施設內 수박재배시 에너지 節約을 위한 夜間溫度의 調節

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Control of Diurnal Night Temperature on Watermelon (*Citrullus vulgaris* S.) for Energy Saving Greenhouse

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Abstract

In winter, most of the energy for a greenhouse crop is supplied during the night. Since watermelon is grown under high night temperature, the experiments were set up to investigate night temperature influence on watermelon in order to obtain the best economic output.

Day temperatures ranged from 25℃ and 30℃; night temperatures ranged from 20℃ to 30℃ at 5℃ interval. Two cultivars of watermelon(*Citrullus vulgaris* S. 'Binna' and 'Kamro') treated with 30/30℃ yielded maximun leaf areas, flowers and leaf numbers. 30(14h)/25(10h)℃ or 30(12h)/25(12h)℃ grown plants had higher germination ratio and more dry weight and chlorophyll than those of 30/30℃ which were the highest temperature integral. Although 25/25℃ and 30/20℃ regime are same average temperature, the growth of watermelons at 30/20℃ was significantly higher than 25/25℃. 'Binna' was growing more than 'Kamro' at the same temperature. Leaf area ratio(LAR) was reduced with increasing DIF temperature from 30/30℃ to 30/20℃, but leaf weight ratio(LWR) was increased.

Key words : watermelon, leaf area ratio, leaf weight ratio, DIF, energy saving.

Introduction

New control systems that will provide better plant growth conditions with low energy use are being developed and marketed[10,11]. Setpoint for temperature in greenhouse crops can be adjusted continuously in order to obtain the best ecomomic output[2,6,8,10,11]. Traditional greenhouse crops are cultivated with the day temperature somewhat higher than the night temperature[11]. In Mediterranean countries, 90% of the consumed energy in greenhouse is consumed during the night by the heating system. Langhans et. al[10]. showed for lettuce the efficiency of "sliding", or averaging night temperature, as a method of energy saving in the greenhouse.

However, night temperature control is an important cost factor and at the same time, it also has a great effect on crop growth and development[3,9]. We investigated the influence of diurnal night temperature on the growth rate of watermelon.

Materials and Methods

Two cultivars of watermelon seeds(*Citrullus vulgaris* S. 'Binna' and 'Kamro') were germinated for 10 days in 25℃ growth chamber in 6 inch plastic pots filled with universal soil. The seed collection was made on September 1994. Temperature was set to be either 30℃ or 25℃ days, and either 30℃, 25℃ or 20℃ nights. After germination, alternating temperatures were obtained by transfering the plants manually everyday of climated greenhouse. Germination tests were performed at temperatures regimes of 30/30℃ 30/25℃, 30/20℃ and 25/25℃ for 10 days. The estimate of the total and average temperature was determined as previously published[4]:

DIF 5= (Day temperature= 30(12h)℃; Night temperature= 25(12h)℃)

- Total temperature: (30℃ x 12h x 30d)+(25℃ x 12h x30d)= 21,600℃
- Average temperature: Total temperature/(30d x 24h)= 27.5℃
- DIF= Day temperature – Night temperature

Growth measurement of dry weight, leaf areas, leaf numbers, flower numbers and chlorophyll contents were obtained at 30 days after treatment. Plants were dried in forced–draft oven at 70℃ for 48h[1]. After chlorophyll extracts were made in 4 ml of 80% acetone using leaf discs for each sample, concentration of chlorophyll was caculated using by Beer's law[1].

Results and Discussion

Temperature control nearly always has the highest priority, above the control of other growth factors like humidity and CO_2. In greenhouse plant production energy may be saved if decrease in growth by low night temperature is compensated for by a rise in day temperature[6,10,11,12,13]. In this point of view, setpoint for night temperature can be used to guide cultural practices to minimize energy use.

The optimum temperature regime for germination of 'binna' and 'kamro' were 35/25℃ and 25/25℃, at which 65.0% and 50.0% more of the seeds, respectively, germinated than the other treatments(Table 1).

Table 1. Percentage germination of watermelons at different alternating temperatures after 10 days.

Day Tem.(℃)	25(12h)[z]	30(12h)	30(12h)	30(12h)
Night Tem.(℃)	25(12h)	20(12h)	25(12h)	30(12h)
Binna	35.0[y]c	47.5b	65.0a	32.5c
Kamro	50.0a	40.0b	42.5b	25.0c

[z]Mean of 40 observation

[y]Mean separation within rows by Duncan's multiple range test (p=0.05)

Table 2 shows that the leaf area and number of leaves increased throughout both day and night temperature. The 30/30℃ treatment produced maximum leaf area and number of leaves, which were higher with high temperature integral, while maximum mean area per leave occurred under the 25/25℃ treatment.

Relative growth rate(RGR) can be separated into net assimilation rate(NAR) and leaf area ratio(LAR)[5]. Changes in RGR due to temperature regime are mainly caused by changes in LAR. LAR, LWR and RGR are growth parameters based on a dry weight interval instead of a time interval[5,7]. Total dry weight of watermelons were the lowest at 25/25℃ and increased with temperature integral, the maximum occurring at 30(12h)/25(12h)℃('Binna') and 30(14h)/25(10h)℃('Kamro'). Also, LAR increased with increasing night temperature from 30/20℃ to 30/30℃. But high night temperature(30/30℃) reduced dry weight and leaf weight ratio(LWR) of watermelons, as compared to 30/25℃.

Table 2. Effect of different treatment with alternating periods with night temperature on leaf areas(Means±SE) and number of leaves of watermelon.

Day/night	Average	Kamro			Binna		
Temp.(C)	Temp.(C)	Leaf area	NL	MLA	Leaf area	NL	MLA
30(12h)/30(12h)	30.0	586.5±15.6	26.5	22.2±1.2	620.5±22.5	33.5	18.5±0.7
30(14h)/25(10h)	27.9	575.4±46.4	22.0	26.2±1.5	615.7±20.2	27.3	22.5±0.9
30(12h)/25(12h)	27.5	549.5±43.3	20.1	27.3±1.9	614.0±21.4	26.1	23.5±1.1
30(10h)/25(14h)	27.1	501.0±35.8	16.8	30.2±1.8	553.7±18.5	22.1	25.1±1.8
30(12h)/20(12h)	25.0	416.8±28.1	14.6	29.4±2.0	500.0±17.8	19.5	25.7±1.7
25(12h)/25(12h)	25.0	373.8±31.3	10.5	35.6±2.5	439.3±15.6	12.0	36.6±2.5

Leaf area(cm^2), NL:No. of leaves, MLA:Mean area per leaf(cm^2)

Presumably, high night temperature resulted in loss of respiratory CO_2, which reduced dry weight accumulation. Although 30/20℃ and 25/25℃ are same temperature integral, leaf area, dry weight, chlorophyll content and number of flowers were always lower at 25/25℃ than 30/25℃ in watermelons. This agrees well studies of Heuvelink[5] showing that the effect of different temperature regime at the same temperature integral was the same or greater as for dry weight and leaf area.

Total chlorophyll at 30/20℃ was 1.7%('Binna') and 4.6%('Kamro') higher than 25/25℃ at the same temperature integral. Chlorophyll content and number of flowers were lower in those watermelon exposed to the 10 hour photoperiod than the watermelon grown under the 14 hour photoperiod at 30/25℃. The number of flowers were the highest at 30/30℃ and decreased with decreasing temperature integral. This experiments suggested that the growth of watermelon was affected in the different temperature variation rather than in the same temperature integral. For instance, when the influences of temperature regime for watermelon are

Table 3. Effect of different treatment with alternating periods with night temperature on dry weights(Means±SE), leaf area and leaf weight ratios of watermelon.

Day/night	Average	Kamro			Binna		
Temp.(C)	Temp.(C)	DWT	LAR	LWR	DWT	LAR	LWR
30(12h)/30(12h)	30.0	2.27±0.23	0.258	0.517	2.57±0.15	0.241	0.495
30(14h)/25(10h)	27.9	2.38±0.24	0.242	0.532	2.59±0.15	0.238	0.540
30(12h)/25(12h)	27.5	2.25±0.24	0.244	0.520	2.70±0.14	0.227	0.544
30(10h)/25(14h)	27.1	2.05±0.21	0.244	0.517	2.45±0.13	0.226	0.531
30(12h)/20(12h)	25.0	1.73±0.20	0.241	0.587	2.22±0.14	0.225	0.551
25(25h)/25(12h)	25.0	1.45±0.15	0.258	0.589	2.16±0.16	0.203	0.507

DWT:dry weight(g), LAR:Leaf area ratio(leaf area/DWT:cm^2mg^{-1}), LWR:Leaf weight ratio (total dry weight of leaves/total dry weight of plants)

Table 4. Effect of different treatment with alternating periods with night temperature on chlorophylls(Means±SE) and number of flowers in watermelon.

Day/night	Average	Kamro		Binna	
Temp.(C)	Temp.(C)	Total chl.	No.flower	Total chl.	No.flower
30(12h)/30(12h)	30.0	44.9±1.0	5.3	47.4±1.8	9.8
30(14h)/25(10h)	27.9	45.4±1.0	3.0	48.1±1.5	7.8
30(12h)/25(12h)	27.5	44.2±0.8	2.8	47.7±1.4	6.0
30(10h)/25(14h)	27.1	40.5±0.9	2.0	45.5±1.0	4.8
30(12h)/20(12h)	25.0	42.8±1.0	2.0	47.5±1.5	4.0
25(12h)/25(12h)	25.0	40.9±1.2	1.5	46.7±1.4	3.0

compared, 30/25℃ or 30/20℃ were more effective than at either 30/30℃ or 25/25℃ in yield and energy saving, respectively.

摘　要

겨울철 대부분의 시설재배 채소는 야간 온도가 떨어지기 때문에 많은 열 에너지를 공급함으로써 夜溫을 높여 생장시키기 때문에 에너지 손실이 많다. 본 실험은 수박의 經濟的 出荷를 목적으로 夜溫에 대한 생장 효과를 조사하였다. 낮의 온도를 25℃와 30℃로 하고 야간의 온도는 20℃에서 30℃로 5℃ 간격을 두고 처리하였다.

두 품종 수박(빛나, 감로) 모두 30/30℃ 처리에서 葉面積, 開花數 및 葉數가 가장 많았다. 30(14h)/25(10h)℃과 30(12h)/25(12h)℃ 처리구에서는 發芽率 및 乾重과 葉綠素의 함량이 夜溫을 높인 30/30℃ 처리구 보다 높은 경향을 보였다. 25/25℃와 30/20℃는 평균 온도가 같을지라도 수박의 생장에 있어서는 30/20℃ 처리구가 25/25℃에 비하여 생장이 우수하였다. 빛나는 동일 조건에서 감로보다 생장이 우수하였다.

乾重 葉面積率은 30/30℃와 30/20℃ 사이의 온도에서 DIF가 증가함에 따라 감소되었으나, 乾重 葉重率은 증가 되었다. 施設內 夜溫을 적절히 낮추어 재배하는 방법이 겨울철 에너지 소모 방지와 수박의 생장에 도움을 줄것

으로 기대된다.

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