The effects of yield properties, antioxidant contents, and pollen viability of adzuki bean (Vigna angularis L.) response in temperature gradient greenhouse and growth periods

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Abstract

The quality and yield of crops produced by field cultivation are expected to decrease for the recent global climate change caused by high temperature. The plant reproductive stage associated with crop yields is vulnerable to unusal temperatures. This study analyzed the yield properties, antioxidant contents, and pollen viability of 'Arari' adzuki bean (Vigna angularis L.) under high temperature stress in a temperature gradient greenhouse which forms 0 to 6° C above the outside in 2022, Miryang, Korea. We divided the growth periods by vegetative, anthesis and mature stage, and the highest period was vegetative stage compared by mean of DMT(daily mean temperature) among vegetative stage (con: 27.5°C, T4: 30.5°C), anthesis stage (con: 24.3°C, T4: 27.0°C), mature stage (con: 21.8°C, T4: 26.4°C). The lowest yield (4.15±3.15 g) was the highest temperature (T4: low, 21.4°C; average, 27.0°C; high, 34.6°C) during the anthesis stage. The growth and yield were good at 40.5°C in the vegetative stage, but when the average temperature was 27.0°C or higher, growth was poor and the yields were decreased during the flowering period. Total polyphenol and flavonoid contents were increased and the pollen viability was 40.75% in the whole growth period by high temperature (T4: low, 22.9°C; average, 28.8°C; high, 36.9°C). These results represented that the antioxidant levels increased when the antioxidant component was affected at higher temperatures than normal temperatures and the pollen viability related yield decreased as the temperature increased. Our result are reported as the basic data for field growers and breeding of thermos-tolerance in adzuki beans to prepare for the changeable future climate.

Materials & Methods

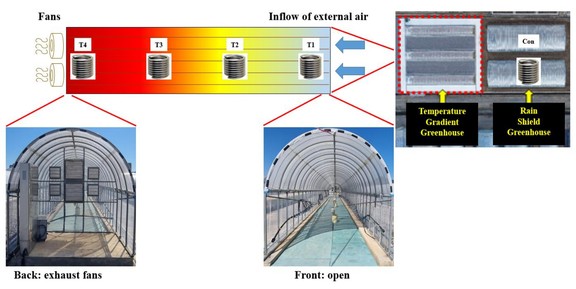

Figure 1. Pictures and schematic illustration of a temperature gradient greenhouse. Con: rain shield greenhouse, T1: control + 1°C, T2: control + 2°C, T3: control + 3°C, T4: control + 4°C.

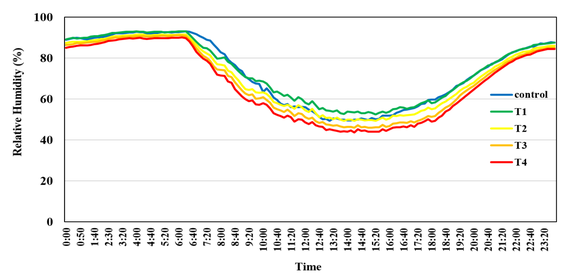

Figure 2. The daily average temperature according to the high-temperature treatment in 2021 and 2022. Con: rain shield greenhouse, T1: control + 1°C, T2: control + 2°C, T3: control + 3°C, T4: control + 4°C, WGP: whole growth period, VS: vegetative stage, AS: anthesis stage, MS: mature stage.

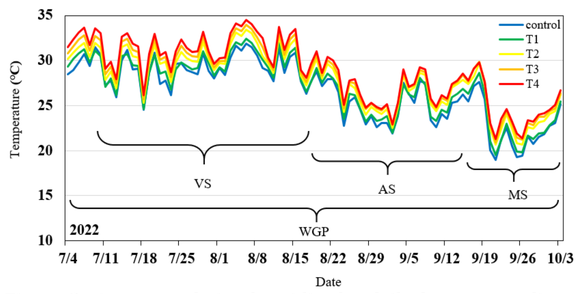

Figure 3. Average relative humidity by daily hours according to the high-temperature treatment of temperature gradient greenhouses in 2021 and 2022. Control: rain shield greenhouse, T1: control + 1°C, T2: control + 2°C, T3: control + 3°C, T4: control + 4°C.

Result

Table 1. Growth components of "Arari" grown to high temperatures in 2022.

Treatment[z]		Stem length (cm)	Stem diameter (mm)	No. of nodes	No. of branches
Con		54.2±4.6 abcd	7.1±0.4 abc	15.9±0.9 ab	3.6±1.4 ab
WGP	T1	53.4±5.0 bcde	7.4±0.8 a	15.1±0.7 abc	3.7±1.1 ab
	T2	57.4±2.5 ab	6.6±0.6 bcd	15.5±0.5 abc	3.0±0.8 b
	T3	57.4±4.4 ab	6.8±0.6 abc	15.9±1.1 ab	4.0±0.5 ab
	T4	57.2±4.7 ab	6.6±0.7 bcd	15.6±1.3 abc	4.4±1.0 a
VS	T1	52.1±6.7 cde	7.1±1.2 abc	14.6±1.2 c	4.0±1.6 ab
	T2	56.1±3.5 ab	6.4±0.5 cd	15.0±0.8 bc	4.0±1.1 ab
	T3	55.3±3.1 ab	6.4±0.7 cd	15.2±1.3 abc	3.8±0.8 ab
	T4	57.2±3.5 ab	6.0±0.9 d	15.4±1.1 abc	3.8±1.5 ab
AS	T1	50.1±4.2 def	7.1±0.4 abc	15.6±0.5 abc	3.6±1.5 ab
	T2	53.6±4.8 bcde	7.1±0.6 abc	15.9±1.3 ab	3.3±1.1 ab
	T3	52.9±4.2 bcde	6.9±0.7 abc	15.8±0.9 ab	3.3±0.9 ab
	T4	49.4±4.2 ef	7.1±0.9 abc	15.2±0.8 abc	3.8±1.0 ab
MS	T1	47.2±3.5 f	7.3±0.8 ab	16.2±1.1 a	4.0±1.3 ab
	T2	58.8±5.6 a	7.0±0.5 abc	15.9±1.0 ab	3.3±0.5 ab
	T3	54.4±5.4 abcd	6.6±0.7 bcd	15.3±0.9 abc	3.2±1.1 ab
	T4	50.3±5.7 def	7.0±0.7 abc	14.9±1.6 bc	3.8±1.2 ab

[z]Con: rain shield greenhouse, T1: control + 1℃, T2: control + 2℃, T3: control + 3℃, T4: control + 4℃, WGP: whole growth period, VS: vegetative stage, AS: anthesis stage, MS: mature stage.

[y]Data represent the means ± SD. Means represented by the same characters in a column are not significantly different from Duncan's multiple ranges test (DMRT) at the 5% level.

Table 2. Yield components of "Arari" grown to high temperatures in 2022.

Treatment[z]		No. of pods	100-seed weight (g)	Yield (g)
Con		12.8±5.2 abc	17.4±1.0 ab	53.7±9.9 ab
WGP	T1	11.9±4.6 abcd	16.1±0.8 abcde	46.6±5.9 abcde
	T2	11.9±4.0 abcd	14.9±0.3 e	36.7±1.7 def
	T3	11.2±4.8 abcd	13.1±0.6 ef	30.8±2.6 f
	T4	11.7±5.9 abcd	12.2±1.0 g	29.5±3.4 f
VS	T1	8.6±4.9 d	17.7±0.9 ab	33.7±2.0 ef
	T2	9.6±4.2 cd	17.8±1.7 a	39.3±5.1 cdef
	T3	10.7±5.0 bcd	17.6±0.5 ab	46.1±1.4 abcde
	T4	11.4±6.0 abcd	17.8±1.1 a	41.0±14.4 bcdef
AS	T1	11.7±6.5 abcd	17.3±0.7 abc	54.1±0.1 ab
	T2	13.2±4.2 abc	15.7±0.7 cde	53.4±11.3 ab
	T3	11.7±4.0 abcd	15.4±0.1 e	46.7±11.9 abcde
	T4	10.3±5.4 cd	14.7±0.7 e	30.5±12.8 f
MS	T1	12.3±4.5 abcd	17.1±0.7 abcd	51.7±3.4 abc
	T2	14.7±4.4 a	16.1±0.8 bcde	57.5±2.0 a
	T3	14.6±4.4 ab	14.5±0.9 ef	54.5±4.5 ab
	T4	12.1±4.8 abcd	15.6±1.0 cde	48.3±3.7 abcd

[z]Con: rain shield greenhouse, T1: control + 1℃, T2: control + 2℃, T3: control + 3℃, T4: control + 4℃, WGP: whole growth period, VS: vegetative stage, AS: anthesis stage, MS: mature stage.

[y]Data represent the means ± SD. Means represented by the same characters in a column are not significantly different from Duncan's multiple ranges test (DMRT) at the 5% level.

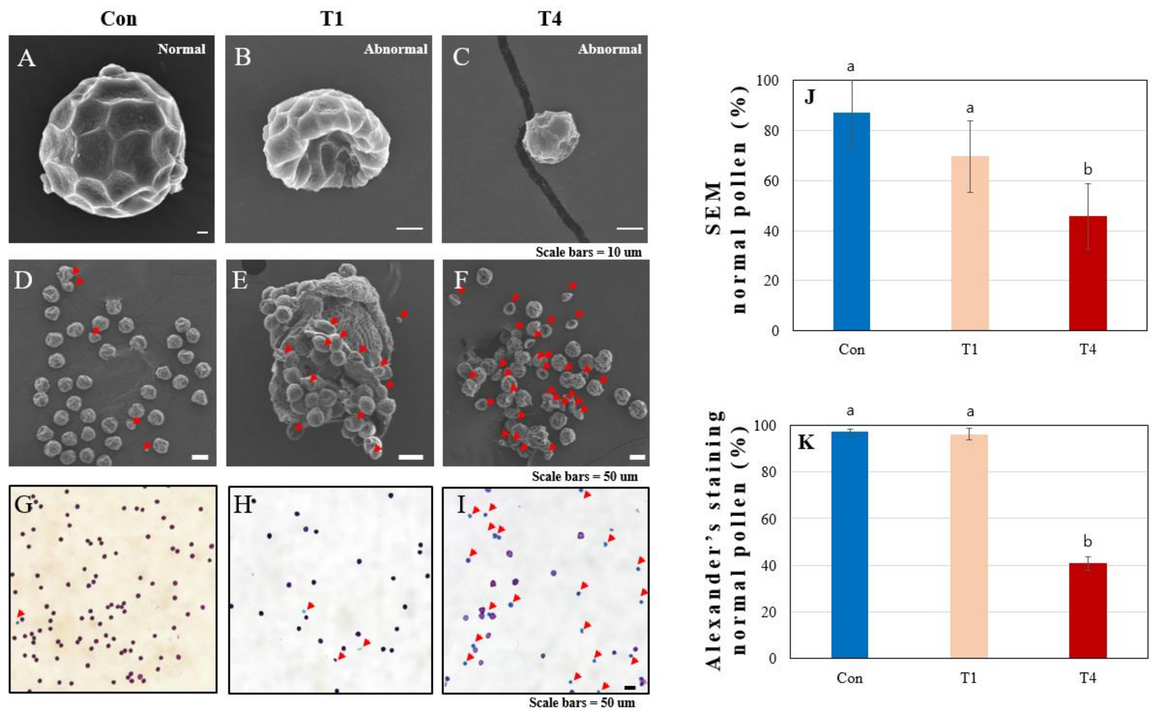

Figure 4. The pollen morphology and pollen viability of V. angularis cv. "Arari" at high temperatures in 2022. (A - F: Scanning electron microscopy (SEM) of pollen grains by high-temperature treatment control, T1 and T4; G-I: Alexander's staining of pollen grains by high temperature treatment control, T1 and T4; J and K: The proportion of normal pollen by scanning electron micrographs (SEM) and Alexander's staining (Con: rain shield greenhouse, T1: control + 1°C, T4: control + 4°C). The red arrows indicate abnormal pollen. Error bars indicate standard deviations, and differences were tested with one-way ANOVA, as indicated with letters, using Duncan's multiple tests ($p < 0.05$).

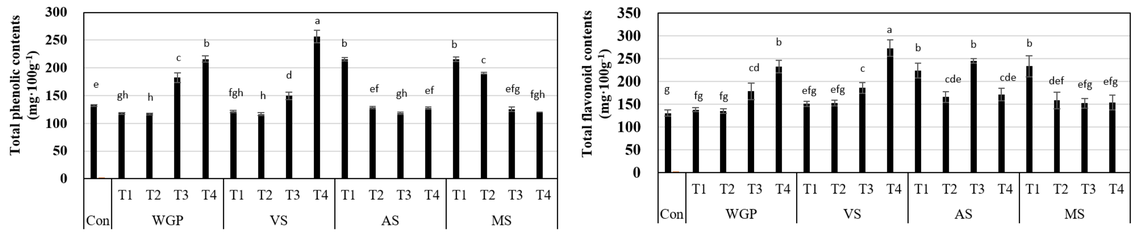

Figure 5. Comparison of total phenolic contents and total flavonoid contents of "Arari" in 2022. Error bars indicate standard deviations and differences were tested with one-way ANOVA, as indicated with letters, using Duncan's multiple tests ($p < 0.05$). T1: control + 1°C, T2: control + 2°C, T3: control + 3°C, T4: control + 4°C.

Reference

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