower or in some extreme cases the flowering may cease completely [15]. Nights cooler than 18°C are considered as non-inductive nights [11] and if the night temperature continuously deviate 5°C from normal (21-30°C) during inductive period inhibits flowering [16]. Photoperiod is another significant stimulus controlling the flowering (Garner and Allard (1920). Sugarcane flower initiation requires a narrow range of 12.5 to 12h photoperiod [14, 15]. Now many researchers agree that most of the clones require photoperiod of 12hr 35 min. The plants are unable to flower with a difference of 15 minutes fluctuations [17, 14, 9, 11]. Though sugarcane requires shortening day lengths as signal to flowering, Coleman [14] was able to induce flowering in H-37-1933 clone under a fixed day length of 12hr 25min. However, it is not true for all the clones as the shortening day lengths are signal to flower in sugarcane [18]. Flowering can be induced in most of the clones by decreasing day length from 12hr 30min to 12hr at 60sec per day [19-21, 7, 22]. Flowering intensity is reduced if any of the development stage is interrupted due to lack of its optimal conditions of temperature, day length or moisture [11, 8].

Sugarcane holds prime position among major crops with its 0.7 percent share to overall Gross Domestic Product. Sugarcane Breeding Sub-Station (SBSS), Murree is a major hope to heighten the progress of sugarcane crop particularly in Punjab. Topographic situation (400m elevation) of SBSS experimental site provides relatively suitable temperature when natural photoperiod stimulus passes. This allowed most of the sugarcane clones tested to produce flowers. This paper points out these geographical factors and other different environmental parameters of the location assisting the sugarcane to flower. Present study is the first report on sugarcane flowering from Pakistan converging intensions on the ability to and limitation of flowering at this sub-station.

MATERIALS AND METHOD

Varying number of lines/varieties/genotypes is sown every year in March. Flowering is obtained from both plant and first ratoon crop. From 2013 to 2017, 153, 151, 142, 177 and 157 number of genotypes were studied, respectively. Overall during the study period, 207 varieties/lines were studied for the flowering behavior from different resources (Table-1). Flowering period spans from previous year October to the July of flowering year. Flowering data were used to be taken on dates of appearance of flag leaf, emergence and completion of inflorescence and harvesting completion and harvesting. But here data regarding flag leaf and emergence will be considered to describe the behavior of different clones to flower. During each flowering season, data were recorded with appearance of first flag in the field. Each stalk that has developed a flag leaf was given a tag with number on it and rest of the data were recorded against this tag number for that stalk.

Clones were characterized as early, intermediate and late flowering under natural conditions of Murree. Early clones start flowering from November, Intermediate from March and late ones from May. Extremes of day and night temperature were recorded using Six's Minimum and Maximum Thermometer [23]. Humidity was recorded using psychrometeric hygrometer [24, 25] with relative humidity tables. Rainfall was recorded by using an ordinary rain gauge in millimeters.

RESULTS AND DISCUSSION

Sugarcane flowering is a blessing for the breeder as an essential tool to evolve new varieties. Behavior of sugarcane clones to flower is very irregular showing very sensitive relationship to few environmental factors and that it is somewhat similar even under conditions favorable for their flowering. At SBSS Murree, location of the site offers some favorable factors which in combination provide satisfactory conditions to some clones to flower. Mountains play vital role to promote flowering in latitudes farther from the equator most probably by controlling temperature fluctuations. Jeswiet [26] observed good flowering in mountainous region. While studying the effect of different altitudes on flowering, Torrecilla *et al*., [27] reported marked increase at 400 meter and that the pollen fertility and altitude are negatively correlated. Greater flowering intensities have been observed by Jeswiet [26] at 500m, Van-Breemen *et al*., [28] at 450m, Clements and Awada [29] at 390m and by others [30-32] at almost similar altitudes.

Plantation made in March allows the plants to attain the physiological maturity. By approach of photo-inductive period in the second week of September they attain the age of 6 months enough to respond the inductive day-length. Majority of the authors [15, 11, 33] reported 6 months of physiological maturity or 2 to 4 well exposed internodes required to respond to flowering stimulus. However, differences in age to perceive the photo-inductive day-length have been observed [19]. According to researchers observation, genotypes (HSF-240 and S-08-FD-19) germinated in the last week of June (2017) developed flag leaf in third week of November. It shows stalks became responsive to flowering stimulus at 2 and half month of their physiological age as reported by Goesnell [13]. He was of the view that ripeness to flower age occurs at 2 to 3 months or at formation of 3 naked internodes.

There are different stages of flowering occurring in regular and uninterrupted successions in tropics and some subtropics with suitable environment. In these areas floral primordia once developed will result in emergence of inflorescence after four to six weeks [4]. In South Louisiana Cost (Grand Isle), they witnessed clear distinction of sugarcane flowering stages due to below normal temperature. At that place under normal or above normal temperature, floral primordia developed in October continue their growth and emerge in November. However, in years with cold progressions, these floral initials resume their growth in January and emerge in March or even in May. The sub-station at Murree, being almost on same distance (33.4^{o}N) from equator as Grand Isle (29^{o}N) encounters same flowering patterns. Here floral initials develop in last week of September and emergence is observed very often in last week of October (line BJ-6431) but sometime in November (lines BJ-6431, S-05-FD-317, S-08-FD-19) and mostly in December (HSF-240, CP-83-1968, CoL-8, Co-602 & 464). Apical meristems of two very early flowering lines (BJ-6431 & S-05-FD-317) were dissected to observe the development of inflorescence on October 16. Line BJ-6431 was found with ~4cm inflorescence and got emerged in last week whereas other line was caught with very young inflorescence (~2mm) and emerged in second week of November. These genotypes are included in the early flowering group (Table-1). In most of the varieties/lines floral primordia were dormant on facing very cold conditions (8.3^{o}C) of December, January and February. They resume their growth in February and do emerge in March which gives peak flowering in April and May. These genotypes are grouped into intermediate or late flowering (Table-1), although differences in days either to flag appearance or to arrow development for different tillers of same genotypes have been found [34]. Early or late flowering varieties develop floral primordia at same time but the amount of growth of inflorescence differentiates between them [35, 17]. However, contradictions to this simultaneous formation of floral primordia are existing [36, 29, 1]. While examining apices of 78 varieties, Chu and Separion [37] confirmed that floral initiations among all sugarcane genotypes are not simultaneous and pointed out low temperature and moisture responsible for delayed floral initiations. Differences in flowering among varieties based on flowering quantity [38] and factors influencing it like crossing solution, rainfall, nitrogen levels and irrigation have been reported [39-42, 35].

Table-1: Characterization of varieties/lines studied at SBSS, Murree from different source of origin

Sr#	Origin/Country	# of Lines	Flowering	Early	Intermediate	Late
1	Australia	20	9	--	5	4
2	Brazil	30	5	--	3	2
3	China	1	0	--	--	--
4	Cuba	8	1	--	--	1
5	India	18	16	6	6	4
6	Mauritius	3	0	--	--	--
7	Pakistan	11	7	4	2	1
8	Philippines	4	0	--	--	--
9	Puerto Rico	3	1	1	--	--
10	South Africa	14	8	4	3	1
11	Sri Lanka	4	0	--	--	--
12	USA	72	26	2	19	5
13	West Indies	10	7	1	5	1
14	Other	9	6	2	2	2
	Total	207	86	20	45	21

At SBSS, Murree flowering generally starts from November but the line (BJ-6431) started flowering in October. Flowering stimulus is available only for 2 weeks in September and primary stalks perceive this, shifting their growth from vegetative to reproductive phase. Only few stalks from some of the varieties/lines are able to emerge flowers in November and December. Then the development of the inflorescence is trapped and retarded by the reduced temperatures of November to February (Table-2). Brett [39] reported that low temperature adversely affects development of inflorescence.

Although flowering at SBSS, Murree is relatively poor as compared to high flowering countries, however, fewer clones flower profusely and regularly every year. Also these profusely tasseling clones are observed as early flowering. Sparsely flowering clones are usually late flowering. A similar flowering behavior of varieties was observed by the Brett [39]. It may be because of the reason that early development of floral initials in early and intermediate tasseling clones got favorable conditions for long time as compared to ones in late flowering. In case of late flowering clones floral initials developed in few stalks continue their growth in May when the maximum temperature is almost favorable (Table-2) and get emerge in June. However, in June much higher temperature (33^{o}C) not only ceases the further differentiation of floral initials but also adversely affects the emergence of inflorescence marking the end of flowering season. Van Breemen *et al*., [28], Antoni [43], Ellis *et al.*, [44] and Julien *et al.*, [6] reported a negative impact of temperature above 31^{o}C. In an artificial photoperiod regime, a faulty increase in maximum temperature (32 to 33^{o}C) was observed to suppress the full flowering potential of clones [3].

Good tasseling is favored by the factors other than photoperiod and temperature, particularly rainfall [45, 46]. In Java, Jesweit [26] observed profuse flowering in years with well distribution of rainfall. Similar observations of intensive flowering in Florida, Coimbatore and Mayaguez were reported by Katraman [47]. At this sub-station, annual rainfall of 1155.3mm is recorded. Kwajaffa and Olaoye [48], while studying the flowering pattern among 30 exotic sugarcane germplasm accessions in Nigeria reported annual precipitation of 1250 to 1500mm. Pereira *et al.*, [49] observed flowering in genotype, NA-56-79 in years with average rainfall of 198mm than 65mm in non-flowering years. From Table-2, it is clear that year (2015) with maximum rainfall (1643mm) has highest number of flags and number of arrows/tassels. This Table-1 signifies the occurrence of rainfall for profuse flowering during emergence period. In the inductive periods of 2014 and 2016 there were only 17 and 6 rainy days with total rainfall of 238 and 104mm respectively, relatively lower than other years. Floral initials developed during these years yielded maximum number of arrows, 1722 in 2015 and 1217 in 2017. Rainfall probably has role in emergence by developing humid environment as Melloni *et al.*, [34] increased the humidity above 80% to create conditions of rainy climate. Well distribution of the rainfall in the later month of flowering season (2015) extended the flowering for couple of weeks to July. Probably due to rainfall in the June, day temperature reduced to 31^{o}C that allowed the flags to emerge. At the same time importance of minimum temperature is again signified. In 2017, even the rainfall was low during whole of the flowering period with minimum number of rainy days when compared to the 2015, maximum number of varieties/lines produced either flags or arrows. It is due to 2.3^{o}C increase in minimum temperature of 2017 flowering period than that of 2015.

Table-2: Overview of environmental parameters from 2013-17 in comparison with flowering data

Year	2013				2014				2015				2016				2017				Temperature		Rainfall[h]
Character[a]	**Flags**		**Arrows**	**RD**[f]	**Flags**		**Arrows**	**RD**	**Flags**		**Arrows**	**RD**	**Flags**		**Arrows**	**RD**	**Flags**		**Arrows**	**RD**			
Genotypes[b]	57(37%)		47(31%)		60 (40%)		52(35%)		76 (54%)		60(42%)		67 (38%)		47(27%)		87 (56%)		72(46%)				
Data[c]	2368		1057		1894		920		2458		1722		1390		692		2325		1217				
Month	**Max**[d]	**Min**[d]	**RF**[e]		**Max**	**Min**	**RF**		**Max**	**Min**	**RF**		**Max**	**Min**	**RF**		**Max**	**Min**	**RF**		**Max**[g]	**Min**[g]	
January	16.0	6.3	17.6	2	17.3	5.7	24.4	3	18.1	5.9	24.1	2	17.6	6.7	56.8	4	14.1	6.6	313.2	11	16.6	6.3	87.2
February	16.2	7.9	307.3	9	18.7	6.3	79.5	7	18.5	6.4	127.3	11	19.8	7.9	112.0	2	18.9	9.6	64.7	3	18.4	7.6	138.2
March	22.0	12.0	88.4	5	19.6	7.5	516.9	14	20.7	11.3	301.8	14	22.0	11.9	294.2	10	21.3	10.3	71.9	4	21.1	10.6	254.7
April	25.9	14.1	92.9	9	25.8	11.2	45.1	7	24.5	15.5	303.9	11	27.5	15.3	41.3	4	28.3	15.2	122.5	6	26.4	14.3	121.1
May	31.5	19.4	27.5	3	29.5	17.1	122.2	6	31.2	18.6	79.8	6	33.1	18.3	213.4	5	31.6	20.0	10.3	2	31.4	18.7	90.6
June	33.0	22.2	167.6	8	34.3	22.6	63.7	6	31.2	19.1	215.1	11	33.9	22.2	144.5	9	32.8	20.6	182.1	10	33.0	21.3	154.6
July	30.	21.	278.8	11	31.	20	404.0	10	29.	21	615.3	19	31.	20	434.7	13	29.	21	294.9	10	30.	21.	405.5

	3	3			2	.8			9	.0			1	.8			8	.4			5	1	
August	28.5	20.4	398.5	20	30.3	20.6	140.4	8	29.7	20.8	292.5	8	30.2	19.8	239.9	13	29.1	21.0	237.8	17	29.5	20.5	261.8
September	29.0	18.4	187.6	9	28.4	18.0	288.3	9	29.9	17.2	220.9	8	30.5	20.1	87.8	5	30.0	19.9	55.1	4	29.5	18.7	167.9
October	27.4	16.5	22.0	3	24.7	13.8	60.2	7	25.8	14.5	221.3	6	26.9	16.8	27.5	1	28.6	17.0	32.7	1	26.7	15.7	72.8
November	20.9	9.5	15.5	1	24.8	10.1	17.2	1	21.0	10.4	91.9	3	24.3	13.1	0.0	0	21.5	12.1	32.7	3	22.5	11.0	31.5
December	19.6	7.7	12.6	2	21.1	7.0	0.0	0	18.3	7.1	56.4	2	22.0	12.1	0.0	0	19.0	9.4	114.3	3	20.0	8.7	36.7
Yearly	24.2^{i}	13.4^{i}	939^{j}	82	24.4	11.9	1218	78	23.9	12.6	1643	101	25.8	14.4	978	66	24.6	14.1	999	74	24.6	13.3	1155.3
Flowr Period	21.1^{k}	11.7^{k}	882^{l}	53^{r}	21.8	10.2	1026	52	22.3	10.4	1203	61	22.1	10.8	1308	44	22.6	12.7	641	32			

a: Flowering character; b: Number of varieties/lines producing either flags/arrows. The %age shows the proportion of flowering lines from total number of lines available; c: Flowering data; d: Average maximum and minimum temperatures (^{o}C) of particular month; e: Average rainfall (mm) of the month; f: Number of rainy days. g: Average maximum and minimum temperatures (^{o}C) of particular month from 2013-17; h: Average rainfall (mm) for the month from 2013-17; i: Average of the year except July and August; j: Sum of rainfall for the year except July and August; k: Average from Previous year September to current year March; l: Sum from previous year September to current year May; r: Sum of rainy days from previous year September to current year May.

Characterization of genotypes according to their flowering behavior will help in synchronous crossing. Very old technique used by Kataraman [50] is adopted while hybridizing genotypes. Parents are planted in adjacent lines while their inflorescences were covered with cloth bags to avoid stray pollen and to ensure hand pollination. Sugarcane flowers freely when day-length shortens at 30 to 60 seconds a day [7, 22] whereas Murree has high rate (~120 seconds per day) of day-length reduction. Too low temperatures in combination with rapidly reducing day length adversely affect viable pollen production and limit the development of inflorescence in most of the varieties/lines, respectively. The relation of low temperature to pollen viability and ultimately seed setting is observed while sowing of fuzz. Brett [39] observed increased pollen fertility inside the glasshouse. To emphasize the significance of temperature in viable seed setting he (1953) stated seedling production from two tassels (NCo-310) from field and two from glasshouse. In case of glasshouse 1574 seedlings produced while those from field produced only 158. Prevalence of temperature below 15^{o}C before or during flowering results in male sterility and anther abortion [51]. So, no germination of seedlings from fuzz collected from inflorescences that emerged in November, December, January and February as well as in March may possibly be due to this reason.

CONCLUSION

Topographic location of the sugarcane breeding sub-station, Murree offers relatively favorable climate to sugarcane for flowering to some extent. Rapidly decreasing day length imparts sparse flowering to most of the genotypes by reducing the number of photo-inductive days. Temperature much below the normal not only reduces the pollen viability in both emerged and developing inflorescence but also the flowering intensities by impeding floral organization. At SBSS, Murree, if the temperatures remain high enough to ensure viable pollen production, it will permit the sugarcane hybridization under natural environmental conditions. However, it will allow only those genotypes to be involved in breeding program that emerge naturally and the emergence problem will remain as such for shy flowering clones.

ACKNOWLEDGEMENT

The authors are thankful to the Sugarcane Research Institute (SRI), Faisalabad for facilitating in all aspects to study the flowering behavior. They are also thankful to SRI for providing breeding material.

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