Assessment of the effects of different transplanting dates, planting geometry and training techniques on the yield traits, productivity and quality of cucumber (*Cucumis sativus* L.) under naturally ventilated polyhouse

ABSTRACT

The study aims to investigate the effect of date of transplanting, planting geometry and training system on the fruit quality, fruit yield and economics of cucumber (*Cucumis sativus* L.) under naturally ventilated polyhouse. The experiment was carried out during the off-season in 2017 at the Research Farm of the Department of Agricultural Engineering, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India. The experiment was laid out in Factorial Randomized Block Design with three replications, consisting of eighteen treatments, comprising of three dates of transplanting (1st fortnight of March, 2nd fortnight of March and 1st fortnight of April), two planting geometry viz., 60 cm x 30 cm, 75 cm x 30 cm and three training systems viz., two shoots, three shoots and four shoots. Results revealed that plants transplanted earlier (1st fortnight of March) at a wider spacing of (75 cm x 30 cm) recorded a significantly higher number of fruits per plant, fruit length, fruit weight and total soluble solids, while maximum fruit yield was recorded under closer spacing of 60 cm x 30 cm. With regards to the number of shoots per plant, plants with three shoots recorded significantly higher fruit yield. So it can be concluded that plants transplanted in the 1st fortnight of March, trained to three shoots and spaced at 60 cm x 30 cm apart were found to be the best for higher fruit yield and better quality of the produce.

Keywords: Cucumber, Fruit yield, Protected agriculture, Quality, Soilless culture

Introduction

Cucumber (*Cucumis sativus* L., 2n = 14) is a member of the Cucurbitaceae family, which encompasses 118 genera and 825 species. It holds a significant position among cucurbitaceous vegetables. This crop is characterized as cross-pollinated and can be cultivated during both summer and rainy seasons. Being a thermophilic plant, it is vulnerable to frost and thrives in temperatures ranging between 18-30°C. Cucumbers are comprised of approximately 96% water content, contributing to enhanced hydration. Rich in dietary fibre and antioxidants such as tannins and flavonoids, which protect the crop from harmful free radicals and potentially lower the risk of chronic ailments. In recent times, cucumber's medicinal attributes have propelled its popularity, resulting in heightened demand and increased yield for farmers within a short cultivation period. However, the vulnerability to frost during the winter season poses a challenge, causing damage and hindrance to successful cultivation. This limitation negatively impacts various aspects of cucumber production, including growth, fruit development, and the overall supply chain. To overcome such challenges, protected cultivation techniques in polyhouses have emerged as a viable solution, offering a controlled environment conducive to optimal crop growth and development (Kumar *et al.*, 2018). "Cucumber is increasingly favoured for greenhouse cultivation due to its indeterminate growth pattern, responsiveness to training and pruning, and the development of gynoecious parthenocarpic hybrids. The timing of transplanting plays a crucial role, as selecting the right date positively influences plant growth and development, leading to maximized crop yield and efficient land utilization" (Longjam and Devi, 2017). "Greenhouse cucumber production emphasizes the importance of appropriate planting density to enhance per-unit-area productivity by effectively using available space and nutrients. Prior research has highlighted that proper row spacing impacts crop growth and yield. Moreover, spacing influences not only plant characteristics but also insect and weed interactions, disease susceptibility, soil conditions, germination and emergence" (Sanni and Adenubi, 2010) [15].

Training methodologies exhibit variability based on cucumber cultivars, diverse growth patterns and varying plant densities. The adoption of distinct training systems enhances a plant's capacity to access the requisite sunlight, thereby creating a conducive micro-environment and mitigating the risks of fungal and insect-related issues. The manipulation of canopy structure through suitable spatial arrangements, achieved through strategic training, emerges as a pivotal management approach in achieving desirable and marketable yields in the greenhouse cultivation of cucumbers (Shivaraj *et al*., 2020). In the Indian context, there exists a scarcity of comprehensive investigations concerning cucumber production within protected environments. Therefore, present study aimed to observe the effect of the date of transplanting, planting geometry and training system on the fruit yield and fruit quality of cucumber (*Cucumis sativus* L.) under naturally ventilated polyhouse which would be beneficial for farmers.

Materials and Method

The experiment was conducted at the Research Farm of the Department of Agricultural Engineering, College of Agriculture, CSKHPKV, Palampur, Himachal Pradesh during off season in 2017. The experiment was laid out in a factorial randomized block design which was replicated thrice. There were eighteen treatment combinations, which encompassed varying transplanting dates, planting geometry and training methods. The size of the playhouse measured 20 meters in length and 12 meters in width, resulting in a total area of 240 square meters. This structure was enclosed using aluminium sheets in conjunction with ultraviolet-stabilized low-density polyethene sheets, which were 200 microns thick. Mean annual rainfall ranges between 2000 to 2500 mm, with minimum and maximum temperatures of 10.31°C to 24.00°C and 21.64°C to 37.07°C, respectively. On average, the temperature within the greenhouse remained consistently 6.50°C higher compared to the external environment outside the playhouse. Throughout the growth phase of the crop, the relative humidity inside the playhouse varied between 35.1% and 77.8%. The experimental site was properly tilled and prepared manually. Beds of size 3.0 m x 1.2 m were thoroughly prepared and sterilized using a 4% formalin solution. The hybrid 'Isetis' seeds were sown in plastic plug trays containing a soilless mixture composed of coco peat, perlite, and vermiculite in a proportion of 3:1:1. After a transplantation period of 30-35 days, the plants were subjected to diverse training approaches based on the treatment variations, including two-shot, three-shoot, and four-shoot training methods. Nylon threads were employed for staking the plants. Five plants from the net plot were tagged to record yield parameters like harvest duration (days), number of fruits per plant, fruit length (cm), fruit width (cm), fruit weight (kg), fruit yield per plant (kg), fruit yield ($kg100m^{-2}$). Regarding quality attributes, the total soluble solids were measured utilizing a handheld refractometer and the data were averaged and subsequently analyzed. An economic evaluation of cucumber production within the playhouse context was conducted, factoring in the prevailing input costs and market prices for the produce.

The analysis of variance (ANOVA) was performed to determine the significance of variation among the treatments while the statistical significance of various effects was tested at a 5% probability level. The data collected for various characters were subjected to statistical analysis following the methodology established by Cochran and Cox (1963).

Results and Discussion

Yield attributes and yield

Harvest duration (days)

Different dates of transplanting significantly influenced the harvest duration**.** Maximum harvest duration was recorded in 1st fortnight of March followed by 2nd fortnight of March and 1st fortnight of April transplanting. Throughout flowering and fruit setting, the weekly average temperature remained notably low which might have resulted in prolonged harvest duration. Similar results were also reported by Longjam and Devi (2017).

Planting geometry and training systems also significantly influenced the harvest duration of cucumbers. The wider spacing of 75 cm x 30 cm and plants were trained to two shoots resulted in a prolonged harvest duration than other combinations. The reason for the earliest picking might be due to the availability of good sunshine and more uptake of nutrients leading to the accumulation of increased photosynthates and induction of early flowering compared to closer spacing and exposure of fruits to sunlight and aeration might have contributed to the occurrence of two earlier harvests among plants trained to two-shoots. Results were also in consonance with reports of Premlatha *et al*. (2006) and Ara *et al*. (2007).

Number of fruits per plant

Different dates of transplanting, planting geometry and training systems significantly influenced the number of fruits per plant. Early transplanting in the 1st fortnight of March with three shoots, spaced at 75 cm x 30 cm produced significantly more fruits per plant. This could be attributed to the fact that there were more flowers per plant and fruit-producing shoots and availability of growth factors viz., nutrients, air and moisture which ultimately led to a higher yield of fruits per plant. Kapuriya and Ameta, (2017) and Kumari *et al*. (2020) also indicated a significant increase in the number of fruits per plant.

The interaction of planting geometry and training systems significantly affected the number of fruits per plant. The maximum number of fruits were produced by plants with the spacing of 75 cm × 30 cm and three shoots, which was statistically equivalent to three shoots-trained plants spaced at 60 cm × 30 cm and two shoots-trained plants spaced at 75 cm x 30 cm (Table 2).

Fruit length (cm), Fruit breadth (cm) and Fruit weight (gm):

Effect of different times of transplanting, planting geometry and training system on the growth of cucumber was found to produce a significant effect on fruit length (cm), fruit breadth (cm) and fruit weight (gm). Fruit length was significantly influenced by different dates of transplanting, spacing and training systems. The highest means fruit length was observed when the crop was transplanted in the 1st fortnight of March, under wider spacing of 75 cm x 30 cm and trained to two shoots than other treatment combinations. The lowest was recorded in 1st fortnight of April, with closer spacing of 60 cm x 30 cm and four shoot plants.

Fruit breadth was also significantly influenced by different dates of transplanting, planting geometry and training systems. Maximum fruit breadth was recorded under a wider spacing of 75 cm × 30 cm, plants trained to two shoots and transplanted in the first fortnight of March while the lowest was observed in the four shoots-trained plants, spaced at a spacing of 60 cm × 30 cm and transplanted in the first fortnight of April. This could be attributed to the translocation of more photosynthates from source to sink, the availability of enough assimilates for young fruits in two shoot plants and favourable environmental factors like moisture, light, nutrients and less competition among themselves in wider spacing. Our observations in this regard have been substantiated by findings of several other workers like Andesina and Benjamin, (2016); Kumar et al. (2018); Kumari et al. (2020) and Shivraj et al. (2020).

It was demonstrated that when transplanting was done in the first fortnight of March, planted at a spacing of 75 cm × 30 cm and trained to two shoots, resulted in the highest mean fruit weight, while the lowest was observed in the first fortnight of April, wider spacing (60 cm × 30 cm) and four shoots. This might be due to enhanced nutrient uptake and the accumulation of enough photosynthates to allow for better fruit size (length and breadth) and greater exposure of the plants to sunlight in two shoots. The findings agreed with studies of Aniekwe and Anike, (20015) and Kapuriya and Ameta, (2017).

The interaction effect of planting geometry and training systems significantly influenced the fruit weight (Table 2). It is revealed that three shoot-trained plants spaced at 75 cm × 30 cm significantly recorded the higher fruit weight which was statistically at par with two shoot-trained plants with both the spacing.

Fruit yield (kg100m^{-2})

The results of the research showed that fruit yield was significantly affected by different dates of transplanting and the highest mean fruit yield was recorded in the first fortnight of March, followed by the second fortnight of March and the lowest in the first fortnight of April. Planting geometry and training system also had the significant effect on fruit yield. Significantly higher fruit yield was obtained with plants trained to three shoots and closer spacing of 60 cm × 30 cm, whereas the lowest fruit yield was recorded with plants trained to two shoots and four shoots and wider spacing of 75 cm × 30 cm. This may be due to the favourable climatic conditions that persisted throughout the crop's growth cycle and led to increased vegetative growth, which in turn contributed to more flowers, more number of fruits, and maximum fruit weight and volume. The results corroborated with the findings of Dhillon *et al*. (2017); Kumar *et al*. (2018) and Shivraj *et al*. (2020).

The interaction effect of planting geometry and training systems also had a significant effect on fruit yield. The highest fruit yield/100m^2 was recorded from three shoot-trained plants, spaced at 60 cm × 30 cm which was significantly higher than other treatment combinations of this study (Table 3).

Total soluble solids ($^{\circ}$brix)

The quantity of sugars in the fruit juice was indicated by the total soluble solids content. So, for processed products, a high total soluble solids content is preferred. Different dates of transplanting and planting geometry had significant effects on total soluble solids, however, training systems had no significant effect on the TSS. The crop was transplanted with a wider spacing of 75 cm × 30 cm during the first fortnight of March to get the highest TSS. This may be ascribed to the favourable climate that prevailed throughout the crop growth period of the crop transplanted in the first fortnight of March and the efficient use of sunlight at wider spacing. These results are supported by the work of Dhillon *et al.* (2017), Maragal et al. (2018) and Kumari *et al*. (2020).

Conclusion

Transplanting of cucumber in the 1st fortnight of March, trained to three shoots and spaced at 60 cm × 30 cm apart was proved to be the best treatment for higher fruit yield and better quality of the produce. Hence, transplanting of cucumber at a spacing of 60 cm × 30 cm in the 1st fortnight of March and the plants trained to three shoots can be recommended for growing cucumber in cost-effective naturally ventilated poly house for enhanced and superior-quality fruits of cucumber in mid-hills of Himachal Pradesh.

Table 1: Effect of dates of transplanting, planting geometry and training systems on the fruit yield and quality of cucumber

Treatments	Harvest duration (days)	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Fruit yield ($kg100m^{-2}$)	TSS ($^{\circ}$brix)
1st fortnight of March	59.37	24.25	177.86	18.21	6.40	1154.02	2.63
2nd fortnight of March	52.22	21.81	168.15	16.67	6.05	964.44	2.42
1st fortnight of April	48.65	20.37	159.37	15.56	5.91	816.48	2.40
SEm ±	**0.12**	**0.24**	**2.50**	**0.15**	**0.04**	**14.42**	**0.03**
CD(P=0.05)	**0.37**	**0.68**	**7.18**	**0.42**	**0.12**	**41.43**	**0.10**
60 cm x 30 cm	52.92	21.46	161.41	16.50	5.90	1024.02	2.40
75 cm x 30 cm	53.91	22.82	175.52	17.13	6.34	932.61	2.63
SEm ±	**0.10**	**0.19**	**2.04**	**0.12**	**0.03**	**11.77**	**0.03**
CD(P=0.05)	**0.30**	**0.56**	**5.87**	**0.34**	**0.10**	**33.83**	**0.10**
Two shoots	58.86	22.36	179.67	17.61	6.39	978.16	2.46
Three shoots	51.48	23.27	167.27	16.75	6.13	1084.69	2.57
Four shoots	49.90	20.79	158.45	16.08	5.84	872.09	2.42
SEm ±	**0.12**	**0.24**	**2.50**	**0.15**	**0.04**	**14.42**	**0.03**

CD(P=0.05)	0.37	0.68	7.18	0.42	0.12	41.43	NS

Table 2: Interaction effect of planting geometry and training system on number of fruits per plant and fruit weight (g)

Planting geometry	Training systems					
	Number of fruits per plant			Fruit weight		
	Two shoots	Three shoots	Four shoots	Two shoots	Three shoots	Four shoots
60 cm x 30 cm	21.41	23.18	19.80	177.66	152.41	154.15
75 cm x 30 cm	23.31	23.36	21.78	181.68	182.12	162.75
CD(P=0.05)		**0.96**			**10.16**	

Table 3: Interaction effect of planting geometry and training systems on f fruit yield (kg/100m^2)

	Training systems

Planting geometry	Fruit yield (kg/100m^2)		
	Two shoots	Three shoots	Four shoots
60 cm x 30 cm	987.16	1202.76	882.16
75 cm x 30 cm	969.17	966.62	862.02
CD(P=0.05)		**58.59**	

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