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Effect of planting date on canopy characters and capsule production in *Hibiscus sabdariffa* (var. sabdariffa) grown in the boundaries of rice field

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Abstract: A field experiment was conducted at Mymensingh ($24^0 75^/$N and $90^0 50^/$ E) to investigate the effect of normal (April) and late (October) planting on canopy structure, yield and yield attributes in sorrel (*Hibiscus sabdariffa* var. sabdariffa). Seeds were sown in the four dates viz., 15-April, 15-June, 15-August and 15-October to assess phenology, morphological characters, dry mass yield, flower and capsule production of sorrel grown in the boundaries/ Ails of rice field. Flowering and maturity duration was much longer in 15-April planting (288 and 322 days, respectively) than in 15-October planting (135 and 190 days, respectively). Plants became progressively shorter, thinner and produced fewer branches resulting in smaller canopy with increasing delay in planting time. Plant height, number of primary branches and capsules were also more in 15-April planting (239.59 cm, 38.66 plant^{-1} and 211 plant^{-1}, respectively) than in 15-October planting (105.81 cm, 22.66 plant^{-1} and 25.33 plant^{-1}, respectively).Total dry mass (TDM) production and its partitioning into capsule growth were better at 15-April and gradually decreased with the progressive delay in planting (June, August and October). Flower and capsule production was also more in 15-April planting (410 and 236 plant^{-1}, respectively) than in the other planting dates. It may be concluded that seed sown in the 15-April may be better for larger canopy and increased capsule yield.

Key word: Sorrel, phenology, morphology, dry mass, edible calyx.

Introduction

Sorrel (*Hibiscus sabdariffa* L. var. sabdariffa) is reputed for its fleshy edible calyx and is one of the most important industrial crop of the family Malvaceae in the tropics and subtropics. Its vernacular names in English are Vinegar plant, Red sorrel, Roselle, Jamaica sorrel; Jelly okra and lemon bush (Morton, 1987). In Hindi, sorrel is called “lal-ambari”, “patwa”; in Bangla “chukar”, “lal-mesta”; in Franch “roselle”; in portuguese “vinareira” and in Spainish “Jamaica” (McClaleb, 1998). It is grown in homestead garden for preparing jelly in West Africa and Asia (India, Bangladesh, Malaysia). It is widely distributed in the West-Indies and Central America (Morton, 1987). The main edible part is the persistant calyx (both fresh and dry). The red fresh calyxes are used to make jam (Gamal *et al.,* 1984), jelly and drinks (Purseglove, 1982). It is used in fruit salad, teas or refreshments of special flavour and taste, liquors, wines, syrups, ice-creams, dyes and flavours (Teske and Trentini, 1995). Leaves of sorrel are used to sour the curry or “dal” preparation in Bangladesh. Its young leaves are used as vegetable (Patil, 2004). Calyxes contain acids, the most important constituent being hibiscic acid, in addition to aspartic, lactic, citric, malic and tartaric acids. The fresh calyxes contain crude protein (1.46%) and carbohydrates (5.86%) and traces of fiber, calcium, iron, carotene and vitamin C in leaves (Teske and Trentini, 1995). Sorrel could be an important crop in Agroforestry system in Bangladesh. It is a short day plant with annual woody-based subshrub, growing to 2–2.5 m tall (Morton, 1987). The leaves are simple, deeply 3-5 lobed, 8–15 cm long, arranged alternately on the stems and branches. The flowers are 8–10 cm in diameter, white to pale yellow with a dark red spot at the base of each petal, and posseses stout fleshy persistant and accrescent calyx at the base, 1.5–2 cm wide, enlarging to 3–3.5 cm, fleshy and bright red as the capsule matures (Purseglove, 1982 and Islam, 2007).

Planting time is an important factor for the development of canopy structure, and yield and yield attributes. Both canopy structure and yield attributes are markedly influenced by date of planting and population density in pigeonpea (Omanga *et al*., 2000; Fakir and Islam, 2007; Islam and Fakir, 2007). At early planting and wide spacing, plant develops wide canopy and produces more flowers and capsules per plant. At late planting, plants become smaller with few branches that decrease flower and capsule production. But at late planting, yield could be compensated by high density planting. Crop performance and crop yield of sorrel was significantly reduced in the intercropping system compared to sole cropping (Fadl and Gebauer, 2004). Sorrel could be grown in the border (‘Ail’) of rice field. Total ails area is about 288500 hectares which is more than greater ‘Bogra District’. It is possible to bring these lands under agroforeatry system. Although information on the effect of time of planting on growth and yield in sorrel either in monocrop or in intercrop is available in the literature (Salim *et al*., 1993; Lakshmi *et al*., 1995; Castro *et al*., 2004; Hanchanlert *et al.,* 2005), there is only one report of the effect of planting date on canopy structure, capsule production of the plant grown in the boundaries of rice field in Bangladesh (Islam, 2007). Therefore, it is necessary to carry out research in this aspect in Bangladesh. Detail objectives were to investigate the effect of planting date on i) morphological characters; ii) flower and capsule production; iii) dry mass production and partitioning; and iv) their relationships with calyx and capsule yield in sorrel (*Hibiscus sabdariffa* L. var. sabdariffa).

Materials and Methods

The experiment was conducted at the Field Laboratory, Department of Crop Botany, Bangladesh Agricultural University (24°75′ latitude and 90°50′ longitude, elevation 18 m), between April 2006 and April 2007. The soil was silty loam, imperfectly to poorly drained permeability having pH 7.10. Organic matter, total nitrogen, phosphorus and potassium content of the soil were 2.16%, 0.11%, 36.50 ppm and 0.10 me%, respectively. A pit size of 50 cm × 50 cm × 50 cm was prepared in ails around rice field in such a way that its upper level remained at least 10 cm above the ground level for providing good drainage with plant to plant distance of 1.00 m. Full amount of cowdung, TSP and MP at the rate of 1500g pit^{-1}, 100 g pit^{-1} and 80 g pit^{-1}, respectively and 2/3rd of urea (20 g pit^{-1}) were applied in the pits as basal and the rest of the urea was applied after two months from seed sowing. Six to eight seeds were sown in each pit at 2-2.5 cm depth and finally thinned to one plant pit^{-1} at 30 days after sowing. During seedling establishment watering was done but latter on, no irrigation was given due to rainfall. Other cultural practices were carried out as and when necessary.

Seeds were planted in four dates (treatments), each at 15-April, 15-June, 15-August, and 15-October, 2006. For convenience, the planting dates will be designated as April, June, August and October. Four boundaries (40 m long × 1 m wide × 1 m height) or "Ails" of rice field were used as four replications. The experiment was laid out in a randomised complete block design. There were 10 plants, one meter apart in a single line in each replication and constituted a plot for a particular date of planting. Maturity of the crop was ascertained when 70-80% of capsules were dried and turned brown. Plants were harvested between first and second week of April, 2007.

Data were collected on different morphological and reproductive characters such as plant height; stem base diameter (at 10 cm from base); number of primary branches plant^{-1}; buds plant^{-1}; flowers plant^{-1} and capsules plant^{-1}. Fertility or reproductive efficiency (RE) was counted as follows: % flower set to bud = (total number of flowers ÷ total number of buds) × 100; % capsule set to bud = (total number of capsule ÷ total number of buds) × 100; % capsule set to flower = (total number of capsule ÷ total number of flowers) × 100. Fresh and dry (80±2^{0}C for 48h) weights of different plant parts were determined. Dry capsule yield plant^{-1} was estimated from five tagged plants from each plot. Seed yield plant^{-1} was obtained by harvesting all the plants. Total dry mass (TDM) was also estimated by collecting and oven drying the five sampled plant parts excluding root. The collected data were complied and analysed for statistical significance. The mean differences were evaluated by Duncun's New Multiple Range Test (Gomez and Gomez, 1984).

Results

Morphological characters: Plant height was progressively shortened with delay in planting (Table 1). The tallest plant (239.59 cm) was found in April planting date and shortest (105.81 cm) in October and indeterminate in June and August planting (mean of 115.90 cm). Stem diameter also followed the same trend. The number of branches plant^{-1} was also greater in April planting (38.66) than the June (29.66), August (26.00) and October plantings (22.66). The percentage of effective branches that bore at least one matured capsule increased over time April to August planting but it decreased in October planting. The number of capsules plant^{-1} was again greater in April planting (211.00) than in the June (122.66), August and October planting (average of 47.99). Fresh weight of calyx/plant followed the following ranking: April (476.86 g) > June (277.22 g) > August (158.29 g) > October (56.49 g). The yield of fresh weight of calyx was decreased progressively with delay in planting date. The seed yield followed a trend similar to that of calyx yield (Table 1).

Table 1. Effect of date of planting (DOP) on some important morphological features, calyx and seed yield in sorrel (*Hibiscus sabdariffa* var. sabdariffa)

DOP (2006)	Plant height (cm)	Stem diameter (cm)	Branch/ plant (no.)	Capsule/ plant (no.)	Fresh calyx wt./plant (g)	Seed yield/ plant (g)
15-April	239.59 a	1.88 a	38.66 a (55.10)†	211.00 a	476.86 a	84.24 a
15-June	183.31 b	1.25 b	29.66 b (60.65)	122.66 b	277.22 b	47.22 b
15-August	146.88 bc	1.03 bc	26.00 c (66.73)	70.66 c	158.29 c	25.86 c
15-October	105.81 c	0.77 c	22.66 d (52.79)	25.33 c	56.49 d	7.27 d

In each column, figures bearing uncommon letter(s) differ significantly at $P \leq 0.05$ by DMRT;
† : Percentage effective branch that bore at least one matured capsule.

Flower production and fertility efficiency: Generally, number of buds, flowers and capsules plant^{-1} decreased with delay in planting (Table 2). Results showed that number of buds/plant was greater in April planting (686.20) than that in the June (247.20), August (156.60) and October (66.20) planting. Number of flowers and capsules plant^{-1} followed a trend similar to that of buds plant^{-1} (Table 2). Similar result was also observed in case of seed yield plant^{-1}. Seed yield plant^{-1} was highest at April planting (89.13 g) and lowest in the October planting (7.41 g). Effect of date of planting on fertility efficiency i.e. per cent flower production to bud, per cent capsule set to bud and per cent capsule set to flower production were significant ($P \leq 0.05$) (Table 2). Per cent flower to bud was increased from 59.71% in April planting to 73.55% in June, followed by a decline to 66.34% at August and 54.42% in the October. Per cent capsule production to bud followed a trend similar to that of per cent flower to bud production. In contrast, per cent capsule to flower was smaller in April (58.15%) than in the other plantings (average of 66.77%) (Table 2).

Dry mass (DM) production: Total DM production (TDM) was decreased with successive delay in planting time. The TDM was significantly greater in April planting (872.95 g/plant) than in June (317.82 g/plant) and August and October (mean of 98.11 g/plant) (Table 3). Generally, DM partitioning into plant parts was decreased with increasing delay in planting date (Table 3). Main stem plus petiole growth was greater in April planting (169.62 g) than that in the June (86.82 g), August and October planting (average of 22.23 g). Dry mass (DM) distribution into branch growth followed a trend also similar to mainstem plus petiole growth. Dry mass partitioning into leaf growth followed the following ranking: April (62.09 g) > June (21.37 g) > August (14.70 g) > October (5.56 g). Dry mass partitioning into husk and seed followed a trend similar to that of leaf growth (Table 3). The percentage of TDM partitioning into mainstem and petiole growth remained similar over time, leaf growth slightly increased, and branch growth markedly decreased over time.

Table 2. Effect of date of planting (DOP) on flower and capsule production, and reproductive efficiency in sorrel (*Hibiscus sabdariffa* var. sabdariffa)

DOP (2006)	Buds/ plant (no.)	Flower/ plant (no.)	Capsule/ plant (no.)	Seed yield/ plant (g)	% Flower to bud	% Capsule to bud	% Capsule to flower
15-April	686.20 a	410.00 a	236.40 a	89.13 a	59.71 c	34.58 d	58.15 b
15-June	247.20 b	181.00 b	122.00 b	47.50 b	73.55 a	49.57 a	67.46 a
15-August	156.60 c	104.20 c	68.00 c	24.87 c	66.34 b	43.31 b	65.29 a
15-October	66.20 d	36.00 d	25.40 d	7.41 d	54.42 c	38.35 c	70.56 a

In each column, figures bearing uncommon letter(s) differ significantly at $P \leq 0.05$ by DMRT.

Table 3. Effect of date of planting (DOP) on dry mass (DM) production and partitioning into plant parts in sorrel (*Hibiscus sabdariffa* var. sabdariffa)

DOP (2006)	Dry mass (g)						Total DM/ Plant(g)
	Main stem + petiole	Leaf blade	Branch	Calyx	Husk	Seed	
15-April	169.62 a (19.43) †	62.09 a (7.11)	459.42 a (52.63)	49.79 a (5.70)	47.77 a (5.47)	84.24 a (9.65)	872.95 a
15-June	86.82 b (27.32)	21.37 b (6.72)	105.52 b (33.20)	29.41 b (9.25)	27.46 b (8.64)	47.22 b (14.85)	317.82 b
15-August	34.54 c (22.86)	14.70 c (9.77)	41.76 c (27.78)	15.54 c (10.33)	17.93 c (11.92)	25.86 c (17.20)	150.32 c
15-October	9.93 c (21.63)	5.56 d (12.12)	11.79 c (25.69)	5.15 d (11.33)	6.19 d (13.48)	7.27 d (15.84)	45.90 c

In each column, figures bearing uncommon letter(s) differ significantly at $P \leq 0.05$ by DMRT;
† : Figure within parenthesis indicates percentage of total dry mass.

Plant cycle: Generally plant cycle or life cycle was shortened from the first to the last planting (Fig. 1). The flowering of plants started at 228 days after planting (DAP) when seeds were sown in April (first planting) but required only 90 DAP in October (last planting). The maximum flowering (number of flowers plant^{-1}) occurred around 245 DAP in April but 100 DAP in October. The life cycle of plants, the number of days from planting to harvesting varied among planting dates. April enabled a longer cycle (322 days), June and August provided an intermediate (267 and 232 days, respectively), and October had shorter cycle, 190 days (Fig. 1).

Correlation: Fresh calyx yield plant^{-1} had positive and significant correlation with plant height, stem thickness; branch, flower and capsule production, and total dry mass yield (Table 4). Capsule and seed yield also showed significant and positive correlation with above morphological characters (Table 4). TNDB-100 (649.0 cm^{2} hill^{-1}) which was statistically similar to check variety Binadhan 4 (651.9 cm^{2} hill^{-1}) and RD-2586 (662.7 cm^{2} hill^{-1}). AT 65 DAT, the highest leaf area was produced by PR-26305-M-2 (1466.3 cm^{2} hill^{-1}) and the lowest leaf area was produced by TNDB-100 (953.8 cm^{2} hill^{-1}) which was followed by RD-2586 (991.2 cm^{2} hill^{-1}) (Table 2). This results among the advanced rice lines/variety PR-26305-M-2 had maintained the maximum leaf area hill^{-1} at all sampling dates.

Table 4. Simple correlation coefficient (r value) for different morphological parameters and yield attributes with calyx weight/plant, capsule/plant and seed yield/plant in sorrel

Independent variable / Dependent variable	Plant height (cm)	Stem diameter (cm)	Branch/ plant (No.)	Calyx weight /plant (g)	Flower/ plant (No.)	Capsule/ Plant (No.)	TDM/ plant (g)
Calyx weight/plant	0.941**	0.926**	0.913**	-	0.978**	0.989**	0.967**
Capsule/plant	0.979**	0.987**	0.959**	0.923**	0.993**	-	0.970**
Seed yield/plant	0.966**	0.979**	0.972**	0.920**	0.989**	0.989**	0.969**

*, ** = Significant at 5 and 1% level of probability, respectively; N= 12 (4 Planting dates × 3 Replications)

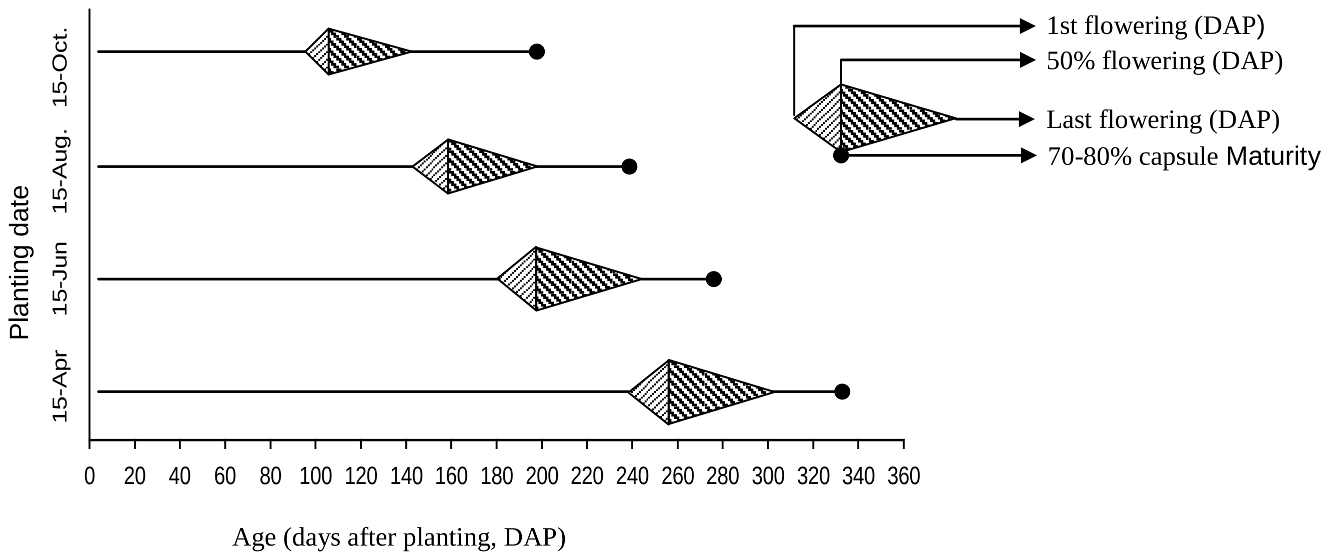

Fig. 1. Schematic reproduction of flowering period, fructification and maturity of sorrel (*Hibiscus sabdariffa* var. sabdariffa) grown at different planting times

Discussion

Sorrel is a short day plant (SDP) (Morton, 1987). Planting time is an important factor for growth and yield of photoperiodically controlled plant like SDP. Under Bangladesh condition, short day begins from July and photoperiod decreases until December (Table 5). Temperature increases between April and July/August followed by a decline to lowest in January (Table 5). Typical response of SDP to photo- and thermo-period occurred in the experiment in response to four sowing dates (April, June, August and October). Planting seeds around April may be considered ideal time especially after a shower in the month and with the successive delay in seed sowing (June, August, October), plants experienced shorter photoperiod and lower temperature (Table 5). Therefore, plants became progressively shorter, thinner and produced fewer branches resulting in smaller canopy with increasing delay in planting date (Table 1). The present result is similar to the report of Islam and Fakir (2007) who observed that all components of the canopy structure were decreased with the progression of delay in planting time in pigeonpea. Sorrel is waterlogging sensitive plant and establishment of the plant stand in the prevailing rainy season (Table 5) especially between May and September, under Bangladesh condition, remains very difficult. Plants with fewer branches in delayed planting may have provided fewer loci for reduced flower production (Table 2) and hence produced smaller capsule yield in the later planting date than in the earlier ones (Table 1). Plants, from seeds sown in April, flowered in November but plants, from seeds sown in October, did not commence flowering in November or even December although they already possibly perceived the shorter photoperiodic stimuli. The results indicated that certain vegetative growth or sugar accumulation probably is needed to activate photoperiodic signal. This is related to the findings of Takimoto (1960) who observed that substrates provided by photosynthesis have some effect on the ability of the plant to produce flower in *Pharbitis Nil*. However, further investigation is needed to clarify the issue. Further, capsule production is a function of flowers/plant and % capsule set. In the current investigation, number of flowers/plant decreased from 410 (early or normal planting April) to 181 (June), 104 (August) and 36 (very late, October) but % capsule set to flower increased from 58.15 (April) to 67.47 (average of June, August, October). With increasing delayed in planting date, the flower production decreased but % capsule set increased resulting in reduced yield of capsule/plant and it appeared that the stronger influence of the former offset the later resulting in fewer capsule yields (Table 2). This result indicates that sink (flower) production is more important than sink survivability (% capsule set). Reduced capsule production was also noted by Castro (2004) in Brazil, Lakshmi *et al.* (1995) in India and Salim *et al.* (1993) in Egypt under late planting. With delayed planting, like capsule production, seed yield/plant also decreased between April and October planting (Table 1- 3) and is again supported by Castro (2004), Lakshmi *et al.* (1995) and Salim *et al.* (1993).

Table 5. Monthly rainfall, air temperature, humidity, wind and day length in the experimental site during the study period (April 2006 to April 2007)

Month	* Rainfall (mm)	**Air temp.			** Relative Humidity (%)	** Day length (hr)
		Max.	Min.	Average		
April, 2006	146.6	30.98	21.92	26.45	80.23	12.00
May	413.2	34.40	34.14	28.09	82.55	12.50
June	335.5	31.13	25.75	28.44	87.67	13.30
July	306.5	32.03	26.69	29.36	86.52	13.40
August	365.8	39.45	26.43	29.44	85.42	12.70
September	441.4	31.55	25.76	28.66	88.63	12.40
October	35.0	32.10	23.24	27.67	87.77	11.80
November	00.2	28.88	18.30	23.59	86.07	11.04
December	00.0	26.22	13.48	19.85	85.16	10.50
January	00.0	23.64	10.80	17.22	82.92	10.40
February	55.2	25.41	15.73	20.52	81.11	11.00
March	18.8	29.13	14.77	23.45	75.42	11.50
April, 2007	207.9	30.44	22.16	26.30	82.40	12.00

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh.
* Monthly total. ** Monthly average

In vinegar plant, calyx yield (both fresh and dry) is an important aspect since it is used in making Jam/Jelly/Tea (Gamal *et al.* 1984). In the present study, calyx yield was much greater in April planting and decreased drastically in the latter plantings (Table 1, 3). This was because of fewer and smaller capsules/plant was produced in the later plantings. However, dry mass (DM) distribution i.e. % DM partitioning into calyx growth increased from 5.7% (April planting) to double (10.33%) at latter plantings (average of June, August and October). However, inspite of increasing partitioning of DM into calyx growth, calyx yield remained smaller in the later plantings since the magnitude of capsule production and capsule size decreased markedly in such way that these two masked the effect of increased partitioning of DM into calyx growth resulting in poor calyx yield in the later plantings than in the earlier ones (Table 3).

From the above discussion it is concluded that April may be the proper time of planting to get better flower, capsule and dry mass (DM) production. Positive and significant correlation of calyx and capsule yield with plant height, stembase thickness, branch and flower number, and total dry mass yield suggest that robust plant with increasing flower production may be used as indices for improved calyx and capsule production in sorrel.

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