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Performance of Parthenocarpic Cucumber (*Cucumis sativus* L.) Under Varying Mulch and Plant Geometry

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ABSTRACT

Various plastic mulches are widely accessible on the market; however, Indian farmers are unaware of their efficacy at varying spacings under protected conditions. In order to discover the effect of mulch and spacing on parthenocarpy cucumber under protected conditions, research was undertaken at Vegetable Research Farm during the rainy season of the year 2021-22 in Split Plot Design comprising five levels of mulches, i.e. (M_1) double shade plastic mulch, (M_2) black polyethylene mulch, (M_3) transparent plastic mulch, (M_4) paper mulch and (M_5) no mulch and three plant-to-plant spacing's i.e. (S_1) 30, (S_2) 45 and (S_3) 60 cm. (M_1) Double shade plastic mulch recorded minimum node at which first flower appears, days to initiation of first flowering, days to 50% flowering, days to first picking and inter-nodal length whereas the maximum duration of flowering, fruit length, fruit weight and fruit yield per plant. However, the number of flowers/plant and number of fruits per plant were recorded significantly higher under (M_2) black polyethylene mulch. Highest benefit: cost ratio was found under (M_4) paper mulch. Among different spacings, 70 × 30 cm recorded statistically maximum number of flowers per plant, fruit length, fruit yield per plant, fruit yield in Kg per m^2, minimum days to first picking and maximum benefit: cost ratio. The interaction of mulch and spacing was non-significant for all the parameters except for total soluble solids and benefit: cost ratio. Although (M_4) paper mulch exhibited maximum benefit: cost ratio but cucumber crop performed best under the (M_1) double shade plastic mulch followed by (M_2) black polyethylene mulch. The main challenge to growing the parthenocarpic cucumber in polyhouse was higher plant densities which may restrict air movement and promote humid conditions favorable for disease development and prevent effective fungicide application. Many researchers studied the effect of spacing on cucumber production but the reports are contradictory to each other in terms of adopting closer or wider spacing.

Keywords: *Interaction, Plastic mulch, Parthenocarpy, Plant geometry, Protected cultivation, Cucumis sativus.*

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a popular annual vegetable crop that belongs to the Cucurbitaceae family. It is typically monoecious, although additional sex types such as androecium, gynoecium, hermaphrodite and andromonoecies' have been observed [3]. Cucumber is a popular vegetable across the world due to its crisp taste and texture. Its immature fruits are utilized in salads, pickles, raita and commercial brines [4]. It includes between 93 - 95 percent water. It has higher content of fiber and lower in calories (15 calories per 100 grams) [11].

Cucumber cultivation in open fields is currently a common practice in India during the spring, summer and rainy-autumn seasons, but it is subject to a variety of abiotic and biotic stresses. As a result, it is necessary to grow cucumbers in a greenhouse for improved yield and quality production owing to enhanced photosynthetic rate, better management (Sharma 2016), and the utilization of new technological breakthroughs [20].

Mulching is another beneficial agronomic strategy for safeguarding crops from unfavourable weather conditions. It modifies the microclimate around the plant by adjusting the surface's radiation modesty (absorbivity versus reflectivity). It helps to conserve soil moisture, manage weed infestations, regulate soil temperature and most critically, prevent soil-borne diseases such as root-knot nematode (Meloidogyne spp.) [5]. Black polyethylene mulch absorbs solar energy, raising warmth and regulating weed development ([14]; [22]; [8]). Transparent plastic mulch has also been demonstrated to improve earliness by three weeks in cool areas.

On the other side, plant geometry is one of the most significant variables in reducing competition among plants with similar cultural requirements, maximizing space usage and repelling insects. It also improves the environment in terms of wind and moisture [15] and increases the interaction of beneficial microorganisms in the soil rhizosphere [16]. Research on plant geometry and mulch combination in protected settings is scarce, particularly in polyhouse horticulture. Farmers are looking for better cultivars to fulfil the high volume and quality requirements of polyhouse-grown cucumbers. Keeping all of this in mind, the study was designed to determine the effect of different mulch and spacing on cucumber growing under protected conditions.

MATERIALS AND METHODS

The trial has been carried out during the rainy season, 2020-21 under semi Hi-tech polyhouse at Vegetable Research Farm. The trial was arranged in Split plot Design with three replications comprising of 15 treatment combinations which consisted five mulches *viz* (M_1) double shade plastic mulch, (M_2) black polyethylene mulch, (M_3) transparent plastic mulch, (M_4) paper mulch and (M_5) no mulch and three plant to plant spacings *viz.*

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(S_1) 30, (S_2) 45 and (S_3) 60 cm and row to row 70 cm in each. The seeds of hybrid Kian were sown in plug trays by using soilless media on 25th August and transplanted after 35 days in semi Hi-tech poly-house. Five plants from each treatment and replication were randomly tagged and the observations were recorded on growth, yield and quality parameters viz. nodes at which first flower appears, days to initiation of first flowering, days to 50% flowering, duration of flowering (days), number of flowers per plant, days to first picking, number of fruits per plant, fruit length (cm), fruit girth (cm), fruit weight (g), fruit volume (cc), fruit specific gravity (g/cc) and total soluble solids (°brix). The present study's data was statistically examined using the method R studio software at a 5% threshold of significance [17].

RESULT AND DISCUSSION

Node at which first flower appears

Appearance of first flower is an important trait in terms of earliness and high yield. The presence of flower at the lowest node influence availability of fruit prior to flower present at highest node due to the quick availability of nutrients near the root zone. The M_1-double shade plastic mulch observed statistically lower node at which first flower appeared (1.41) among all other treatments. Further, black polyethylene mulch observed the node at which first flower appears (2.21) which was significantly at par with transparent plastic mulch (2.45 node) and paper mulch (2.41 node). Among the different spacing, appearance of first flower on the lowest node was recorded in the spacing S_1-70 × 30 cm (1.99). Whereas; the flower on the highest node was recorded in the spacing S_3- 70 × 60 cm (2.48) followed by the spacing S_2- 70 × 45 cm (2.34 node). The presented data showed that different types of mulches had significant effect on node at which first flower appears (Table-1). While, [18] reported significant result (4.32) to nodal position of first flower at wider spacing of 60 × 60 cm that might be due to availability of more sunshine which resulted in the growth of flower bud at wider spacing.

The interaction between mulch and spacings had no significant effect on node at which first flower appears. However, the interaction effect of M_1S_3 -double shade with 70 × 60 cm (1.34 node) recorded the lowest nodal position of first flower followed by M_2S_1 -black plastic mulch with 70 × 30 cm) (1.72 node).

Days to initiation of first flowering

The minimum number of days to initiation of first flowering (20.57 days) was observed in double shade plastic mulch. The effect may be due optimum soil temperature and microclimate created due to mulch treatment. Whereas, the maximum number of days to initiation of first flowering (28.29 days) was recorded in M_5-no mulch. In an experiment, [11] observed minimum days to initiation to first flower (38.67) in black polythene mulch as compare to white polythene mulch (41.00) and un-mulched (45.00) in sponge gourd. The data in the table-1 showed that there was significant difference among different spacings related to days to initiation of first flowering. The minimum number of days to initiation of first flowering (23.32) was taken up by S_1 -70 × 30 cm, though S_2 -70 × 45) and S_3 -70 × 60) recorded (24.48) and (24.98) days to initiation of first flower respectively, which were statistically at par with each other. In an experiment by [13] stated that wider spacing of 60 × 55 cm induces early flower initiation (30.93 days) as compared to the spacing of 60 × 35 cm (33.47 days).

The results of [20] observed that minimum days to initiation of first flowering (41.10 days) were observed in the spacing of 60 × 50 cm in cucumber as compared to 60 × 30 cm spacing. This is because of more sunshine and nutrient uptake as compared to closer spacing. The interaction effect of mulches and spacing were found to be non-significant on days to initiation of first flowering.

Days to 50% flowering

The data represented in the Table-1 was statistically significant which indicated that minimum days to 50 % flowering (35.93 days) were recorded in M_1 -double shade plastic mulch. These findings are in agreement with the findings of [5] who reported that the earlier 50 % flowering (27.69 days) was recorded in black polyethylene mulch. Likewise, [21] reported that black polyethylene mulch recorded maximum days to 50% flowering (19.75 days) in cucumber *cv.* Super Dominus.

The cucumber planted at different plant-to-plant spacings had a significant effect on number of days to 50 % flowering. The minimum days to 50% flowering (37.00 days) were recorded in S_1 -70 × 60 cm. The findings of [19] recorded minimum days to 50% flowering in the spacing of 60 × 60 cm as compared to 60 × 30 cm spacing (28.6). The interaction effect of mulches and spacings was found to be non-significant for days to 50% flowering.

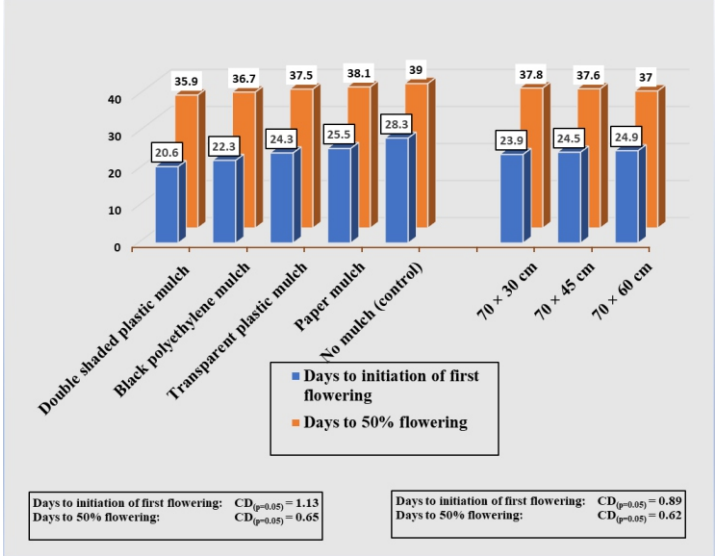

Fig. 1 Effect of mulches and plant geometry on genotype for days to initiation of first flowering and days to 50% flowering

Duration of flowering (days)

The results from the table-1 depicted those different mulches had no significant effect on duration of flowering. However, the maximum duration of flowering (119.70 days) was recorded in M_1- double shade plastic mulch followed by M_2- black polyethylene mulch (118.82 days). Whereas, M_5- no mulch (117.18 days) took minimum number of days to duration of flowering.

Similarly, the different spacings also observed non-significant effect on the duration of flowering in cucumber (Table-1) that maximum flowering duration (118.44 days) was recorded in S_3-70×60 cm and minimum days of duration of flowering (117.96 days) in S_2 -70 × 45 cm. The interaction effect of mulches and spacing were non-significant for duration of flowering in cucumber.

Number of flowers per plant

The maximum number of flowers per plant (21.84) were recorded in M_2– black polyethylene mulch which was significantly at par with M_2 – double shade plastic mulch (21.52). The earliest flowering of cucumber crop in double shade plastic mulch may be due to absorbance of light by black color that raised the soil temperature which ultimately enhanced the growth of cucumber plants. In an experiment of [7] stated that the number of flowers per plant was maximum in rice hull mulch (14.97) as compare to white and black plastic mulch in cucumber crop.

It is clear from the data that number of flowers per vine was significantly influenced by various plant to plant spacing (table no. 1). The cucumber planted at spacing of S_1 -70 × 30 cm recorded statistically higher number of flowers per plant (21.15) among other spacings. While, the spacing of S_2 -70 × 45 cm (20.59) and S_3 - 70 × 60 cm (20.03) were found to be statistically at par for the number of flowers per plant.

The interaction effect of different mulch and spacing were statistically non-significant to the number of flowers per plant. The treatment combination M_2S_1-black polyethylene mulch with 70 × 30 cm observed maximum number of flowers per plant (22.51) followed by with M_2S_2 -black polyethylene mulch with 70 × 45 cm (22.32).

Number of fruits per plant

The maximum number of fruits per plant (19.84) was recorded with M_2-black polyethylene mulch which was statistically at par with M_1-double shade mulch (19.71) followed by M_3-transparent plastic mulch (18.79) and M_4-Paper mulch (18.00). This difference between mulched and unmulched treatments might be attributed to improved vegetative development of plants, which results in a higher number of blooms, and hence an increase in the number of fruits set. Similarly, greater output in mulched plants might be due to higher soil moisture content and warmth. However, lower number of fruits on un-mulched plants was attributed to relatively poor growth when compared with mulched plant. As polyethylene mulches improved stand establishment and fruit number as compared to un-mulched (control). The results are in conformity with the findings of [5] who concluded that black plastic mulch recorded the higher number of fruits/plant (33.62) as compared to white plastic mulch (28.51) and control (28.51) in cucumber. Similarly, the results of [13] recorded maximum number of fruits/plant (28.48) in plastic black mulch in spring season in cucumber. While, [7] who find that the maximum number of fruits/vine (8.30) was recorded under rice hull mulch as compared to black polyethylene mulch (4.64).

The maximum number of fruits per plant (19.27) was recorded at closer spacing (70 cm × 30 cm) which was significantly higher than intermediate spacing (70 cm × 45 cm) (18.89) and wider spacing 70 cm × 60 cm (17.94). This might be due to a greater number of flowers per plant at closer spacing which leads to maximum fruits per plant. Similarly, the results of [1] (20.21) in the spacing of 15 x 45 cm in cucumber. While, the results of [13] observed maximum number of fruits per plant (36.60) in the intermediate spacing of 60 × 45 cm in cucumber. The interaction between mulches and different spacings was found non-significant.

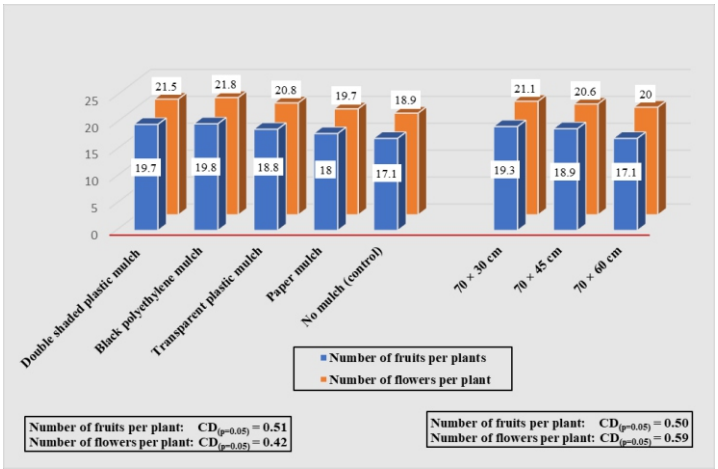

Fig. 2 Effect of mulches and plant geometry on genotype for number of fruits per plant and number of flowers per plant

Days to first picking

The number of days taken to first picking was significantly affected by different types of mulches. Among various types of mulches minimum number of days to first harvest (41.96 days) was observed in M_1-double shade mulch which was statistically at par with M_2-black plastic mulch (42.72 days). These findings are backed up by [21] who reported that the minimum number of days to first picking (44 days) in black polyethylene mulch may be due to less reflectance of light inducing more moisture retention near root zone which increased more absorption of nutrient.

In case of different spacings there was significant effect related to days to first picking. From the table-1 the data revealed that the minimum number of days to first picking (42.70) was taken up by S_1-70 × 30 cm followed by S_3-70 × 60 cm (43.47) and S_2 -70 × 45 cm (44.10). [6] recorded the minimum/maximum days to first picking (35.00) under the spacing of 70 × 30 cm as compare to spacings 70 × 60 cm. Whereas, [13] reported that the minimum days to first picking (39.93) were found in the spacing of 60 × 55 cm over spacing of 60 × 35 cm. The interaction between mulch and spacing had no significant effect on days to first picking in cucumber.

Fruit length (cm)

The use of M_1 – double shade plastic mulch recorded significantly maximum fruit length (18.40 cm) among other treatment. While, M_2- black polyethylene mulch (17.88 cm), M_3-transparent plastic mulch (17.52 cm) and M_4- paper mulch (17.77 cm) was found statistically at par. Similar results have been reported by [2] also recorded the maximum fruit length (18.41 cm) under black polyethylene mulch in cucumber.

The cucumber planted at different spacings significantly affected the fruit length of cucumber. The maximum fruit length (18.04 cm) was recorded in S_1 -70 × 30 cm followed by S_2 -70 × 45 cm (17.65 cm) which was statistically at par with S_3 -70 × 60 cm (17.28 cm). [19] recorded the maximum fruit length (15.5 cm) under the spacing of 60 × 30 cm. Likewise, [9] recorded maximum fruit length (16 cm) in the row spacing of 1.5 m. Whereas, [10] recorded the maximum fruit length (18.33 cm) under the spacing of 45 × 60 cm as compared to 45 × 20 cm spacing (15.20 cm). While, [13] recorded the maximum fruit length (15.98 cm) under the spacing of 60 × 45 cm. The interaction between different mulch and spacing had no significant effect on fruit length.

Fruit girth (cm)

The investigation of data discovered that there was non-significant effect of plastic mulch on fruit girth. However, the maximum fruit girth (4.43 cm) was recorded under M_5 – no mulch and the lowest fruit girth (3.66 cm) was recorded in M_1 – double shade plastic mulch.

There was no significant effect of spacing on fruit girth. The maximum fruit girth (3.98 cm) was recorded in S_1 -70 × 30 cm followed by S_2 – 70 × 40 cm (3.94 cm) and S_3 – 70 × 60 cm (3.93 cm). Whereas, [18] and [13] observed that different spacings create significant effect on fruit girth.

The interaction effect of different mulches and spacing had no significant effect on fruit girth.

Fruit weight (g)

Extreme fruit weight (160.88 g) was recorded in M_1 –double shade plastic mulch followed by M_2-black polyethylene mulch (158.22 g) and M_3- transparent plastic mulch (155.69 g). Similar findings have been reported by [2] who stated that black plastic mulch recorded significantly higher fruit weight (206.98 g) as compared to white plastic mulch (204.75 g) and control (181.67 g).

Among different spacing there is no significant effect on fruit weight of cucumber. However, the maximum fruit weight (155.01 g) was observed in S_1 -70 × 30 cm. However, significant effect of different spacing on fruit weight was concluded by [18] in cucumber.

The interaction between different mulch and spacing had no significant effect on fruit weight.

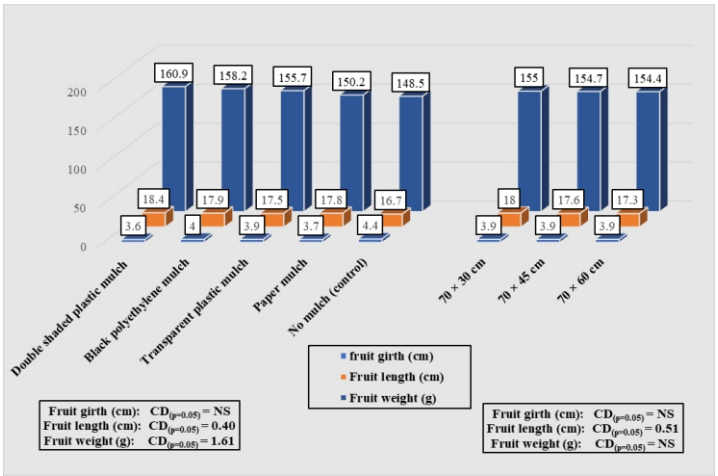

Fig. 3. Effect of mulches and plant geometry on genotype for fruit length (cm), fruit girth (cm) and fruit weight (g).

Fruit volume (cc)

The data revealed that the maximum fruit volume (170.34 cc) was recorded in M_2 - black polyethylene mulch followed by M_4 - paper mulch (160.12 cc), M_5- no mulch (157.95 cc) and M_3- transparent plastic mulch (141.90 cc). However, the maximum fruit volume (165.52 cc) was recorded in the plant spacing S_1 -70 × 30 cm. Whereas, the lowest fruit volume (153.19 cc) was recorded in S_3 -70 cm × 60 cm followed by S_2 -70 cm × 45 cm (159.69 cc). Similar findings have been reported by [20] who posited non-significant effect on fruit volume under different spacing. The interaction between different plastic mulch and spacing had non-significant effect on fruit volume.

Fruit specific gravity (g/cc)

A perusal of data (Table-1) revealed that the fruit specific gravity was non-significant to the different type of plastic mulches.

However, the maximum fruit specific gravity (1.12 g/cc) was recorded in M_3- transparent plastic mulch followed by M_1-double shade mulch (0.92 g/cc), M_5-no mulch (0.91 g/cc), M_4-paper mulch (0.90 g/cc) and M_2-black polyethylene mulch (0.88 g/cc).

Among the different spacing fruit specific gravity had non-significant variation. The data from the table 4.15 revealed that the maximum fruit specific gravity (1.07 g/cc) was recorded in the plant spacing S_1 -70 × 30 cm. Whereas, the minimum fruit specific gravity (0.81 g/cc) was recorded in S_2 -70 cm × 45 cm followed by S_3 -70 cm × 60 cm (0.95 g/cc). Similar results have been reported by [20] who gave non-significant results to the fruit specific gravity under different spacing in cucumber. The interaction between different plastic mulch and spacing had non-significant effect on fruit specific gravity.

Total soluble solids (°brix)

The data in the table-2 showed that dissimilar mulches had no important effect on Total Soluble Solids (TSS °brix). The data revealed that the maximum TSS (4.37 °brix) was measured in M_2 – black polythene mulch followed by M_3– no mulch (4.36 °brix). The minimum TSS was recorded in M_4- paper mulch (4.13 °brix) followed by M_1-double shade plastic mulch (4.28 °brix). In an experiment of [12] recorded significant consequence of mulching on total soluble solids in summer squash.

Among different spacings, there was no significant effect on total soluble solids in cucumber. The maximum TSS was observed in S_3 – 70 × 60 cm (4.35 °brix) followed by S_2 -70 × 45 cm (4.34 °brix) and S_1 -70 × 60 cm (4.22 °brix). Similar outcomes have been reported by [20] who also posited non-significant effect on TSS under various spacing.

The data in the table-1 showed that interaction between mulch and spacing had significant effect on total soluble solids. The maximum TSS (4.67 °brix) was observed in the treatment combination of M_2S_1 -black polyethylene mulch with 70 × 30 cm followed by M_3S_3 -transparent mulch with 70 × 60 cm (4.53 °brix). Whereas, the minimum TSS (4.02 °brix) was observed in the treatment combination of M_5S_2 - no mulch with 70 × 45 cm. Such effects of the interaction might be due to mutual complementary effect of spacing and mulch.

CONCLUSION

Cucumber plants cultivated with double-shaded plastic mulch outperformed all other treatments in terms of growth and yield. Black polyethylene mulch was also proven to produce the most blooms and fruits per plant. Plants spaced to cm showed considerable improvement in all metrics, except for minimum days to 50% blooming and quantity of fruits/plant, which were greater at 70 × 60 cm spacing. Although double shade plastic mulch with plants spaced to 70 × 30 cm had maximum output, paper mulch with 70 × 30 cm recorded greater benefit: cost in the protected environment. Plastic mulch was found to boost cucumber growth and quality when planted at a 70 × 30 ratio. However, paper mulch is less as compare to plastic which could also be used as alternate to plastic mulch.

FUTURE PROSPECTS

Small farmers will become more common in the future, but agricultural acreage for agriculture will decline. As a result, protected farming is the only way to meet society's expectations for high-quality, bulk food. Mulching is another strategy that improves product output and quality. Consumers today are more conscious and seek higher quality food.

So, to suit customer needs, cultivating crops in a protected environment with plastic mulches is an effective method of supplying high-quality product. As a result, to maximize profits in a protected environment, Punjab farmers are advised to use double-shaded plastic mulch.

AUTHOR'S CONTRIBUTION

Conceptualization of research work and experimental design (Rohini and Gagandeep Singh); Field/lab experiment execution and data collection (Rohini and Gagandeep Singh); Data analysis and interpretation (Rohini and Gagandeep Singh); Manuscript preparation (Rohini and Gagandeep Singh).

DECLARATION

All the authors of this research paper declare no conflict of interest.

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Table 1: Effect of different plant geometry and mulch on flowering traits of parthenocarpic cucumber (Cucumis sativus L.)

S.no.	Treatments	Node at which first flower appears	Duration of flowering (days)	Days to first picking	Fruit volume (cc)	Fruit specific gravity (g/cc)	Total soluble solids (°brix)	Fruit yield/m² (Kg)	Benefit: cost ratio
	Mulch								
1	Double shade plastic mulch	1.4^{c}	119.7^{a}	41.9^{c}	109.9	0.9	4.3	10.7^{a}	1.6^{d}
2	Black polyethylene mulch	2.2^{b}	118.8^{ab}	42.7^{c}	170.3	0.9	4.4	10.2^{b}	2.6^{b}
3	Transparent plastic mulch	2.4^{b}	117.8^{bc}	43.7^{b}	141.9	1.1	4.4	9.9^{b}	2.4^{c}
4	Paper mulch	2.4^{b}	117.7^{bc}	43.9^{ab}	160.1	0.9	4.1	9.3^{c}	3.1^{a}
5	No mulch	2.9^{a}	117.9^{c}	44.8^{a}	157.9	0.9	4.3	8.8^{c}	2.6^{b}
6	LSD	0.94***	1.46*	0.93***	NS	NS	NS	0.46***	0.19***
	Spacing								
1	70 × 30 cm	1.9	118.3	42.7^{ab}	165.5	1.1	4.2	13.6^{a}	3.4^{a}
2	70 × 45 cm	2.3	117.9	44.1^{a}	159.6	0.8	4.3	9.2^{b}	2.3^{b}
3	70 × 60 cm	2.5	118.4	43.5^{b}	153.2	0.9	4.4	6.6^{c}	1.7^{c}
4	LSD	NS	NS	0.902*	NS	NS	NS	0.28***	0.10***
5	**Interaction Mulch × spacing**	NS	NS	NS	NS	NS	-	NS	-

*Where *** depicts $p < 0.001$, ** as $p < 0.01$, * as $p < 0.05$ and NS – non-significant*

Table 2: Interaction effect of mulch and plant geometry on total soluble solids and benefit: cost ratio

S.no.	Interaction	Total soluble solids (°brix)	Benefit: cost ratio
1	Double shade with 70 × 30 cm	4.1^{fg}	2.2^{gh}
2	Black polyethylene mulch with 70 × 30 cm	4.7^{a}	3.6^{bc}
3	Transparent mulch with 70 × 30 cm	4.2^{defg}	3.4^{c}
4	Paper mulch with 70 × 30 cm	4.1^{fg}	4.2^{a}
5	No mulch with 70 × 30 cm	4.6^{ab}	3.7^{b}
6	Double shade with 70 × 45 cm	4.4^{bcde}	1.3^{k}
7	Black mulch with 70 × 45 cm	4.2^{defg}	2.6^{e}
8	Transparent mulch with 70 × 45 cm	4.3^{cdef}	2.3^{fg}
9	Paper mulch with 70 × 45 cm	4.1^{efg}	3.0^{d}
10	No mulch with 70 × 45 cm	4.0^{g}	2.5^{ef}
11	Double shade with 70 × 60 cm	4.3^{cdef}	1.3^{jk}
12	Black polyethylene mulch with 70 × 60 cm	4.2^{defg}	1.7^{i}
13	Transparent mulch with 70 × 60 cm	4.5^{abc}	1.6^{ij}
14	Paper mulch with 70 × 60 cm	4.1^{efg}	2.0^{h}
15	No mulch with 70 × 60 cm	4.4^{abcd}	1.7^{i}
16	LSD	0.26***	0.23***

LSD- Least significant difference

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