Effect of Plant Growth Regulators on Lodging in Rice

Lee, Sang-Chul* and S.K. DeDatta**

植物 生長 調節劑가 벼 倒伏에 미치는 影響

李相哲* · 에스 케이 디다타**

ABSTRACT

The experimental growth regulators Hoe78784 and PP-333 significantly reduced lodging in all rices. However, they did not significantly affect the crop vegetative characteristics and yield components, except by decreasing plant height when both growth regulators were applied at booting stage. Grain yield of IR21820-154-3-2-2-3 increased due to reduced lodging when Hoe78784 and PP-333 were applied at booting. These growth regulators increased the thickness and diameter of the culm. Applying CCC did not affect lodging in all test varieties. CCC-treated varieties and the control showed lower number of vascular bundles and culm thickness and diameter of the third and fourth internodes. Hoe78784 and PP-333 significantly reduced internode length from the second to the third internode in short-statured varieties. In tall varieties, reduction extended up to the fourth internode. Culm N content of the varieties did not significantly differ among treatments, except in IR8. Culm P content also did not differ singifficantly among treatments. although K and Si content was the highest than control when Hoe78784 was applied.

Key words : Plant growth regulators, lodging, rice

INTRODUCTION

The world's food demand is incereasing every year and rice production must increase to be able to supply the growing demand of at least 6billion people by the year 2000. Lodging in rice results in the reduction of grain and straw yields and deterioration in their quality besides increasing harvesting cost. The use of growth regulators against can be effective because culm elongation determines lodging. Since the 1950's, a number of growth regulators on rice plants have been studied, but these are not sufficient. Rademacher and Jung(1981) reported that of 60 different commecially available growth-regulating substances, only chlormequat chloride, mepiquat chloride and ethephon are used in cereal production. These growth retardants have not been intensively studied, but have shown variable results in rice. At present, many new growth regulators like BAS-106, PP-333, EL-500, S-3270, NTN-821 and CGR-811 have exhibited substantial success in lodging control(Nickell, 1983).

Their application increases plant resistance to certain environmental stresses, controls crop height, increases tiller and enhances yield. These growth regulators are currently being evaluated in rice cropping systems. Kwon and Yim(1986) reported that paclobutrazol application during tillering of transpanted rice does not seem to prevent lodging. But its application during the reproductive stage at low N levels more or less reduces culm length. At high

* 慶北大學校 農科大學 College of Agriculture, Kyungpook University, Taegu 702-701, Rep. of Korea.
** 國際米作硏究所 (IRRI) International Rice Research Institute, P.O. Box 933, Manila, Philippines.

rates, paclobutrazol tended to reduce grain yield by 50%. The meiotic stage is most vulnerable to lodging. Similarly, with CGR-811[IN-C4-chloro-2-(x-hydroxy benzyl) phenyl T] applied just after seeding and the day before transplanting, lower internodes are shorter, and number of panicles, percentages of well-ripened grains and yield increase. Lodging is also lesser in plants treated with CGR-811(inabenfide) the day before transplanting. CGR-811 can be used from the nursery bed to the panicle base differentiation stage(Shirakawa et al., 1984). Izumi et al. (1984) found that uniconazale at 12g ai/ha reduced lodging and increased yield.

The three triazod compounds, NTN 84, PP-333 or paclobutrazol and S3307 or S327, have similiar stuctures, when applied around regulators, CCC, Decreases dry matter yield, leaf area index and assimilatory area, the last two by shortening the stems and reduction leaf sheath area. It also delays panicle emergence by up to 8 days. CCC does not affect N uptake per unit area of land but increases N percentage in dry matter. Applying CCC daminozide, NAA and TIBA at 20 to 40 days after sowing seeds in the seeding nursery significantly reduce plant height(Hou, 1983). At transplanting, seedlings treated with CCC, TIBA and NAA are shorter and have thicker stems than untreated seedlings. TIBA, NAA and daminozide do not affect the culm lodging resistance(clr) value(IRRI, 1964), and plant height was reduced by 10% with CCC and 28% with TIBA. Yamada et al(1962) reported that spraying TIBA effectively promotes tillering, suggesting that tillering in rice plants can be controled by auxins or antiauxins. Resistance to lodging is in influenced by the interactions of the environmental physiological factors for culm growth.

There are already existing methods to improve lodging resistance, such as by breeding and selection and cultural management. Morever, plant growth regulators have been used in cereals to minimize lodging. Plant growth regulators have been used in crop production to determine if they can be used to control growth of rice plants and variable success has been achieved. Although basic research is still going on, some methods have been developed to improve lodging resistance of rice, such as selection of varieties with short and strong culms, improved cultural practices like water management and mixed seeding or planting of varieties with different lodging resistance. The objective of this study were 1) to determine the effect of different growth regulator application on lodging reactions, 2) to investigate the plant characteristics that can induce lodging and 3) to examine the relationship between lodging resistance and specific morphological characters.

MATERIALS AND METHODS

Experiment 1. Effect of Cycocel and Hoe78784 on Lodging Prevention in Rice

The experiment was conducted on IRRI by using a split plot design with four replications. The varieties were the main plots, subplots were plant growth regulators and subplot was the application time of plant growth regulators. Plots measured 5×4M. IR8, IR36, IR64 and IR21820-154-3-2-2-3 were planted at 20×20cm hill spacing. The growth regulator CCC(1.5Kg ai/ha) was foliar sprayed at booting and heading stage, while Hoe 78784(150Kg ai/ha) was foliar sprayed at booting stage due to a shortage of its supply. Nitrogen fertilizer as urea, P as superphosphate, and K as Muriate of potash each at 60 Kg/ha were basal broadcast and incorporated (BB & I) using a power weeder. The remaining 30Kg n/ha was topdressed at panicle initiation(PI). Plots were flooded to a 2-to 3-cm depth at 5 days after transplanting (DAT) and maintained at 5cm until ripening stage. Drainage was imposed at 12 days before harvesting (DBH). Thiobencarb (S-((4-chlorophenly) methyl)diethyl carbamothioate) at 1.0Kg ai/ha +2, 4-D(2, 4-dichlorophenoxyl acetic acid) at 0.5Kg ai/ha was applied at DT for weed control. Hand weeding was done when necessary while insect and disease control was optimum. Harvesting was done when more than 90% of the spikelets had ripened. Grains were harvested from a 5-m^2 harvest area that was free from border effects.

Fourplaces, each mesasuring 0.08m^2, were selected for plant sampling at harvest time. Internode length, leaf area, stem and leaf dry weight, bending index, degree of lodging and nutrient composition were then measured. Internode length was measured before harvest from the tip of the panicle to ground level of the main culm. Leaf area(cm^2) was measured by using a leaf area meter(Model AAM-7, Hayashi Denko, Japan). For the leaf and root dry weights, plant samples, oven-dried at 110℃ for 24hrs., were weighed and values were expressed in g/3 hills. Bending index was measured with a spring scale and expressed as stress in grams neede to buckle the middle portion of a plant to 30℃ under field conditions : where in 0.1 bending index=100g pushing force, 1.0g=1000g and so on. Degree of lodging was rated by visual scoring. Percent N, percent P, percent K and percent Si were determined before harvest from plant sampled collected outside the harvest and sampling areas.

Plant height was measured at harvest from the base of the plant to the tallest panicle. Tillers were counted from 8 designed hills/plot and converted to tiller number per hill. Grain yield was determined from 125 hills at the center of each plot and converted to tone per hectare at 14% mointure content. Eight hills were sampled outside the 5-m^2 harvest area to determine yield components using procedures described by Gomez(1972)

Experiment 2. Effect of Plant Growth Regulators on Lodging Prevention in Rice

Experiment was conducted in IRRI follow a split -plot design with four replication. The varieties were the main plots and the subplots were the plant growth regulators. Plot size was 4×4M and planting space 20×20cm. IR36, IR42, IR64 and IR21820-154-3-2-2-3 were tested. Growth regulators Hoe 78784(300g ai/ha), CCC(1.5Kg ai/ha) and PP -333(300g ai/ha) were applied at booting stage. Cultural practices and plant measurement procedures were the same as in experiments except for the third anf forth internodes from downwards selected for anatomical observations. Portions 2cm long from each internode were sliced using a razor blade to a thickness of 20-30 microns. Diameter of culm, number of uascular bundles and culm thickness were determined microscopically, and values reduced to fractions. Thickness of culm wall was obtained by measuring the average distance from the periphery of a cross section to its inner boundary. The number of vascular bundles was ascertained by counting those which appeared in a cross section of the culm. Culm diameter was obtained by measuring the longest and shortest diameter of the eight samples using a calibrated , icroscope and computing for the average.

RESULTS AND DISCUSSION

Experiment 1. Effect of Plant Growth Regulators on Lodging Prevention in Rice

Lodging Reduction

IR8 and IR64 did not lodge in all treatments, while IR21820-154-3-2-2-3 showed 10-19% lodging with CCC treatment at booting and heading, repectively (Table 1). With Hoe78784, lodging in IR21820-154-3-2-2-3 and IR36 were effectively suppressed. IR21820-154-3-2-2-3 was more susceptible to lodging than IR36, probably due to tis higher stem elongation. Applying growth retardants certainly prevents lodging but may slightly reduce grain yiled under adverse environmental conditions. However, the effect of growth retardance may be further improved by manipulating the normal growth pattern and development of the plant. Nevertheless, the use of plant growth regulators offers one way of preventing lodging and increasing grain yield due to its effect on plant growth and development.

Table 1. Effect of growth regulators on lodging of test rices.

TREATMENT	APPLICATION	LODGING (%)[a]			
		IR8	IR36	IR64	IR21820-154-3-2-2-3
CCC	Booting	0a	1a	0a	19a
CCC	Heading	0a	0a	0a	10a
Hoe 78784	Booting	0a	0a	0a	0b
Control		0a	8a	0a	18a

[a] In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 2. Effect of growth regulators on bending index of test rices.

TREATMENT	APPLICATION TIME	BENDING INDEX[a]							
		IR8		IR36		IR64		IR21820 154-3-2-2-3	
		45°	30°	45°	30°	45°	30°	45°	30°
CCC	Booting	1.9	3.1	1.5	2.5	1.8	3.0	1.5	2.8
CCC	Heading	2.1	3.3	1.7	2.7	1.9	3.3	2.8	3.1
Hoe 78784	Booting	2.0	3.2	1.6	2.6	1.8	2.9	1.6	3.1
Control		1.8	3.0	1.3	2.5	1.8	3.0	1.5	2.7

[a] All values are not significantly different at the 5% level by DMRT.

Bending Resistance

Bending to 45 angle and 30 angle was not affected by different treatments, application time and varieties except for IR36 (Table 2). CCC and Hoe78784 application slightly increased bending resistance of IR36, although not significantly. Results did not agree with Hou (1983) who reported that even though no natural lodging occurred with CCC, higher lodging resistance values were obtained and compared with those of the untreated check. In another experiment, Hou (1983) obtained higher clr value in wet-seeded rice and ratooned crops treated with CCC+Kinetin. Tolbert (1960) added that CCC inhibits the growth of wheat and prevents lodging at maturity.

Grain Yield

IR21820-154-3-2-2-3 yield highest when CCC was applied at heading and lowest in the control and when Hoe78784 was applied at booting. However, difference was not significant among treatments (Fig. 1). IR36 did not have significantly yield difference between treated groups and the control. IR8 and IR64 likewise did not differ significantly, but Hoe78784 reduced slightly, nonsignificantly, the grain yiled. Basnet (1984) reported that increases in grain yiles of IR42 and IR58 with CCC were more consistent than those of the control for five seedling ages. Pinthus and Halevy (1965) also reported that CCC applied at 10 Kg/ha increased grain yiled of wheat by 30% mthrough production of more kernels per spikelet. In the experiments of Chalakhyan and Aruthnuyan (1968), CCC increased alfalfa yield by 35% from enhancing N-fixation in the presence of carbohydrates translocated to the roots. Shahi et al. (1979) and Pikush et al. (1976) reported that combining high N levels and CCC increases rice yield. Morever, CCC applied at a certain growth stage modifies yield components which increase yields (Biawas and Choudhuri, 1977).

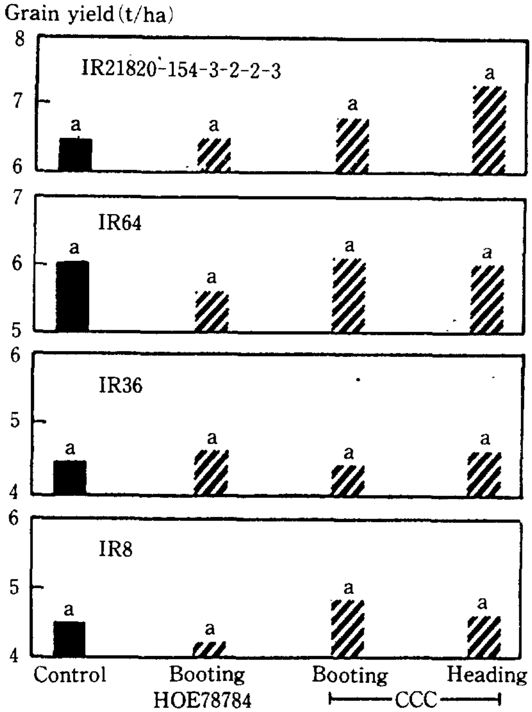

Fig. 1. Grain yield of four rices as affected by different growth regulators. Within a variety or line, bars having a common letter are not significantly different at the 5% level by DMRT.

Yield Components

The growth regulators generally did not have a significant effect on yield components of all test rices (Table 3). In IR8, only straw weight significantly differed among treatments. IR36 and IR64 had significant difference only in filled spikelet percentage and panicle length when Hoe78784 was allpied at booting. These results do not agree with earlier explanations of Biswas and Chouhuri (1977) that CCC increased grain yields due to the cumulative contribu-

Table 3. Effect of growth regulators on yield components[a] of test rices.

TREAT-MENT	APPLI-CATION TIME	PANICLE COUNT (no./10 hills)	PANICLE LENGTH (cm)	FILLED SPIKELET (%)	STRAW WEIGHT (g/m)
			IR8		
CCC	Booting	29a	22a	82a	33a
CCC	Heading	24a	21a	80a	33a
Hoe 78784	Booting	29a	23a	80a	22b
Control		29a	24a	83a	31a
			IR36		
CCC	Booting	17a	20a	90a	18a
CCC	Heading	17a	16a	80ab	18a
Hoe 78784	Booting	16a	18a	84b	16a
Control		18a	19a	89ab	a
			IR64		
CCC	Booting	23a	22ab	92a	21a
CCC	Heading	23a	24a	94a	20a
Hoe 78784	Booting	23a	21b	92a	24a
Control		20a	22ab	91a	22a
			IR21820-154-3-2-2-3		
CCC	Booting	25a	25a	88a	26a
CCC	Heading	24a	25a	88a	30a
Hoe 78784	Booting	22a	24a	84a	27a
Control		25a	23a	86a	34a

[a] In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

tion of all the yield components in their field trial ; and with reports of Gej and Vlodkowski (1978) that CCC increased the spikelets per panicle by 26-29% and the translocation of assimilates to the graind.

Vegetative Characteristics

The growth regulators and nonsignificant effect on leaf area and tiller number of all varieties (Table 4). IR8 showed decreased plant height when applied with CCC at heading. With Hoe78784 applied at booting IR8 gave lighter stem weight than the untreated and CCC-treated groups. Vegetative characteristics of IR64 were not significantly affected. In IR36, Hoe78784 reduced plant height when applied at bootin, although not significantly. Its other characteristics were not affected by CCc nor Hoe78784. For IR21820-154-3-2-2-3, plant height was significantly decreased with Hoe78784 and CCC application at booting. These results agree with those of Yamada (1976) that CCC did not affect plant height but increased tiller number, although the effect on tiller number was not clear from the results obtained. However, Gej and Vlodkowski (1978) reported that soil application of 22mg CCC at the stem elongation stage of wheat decreased stem length by 26-29% but did not affect the total dry matter accumulation. Tolbert (1980) added that CCC could reudce the plant height of 30-day-old transplanted wheat and barley seedlings by 40%. CCC treatment in all varieties did not affect internode elongation (Table 5). On the other hand, applying Hoe78784 in IR21820-154-3-2-2-3 decreased elongation in the first to the fifth internodes, thus preventing lodging. Hoe78784 did not significantly reduce internode length in IR8, IR36 and IR64, but in general, Hoe78784 consistently shortened culm length up to the fourth internode.

Nutritional Aspect

There were no significant differences in culm N content among treatments in all varieties except in IR8. With Hoe 78784 applied at booting, culm N content of IR8 was higher compared with that of the control (Fig.2). Hoe78784 increased culm N content in all varieties except in IR46. There eas no relationship between lodging resistance and culm N content. This result is in contrast with the findings of Humphuries et al. (1965) that CCC increased the percentage of N in wheat because CCC slightly affected N uptake per unit area. Culm P content was the same

Table 4. Effect growth regulators on the vegetative characteristics[a] of four rice varieties.

TREAT-MENT	APPLI-CATION TIME	PLANT HEIGHT (cm)	TILLER COUNT (no./m^2)	LEAF AREA (cm^2/tiller)	STEM WEIGHT (g/hill)
		IR8			
CCC	Booting	82ab	96a	284a	33a
CCC	Heading	80b	115a	289a	33a
Hoe 78784	Booting	84ab	110a	299a	22b
Control		87a	119a	305a	31a
		IR36			
CCC	Booting	62a	157a	173a	18a
CCC	Heading	62a	169a	151a	19a
Hoe 78784	Booting	57a	165a	139a	16a
Control		64a	158a	164a	18a
		IR64			
CCC	Booting	78a	134a	264a	21a
CCC	Heading	79a	138a	330a	20a
Hoe 78784	Booting	76a	132a	324a	24a
Control		78a	119a	240a	22a
		IR21820-154-3-2-2-3			
CCC	Booting	91b	141a	255a	26a
CCC	Heading	98a	146a	229a	28a
Hoe 78784	Booting	85b	139a	293a	27a
Control		92ab	140a	219a	34a

[a] In a Column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 5 Effect of growth regulators on internode elongation of four rice varieties.

TREATMENT	APPLICATION TIME	DOSAGE	INTERNDE LENGTH (cm)[a] 1st	2nd	3rd	4th	5th	6th
		IR8						
CCC	Booting	3000g/ha	28a	7a	7a	3a	2a	1a
CCC	Heading	3000g/ha	27a	8a	4b	3a	1a	-
Hoe 78784	Booting	150ai/ha	28a	6a	5b	2a	1a	1a
Control			29a	8a	6ab	3a	2a	1a
		IR36						
CCC	Booting	3000g/ha	28a	13a	6a	4a	2a	1a
CCC	Heading	3000g/ha	28a	13a	6a	2b	1a	-
Hoe 78784	Booting	150ai/ha	26a	12a	5a	3b	1a	1a
Control			26a	14a	7 a	4a	2a	2a
		IR64						
CCC	Booting	3000g/ha	32a	15a	9a	5a	2a	1a
CCC	Heading	3000g/ha	31a	16a	7a	4a	2a	-
Hoe 78784	Booting	150ai/ha	30a	15a	8 a	5a	2a	1a
Control			32a	15a	8a	5a	2a	1a
		IR21820-154-3-2-2-3						
CCC	Booting	3000g/ha	35ab	19a	11a	5a	3b	2a
CCC	Heading	3000g/ha	36a	19a	10ab	5a	3b	-
Hoe 78784	Booting	150ai/ha	33b	16b	9b	4b	3b	2a
control			36a	19a	11a	6a	4a	2a

[a] In a column, means followed by a common letter(s) are not significantly different at the 5% level by DMRT.

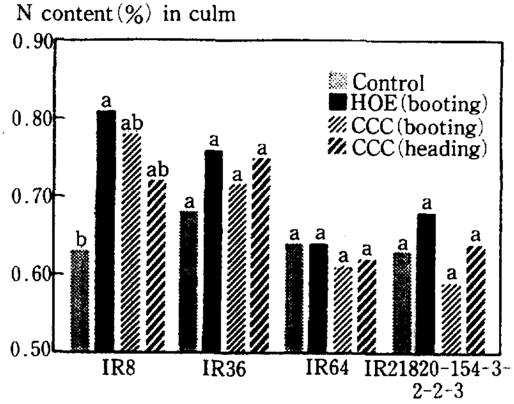

Fig.2. Culm N content of four rices as affected by plant growth regulators. Within a variety or line, bars with a common letter are not significantly different at the 5% level by DMRT.

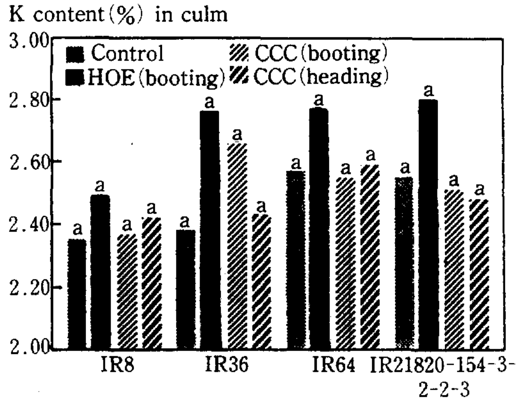

Fig.4. Culm K content of four rices as affected by plant growth regulators. Within a variety or line, bars with a common letter are not significantly different at the 5% level by DMRT.

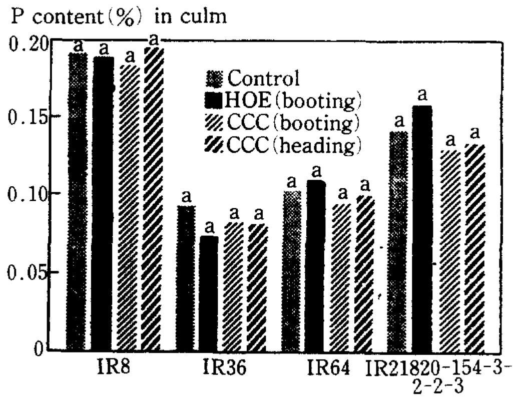

Fig.3. Culm P content of four rices as affected by plant growth regulators. Within a variety or line, bars with a common letter are not significantly different at the 5% level by DMRT.

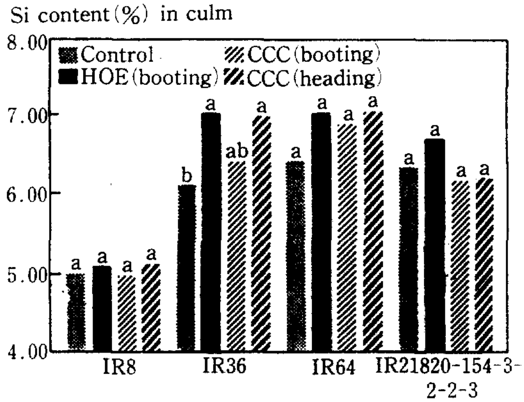

Fig.5. Culm Si content of four rices as affected by plant growth regulators. Within a variety or line, bars with a common letter are not significantly different at the 5% level by DMRT.

among treatments in all varieties (Fig.3). Potassium content also did not differ significantly among treatment (Fig.4), although K content was highest with Hoe78784. High K content might have favored lodging resistance in all test varieties. Culm Si content between Hoe 78784 and control. In IR 21820-154-3-2-2-3 a higher though nonsignificantly Si content was obtained with Hoe78784 applied at booting. (Fig.5). Silicon is believed to strengthen hollow-strawed grasses and its deficiency is seen by a number of workers as the cause of lodging. However, the importance of Si from the standpoint of straw strength has also been questioned. Vaidys and Malkani (1963) did not conclude any possible relationship between the Si content of wheat plants and their lodging behavior.

Experiment 2. Effect of Plant Growth Regulators on Lodging Prevention in Rice (1986 WS)

Lodging Reaction

IR42 and IR64 had zero lodging in all treatments (Table 6). IR36 had 3% lodging in the control and zero lodging with the use of PP-333, CCC and Hoe78784. IR21820-154-3-2-2-3 exhibited 41% lodg-

Table 6. Effect of plant growth regulators on lodging four rice varieties.

TREAT-MENT	LODGING (%)[a]			
	IR36	IR42	IR64	IR21820-154-3-2-2-3
Control	3a	0a	0a	39a
PP-333	0a	0a	0a	13b
CCC	0a	0a	0a	41a
Hoe 78784	0a	0a	0a	0c

[a] In a column, Treatment means having a common letter are not significantly different at the 5% level by DMRT.

ing using CCC and 39% in the control. PP-333 reduced lodging and Hoe78784 effectively suppressed lodging in IR21820-154-3-2-2-3. Between IR36 and IR21820-154-3-2-2-3, the latter was more susceptible to lodging. hoe78784 apparently was most effective against lodging in IR36 and IR21820-154-3-2-2-3. However, CCC, hoe78784 and PP-333 effectively controlled lodging in the resistant varieties IR42 and IR64. results of this experiment do not agree with the findings of Das Gupta (1971) in upland field experiment that foliar spraying of CCC at 10 and 21 days after sowing showed lesser effect in lodging prevention, woth only an 8% difference in lodging occurring between CCC treaments and control. Kwon and Yim (1986) reported that application of paclobutrazol during the tillering stage of transplated rice does not seem to prevent logding. However, soil treament with PCP after the active tillering atage effectively controlled excessive vegetative growth and strengthened lodging resistance by controlling elongation of the basal internodes and increasing breaking resistance of culm (Hashizume and Yamagishi, 1969). Humphries (1968) observed that lodging in wheat, oats and barley can be reduced or prevented and grain yield increased with CCC.

Grain Yield

Grain yield of IR36 did not significantly differ among the differrent treatments. Hoe78784 applied at booting stage decreased IR36 grain yield due to reduced panicle length. Leaf area and dry matter production, however, were not affected. IR42 yield highest in the control and CCC treatments : lower yields were recorded with PP-333, and lowest yiled with Hoe78784. Hoe78784 reduced yield at high con-

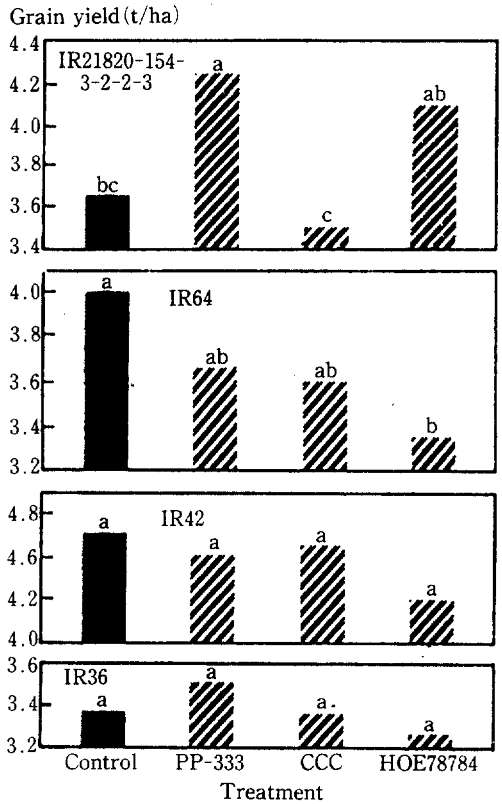

Fig. 6. Grain yield of rice varieties as affected by plant growth regulators. Within a variety or line, bars with a common letter(s) are not significantly different at the 5% level by DMRT.

centrations. IR64, like IR42, yielded highest in the control. its yield was equal in PP-333 and CCC treatments severely decreased due to lodging (Fig. 6). Das Gupta (1971) reported that there were no significant effects on grain yield from various CCC treatments, and that grain yield in the control was not significantly different form the treated crops. Khan et al. (197), however, found that one application of 40 ppm CCC to Safri 17, a late-maturing, tall indica cultivar, at the early or late tillering strages of crop growth prevented lodging and increased yield significantly over the untreated check. Also, 40ppm CCC sprayed at mid-tillering reduced plant height and plant vigor, and increased grain yield by 6% over the control (Urkurkar and Chandravanshi, 1987). CCC with optimum fertilizer application helped minimizing vegetative growth thus diverting the physiological activities towards grain production. Paclobutrazol applocation at higt rates tends to grain yield by 5% (Kwon and Yim, 1986), although Kohli (1984) found that PP-333 retards vegetative growth and diverts assimilates during reproductive growth, thus increasing yield potential.

Yield Components

The growth regulators generally did not significantly affect yield components of all test rices (Table 7). However, panicle number of IR36 decreased by 25 with Hoe78784 and increased by 6/m² with PP-333. Hoe78784 applied to IR64 also reduced panicle length. PP-333 produced high filled spikelet percentage and 100-grain weight in IR21820-154-3-2-2-3. Panicle length was the greatest (24cm) with CCC application in IR21820-154-3-2-2-3. CCC also gave high filled spikelet percentage (85%) and panicle number but short panicle length, spikelet fertility and 100-grain weight with CCC. ingeneral, PP-333 and CCC were effective against lodging in resistant varieties IR42 and IR64. In contrast, Hoe78784 produced low yield component values in all test varieties. Findings corroborate with the report of Das Gupta (1971) that non significant difference occurs in the numbber of panicle-bearing tillers in various CCC treatments, although CCC produces a smaller but significant number of panicle-bearing tillers compared to the control. However, the findings do not agree with earlier reports that CCC increases panicle number (Humphries et al., 1965; Barrett and Mees (1967). Humohries et al. (1965) summarized that CCC-treated wheat had lesser infertile spikelets, more grains per panicle, higher grain yield and lesser 1000-grain weight per panicle.

Vegetative Characteristics

Except for CCC, the plant growth retardants reduced plant height of all varieties (Table 8). Leaf area of all the varieties was not significantly different from other and the control. Tiller number also was not significantly different except in IR36 which had tillers when treated with Hoe78784 and PP-333. Plant dry weight was not significantly different between treatments and varieties. In general, IR36 had the greatest tiller number and leaf area but the lowest stem and leaf dry weights. IR21820-154-3-2-2-3 plants were the tallest. IR42

Table 7. Effect of plant growth regulators on yield components of four rice varieties.

TREAT-MENT	PANICLE LENGTH (cm)	FILLED SPIKELET (%)	100-GRAIN WEIHHT (G)	PANICLE NUMBER (no./m²)
		IR36		
Control	20a	84a	2.35a	363ab
PP-333	19a	85a	2.26a	369ab
CCC	19a	85a	2.30a	398a
Hoe 78784	18a	85a	2.30a	338b
		IR42		
Control	21a	86a	2.24a	291a
PP-333	21a	82a	2.26a	307a
CCC	22a	88a	2.26a	282a
HOE 78784	20A	88A	2.14A	272A
		IR64		
Control	22a	83a	2.75a	291a
PP-333	22a	80a	2.79a	307a
CCC	23a	79a	2.82a	322a
Hoe 78784	20b	83a	2.56a	313a
		IR21820-154-3-2-2-3		
Control	23ab	76a	2.25ab	254a
PP-333	22ab	83a	2.27a	275a
CCC	24a	77a	2.21ab	272a
Hoe 78784	21b	81a	2.11b	282a

[a] In a column, treatment means having a common letter are not significantly different at the 5% level by DMRT.

Table 8. Leaf area, plant height, tiller number and dry weight of four rice varieties as affected by plant growth regulators.

TREATMENT	LEAF AREA (cm^2/3 hills)	PLANT HEIGHT (cm)	TILLER COUNT (no./hill)	DRY WEIGHT (g/3 hills)
		IR36		
Control	1456a	82a	12b	38a
PP-333	1669a	75b	15a	36a
CCC	1389a	77ab	14ab	33a
Hoe 78784	1716a	74b	15a	37a
		IR42		
Control	1047a	88a	11a	62a
PP-333	1139a	82bc	11a	66a
CCC	1075a	87ab	11a	60a
Hoe 78784	1311a	80c	11a	69a
		IR64		
Control	1493a	88a	11a	58a
PP-333	1526a	74b	11a	53a
CCC	1531a	88a	11a	51a
Hoe 78784	1545a	76b	12a	46a
		IR21820-154-3-2-2-3		
Control	1089a	90b	12a	44a
PP-333	1208a	85b	11a	47a
CCC	976a	95a	11a	45a
Hoe 78784	1099a	86b	12a	45a

[a] In a column, treatment means having a common letter are not significantly different at the 5% level by DMRT.

Table 9. Effect of plant growth regulators on internode elongation of four rice varieties.

TREATMENT	INTERNODE ELONGATION (cm)[a]			
	2nd Internode	3rd Internode	4th Internode	5th Internode
		IR36		
Control	13a	6ab	3a	1a
PP-333	9b	5b	3a	1a
CCC	11a	7a	3a	1a
Hoe 78784	8b	5b	3a	1a
		IR42		
Control	16a	8a	7a	3a
PP-333	13b	6b	5b	3a
CCC	16a	8ab	6ab	2a
Hoe 78784	14b	7ab	5b	3a
		IR64		
Control	15a	7a	6a	2a
PP-333	11b	6b	5a	3a
CCC	15a	8a	5a	2a
Hoe 78784	12b	6ab	5a	2a
		IR21820-154-3-2-2-3		
Control	15ab	10a	6a	3a
PP-333	15ab	8b	6ab	3a
CCC	17a	9b	6a	3a
Hoe 78784	13b	7c	5b	3a

[a] In a cloumn, treatment meas having a common letter(s) are not significantly different at the 5% level by DMRT.

had the highest stem and leaf dry weights, but least tiller number. Leaf area of rices did not significantly differ among treatments. However, IR64 had the widest leaf area. In contrast to results, Galjcenko (1952) reported that high area weakens the resistance of plants to lodging. Hou(1983) reported that CCC applied 20 to 40 days after sowing seeds in the nursery significantly reduced plant height. Furthermore, CCC-treated transplanted seedlings were shorter and had thicker stems than the untreated seedlings. There is much disagreement among workers regarding the association of plant height with lodging, though majority conclude that short and stiff-strawed varieties are less likely to lodgred. IR36 had shorter internode compared with the other varieties. In short-satured varieties(IR36 and IR64), growth retardants reduced internode length in the second and third internodes(Table 9). Tall varieties had a significant reduction up to the fourth internode. Hoe78784 and PP-333 consistently shortened internode length in all test varieties while CCC did not Kwon and Yim(1986) reported that PP-333 shortened plant height and culm length, particularly when applied qt 200g/ha at the meiotic stage of rice plants. PP-333 also shortened the upper third internode and decreased lodging index without reducing yield. Takano (1969) stated that the shortner the length of the fourth internode, the greater the breaking strength of culms. Im some cases, the longer the length of the fourth internode, the greater the culm breaking strength.

The effect of PCP on internode elongation was also studied studied by Hashizume and Yamagishi (1969). They found that soil treatment with PCP after effective tillering successfully controlled excessive vegetative growth and strengthened the rice plant resistance to lodging, because PCP controlled the elongation of basal internodes and increased breaking resistance of culm. In general, Hoe78784 and PP-333 increased thickness and diameter of the third and fourth internodes in all varieties, while CCC and the control produced lesser thickness, diameter and number of vascular bundles of the third and fourth internodes(Table 10, 11, 12).

Table 10. Culm thickness(mm) of third and fourth interrnode of four rice varieties as affected by plant growth regulators.

TREAT-MENT	IR36	IR42	IR64	IR21820-154-3-2-2-3
		3rd internode		
Control	0.40	0.46	0.49	0.43
PP-333	0.51	0.49	0.51	0.51
CCC	0.44	0.45	0.46	0.44
Hoe 78784	0.53	0.51	0.54	0.51
		4th internode		
Control	0.53	0.60	0.65	0.58
PP-333	0.61	0.63	0.74	0.67
CCC	0.56	0.57	0.68	0.60
Hoe 78784	0.63	0.67	0.76	0.69

Table 11. Culm diameter(mm) of third and fourth internode of four rice varieties as affected by plant growth regulators.

TREAT-MENT	IR36	IR42	IR64	IR21820-154-3-2-2-3
		3rd internode		
Control	3.4	3.6	4.0	3.8
PP-333	3.9	4.2	4.3	4.1
CCC	3.6	3.6	3.8	3.8
Hoe 78784	3.9	4.1	4.4	4.0
		4th internode		
Control	3.8	4.7	4.8	4.4
PP-333	4.2	5.0	5.3	5.0
CCC	3.8	4.7	4.9	4.5
Hoe 78784	4.7	5.5	5.4	5.1

Table 12. Vascular number of third and fourth internode of four rice varieties as affected by plant growth regulators.

TREAT-MENT	IR36	IR42	IR64	IR21820-154-3-2-2-3
		3rd internode		
Control	24	28	28	29
PP-333	25	30	29	30
CCC	24	28	28	26
Hoe 78784	26	30	29	28
		4th internode		
Control	25	31	29	28
PP-333	26	29	29	28
CCC	26	30	28	28
Hoe 78784	26	30	30	29

摘　要

生長調節劑인 Hoe78784와 PP-333의 處理는 公試된 모든 品種에 있어서 倒伏이 현저하게 減少하는 현상을 보였으나, 穗孕期때 이들 處理는

草長의 減少를 제외하고는 營養生長器官과 數量構成要素에는 크게 影響을 미치지는 않았다. Hoe78784와 PP-333의 處理는 倒伏의 감소로 因한 IR21820-154-3-2-2-3의 數量 增大를 가져왔으며, 이와같은 倒伏의 減少는 形態的인 特徵 面에서 生長調節劑 處理로써 管의 두께와 直徑과 有管束 數를 增加시켰다. Cycocel(CCC)의 處理는 Hoe78784와 PP-333을 處理한 것 보다 有管束의 數, 管의 두께 , 3, 4번째 마디의 直徑이 낮게 나타났으며, 모든 處理區에서 倒伏의 減少 影響이 전혀 나타나지는 않았다. 短稈種(IR36)에서의 Hoe78784와 PP-333의 處理는 2, 3번째 節幹의 伸長이 현저하게 減少되었으며, 長稈種에서는 4번째 節稈까지 儉素되었고 倒伏에 가장 크게 影響을 미치는 節稈은 세번째 및 네번째 節稈인 것으로 나타났다. 生長調節劑 處理區에 있어서 植物體內의 營養關係는 窒素含量에 있어서 無處理區와 큰 差異는 없었으나, IR8에 있어서의 窒素含量은 높게 나타났으며 燐酸의 含量은 모든 品種에 있어서 뚜렷한 變化가 나타나지는 않았다. 또한, 칼륨의 含量도 處理區와 無處理區간에 뚜렷한 差異를 보이지 않았지만, Hoe78784를 處理하였을 때에는 칼륨과 硅酸의 含量이 無處理區보다는 높게 나타났다.

LITERATURE CITED

1. Berrett, D.W.A. and G.C. Mees. 1967. The control of lodging in creals by 2-chloroethyl ammonium chloride(CCC), J. Agri. sci. 68 : 39-46.
2. Basnet, B.M.S. 1984. Chemical manipulation of seeds and seedings for increasing grain yield in transplanted rice. M.S. Thesis. University of the Philippines at Los Banos, Philippines. 162p.
3. Biswas, A.K. and MA.A. Choudhuri. 1977. Analysis of yield components in relation to yield of rice sprayed with hormones and nutrients at different growth stages. Indian Agric. 21(1) : 33-39.
4. Chalakhan, M.K. and R.S. Arutyunuyan. 1968. Effect of chlormequat on the growth, nodulation and rhizospere micro-organisms of leguminous plants. Biol. 21 : 3-11.
5. Das Gupta, D.K. 1971. Effects of CCC and Grain yield of upland and swamp rice in Sierea Leonne. EXP. Agric. 7 : 157-160.
6. Agijcenko, I.N. 1952. Mprphological characteristics of spring wheat in connection with lodging. Dakl. Obsh. Sobr. Ak. Nauk. S.S.S.R. 83 : 749-752.
7. Gej, B. and M.Vlodkowski. 1978. The effect of CCC on the CO_2 assimilation and growth of some crops. Rocznki Ndak. Philippines. 46p.
8. Gomez, K.A. 1972. Technique for field experiment with rice. International Rice Research Institute, Los Banos, Philippine. 46p.
9. Hashizume, A. and A. Yamagishi. 1969. Studies on growth regulation of rice plants by soil treatment with pentachlorophenol(PCP). Proc. Crop Sci. Soc. Japan. 38(3) : 388-395.
10. Hou, F.F. 1983. Effect of plant growth regulators and herbicide on weed community composition, sprouting development and grain yield of main and ratoon rice. M.S. Thesis. Univ. of the Philippines at Los Banos, Los Banos, Philippines. 173p.
11. Humphries, E.S. 1968. CCC and cereals. Field crops abstr. 21 : 91-99.
12. Humphries, E.C., P.J. Welbank and K.J. Witts. 1965. Effect of CCC(Chlorocholine chloride) on growth and yield of spring wheat in the field. Applied Biol. 56 : 351-360.
13. IRRI(International Rice Research Institute). 1964. p.37-48. In annual report for 1963. International Rice Research Institute(IRRI), Los Banos, Philippines.
14. Izumi, K., I. Yamaguchi, H. Wada, H. Oshio and N, Tskshashi. 1984. Effect of a new plant growth regardant (E)-1-(4-chlorophenyl) -4-4-Dimethyl-2-(1, 2, 4-triazol-1-Y) -1-penten-3-0(S-330)) on the growth and gibberellin content of rice plant cells. Plant Cell Physio. 25(4) : 611-617.
15. Khan, R.A., B.P. Dubey and M.L. Kashyap. 1976. Prevention of lodging losses in rice. ORYZA 13(2) : 129-130.
16. Kohli, A. 1984. Paclobutrazol, a versatile new plant growth regulator as an effective tool in crop management. Imperial Chemical Industries Japan Ltd. Bull. 15p.

17. Kwon, Y.W. and K.O. Yim. 1986. Paclobutrazol in rice. p.128-137. In plant growth regulators in agriculture. Food and Fertilizer Technology Center for the Asian-Pacific region.

18. Nickell, L.G. 1983. The role of growth regulators and hormone in enhancing food production. p.601-606. In Chemistry and world food supplies : the new frontiers. CHEMRAWN II. Pergamon Press.

19. Pikush, G.R., A.L. Grinchenko and M. Pikutin. 1976. How to prevent lodging of cereals. Tak. Zapohigti, Vilyagannyn, Khliniv. Kiev, Ukranian SSR, Urozhai. 136p.

20. Pinthus, M.J. and A.H. Halevy. 1965. Prevention of lodging and increase in yield of wheat treated with CCC. Israel J. Res. 15 : 159-161.

21. Rademacher, W. and J. Jung. 1981. Comparative potency of various synthetic plant retardants on the elongation of rice seedlings. Z. Ackerfillanzenb. 150(5) : 363-371.

22. Shahi, N.H., P.S. Gill, S.N. Thind and M.S. Maskina. 1979. The effect of seedling age at transplanting on rice in saline-sodic soils of Northwest Indian. Exp. Agric. 13 : 169-175.

23. Singh, J.M. and J. Takahashi. 1962. Effect of varying dates of topdressing of nitrogen on plant characters leading to tendency for lodging in rice. Soil Sci. Plant Nutr. 8(5) : 169-176.

24. Takano, H. 1969. On the lodging prevention of rice plant by 2, 4-D. (Jap.) Bull. Fukui Agric. Exp. Sta. 6 : 25-37.

25. Tolbert, N.E. 1960. (2-chloroethyl)trimethylammonium chloride and related compounds as plant growth substances. PlantPhysiol. 35 : 380.

26. Urkurkar, J.S. and B.R. Chandravanshi. 1987. Cultural and chemical methods to prevent lodging and stabilize yield of a tall indica rice. IRRN 9(5) : 22.

27. Vaidya, J.J. and S.M. Malkani. 1963. Lodging resistance in durum varieties of wheat. Indian J. Gennet. 23 : 25-29.

28. Yamada, N. 1976. Chemical control of crops : chemical control of plant growth and development. Tokyo, Nogyo, Gijutsu Kyokai. 246p.

29. Yamada, N., H. SURE, and H. NAKAMURA. 1962. Chemical control of plant growth and development. Proc. Crop Sci. Soc. Jap. 31 : 258-262.