

Vegetative and Bulb Growth of Garlic (*Allium sativum* L.) in Response to Various Levels of Temperature

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ABSTRACT

Garlic (*Allium sativum* L.), one of the oldest cultivated crops, is the most widely used. It is consumed in both fresh and dried forms as an important ingredient for flavouring various vegetarian and non-vegetarian dishes. In addition, garlic has several medicinal values such as anticancer, antibacterial, and antifungal agents, etc. In this study, the effects of various levels of temperature on vegetative growth and bulb development of garlic were investigated. High temperature above 23°C enhanced vegetative growth (shoot height, pseudo-stem diameter, and number of leaves) during the initial stage of growth, suggesting that the high temperature is favorable to the growth of the aerial part of garlic. However, bulb development and growth during the intermediate or final stage of growth was great in the temperature ranges of 17-23°C. Furthermore, the bulb quality at harvest was significantly high in temperature below 20°C, whereas generally low in high temperature, especially at temperatures over 30°C. Cross section of garlic bulbs showed that cloves were formed normally in the temperature ranges of 14-17°C, while, in the temperature below 14°C or above 17°C, secondary growth of cloves was induced.

INTRODUCTION

Garlic (*Allium sativum*), one of a vegetable crops of major importance for many countries in the world, has been cultivated since ancient times. It is mainly used as spice, seasoning and flavoring agents for foods with significant beneficial effect on human health. Garlic is originated from Central Asia and spread to other parts of the world. According to FAO, the world annual production of garlic is about 10 million tones, and China and South Korea are most largely producers (FAO, 2001).

Temperature is one of the primary environmental regulators of crop growth, development, yield, and quality. Crops have basic requirements for temperature to complete their life cycle. Therefore, cardinal temperatures, minimum, optimum, and maximum, vary among crop species and among the processes within a species. In addition, temperature extremes such as high and low temperatures can have damaging effects on crop performance. High temperature causes reduction in storage root formation and growth through the changes in plant hormone synthesis or activation and dry matter partitioning and bulking of storage roots and/or tubers. The possible impacts of temperature have not yet been fully comprehended for most species of root and tuber crops including sweet potato, potato, onion, garlic, etc. Three important physiological events in the growth phase of garlic plants are responsible for final crop productivity, namely clove initiation, bulb development, and maturity, which are control by temperature. The present study on the effects of various temperature on vegetative growth and bulb development of garlic were investigated.

MATERIALS & METHODS

■ **Plant materials and Culture conditions** : garlic (*Allium sativum* L.) was planted on 20 December 2013 in Soil-Plant-Atmosphere research (SPAR) chambers under different levels of day/night temperature (11/07, 14/10, 17/12, 20/15, 23/18, 28/23°C)

■ **Growth characterization** : The characters of shoot (height, pseudo-stem diameter, leaf numbers) and bulb (height, diameter, fresh weight, clove numbers, clove weight, etc.) were measured.

■ **Chlorophyll fluorescence measurements** : The fluorescence induction kinetics were measured with a portable fluorometer, Plant Efficiency Analyzer (PEA; Hansatech Ltd., King's Lynn, Norfolk, England), in a fast kinetics mode with 1500 $\mu\text{mol}/\text{m}^2/\text{s}$ of actinic light.

■ **Determination of nutritional and chemical composition** : Mineral nutrients and free sugars of garlic bulbs were determined according to the method of Petropoulos et al (2015), with some modifications.

■ **Statistical analysis** : Analysis was performed using the SPSS statistical package version 7.5 (SPSS Inc., Chicago, USA).

RESULTS

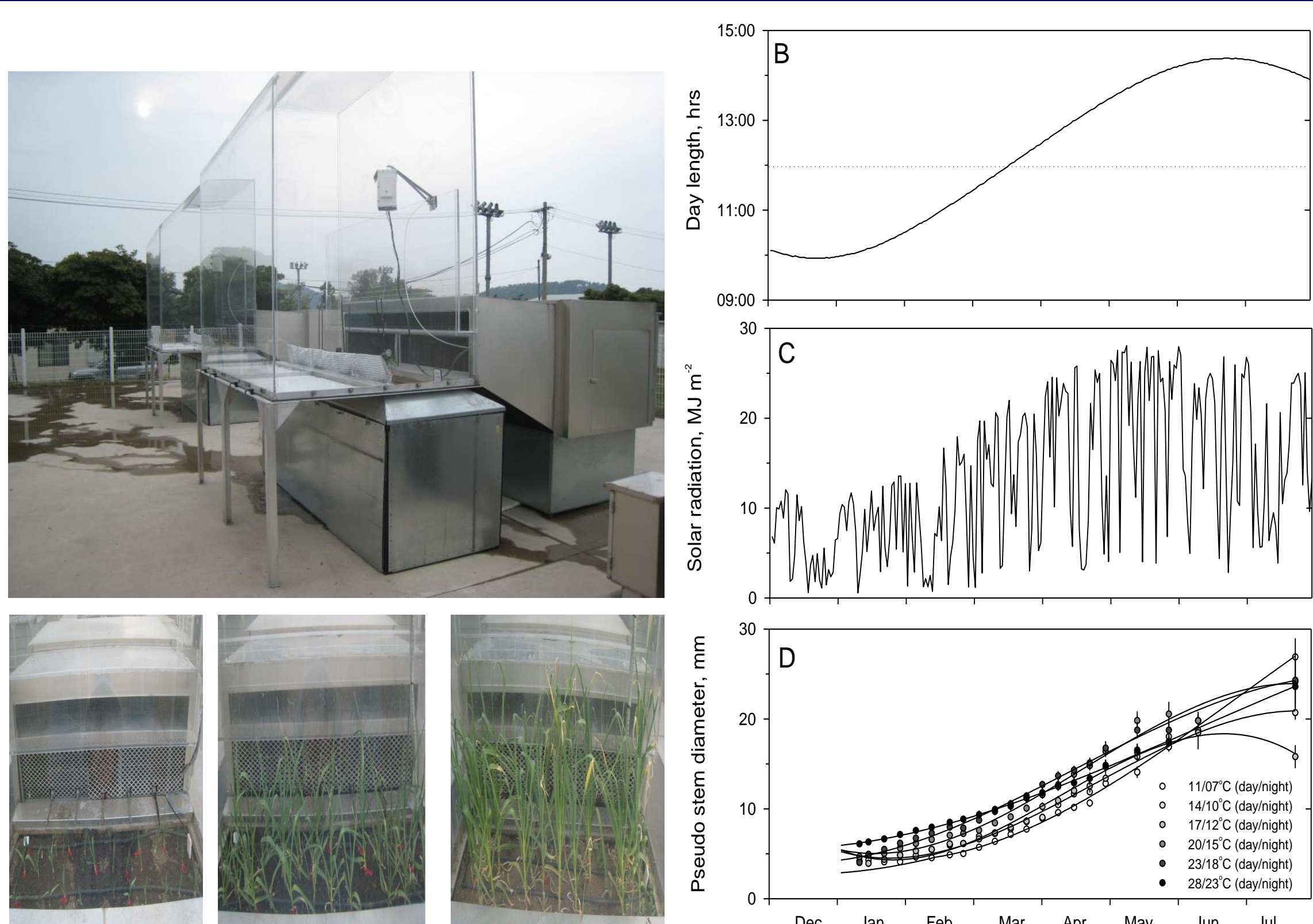


Figure 1. Culture system (A) and seasonal changes of day length (B), solar radiation (C), and pseudo-stem development (D) during growth of garlic plants under different levels of temperature.

Table 1. Morphological characters of garlic plants grown under different levels of temperature

Temperature (day/night)	Pseudo stem diameter (mm)	Bulb height (mm)	Bulb diameter (mm)	Bulb fresh weight (g)	Clove number/Bulb	Normal clove number/Bulb	Clove fresh weight (g)
11/07°C	26.9±2.37 a	38.1±0.79 bc	47.4±1.20 bc	52.8±4.81 cd	8.0±0.63 b	5.4±1.12 bc	3.6±0.45 c
14/10°C	20.7±0.78 ab	42.0±1.65 ab	55.5±1.65 ab	75.3±4.38 bc	7.8±0.58 b	7.6±0.68 ab	6.7±0.56 ab
17/12°C	15.8±1.28 b	43.0±1.55 ab	59.6±3.03 a	85.0±9.87 ab	10.0±0.00 ab	9.2±0.37 a	7.2±0.63 a
20/15°C	24.1±2.58 a	46.9±1.34 a	65.4±3.51 a	110.1±9.69 a	11.0±1.05 a	6.2±1.39 abc	5.2±0.52 abc
23/18°C	24.3±4.00 a	40.0±3.88 bc	58.1±6.19 a	79.3±16.3 bc	8.0±1.41 b	3.4±1.66 c	4.7±0.65 bc
28/23°C	23.6±0.71 a	33.9±1.41 c	38.0±1.55 c	31.6±2.32 d	0.0±0.00 c	0.0±0.00 d	0.0±0.00 d

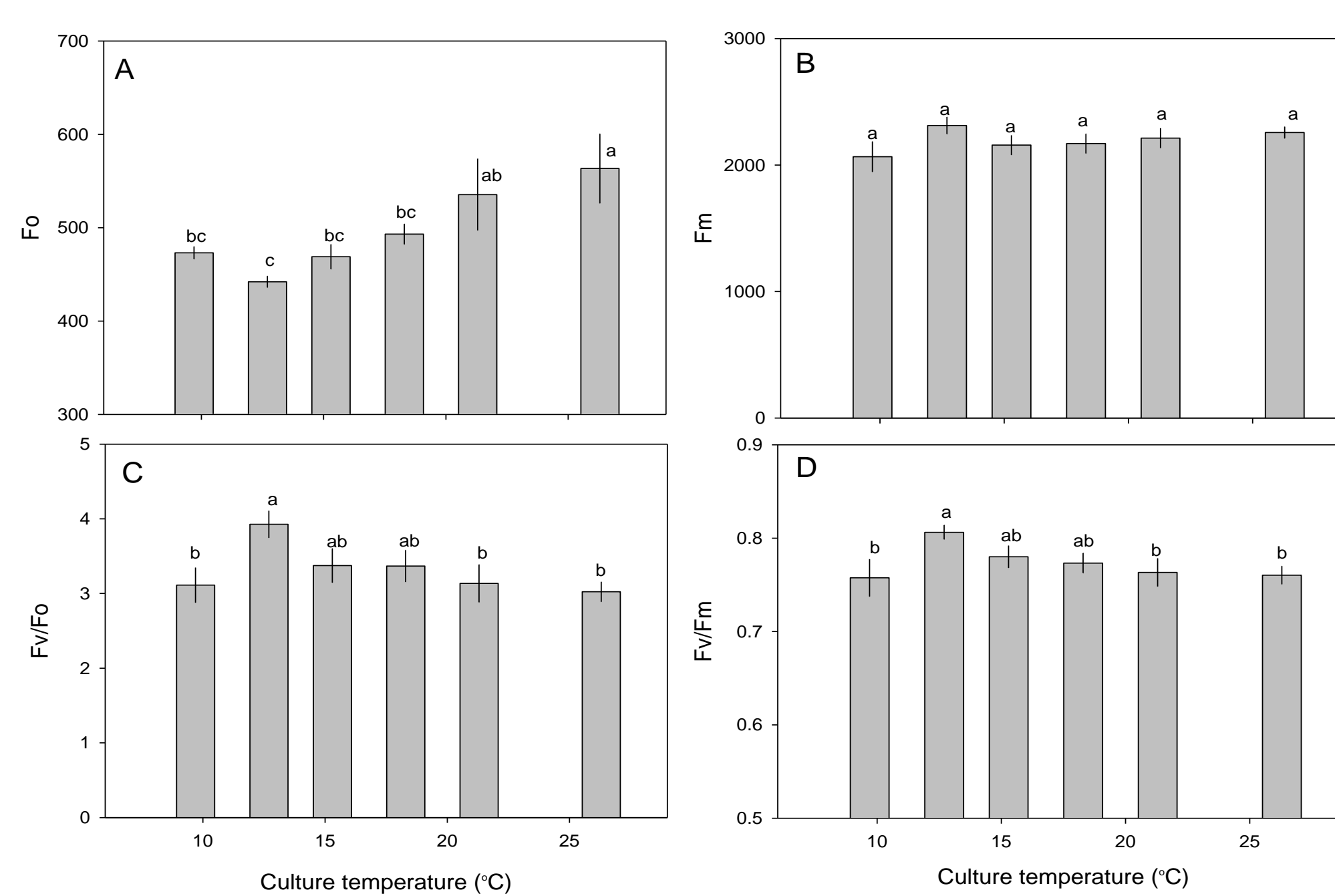


Figure 4. Changes of initial fluorescence (Fo), maximal fluorescence (Fm), potential photochemical efficient (F_v/F_o) and photochemical efficiency of photosystem II (F_v/F_m) in leaves of garlic plants under different levels of temperature

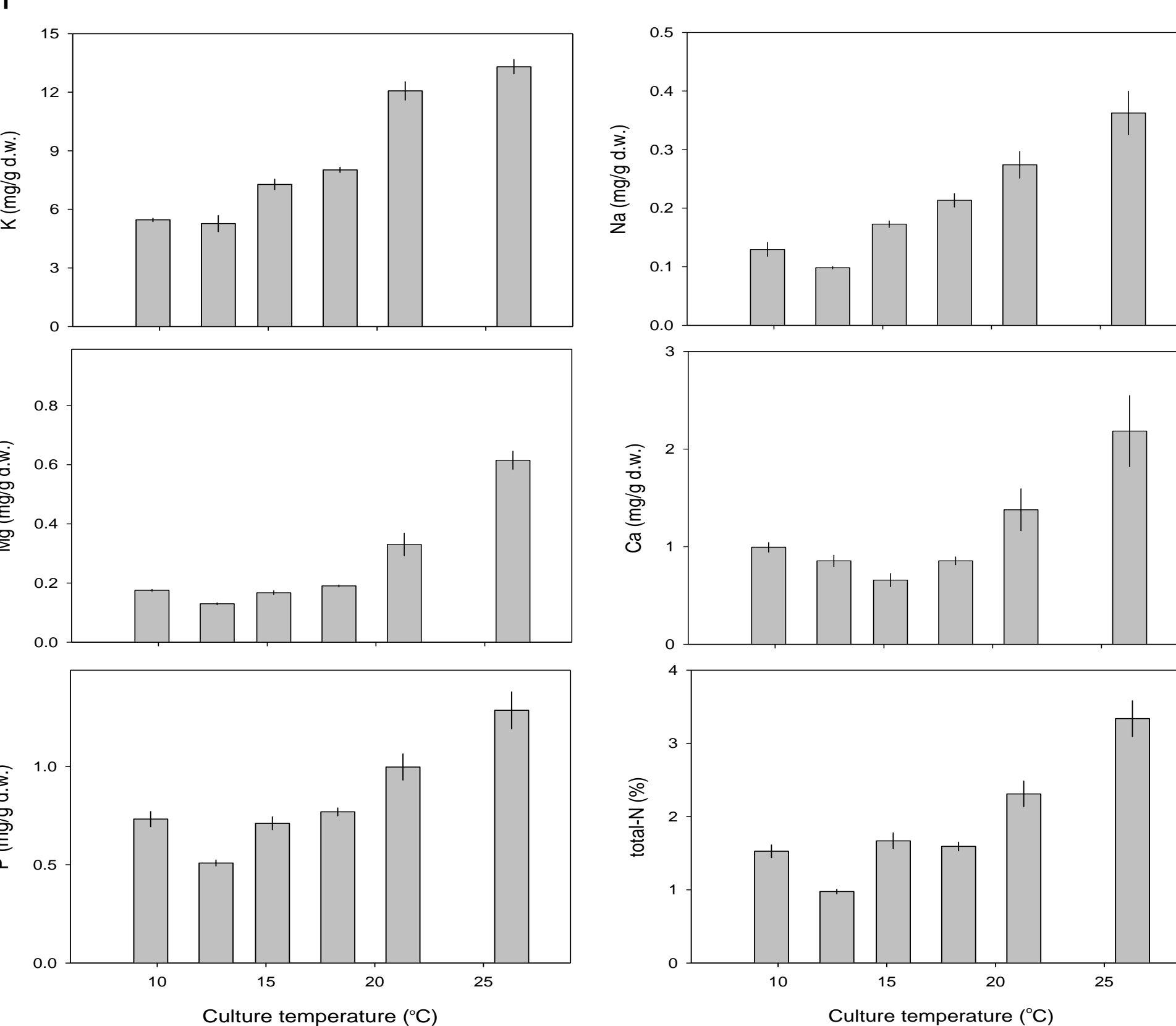


Figure 5. Contents of K, Na, Mg, Ca, P, total-N in bulbs of garlic plants grown under different levels of temperature.

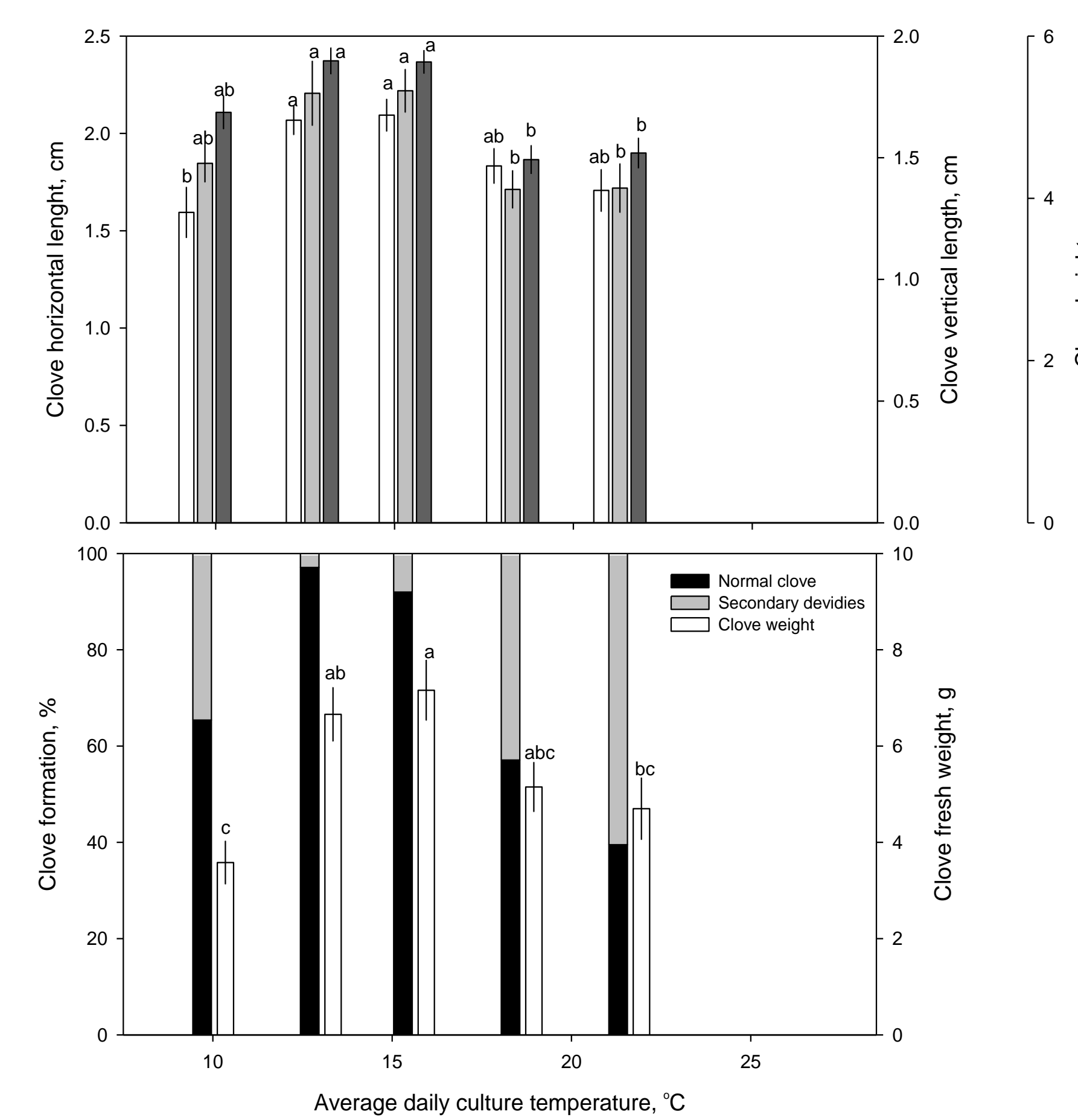


Figure 3. Shape characters and weight in cloves of garlic plants grown under different levels of temperature

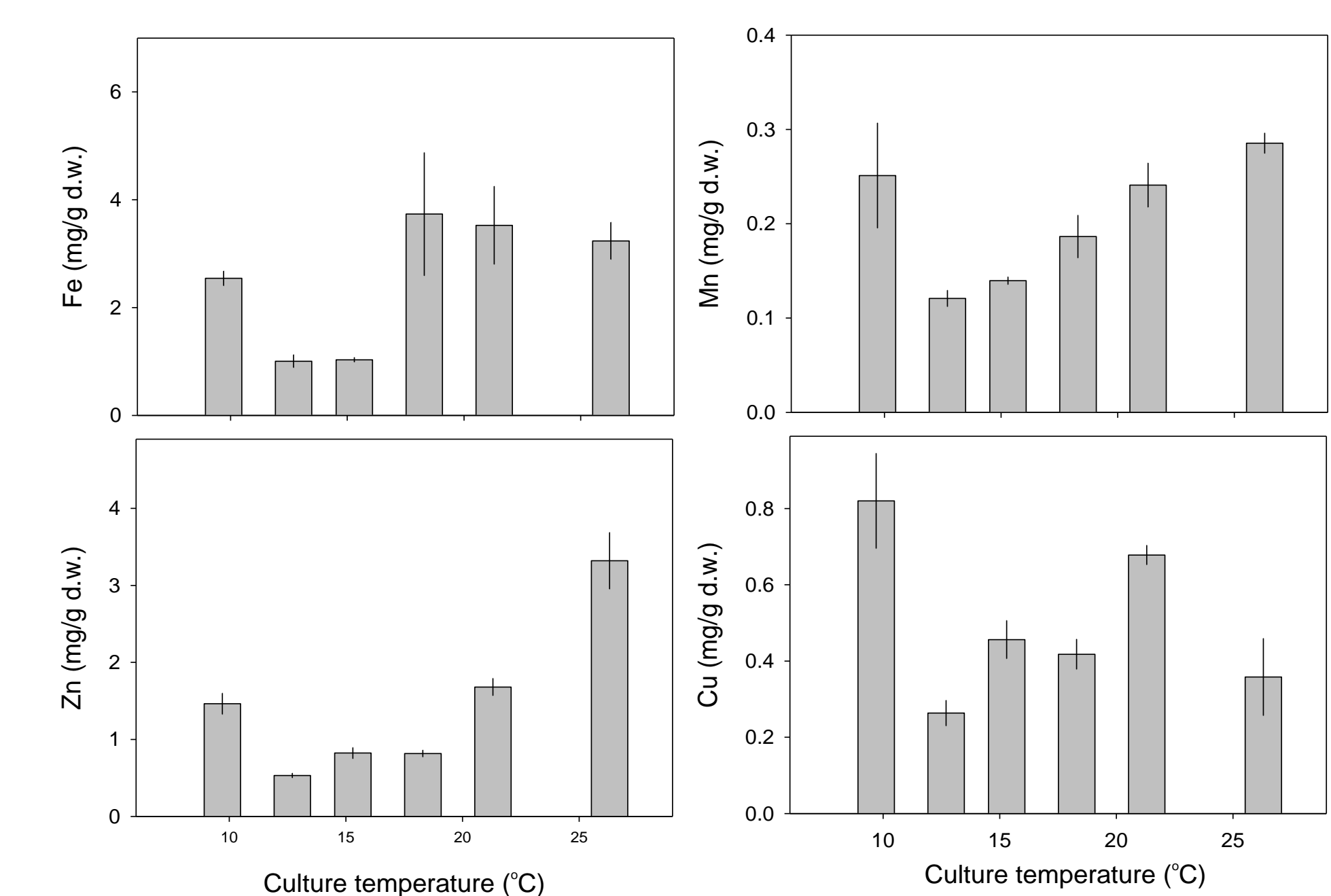


Figure 6. Contents of Fe, Mn, Zn, Cu ions in bulbs of garlic plants grown under different levels of temperature.

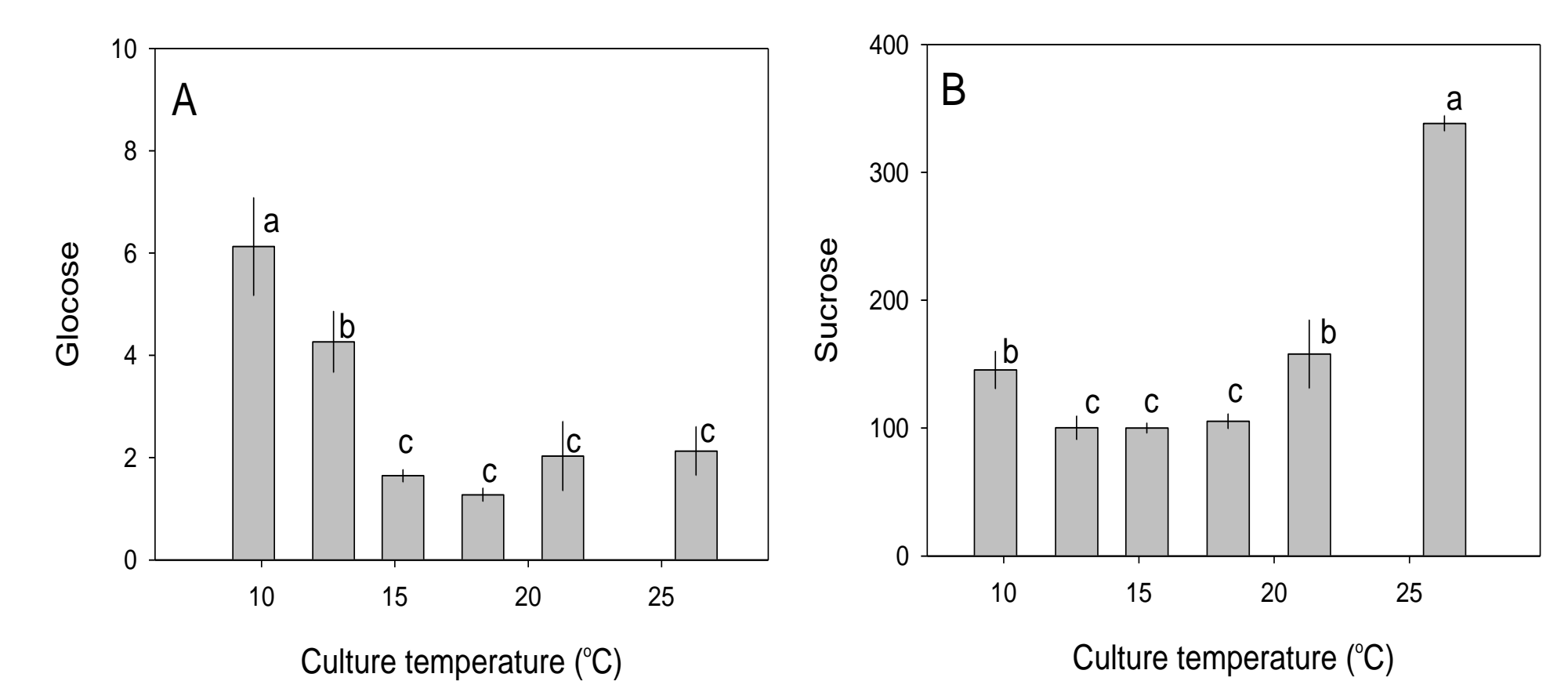


Figure 7. Glucose and sucrose concentrations in bulbs of garlic plants grown under different levels of temperature.

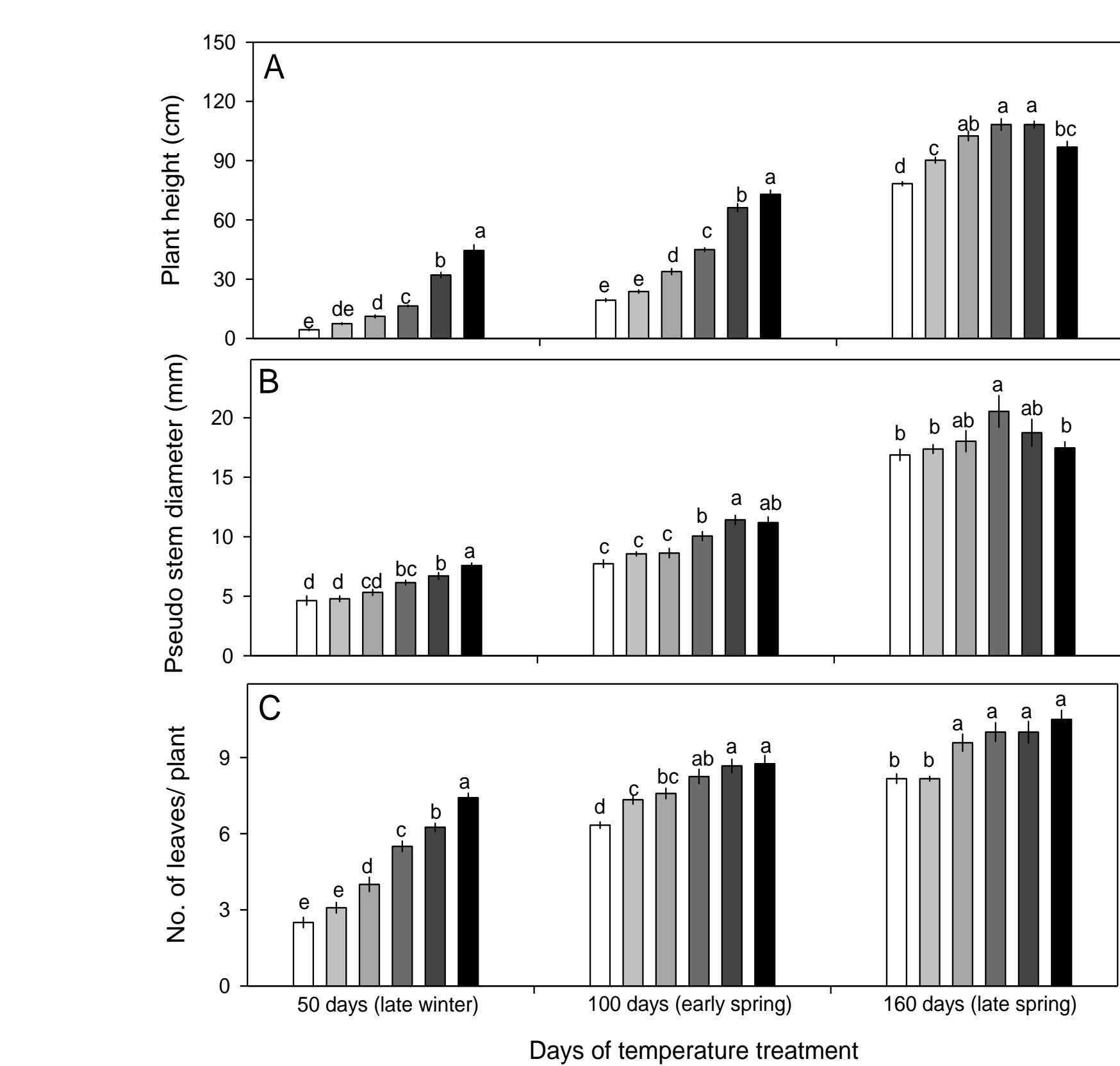


Figure 2. Effect of temperature on plant height (A), pseudo-stem diameter (B), and leaf number (C) of garlic plants grown under different levels of temperature for 50, 100, and 160 days.



Figure 2. The bulb shapes and cross sectional views of garlic plants grown under different levels of temperature (11/7, 14/10, 17/12, 20/15, 23/18, 28/23°C).

CONCLUSION

- The high temperature affects positively on growth of the aerial part of garlic in the initial stage of growth.
- Bulb development, growth and quality during the intermediate or final stage of growth of garlic plants was great in the temperature ranges of 17-23°C.
- Cross section of garlic bulbs showed that cloves were formed normally in the temperature ranges of 14-17°C, while, in the temperature below 14°C or above 17°C, secondary growth of cloves was induced.
- The F_v/F_o and F_v/F_m values were high at 14-17°C, and decreased above 20°C.

REFERENCES

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