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MITIGATION OF CLIMATE CHANGE EFFECT IN SWEET PEPPER (*Capsicum annuum* L.) THROUGH ADJUSTMENT OF PLANTING TIME

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Sweet pepper (*Capsicum annuum* L.) is one of the most popular and high value vegetable crops grown for its immature fruits throughout the world. In Pakistan it is cultivated as warm season crop in open fields during summer and in plastic tunnels during winter. Optimum planting date in sweet pepper production is key to better yield as it determines the period of maximum crop potential, efficient use of resources, lesser competition of plants with weeds and insect pests. It is the need of time to understand the negative impact of climate change on phenological development of sweet pepper. Therefore, the current study was designed to mitigate the effect of climate on growth and yield of sweet pepper cultivars at agro-ecological area of Multan, Pakistan by adjusting planting date. Three transplanting dates (*viz*. February 15th, March 2nd and March 16th) were evaluated during year 1 whereas five transplanting dates (*viz.* February 1st, February 15th, March 2nd, March 16th and April 1st) were assessed during year 2. There were three sweet pepper cultivars (Ganga, Winner and Savio) under study. Overall plant growth (stem height, average canopy diameter, number of leaves per plant and fresh and dry mass of plant parts) was significantly higher in the earliest planting dates (*viz*. February 15th in year 1 and February 1st in year 2) and it reduced as the planting was delayed. Plant yield, number of fruits and average fruit weight were also significantly greater in the earliest planting dates, and significantly lesser in later planting dates. During year 1, the effect of cultivar was prominent, and Winner performed better regarding growth characteristics while the effect was non-significant on yield attributes except average fruit weight which was also significantly higher in Winner as compared with other two cultivars. During year 2, cv. Winner performed better in growth attributes, whereas significantly greater number of fruits was found in cv. Savio, average fruit diameter was greater in cv. Winner and average fruit length was higher in cv. Ganga. It is concluded that nursery of sweet pepper should be planted in 1st week of February to achieve maximum growth and yield of fruits. In cultivar selection, cv. Winner should be preferred among sweet pepper hybrids.
Key words: *Capsicum annuum,* growth attributes, leaf area index, planting dates, sweet pepper cultivars, yield attributes.

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is one of the most popular and high value vegetable crops grown for its immature fruits throughout the world (Lodhi *et al.*, 2014). It is used as fresh in salad form as well as cooked vegetable. Nutritionally, it is rich in vitamin A (when ripe), vitamin C, E, K and folate. It is also a good source of antioxidant compounds (Oladitan, 2017). It is considered as 3rd most important crop in Solanaceae family after potato and tomato. Globally, India is the leading producing country followed by China. In Pakistan it is a cash crop and cultivated in open fields in summer season and in plastic tunnels during winter (Hussain and Abid, 2011). Crop raised in open fields have to face environmental changes more severely as compared to protected cultivation. High day and night temperatures negatively affect vegetative growth, flowering, fruit set and resultantly yield of the sweet pepper (Erickson and Markhart, 2001). Sweet pepper is more sensitive to high temperature and set lesser fruits at high night temperatures as compared with hot pepper. Pollen fertilization is severely reduced below 15 °C and above 32 °C due to poor pollen development. Temperature is considered as the key environmental factor affecting whole phenomenon of plant growth and development ranging from seed germination to seed maturation. Although sweet pepper is a warm season crop, but its yield is severely reduced in hot summer when temperature exceeds 35 °C. Optimum planting date in sweet pepper production is the key to better yield as it determines the period of maximum crop potential, efficient use of resources and lesser competition of crop with weeds and insect pests.

In various studies, it has been reported that climate change had negative impact on yield of agricultural crops and ecological systems in developing as well as developed countries (IPCC, 2014). The most alarming situation of climate change is the increased in mean temperature at global level. In most Asian countries, the numbers of cold days as well nights have decreased whereas integer of hot days and nights has been decreased since 1950. In a recent IPCC report, it was concluded that the warmest decade was 2001-2010 and the hottest year was 2014 as compared with past years. A similar warming trend was also reported in Punjab, Pakistan in last three years and mainly after 2000s (Gordo and Sanz, 2005; Wang *et al.*, 2011). The mean temperature is constantly increasing and is expected to increase 2-4 °C by the end of this century and this climate change conditions may have significant impact on agricultural production (Ahmad *et al.*, 2015). Under this elevated temperature scenario, planting date optimization may be an environment friendly approach to synchronize plant growth stages with optimum temperatures (Jalota *et al.*, 2012).

Appropriate planting date ensures better crop growth and economic yield (Islam *et al.*, 2010; Waha *et al.*, 2012). Few studies reported the effect of planting date on sweet pepper growth and yield (Kamboj and Sharma, 2015; Prasannakumar *et al.*, 2015**;** Oladitan, 2017; Chatterjee *et al.*, 2018). Oladitan (2017) concluded that green pepper growth and yield increase at proper planting date and it also supports the availability of fruit for a longer period in the season. Correct planning time results in good yield with better quality fruits and on the other hand improper planting date reduces yield with poor quality fruits. Early planting date resulted in good yield as compared with late planting (Hamma *et al.*, 2012). Time of planting has marked effect on the crop yield due to change in climatic conditions (temperature variations, frequency and amount of wet and dry periods) that strongly correlates with crop phenological phases (Drewniak *et al.*, 2013; Tsimba *et al.*, 2013; Wolf *et al.*, 2015). Selection of accurate planting window for a specific crop hybrid for a particular location is also very important consideration for better crop management. Therefore, the aim of present study was to evaluate the effect of different planting dates on growth and yield of sweet pepper cultivars under changing climate scenario at agro-ecological area of Multan, Pakistan.

MATERIALS AND METHODS

Study area: Field trials were conducted at the vegetable research area, Department of Horticulture, Bahauddin Zakariya University, Multan Pakistan (30.2570 ºlatitude N, 71.5150 longitude ºE, and 130 m elevation from sea level). The experimental site is located in the semi-arid area of Pakistan. Meteorological data of the site are given in Figure 1 and 2.

Experimental procedures**:** The experiment was performed during 2017 (Year 1) and 2018 (Year 2). During year 1, three transplanting dates (*viz.* February 15^{th}, March 2^{nd} and March 16^{th}) were evaluated whereas five transplanting dates (*viz.* February 1^{st}, February 15^{th}, March 2^{nd}, March 16^{th} and April 1^{st}) were assessed during the year 2. The average temperature was 15.5, 17 and 19 ºC at 1^{st}, 2^{nd} and 3^{rd} transplanting dates, respectively during 2017. Whereas it was recorded 12, 13, 14, 18 and 23 ºC at 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} transplanting dates, respectively during 2018. Seeds of three sweet pepper cultivars (Ganga, Winner and Savio) were purchased from local seed market and planted in germination trays containing mixture of silt + peat moss (1:1 v/v). Seeds were sown for different transplantings during the months of December 2016 and January 2017 for 1^{st} year crop and November 2017, December 2017 and January 2018 for 2^{nd} year crop. Trays were placed in shade in nursery area. Growing medium was kept moist until germination and then irrigation was applied according to the requirement. After 3 weeks of germination, seedlings were fertigated with 0.1% Urea (46% N).

For land preparation, fully rotten FYM was applied @ 30 t/ha. Afterwards, the field was prepared by levelling and ploughing it 3-4 times followed by rotavating. Recommended doses of phosphorus 75 kg/ha and potassium 60 kg/ha were applied at the time of land preparation. Urea was applied @125 kg/ha in two split doses i.e. 1^{st} at the land preparation time and second dose was applied at flowering stage. Net plot size was 7.2 m^2. Ridges were prepared 60 cm apart. About forty days old seedlings were used for transplanting in the field. Seedlings were dipped in fungicide "thiophanate methyl" before transplanting. Seedlings were transplanted on top of ridges, maintaining the plant-plant distance 30 cm. Irrigation was applied immediately after transplanting and further irrigations were applied with respect to the crop requirement. The numbers of irrigations from transplanting to harvesting during 2017 were 19, 16 and 13 at February 15^{th}, March 2^{nd} and March 16^{th} transplantings, respectively. While, during 2018, the numbers of irrigations were 17, 16, 14, 13 and 12 at February 1^{st}, February 15^{th}, March 2^{nd}, March 16^{th} and April 1^{st} transplantings, respectively. Weeding through manual hoeing was performed 3 times during crop growth period and insect-pests control measures were adopted according to their threshold level.

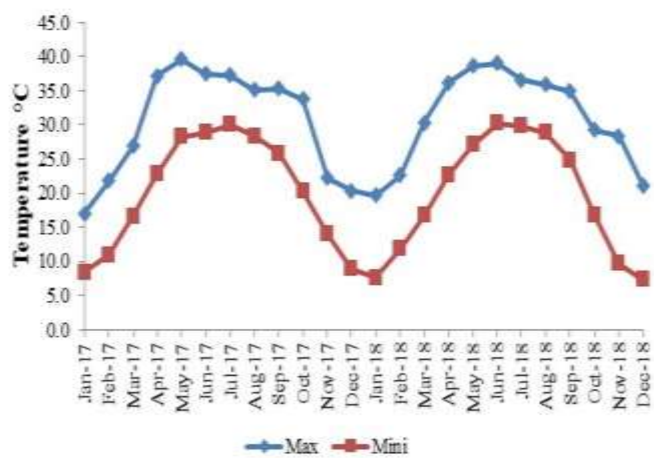

Figure 1. Monthly maximum and minimum temperature at Multan during January 2017 to December 2018 (source: Pakistan Meteorological Department).

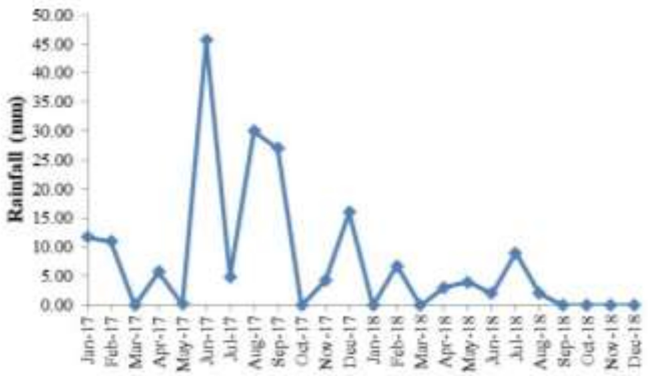

Figure 2. Rainfall occurring at Multan during January 2017 to December 2018 (source: Pakistan Meteorological Department).

Data collection: In the experimental trials, half of the plot area was used for growth and biomass studies and the other half was kept for the final harvest data.

Crop growth: Five plants were tagged for periodic determination of stem height, number of leaves per plant, average canopy diameter, stem diameter at different times of crop development and before the final harvest of plants**.** First sampling for growth parameters was done after six weeks of transplanting then after every two weeks interval. Plant fresh and dry biomass was determined in the same way in each cropping season at every two weeks interval. For destructive sampling, five plants were uprooted from each plot in each sampling. The plants were separated into leaves, stem, roots and fruits (when present). Fresh and dry weights of component fractions of plant (leaf, stem, root and fruit) were determined. For dry weight determination samples were oven dried at 65 ºC for 48 hours up to constant weight. For leaf area calculations, 5-10 green leaves were taken, and their leaf area was measured with an electronic leaf area meter (Licor, model 3100, USA). Leaf area index (LAI) was calculated as the ratio of leaf area to land area.

Yield and yield components: The tagged plants for periodic data collection were also used for yield estimation. About 3-4 pickings of marketable fruits were done during the crop period. Fruit fresh weight, fruit length and fruit diameter were recorded and then the fruits were dried as described above to estimate the dry weight of fruits. For final fruit yield, fruit weight of all pickings was added to calculate the fruit fresh weight per plant. Number of fruits per plant was also calculated by adding the number of fruits in each picking.

Statistical analysis: The experiment was performed according to Randomized Complete Block Design with split-plot arrangement. Transplanting date was assigned as the main plot factor while the cultivar was used as sub-plot factor. All treatments were replicated three times. The statistical analysis of the data was performed using the Statistix 8.1 analytical software (Tallahassee Florida, USA). Analysis of variance technique was employed to test the overall significance of the data, while the least significance difference (LSD) test at P = 0.05 was used to compare the means (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Statistical analysis of the data indicated that there were significant differences among the different transplanting dates and also among the cultivars for various parameters recorded during 2017 and 2018. As there were different levels for transplanting dates for both years, so the results are discussed separately.

Growth and biomass accumulation: Plant growth characteristics including stem height, average canopy diameter and number of leaves per plant were significantly affected by the transplanting dates during both the years. During year 1, significantly greater stem height (46.03 cm), average canopy diameter (41.93 cm), and number of leaves per plant (238) were recorded at February 15th transplanting date, as compared with other two transplantings. Regarding fresh and dry weights of plant parts, significantly higher fresh and dry weights of leaf, stem and root were produced at February 15th transplanting date. While significantly lower fresh and dry weights of leaf, stem and root were exhibited at March 16th transplanting date (Table 1).

Concerning the effect of cultivars, cv. Winner exhibited significantly taller plants (40.87 cm), greater average canopy diameter (40.77 cm), and higher number of leaves per plant (208) as compared with other two cultivars. Similarly, the cv. Winner produced significantly higher leaf fresh weight (240.78 g), stem fresh weight (254.79 g) and root dry weight (10.51 g), as compared with cv. Ganga and cv. Savio. Stem

Table 1. Effect of different transplanting dates on growth characteristics of sweet pepper during 2017.

Transplanting date	Stem height (cm)	Average canopy diameter (cm)	No. of leaves per plant	Leaf fresh weight (g)	Leaf dry weight (g)	Stem fresh weight (g)	Stem dry weight (g)	Root fresh weight (g)	Root dry weight (g)
February15th	46.03 a	41.93 a	237.78 a	251.36 a	40.70 a	264.53 a	40.51 a	29.85 a	10.74 a
March 2nd	33.53 b	35.96 ab	165.44 b	172.40 b	34.15 ab	220.44 ab	32.14 ab	28.04 a	8.99 ab
March 16th	31.98 b	31.60 b	153.17 b	153.82 b	27.16 b	180.59 b	25.60 b	16.76 b	6.60 b
LSD value	7.92	7.39	50.04	61.89	8.96	54.77	10.12	4.59	2.44

Means sharing different letter(s) in a column are statistically significant at $p < 0.05$

Table 2. Effect of different cultivars on growth characteristics of sweet pepper during 2017.

Cultivar	Stem height (cm)	Average canopy diameter (cm)	No of leaves per plant	Leaf fresh weight (g)	Leaf dry weight (g)	Stem fresh weight (g)	Stem dry weight (g)	Root fresh weight (g)	Root dry weight (g)
Ganga	33.22 b	33.84 b	159.33 b	165.45 b	30.93a	200.68 b	28.74 b	22.89a	7.28 b
Winner	40.87 a	40.77 a	207.78 a	240.78 a	36.54a	254.79 a	31.11 b	26.93a	10.51 a
Savio	37.45 a	34.87 b	189.28 ab	171.35 b	34.53a	210.09 b	38.41 a	24.85a	8.55 b
LSD value	3.53	4.33	31.98	37.68	6.64	27.60	5.87	4.71	1.59

Means sharing different letter(s) in a column are statistically significant at $p < 0.05$

dry weight was found the highest (38.41 g) in cv. Savio, followed by cv. Winner and cv. Ganga (Table 2).

The performance of sweet pepper cultivars at different transplanting dates was found significant. All the studied cultivars produced the maximum dry biomass in February 15th transplanting however it reduced in March 2nd transplanting and then slightly increased in March 16th transplanting. In the February 15th transplanting of year 1, significantly greater dry biomass was recorded in Winner and significantly lesser dry biomass was recorded in Ganga. In the March 2nd transplanting, cv. Savio produced the highest dry biomass and cv. Ganga produced the lowest. In the March 16th transplanting, significantly highest dry biomass was recorded in cv. Winner and lowest in cv. Ganga (Figure 3).

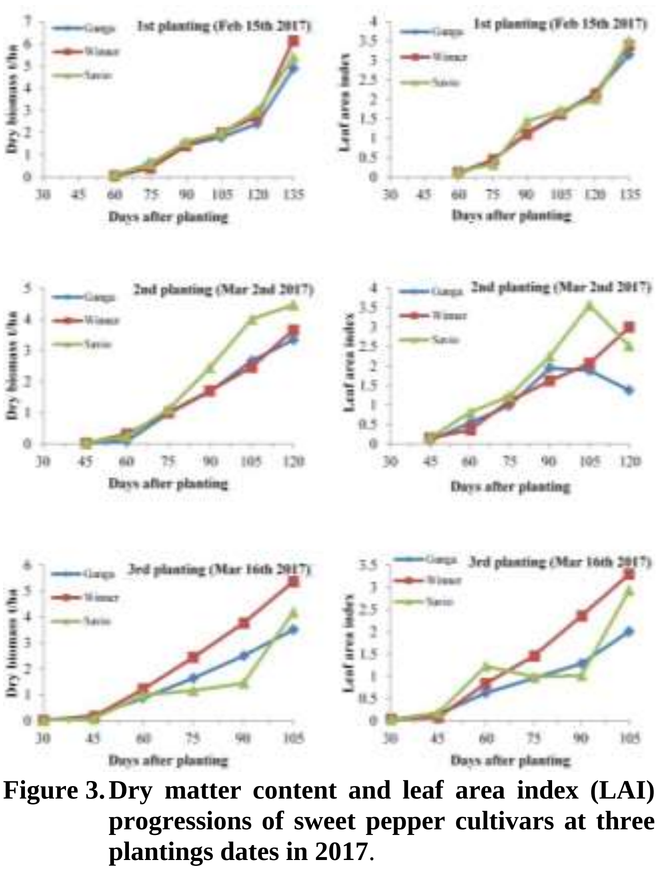

Figure 3. Dry matter content and leaf area index (LAI) progressions of sweet pepper cultivars at three plantings dates in 2017.

During year 2, the highest values for stem height (49.17 cm), average canopy diameter (49.73 cm) and number of leaves per plant (278) were recorded at February 1st transplanting date. The values for these growth parameters consistently decreased in the latter transplantings and the lowest were exhibited in April 1st transplanting. Correspondingly, significantly higher leaf fresh weight (154.92 g), leaf dry weight (22.45 g), stem fresh weight (162.44 g), stem dry weight (29.36 g), root fresh weight (16.80 g) and root dry weight (5.52 g) were recorded at February 1st transplanting date when compared with all other transplanting dates. The values of the concerned parameters decreased as the transplanting was delayed and the lowest were noted in April 1st transplanting (Table 3).

Regarding the individual effect of cultivars, cv. Winner produced significantly taller (47.44 cm), and wider (41.37 cm) plants, as compared with cv. Savio and cv. Ganga. The latter two cultivars were statistically at par with each other. The highest leaf dry weight (14.04 g) and stem fresh weight (93.05 g) were recorded in cv. Winner and the lowest were found in cv. Ganga. Cv. Savio exhibited the higher values for stem dry weight (16.23 g), root fresh weight (9.26 g) and root dry weight (3.16 g) as compared with Winner and Ganga cultivars. The cultivars Savio and Winner behaved statistically alike (Table 4).

The summarized results of growth characteristics presented in Tables 1-4 exhibited that different transplanting dates had significant effects on growth of sweet pepper cultivars during both years. Early planting in both years gave the maximum values for growth parameters as well as yield attributes.

The synchronization crop growth stage at the particular temperature was affected by the climate conditions as well cultivar to be studied. Brunching node Emergence, flowering and then fruit setting was severely affected by the prevailing day and night temperatures during crop growth period. Various studies reported the effect of elevated temperature on crop phenological stages (He *et al.*, 2015; Ahmad *et al.*, 2017). Besides other agricultural practices, cultivar selection and its planting time are the crucial factors deciding crop yield. The differential response by various cultivars may be due to differences in their genetic constituents and variable environmental conditions (Bergefurd *et al.*, 2011).

The similar findings were observed by (Islam *et al.*, 2010; Oladitan and Akinseye, 2014). This may be due to the

Table 3. Effect of different transplanting dates on growth characteristics of sweet pepper during 2018.

Transplanting date	Stem height (cm)	Average canopy diameter (cm)	No. of leaves per plant	Leaf fresh weight (g)	Leaf dry weight (g)	Stem fresh weight (g)	Stem dry weight (g)	Root fresh weight (g)	Root dry weight (g)
February 1st	49.17a	49.73a	278.33a	154.92a	22.45a	162.44a	29.36a	16.80a	5.52a
February 15th	48.93a	44.62a	210.3b	94.16b	14.75b	111.70b	17.77b	11.22b	3.51b
March 2nd	43.77ab	35.24b	193.79bc	83.35bc	11.38b	67.17c	11.32bc	6.41c	2.18bc
March 16th	36.08c	31.62b	150.58c	51.34cd	9.97b	41.71cd	8.22bc	4.54cd	1.45c
April 1st	38.56bc	24.60c	84.78d	18.93d	2.84c	12.61d	2.25c	2.08d	0.74c
LSD value	5.40	6.30	51.18	35.53	6.40	43.15	10.25	2.95	1.69

Means sharing different letter(s) in a column are statistically significant at $p < 0.05$

Table 4. Effect of different cultivars on growth characteristics of sweet pepper during 2018.

Cultivar	Stem height (cm)	Average canopy diameter (cm)	No. of leaves per plant	Leaf fresh weight (g)	Leaf dry weight (g)	Stem fresh weight (g)	Stem dry weight (g)	Root fresh weight (g)	Root dry weight (g)
Ganga	41.21b	33.74b	167.17a	70.78a	9.24b	58.77b	10.10b	6.54b	2.14b
Winner	47.44a	41.37a	196.57a	85.78a	14.04a	93.05a	15.03a	8.84a	2.73ab
Savio	41.26b	36.37b	186.95a	85.05a	13.55a	85.54a	16.23a	9.26a	3.16a
LSD value	3.55	3.01	25.45	19.42	2.95	18.01	4.34	1.64	0.66

Means sharing different letter(s) in a column are statistically significant at $p < 0.05$

favorable environmental conditions prevailing during the early plantings which promoted growth (stem length, number of leaves and plant width) and biomass of sweet pepper. Fresh and dry masses of the plant parts gave similar trend in planting date effect. Early transplantings acquire sufficient time for plants for their optimum growth and development (Sharma *et al.*, 2015)

The significant variation in dry biomass was found when describing the performance of sweet pepper cultivars at different transplanting dates. Significantly greater dry biomass was recorded in February 1st transplanting and it significantly reduced as the transplanting date was delayed till April 1st. The effect of cultivars was prominent in the February 1st transplanting. Cv. Savio exhibited higher dry biomass when compared with cv. Winner and cv. Ganga. In February 15th transplanting, cultivars did not showed significant variation in dry biomass. However, in March 2nd and March 16th transplantings, cv. Winner showed significantly higher dry biomass as compared with Savio and Ganga. In April 1st transplanting Winner also produced higher dry biomass than Savio and Ganga cultivars (Figure 4).

Leaf Area Index: Leaf area index (LAI) was significantly affected by the transplanting dates and cultivars during both years. During year 1, In February 15th transplanting, LAI in all cultivars gradually increased till 135 days after planting. In March 2nd transplanting LAI gradually increased in cv. Winner till the 120 days after transplanting; however, in Savio it increased up to 105 days after transplanting and then decreased. In cv. Ganga it increased up to 90 days after transplanting and then slightly reduced. In March 16th transplanting, LAI was found the highest in cv. Winner and it gradually increased in its whole crop period i.e. 105 days after transplanting. The lowest LAI was recorded in cv. Ganga and it also increased gradually in its crop period. The cv. Savio showed distinct behavior in March 16th transplanting of year 1. LAI in cv. Savio initially increased then slightly decreased and afterwards increased rapidly (Figure 3).

During Year 2, significantly higher LAI was attained in February 1st transplanting, and it reduced as the transplanting date was delayed and the lowest LAI was recorded in April 1st transplanting. In February 1st transplanting, significantly higher LAI was obtained in cv. Savio and lower LAI was produced in cv. Ganga. Cv. Winner showed distinct behavior as LAI increased up to 120 days after transplanting and then decreased. In February 15th transplanting, the highest LAI was recorded in Winner and it showed similar trend as observed in February 1st transplanting. Cv. Savio and cv. Ganga showed lesser LAI as compared with cv. Winner. In March 2nd transplanting, the effect of cultivars was not so significant. In March 16th transplanting, LAI increased in Winner up to 90 days after transplanting, however in Savio and Ganga it increased up to 75 days after transplanting and then gradually reduced. In April 1st transplanting, LAI was higher in Winner and it rapidly increased at early growth days and then slightly decreased and afterwards gradually increased up to 75 days after transplanting. The lowest LAI was noted in Savio preceded by Ganga 75 days after transplanting (Figure 4). In early transplanting dates, LAI increased gradually with crop growth, however in later plantings especially in April 1st transplanting, LAI value was found the lowest.

As LAI represents plant canopies so it is evident from the Figure 3 and Figure 4 that at later transplantings it reduced with the crop growth stages. It may be due to the high temperature and low humidity which suppressed vegetative growth of plants. Koner *et al.* (2015) also found that early plantings coupled with favorable climatic conditions promoted growth and development in sweet pepper cultivars. Chatterjee *et al.* (2018) also concluded that favorable climatic conditions linked with planting date had a positive effect on sweet pepper growth and yield attributes.

Yield attributes: Sweet pepper yield was significantly affected by the transplanting dates during both study years. During year 1, the higher values for average fruit weight (33.69 g), fruit fresh weight per plant (221.24 g) and fruit yield (12.29 t/ha) were recorded at February 15th transplanting, when compared with March 2nd and March 16th transplantings. The latter two transplantings were statistically alike. Fruit size was also influenced by the transplanting dates. The maximum average fruit width (49.00 mm) and maximum average fruit length (42.80 mm) were recorded at February 15th transplanting and minimum was obtained in March 16th transplanting (Table 5).

Concerning the effect of cultivars, cv. Winner exhibited the highest average fruit fresh weight (29.49 g) followed by cv. Ganga and being the lowest in cv. Savio. The other yield related parameters were not affected by the cultivars during year 1 (Table 6).

During year 2, the maximum values for number of fruits per plant (15.49), average fruit diameter (50.21 mm), fruit length (50.11 mm), fruit fresh weight per plant (442.89 g) and yield (24.61 t/ha) were recorded at February 1st transplanting date and the minimum were produced in April 1st (Table 7).

Concerning the effect of cultivars, a greater number of fruits per plant (7.58) was recorded in cv. Savio and significantly lesser was exhibited in cv. Winner. The average fruit width (46.82 mm) was recorded higher in Winner and lower in cv. Savio. The average fruit length was recorded higher in cv. Ganga (42.66 mm) and significantly lower in cv. Winner (Table 8).

Sweet pepper cultivars showed wide variation in fruit yield (t/ha) at different transplanting dates. During year 1, fruit yield significantly reduced as the transplanting date was delayed from February 15th to March 16th. The significantly higher fruit yield (13.22 t/ha) was recorded at February 15th transplanting in cv. Winner, and significantly lower yield (11.65 t/ha) was obtained in cv. Ganga at the same transplanting date (Figure 5).

During Year 2, similar trend was observed as in year 1. Yield reduced as the transplanting date was delayed. The highest yield was recorded in February 1st transplanting in cv. Savio (26.83 t/ha) and the lowest yield (22.53 t/ha) was noted in cv. Winner. In February 15th transplanting, yield was significantly

Table 5. Effect of different transplanting dates on yield attributes of sweet pepper during 2017.

Transplanting date	Number of fruits per plant	Avg. fruit width (mm)	Avg. fruit length (mm)	Fruit fresh weight per plant (g)	Yield (t/ha)	Avg. fruit weight (g)
February 15th	6.83 a	49.0 a	42.80 a	221.24 a	12.29 a	33.69 a
March 2nd	4.37 b	36.23 b	32.39 b	104.01 b	5.78 b	25.00 ab
March 16th	3.59 c	27.94 c	25.96 c	59.14 b	3.29 b	16.35 b
LSD value	2.18	4.86	2.70	65.37	3.63	7.14

Means sharing different letter(s) in a column are statistically significant at $p < 0.05$

Table 6: Effect of different cultivars on yield attributes of sweet pepper during 2017.

Cultivar	Number of fruits per plant	Avg. fruit width (mm)	Avg. fruit length (mm)	Fruit fresh weight per plant (g)	Yield (t/ha)	Avg. fruit weight (g)
Ganga	4.22 a	35.09 a	32.13 a	107.11 a	5.95 a	24.95 ab
Winner	4.74 a	39.76 a	35.00 a	143.87 a	7.99 a	29.49 a
Savio	5.82 a	38.32 a	34.02 a	133.42 a	7.41 a	20.61 b
LSD value	2.18	4.86	2.70	65.37	3.63	7.14

Means sharing different letter(s) in a column are statistically significant at $p < 0.05$

Table 7. Effect of different transplanting dates on yield attributes of sweet pepper during 2018.

Transplanting date	Number of fruits per plant	Avg. fruit width (mm)	Avg. fruit length (mm)	Fruit fresh weight per plant (g)	Yield (t/ha)	Avg. fruit weight (g)
February 1st	15.49 a	50.21 a	50.11 a	442.89 a	24.61 a	29.28 a
February 15th	6.94 b	49.01 a	41.81 b	194.27 b	10.79 b	29.70 a
March 2nd	3.46 c	43.30 b	43.61 b	83.24 c	4.62 c	28.90 a
March 16th	2.95 c	42.94 b	38.71 b	51.45 c	2.86 c	20.94 a
April 1st	2.63 c	37.71 c	32.14 c	46.84 c	2.60 c	16.27 a
LSD value	2.87	4.71	6.21	86.50	4.80	10.48

Means sharing different letter(s) in a column are statistically significant at $p < 0.05$

Table 8. Effect of different cultivars on yield attributes of sweet pepper during 2018.

Cultivar	Number of fruits per plant	Avg. fruit width (mm)	Avg. fruit length (mm)	Fruit fresh weight per plant (g)	Yield (t/ha)	Avg. fruit weight (g)
Ganga	6.34 ab	44.74 ab	42.66 a	163.40 a	9.07 a	24.02 a
Winner	4.96 b	46.82 a	39.20 b	153.24 a	8.51 a	28.36 a
Savio	7.58 a	42.34 b	41.97 ab	174.57 a	9.70 a	22.68 a
LSD value	2.22	3.25	2.79	67.00	3.72	8.14

Means sharing different letter(s) in a column are statistically significant at $p < 0.05$

lesser than February 1st transplanting in all the studied cultivars and no significant variation was recorded among cultivars.

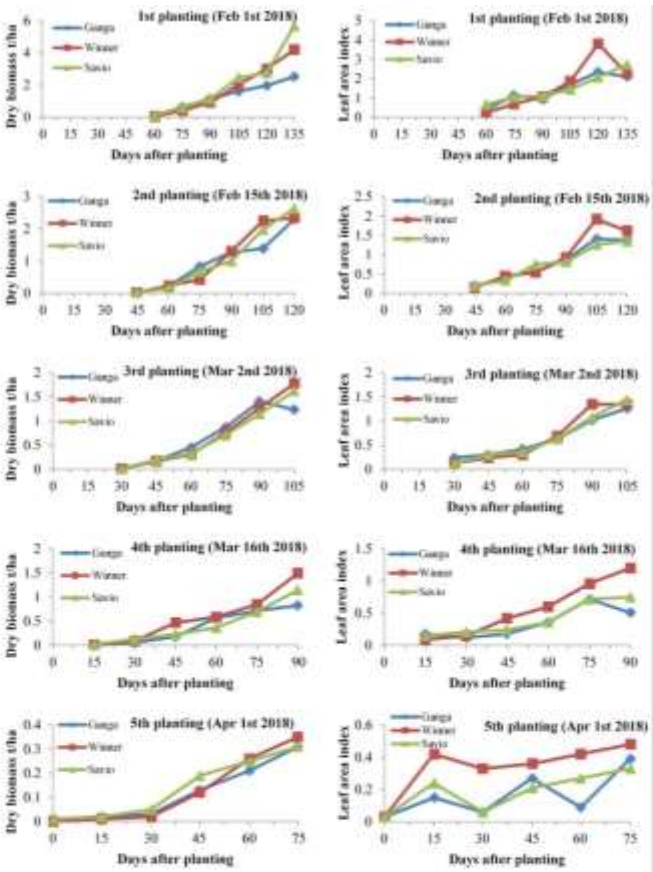

Figure 4. Dry matter content and leaf area index (LAI) progressions of sweet pepper cultivars at five plantings dates in 2018.

In March 2nd transplanting, the cultivar Savio gave the maximum yield (6.06 t/ha) and cv. Ganga gave the minimum yield (2.81 t/ha). In March 16th transplanting, the effect of cultivars was not significant. April 1st transplanting gave the minimum yield among all the transplanting dates. The cultivars performance also significantly varied on this transplanting date; significantly greater yield was noted in cv. Winner (3.45 t/ha) and lower was found in cv. Savio (2.05 t/ha) (Figure 6).

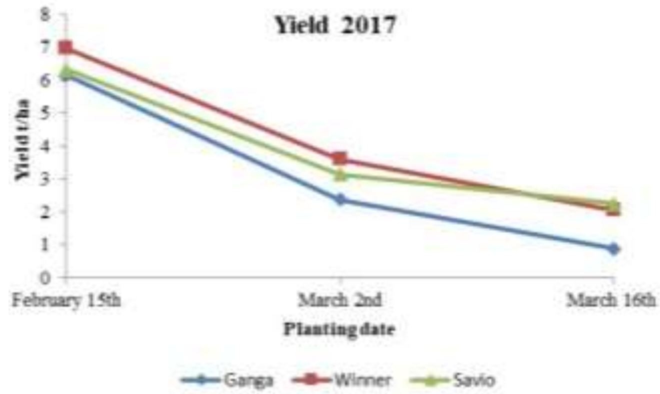

Figure 5. Fruit yield of three sweet pepper cultivars at different planting dates in 2017.

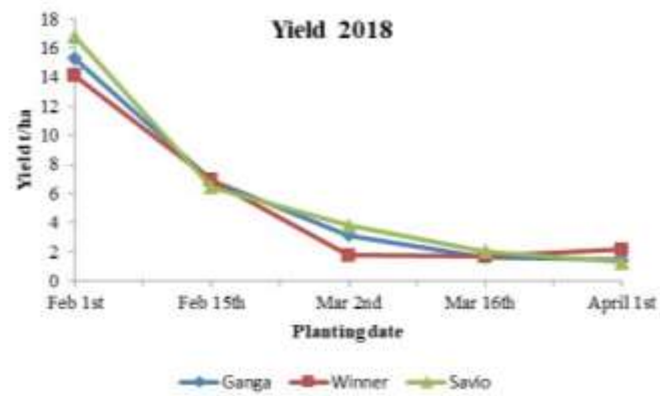

Figure 6. Fruit yield of three sweet pepper cultivars at different planting dates in 2018.

In combination with vegetative growth, flowering, number of fruits, fruit yield and quality were better in earliest transplanting and significantly reduced in late transplantings. February 15th transplanting in year 1 and February 1st transplanting in year 2 gave significantly higher yields as compared with their respective late plantings. April 1st planting in year 2 gave the minimum yield. In early transplanting dates, temperature at flowering, pollination and fruit set was more favorable and resulted in greater number of fruits and higher yield. Moreover, plants had sufficient time for plant growth and development due to optimum climatic conditions prevailed during cropping period. In case of late transplanting, higher temperature at flowering may cause pollen desiccation, pollen death, lesser fruit set and reduced yield.

Our findings for yield attributes are related with those of Mends-Cole *et al.* (2019) who reported that high temperature caused flower drop and reduced fruit set and lower yields. Uarrota (2010) also related the lesser fruit set with climatic factors including high temperature and lower humidity as well on genetic variation. According to Mariame and Gelmesa (2006), wide variations in fruit yield at different transplanting dates can be attributed to differences in genetic variability of the cultivars and their agro-ecological adaptations.

Erickson and Markhart, (2001) also reported that fruit yield was reduced at higher average temperature due to lesser fruit set. This may be due to the prevailing favorable environmental conditions for flowering and subsequent fruit set for attaining optimum yields (Nahardani *et al.,* 2013). Taskovics *et al.* (2010) also concluded that high temperature above 35 °C severely reduced pollination and fruit set resultantly less developed fewer fruits were produced. Night air temperature is considered more important than day temperature for better production of sweet pepper. Flowers drop and do not set fruits when night air temperature exceeds 32 °C. A split in fruit set continuum occurred due to flower drop and resulted in reduced yield (Erickson and Markhart, 2001). Thus, introduction of new cultivars with longer growing season requirement (temperature tolerance) and adjustment of transplanting date are the key factors to mitigate the negative impact of climate change (elevated temperature) for pepper growing in arid and semi-arid areas of Punjab, Pakistan and other regions across the globe.

Conclusions: In sweet pepper, vegetative growth, fruit yield and quality were significantly affected by the transplanting dates as well as cultivars. It is concluded from the results that the maximum plant growth and yield was exhibited in the earliest planting dates i.e. February 15th during the year 2017 and February 1st during the year 2018, and it markedly reduced in the latter plantings. Regarding cultivars, Winner performed better among the studied cultivars. In agro-ecological region of Multan, about forty days old nursery of sweet pepper should be transplanted on 1st February in the field to attain better growth and higher yield with good quality fruits. Further research should be conducted to evaluate more sweet pepper cultivars at varying transplanting dates in order to mitigate the negative impact of climate change.

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