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Effect of planting dates on plant growth, yield and quality in different strawberry (*Fragaria* × *ananassa*) varieties in subtropics of eastern India

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ABSTRACT

Study was undertaken to standardize the planting time of strawberry (*Fragaria* × *ananassa* Duch.) in agro-climate of Bihar, during 2012-2013. The experiment was laid out in split plot design with three varieties namely Sweet Charlie, Festival and Winter Dawn as sub plot with four planting dates, viz. 15 October, 1 November, 15 November and 1 December as main plot with three replications at experimental plot of BAC, Sabour, Bihar. 15 October planting exhibited maximum growth and took longest duration to initiate flowering and fruit set with largest fruit size which was at par with 1 November planting. 1 November planting had maximum number of fruits and yield/plant. Least plant growth and fruit yield was recorded in 1 December planting. Among the cultivars studied, variety Winter Dawn exhibited maximum plant growth however maximum yield of 355.04 g/plant was recorded in var. Festival. Variety Sweet Charlie having minimum fruit size and weight produced highest number of fruits, i.e. 22.48 fruits/plant and excelled in TSS, total sugars and ascorbic acid content. Variety Winter Dawn was found suitable for 15 October planting whereas var. Festival and Sweet Charlie performed better in 1 November planting.

Key words: Planting date, Quality, Strawberry,Variety, Yield

The strawberry (*Fragaria* × *ananassa* Duch.) is an Octaploid (x=7, 2n=56) species belonging to the family Rosaceae and is one of the most attractive, delicious, refreshing soft fruit with loads of nutritive value and distinct aroma. It is considered as temperate perennial herb but it act as annual plant in sub tropics. In India, it is mainly grown in hills of Himachal Pradesh, Jammu and Kashmir and Uttarakhand (Rana and Chandel 2003) but in recent time it is successfullycultivated in sub tropics and plains of India using plasticulture and day neutral varieties. The temperature and photoperiods have the considerable effects on growth and yield of the strawberry probably through the control of the production of plant hormones. High growth rates of strawberries are maintained at day temperatures of 22-23°C. An average growing temperature of 15°C has been reported for most of the strawberry cultivars and species, though it grows well at a temperature ranging between 20°C and 26°C. Delayed planting limits the fruit availability for a very short period of one and a half month (Singh *et al.* 2007).

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For successful cultivation, planting time plays an important role. Strawberry can be planted at different times of the year depending on variety, location and climate (Galleta and Bringhurst 1990, Sharma and Sharma 2004). Both planting time and varieties have been recognized to influence fruit production as well as quality and availability of strawberry. Being a high remunerative and short duration crop it is catching up among farmers but very little information is available regarding suitable planting time of strawberry in gangetic plains of India. Therefore, an investigation was conducted to standardize the planting time of different varieties of strawberry in agro-climatic condition of Bihar.

MATERIALS AND METHODS

The field experiment was conducted at research plot of Horticulture Garden of Bihar Agricultural University, Sabour, Bhagalpur during 2012-13. The experimental site falls in sub-humid, sub-tropical gangetic plain of Eastern India. This region experiences semi-arid sub-tropical climate having winter season from November to February with December and January being the coldest months. The average minimum and maximum temperatures during the cropping period were 11.02°C and 26.38°C, respectively. The maximum average temperature of 37.74°C was noted in the 2nd week of April, 2013 and the lowest minimum average temperature of 3.01°C was in the 2nd week of January, 2013. The soil on the experimental plot was slightly

alkaline with light texture having pH 7.65, organic carbon 0.46%, available nitrogen 62.72 kg/ha, phosphorous 199.18 kg/ha and potassium 198.45 kg/ha. The region experiences hot wind from mid-April to May and rainfall from June to September. The annual average rainfall of the region is around 120 cm, 70% of the total rainfall is received during July-August.

The experiment was laid out in a split plot design with planting dates as main plot and varieties under sub-plot with three replications. Three strawberry varieties, viz. Sweet Charlie (V_1), Festival (V_2) and Winter Dawn (V_3) were used as sub-plot with four planting dates, viz. 15 October (D_1), 1 November (D_2), 15 November (D_3) and 1 December (D_4) as main plot. Strawberry plants with 4-5 leaves were planted on properly leveled 1 m wide and 35 cm raised bed on different planting dates at a planting distance of 20 cm (plant to plant) × 30 cm (row to row) with plot size of $3m^2$ accommodating 30 plants/plot and the distance between the plots was 50 cm. Ten plants under each treatments were randomly selected and tagged for taking observations on plant growth, yield and fruit quality parameters. Similar cultural practices for nutrient, weed and plant protection managements were adopted for all treatments.

Weekly average of all parameters was calculated for complete cropping season. Daily weather data of maximum and minimum temperature, humidity at 8 AM and 2 PM were taken from university observatory from 1st date of planting till final harvest. Averages of all parameters for first six weeks for each planting date were calculated to study the weather condition during vegetative growth period and depicted in Table 1.

Data were recorded on plant height, plant spread, leaf area and number of leaves in the randomly selected plants at ultimate growth stage of each treatment and average were calculated. Days taken to blooming and fruit set initiation were counted from planting date when minimum of five plants under each treatment started blooming and initiated fruit set. The fruits were analyzed for physicochemical properties from each ten randomly selected plants under all the treatments. Fruit size (length and breadth) was recorded by using the digital slide caliper, whereas fruit weight was taken using digital top pan balance. The harvesting span was recorded in days from date of first harvest till final harvesting under each treatment. Final harvest was considered when flowering was in less than 25% plants under each treatment. After completion of harvesting, tagged plants were uprooted and number of crowns developed in each plant was counted and average was calculated. The uprooted plants were cleaned properly and air dried to remove the excess moisture. Afterward the plants were kept in oven at 70°C till the weight was constant upto 2 days. Marketable yield/plant was recorded on the basis of fruits that were free from any infection and had fruit weight of more than 8 g.Total soluble solids (TSS) were determined with digital refractometer model ATAGO PAL 1.Titrable acidity was determined by standard method. Reducing and total sugar were estimated by Lane and Eynon (1923) copper titration method. The ascorbic acid content of the juice was determined by titrating freshly extracted juice against 2,6-Dichloro indophenols dye as per method of AOAC (1984). The data collected on each parameter were analyzed as per the method of Gomez and Gomez (1990) at significant level of $P \leq 0.05$.

Table 1 Average weather data during initial stage of plant growth under different planting dates

Planting date	Temperature (°C)		Relative humidity (%)	
	Maximum	Minimum	Maximum	Minimum
15 Oct. 2012 (D1)	28.16	14.76	87.16	54.13
1 Nov. 2012 (D2)	26.84	11.56	88.59	47.92
15 Nov. 2012 (D3)	24.48	9.18	91.37	54.46
1 Dec. 2012 (D4)	19.98	7.43	94.02	64.71

RESULTS AND DISCUSSION

Weather data

Weather data depicted in Table 1 showed that average maximum and minimum temperature and humidity during early plant growth period, i.e. first six weeks varied with different planting date. For 15 October planting (D_1), the average maximum and minimum daily temperatures were 28.16°C and 14.76°C, respectively. 1 November planting had maximum and minimum temperature of 26.84°C and 11.56°C. The lowest value of average maximum (19.98°C) and minimum (7.43°C) temperature were recorded in 1 December planting. The humidity at 8.0 AM varied from 94.02% (D_4) to 87.16% 15 October planting and average humidity at 2.0 PM varied from 47.92% on 1 November planting to 64.71% on 1 December planting.

Effect of planting dates on plant growth, flowering and fruit set of strawberry cultivars

The effect of planting time and varieties on vegetative growth, flowering and fruit set initiation has been depicted in Table 2 and interaction effects have been depicted in Table 3. It is evident that plant height, plant spread, number of leaves/plant, leaf area, number of crown/plant, dry matter content, flower and fruit set initiation in plants varied with planting dates. Effect of varieties was also significant on all these parameters except number of crowns/plant. Interaction effect of varieties and planting dates was significant pertaining to plant height, plant spread, number of crowns per plant and time taken for flower initiation. The maximum plant height (29.12 cm) and plant spread (28.89 cm) was recorded in 15 October planting. It gradually decreased with advancement of planting date. Least plant height (16.04 cm) and plant spread (16.26 cm) were noted in 1 December planting. Among varieties, Winter Dawn exhibited highest growth with plant height of 25.69 cm and plant spread of 25.71cm

Table 2 Effect of planting date on plant growth, flowering and fruiting in different strawberry varieties

Treatment	Plant height (cm)	Plant spread (cm)	Number of leaves/plant	Leaf area (cm^2)	No. of crowns/ plant	Dry wt./ plant (g)	Initiation of flowering (days)	Initiation of fruiting (days)
Planting dates (D)								
15 Oct. (D_1)	29.12	28.89	42.21	54.97	3.98	50.68	50.44	64.44
1 Nov. (D_2)	27.79	28.26	41.63	49.52	3.66	45.99	46.70	58.47
15 Nov. (D_3)	22.8	23.44	37.25	44.22	2.63	41.93	43.5	61.78
1 Dec. (D_4)	16.04	16.26	26.21	37.83	1.92	29.51	41.46	57.07
Varieties (V)								
Sweet Charlie (V_1)	20.63	21.18	34.8	40.96	3.00	39.14	50.10	62.8
Festival (V_2)	25.49	25.76	38.6	46.25	3.15	42.81	46.15	63.62
Winter Dawn (V_3)	25.69	25.71	37.07	52.69	2.99	44.13	40.83	54.9
CD (P=0.05)	3.135	1.460	1.976	2.302	NS	1.920	2.684	3.099

Table 3 Interaction effects of planting date and varieties of strawberry on plant growth, flowering and fruiting

Treatment	Plant height (cm)	Plant spread (cm)	Number of leaves/plant	Leaf area (cm^2)	No. of crowns/plant	Dry wt./plant (g)	Initiation of flowering (days)	Initiation of fruiting (days)
V_1D_1	24.08	24.13	37.47	48.21	4.22	46.2	57.2	68
V_2D_1	31.12	30.02	42.89	53.09	2.71	51.32	52.13	64.13
V_3D_1	32.15	31.63	46.26	63.6	5.02	54.51	42.0	53.2
V_1D_2	23.03	24.01	39.31	44.24	3.14	43.09	51.23	59
V_2D_2	30.01	30.52	44.15	50.11	4.24	46.75	47.8	64.2
V_3D_2	30.32	30.24	41.42	54.21	3.62	48.14	41.4	52.2
V_1D_3	20.09	21.15	36.17	40.61	2.64	40.23	47.00	65.2
V_2D_3	24.57	25.05	39.24	43.33	3.16	42.17	43.13	68.13
V_3D_3	23.75	24.12	36.33	48.7	2.11	43.38	40.00	60
V_1D_4	15.31	15.42	26.23	30.76	2.01	27.04	45.00	59
V_2D_4	16.28	16.53	28.13	38.48	2.51	31.0	41.2	58
V_3D_4	16.04	16.83	24.28	44.22	1.92	30.44	38.13	54.2
V at same D	3.135	3.135	NS	NS	0.335	NS	3.41	NS
D at same V	3.546	3.546	NS	NS	0.290	NS	2.01	NS

which was at par with var. Festival and var. Sweet Charlie had minimum plant height and spread of 20.63 cm and 21.18 cm, respectively. Interaction effect of varieties and planting dates were also found significant and maximum height of 32.15 cm was recorded in var. Winter Dawn when planted on 15 October and least height of 15.31 cm was observed in var. Sweet Charlie on 1 December planting. 15 October planting produced highest number of leaves per plant (42.21) and leaf area (54.97 cm^2) while least number of leaves was recorded in 1 December planting. Variety Festival produced highest number of leaves per plant (38.6) that was at par with var. Winter Dawn but leaf area was significantly highest in var. Winter Dawn (52.69 cm^2). Weather parameters like temperature and relative humidity prevailing at the time of planting and early growth stage might have played significant role in plant growth as the highest average maximum (28.16°C) and minimum (14.76°C) temperature during early plant growth was during 15 October planting and it was the lowest during 1 December planting with maximum mean temperature of 19.98°C and minimum mean temperature of 7.43°C, respectively (Table 1). The environmental condition especially favourable temperature was helpful in retaining more vegetative growth as reported by Palha *et al.* (2012) and Grout and Millan (1985). Kher *et al.* (2010) reported significantly higher plant height, plant spread and leaf area in 9 October planting than other planting dates under sub-tropical conditions of Jammu. Varietal response of plant growth in strawberry has been reported by various workers in different agro-climate (Das *et al.* 2007, Menzel and Waite 2006, Rahman *et al.* 2014). Interaction effect revealed that var. Winter Dawn produced maximum number of crown when planted on 15 October while var. Festival produced highest crown when planted on 1 November. The report of Lal and Rao (2010) was also in the same tune who found that the

plant size influenced by different environmental and edaphic factors in some of the strawberry cultivars in Garhwal Himalayan conditions. Consequently, maximum dry matter content in strawberry plants was noted in 15 October planting followed by 1 November planting and least value were noted in 1 December planting irrespective of varieties.

The maximum time to initiate flowering and fruit set was recorded under 15 October planting (50.44 and 64.44 days) and minimum duration of 41.46 days and 57.07 days were recorded in 1 December planting respectively. It seems that prevailing temperature played important role in flower initiation. 15 October planting initiate flowering when average maximum and minimum temperature were 22°C and 10°C, respectively. 1 December planting could reach the temperature favourable for flowering earlier and took only 41 days after planting when average maximum and minimum temperature were 15.40°C and 4°C, respectively. Earlier works on strawberry in different agro climate also enunciated the role of temperature in flowering of strawberry (Sonstedy *et al.* 2013). Among varieties, Winter Dawn was the earliest to flower and fruit set and took 40.83 days from planting to initiate flowering whereas Sweet Charlie took maximum duration (50.10 days) to flower. Interaction revealed that var. Winter Dawn was the earliest to flower on all planting dates and Sweet Charlie was the latest for flower and fruit set initiation. Varietal response to flower and fruit set initiation has also been reported by earlier workers (Rahman *et al.* 2014 and Das *et al.* 2007).These variations may be due to the fact that cultivars differ significantly in their chilling requirement (Joolka and Badiyala 1983), temperature and photoperiod (Palencia *et al.* 2013) and genetic make-up to respond flowering and fruiting (Li *et al.*1993).

Effect of planting dates on yield parameters of strawberry cultivars

The yield parameters like fruit size and weight, number of fruits/plant, yield/plant, harvesting span and marketable yield were recorded having significant effect of planting dates and varieties (Table 4) and their interaction effects were also significant (Table 5).The largest fruit size (3.93 cm and 3.8 cm) was recorded in var. Festival which was at par with Winter Dawn. Significant interaction effect reflected that the largest fruits were produced in var. Festival when planted on 1 November. The maximum fruit weight (17.18 g), number of fruits/plant (24.62) and fruit yield/plant (404.46 g) was recorded in 1 Nov. planting followed by 15 October planting. The variable micro-climate developed under different planting date might be the probable reason for varying fruit size under different planting date. The maximum number of fruits/plant and yield was also noted under these planting dates. Under these planting dates, plants got more time and congenial temperature for plant growth before flowering and produced more number of leaves/plant that acted as source of more photosynthates consequently larger fruit weight and yield/plant.

Among varieties, the highest fruit weight (16.39 g) and fruit yield (355.04 g/plant) was noted in var. Festival. The largest numbers of fruits/plant were recorded in var. Sweet Charlie (22.48) and the lowest fruit weight (14.39 g) was recorded in var. Winter Dawn on 1 December planting. The interaction effect of planting dates and varieties revealed the highest fruit weight (17.84 g) in var. Festival when planted on 1 November. Similarly, var. Winter Dawn produced maximum number of fruits/plant (26.80) in 15 October planting while var. Winter Dawn recorded minimum in 1 December planting. However, the maximum yield was recorded in var. Festival on 1 November planting. Some workers like Badiyala and Bhutani (1990) and Kher *et al.* (2010) also reported decrease in yield with the delaying of planting in variety Tioga in Himachal Pradesh and variety Chandler in Jammu region, respectively. Findings of Menzel and Smith (2011) and Rahman *et al.* (2014) also in the same tune. These differences in fruit size, weight and yield may be varied due to were agro-climatic conditions (Hassan *et al.* 2001 and Verma *et al.* 2002). So, yield in strawberry planting depend on

Table 4 Effect of planting date on yield attributes in different strawberry varieties

Treatment	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	No. of fruits/ plant	Fruit yield (g/ plant)	Harvesting span (Days)	Marketable yield (g/plant)
Planting dates (D)							
15 Oct. (D_1)	4.05	4.05	15.84	23.53	361.59	83.33	282.09
1 Nov. (D_2)	3.98	3.96	17.18	24.62	404.46	83.80	358.06
15 Nov. (D_3)	3.83	3.62	15.36	20.73	318.47	70.73	271.75
1 Dec. (D_4)	3.30	3.30	14.39	16.51	255.78	62.67	196.63
CD (P=0.05)	0.128	0.280	0.585	0.547	23.186	7.1516	10.333
Varieties (V)							
Sweet Charlie (V_1)	3.66	3.65	14.89	22.48	338.47	76.25	275.87
Festival (V_2)	3.93	3.80	16.39	21.60	355.04	76.50	304.56
Winter Dawn (V_3)	3.79	3.73	15.81	19.97	311.71	72.65	250.97
CD (P=0.05)	0.232	NS	0.730	1.168	15.611	NS	15.96

Table 5 Interaction effects of planting date and varieties of strawberry on yield attributes

Treatment	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	No. of fruits/ plant	Fruit yield (g/ plant)	Harvesting span (Days)	Marketable yield (g/plant)
V_1D_1	3.70	3.81	14.40	22.20	320.67	79.00	244.52
V_2D_1	4.15	3.92	16.31	21.60	351.72	75.00	304.14
V_3D_1	4.33	4.41	16.81	26.80	412.38	96.00	297.61
V_1D_2	3.45	3.55	16.03	26.20	419.12	87.00	357.81
V_2D_2	4.41	4.19	17.84	24.33	433.81	82.40	381.26
V_3D_2	4.08	4.16	17.66	23.33	360.46	82.00	335.11
V_1D_3	3.79	3.91	14.92	23.33	348.62	70.00	299.37
V_2D_3	3.89	3.65	15.81	21.07	332.71	71.20	295.36
V_3D_3	3.82	3.30	15.36	17.80	274.07	71.00	220.52
V_1D_4	3.19	3.36	14.20	18.20	265.48	69.00	201.77
V_2D_4	3.27	3.47	15.59	19.40	301.93	62.00	237.48
V_3D_4	2.94	3.06	13.39	11.93	199.94	57.00	150.65
V at same D	0.470	0.445	1.496	2.357	33.068	10.985	32.440
D at same V	0.400	0.409	1.327	1.983	34.375	11.092	28.006

a large number of factors amongst which are the bearing potential of the cultivar, development of plants, weather conditions (Kiprijanovski and Arsov 2004). Thus, it can be inferred that mid-October to start of November is the ideal time of planting strawberry in gangetic plains of Bihar. Strawberry var. Festival produced maximum yield /plant due to heaviest and maximum number of fruits/ plant. These results were in conformity with the findings of Recupero *et al.* (1989) who reported varietal response with larger berries in Chandler, Pajaro and Selva. These differences in fruit size are primarily due to genetic make-up of genotype, plant vigour, competition among fruits in the inflorescence; number and size of developed achenes in different climatic conditions were the probable reason for difference in fruit size and yield as reported by Moore *et al.* (1970).The longest harvesting span (96 days) was noted in var. Winter Dawn when planted on 15 October and shortest harvesting span (57 days) was observed on 1 December planting in the interaction effect of planting dates and varieties.

Effect of planting dates on biochemical parameters of fruit of strawberry cultivars

Effect of planting dates and varieties were found significant on quality parameters like TSS, sugar, acidity, ascorbic acid and anthocyanin content in fruits but their interaction was not significant except in sugar content. 1 November planting fruits had higher TSS (9.34 ^{0}Brix) and total sugars (5.88%). Strawberry planted in early season produced fruits with higher TSS and ascorbic acid content

Table 6 Effect of planting date on biochemical parameters in different strawberry varieties

Treatment	TSS (%)	Reducing sugar (%)	Total sugar (%)	Acidity (%)	Ascorbic acid (mg/100g pulp)	Anthocyanin (mg/100g pulp)
Planting dates (D)						
15 Oct. (D_1)	8.52	2.73	5.84	0.55	54.12	70.27
1 Nov. (D_2)	9.34	2.60	5.88	0.52	58.67	73.3
15 Nov. (D_3)	8.74	2.27	4.94	0.56	55.88	75.48
1 Dec. (D_4)	8.12	2.03	4.49	0.62	55.01	68.37
CD (P=0.05)	0.282	0.081	0.117	0.035	1.628	2.46
Varieties (V)						
Sweet Charlie (V_1)	9.63	2.68	5.73	0.48	57.62	73.73
Festival (V_2)	8.36	2.4	5.17	0.53	55.45	78.29
Winter Dawn (V_3)	8.05	2.15	4.92	0.68	54.69	63.55
CD (P=0.05)	0.381	0.110	0.211	0.026	2.110	2.879

Table 7 Interaction effect of planting date and varieties of strawberry on biochemical parameters

Treatment	TSS (%)	Reducing sugar (%)	Total sugar (%)	Acidity (%)	Ascorbic acid (mg/100g pulp)	Anthocyanin (mg/100g pulp)
V_1D_1	9.13	2.92	6.31	0.47	54.3	72.5
V_2D_1	8.59	2.98	5.63	0.52	55.34	76.1
V_3D_1	7.85	2.28	5.57	0.65	52.71	62.2
V_1D_2	11.3	3.14	6.72	0.45	61.5	74.3
V_2D_2	8.34	2.57	5.75	0.49	57.24	80.2
V_3D_2	8.37	2.1	5.01	0.62	57.73	65.4
V_1D_3	8.69	2.37	5.12	0.46	57.91	78.3
V_2D_3	8.29	2.13	4.82	0.52	55.13	82.05
V_3D_3	7.37	2.31	4.87	0.69	54.6	66.1
V_1D_4	9.4	2.27	4.78	0.52	57.23	69.8
V_2D_4	8.21	1.93	4.47	0.59	54.07	74.8
V_3D_4	8.6	1.89	4.21	0.74	53.72	60.5
V at same D	NS	0.226	0.428	NS	NS	NS
D at same V	NS	0.198	0.364	NS	NS	NS

as stated by Singh *et al.* (2007) and Rahman *et al.* (2014). When planted in later stage might have exposed to high temperature resulting in low TSS and sugar content (Hassan *et al.* 2001). Among varieties, Sweet Charlie possessed maximum TSS, total and reducing sugars and ascorbic acid content but anthocyanin was maximum in variety Festival. The present study was in consonance with findings of Singh *et al.* (2008), Lal and Rao (2010) and Sharma and Sharma (2006) who recorded variation in TSS and acidity due to genetic makeup in strawberry genotypes.

Strawberry varieties performed differently with different planting dates in a cropping season. The study indicated that variety Winter Dawn performed well with respect to plant growth, earliness in flowering and fruiting and yield on 15 October planting whereas var. Festival and Sweet Charlie performed better in 1 November planting in sub-tropical climate of Bihar. Variety Festival was the best with respect to marketable yield. Quality of Sweet Charlie and Festival in terms of TSS and sugar content was better as compared to Winter Dawn.

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