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Effect of Some Growth Regulators on Growth Efficiency of *Panax ginseng*

Hoon Park, Jong-Hyuk Yoon and Mee-Kyoung Lee
Korea Ginseng and Tobacco Research Institute, Science Town, Daejeon 302-345, Korea
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高麗人蔘의 生長効率에 미치는 數種 生長調節劑의 効果

朴 薰·尹鍾赫·李美京
韓國人蔘煙草硏究所
(1988년 11월 19일 접수)

Abstract

P. ginseng seedlings treated with GA, 2,4-D and B-9 (N,N-dimethylsuccinamic acid) were grown under dark. Growth efficiencies (E_1 = St/Ro, E_2 = St/(Ro-Rt), E_3 = (Ro-Rt)/Ro where St. Ro and Rt are shoot weight, initial root weight and root weight at time t. respectively) and other related factors and their interrelationship were investigated. E_1 and E_3 showed quadratic relation with temperature change while E_2 showed negative linear relation. E_1 depended on more E_3 component than E_2 component. The values of E_2 and E_3 are almost same. E_2 was greater than that reported previously suggesting large variation between roots. GA greatly increased E_2 and E_3 in supraoptimum temperature range while B-9 greatly decreased E_3 in all temperature range and E_2 in suboptimum range. Shoot weight showed highly significant positive linear correlation with substrate amount in most cases of PGR and temperature and with respiration loss in some cases. Respiration loss showed significant linear correlation positively with E_1 and E_3 and negatively with E_2 only in suboptimal temperature range.

Introduction

The growth rate of Korea ginseng (*Panax ginseng*) is very slow. The reason seems not solely due to the low light intensity (about 5% of total solar radiation) under which ginseng plants normally grow since photosynthetic rate[1] is about two third of rice plant per leaf area bases.

High temperature decreased photosynthesis[1] but more severely retarded shoot growth under dark.[2] Shoot growth efficiency (shoot weight produced per root weight loss) from root under dark was very poor (37.5% at maximum) at optimum temperature and extremely low at high temperature. This such low growth efficiency was pointed out as a potential factor for slow growth of ginseng plant.[3]

Through this investigation we aimed to confirm the value of growth efficiencies at various temperature, especially suboptimal temperature and to investigate the effect of some growth regulators on growth efficiency, especially at supraoptimum temperature.

Materials and Methods

Plant: Overwintered ginseng seedlings were digged from the seed bed in early April, washed lightly and weighed each root.

Growth regulator: Commercial GA, 2,4-D and B-9 (daminozide; N,N-dimethylsuccinamic acid) were purchased from market.

Growth temperature: Washed roots were immersed in each growth regulator solution (GA and 2,4-D were) 100 ppm, B-9 was 1000 ppm) for 10 minutes and wrapped with wet cheese cloth. They were kept in dark incubator with 5 °C temperature intervals from 5 °C to 30 °C for three weeks. Harvested samples were separated into shoot and root, dried at 70 °C with forced draft oven and weighed.

Calculation of growth efficiencies and their relations with other factors: Efficiencies, E_1, E_2 and E_3 were defined as follow. $E_1 = St/Ro$, $E_2 = St/(Ro\text{-}Rt)$, $E_3 = St/(Ro\text{-}Rt)/Ro$. Thus $E_1 = E_2 \cdot E_3$, where St is final shoot weight, Ro initial root weight and Rt final root weight. Respiration loss is considered as the substraction of shoot weight from substrate, that is, $(Rm + Rg) = (Ro\text{-}Rt)\text{-}St$ where Rm and Rg are maintenance and growth respiration, respectively. Linear, quadratic correlation and Duncan's multiple range test (DMRT) were done when need for the relationship among growth efficiencies and other factors.

Results and Discussion

Total shoot growth efficiency(E_1) at various temperatures and with growth regulators were shown in Table 1. In all treatments E_1 showed quadratic curve with temperatures. Maxima appeared at 15 °C indicating that optimum growth temperature is 15 °C. B-9 greatly decreased E_1 comparing with control. High temperature affected E_1 than low temperature did. Only GA significantly increased E_1 at high temperature

Table 1. Effect of growth regulators and temperature on total shoot growth efficiency(E_1) of *P. ginseng* seedling grown under dark

Temp. (°C)		5		10		15		20		25		30	
		%	DMRT	%	DMRT	%	DMRT	%	DMRT	%	DMRT	%	DMRT
Cont.	%	17.7	a	30.7	a	34.9	a	28.6	a	15.3	b	5.7	b
	DMRT	c		b		ab		b		c		d	
GA	%	20.7	a	23.5	bc	35.2	a	31.3	a	23.1	a	9.1	a
	DMRT	b		b		a		a		b		c	
2,4-D	%	19.2	a	27.4	ab	35.3	a	31.4	a	14.0	b	6.3	b
	DMRT	c		b		a		b		d		d	
B-9	%	14.0	b	20.0	c	25.2	b	18.3	b	8.7	c	6.9	ab
	DMRT	c		b		a		a		d		e	

The different letters among temperatures or treatments indicate significant difference(p = 0.05) by DMRT.

Table 2. Shoot growth efficiency(E_2) at various temperatures with growth regulators in *P. ginseng* seedling grown under dark

Temp. (°C)		5		10		15		20		25		30	
		%	DMRT	%	DMRT	%	DMRT	%	DMRT	%	DMRT	%	DMRT
Cont.	%	71.6	a	65.7	a	59.5	b	50.9	d	37.5	b	26.7	b
	DMRT	a		b		c		d		e		f	
GA	%	62.9	b	57.1	a	56.8	c	56.1	b	47.2	a	27.8	b
	DMRT	a		b		b		b		b		c	
2,4-D	%	62.9	b	63.6	a	62.6	a	54.1	c	35.9	b	32.5	a
	DMRT	a		a		a		b		c		c	
B-9	%	57.9	c	56.9	a	59.4	b	60.2	a	36.4	b	33.8	a
	DMRT	a		a		a		a		b		b	

The different letters indicate significant difference(p = 0.05) within temperature or growth regulators by DMRT.

Table 3. Growth substrate efficiency(E_3) at various temperatures with growth regulators in *P. ginseng* seedling grown under dark

Temp. (°C)		5		10		15		20		25		30	
		%	DMRT	%	DMRT	%	DMRT	%	DMRT	%	DMRT	%	DMRT
Cont.	%	25.4	b	47.0	a	57.8	a	55.9	a	40.8	ab	21.7	b
	DMRT	c		b		a		a		b		c	
GA	%	33.1	a	47.2	a	62.3	a	55.4	a	49.0	a	34.1	a
	DMRT	b		ab		a		a		ab		b	
2,4-D	%	32.3	ab	45.6	a	57.8	a	58.1	a	38.7	b	20.5	b
	DMRT	c		b		a		a		c		d	
B-9	%	24.3	bc	35.5	a	41.4	b	30.4	b	23.9	c	21.0	b
	DMRT	d		b		a		c		d		d	

The different letters indicate significant difference(p = 0.05) within temperature or growth regulators by DMRT.

(25°, 30°C) than control.

The shoot growth efficiency(E_2), shoot weight per substrate weight, was shown in Table 2. E_2 showed linear decrease with temperature increase except B-9 which showed quadratic tendency. All growth regulators showed increasing effect on E_2 in high temperature range. GA appeared most effective at 20°C and 25°C while 2,4-D and B-9 were most at 30°C.

The growth substrate efficiency(E_3), total substrate weight per initial root weight, was shown in Table 3. All treatments showed quadratic relation with temperature. Maximum E_3 appeared mostly at 15°C. Growth regulators mostly decreased E_3 in high temperature range. Only GA showed the increased effect at 30°C. From the above results only GA can be effective for the increase of growth efficiency under high temperature environments. But only one concentration of each PGR was tested in this time. The effect of other concentrations should be tested.

Simple correlations between growth efficiencies in various growth temperature

Table 4. Simple correlation between growth efficiencies(E) in *P. ginseng* seedling treated with PGR

Efficiency	E_1E_2			E_1E_3			E_2E_3		
Temperature(°C)	5-15	15-20^a	20-30	5-15	15-20^a	20-30	5-15	15-20^a	20-30
Control	-0.725**	0.668*	0.937***	0.979***	0.793**	0.967***	-0.816***	0.119	0.850***
GA	0.007	0.670*	0.923***	0.745**	0.959***	0.883***	-0.625*	0.437	0.663**
2,4-D	0.088	0.772**	0.860***	0.945***	0.425	0.954***	-0.265	-0.169	0.700**
B-9	0.089	-0.394	0.925***	0.905***	0.926**	0.830***	-0.251	-0.484	0.562*

n = 15(a ; n = 10), *,**,*** ; p = 0.05, 0.01, 0.001

Table 5. Simple correlation between shoot growth(St) and substrate or respiration loss in *P. ginseng* seedling treated with PGR

Temp.(°C)	Substrate(Ro-Rt)			Resp. loss(Rm + Rg)		
	5-15	15-20^a	20-30	5-15	15-20^a	20-30
Cont.	0.984***	0.927***	0.941***	0.446	0.547	0.719**
GA	0.722**	0.661*	0.833***	0.017	0.585	0.477
2,4-D	0.996***	0.876***	0.960***	0.138	0.886***	0.225
B-9	0.962***	0.991***	0.587	0.558*	0.762**	0.409

n = 15(a ; n = 10), *,**,*** ; p = 0.05, 0.01, 0.001

ranges were shown in Table 4. E_1 and E_3 showed significant positive correlation at all temperature ranges in each growth regulator while E_1 and E_2 showed such correlation only at high temperature range indicating the greater dependency of E_1 to E_3 than E_2. The indications are that overall shoot growth efficiency per initial root weight is affected more by the substrate availability than use efficiency of substrate for shoot growth. But E_2 contribution to E_1 becomes greater at high temperature range. Thus the selection of growth regulator to overcome high temperature damage appeares to be based on the effect on E_2 in high temperature range.

The relationship between shoot weight and substrate amount was shown in Table 5. There are highly significant linear relation in all temperature ranges in all growth regulators tested. The relationship between shoot weight and respiration loss was shown also in Table 5. There are positive trend but significant cases were very rare. The positive trend with respiration loss suggests that maintenance respiration(Rm) loss might be small in comparison with growth respiration(Rg). This result is well accordance with the little effect of Rm on shoot growth efficiency E_2[3]. The poor growth at high temperature is not due to the respiratory consumption but the small substrate amount that limits not only shoot growth but also respiratory substrate.

The relationship between respiratory loss and growth efficiencies was shown in Table 6. Respiratory loss more affected growth efficiencies in low temperature range where the shoot growth was poor.

Table 6. Simple correlation between respiration loss(Rm + Rg) and growth efficiencies in *P. ginseng* treated with growth regulators.

Efficiency	E_1			E_2			E_3		
Temp.(°C)	5-15	15-20[a]	20-30	5-15	15-20[a]	20-30	5-15	15-20[a]	20-30
Cont.	0.789***	-0.068	0.556*	-0.829***	-0.147	0.694**	0.882***	0.227	0.337
GA	0.314	0.225	-0.027	-0.875***	-0.212	0.393	0.847***	0.355	-0.258
2,4-D	0.740**	-0.365	0.696**	-0.584*	-0.755*	0.829***	0.764***	0.356	0.372
B-9	0.712**	0.938***	-0.376	-0.461	-0.302	0.143	0.854***	0.901***	-0.659

n = 15(a; n = 10), *,**,***; p = 0.05, 0.01, 0.001

In optimal and suboptimal temperature range the respiration loss showed negative correlation with shoot growth efficiency(E_2) but positive correlation with growth substrate efficiency(E_3). Such results are well expected since respiration loss is included into the total substrate but the shoot weight is the remainder from substraction of respiratory loss from total substrate. In high temperature range the respiration loss showed positive correlation with E_2 and negative trend with E_3 indicating that substrate amount must be high for the high E_2. Even though respiration loss is greater and that substrate limitation is more attributed to respiration loss in high temperature range the respiration loss is not the main cause for substrate limitation.

Total shoot growth efficiency(E_1) depends more on growth substrate efficiency(E_3) but in high temperature range the dependency of shoot growth efficiency from substrate(E_2) becomes greater. To overcome the high temperature damage on poor growth certain growth regulator that can increase one or both E_2 and E_3 may be usable. since GA significantly increased E_2 in high temperature range it is worthwhile to evaluate the effect on E_2 at other growth stages or of other substrate such as photosynthates.

References

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要 約

高麗人蔘의 苗를 GA, 2,4-D 및 B-9로 처리하여 暗下에서 生育시켰다. 生長効率($E_1 = S_t/R_o$, $E_2 = S_t/(R_o-R_t)$, $E_3 = (R_o-R_t)/R_o$, 여기서 S_t는 지상부중, R_o와 R_t는 초기와 일정시간

후의 뿌리의 무게임)과 기타 관련된 要因 및 이들 상호관계를 조사하였다. E_1과 E_3는 溫度變化에 이차식 관계를 보인 반면 E_2는 負의 직선 상관을 보였다. E_1은 E_2보다 E_3에 더 의존하였다. E_2와 E_3값은 거의 같았다. E_2는 전에 보고된 값보다 커서 뿌리간 큰 차이가 있음을 나타낸다. GA는 高溫域에서 E_2와 E_3값을 증대시켰으며 B-9은 모든 온도에서 E_3를 크게 감소시켰고 低溫域에서 E_2를 감소시켰다. 地上部重은 대부분의 生長調節劑와 溫度에서 基質量과 有意正相關을 보였으며 몇경우에는 呼吸消耗量과 有意正相關을 보였다. 呼吸消耗量은 低溫域에서만 E_1 및 E_3와는 有意正相關을 E_2와는 有意負相關을 보였다.