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Effect of Applied GA_3 and Paclobutrazol, an Inhibitor of GA Biosynthesis, on the Growth of Internodes and Panicle of the Rice Plants

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GA_3와 GA 生合成 抑制劑 處理가 水稻의 節間伸長 및 穗의 發育에 미치는 影響

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ABSTRACT

Recently several synthetic chemicals inhibiting biosynthesis of gibberellic acids were found to be effective in preventing cereal crops from lodging by reducing culm length.

The present study aimed to clarify the extent of practical manipulation of the culm length of the rice crop by changing the endogenous level of gibberellic acids with exogenous application of GA_3 or GA biosynthesis inhibitor.

Three rice cultivars, 'Jinheung', 'Minehikari' (Japonica) and 'Hangangchal' (semi-dwarf Indica x Japonica) were treated with GA_3 (0, 20, 50 and 100 ppm solution) and an anti-gibberellin, paclobutrazol (0, 100,200 and 300 g ai/ha) at three growth stages (maximum tillering, panicle initiation and meiotic stage), respectively.

The application of GA_3 (50, 100 ppm) at maximum tillering stage and panicle initiation stage promoted the elongation of the 5th internodes from the top and GA_3 applied at meiotic stage promoted remarkably the elongation of the 3rd internodes. Culm was most elongated when GA_3 was applied at maximum tillering stage in 'Jinheung', at panicle initiation stage in 'Minehikari' and at meiotic stage in 'Hangangchal'.

Paclobutrazol shortened the 4th and 5th internodes from the top when it was applied at maximum tillering stage and panicle initiation stage and the 2nd and 3rd internodes when it was applied at meiotic stage in the three cultivars.

The semi-dwarf Indica x Japonica variety responded to a greater extent to the GA_3 and to a less extent to the anti-gibberellin than the Japonica varieties.

The effect of GA_3 and paclobutrazol on the panicle length and the number of spikelets per panicle varied with time and dose of their application as well as with variety.

INTRODUCTION

Since Kurosawa's discovery of gibberellic acid in "Baganae" fungus (*Gibberella fujikuroi*) during 1920's, many efforts have been made by many scientists to elucidate the nature of gibberellic acid and its physiological roles as a plant growth subst-

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ance.

A considerable findings in this area have been established to an extent that it has been possible to regulate plant growth artificially by use of GAs. Meanwhile, various plant growth regulators, either natrually occurring or synthetic, have been demonstrated to be able to alter plant growth and/or development at various stages in life cycle.[14]

One of the most obvious functions of GAs is to regulate cell division and extention, especially the growth of internodes.[6,11] Stowe and Yamaki (1936)[11] reported that the elongation of stems in many plant species was promoted by the application of gibberellin. The endogenous GAs in rice plants vary, being affected by growth stage and growth conditions(Osada et al, 1973),[8,17] and by rice cultivars (Suge, 1971).[13] By Shimizu' report (1964), gibberellin when applied to rice plants by foliar spray during the late-vegetative growth stage enhanced the elongation of internodes growing at that time.[10] Active GA contents within rice plants are higher when grown under the high level of nitrogen-fertilizer.[8]

Pesistence of lower GA content in a rice cultivar under the same condition is due to its internal genetic characteristics and that is related to dwarfism.[7,17]

Cultivars having a lower endogenous GA level are more responsive to exogenous GAs.[3,4] On the basis of the relationship between GA content and the elongation of internodes, a substance limiting biosynthesis of endogenous GAs or inactivating GAs ready-present within plants, anti-gibberellin, is supposed to be useful in regulating the elongation of internodes. In this regard several anti-GAs have been developed recently: inabenfide(CGR811), paclobutrazol (PP 333), tetcyclacis (BAS 106 W), uniconazole (S 3307) *et cetra.*

Objective of this experiment is to clear the responsiveness of rice cultivars to exogenous GA and GA biosynthesis inhibitor, paclobutrazol, and to regulate effectively the elongation of internodes of rice plants for practical uses of GAs and anti-GAs.

MATERIALS & METHODS

Three rice varieties, Jinheung, Minehikari and Hangangchal were sown on April 15, and 45 day-old seedlings were transplanted on May 25, 1983. Transplanting in the field was performed with 30cm in spacing and 15 cm in width.

Fertilizers were applied at the rate of 100kg N, 80kg P_2O_5 and 80kg K_2O/ha. Four different levels (0, 20, 50 and 100 ppm) of GA_3 solution were sprayed directly to the foliage of rice plants with six replicates.

Paclobutrazol was soil-applied at the rate of 0, 100, 200 and 300g a.i. per hectare (0.6% active ingredient granular formulation).

The internode and panicle lengths and the number of spikelets per panicle of two main tillers per hill with six replicates were measured at harvesting time. Culm length of tillers within a hill were measured with three replicates in order to know the distribution of culm length within a hill for the treatment of paclobutrazol at panicle initiation stage.

Table 1. Heading date and culm length of the untreated rice varieties and application time of GA_3 and paclobutrazol.

Variety	Type	Culm length	Heading date	Application time	
				Date	Growth stage
Jinheung	Japonica	90 cm	Aug. 20	July 6	maximum tillering stage
Minehikari	Japonica	79	Aug. 22	July 16	panicle initiation stage
Hangangchal	Indica × Japonica	63	Aug. 15	Aug. 5	meiotic stage

RESULTS & DISCUSSION

1. Effects of Applied GA_3 and Anti-GA on Plant Height (culm length).

Foliar applications of GA_3 promoted culm elongation in almost all treatments. Japonica variety Jinheung having longer culm than Minehikari or Hangangchal was more elongated by 4.5-15.6% over the untreated when GA_3 was applied at the rate of 100ppm and was most elongated when it was applied at maximum tillering stage as shown in Table 2. Minehikari showed a promotive effect of GA_3 on the elongation of culm even when it was applied at a lower rate of 20ppm. GA_3 induced about 15% more elongation in culm of Minehikari over the untreated when it was applied at the rate of 100ppm at maximum tillering and panicle initiation stages.

When GA_3 was applied at 20, 50 and 100ppm at meiotic stage, Hangangchal was more elongated by 26.0, 38.9, 44.1%, respectively, over the untreated.

GA_3 induced dramatic promotion of culm elongation of a semi-dwarf variety, Hangangchal, compared with the two Japonica varieties. In the present study the taller variety was less responsive to the GA_3 in culm elongation in the three tested varieties.

These results agree with Matsunaga et al (1980)'s report that semi-dwarf rice varieties had lower level of endogenous gibberellic acids and were more responsive to exogenous GA_3[7] Harada and Vergara[3,4] also showed that tall and short lines of rice were differently responsive to gibberellin: short line which has a semi-dwarf gene of Dee-jeo-woo-gen was lower in endogenous GA level and more responsive to exogenous GA than the tall lines.

Table 3 shows the effect of paclobutrazol, an anti-GA, on the plant height. All tested varieties were retarded in culm growth significantly in almost all plots by the application of paclobutrazol.

The culms of the tested rice varieties were increasingly shortened with increased rate of paclobutrazol at all three application times and were most shortened as it was applied at meiotic stage. Jinheung and Minehikari were more shortened by 22.7cm and 17.4cm, respectively, in culm length over the untreated as it was applied at meiotic stage, whereas Hangangchal was 9.2cm shorter in the treated plots

Table 2. Effect of foliar applied GA_3 on the growth of the culm of rice cultivars, Jinheung, Minehikari and Hangangchal.

Treatment time \ Variety Conc. (ppm)		Culm length		
		Jinheung	Minehikari	Hangangchal
		cm %	cm %	cm %
T_1	20	87.6 (95.8)	87.1 (108.2)	66.4 (112.7)
	50	95.7 (104.7)	90.9 (112.9)	68.6 (116.5)
	100	105.7 (115.6)	92.9 (115.4)	73.6 (125.0)
T_2	20	89.2 (97.6)	81.9 (101.7)	66.7 (113.2)
	50	87.7 (96.0)	87.8 (109.1)	69.9 (118.7)
	100	98.0 (107.2)	97.3 (115.9)	78.0 (132.4)
T_3	20	86.2 (94.3)	80.1 (99.5)	74.2 (126.0)
	50	90.1 (98.6)	86.3 (107.2)	81.8 (138.9)
	100	95.5 (104.5)	88.9 (110.4)	84.9 (144.1)
Non-treatment		91.4 (100)	80.5 (100)	58.9 (100)
F - value		6.45**	15.24**	41.31**
LSD (5%)		3.9	3.1	3.3

* Note: T_1 ; maximum tillering stage.
T_2 ; panicle initiation stage.
T_3 ; meiotic stage.

Table 3. Effect of soil-applied Paclobutrazol on the growth of the culm of rice cultivars, Jinheung, Minehikari and Hangangchal.

Treatment time	Variety Dose g ai/ha	Culm length		
		Jinheung	Minehikari	Hangangchal
		cm %	cm %	cm %
T_1	100	86.5 (96.3)	72.4 (94.4)	65.6 (99.2)
	200	83.7 (93.2)	67.2 (87.6)	61.8 (93.5)
	300	72.0 (80.2)	61.7 (80.4)	60.9 (92.1)
T_2	100	87.0 (96.9)	75.9 (99.0)	66.5 (100.6)
	200	76.7 (85.4)	70.7 (92.2)	64.3 (97.3)
	300	77.7 (86.5)	66.1 (86.2)	60.9 (92.1)
T_3	100	84.8 (94.4)	72.3 (94.3)	64.3 (97.3)
	200	82.1 (91.4)	66.0 (86.0)	63.8 (96.5)
	300	67.1 (74.7)	59.2 (77.2)	56.9 (86.1)
Non-treatment		89.8 (100)	76.6 (100)	66.1 (100)
F - value		17.91**	19.56**	16.61**
LSD (5%)		3.3	2.8	1.9

* Note: T_1 ; maximum tillering stage.
T_2 ; panicle initiation stage.
T_3 ; meiotic stage.

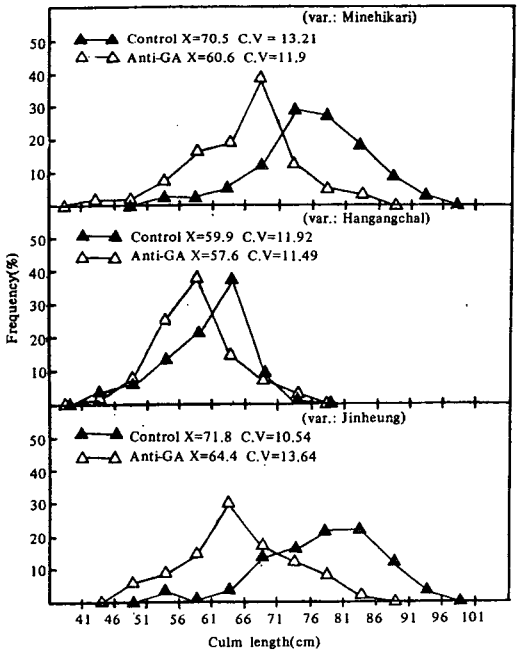

Fig. 1. Distributions of culm length within a hill when Paclobutrazol was applied at the rate of 200g ai per ha under the standard level of N-fertilizer(100kg/ha).

than in the untreated.

Fig. 1 shows that paclobutrazol applied at the rate of 200g ai/ha at panicle initiation stage reduced more or less consistently culm length of all panicles within a hill.

Usually it takes 4 to 5 days in heading of all panicles within a hill. This means a variation in the developmental stages of panicle initiation and growth within a hill. The effect of exogenous GA and anti-GA has been shown much dependent on the developmental stage of plant organs. The present result of similar proportional reduction in culm length of all panicles within a hill appears to offer a rather practical merit in regulation of plant height to cope with lodging problem.

The varietal and growth-stage differences in response to paclobutrazol were counter to the results obtained for GA_3 treatment. Thus, we may infer that the effect of GA_3 or anti-GA on culm elongation is dependent on the endogenous level of active GA whether the gibberellin are either biosynthesized or exogenously applied.

2. Internodal Responses to GA_3 and Anti-GA.

The elongation response of each internodes to

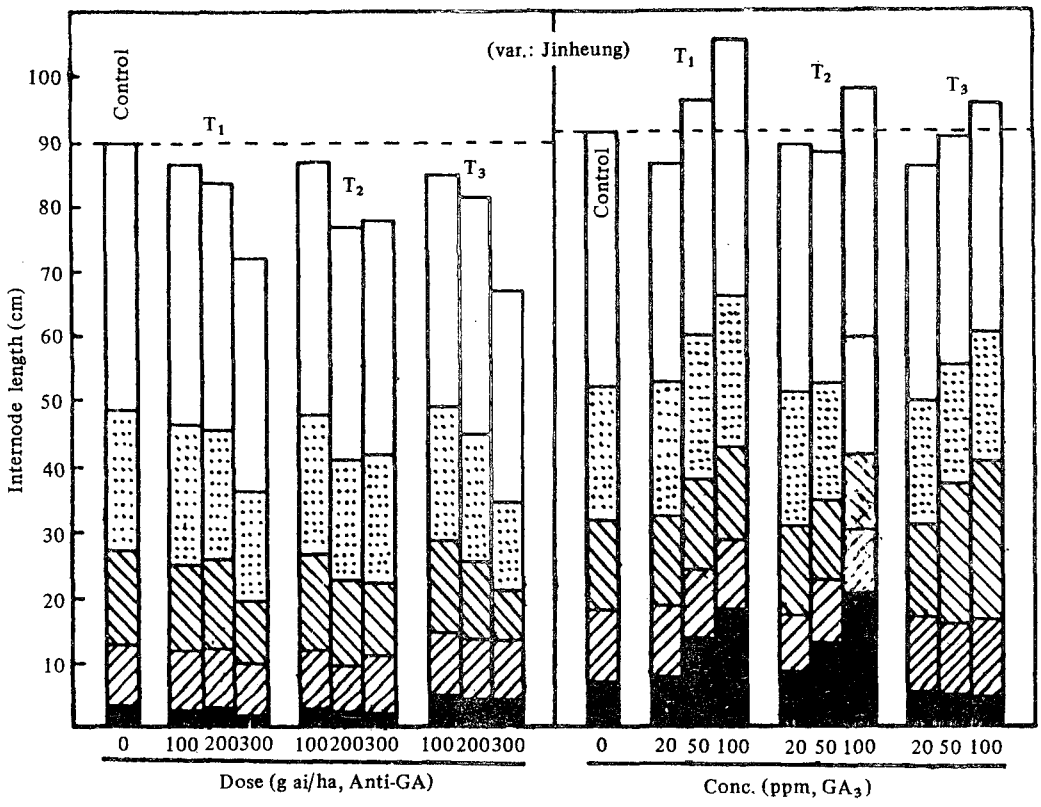

Fig. 2. Effect of Paclobutrazol or GA on the elongation of internodes when it was applied at the different stages of the rice cultivar, Jinheung.

Note: T_1 ; maximum tillering stage.
T_2 ; panicle initiation stage.
T_3 ; meiotic stage.

GA_3 or paclobutrazol was much dependent on the application time as shown in the Fig. 2, 3, and 4. When paclobutrazol was applied at maximum tillering and panicle initiation stages, lower internodes were mainly shortened while the 5-6th internodes were dramatically elongated by GA_3 applied at those stages in all tested varieties. The GA_3 promoted conspicuously the elongation of the 3rd internode when it was applied at meiotic stage (10 to 17 days before heading). In contrast, paclobutrazol inhibited the growth of the 3rd internode when it was applied at meiotic stage. It is generally known that the elongation of internodes below the 4th from the top in the rice plant finish about 10 to 15 days before heading and the 3rd internode continues to elongate steadily from about 20 days before heading just until heading.[5,9,12] Such results are well understood in relation to the differentiation and growth time of each internode.

Shimizu[10] has shown that gibberellin applied during the period of vegetative growth promoted the growth of internodes elongating vigorously at that time and that it was so for the upper internodes with GA applied just before heading. Similar results were also reported by Takahashi et al[16] and Shrestha[15].

It can be recognized that GA plays a crucial role in the elongation of internodes and thereby culm length. The growth of culm may be easily controlled by modifying the endogenous GA level by application of anti-GA or GA and knowledge on the change in the level of endogenous GA for each variety

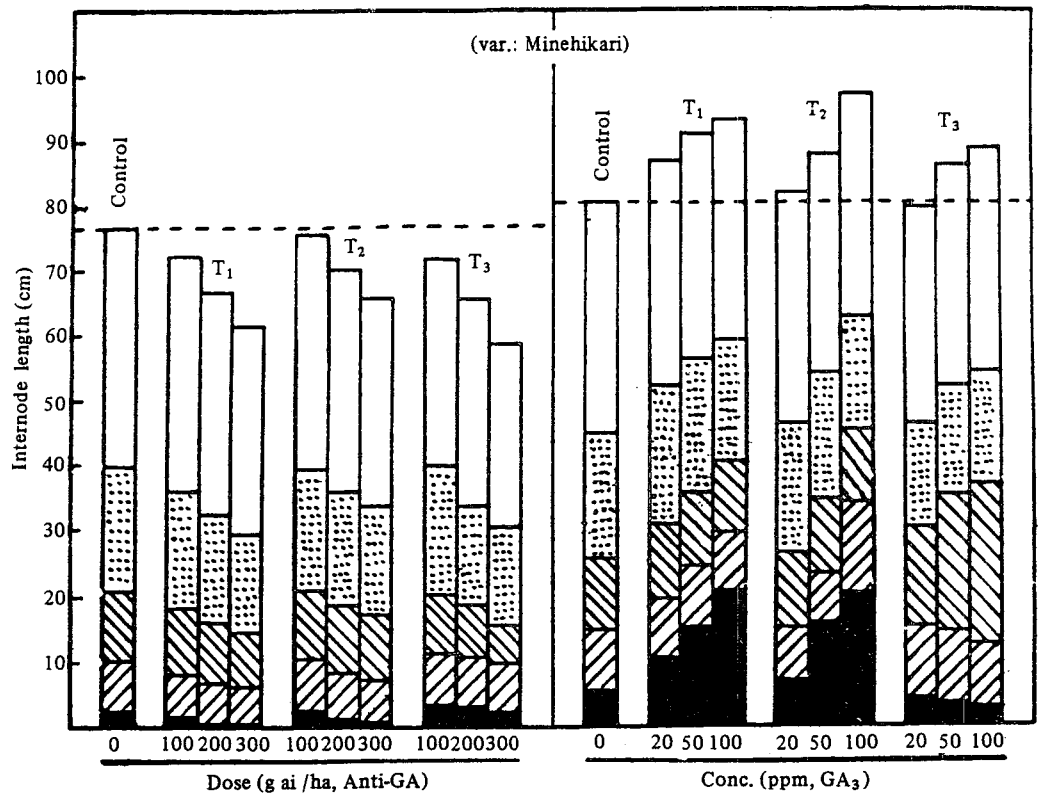

Fig. 3. Effect of Paclobutrazol or GA_3 on the elongation of internodes of the rice cultivar, Minehikari.

seems to be required to control the culm height to the desired extent.

3. Effect of GA and Anti-GA on the Growth of Panicles.

Table 4 and 5 shows the effect of GA and paclobutrazol on the panicle length and the number of spikelets per panicle. The growth of panicles as affected by GA_3 application appeared to be dependent on varieties, time and rate of its application. In Jinheung, panicle length was somewhat shortened when GA_3 was applied before meiotic stage, whereas panicle length was rather longer over the untreated when it was applied at meiotic stage. The elongation of panicles tended to be promoted just when it was applied at meiotic stage in Minehikari and at panicle initiation and meiotic stages in Hangangchal, but there was not any consistent tendency in their responses with increased rates of GA_3. According to a report[15] the application of GA at higher rate (more than 50ppm) at panicle initiation stage to a few rice varieties also resulted in reduction in pancle length, and if it was applied at a lower rate there was no obvious response.

Panicle length, however, tended to be shorter gradually with increasing rate of paclobutrazol as it was applied at meiotic stage in all tested varieties. Paclobutrazol, even if applied at panicle initiation stage resulted in a shorter panicle for which it seems to affect persistently GA level within plant body during rather a broader period of growth since it was soil-applied. In view of the fact that young panicles of the rice plants begin to elongate clearly around 20 days before heading and end its growth about 5 days before heading,[5,9] it is well understood that the changes in GA content within plant body due to applied GA_3 or paclobutrazol were involved in the growth of panicles elongating at

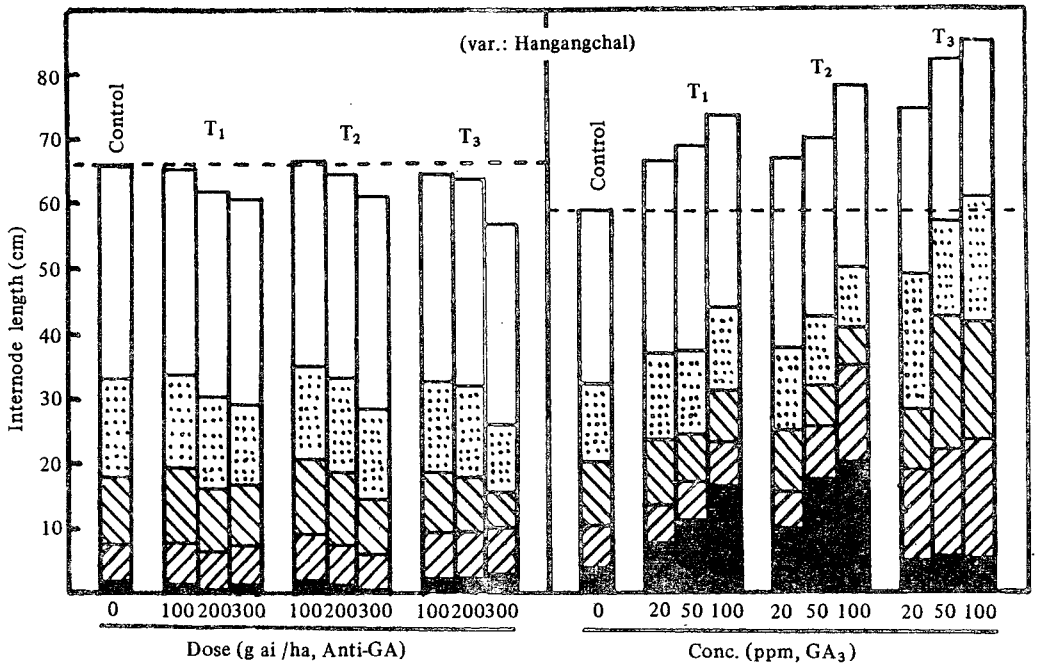

Fig. 4. Effect of Paclobutrazol or GA on the elongation of internodes of the rice cultivar, Hangangchal.

Table 4. Effect of applied GA_3 on the growth of panicle.

Variety		Jinheung		Minehikari		Hangangchal	
Treatment time	Conc. (ppm)	Panicle length (A)	No. of spikelets per panicle (B)	(A)	(B)	(A)	(B)
T_1	20	20.8cm	112	21.2cm	98	24.3cm	119
	50	20.1	113	19.7	99	24.3	127
	100	21.6	118	18.0	93	22.6	122
T_2	20	21.7	117	19.3	92	24.9	127
	50	22.2	113	18.8	93	24.6	116
	100	20.8	114	17.7	90	24.1	125
T_3	20	22.0	112	21.5	97	24.0	119
	50	23.0	109	21.0	94	24.2	121
	100	23.7	111	20.8	97	25.6	124
Non-treatment		22.3	108	19.1	93	23.3	126
F-value		2.62*	3.01*	3.72*	6.42**	3.41*	2.02NS
LSD (5%)		1.1	6.2	1.2	4.7	1.2	–

that time.

GA_3 or paclobutrazol promoted or inhibited the elongation of internodes and also interacted in the growth of panicles. The mode of interaction of GA_3 or anti-GA in the growth of culm and panicle is shown in the Fig. 5. There was no clear relationship between panicle length and culm length in all tested varieties when GA_3 was applied. With the application of paclobutrazol, however, culm length was highly positively correlated with panicle length in

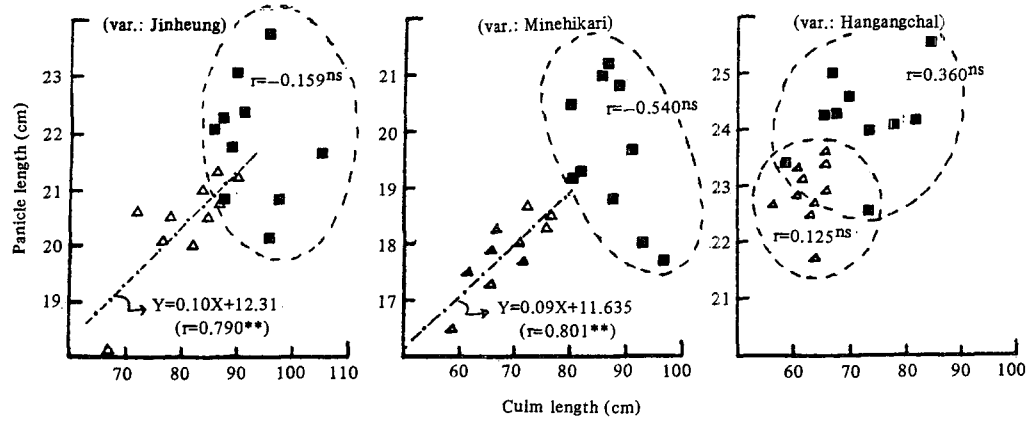

Fig. 5. Relationships between culm length and panicle length when GA_3 (■) or Paclobutrazol (△) was applied.

Table 5. Effect of Paclobutrazol on the growth of panicle.

Variety		Jinheung		Minehikari		Hangangchal	
Treatment time	Dose g a.i/ha	Panicle length (A)	No. of spikelets per panicle (B)	(A)	(B)	(A)	(B)
T_1	100	21.3cm	99	18.7cm	87	23.4cm	123
	200	21.0	83	18.3	85	23.1	127
	300	20.6	85	17.5	84	23.3	120
T_2	100	20.8	101	18.3	90	22.9	126
	200	20.1	95	18.0	83	21.7	120
	300	20.5	92	17.9	80	22.8	117
T_3	100	20.5	104	17.7	89	22.7	128
	200	20.0	105	17.3	88	22.6	125
	300	18.1	101	16.5	86	22.7	124
Non-treatment		21.2	104	18.5	88	23.6	128
F-value		8.4**	3.25*	12.6**	4.7**	3.5*	2.79*
LSD (5%)		0.7	5.7	0.5	3.4	0.7	5.4

the two Japonica varieties, Jinheung and Minehikari, but not in the Indica x Japonica, Hangangchal. Thus, it may be well understood that Japonica varieties characterized by longer culm and shorter panicle are different in their responses to exogenous GA_3 from a semi-dwarf rice variety, Hangangchal, when it was applied at meiotic stage, spikelets having completed their differentiation.

The number of spikelets per panicle increased some or less in the two Japonica varieties by the application of GA_3 only at maximum tillering stage, but not in Hanganchal. The application of paclobutrazol resulted in a decrease in the number of spikelets per panicle as it was applied at maximum tillering stage or panicle initiation stage. There was no reduction in spikelet number as expected, when it was applied at meiotic stage spikelets having completed their differentiation.

摘　　要

水稻品種의 GA_3에 대한 節間伸長反應을 지베렐린 生合成 沮害劑인 Paclobutrazol과 關聯시켜 評價하여 效果的으로 벼의 節間伸長을 調節하고자 本 實驗을 遂行하였다.

진흥, 미네히까리, 한강찰벼를 供試하여 生育時期

別(最高分蘖期, 幼穗形成期 및 減數分裂期)로 GA_3는 0, 20, 50, 100 ppm 溶液을 葉面撒布하였고, Paclobutrazol은 10a당 成分量으로 0, 10, 20, 30 g을 각각 土壤에 處理하여 얻은 結果를 要約하면 다음과 같다.

1. GA_3는 最高分蘖期와 幼穗形成期에 處理하였을 때, 第5節間 以下의 伸長을 促進하였으며, 減數分裂期에 處理하였을 때는 第3節間의 伸長을 顯著히 促進하였다.

2. GA_3는 100ppm 溶液을 處理하였을 때 진흥에서는 最高分蘖期에, 미네히까리는 幼穗形成期에, 한강찰은 減數分裂期에 處理하였을 때 稈長은 對照區에 비해 각각 15.6, 15.9, 44.1%로 伸長이 促進되었으며, 한강찰이 GA_3에 가장 민감하게 反應하였다.

3. Paclobutrazol은 最高分蘖期와 幼穗形成期에 處理하였을 때 第4, 5節間의 伸長을 抑制하였으며, 減數分裂期에 處理하였을 때는 第2, 3節間, 특히 第3節間의 伸長을 현저히 抑制하였다.

4. Paclobutrazol은 處理濃度가 增加함에 따라 稈의 伸長이 抑制되었으며, 減數分裂期에 處理할 때 가장 抑制되어, 對照區에 비해 진흥은 25.3%, 미네히까리는 22.8%, 한강찰은 13.9%程度 稈長이 短縮되었고, 한강찰이 Paclobutrazol에 가장 둔감한 反應을 나타냈다.

5. Paclobutrazol은 株內 모든 이삭들의 稈長을 고르게 減少시켜 株內 稈長의 變異는 對照區와 거의 差異가 없었다.

6. 減數分裂期에 GA_3를 처리하면 세 품종 모두에서 다소 穗長이 길어지나, GA_3를 100 ppm의 高濃度로 減數分裂期 以前에 處理하면 진흥과 미네히까리 품종에서만 穗長이 짧아졌다.

7. Paclobutrazol을 幼穗分化期 以後에 處理하면 穗長은 處理濃度가 增加함에 따라 짧아지는 경향이었다.

8. GA_3나 Paclobutrazol을 處理하였을 때 稈長과 穗長과의 相關關係는 Paclobutrazol을 진흥과 미네히까리에 處理한 경우에만 고도의 正의 相關關係를 인정할 수 있었다.

9. 穗當 穎花數는 GA_3를 最高分蘖期에 處理한 경우, 진흥과 미네히까리에서만 減少되었으나 한강찰에서는 差異가 없었다. Paclobutrazol 處理에 의해서는 最高分蘖期나 幼穗分化期에 處理하면 穗當 穎花數가 감소하였으나 減數分裂期에 處理하면 穗當 穎花數가 變하지 않았다.

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