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EFFECT OF HIGH TEMPERATURE STRESS ON THE PERFORMANCE OF TWELVE SWEET PEPPER GENOTYPES

S. R. SAHA[1], M. M. HOSSAIN[2], M. M. RAHMAN[3]
C. G. KUO[2] AND S. ABDULLAH[3]

Abstract

A study on heat tolerance in sweet pepper was conducted at the Asian Vegetable Research and Development Centre (AVRDC), Taiwan from December 1999 to May 2000. Experiments were carried out to investigate the influence of 29/23°C and 24/18°C stress on 12 sweet pepper genotypes on growth, development, reproductive behaviour and yield potentialities and to verify the results of the phytotron study. Performance of 12 sweet pepper genotypes was evaluated under two different temperature regimes of 24/18° C and 29/23° C in the phytotron. Plant height was found higher at 29/23° C compared to 24/18° C. High temperature reduced percent fruit set as well as size of fruits. Individual fruit weight was higher (7.44-125.00 g) when grown at 24/18°C and lower (5.35-103.80 g) at 29/23°C. Out of 12 genotypes, SP00l, SP002, SP004, and SP012 performed poor in respect of per plant yield at higher temperature compared to the lower temperature. So, these four genotypes were considered to be heat sensitive than the others. Leaf proline content of the sensitive genotypes decreased under the high temperature conditions and the heat tolerant lines produced higher amount of proline indicating the role of proline in expressing the heat tolerant capability of sweet pepper genotypes concerned.

Keywords : High temperature stress, performance, sweet pepper.

Introduction

Sweet Pepper is a high valued crop in Bangladesh. Peppers are grown as an annual crop in temperate regions. The optimum temperature favourable for growth of sweet pepper ranges between 20 and 25°C. When temperature falls below 15°C or exceeds 32°C, growth is usually retarded and yield decreases. Heat stress is a major factor influencing the productivity and adaptation of wild and cultivated plants. Bell pepper is not an established crop anywhere in the tropical lowlands and it needs to go through a whole process of tropicalization. When large fruited bell peppers are exposed to environmental stresses during the flowering and fruiting period, abscission of flowers and flower buds may occur (Cochran, 1936). This loss of reproductive structures can result in serious yield

[1]Senior Scientific Officer, Plant Physiology Section, HRC, Bangladesh Agricultural Research Institute (BARI), Gazipur, [2&3]Professor, Dept. of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, [4]Plant Physiologist, AVRDC, Taiwan, [5]Scientific Officer, TCRC, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh.

decrease, and constitutes a major risk factor in pepper production. Although the abscission can be caused by several factors, such as extremes of temperature, lack of moisture or low light conditions, high temperature appears to be the most common cause (Cochran, 1936). High temperature has an adverse effect on fruit-set (Dorland and Went, 1947) in bell pepper. Poor fruit-set was believed to be one of the major barriers to the tropical adaptation of bell pepper. Song *et al.* (1976) observed decreased fruit-set in pepper as temperatures were raised from 18/13° to 23/18° and 33/28°C.

Bell peppers can also be grown during winter season in Bangladesh but fruit-set percentage is low since the crop is mainly developed for temperate region. So, genotypes with heat stress tolerant capability may be grown successfully under Bangladesh situation following specific cultural practices which may help improve the fruit-set percentage along with less infestation of insect-pest and diseases. The above discussion indicates that the effects of high temperature on the growth and reproductive behaviour of sweet peppers are to be studied with the new materials of AVRDC to proceed on for the development of suitable variety for tropical condition like Bangladesh. Therefore, the present investigation was undertaken to investigate the vegetative growth, reproductive behaviour and proline content of leaves of the bell pepper genotypes as affected by high temperature

Materials and Method

An investigation was carried out at the Asian Vegetable Research and Development Center (AVRDC), Taiwan to observe the performance of twelve AVRDC accessions and breeding lines of sweet pepper at different temperature regimes during the period from December 1999 to Mid-May 2000. To minimize tobamoviruses seed infection, seeds were soaked in a 10% (w/v) solution of trisodium phosphate (TSP) for 30 minutes and then transferred them to a same fresh solution for two hours and then rinsed in running water for 45 minutes.

The seeds were sown on 10 December 1999 in 70-cell seedling trays with sowing medium in green house. The sowing medium used in the present study was 70% peat-moss and 30% coarse vermiculite. Two seeds were sown in each cell at a depth of 1 cm and three days after germination when first true leaf appeared, one seedling was thinned out keeping the good one intact. Before transferring, the seedlings were hardened by exposing them to direct sunlight for 4-5 days. After hardening, the seedlings were transferred to pots of 17 cm height and 14.5 cm diameter. The pots were filled up with AVRDC potting mixture, which was prepared by mixing soil, compost, and sand in the ratio of 3:1:1. The potting mixture was autoclaved at 120 °C for 30 minutes for sterilization.

After one week of transplanting the seedlings in the larger pots, they were placed in two walk-in plant growth chambers (phytotron) one maintaining 24/18°C and the 29/23°C day/night temperatures, respectively. In both types of growth chambers, a constant 14 hours light conditions and 10 hours dark conditions were maintained throughout the study period. Photosynthetically active radiation (PAR) in both the growth chambers varied from 350-400 $\mu molm^{-2}S^{-1}$ as measured at the top of the canopy with a LI-COR (Lincoln, Nebraska, USA) model 1903 quantum flux sensor. The radiation sources consisted of cool white fluorescent (CWF) lamps and general incandescent lamps. The relative humidity inside the chamber was around 65±5%. Carbon dioxide levels were approximately 350 gm^{-3}.

Two separate single factor experiments were conducted. The randomized complete block design was used. Each experiment was conducted in phytotron.

Fruits of sweet pepper were harvested when reached full size of edible maturity depending on the germplasm and became firm but before turning colour (Yellow, Orange or Red) as per Berke *et al.* (1999).

The different morphological, physiological and yield and yield contributing characters of the genotypes were recorded as follows: Plant height (cm), percent fruit set, fruits per plant, individual fruit weight (g), yield per plant (g), fruit length (mm), fruit diameter (mm).

Proline estimation : After three weeks of growth in the growth chamber, young leaves (2nd and 3rd leaf) were used for proline estimation following the methods developed by Troll and Lindsley (1955).

The data recorded on different parameters were analyzed statistically with the help of computer 'MSTAT' program. The difference between treatment means were compared by Duncan's Multiple Range Test (Gomez and Gomez, 1984) for interpretation of results.

Results and Discussion

Plant height : Plant height of different genotypes significantly differed at different growth stages. The stages of growth were 30, 60, and 90 days after transplanting and at final harvest. Plant height ranged from 41.33 to 71.62 cm at 24°/18°C and 53.00 cm to 84.33 cm at 29°/23°C temperature. The growth rate pertaining to the plant height was found to be low at 60 and 90 days after transplanting under both the low and high temperature conditions and plants attained higher growth at high temperature than low temperature (Fig.1). Genotypic differences came out regarding height of plants when pot plants were grown under 24/18°C as well as 29/23°C temperature, respectively, in the phytotron (Fig. 2). The plant height of SP006 was the highest (71.67 cm) at low temperature and SP00l was the lowest (41.33 cm). At high temperature of 29/23°C, the plant height of 12 sweet pepper accessions ranged from 53.00 cm in SP00l to 84.33 cm in 5P002. The plant height recorded in this investigation under low and high temperature conditions implied that at higher temperature of 29/23°C, all the genotypes had the tendency to grow vertically with much more rate than the plants raised under the comparatively low temperature of 24/18°C (Fig. 2). Bakker and Uffelen (1998) stated that plant height was significantly correlated to 24-h mean temperature as well as day/night temperature amplitude. Rylski and Spigelman (1986b) obtained plant height of sweet pepper lower in the field condition (66.2 cm) and high in the screen house where temperature was higher than open field (95.1 cm).

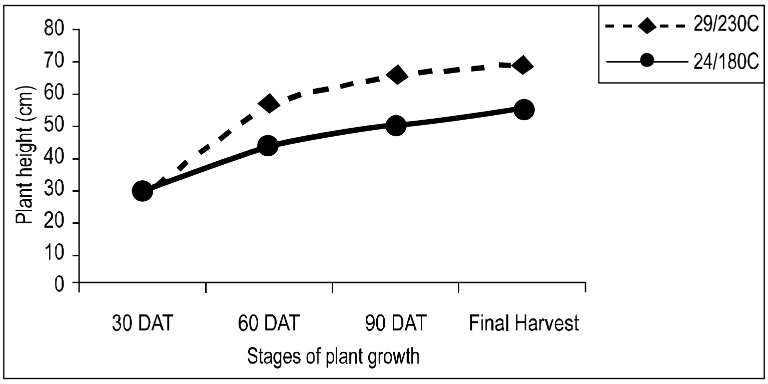

Fig. 1. Plant height of sweet pepper due to temperature effect at different growth stages.

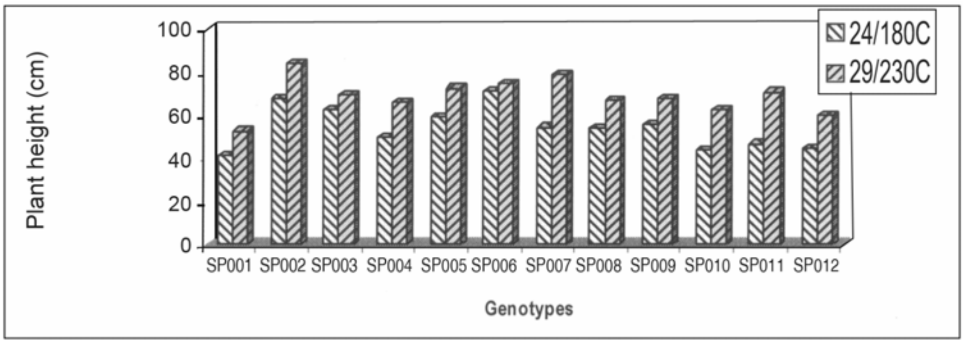

Fig. 2. Genotypic difference in plant height at final harvest due to high and low temperature,

Percent fruit set : Percent fruit set varied from 14.63 to 56.17 at 24°/18°C being the lowest in SP011 and the highest in SP002. Under high temperature condition, it was 48.86% in SP002 and 10.47% in SP00l. Percent fruit set was around 20 in case of four germplasms out of twelve (Table 1). Fifty percent genotypes set fruits in the range from 21.87 to 28.15. It could be observed that the percent fruit set of all the genotypes were lower at higher temperature and higher at comparatively low temperature. Rylski and Spigelman (1982) found 12% fruit set at 24°C night temperature and 22.8% at 18°C night temperature. Again, at higher day temperature of 28°C, they obtained 38.5% fruit set while at 25°C day temperature, they calculated 42.2% fruit set. Huberman *et al.* (1997) stated that high temperature reduced indole-3-acetic acid levels and particularly auxin transport capacity in the reproductive organs which ultimately induced reproductive organ abscission in pepper and in consequence reduced percent fruit set.

Number of fruits per plant : The different entries under investigation varied greatly in producing fruits per plant in both high and low temperature conditions (Table 1). The number of fruits produced per plant ranged from 1.67 to 21 being the lowest in the genotype SP01l and SP005 and the highest in SP002 at low temperature. SP003 and SP006 produced fruits per plant numbering around 2 only at low temperature condition. On the contrary, the genotypes SP002 and SP009 produced the maximum number of fruits per plant, 14.33 and 15.67, respectively, at 29/23°C. Sanchez *et al.* (1993) obtained 6.6 to 12.4 fruits per plant in bell pepper under varied plant spacing. Rylski and Spigelman (1982) got the result that at higher night temperature of 24°C and lower night temperature of 18°C, the number of fruits produced per plant were 6.6 and 12.6, respectively. It indicated that the lower night temperature of 18°C produced more number of fruits per plant, whereas, at higher day temperature of 28°C, 9.2 fruits were produced per plant and at 25°C day temperature it was 10.1.

Individual fruit weight : Individual fruit weight ranged from 7.44 g to 125.00 g (SP00l and SP012, respectively) at low temperature and 5.35 g to 103.80 g (SP00l and SP008, respectively) at 29/23°C temperature (Table 2). High temperature 29/23°C influenced the individual fruit weight and it was reduced compared to the fruits produced at low temperature. Rylski and Spigelman (1986b) obtained 145 g per fruit weight in open field and 175 g in the screen house during winter season in hot inland areas of Israel. Wien and Zhang (1991) obtained individual fruit weight ranging from 15.9 g to 24.3 g in Shamrock Bell pepper under higher temperature of 27/21°C (day/night). Bakker (1989) found higher individual fruit weight of 119.7 to 1319 g under different humidity levels grown at 23/18°C (day/night) temperature.

Table 1. Percent fruit set, number of fruits per plant and individual fruit weight (g) of 12 sweet pepper genotypes at different temperature regimes grown at AVRDC, Taiwan during 1999-2000.

Genotypes	% Fruit set at temperature		Number of fruits per plant at temperature		Individual fruit weight (g) at temperature	
	24/18°C	29/23°C	24/18°C	29/23°C	24/18°C	29/23°C
SP00l	30.25b-e	24.25c	7.44c	5.35f	17.00b	5.33b
SP002	56.17a	48.86a	11.62c	9.31f	21.00a	14.33a
SP003	17.75fg	15.55de	66.58b	42.24de	2.00cd	4.33bc
SP004	31.73bcd	25.19c	69.95b	37.87de	3.33cd	2.00c
5P005	22.2efg	12.50e	48.11b	64.92c	1.67d	3.00bc
SP006	24.25c-f	28.15c	72.38b	42.76de	2.33cd	4.33bc
SP007	33.85b	39.25b	60.22b	49.00d	3.33cd	5.00b
SP008	25.35b-f	24.33c	68.30b	103.80a	3.67cd	4.67b
SP009	55.29a	24.67c	68.08b	35.94e	3.33cd	15.67a
SP010	32.50bc	21.87cd	75.93b	40.12de	4.33c	5.00b
SP01l	14.63g	10.47e	109.80a	81.64b	1.67d	4.00bc
SP012	24.40 def	12.69e	125.00a	69.27c	3.67cd	2.67bc
Level of significance	**	**	**	**	**	**
CV (%)	15.39	15.97	29.49	12.90	24.11	23.37

In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT.

Individual fruit weight : Individual fruit weight ranged from 7.44 g to 125.00 g (SP00l and SP012, respectively) at low temperature and 5.35 g to 103.80 g (SP00l and SP008, respectively) at 29/23°C temperature (Table 2). High temperature 29/23°C influenced the individual fruit weight and it was reduced compared to the fruits produced at low temperature. Rylski and Spigelman (1986b) obtained 145 g per fruit weight in open field and 175 g in the screen house during winter season in hot inland areas of Israel. Wien and Zhang (1991) obtained individual fruit weight ranging from 15.9 g to 24.3 g in Shamrock Bell pepper under higher temperature of 27/21°C (day/night). Bakker (1989) found higher individual fruit weight of 119.7 to 1319 g under different humidity levels grown at 23/18°C (day/night) temperature.

Yield per plant : Variation was also found regarding per plant yield among the genotypes grown under both 24/18°C and 29/23°C. The highest per plant yield was achieved by the genotype SP009 (242.50 g) at low temperature and the same genotype also gave the highest per plant yield at higher temperature but the yield at the later situation was near about double than lower temperature (Table 2). The genotypes SP00l, SP002, SP004, and 5P012 showed the lower performance pertaining to per plant yield compared to the other genotypes. It was also found that the total yield per plant in most of the genotypes was higher at higher temperature than that of the low temperature. Cochran (1932) obtained per plant yield under warm condition ranging from 10.0 g to 795 g. The range being very high compared to the present investigation. But when Cochran studied under normal day length condition, yield varied from 65.9 g to 803.3 g which was also very high. This high yield might be due to the differences in the genotypes as well as variation in other environmental conditions.

Table 2. Yield/plant (g), fruit length (mm) and fruit diameter (mm) of 12 sweet pepper genotypes at different temperature regimes grown at AVRDC, Taiwan during 1999-2000.

Genotypes	Yield/plant (g) at temperature		Fruit length (mm) at temperature		Fruit diameter (mm) at temperature	
	24/18°C	29/23°C	24/18°C	29/23°C	24/18°C	29/23°C
SP00l	82.33h	31.05e	59.47f	49.01e	23.16f	18.63d
SP002	136.70d	56.83de	67.74ef	56.07de	28.00e	26.35c
SP003	106.10efg	124.70b-e	81.24be	71.45c	52.32c	38.98b
SP004	117.90e	52.56de	84.87b	82.95b	52.96c	41.30b
SP005	79.94h	93.17cde	66.04def	48.48e	46.08d	42.34b
SP006	92.38gh	145.70bcd	69.l0de	49.69e	51.50c	48.45a
SP007	97.92fg	170.00bc	60.88ef	56.18de	58.18b	53.44a
SP008	111.50ef	161.50bc	78.38bc	68.65 c	56.21bc	50.77a
SP009	242.50a	437.00a	121.30a	110.90a	45.08d	39.72b
SP010	118.l0e	219.30b	67.29def	59.47d	58.76b	50.17a
SP01l	187.70c	189.10bc	73.00cd	67.20c	65.97a	40.83b
SP012	227.30b	106.50cde	74.27cd	63.64cd	58.59b	53.29a
Level of significance	**	**	**	**	**	**
CV(%)	6.51	32.54	6.69	6.65	5.65	6.58

In a column, means followed by common letters are not significantly different from each other at 1% level of probability by DMRT.

Fruit length : The length of fruit was highly influenced by the high and low temperatures. It was also observed the fruit size reduced remarkably due to high temperature (Table 2). The maximum fruit length (121.30 mm) was measured in SP009 at low temperature, while the lowest in SP00l (59.47 mm). The genotype SP009 gave the highest fruit length at higher temperature also and the genotype SP00l (49.01mm) also gave the least fruit length when grown under low temperature condition. The fruit length of sweet pepper was 92.00 mm under screen house and 87.00 mm in the open field (Ryiski and Spigelman, 1986b). Fruit weight, length, and width were the greatest at the temperature of 25/18°C (day/night), which is in agreement with the present findings (Ali and Kelly, 1982).

Fruit diameter: Fruit diameter ranged from 23.16mm to 65.97mm in SP00l and SP01l, respectively, under low temperature condition. (Table 2). Under high temperature condition, SP007 produced fruits with the highest diameter (50.77 mm). SP00l showed the lowest fruit diameter (71.00 mm) in screen house (Ryiski and Spigelman, 1986a) and 67.00 mm under the open field condition.

Proline content in leaves : Under lower temperature of 24/18°C, the genotypes SP002 produced the higher amount of proline (0.22 µ mol/g FW) and it was superior to other accessions. Marked variation was observed on the production of leaf proline under high temperature condition (29/23°C).The genotype SP009 had the higher proline content (0.09 µ mol/g FW) under high temperature condition,

Table 3. Proline content of leaves of 12 sweet pepper genotypes under two different temperature regimes grown at AVRDC, Taiwan during 1999-2000.

Genotypes	Proline content of leaves (µmol/g FW) at temperature	
	24/18°C	29/23°C
SP00l	0.12b	0.06fgh
SP002	0.22a	0.03h
SP003	0.05d	0.11bcd
SP004	0.09cde	0.04gh
SP005	0.05e	0.07efg
SP006	0.04ef	0.13abc
SP007	0.03f	0.08c-f
SP008	0.04ef	0.14ab
SP009	0.03f	0.16a
SP010	0.06d	0.l0de
SP011	0.05d	0.07efg
SP012	0.09cde	0.07efg
Level of significance	**	**
CV (%)	18.37	15.97

In a column, means followed by common letters are not significantly different from each other at 1 % of level of probability by DMRT.

which was statistically at par with the genotypes SP006 and SP008. Proline content of the sensitive genotypes decreased under high temperature conditions compared to low temperature and the heat tolerant variety produced higher quantity of proline in leaf under high temperature conditions. Thus, from the Table 3, it seemed that the four lines viz., SP00l, SP002, SP003, and SP012 were not heat tolerant, which is in consonance with the categorization of the genotypes pertaining to the traits investigation data. Kuo *et al.* (1986) studied the leaf proline content of tomato under high temperature condition and they found that under high temperature condition, proline content increases as has been reflected in this investigation.

Conclusion

On the basis of the results of the experiment, it may be concluded that percent fruit-set and fruit size in plants raised at 24/18°C was higher than at 29°/23°C. Yield per plant was higher at 29/23°C than 24/18°C. Eight genotypes, namely SP003, SP005, SP006, SP007, SP008, SP009, SP010, and SP01l were found to be heat tolerant and the rest four were heat sensitive. Proline content in heat tolerant genotypes was comparatively high than the sensitive ones. Based on the investigations, SP006, SP007, SP008, SP009, SP010, and SP011 may be recommended as heat tolerant genotypes to proceed on for varietal development of sweet pepper in Bangladesh.

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