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Enhancing Strawberry Productivity Using Drip Irrigation, Plastic Mulch, and New Cultivars in Bangladesh

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Strawberry (*Fragaria ×ananassa*) is a relatively new crop in Bangladesh that has excellent potential since it can be grown during the cool season when less fruit is available. However, strawberry productivity is low due to the underutilization of improved production techniques. To address production constraints identified by Bangladeshi farmers, a study was conducted at Rajshahi University to compare the use of drip irrigation, plastic mulch and University of Florida (UF) cultivars with the current farmer practice in Bangladesh during the 2018–2019 season. The field trial was conducted using a split-plot design in which main plot treatments were either System 1 (drip irrigation with black plastic mulch) or System 2 (furrow irrigation with straw mulch) were arranged in a block design with restricted randomization and replicated four times. In the subplots, the UF strawberry cultivars 'Florida Radiance' and Sweet Sensation® 'Florida 127' were compared with Bangladeshi cultivars 'RU-2' and 'RU-3'. System 1 resulted in lower water use [655,578 gallons/acre (gal/acre)] than System 2 (994,381 gal/acre). System 1 plants had greater survival, vigor, and vegetative growth than System 2 plants. Flowering occurred earlier in System 1 than in System 2. Total marketable yield was generally higher with System 1 (697.5 g/plant) than with System 2 (450.6 g/plant). 'Florida 127' had the highest total marketable yield and produced fruits with higher total soluble solids than the other cultivars throughout the season. Therefore, a combination of drip irrigation with black plastic mulch and the 'Florida 127' strawberry cultivar appears to be the best option for enhancing strawberry productivity in Bangladesh.

As a relatively new crop in Bangladesh, knowledge about strawberry within the public and academic spheres is limited. However, strawberry production has been increasing during the cool season from November to April when many fruits commonly grown in Bangladesh are not available. Expansion of strawberry production in Bangladesh will increase fruit availability during this period of fruit scarcity (Ahmad and Uddin, 2012). Additionally, because strawberry production may allow the farmers of Bangladesh to earn lucrative profits from a small land area, their interest in the crop has been increasing. A farmer could easily earn $14,826 to $18,533 (US) from a strawberry crop on one hectare of land during the winter season (BSS, 2015). Including strawberry in existing crop rotations of rice and vegetables and between tree rows of young orchards may enhance the economic productivity of existing cropping systems.

Strawberry is now grown in a few regions of Bangladesh, with the greatest concentration in the northern region, which has the most favorable growing conditions. The climate in Bangladesh is sub-tropical with hot summers (May–August) and mild winters (December-February) (Rahman et al., 2015). Initially, only a few farmers were involved in strawberry cultivation, but the number of strawberry farmers has gradually increased as more farmers recognize that the crop can be commercially viable. However, Bangladesh has only a few locally developed strawberry cultivars namely BADC Strawberry, BARI Strawberry-1, 'RU-1', 'RU-2', and 'RU-3' (Chowhan et al., 2016; Rahman, 2009). Farmers usually use the indigenous strawberry cultivars; however, some research stations have evaluated imported cultivars such as 'Strawberry Festival', 'Florida Radiance', 'Sweet Charlie', 'Camarosa', and 'FL 05-107' (Chowhan et al., 2016; Rahman et al., 2015).

Selecting adapted cultivars is considered by Asrey and Singh (2004) to be the most important factor for fruitful strawberry production. However, the performance of strawberry cultivars also depends on transplant quality (Johnson et al., 2005; Le

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Miere et al., 1998; Perez de Camacaro et al., 2004; Shokaeva, 2004). As a relatively new crop in Bangladesh, research emphasis has been placed on comparing strawberry cultivar yield, yield contributing characteristics, and fruit quality (Rahman et al., 2015). In previous work, Biswas et al. (2009) focused on using somaclonal variation to develop new cultivars. Although BARI Strawberry-1, a released of the Bangladesh Agricultural Research Institute, had the higher total soluble solids than 'Camarosa' and 'Strawberry Festival' it was considered to be unable to meet the increasing demand for strawberries in Bangladesh due to low yields (Chowhan et al., 2016). Genotypes FA 005, FA 006, and FA 007 from local and exotic sources performed well based on physico-chemical characteristics among thirteen genotypes tested in subtropical climates (Rahman et al., 2015).

In addition to better cultivars, technology such as plasticulture and drip irrigation may also have potential for improving strawberry productivity. Plasticulture systems have been shown to provide better soil moisture conservation, weed control, fertigation application efficiency, fruit size, and early yield than a conventional matted row system (O'Dell and Williams, 2000). In the Sylhet district of Bangladesh, micro-drip irrigation with plasticulture enhanced plant growth and development, reduced chemical use and production cost, and improved fruit quality and yield of tissue culture plantlets of strawberry compared to the conventional practice with no mulch and manual irrigation (Zobayer et al., 2011). While black plastic mulch and straw mulch was compared for strawberry production by Rannu et al. (2018), their study evaluated a single germplasm line (FA-007) and did not evaluate drip irrigation.

Farmers in Bangladesh are commonly using the 'RU-2' and 'RU-3' strawberry cultivars, which are characterized by good canopy size, large fruits, uniform color, anthracnose resistance and relatively higher yield among the Bangladeshi cultivars (Rahman, 2009). Cultivars developed for use in Florida may prove to be well-adapted to the subtropical conditions in Bangladesh and may offer improved quality and productivity compared to local cultivars. 'Florida Radiance' (marketed as 'Florida Fortuna' outside of the USA) was released in 2008 by the University of Florida (UF) (Chandler et al. 2009) and is adapted to regions where winter and early spring production is practiced. While having a number of desirable characteristics that make it well suited to the winter plasticulture production system, fruit firmness is just acceptable and disease susceptibility requires careful management to limit plant and fruit loss due to pathogens (Whitaker et al., 2016). A more recently released UF cultivar, Sweet Sensation® 'Florida 127' is also highly adapted to the winter plasticulture growing system, and produces a plant that is compact, robust and upright with long pedicels that facilitate easy harvesting (Whitaker et al., 2017). The fruits are uniform and large with prolonged shelf life and high Brix content. The plants are resistant to anthracnose but susceptible to botrytis. Low strawberry productivity in Bangladesh is likely due to the underutilization of improved production techniques. To address production constraints identified by Bangladeshi farmers as a means of improving strawberry productivity and quality, a study was undertaken to compare the use of drip irrigation, plastic mulch and new cultivars with the current farmer practice in Bangladesh.

Although common in many other areas with subtropical strawberry production, the annual hill (raised bed) system with plastic mulch and drip irrigation is not well understood by Bangladeshi farmers. As a result, there is a need for relevant research and extension of these methods to strawberry farmers. Therefore, the objective of this study was to evaluate drip irrigation, plastic mulch, and University of Florida cultivars for improved strawberry productivity in Bangladesh.

Materials and Methods

A field trial was conducted at Rajshahi University (RU) (lat. 24°36'N, long. 88°64'E), Bangladesh, during the 2018–19 growing season. The soil texture of the RU experimental site is classified as clay loam with 2.5% organic matter and pH of 6.9 (Islam et al., 2017). The experimental land was prepared by tillage to an approximate depth of 15 cm (Power tiller, SIFANG-121, Sifang, China). The trial was conducted using a split-plot design in which main plot treatments were either System 1 (drip irrigation with black plastic mulch) or System 2 (furrow irrigation with straw mulch) were arranged in a block design with restricted randomization and replicated 4 times. The subplot treatments were strawberry cultivars: 'RU-2', 'RU-3', 'Florida Radiance,' and Sweet Sensation® 'Florida 127'. The plug transplants of 'RU-2' and 'RU-3' were obtained from Akafuji Agro-technologies farm (Rajshahi, Bangladesh) and 'Florida Radiance,' and 'Florida 127' plug transplants were obtained from an Ekland Marketing Company-affiliated nursery in India (Zopar Exports Pvt. Ltd., Aizawl, Mizoram, India). Strawberry cultivars were randomly assigned to the subplots. Beds were prepared manually on 1.2-m centers with approximate bed heights and widths of 18 cm and 71 cm for System 1 and 10 cm and 71 cm for System 2, respectively.

For System 1 black plastic mulch (0.09-mm thickness; BPS Industries Corp., Beijing, China) was laid manually on the surface of raised beds prior to transplanting, and a single drip tape line (7.5 L/30 m, 0.03-mm thickness, 140-mm diameter, 30.5-cm emitter spacing, Advanced Plastic Technology, Barletta, Italy) was placed along the center of the bed during the laying of the mulch film. System 2 utilized locally sourced straw mulch. Colored spray paint (for plastic mulch plots) and wooden stakes (for straw mulch plots) were used to divide the beds into plots 2.29 m in length. At RU, 14 strawberry plug transplants per plot were planted in two offset rows per bed with a between-row spacing of 30.5 cm and a 38-cm within-row spacing on 26 Nov. 2018. Planting holes were punched through the plastic mulch using metal stakes to facilitate transplanting.

Crop Management. Drip irrigation was applied in System 1 twice a day for 55 minutes per application until December, and 70 minutes per application from January to March to maintain optimal soil moisture content for strawberry growth and yield (Sanchez, 2018). Water was supplied by gravity feed from an elevated water tank (500 L, Gazi Tank, Dhaka, Bangladesh), which was filled by an electric pump. In System 2, irrigation was applied at 15-day intervals after transplant establishment. During establishment, transplants were irrigated with a watering can (1.5-L Plastic Can, Fixit.Com.BD, Dhaka, Bangladesh). Soil moisture was monitored at 7-d interval in each system using a tensiometer (Irrometer, Model-P, Shelburne, VT 05482, Part number-P-2001, portable soil water tension detector; Mega Depot, LLC, Hinesburg, VT).

Diammonium phosphate (68 kg/ha) and muriate of potash (17 kg/ha) were applied as basal fertilizers during land preparation for System 2. A mixture of urea, muriate of potash, calcium nitrate, magnesium nitrate, zinc sulfate, and borax (6:8:2:0.4:0.02:0.02) at 5.9 kg/week/ha was applied throughout the season via the drip tape in System 1 and as manual spray applications for System 2. All fertilizers were purchased from the local Bangladesh market.

Data collection. Data were collected from the inner the plants within each row to avoid border effects. Plant vigor was assessed using a scale of 0 to 10 with 0 being dead plants and 10 being the most vigorous plants, a slightly modification of the method used by Monfort et al. (2007) (0–10 rating used instead 1–10). Strawberry transplant survival was assessed at 2 and 4 weeks after transplanting and expressed as a percentage. Days to first flowering was assessed as the number of days from planting to the first flower opening in each plot. Numbers of runners and leaves were assessed from six randomly selected plants per plot. Crown size was measured on four randomly selected plants using digital slide calipers. A ruler was used to measure the width and length of the canopies of four randomly selected plants and canopy size was calculated as an area by multiplying the two measurements.

Strawberries were harvested by hand early in the day while air temperatures were cool, every 3–4 d. The fruit was harvested at commercial maturity after > 80% of the fruit surface turned a uniform red color. Immediately after harvest, strawberries were sorted into marketable and unmarketable (cull) fruits. The number and fresh weight of marketable and cull fruits were determined from 10 sample plants per plot. The fruit yields from January through March are considered the total yield. Total soluble solids (TSS) were measured as degrees Brix once per month (Digital/Brix/RI-Check Refractometer, Reichert Technologies, Inc. Japan).

Statistical analysis. Data were analyzed using the GLIMMIX procedure of SAS Version 9.4 (SAS Institute Inc, Cary, NC). The main effects of irrigation system and cultivar and their interaction were considered fixed. Least squares mean separation was accomplished using the Tukey-Kramer adjustment. The level of significance used was 5%. Repeated measures analysis was used for variables for which the effect of the treatments on the same experimental unit at several different times.

Results

Soil moisture. More uniform soil moisture was observed with System 1 than with System 2 throughout the season (Fig. 1). On 22 Feb., soil moisture was very high in both systems due to heavy rainfall. Irrigation water use was lower with System 1 than System 2, which was expected (Table 1). This was because the drip irrigation could be controlled more precisely than the furrow irrigation. System 1 (655,578 gal/acre) provided more efficient water use with 338,803 gal/acre less water used than System 2 (994,381 gal/acre).

Table 1. Comparisons of irrigation water use in drip irrigation and furrow irrigation systems

System (S)	Duration	GPA[z]
S1 = Drip irrigation + plastic mulch	26 Nov.–29 Mar.	655,578
S2 =Furrow irrigation + straw mulch	26 Nov.–29 Mar.	994,381
Difference	–	338,803

[z]GPA = gallons per acre (gal/acre).

Plant survival, vigor, crown diameter and days to first flower. Significantly higher plant survival was obtained with System 1 than System 2 (Table 2). Transplant mortality was higher with 'Florida Radiance' compared to the other strawberry cultivars tested. A similar trend was found for plant vigor in both systems. In the case of vigor, 'Florida 127' performed better than 'Florida Radiance' and 'RU-2' but did not differ from 'RU-3'. A significant difference in days to first flower was obtained with the two systems. Earlier flowering occurred with System 1 than with System 2. However, there was no difference in days to flowering among the strawberry cultivars.

At 8 and 12 weeks after transplanting, there was a significant system by cultivar interaction for crown diameter and, therefore, the simple effects of system and cultivar were assessed for these sample dates (Table 2). However, the system by cultivar interaction was not significant at 4 and 16 WAT for crown diameter and the main effects of system and cultivar are presented for these dates. At all four sample dates crown diameter was greater for System 1 than System 2. When cultivars were compared, 'Florida 127' had larger crown diameter than 'Florida Radiance' and 'RU-2' with no statistical differences with 'RU-3' at 4 WAT. At 8 and 12 WAT no difference in crown diameter was apparent among the cultivars in System 1; however, in System 2 'Florida 127' had the largest crown diameter. 'Florida Radiance' had the smallest crown diameter at 8 WAT in the System 1 with no difference observed among 'Florida Radiance', 'RU-2', and 'RU-3' at 12 WAT. By 16 WAT. Averaged over system, 'Florida127' had the largest crown diameter of the four cultivars.

Leaf number, canopy size, and runner number. There was no interaction between system and cultivar for leaf number at 4 and 8 WAT but a significant system by cultivar interaction was found at 12 and 16 WAT (Table 3). Leaf number was higher with System 1 than System 2 at 4 and 8 WAT. 'Florida 127' produced more leaves than 'Florida Radiance' and 'RU-2' but leaf number was not statistically different from that of 'RU-3' at 4 WAT. Cul-

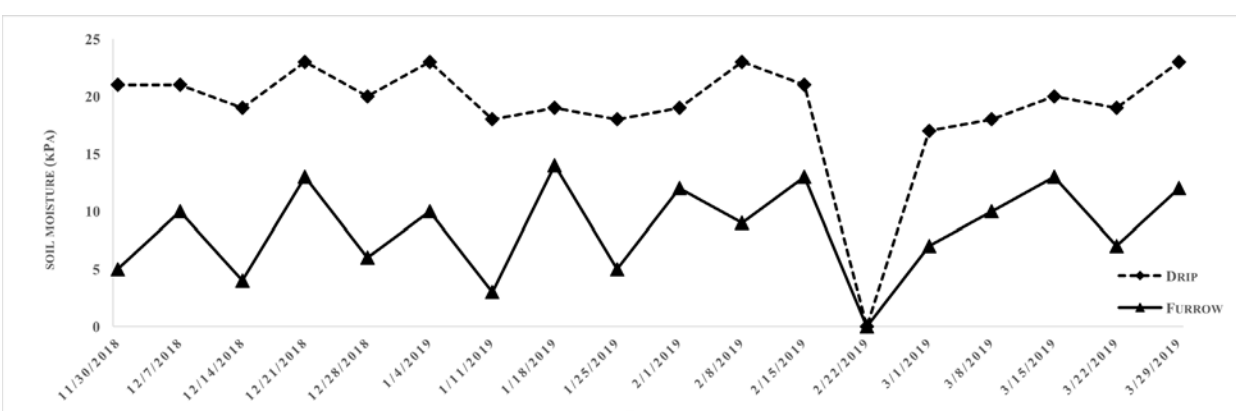

Fig. 1. Soil moisture (kPa) at a weekly interval in drip and furrow irrigation systems measured using tensiometers.

Table 2. Effect of production system and strawberry cultivar on plant survival, vigor, days to first flower, and crown diameter.

	Plant survival (%)		Plant vigor		Days to	Crown diameter (cm)					
Treatments	2 WAT[z]	4 WAT	2 WAT	4 WAT	first flower	4 WAT	8 WAT		12 WAT		16 WAT
System (S)											
S1[y]	91.5 a	87.5 a	6.3 a	6.9 a	36.9 b	0.85 a	–		–		3.5 a
S2[x]	73.7 b	71.0 b	3.9 b	4.6 b	40.9 a	0.70 b	–		–		2.6 b
Cultivar (C)							S1	S2	S1	S2	
Florida 127	83.9 a	79.5 a	6.0 a	6.8 a	38.3	0.80 a	1.6 a	1.3 d	2.8 a	2.0 c	3.2 a
Florida Radiance	71.4 b	67.9 b	4.3 b	5.3 b	39.1	0.75 b	1.4 c	1.2 d	2.3 b	1.9 c	2.9 b
RU-2	85.7 a	83.9 a	4.9 b	5.1 b	39.5	0.76 b	1.5 b	1.2 d	2.4 b	2.0 c	3.0 b
RU-3	89.3 a	85.7 a	5.1 ab	5.9 ab	38.9	0.77 ab	1.5 b	1.2 d	2.5 b	2.1 c	3.0 b
Significance											
System (S)	**	**	***	***	***	***	***		***		***
Cultivar (C)	***	***	***	**	NS	**	***		***		***
S × C	NS	NS	NS	NS	NS	NS	***		***		NS

[z]WAT = weeks after transplanting.
[y]S1 = drip irrigation with black plastic mulch.
[x]S2 = furrow irrigation with straw mulch.
Least squares means in columns followed by the same letters do not differ significantly according to the Tukey-Kramer test.
NS, **, *** indicate nonsignificant or significant at $P < 0.01$ and 0.001, respectively.

Table 3. Effect of production system and strawberry cultivar on leaf number and canopy size[z].

	Leaf number/plant						Canopy size (cm^2)			
Treatments	4 WAT[z]	8 WAT	12 WAT		16 WAT		4 WAT	8 WAT	12 WAT	16 WAT
System (S)										
S1[y]	5.6 a	10.6 a	–		–		67.6 a	158.3 a	237.8 a	330.4 a
S2[x]	4.5 b	7.9 b	–		–		40.5 b	85.3 b	163.2 b	232.3 b
Cultivars(C)			S1	S2	S1	S2				
Florida 127	5.6 a	9.6	23.0 a	14.3 c	36.5 a	23.5 c	55.9	132.7	217.8	299.7
Florida Radiance	4.5 c	8.8	18.3 b	14.0 c	31.8 b	21.5 c	49.8	111.1	188.3	268.6
RU-2	5.6 bc	9.1	20.3 ab	14.3 c	29.3 b	21.5 c	55.6	121.6	199.7	281.0
RU-3	5.5 ab	9.6	18.5 b	13.8 c	31.5 b	23.0 c	54.9	121.6	196.2	275.9
Significance										
System (S)	*	***	***		**		*	***	*	***
Cultivar (C)	**	NS	**		***		NS	NS	NS	NS
S × C	NS	NS	**		*		NS	NS	NS	NS

[z]WAT = weeks after transplanting.
[y]S1 = drip irrigation with black plastic mulch.
[x]S2 = furrow irrigation with straw mulch.
Least squares means followed by the same letters within columns do not differ significantly according to the Tukey-Kramer test.
NS, *, **, *** indicate nonsignificant or significant at $P < 0.05$, 0.01, and 0.001, respectively.

tivars did not differ in leaf number at 8 WAT. 'Florida 127' with System 1 and produced more leaves than 'Florida Radiance' and 'RU-3' at 12 WAT and had more leaves than all other cultivars at 16 WAT (Table 3). The canopy size of strawberry plants in System 1 was larger than in System 2 throughout the season. However, strawberry cultivars did not differ in canopy size at any of the sample dates. Runner production was very low and there was no significant effect of treatments at 4, 8, 12, and 16 WAT (Table 4).

Total soluble solids and fruit yield. For TSS, the system by cultivar interaction was not significant in January, but a significant interaction was observed in February and March. In January, System 1 produced sweeter fruits than System 2 (Table 4). 'Florida 127' resulted in sweeter fruits than other cultivars. In System 1 'Florida 127' produced sweeter fruits than the other cultivars in February and March. Only 'Florida 127' resulted in higher TSS in System 1 than System 2 in February and March. For the other three cultivars there was no difference in TSS between the systems. In general, 'Florida Radiance' had higher TSS than both 'RU-2' and 'RU-3'.

In the case of number of marketable fruit number and weight in January, a significant system by cultivar interaction was obtained (Table 5). In System 1, 'Florida 127' produced more fruits than 'Florida Radiance' and 'RU-2', but its marketable fruit number was not different from that of 'RU-3'. For fruit weight in January, in System 1 marketable fruit weight was highest with 'Florida 127'. In System 2 there was no cultivar difference in either fruit number or fruit weight in January.

There was no system by cultivar interaction for marketable fruit number and fruit weight in February and March and for season total marketable fruit number and fruit weight (Table 5). The System 1 produced more fruits than System 2. In February, 'Florida 127' produced more fruits and greater fruit weight than 'RU-3' with no difference when compared with 'Florida Radiance' and 'RU-2'. In March, 'Florida 127' produced more fruits

Table 4. Effect of production system and strawberry cultivar on runner number and total soluble solid.

Treatments	Runner number 4 WAT[z]	8 WAT	12 WAT	16 WAT	Total soluble solids (°Brix) Jan.	Feb.		Mar.	
System (S)									
S1[y]	1.3	1.5	1.6	1.3	7.3 a	–		–	
S2[x]	1.2	1.4	1.6	1.4	7.1 b	–		–	
Cultivar (C)						S1	S2	S1	S2
Florida 127	1.0	1.6	1.5	1.5	8.1 a	8.9 a	8.2 b	9.2 a	8.6 b
Florida Radiance	1.1	1.3	1.4	1.1	7.3 b	7.6 c	7.7 c	8.0 b	8.1 b
RU-2	1.4	1.6	1.8	1.3	6.6 c	7.0 d	6.9 d	7.1 c	7.2 c
RU-3	1.4	1.4	1.8	1.4	6.8 c	7.1 d	6.9 d	7.2 c	7.1 c
Significance									
System (S)	NS	NS	NS	NS	*	**		NS	
Cultivar (C)	NS	NS	NS	NS	***	***		***	
S × C	NS	NS	NS	NS	NS	***		*	

[z]WAT = Weeks after transplanting

[y]S1 = Drip irrigation with black plastic mulch.

[x]S2 = Furrow irrigation with straw mulch.

Least squares means in columns followed by the same letters do not differ significantly according to the Tukey-Kramer test.

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and greater fruit weight than 'RU-2' and 'RU-3' with no differences when compared with 'Florida Radiance'. In the case of season total marketable fruit number and fruit weight, 'Florida 127' produced more yield than the other cultivars. 'Florida 127' had a larger fruit size (data not shown) and produced more fruits than other cultivars possibly explaining some of the cultivar differences in this study.

In contrast, no significant effect on number of unmarketable fruits was observed due to system and cultivar (Table 5). Also, unmarketable fruit weight was not significant throughout the

Table 5. Effect of production system and strawberry cultivar on yield of marketable and unmarketable (cull) fruits.

Treatments	Marketable fruit number/plant Jan.		Feb.	Mar.	Total	Cull fruit number/plant Jan.	Feb.	Mar.	Total
System (S)									
S1[z]	–		16.4 a	25.3 a	52.6 a	4.9	7.0	13.0	24.9
S2[y]	–		9.7 b	19.1 b	36.4 b	5.1	8.3	12.0	25.4
Cultivar (C)	S1	S2							
Florida 127	13.7 a	7.8 bc	14.6 a	24.6 a	50.0 a	5.1	7.6	12.0	24.7
Florida Radiance	10.0 bc	8.3 bc	13.0 ab	22.0 ab	44.1 b	4.9	8.0	12.8	25.7
RU-2	9.3 bc	7.3 c	12.8 ab	21.1 b	42.1 b	4.3	6.8	12.6	23.7
RU-3	11.0 ab	7.3 c	11.8 b	21.0 b	41.9 b	5.6	8.1	12.6	26.3
Significance									
System (S)	**		*	**	**	NS	NS	NS	NS
Cultivar (C)	*		*	*	**	NS	NS	NS	NS
S × C	**		NS	NS	NS	NS	NS	NS	NS

Treatments	Marketable fruit wt (g/plant) Jan.		Feb.	Mar.	Total	Cull fruit wt (g/plant) Jan.		Feb.	Mar.	Total
System (S)										
S1	–		229.3 a	320.5 a	697.5 a	–		44.8	83.4	158.9
S2	–		122.6 b	235.3 b	450.6 b	–		49.9	77.1	152.6
Cultivar (C)	S1	S2				S1	S2			
Florida 127	185.3 a	95.5 cd	200.3 a	310.3 a	650.9 a	39.8 a	21.8 ab	47.9	78.9	157.5
Florida Radiance	137.5 bc	98.8 bcd	177.5 ab	274.3 ab	569.9 b	31.5 ab	18.5 b	45.1	74.9	145.0
RU-2	126.0 bcd	90.8 d	164.6 b	264.4 b	537.4 b	23.5 ab	29.8 ab	42.8	86.9	156.3
RU-3	142.0 b	85.8 d	161.5 b	262.6 b	538.0 b	28.0 ab	32.8 ab	53.6	80.4	164.4
Significance										
System (S)	**		*	**	**	NS		NS	NS	NS
Cultivar (C)	**		**	*	***	NS		NS	NS	NS
S × C	**		NS	NS	NS	**		NS	NS	NS

[z]S1 = Drip irrigation with black plastic mulch.

[y]S2 = Furrow irrigation with straw mulch.

Least squares means in columns followed by the same letters do not differ significantly according to the Tukey-Kramer test.

NS, *, **, *** indicate nonsignificant or significant at $P < 0.05$, 0.01, and 0.001, respectively.

season except in January when the system by cultivar interaction was significant. This was due to the highest unmarketable fruit weight occurring with 'Florida 127' in System 1 and the lowest unmarketable fruit weight occurring with 'Florida Radiance' in System 2.

Discussion

The drip irrigation system allowed for the maintenance of soil moisture within the top 30–40 cm of soil where much of the strawberry root system occurs. Drip irrigation use also helps to avoid excessive water loss due to percolation and infiltration (Morillo et al., 2017). In India, popularity and adoption of drip irrigation has expanded due to better water use efficiency and ensured higher yield with various crops (Panigrahi et al., 2012). Water use efficiency was higher with a drip irrigation system than a furrow irrigation system in research findings reported by Hoppula and Salo (2007) and Kumar et al. (2012). This is due to the fact that drip irrigation supplies water directly to the root zone with less water loss by evaporation and less leaching of soil-applied fertilizers compared with surface irrigation (Sharma et al., 2005).

Drip irrigation maintained more uniform soil moisture with more consistent plant growth and development than furrow irrigation in this study. A similar response was observed by Zobayer et al. (2011) in Sylhet Bangladesh. They mentioned that plant growth and development of strawberry transplants propagated using tissue culture were better with the micro-drip irrigation and plasticulture system. A similar response was obtained in this study in which System 1 with black plastic mulch and drip irrigation resulted in better plant growth than System 2, a more traditional system with less frequent furrow irrigation and straw mulch. Drip irrigation gave higher yield than the furrow irrigation system. These results are in agreement with the findings of Fahad and Hagemann (1992), Kachwaya et al. (2016), Minami et al. (1982), and Yuan et al. (2004).

Ahmad et al. (2014) reported that groundwater use is unsustainable in parts of Bangladesh and that its use for irrigation is threatened in some areas due to falling water tables. Rajshahi, where strawberries are grown, was identified as an area with low water productivity. To address this constraint, changing to more sustainable agronomic practices along with improved technology and promoting its adoption were recommended by Ahmad et al. (2014). The cost of new technology such as plastic mulch, drip irrigation, and new cultivars is often a barrier to adoption by growers. However, government subsidies for agriculture may be available to offset the cost of new technology through programs such as the National Agricultural Technology Project, which are intended to increase agricultural productivity and farm income (World Bank, 2014).

Adnan et al. (2017) observed significant variation in strawberry plant growth due to variety and mulch effect. They found that black plastic mulch resulted in better plant growth and higher strawberry flower number per plant than water hyacinth mulch and straw mulch. An increase in strawberry flower number per plant due to use of black and silver mulch was also reported by Ali and Redwan (2008). A similar response was observed in this study where black plastic mulch with drip irrigation system resulted in earlier flowering compared to straw mulch with furrow irrigation. Black plastic mulches are generally used during the cool season when they can warm the soil, enhance growth, and contribute to early yields. Not only do organic mulches limit soil warming, but those with high carbon to nitrogen ratios can also affect nitrogen availability to the crop. Number of fruits per plant, fruit fresh weight and fruit number were highest with black plastic mulch when compared with water hyacinth mulch and straw mulch (Adnan et al., 2017), which is consistent with the results from this experiment. Black mulch facilitated the growth and development of strawberry plants in several other studies resulting in higher fruit yield than straw mulch (Baumann et al. 1995; Shiow et al., 1998; Vander Meulen et al. 2006).

Previous evaluations of strawberry germplasm in Bangladesh showed that strawberry traits such as uniformity, shape, color, and fruit yield varied with genotype (Rahman et al., 2013, Rahman et al., 2014, Rahman et al., 2015). Although strawberry yield potential can vary due to cultivar (Himelrick et al., 1993; Himelrick and Akridge, 1999), genotype alone may not account for the difference in productivity observed with the two Florida cultivars. 'Florida 127' resulted in the highest marketable fruit yield in this study, out yielding even 'Florida Radiance'. This was a curious result since in Florida, Whitaker et al. (2015) found no significant difference in the per plant yield of 'Florida 127' and 'Florida Radiance' over two consecutive seasons. It is possible that 'Florida 127' is better adapted to growing conditions in Rajshahi where the soil is a clay loam with a higher organic matter content than the sandy soil in Florida where the previous study was conducted. Better adaptability may also explain less mortality, greater vigor, and larger crown diameter by 16 WAT with 'Florida 127' than with 'Florida Radiance'. Further, the Rajshahi study was conducted without soil fumigant, fungicides, and pesticides. Thus, differential susceptibility of the two cultivars to biotic and abiotic conditions may account for the lower yield in 'Florida Radiance' in Rajshahi. In the current study, the highest TSS content was observed in 'Florida 127' among the four cultivars tested. This result is consistent with the performance of 'Florida 127' in Florida where soluble solids content and trained sensory panels ratings were higher in more assessments with 'Florida 127' than with 'Florida Radiance' (Whitaker et al., 2015).

In general, drip irrigation with black plastic mulch resulted in lower water use and better growth and yield of strawberry than furrow irrigation and straw mulch. 'Florida 127' resulted in higher marketable yields and higher total soluble solids content than 'Florida Radiance' and two Bangladeshi cultivars. Therefore, a combination of drip irrigation with black plastic mulch and the Florida 127 strawberry cultivar appears to be the best option for enhancing strawberry productivity in Bangladesh. The study will need to be repeated before recommendations can be made. Options for providing growers with legally sourced, high quality 'Florida 127' transplants will also need to be explored.

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