# Varying Intra-Row Spacing and Mulching Effect on Growth and Yield

# of Parthenocarpic Cucumber

# (*Cucumis sativus* L.) under Protected Conditions

## ABSTRACT

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| A field experiment was conducted during two consecutive seasons, 2023 and 2024, at the Horticultural Research Farm, Department of Horticulture, Naini Agricultural Institute, SHUATS, Prayagraj, to assess the effect of different mulching materials and plant spacings on the growth, flowering, and yield of cucumber. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and fifteen treatment combinations comprising five mulches- Double Shaded Mulch (M1), Transparent Mulch (M2), Black Mulch (M3), Straw Mulch (M4), and No Mulch (M5)-and three spacings: 70 × 30 cm (S1), 70 × 45 cm (S2), and 70 × 60 cm (S3). The results revealed significant differences in all observed parameters. Among mulches, straw mulch (M4) showed superior performance in most traits, recording the highest fruit length (14.87 and 18.87 cm), fruit girth (12.49 and 14.47 cm), fruit weight (123.99 and 124.20 g), and yield (15.80 and 16.92 q/1000 m²). In terms of spacing, 70 × 45 cm (S2) spacing significantly improved vegetative and yield traits, yielding the highest vine length (3.64 and 4.87 m), fruit length (16.76 and 21.14 cm), and yield (16.74 and 17.86 q/1000 m²). The interaction of M4S2 (Straw Mulch + 70 × 45 cm) consistently produced the best results across both years, with maximum vine length, fruit size, and yield (18.00 and 19.12 q/1000 m²). |

*Keywords: Black mulch; cucumber; double-shaded mulch; mulching and transparent mulch.*

## 1. INTRODUCTION

Cultivated cucumber is botanically known as *Cucumis sativus* L. and is native to India. It has the diploid chromosome number of 2n=14, and *Cucumis hardwickii* is the probable progenitor of cultivated cucumber. Cucumber is one of the important monoecious annual vegetable crops in the Cucurbitaceae family that has been cultivated by man for over 3000 years. Cucumber is an essential and commercially popular cucurbitaceous vegetable crop holding a coveted position in the vegetable market. They are the largest producer of biological water among the vegetable crops and are easily digestible and therefore are recommended even to patients suffering from weakness or other illnesses. It is a rich source of valuable nutrients and bioactive compounds used not only as food but also in therapeutic medicine and cosmetology. Cucumber is a very popular vegetable throughout the world for its crispy taste and texture. The immature fruits of cucumber are used as salad and for making pickles, raita and brined on a commercial scale (Tewari et al.2024). Cucumber is used for different purposes, like as salad, table purposes and pickling, but is mostly used for salad purposes. The fruit of the cucumber is said to have a cooling effect, prevent constipation and check jaundice and indigestion. It contains (96.3g) water, (0.4g) protein, (0.1g) fat, (0.3g) minerals, (0.4g) fibre, (2.5g) carbohydrate, (13Kcal) energy, (10mg) calcium, (25mg) phosphorus, (1.5mg) iron, (0.33mg) thiamine, (0.2mg) niacin, (7mg) vitamin C per (100g) edible portion. Protected cultivation technology is the advanced cultivation technique wherein the microclimate surrounding the crop is partially or fully controlled and modified as per the requirement of the crop (Tejaswini et al. 2024). Protected cultivation technology is based on the principle of the greenhouse effect. The greenhouse effect is the phenomenon of an increase in the ambient temperature due to the production of excess greenhouse gases like carbon dioxide. The covering material of the greenhouse structure acts in a similar way, as it is transparent and permeable to shorter wave radiation but does not allow the longer wave radiation to escape outside. During the daytime, solar radiation with shorter wavelengths enters and penetrates through the greenhouse covering material and gets reflected from the ground surface. The reflected radiation becomes long-wave radiation and gets entrapped inside the greenhouse structure by the covering material. This causes an increase in the greenhouse temperature. A comparative study revealed that the protected cultivation of high-value crops like cucumber is highly remunerative as compared to open field 3 cultivation. Even though the cost of cultivation is higher under protected cultivation, the higher yield of cucumber with high net return can be achieved under polyhouse conditions as compared to open field conditions (Kumar et al. 2014). Protected cultivation of vegetables has emerged as an alternate production technology to overcome several biotic and abiotic stresses and to break the seasonal barrier to production. It gives a boost to the nutrient and irrigation use efficiency, along with the proper utilisation of natural resources. This technology is being employed popularly for the year-round and off-season production of high-value commercial crops like capsicum, tomato and cucumber. Increased yield with high photosynthetic efficiency and reduction in transpirational loss are some of the added advantages associated with this technology. The performance of cucumber grown inside the shade net was comparatively superior in comparison to open field condition and total fruit yield recorded from shade net with 35, 50 and 75 per cent shading were 238.4, 245.2 and 273.2 q/ha, respectively which were 8 to 10 times more than open field condition i.e. 36.3 q/ha (Kaur et al. 2017). In addition to that, the infestation by pests and diseases under protected conditions is scaled down as compared to open field conditions, as it is covered and isolated from the outside environment. Infestation of sucking pests like aphids and white fly was reduced considerably under the shade net house of 35% (Kaur et al. 2021). Success in the cultivation of cucumber under polyhouse conditions during the off-season can be attained by the use of a suitable cucumber hybrid, like a parthenocarpic variety or gynoecious hybrid, along with adequate incorporation of nutrients, which becomes indispensable for the growth and development. Cucumber gynoecious varieties are those which produce pistillate flowers predominantly and have the ability to set fruit without pollination and fertilisation, even under lower temperatures and in short-day conditions (Khadka et al. 2017), making efficient utilisation of the land, water, nutrients and other resources. These plants produce fruit that is mild in flavour, soft-seeded to seedless in nature, and has a thin edible skin that requires little peeling. However, the use of gynoecious hybrids for cultivation under tropical climatic conditions is not recommended as they are highly unstable at high temperature conditions. Sex modification is a major constraint associated with the cultivation of gynoecious hybrids under tropical climatic conditions and will produce deformed and bitter fruit, which will result in a reduced marketable value as it is not preferred by the consumer. Cucumber is well grown in warm, temperate and cool tropical regions of the world. The growth and development of crops are favoured by temperatures above 20°C; however, it can also survive at 32°C. It grows well under high light intensity and humidity conditions but is susceptible to frost. Due to various biotic and abiotic factors, the cucumber cultivation is more successful under protected conditions. The protected cultivation technology is utilised for the production of high-quality and high-yield. It increases the harvesting efficiency with a greater yield of straight fruits, exhibiting more plants per acre due to closer rows and adequate spacing (Singh and Aulakh 2018). Cucumber yield and quality are characterised by many factors, including genetic, agronomic and environmental factors. There is very little information available on the production of cucumber under protected conditions in India (Zurbano et al.2021). Both spacing and mulching greatly affect the cucumber production. Mulching is one of the profitable agronomic measures of protecting crops from the vagaries of weather. It helps in conserving soil moisture, controlling weed infestations, regulate soil temperature and most importantly, controlling soil-borne diseases of the crop. The use of plastic mulch is one of the measures of protecting vegetable crops from the attack of root-knot nematode (*Meloidogyne spp.*), positing that the beneficial yield of some vegetable crops to plastic mulches has traditionally been attributed to altered soil temperatures, enhanced moisture conservation and weed control under the plastic mulch. Black plastic is often used in the spring to warm root zone temperatures (Torres-Olivar et al. 2018). Management of proper density under a polyhouse boosts the production per unit area by utilising the available space and nutrients applied. The response of crops to mulch includes earlier production (Jha et al, 2018), greater total yield and reduced insect and disease problems. Use of mulches provides suitable microclimatic conditions for producing superior branch characteristics, number of fruits per plant, fruit size, total yield and marketable yield of cucumber. The type of mulching material used and the color of plastic also affect the yield and quality parameters of cucumbers. In recent years, a great deal of research work has been reported on the uses of mulching in vegetable crops. Plant density contributes to marketable yield in various ways, such as plant’s ability to obtain the sunlight needed for growth and adequate air movement around the plant to reduce the risk of fungus and insect problems. And has been identified as a key management practice for getting maximum marketable yields from greenhouse crops (Kishor et al.2010). The main objectives of mulching are weed control, conservation of soil moisture and modification of soil temperature.Mulching is a non-chemical weed control crop production technique which is an effective alternative to herbicides.

## 2. METHODS AND MATERIALS

The field experiment was conducted during thetwo consecutive seasons *at* the Horticultural Research Farm, Department of Horticulture, Naini Agricultural Institute, SHUATS, Prayagraj. The experiment was laid out into Randomized Complete Block Design (RCBD) with 3 replications with following treatments T1=M1 X S1, T2=M2 X S1, T3=M3 X S1, T4=M4 X S1, T5 =M5 X S1, T6=M1 X S2,T7 =M2 X S2, T8 =M3 X S2, T9=M4 X S2, T10=M5 X S2 T11=M1 X S3 T12=M2 X S3, T13= M3 X S3, T14=M4 X S3 T15=M5 X S3. Standard culture practices recommended for cucumber were followed uniformly in all experimental plots, Where M1= Double Shaded Mulch, M2 = Transparent mulch, M3= Black Mulch, M4 = Straw Mulch M5= No Mulch, S1 = 70 cm X 30 cm, S2= 70cm X 45 cm and S3= 70 cm X 60 cm.

**Parameters observed:** Vine length (m), Days to 50 % flowering, Internodal length, Days to first fruit harvest, Fruit Length, Fruit girth, Fruit weight, Yield per hac.

## 3. RESULTS AND DISCUSSION

**3.1 Vine Length**

As presented in Table 1. It is clear from the data that among the various mulches, maximum vine length was noticed in M5 (4.05 and 5.29m). It was followed by M4 (4.04 and 5.27 m) in both years of the experiment. Whereas the minimum vine length was reported in M1 (3.188 m). In case of spacings, maximum vine length was noticed in S3 (3.64 and 4.87 m), followed by S2 (3.61 m 4.840 m) and S1 (3.57 m and 4.803m). In case of Interaction, maximum vine length was noticed in M5S1 (4.4143m 5.378m) followed by M4S1 (4.130 and 5.365 m) and M5S3(4.123 and 5.358m) whereas minimum in M1S1 and M3S3(3.000m and 4.235m) during both year of experiment.

**3.2 Days to 50% Flowering**

It is clear from the data that among the various mulches, minimum Days to 50% flowering was noticed in M4 (40.66 and 43.65) It was followed by M1 (42.00 and 44.63) and M3 (42.33 and 46.241), whereas maximum (43 889 and 47.780) was observed during both year of the experiment. In case of spacing minimum Days to 50% flowering was noticed in S2 (39.33 and 43.40), followed by (42.86 and 45.99), whereas the maximum was during both years of the experiment (46.06 and 48.04). In case of Interaction, minimum Days to 50% flowering was found in treatment combination (37.66 and 39.75) M3S2 was followed by 39.33 and 42.25 (M2S2), whereas maximum M2S1 (48.33 and 50.23) during both years 2023 and 2024, respectively. These findings are in accordance with Singh et al. (2007**)**.

**Table 1. Effect of spacing and mulching on growth and yield**

| **Treatments** | **Vine length (m)** | | **Days to 50 % flowering** | | **Internodal length (cm)** | | **Days to first fruit harvest** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Mulching** | **2023** | **2024** | **2023** | **2024** | **2023** | **2024** | **2023** | **2024** |
| M1 | 3.18 | 4.42 | 42.00 | 44.63 | 9.72 | 14.06 | 57.77 | 58.97 |
| M2 | 3.40 | 4.64 | 43.88 | 47.78 | 9.92 | 14.20 | 53.88 | 55.08 |
| M3 | 3.33 | 4.56 | 42.33 | 46.24 | 9.44 | 13.50 | 51.88 | 53.08 |
| M4 | 4.04 | 5.27 | 40.66 | 43.65 | 9.30 | 13.48 | 50.33 | 51.53 |
| M5 | 4.05 | 5.29 | 43.88 | 46.76 | 10.07 | 14.47 | 54.11 | 55.31 |
| SE(m) | 0.49 | 1.11 | 0.38 | 0.38 | 0.09 | 0.12 | 2.24 | 0.431 |
| C.D. | 1.43 | 3.23 | 1.12 | 1.12 | 0.28 | 0.35 | N/A | 1.255 |
| **Spacing** |  |  |  |  |  |  |  |  |
| S1 | 3.57 | 4.80 | 42.86 | 45.99 | 9.68 | 13.93 | 53.00 | 54.20 |
| S2 | 3.61 | 4.84 | 39.33 | 43.40 | 9.87 | 13.34 | 45.00 | 46.20 |
| S3 | 3.64 | 4.87 | 46.06 | 48.04 | 10.52 | 14.55 | 56.80 | 58.00 |
| SE(m) | 0.38 | 0.85 | 0.38 | 0.07 | 0.07 | 0.095 | 1.73 | 0.33 |
| **C.D.** | 2.4 | 0.85 | 1.120 | 0.21 | 0.21 | 0.277 | 5.05 | 0.97 |
| **Spacing** |  |  |  |  |  |  |  |  |
| M1 X S1 | 3.00 | 4.23 | 43.33 | 44.43 | 9.76 | 14.07 | 53.00 | 54.20 |
| M2 X S1 | 3.11 | 4.34 | 48.33 | 50.23 | 9.80 | 14.24 | 54.66 | 55.86 |
| M3 X S1 | 3.45 | 4.69 | 42.33 | 43.77 | 9.50 | 13.56 | 52.00 | 53.20 |
| M4 X S1 | 4.13 | 5.36 | 40.66 | 42.75 | 9.40 | 13.30 | 50.66 | 51.86 |
| M5 X S1 | 4.14 | 5.37 | 43.66 | 46.77 | 9.98 | 14.47 | 54.66 | 55.86 |
| M1 X S2 | 3.13 | 4.36 | 39.30 | 44.69 | 9.90 | 13.62 | 53.33 | 54.53 |
| M2 X S2 | 3.44 | 4.67 | 39.33 | 42.25 | 9.60 | 13.11 | 49.00 | 50.20 |
| M3 X S2 | 3.543 | 4.77 | 39.33 | 46.21 | 9.70 | 12.95 | 47.66 | 48.86 |
| M4 X S2 | 4.00 | 5.23 | 37.66 | 39.75 | 9.50 | 13.13 | 45.66 | 46.86 |
| M5 X S2 | 3.91 | 5.14 | 40.66 | 44.12 | 9.850 | 13.81 | 49.33 | 50.53 |
| M1 X S3 | 3.43 | 4.66 | 46.33 | 49.71 | 10.50 | 14.480 | 57.00 | 58.20 |
| M2 X S3 | 3.66 | 4.90 | 47.66 | 50.85 | 10.98 | 15.3 | 58.00 | 59.20 |
| M3 X S3 | 3.00 | 4.23 | 45.33 | 48.73 | 10.12 | 14.07 | 56.00 | 57.20 |
| M4 X S3 | 3.99 | 5.22 | 43.66 | 41.53 | 10.00 | 14.00 | 54.67 | 55.86 |
| M5 X S3 | 4.12 | 5.35 | 47.33 | 49.38 | 11.00 | 15.062 | 58.33 | 59.533 |
| SE(m) | 0.493 | 1.922 | 0.385 | 0.666 | 0.167 | 0.212 | 3.884 | 2.173 |
| C.D. | 2.485 | 5.596 | 1.120 | 1.939 | N/A | N/A | N/A | 0.746 |

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| **Treatments** | **Fruit Length (cm)** | | **Fruit girth**  **(cm)** | | **Fruit weight**  **(g)** | | **Yield per hac.**  **(q)** | |
| **Mulching** | **2023** | **2024** | **2023** | **2024** | **2023** | **2024** | **2023** | **2024** |
| M1 | 14.13 | 18.00 | 11.33 | 13.31 | 114.99 | 115.71 | 14.83 | 15.95 |
| M2 | 13.52 | 17.89 | 10.66 | 12.64 | 105.66 | 109.96 | 14.56 | 15.68 |
| M3 | 14.38 | 18.85 | 11.39 | 13.37 | 119.99 | 122.57 | 15.23 | 16.35 |
| M4 | 14.87 | 18.87 | 12.49 | 14.47 | 123.99 | 124.20 | 15.80 | 16.92 |
| M5 | 13.10 | 17.08 | 10.66 | 12.64 | 100.66 | 102.64 | 14.33 | 15.45 |
| SE(m) | 0.20 | 0.14 | 0.07 | 0.11 | 0.94 | 1.00 | 2.04 | 1.180 |
| C.D. | 0.60 | 0.42 | 0.21 | 0.33 | 2.751 | 2.916 | N/A | 3.43 |
| **Spacing** |  |  |  |  |  |  |  |  |
| S1 | 13.34 | 16.83 | 9.038 | 11.01 | 112.19 | 114.9 | 14.90 | 16.02 |
| S2 | 16.76 | 21.14 | 12.89 | 14.87 | 136.39 | 138.3 | 16.74 | 17.86 |
| S3 | 11.90 | 16.44 | 11.99 | 13.97 | 90.59 | 91.84 | 13.18 | 14.30 |
| SE(m) | 0.234 | 0.114 | 0.057 | 0.09 | 0.73 | 0.77 | 0.914 | 0.91 |
| C.D. | 0.600 | 0.331 | 0.167 | 0.26 | 2.13 | 2.25 | 2.662 | 2.66 |
| **Spacing** |  |  |  |  |  |  |  |  |
| M1 X S1 | 10.99 | 16.98 | 10.99 | 12.97 | 53.00 | 114.28 | 15.00 | 16.12 |
| M2 X S1 | 10.00 | 15.84 | 10.00 | 11.98 | 54.66 | 113.13 | 14.70 | 15.82 |
| M3 X S1 | 7.19 | 17.96 | 7.197 | 9.177 | 52.00 | 119.88 | 15.20 | 16.32 |
| M4 X S1 | 8.00 | 18.83 | 8.00 | 9.98 | 50.66 | 120.19 | 15.50 | 16.62 |
| M5 X S1 | 8.99 | 14.54 | 8.99 | 10.98 | 54.66 | 107.05 | 14.30 | 15.42 |
| M1 X S2 | 14.99 | 21.26 | 14.99 | 16.97 | 53.33 | 136.18 | 16.50 | 17.62 |
| M2 X S2 | 13.99 | 20.43 | 13.99 | 15.98 | 49.00 | 135.16 | 16.20 | 17.32 |
| M3 X S2 | 11.99 | 21.64 | 11.99 | 13.97 | 47.66 | 146.44 | 17.00 | 18.12 |
| M4 X S2 | 13.50 | 22.25 | 13.50 | 15.47 | 45.66 | 149.54 | 18.00 | 19.12 |
| M5 X S2 | 10.00 | 20.13 | 10.00 | 11.98 | 49.33 | 124.21 | 16.00 | 17.12 |
| M1 X S3 | 8.00 | 21.26 | 8.00 | 9.98 | 57.00 | 96.6 | 13.00 | 14.12 |
| M2 X S3 | 7.993 | 20.43 | 7.99 | 9.973 | 58.00 | 81.59 | 12.799 | 13.92 |
| M3 X S3 | 14.99 | 21.64 | 14.99 | 16.97 | 56.00 | 101.39 | 13.500 | 14.62 |
| M4 X S3 | 15.99 | 22.25 | 15.99 | 17.97 | 54.66 | 102.8 | 13.900 | 15.02 |
| M5 X S3 | 12.99 | 20.13 | 12.99 | 14.97 | 58.33 | 76.67 | 12.699 | 13.82 |
| SE(m) | 0.12 | 0.25 | 0.12 | 0.20 | 3.884 | 1.735 | 2.044 | 2.044 |
| C.D. | 0.37 | 0.73 | 0.37 | 0.58 | N/A | 5.051 | N/A |  |

**3.3 Internodal Length (cm)**

It is clear from the data that among the various mulches minimum Internodal length (9.30 and 13.48 cm) was noticed in M4. It was followed by M3 (9.44 and 13.50 cm) and M1 (9.72 and 13.50 cm), whereas maximum internodal length (10.07 and 14.47 cm) was noticed in M5. In case of Spacings minimum Internodal lengthwas noticed in S2 8.87 and 13.34 cm) treatment combination was followed by S1 (9.68 and 13.93 cm) and S3 (10.52 and 14.5 cm). In case of Interaction minimum Internodal length was noticed in M4S1 (9.40 and 13.30), followed by M3S1 (9.50 and 13.30 cm), whereas the maximum was in M5S3 (11.00 and 15.06) during both years of the trail, 2023 and 2024, respectively. These results are in accordance with Arshad et al. (2014) and Kumar (2014).

**3.4 Days to First Fruit Harvest (Days after Sowing)**

It is clear from the data that among the various mulches minimum days to first fruit harvest were noticed in M4 (50.33 and 51.53), followed by M3 (51.88 and 53.08) and M2 (53.88 and ab53.089), whereas the maximum was in M1 (57.778 and 58.978) during both year of the experiment. In case of spacing minimum days to first fruit Harvest were noticed in S2 (45.00 and 46.200) followed by S1 (53.00 and 54.200) and S3 (56.800 and 58.00) in both trials. In case of Interaction minimum Days to first fruit Harvest were noticed in M5S2 (45.00 and 46.86) followed by M04S2 (45.667 and 46.86) and M3S2 (47.667 and 48.86), and maximum in M4S3(58.333 and 59.533) during both years of the experiment.

**3.4.1 Fuit length (cm)**

It is clear from the data that among the various mulches, maximum fruit length (14.87 and 18.87 cm) was noticed in It was, followed by M3 (14.38 and 18.85 cm) and minimum in M5 (13.10 and 17.08 cm) during both years of the experiment. In case of spacings, maximum fruit length was noticed in S2 (16.76 and 21.14 cm), followed by S1 (13.34 and 16.83 cm), whereas minimum was in S3 (11.90 cm) during both years of the experiment. In case of Interaction, maximum fruit length was recorded in M4S3 (15.99 and 22.25 cm) which was significantly at par with M3S3 (14.99 and 21.64 cm) and M1S2 (14.99 and 21.26 cm) and minimum in M3S1 (7.19 and 7.960 cm) during both years of the experiment. These results are in accordance with Dhillon et al. (2017).

**3.4.2 Fruit girth (cm)**

It is clear from the data that among the various mulches, maximum fruit girth was noticed in M4 (12.49 and 14.47 cm) It was followed by M3 (11.39 and 13.37 cm) and M1 (11.33 and 13.31) during both years of the experiment. In case of spacings, maximum fruit girth was noticed in S2 (12.89 and 14.87 cm) was followed by S3 and S1 (11.99 and 13.97) and (9.038 and 11.01 cm) respectively. In case of Interaction, maximum fruit girth was noticed in the treatment combination was found in M4S3 (15.99 and 17.97 cm) followed by M3S3 (14.99 and 16.97 cm), M2S2 (13.99 and 15.98 cm) and minimum in M3S1 (7.19 and 9.17cm) during both years of the experiment. Similar results were found in the findings of Prabhu et al. (2006).

**3.4.3 Fruit weight**

It is clear from the data that among the various mulches, maximum fruit weight was noticed in (123.998 and 124.206 gm) It was followed by M3 (119.99 and 122.57 gm) and M1 (114.99 and 115.71) in both years of the experiment. In case of spacings, maximum fruit weight was found in (136.398 and 138.307 gm), followed by S1 (112.198 and 114.908 gm) and S3(90.597 and 114.908gm) during both years of the experiment. In case of Interaction, maximum fruit girth was noticed in M4S2 (149.99 and 114.90) followed by M3S2 (144.00 and 119.880) and M3S2 (144.00 and 146.400gm) in treatment combination was followed by whereas maximum was observed during both years of the experiment. These results are similar to the of Aiyelaagbe et al. (2007).

**3.4.4 Yield per 1000m2**

It is clear from the data that among the various mulches, maximum yield per 1000 m2 was noticed in combination M4 (15.800 and 16.923 q) It was followed by M3 (15.23 and 16.35) and M1 (14.83 and 15.9 q) whereas minimum in M5 (14.33 and 15.45) during both years of the experiment. In case of spacings, maximum yield per 1000 m2 (16.74 and 17.86 q) was noticed in treatment S2 followed by S1 (14.90 and 16.02q) and S3 (13.180 and 14.303q). In case of Interaction maximum yield was noticed in M4S2 (18.00 and 19.12 q) followed by M3S2 (17.00 and 18.123 q) and M1S2 (16.50 and 18.123 q) treatment combination was followed by whereas it was minimum in M5S3 (12.699 and 13.82 q) during both years of the experiment. Similar findings were reported by Narayanamma et al.(2010).

## 4. CONCLUSION

The findings of the present study clearly demonstrate that both mulching materials and plant spacing exerted a significant influence on vine growth, phenological development, and yield-related attributes of the crop during the two consecutive years (2023 and 2024). Among the mulching treatments, M4 consistently outperformed all others, promoting the most vigorous vine growth, earliest flowering, shortest internodal length, earlier fruit maturity, and superior fruit characteristics—including increased length, girth, weight, and overall yield per 1000 m².

In terms of plant spacing, S2 (medium spacing) emerged as the most favourable, striking an optimal balance between vegetative growth and reproductive output. Plants under S2 showed improved canopy architecture, earlier phenological events, enhanced fruit quality, and higher yields when compared to both narrower (S1) and wider (S3) spacing treatments.

The interaction between mulching and spacing further revealed a synergistic effect on crop performance. The combination M4S2 stood out as the most effective treatment, significantly enhancing vine length, flowering and fruiting earliness, and yield-contributing traits such as fruit size, weight, and total productivity per 1000 m². This was closely followed by M3S2 and M1S2, which also showed considerable promise across most parameters. In contrast, M5S3 and M1S1 recorded the poorest performance, underscoring the importance of strategic integration of mulching and spacing for maximising crop potential.

These results underscore the critical role of optimised cultural practices in improving pumpkin productivity and can inform future recommendations for sustainable and efficient cultivation techniques.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

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Competing interests

Authors have declared that no competing interests exist.

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