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Effects of Trinexapac-ethyl on Lodging-related Traits in Transplanted Rice

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ABSTRACT

The objective of this study was to determine trinexapac-ethyl [4-(cyclopropyl- α -hydroxy-methylene)-3,5-dioxocyclohexanecarboxylic acid ethyl ester] effects on lodging-related traits of rice varieties treated at different application rates and times. Trinexapac-ethyl WP was applied at the rate of 10, 20 and 30g ai/10a to Heukjinjubyeo and Daeanbyeo, respectively. Effects of trinexapac-ethyl varied greatly with application time as well as application rate with little differences between rice varieties. As the application rate increased, lodging index, center of gravity and exsertion of panicle above flag leaf decreased, whereas breaking strength and phytotoxicity increased. Exsertion of panicle was greatly influenced by the application time with a little difference by application rate. The most effective application time of trinexapac-ethyl based on lodging index and total internode length (1st-4th node) was 2DBH(days before heading) in Heukjinjubyeo and 17DBH in Daeanbyeo, resulting in reducing total internode length by 12.9 and 9.7cm, respectively. A significant reduction was found at the 1st, 2nd, and 3rd internodes in Heukjinjubyeo, while at the 2nd and 3rd internodes in Daeanbyeo. No significant difference was found among treatments in the panicle length of both rice varieties but the panicle fresh weights of Daeanbyeo were significantly greater in all trinexapac-ethyl treatments compared with that of the control when measured 20 days after heading. Consequently, trinexapac-ethyl treatment significantly improved lodging-related traits of rice plants without affecting rice yield and yield components.

Keywords : trinexapac-ethyl, lodging, growth retardant.

Lodging has been one of the major concerns in rice cultivation. There have been continuing efforts to reduce lodging through cultural practices as well as chemical applications. Lodging causes severe yield loss and makes machine-harvesting difficult, reducing working efficiency about 25% at harvesting (Lim et al., 1992). The amount of nitrogen application, water management, planting density, and cultivars were considered as major factors influencing lodging (Song et al., 1996; Back et al., 1997). Although a lot of researches have been addressed to solve lodging problems, They are still lingering subjects in rice researches.

Heukjinjubyeo, blackish purple-colored rice, is recently gaining popularity as a healthy food. However, it is known for being prone to lodging probably because its ripening stage occurs during hot weather due to its short growth period, inducing early senescence after heading (Lim & Cho, 1988).

Trinexapac-ethyl registered for rice in 1998 appears to have great potential as a growth retardant for rice. Trinexapac-ethyl, which is a GA inhibitor, is absorbed primarily by foliar penetration, almost immediately after application. It suppresses plant growth by interfering with gibberellin biosynthesis but not development, thus reducing cell elongation and subsequent organ expansion (Porpiglia et al., 1990; Grossmann, 1992; Fagerness & Penner, 1998).

Uniconazole application from seeding to 30DBH on direct seeded rice reduced culm length by 3~13% due mainly to the shortening effect of the 4th and 5th internodes (Choi et al., 1991). While, paclobutrazol applied 15 days before heading inhibited the 3rd internode of transplanted rices by 40%, compared to untreated control (Lee et al., 1987). By applying trinexapac-ethyl, field lodging was successfully decreased in the study by Im et al. (1993). These previous reports indicate that the utilization of growth retardants designed to suppress top growth could be a useful measure available for the prevention of lodging in rice cultivation.

Therefore, the objective of this study was to determine the effects of the recently registered growth retardant, trinexapac-ethyl, on lodging-related traits in Heukjinjubyeo and Daeanbyeo.

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MATERIALS AND METHODS

This experiment was conducted at the paddy field of Kyonggido Agricultural Research and Extension Services in 1998. Heukjinjubyeo was transplanted on June 5 and Daeanbyeo on June 1 with 30-day-old seedlings. Rice plants were fertilized at 110-45-57kg/ha (N_2-P_2O_5-K_2O). Growth retardant, trinexapac-ethyl WP was applied to Heukjinjubyeo and Daeanbyeo, respectively, at the rate of 10, 20 and 30g ai/ha with 160 l of water by a hand-held sprayer. Application times were 10 and 2 days before heading (DBH) in Heukjinjubyeo, and 17, 8, and 0 days before heading in Daeanbyeo.

For the measurement of lodging-related characters such as internode length, culm diameter, fresh panicle weight, weight of basal node and breaking strength, sampling was done 30 and 20 days after heading in Heukjinjubyeo and Daeanbyeo, respectively. Fifteen tillers, which were relatively uniform, were selected out of three plants from each experimental unit. Weight of the basal node was obtained from 10cm of the bottom node. Lodging index was calculated with the following formula : [(culm length + panicle length) × top fresh wt.]/breaking strength × 100. The plots were arranged in a randomized complete block design with 3 replications. Each plot size was 16m^2. Rice plants were harvested 45 days after heading for the evaluation of yield and yield components. All statistical analyses were conducted using the Statistical Analysis System (SAS Inst., 1985). Analysis of variance was used to analyze the data. All statistical tests were performed at the α = 0.05 level of significance and treatment means were compared by Fisher's protected LSD.

RESULTS AND DISCUSSION

Lodging-related traits of transplanted rices treated by trinexapac-ethyl at different application times and rates were presented in Table 1. Effects of trinexapac-ethyl varied greatly with application rates with little differences between rice varieties. As the application rate increased lodging index, center of gravity and exsertion of panicle decreased, whereas breaking strength and phytotoxicity increased. Although the greatest efficacy of trinexapac-ethyl was obtained at the application rate of 30g ai/ha, it caused phytotoxicity close to the level that in some cases can

Table 1. Effects of trinexapac-ethyl on lodging-related traits.

Variety	Application		Center of gravity (cm)	Wt. of basal node† (g)	Fresh wt. (g)	Breaking strength (g)	Lodging index	Exsertion of panicle‡ (cm)	Phyto-toxicity (0~9)§
	Time¶	Rate (g ai/ha)							
Heukjin-jubyeo	10DBH	10	49.2	1.6	11.97	430	240	8.4	9.0
		20	48.8	2.0	12.73	468	241	8.1	9.0
		30	46.4	1.9	12.16	495	209	7.4	9.0
	2DBH	10	45.4	1.8	12.78	512	226	5.2	8.3
		20	41.6	2.0	12.25	492	208	4.4	7.3
		30	38.4	2.4	12.55	538	192	3.3	7.0
	Control	-	49.4	1.7	12.25	442	251	8.3	9.0
	LSD (0.05)		------	------	------	------	33	1.1	
Daeanbyeo	17DBH	10	38.3	2.8	16.46	882	142	5.7	9.0
		20	39.5	2.4	18.67	957	131	5.5	7.8
		30	36.7	2.6	16.82	1113	105	5.7	7.0
	8DBH	10	37.9	3.4	16.55	773	166	3.6	8.7
		20	37.3	2.9	16.13	954	119	3.8	7.8
		30	37.7	3.4	17.63	1009	121	2.3	7.3
	0DBH	10	42.2	3.0	17.04	891	154	4.3	9.0
		20	42.0	2.9	16.76	879	148	4.2	8.8
		30	39.4	3.1	16.97	892	149	4.8	8.8
	Control	-	40.6	2.5	16.33	797	165	5.0	9.0
	LSD (0.05)		------	------	------	------	19	1.0	

† Weight of basal node was measured from the 10cm of stem base from soil surface.
‡ Length from flag leaf to panicle node.
§ Phytotoxicity was rated based on 0~9 scale(0=complete death, 9=no injury)
¶ DBH is days before heading.

induce yield reduction due to severe plant damage.

There was no significant difference in the lodging index except in the 8DBH application in Daeanbyeo when applied at the rate of 10g ai/ha, compared with the control (Table 1). However, significant differences in the lodging index were found at the rate of 20g ai/ha with different responses to application times. In general, the breaking strength of Huekjinjubyeo was significantly lower than that of Daeanbyeo, indicating its greater susceptibility to lodging. In addition, lodging index was considerably higher for Huekjinjubyeo compared to Daeanbyeo. In light of this result, lodging might be a great problem in the cultivation of Huekjinjubyeo. Thus, utilization of growth retardants like trinexapac-ethyl could be a useful measure for the prevention of lodging in rice varieties.

Exsertion of panicle was greatly influenced by application times with a little differences by application rates (Table 1 & 2). In Heukjinjubyeo

Table 2. Effects of application times of trinexapac-ethyl on lodging-related characters in Heukjinjubyeo and Daeanbyeo§ .

Variety	Application time	Lodging index	Exsertion of panicle† (cm)	Total internode length(1st-4th) (cm)
Heukjinjubyeo	10DBH	230ab‡	8.0a	86.4a
	2DBH	209b	4.3b	76.6b
	Control	251a	8.3a	89.5a
Daeanbyeo	17DBH	126b	5.6a	70.5b
	8DBH	135b	3.2c	71.3b
	0DBH	150a	4.4b	79.0a
	Control	165a	5.0ab	80.2a

†Length from flag leaf to panicle node.
‡Within columns and the same variety, means followed by the same letter are not significantly different by LSD test (P≥0.05).
§ Each data represents an average across application rates.

Table 3. Internode length and culm diameter of rice treated by trinexapac-ethyl at different application rates and times.

Variety	Application		Length of internode (cm)					Culm diameter (mm)			
	Time‡	Rate (g ai/ha)	1st	2nd	3rd	4th	Total†	1st	2nd	3rd	4th
Heukjin-jubyeo	10DBH	10	34.2	25.8	20.4	6.8	87.2	2.2	3.4	4.2	4.7
		20	33.3	25.4	21.7	8.1	88.5	2.1	3.8	4.3	4.8
		30	31.4	22.2	21.7	8.3	83.6	2.1	3.6	4.3	4.7
	2DBH	10	33.7	23.4	20.5	7.7	85.3	2.1	3.7	4.5	4.7
		20	31.9	16.9	17.4	7.7	73.9	2.1	3.5	4.2	4.7
		30	31.0	15.2	15.9	8.2	70.3	2.1	3.6	4.3	3.3
	Control	-	34.1	25.6	21.7	8.1	89.5	2.1	3.7	4.3	4.7
	LSD (0.05)		2.2	2.3	3.2	ns	4.9	ns	ns	ns	ns
Daean-byeo	17DBH	10	29.7	18.8	14.5	9.1	72.1	1.9	3.3	3.6	4.1
		20	33.6	18.1	12.3	7.8	71.8	1.9	3.2	3.7	4.1
		30	33.0	16.1	11.1	7.3	67.6	1.8	3.3	3.7	4.2
	8DBH	10	33.5	17.1	13.6	9.0	73.3	1.9	3.3	3.8	4.3
		20	33.9	16.3	13.3	10.4	73.9	1.7	3.2	3.6	4.0
		30	32.9	12.3	12.5	8.8	66.6	1.8	3.2	3.8	4.3
	0DBH	10	35.1	19.3	16.5	11.1	82.0	1.8	3.3	3.7	4.0
		20	35.7	17.8	15.4	9.5	78.5	1.8	3.4	3.8	4.2
		30	35.4	16.6	15.4	9.2	76.6	1.9	3.2	3.8	4.2
	Control	-	34.2	20.3	16.1	9.7	80.2	1.8	3.3	3.7	4.2
	LSD (0.05)		ns	2.3	2.0	ns	4.5	ns	ns	ns	ns

nsNonsignificant at the 0.05 probability level.
†Sum of 1st to 4th internode length.
‡DBH is days before heading.

treated at 10 and 2DBH at 20g ai/ha, the exsertions of panicle were 8.1 and 4.4cm, respectively, compared to 8.3cm of the control. In Daeanbyeo, exsertion of panicle averaged across the application rates was the lowest of 3.2cm when applied at 8DBH, following 4.4cm at 0DBH and 5.6cm at 17DBH (Table 2). Although trinexapac-ethyl treatments caused a significant suppression of panicle exsertion depending upon the application time, all the panicles except an insignificant number came out of the flag leaves in all treatments without delaying heading.

The most effective application time of trinexapac-ethyl based on lodging index and total internode length (1st-4th node) was 2DBH in Heukjinjubyeo and 17DBH in Daeanbyeo, resulting in reducing total internode length by 12.9cm and 9.7cm, respectively (Table 2). Significant reduction was found at the 1st, 2nd, and 3rd internodes in Heukjinjubyeo, while at the 2nd and 3rd internodes in Daeanbyeo (Table 3). This result was consistent with a previous report (Im et al., 1993) that the elongation rate of the second internode in rice was most affected by trinexapac-ethyl applied at 12, 7 and 5DBH. In contrary, no significant difference was found in culm diameter at any internodes regardless of the application rates and application times of trinexapac-ethyl. In addition, the application time of trinexapac-ethyl showed a greater effect on the suppression of plant height compared to the application rate.

In the comparisons of the top growth-related qualities following the application of trinexapac-ethyl, no statistical difference was found in panicle length among treatments of both rice varieties. but panicle fresh weights of Daeanbyeo were significantly greater than that of the control when measured 20 days after heading (Table 4). Total weight of the plant top tended to decrease by the application of trinexapac-ethyl in Huekjinjubyeo due probably to the suppression of the top growth, but this trend was not observed in Daeanbyeo. Accordingly, the ratio of panicle weight to total plant top weight increased by the application of trinexapac-ethyl.

Although trinexapac-ethyl significantly improved lodging-related traits of rice plants, no significant differences were found in rice yield and yield components such as the number of panicles per hill, number of grains per panicle, ripening ratio and 1000-grain weight, indicating the great feasibility of trinexapac-ethyl as a preventive measure for lodging in rice cultivation (Table 5). However, this result did not correspond with the report by Lee et al. (1987) that paclobutrazol applied 15 days before heading increased ripening ratio, resulting in a 10% increase in hulled rice yield (Lee et al., 1987). No differences in the yield components could be attributed to the absence of field lodging in the course of this study.

Table 4. Comparisons of the top growth-related quality of rice plants treated with trinexapac-ethyl.

Variety	Application		Panicle length(cm)	Panicle wt.[A)] (g.fw)	Total wt. of the top[B)] (g.fw/plant)	Ratio of A/B (%)
	Time†	Rate (g ai/ha)				
Heukjinjubyeo	10DBH	10	21.3	2.55	10.32	24.7
		20	21.4	2.79	10.39	26.9
		30	21.6	2.58	9.76	26.4
	2DBH	10	22.2	3.11	9.88	31.5
		20	21.6	2.39	9.04	26.4
		30	21.8	3.04	10.57	28.8
	Control	-	21.3	2.51	10.81	23.2
	LSD (0.05)		ns	0.33	0.89	2.8
Daeanbyeo	17DBH	10	19.6	2.67	12.96	20.7
		20	19.7	2.19	13.73	16.0
		30	19.3	2.97	13.32	22.2
	8DBH	10	19.7	2.35	13.05	18.0
		20	19.9	2.41	12.63	19.2
		30	19.5	2.84	14.13	20.3
	0DBH	10	20.0	2.65	13.54	19.6
		20	20.0	2.82	13.26	21.3
		30	20.0	3.33	13.47	24.8
	Control	-	19.6	1.93	12.83	15.0
	LSD (0.05)		ns	0.25	ns	2.9

[ns]Nonsignificant at the 0.05 probability level.

†DBH is days before heading.

Tale 5. Effect of trinexapac-ethyl application on yield components under different application rates and times.

Variety	Application		No. of panicles /hill	No. of grains per panicle	Ripening ratio (%)	1000-grain wt.(g)	Milled rice	
	Time†	Rate (g ai/ha)					kg/10a	Index
Heukjinjubyeo	10DBH	10	13.3	93	89	18.2	356	97
		20	13.9	96	88	18.1	378	103
		30	13.1	97	89	18.4	381	104
	2DBH	10	13.4	95	90	18.7	359	98
		20	13.4	92	87	18.4	359	98
		30	13.8	96	89	19.0	374	102
	Control	-	13.1	96	87	18.1	366	100
	LSD (0.05)		ns	ns	ns	ns	ns	-
Daeanbyeo	17DBH	10	15.0	89	92	22.2	534	102
		20	14.7	88	88	22.2	513	98
		30	14.8	88	90	21.5	515	99
	8DBH	10	15.7	89	90	22.1	537	103
		20	14.6	90	90	21.7	535	102
		30	16.1	91	89	21.8	531	102
	0DBH	10	15.4	91	90	22.5	547	105
		20	15.5	88	90	22.5	550	105
		30	15.4	90	90	22.7	537	103
	Control	-	14.6	88	92	22.6	523	100
	LSD (0.05)		ns	ns	ns	ns	ns	-

[ns]Nonsignificant at the 0.05 probability level.
†DBH is days before heading.

In the light of a significant increase in the panicle fresh weight by the treatment of trinexapac-ethyl, an increase of rice yield could be a reasonable presumption. As long as photosynthetic and respiration rates are not influenced by the application of growth retardants, the surplus of assimilate due to the suppression of top growth might be accumulated on the parts of plant such as grains or roots. However, the increase in panicle fresh weight in this study was not translated into an increase in rice yield, requiring further research on physiological responses of rice plants following trinexapac-ethyl application. In conclusion, trinexapac-ethyl treatments significantly improved lodging-related traits of rice plants without affecting rice yield and yield components. In practical use, priority should be given application times so as to maximize the efficacy of trinexapac-ethyl.

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