Original Article

Mitigate the adverse effect of chilling by cultivate tomato plants under different types of mesh cover for low tunnels

Ahmed S. Mohamed[1], Saber A. Saleh[2], Ahmed A. Glala[1], Samar S. Halawa[3]

1 Horticultural Crops Technology Department, Agricultural and Biological Research Institute, National Research Centre, Dokki, Giza, Egypt

2 Horticulture Dept., Faculty of Agriculture, Al-Azhar University (Assiut Branch), Assiut, Egypt

3 Horticulture Dept., Faculty of Agriculture, Benha University, Moshtohor, Toukh, Egypt

Abstract

Tomato plants are highly sensitive to chilling stress so this experiment was conducted during successive winter seasons of 2020/2021 and 2021/2022 to investigate the possibility of sustaining production and quality of tomato yield under cold conditions by using different types of mesh cover for low tunnels. Two commercial cultivars, i.e., Super gold F_1 and Super streen F_1 were used. Seedlings were transplanted under different types of mesh cover for low tunnels. Three types of mesh cover (63%, 65%, 73%) had done to cover the plants of all tested seasons compared to open field condition (control "without cover"). Results show that significant differences were observed among the two hybrid varieties of tomato studied, in terms of their vegetative growth characteristics (plant height, number of branches, number of leaves, fresh weight, dry weight and leaves area) as well as yield and fruit quality characteristics (Fruit set, total yield, firmness, T.S.S. and Vit. C. 'Super gold' exhibited significantly higher values for these characteristics, compared to 'Super strain B'. Chilling reduced the growth parameters (plant height, number of leaves, number of branches, plant fresh weight, plant dry weight) for control plants (without cover) compared to the coverage treatments (63%, 65%, 73%). Significant highest results in the growth, chemical composition of tomato leaves as well as yield and fruit quality parameters were obtained with covering tomato plants by white mesh cover 63% flowed by 65% of treatments which were best than the chilled plants. Concerning the interaction between hybrid varieties and covering treatments, it can be noticed that Super gold F_1 which grown under white mesh cover 63% recorded a highly significant increases in plant height, number of branches, number of leaves, fresh weight, dry weight, leaves area, N, P, K, total chlorophyll, total proline, total sugars contents, fruit set, total yield, firmness, T.S.S. and Vit. C when compared to Super streen F_1 which grown in open field (without coverage).

Keywords: Tomato (*Solanum lycopersicum*), chilling stress, low tunnels, mesh cover, genotypes.

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INTRODUCTION

Tomato (Solanum lycopersicum) is one of the most important vegetable crops in Egypt and other world countries for fresh consumption, industry processing and exportation as well as for its nutritional, economical and medicinal values. The cultivated area of tomato in Egypt for winter season 2019/ 2020 is 192782 feddan (4200 m^2) with total production of 3501835 tons and an average of 18.165 tons/fed. (Ministry of Agric, Egypt, 2020).

Tomato plants are highly sensitive to low temperature stress (Weiss and Egea-Cortines, 2009 and Mesa et al., 2022; Sheha et al., 2022; Suliman and Saleh, 2022). Where, tomato plants show signs of injury upon exposure to temperature below 10-15°C (Guy, 1990). Several aspects of tomato development also are negatively affected by cold temperature. Low temperature may affect sundry manifestations of crop growth; viz., subsistence, cell division, photosynthesis, sap transmission, growth, flowering and crop yield (Venema et al., 2005; (Goud and Kachole, 2011; Shi et al., 2016; Nievola et al., 2017; Yildiztugay et al. (2017) and Hussain et al. (2018)). Exposure to temperatures below 13°C may inhibit fruit-set (Atherton and Rudich 1986). In addition, reproductive development in tomato is adversely influenced by low temperature, where it causes a reduction of anther fusion rates by 60%, consequently decreases fruit set (Fernandez- Munoz et al., 1995 and Lozano et al., 1998). Thus, a serious reduction in tomato fruit yield and quality was observed in winter and early summer seasons every year in Egypt where level of night temperature drops several times below 10°C. Therefore, tomato and other sensitive plants should have some agricultural practices applied to protect plants from frost damage. Presently, there are tomato genotypes which can

be planted in the different climate. However, commercial agriculture of tomato in Egypt displays seasonality witha lot of the production concentrated in the relatively cool and dry period.

Low tunnels are smaller structural frames that are used to grow different vegetable crops as they modulate microclimate inside They dilate the growing and harvest seasons, sustain yield as well as fruit quality, and protect crops from low-temperature damage during winter (Xiao et al., 2001; Jenni et al., 2006; Kadir et al., 2006;Carey et al., 2009; Wien, 2009; Zhao and Carey, 2009; Rowley et al., 2010, 2011; Singh et al., 2012; Lewers et al., 2017; Petran et al., 2017; Acharya et al., 2020, 2019).

Therefore, the objectives of this study were to evaluate the effect of low tunnel covering with different white mesh cover on vegetative growth, production and quality traits for two genotypes of tomato.

MATERIALS AND METHODS

1. Experimental layout:

This experiment was performed during successive winter seasons of 2020/2021 and 2021/2022 in the experimental station of the Horticultural Department, Faculty of Agriculture at Moshtohor, Benha University to investigate the possibility of sustaining production and quality of tomato yield under cold conditions by using mesh cover. The field of experimental field was clay soil (pH 7.7; EC1.32 dS m^{-1}) and contains 2.2% of organic matter, 18.71 mg kg^{-1} of nitrogen, 17.9 mg kg^{-1} of phosphorus, and 75 mg kg^{-1} of potassium. Two commercial cultivars, i.e., Super gold F_1 (grand green company) and Super streen F_1 (United Genetics Italia company) were used.

Seedlings were transplanted into the open field or in tunnels protected with a different mesh cover on 11th 15th of November at 40 cm apart on one side of ridge 3.5 m long and 1m width with experimental unit area of 10.5m2. Three types of covering (63%, 65%, 73%) had done to cover the plants of all tested seasons compared to open field condition to investigate the growth and productivity of tomato plants under these conditions. The tunnel height was 80 cm above the soil and its wide was one m. A distance of 100 cm was left between each net covering type treatments.

Split plot designed was adopted, with three replicates. Where, treatments of mesh covering were placed in main plots and cultivars in subplots. Each replicate consisted of 4 treatments of coverage treatments (63%, 65%, 73% and the control "without covering") within 2 cultivars treatments (Super gold F_1 and Super streen F_1).

All cultural practices i.e. irrigation, hoeing and weeding, and fertilizer applications keep same for all treatments.

Three plants from each treatment were randomly taken at 75 days after transplanting and the following data were recorded: plant height, leaf area per plant and dry weight of whole plant. Chlorophyll A and B were determined as described by Wettstein (1957). Chemical constituents determination; leaves total nitrogen, phosphorus, potassium and total carbohydrates % were determined in the dry matter of leaves according to Pregl (1945), John (1970), Brown and Lilleland (1946) and Herbert et al. (1971), respectively. Proline and Total soluble sugars concentrations were measured according to the method of Bates et al. (1973) and Dubois et al. (1956), respectively. At flowering stage, fruit set percentage was calculated according to the following equation: Fruit set % × 100. At harvesting time yield expressed as number of fruits per plant and yield per plant (kg) were recorded. Total yield as kg/plot were recorded, then calculated as ton/fed. At breaker stage, three ripe tomato fruits/plot were picked and used for determination of TSS% by hand refract meter and vitamin C, titratable acidity and lycopene according to A.O.A.C. (1990).

All statistical analyses of the recorded data were subjected to analysis of variance as factorial experiments in a split plot design. Mean values among treatments were compared by Duncn's tests at the 5% level of significance according to Snedecor and Cochran (1991).

Results and Discussion

1- Vegetative growth parameters:

Effect of chilling stress on tomato growth was studied as influenced by two hybrid varieties (Super gold F_1 and Super streen F_1) at two different seasons. According to data shown in Table1, significant differences were observed among the two hybrid varieties of tomato studied, in terms of their vegetative growth traits. In general, the maximum of plant height (75.7 and 74.1 cm), number of branches (5.3 and 4.9/plant), number of leaves (60.7and 57.7 /plant), fresh weight (642.2 and 624.9 g /plant), dry weight (98.0 and 95.4 g /plant) and leaves area (1521.1 and 1473.6 cm^2) were noted in Super gold F1 during first and second season, respectively. While the minimum of plant height (71.3and 69.7 cm), number of branches (4.5 and 4.1/plant), number of leaves (55.4 and 52.5 /plant), fresh weight (498.2 and 468.0 g /plant), dry weight (80.1 and 76.2 g /plant) and leaf area (1262.6 and1208.7 cm^2) were recorded in Super streen F_1. The

results are in agreement with Davis et al., 2003, Rab and Ihsan, (2008), Naz et al., 2011, Iqbal et al., (2011), Ali et al., 2013, Ali et al. (2016) who reported variation with cultivars because of genetic makeup and different requirements of environmental condition.

As compared to tomato plants, chilling reduced the growth parameters (plant height, number of leaves, number of branches, plant fresh weight, plant dry weight) compared to the covering treatments (63%, 65%, 73%). Significant highest results in the growth parameters recorded with covering tomato plants by white mesh cover 63% followed by 65% in the second trend which were best than the chilled plants (Ilic et al., 2011; Setiawati et al., 2014; Nangare et al., 2015; Ngelenzi et al., 2017). The results are in line with Sadek and Youssef (2019) who reflected that, white net cover was the most suitable cover for increasing vegetative growth parameters i.e., plant length, number of leaves per plant, stem diameter, fresh and dry weight / plant of common bean plants.

The reduction in plant growth under open field conditions as compared with tunnels conditions may be due to that open field recorded the lowest values of maximum and minimum air temperature compared to all covering treatments. Meanwhile, it is due to the superiority of first type of covers (63%) because this cover represents the lowest ability to reduce solar radiation compared to other types (Sadek and Youssef, 2019). Net covers reduce the mixing of outside and inside air, hence effectively reduce loss of heat to the surrounding atmosphere, which leads to a temperature increase (Tanny et al., 2003). Generally, this may be due to enhanced photosynthesis and respiration due to the favorable micro-climatic conditions under mesh covering (Ramesh and Arumugam, 2010; Rajasekar et al., 2013; Yasoda et al., 2018).

Table 1. Effect of cultivar, mesh cover and the interaction between them on some vegetative growth characters of tomato plants in winter seasons of 2020-2021 and 2021-2022.

Treatments		Plant height (cm)		Number of branches/plant		Number of leaves/plant		Fresh weight (g)		Dry weight (g)		Leaf area (cm^2)	
Cultivar	Mesh cover	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Super gold F_1		75.7A	74.1A	5.3A	4.9A	60.7A	57.7A	642.2A	624.9A	98.0A	95.4A	1521.1A	1473.6A
Super streen F_1		71.3B	69.7B	4.5B	4.1B	55.4B	52.5B	498.2B	468.0B	80.1B	76.2B	1262.6	1208.7B
	63%	77.1A	75.8A	5.8A	5.2A	66.1A	63.4A	648.0A	632.3A	97.9A	94.9A	1585.7A	1491.2A
	65%	75.1B	74.2B	5.0B	4.5B	62.7B	60.0B	600.5B	582.4B	91.3B	89.4B	1492.2B	1452.8B
	73%	72.9C	71.7C	4.7C	4.3C	56.2C	53.9C	553.4C	515.5C	88.6B	84.3C	1416.4B	1359.7C
	Control	68.8D	65.9D	4.1D	3.8D	47.2D	43.0D	478.8D	455.7D	78.3C	74.5D	1073.1C	1061.0D
Super gold F_1	63%	78.3a	77.2a	6.1a	5.6a	68.4a	65.8a	699.1a	686.7a	106.2a	103.2a	1671.8a	1569.3a
	65%	76.3ab	75.7ab	5.5ab	4.9b	64.8b	62.5b	672.8a	661.5a	98.6a	97.8a	1686.4a	1634.5a
	73%	75.5bc	74.5bc	5.0bc	4.5bc	56.8d	54.7cd	634.8b	610.1b	99.1a	95.9a	1606.3ab	1547.3a
	Control	72.6d	69.3d	4.8c	4.4bc	52.6e	47.9e	562.1cd	541.5c	88.0b	84.8b	1119.9de	1143.5d
Super streenF_1	63%	76.0ab	74.5bc	5.4b	4.8b	63.8bc	61.1b	597.0c	577.9bc	89.6b	86.7b	1499.7b	1413.2b
	65%	73.9cd	72.8c	4.6c	4.2c	60.5c	57.6c	528.3d	503.3d	84.1bc	81.1b	1298.0c	1271.1c
	73%	70.3e	68.9d	4.3c	4.0c	55.6de	53.1d	472.1e	420.9e	78.1c	72.8c	1226.6cd	1172.1d
	Control	65.0f	62.6e	3.5d	3.3d	41.8f	38.2f	395.5f	369.8f	68.6d	64.3d	1026.3e	978.6e

Concerning the interaction between hybrid varieties and covering treatments, it can be noticed in Table (1) that Super gold F_1 grown under white mesh cover 63% recorded a highly significant increases in plant height (7.9 and 24.4%), number of branches (11.4 and 26.8%), number of leaves (27.1 and 20.7%), fresh weight (27.3 and 21.7%), dry weight (30 and 49.3%) and leaves area (37.4 and 37.2%) when compared to its control in during first and second season, respectively.

Chemical composition of tomato leaves

No significant differences were found between the hybrid varieties on their mineral constituents i.e., N, P and K (Table, 2). Whereas, total chlorophyll, total proline and total sugars contents were found significantly different among the various cultivars of tomato. The results show that maximum total chlorophyll (6.2 and 5.9 mg/g Dr.Wt), proline (1325 and 1285 µg/g Dr.Wt) and sugars (15.3 and 17.7 mg/g Dr.Wt) contents were reported in Cv. Super gold F_1 during first and second season, respectively. Whereas minimum total chlorophyll (6.0 and 5.6 mg/g Dr.Wt), proline (1072.9 and 895.1 µg/g Dr.Wt) and sugars (15.1 and 14.9 mg/g Dr.Wt) contents were recorded in Super strean F_1 during first and second season, respectively. The results are in line with Mesa et al.(2022).

It was observed that there was a significant reduction in chlorophyll (a+b), total proline and total sugars contents of chilled stress tomato leaves. Plants grown under white mesh 63% showed significant increase compared to chilled plants. These results were obtained in the both seasons and were in agreement with Sadek and Youssef (2019) who found influenced the positive effect of using different net covering on leaves content of chlorophyll reading, nitrogen, phosphorus and potassium.

Regarding the interaction between hybrid varieties and covering treatments, it can be noticed that Super gold F_1 grown under white mesh cover 63% recorded a highly significant increases in their constituents i.e., N, P K total chlorophyll, total Proline and total sugars contents.

In general chilling stress inhibits the photosynthesis of plants by affecting chlorophyll components. Yildiztugay et al. (2017) cited that low temperature (chilling) reduced photosynthetic activity. The decrease in chlorophyll under chilling stress is mainly as a result of damage to chlorophyll caused by active oxygen species (ROS). However, under chilling stress conditions there will be degradation in pigment compositions, which induce decrease in chlorophyll content, (Suzuki et al., 2012). Meanwhile, the favorable effect of the white net covering on plant growth may be due to covering applications protect the membranes from damage and subsequently protect chloroplast membrane which increase chlorophyll content (Sorial Mervat et al. 2010 and El-Shraiy Amal and Hegazi 2010). Moreover, the favorable effect of the white net covering on plant growth may be due to modifying the microclimate around the growing plants, i.e., improving the maximum and minimum air, soil temperatures, radiation and relative humidity as well as enhancing soil properties especially soil moisture content and soil nutrients availability of nitrogen, phosphorus and potassium (Table, 2). Also, sugars accumulation at low temperature play a control regulatory role in many vital processes of photosynthetic plants besides saving the energetic function and considered as important signals that regulate plant metabolism and development (Couee et al., 2006). Moreover they might protect plant cell membranes during cold. Induced dehydration, replacing water species and by acting as hydroxyl scavengers and so, increased membrane stabilization (Couee et al., 2006 and Ruelland et al., 2009).

Table 2. Effect of cultivar, mesh cover and interaction between them on nutrients contents in leaves of tomato plants in winter seasons of 2020-2021 and 2021-2022.

Treatments		N%		P%		K%		chlorophyll (a+b) (mg/g Dr.wt)		Proline (µg/g Dr.Wt)		Total sugars (mg/g Dr.Wt)	
Cultivar	Mesh cover	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Super gold F_1		2.05A	2.11A	0.56A	0.64A	2.54A	2.61A	6.2A	5.9A	1325.8a	1285.5A	15.3A	17.7a
Super streen F_1		2.04A	2.10A	0.56A	0.63A	2.52A	2.60A	6.0B	5.6B	1072.9B	895.1B	15.1B	14.9b
	63%	2.09A	2.15A	0.60A	0.68A	2.51A	2.58A	6.3A	6.0A	1446.9A	1400.9A	17.9A	17.5A
	65%	2.07A	2.08B	0.58B	0.64B	2.49A	2.50B	6.2A	5.8B	1345.5A	1228.3B	15.1B	14.9B
	73%	2.03B	2.04C	0.55C	0.61C	2.49A	2.51B	6.1B	5.7C	994.0B	943.7C	14.0C	14.1C
	Control	1.89C	1.94D	0.50D	0.56D	1.89B	1.95C	5.7C	5.4D	1011.0B	788.2D	13.7D	13.6D
Super gold F_1	63%	2.12a	2.17a	0.61a	0.68a	2.55ab	2.60a	6.4a	6.1a	1718.0a	1704.8a	18.0a	17.5a
	65%	2.06ab	2.11a	0.57ab	0.64ab	2.68a	2.74a	6.2ab	5.9ab	1522.9a	1478.2b	15.2b	15.0b
	73%	2.05ab	2.10ab	0.56ab	0.62ab	2.77a	2.84a	6.2ab	5.9ab	1102.7b	1046.3cd	14.1c	14.4c

	Control	1.97ab	2.05ab	0.52bc	0.59bc	2.17c	2.25bc	5.9ab	5.7ab	959.7b	912.7ef	13.8cd	13.7d
Super streen F_1	63%	2.06ab	2.14ab	0.59ab	0.67ab	2.47ac	2.56ab	6.2ab	6.0a	1175.8b	1097.0c	17.8a	17.4a
	65%	2.08ab	2.06ab	0.58ab	0.63ab	2.29bc	2.26bc	6.2ab	5.8ab	1168.0b	978.4de	15.0b	14.8b
	73%	2.00ab	1.98ab	0.54ac	0.59bc	2.20c	2.18c	6.0ab	5.6ab	885.4b	841.2f	13.9cd	13.8c
	Control	1.80b	1.83b	0.47c	0.53c	1.62d	1.64d	5.4b	5.1b	1062.4b	663.7g	13.6d	13.5d

Yield and fruit quality

Significant differences were observed between the two hybrid cultivars tested in this study (Table, 3) in terms of the yield and their fruit quality characteristics, i.e., fruit set (%), total yield (tons/fed.), firmness (kg/cm²), T.S.S. and Vit. C (%). 'Super gold F_1' exhibited significantly higher values for these characteristics, compared to 'Super streen F_1'. The findings are in line with Rab and Ihsan, (2008). The difference in the total tomato production may be due to the difference in the genetic makeup of different cultivars where, each variety requires different environmental conditions for proper growth and development to produce optimum yield (Davis et al.,2003). The results are in line with Javeria et al. (2012), Singh and Tawari, (2013) and Mesa et al. (2022).

Table 3. Effect of cultivar, mesh cover and interaction between them on yield and its components of tomato plants in winter seasons of 2020/2021 and 2021/2022.

Treatments		Fruit set (%)		Total yield (ton/fed)		Firmness (kg/cm²)		T.S.S (%)		Vit. C (mg/100 ml	
Cultivar	Mesh cover	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Super gold F_1		73.65A	67.55A	4.03	3.71A	2.65A	2.54A	5.94A	5.62A	27.23A	26.50A
Super streen F_1		67.79B	55.75B	3.76B	3.51B	2.50B	2.41B	4.67B	4.46B	25.67B	24.71B
	63%	77.45A	66.87A	4.24A	3.82A	2.88A	2.75A	6.11A	5.95A	28.75A	27.92A
	65%	73.78B	65.51B	4.00B	3.69B	2.71B	2.65B	5.60B	5.37B	27.00B	26.33B
	73%	71.11C	60.96C	3.81C	3.58C	2.49C	2.41C	5.14C	4.85C	25.63C	25.00C
	Control	60.53D	53.28D	3.52D	3.34D	2.22D	2.09D	4.38D	3.99D	24.42D	23.17D
Super gold F_1	63%	80.46a	74.01a	4.37a	3.90a	2.93a	2.81a	6.44a	6.38a	29.17a	28.42a
	65%	77.64ab	72.53a	4.16b	3.76b	2.78ab	2.71ab	6.30a	5.99b	27.92a	27.25a
	73%	74.11b	65.60b	3.96c	3.68bc	2.59c	2.48c	5.88b	5.56c	26.50b	26.08b
	Control	62.38d	58.08cd	3.63d	3.49d	2.31d	2.15e	5.16c	4.54d	25.33bc	24.25c
Super streen F_1	63%	74.43b	59.73c	4.11b	3.74bc	2.83ab	2.68ab	5.77b	5.53c	28.33a	27.42a
	65%	69.93c	58.50cd	3.85c	3.61cd	2.64c	2.60bc	4.90c	4.76d	26.08b	25.42b
	73%	68.12c	56.32d	3.67d	3.48d	2.38d	2.34d	4.41d	4.13e	24.75c	23.92c
	Control	58.67e	48.48e	3.40e	3.20e	2.13e	2.03e	3.61e	3.43f	23.50d	22.08d

The effect of cold stress on flowering and fruit set on the different plant axes had influenced on yield and yield components. It is also observed that treatments considerably differed among of these in their effects since great enhanced fruits set % was obtained by covered plants with white mesh 63% followed by covered plants with white mesh 65% in second order compared to the chilled plants in both seasons (Table 3). These results

were obtained in the both seasons and were in agreement with Nangare et al. (2015); Mutisya et al. (2016); Ngelenzi et al. (2017); Tafoya et al. (2018) and Ngelenzi et al. (2019) who mentioned that developing plants under net covers substantially improved total yields compared to control plants. Results are in line with Sadek and Youssef (2019) who showed that the highest productivity for total yield as well as pod characters (number of pods par plant, average pod weight and T.S.S) were obtained when plants were grown under white net covering.

It is quite clear from Table 3 that total yield per feddan were significantly increased as the results of all applied treatments under studying compared with the chilled tomato plants only, in both seasons. On the contrary, the chilled plants (control) plants were strongly stressed. It is also observed that treatments considerably differed among of their effects since great enhanced total yield per feddan were obtained by cultivate tomato plants cv super gold under low tunnels and covered with mesh coverage 63% compared to chilled plants. This improve can be attributed to modify microclimate under these covers which enhanced fruits production rates, improved total numbers and weight. Moreover, the light environment which created by mesh cover increased average of fruit weight and number of fruits per plant due to the positive effect on increasing of plant biomass by increasing the availability of solar radiation and the efficiency of photosynthetic, promoting the growth rate of individual fruits (Tafoya et al., 2018).

CONCLUSION

It can be concluded that, the observed results may show that tomato plants subjected to chilling stress recorded highly significant reduction in their growth and production parameters especially Super streen F_1 compared with Super gold F_1. But cultivate tomato plants under mesh cover for low tunnels 63% which exerted the most protecting effect in alleviation of chilling injury and modified microclimate as well as increasing the availability of solar radiation which reflect a good performance of tomato plants under chilling with high quantity and good quality of yield.

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