Vegetative Growth, Fruit Development, and Fruit Quality of Pepper (*Capsicum annuum* L.) Plants Under Various Temperature Regimes

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Abstract

Pepper (*Capsicum annuum* L.), belonging to the Solanaceae family, is an economically important crop in Korea and cultivated widely as a spice crop. Pepper plants have originated in South America and spread in a wide range of warm, subtropical and tropical regions throughout the world. During the growing season, various climatic and soil factors, including air temperature, light intensity, and precipitation, and soil conditions, have impacts on the growth and development of pepper plants. Particularly, the temperature is one of most major environmental factors impacting on processes such as flowering, fruit set, and fruit growth. In this study, we investigated the impact of temperature stress on the vegetative growth, fruit development, and the fruit quality of the plants. The temperature ranges of 20-25˚C was optimum for the vegetative growth and fruit development of plants. On the other hand, the high temperature (30˚C) reduced generally the fruit development such as the fruit-set and fruit growth, although enhanced the vegetative growth. The low temperature (15˚C) caused the short shoot height, and the small number of main branches (nodes), whileas resulted in the elongate fruits, and the long green fruit period. Under conditions of optimum temperature (20-25˚C) and high temperature (30˚C), the fruit development was advanced by 15 and 20 days, respectively, compared to that of the plants at low temperature (15˚C). Furthermore, the fruit color change was significantly advanced in the optimum temperature (20-25˚C) and high temperature (30˚C). However, high temperature (30˚C) not only reduced the number of total fruits, but also increased the number of short or malformed fruits. Total free sugar contents of red-ripe fruits were significantly higher in the optimum temperature (20-25˚C), while capsaicinoid contents of red-ripe fruits increased with the rise of temperature in the range of 15 to 30˚C.

Materials & Methods

Plant material and growth conditions : The pepper (*Casicum annuum* L. cv. Muhanjilju) plants were grown under four growth chambers controlled at 15, 20, 25 and 30℃, respectively, and 10 pots one plant was planted were placed in each chamber.

Analysis of plant growth and fruit characteristics : The impacts of temperature on the vegetative growth, fruit development, and fruit quality of pepper plants were determined and analysed 100 days after temperature treatment.

Gas-exchange measurements : Net photosynthetic rate (A), stomatal conductance (g_s), transpiration (E), and dark respiration rate (R_d) were measured on fully-expanded leaves at the 5-6th branches 80 days after temperature treatment with a gas-exchange system (Lcpro$^+$, ADC BioScientific, UK).

Analysis of free sugar and capsaicinoid contents : The samples for total free sugar and capsaicinoid analysis were selected on the fruit of the 5-6th branches 80 days after temperature treatment. The total free sugar content was analysed by the use of high performance anion exchange chromatography coupled with pulse amperometric detection (HPAEC–PAD). Capsaicinoid content was analysed by ultra performance liquid chromatography (UPLC, Waters, USA) equipped with a Acquity UPLC HSS T3 column (100 x 2.1 mm, Waters, USA).

Statistical analysis : The data were analysed using the SPSS statistical package version 7.5 (SPSS lnc., Chicago, USA). Variance analysis of the data was performed using one-way ANOVA and mean values were compared by Duncan's multiple range test at the $p<0.05$ level of significance.

Results

Table 1. Effect of temperature on the vegetative growth of pepper (*Capsicum annuum* L.) plants grown for 100 days under different temperature conditions.

Parameters	Temperature treatments			
	15℃	20℃	25℃	30℃
Plant height (cm)	65.8±1.3c	71.2±3.5bc	78.2±2.7b	97.2±2.3a
Root length (cm)	41.8±1.6a	38.5±0.7a	45.5±6.1a	43.0±3.9a
Node number of main branch	9.6±0.2c	11.6±0.8b	12.8±0.7b	15.0±0.3a
Plant dry weight (g/plant)	87.5±3.4a	91.4±2.8a	102.5±6.9a	102.2±7.2a
Fruit dry weight (g/plant)	56.7±2.8ab	60.6±2.0ab	68.1±5.1a	47.5±10.6b
Leaf dry weight (g/plant)	13.0±0.5b	14.4±0.8b	13.9±0.9b	17.3±1.3a
Stem dry weight (g/plant)	13.3±0.9b	13.6±1.0b	17.2±1.6b	34.2±8.5a
Root dry weight (g/plant)	4.54±0.58a	2.92±0.20b	3.38±0.35b	3.16±0.20b
Shoot/Root (ratio)	19.7±3.0b	31.0±2.8a	30.6±3.8a	32.0±3.6a
Plant water content (%)	82.6±0.58a	83.2±0.38a	78.0±0.63b	78.9±0.65b

Table 2. Effect of temperature on fruit developmental period of pepper (*Capsicum annuum* L.) plants under different temperature conditions.

Developmental stage	Temperature treatments			
	15℃	20℃	25℃	30℃
Anthesis to mature green (days)	30.1±0.2a	25.5±0.4b	21.6±0.2c	18.5±0.3d
Mature green to deep red (days)	16.5±0.2a	11.0±0.3b	7.6±0.2c	5.4±0.2d
Anthesis to mature deep red (days)	45.6±0.6a	36.5±0.4b	29.1±0.3c	23.9±0.3d

Table 3. Photosynthetic characteristics of leaves from pepper (*Casicum annuum* L.) plants grown under different culture condition.

Photosynthetic parameters	Temperature treatments			
	15℃	20℃	25℃	30℃
Net photosynthetic rate (*A*, μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$)	21.5±0.12a	15.2±0.87b	13.0±0.36b	8.0±1.07c
Dark respiration (R_d, μmol $CO_2 \cdot m^{-2} \cdot s^{-1}$)	-1.89±0.10a	-2.07±0.21a	-2.19±0.19a	-2.25±0.09a
Stomatal conductance (g_s, mol $H_2O \cdot m^{-2} \cdot s^{-1}$)	0.25±0.006a	0.17±0.006b	0.17±0.002b	0.12±0.008c
Transpiration rate (*E*, mmol $H_2O \cdot m^{-2} \cdot s^{-1}$)	3.56±0.07a	2.78±0.07b	2.60±0.02b	2.56±0.13b
Intrinsic water use efficiency (*WUE*i, μmol $CO_2 \cdot$mmol H_2O)	6.05±0.10a	5.43±0.21a	5.02±0.14a	3.25±0.56b
Instantaneous transpiration efficiency (*ITE*, μmol ·mol)	86.9±1.76a	86.7±2.17a	75.9±2.64a	42.0±5.30b
Carboxylation efficiency (*CE*, mol·$m^{-2} \cdot s^{-1}$)	0.08±0.001a	0.06±0.001b	0.06±0.002b	0.03±0.002c
Ratio of intercellular to ambient CO_2 concentration (C_i/C_a)	0.56±0.004b	0.57±0.011b	0.59±0.013b	0.72±0.026a
Stomatal limitated value (L_s)	0.44±0.004a	0.43±0.011a	0.41±0.013a	0.28±0.026b

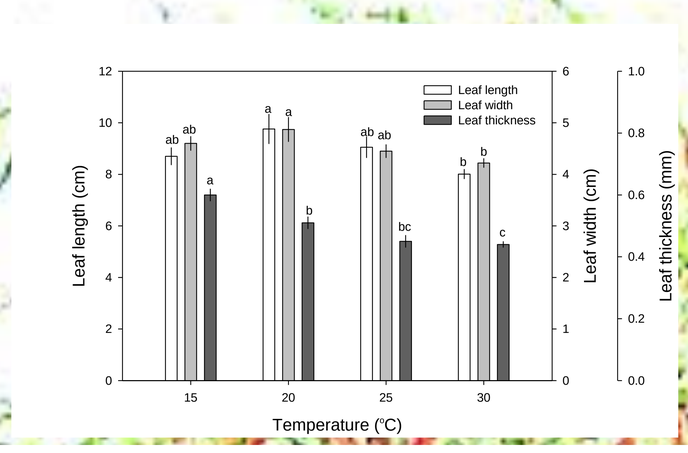

Figure 1. Effect of temperature on morphological traits of leaves from the 5-6th branches of pepper (*Capsicum annuum* L.) plants grown for 80 days under different temperature conditions.

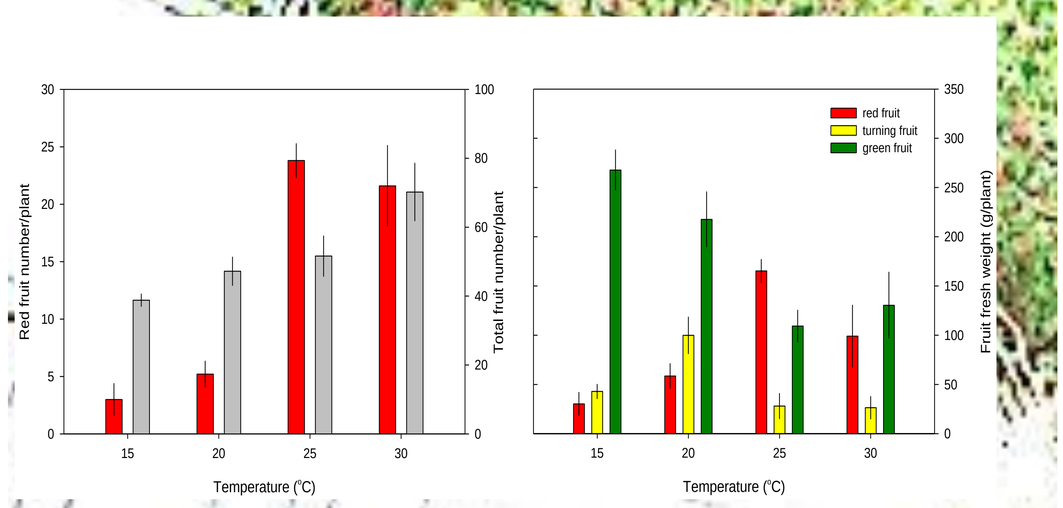

Figure 2. Effect of temperature on fruit numbers and fruit yield of pepper (*Capsicum annuum* L.) plants grown for 100 days under different temperature conditions.

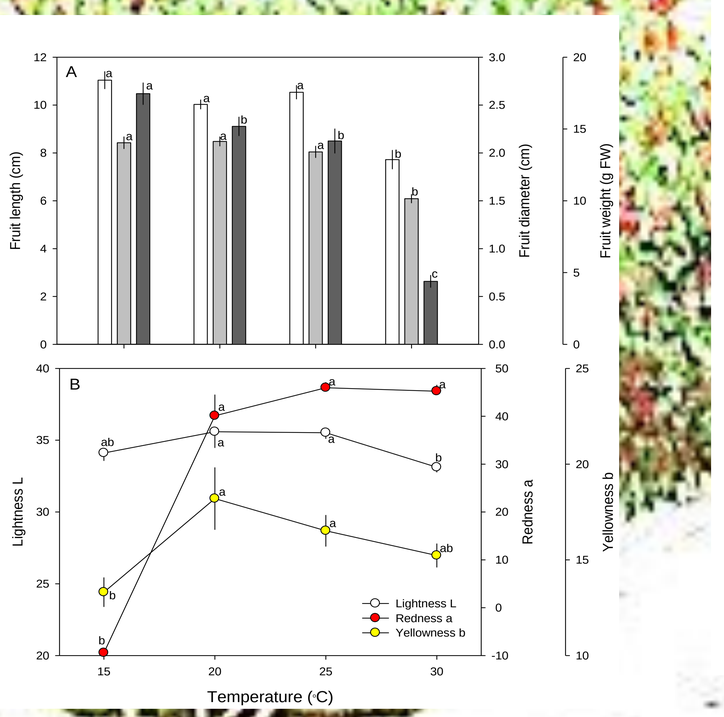

Figure 3. Effect of temperature on morphological traits and surface color characteristics in fruits of the 5-6th branches of pepper (*Capsicum annuum* L.) plants grown for 80days under different temperature conditions.

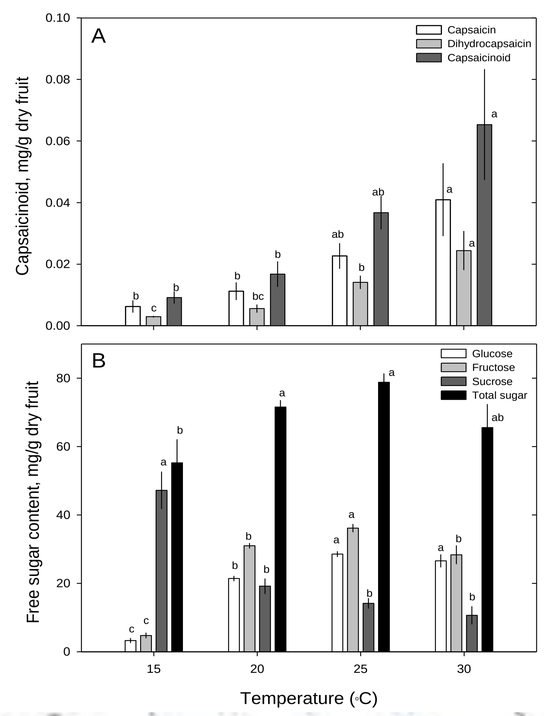

Figure 4. The contents of capsaicinoids and free sugars of fruits of the 5-6th branches of pepper (*Capsicum annuum* L.) plants grown for 80days under different temperature conditions.

Conclusion

Dry weight, pericarp color development, and chemical composition (e.g. total free sugar, capsacine) in fruits as well as photosynthetic rate and respiration rate in leaves were affected during growth period by culture temperature. In Jeju and the southern region of Korea, optimum daytime temperatures required for pepper growth can be easily achieved even in winter while optimum night temperatures cannot. It indicates that winter cold temperature could affect the fruit setting due to poor pollination and delay fruit maturation, and fruit harvest will be delayed in the greenhouse culture. Therefore, heating during the night may be necessary to increase fruit yield and improve fruit quality.

References

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