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植物生長調節劑 處理가 벼(*Oryza sativa* L.) 冷害輕減에 미치는 影響

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Effect of Plant Growth Regulators in Minimizing Low Temperature Stress in Rice(*Oryza sativa* L.)

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Abstracts

This experiment was conducted at Andong county cropping season to investigate rice response and consequent changes in the physiological activities and agronomic characters of rice as affected by growth regulator treatments, and to determine how low temperature controls some plant growth mechanisms. Plant growth regulators, particularly ABA, applied to 15 DAT regardless of concentration, gave higher tar plant height and tiller number after 10 days of low temperature treatment than did the untreated plant. However, the differences in plant height and tiller number among treatments diminished to plant growth. Chlorophyll content seemed to be enhanced by growth regulators under low temperature condition. The 10-day treatment of low temperature decreased chlorophyll content by more than 17% compared with the untreated control. The oxidizing activity of roots decreased sharply to 52.2 after 10 days in low temperature condition. On the other hand, ABA at concentration of 10^{-4}M, highly attains oxiding activity of roots. Generally, plant growth regulators applied at 15 DAT under low temperature reduced grain yield more than did the untreated control which can be attributed to decreased yield components. When growth regulators were applied to booting stage, the tiller number did not show significant difference, whereas the significant difference in culm length at harvest was observed in all treatment as a result of different concentration of growth regulators. The growth regulators generally exhibited a significant effect on yield component except on panicle length. Grain yield of low temperature treated plot at booting stage was significantly influenced by application of growth regulators. This was due to decreased number of spikelet and low filled spikelet percentage. However, TIBA treatment at booting stage showed no significant differences in grain yield.

INTRODUCTION

Rice is produced in tropical and temperate areas although it originated in tropics. However, the high adaptability of rice to varying climates requires optimal temperature ranges during their growth and development. Extremely the high and low temperatures are unfavorable to rice procuction. Temperature effect on rice is very divergent and complex. The common symptoms of low temperature damage include failure to germinate or retarded germination, radicle injury, cotyledon emergence, chlorosis, and accompanying necrosis of newly formed photosynthetic tissue.

It is necessary to develop production technique to reduce cold damage. One way of doing so is to use growth regulators to minimize cold damage. Plant survival amidst a diversity of environment is a reflection of the successful adaptation of plants to its particular ecological niche. In higher plants, there are very strong evidences of the role of hormones, particularly abscisic acid and cytokinins, in controlling the mechanisms of plant response to environmental stress. Evidence that hormones are involved in resistance to low temperature is being accumulated. Abscisic acid (ABA) and gibberellins(GA_3) appear to be the key hormones involved. Exogenous application of ABA has been shown to increase the cold hardness in certain plants (Chen and Gavilertvatana 1979, Rikin et al., 1975). Perhaps, the effect of ABA on decreasing chilling injury was due to improved water balance in plants. ABA may improve the water balance by affecting a decline in transpiration as well as by decreasing root resistance to water efflux (Jones and Mansfield, 1970; Glinka, 1973; Tal and Imber, 1971; Mizrahi et al., 1974). Alternatively, this hormone may directly affect the cell membrane. Since the plant hormone abscisic acid (ABA) is involved in several stress reactions of plants including low temperature stress (Capell and Dorffing 1990), it is not surprising that ABA application has a protective function against chilling, freezing, and drought stress. Flores et al. (1988), and Flores, and Dorffling (1990) listed the number of plant species that respond to ABA application with an increase in chilling tolerance. Among them was rice. This study was conducted to investigate rice response and the consequent changes in the physiological activities and agronomic characters of rice as affected by growth regulator treatments and to determine how low temperature controls some plant growth mechanisms.

MATERIALS AND METHODS

The experiments were conducted in Andong county using a split plot design with three replications. The low temperature treatment was in main plot and the plant growth regulator treatments were in subplot. Dongjinbyeo was broadcasted uniformly on a raised bed of puddled soil on April 1st. Thirty five days old seedlings were transplanted with 2-3 seedlings/hill and 30×13.5cm hill spacing. The growth regulators, 10^{-4}M and 10^{-5}M of ABA(abscisic acid), BA(benzyl adenine), TIBA(2, 3, 5-triiodobenzoic acid), were sprayed at 15 days after transplanting and booting stage. Fertilizers at 9-8-8(N-P-K Kg/10a) were basally applied. Another nitrogen 3Kg/10a was topdressed at the tillering stage. Low temperature treatments were imposed in plots by using flowing water 14℃-16℃ for 10 days after 14~16℃ transplanted and booting stage. The plots were continuously irrigated at a shallow depth after transplanting. The water level necessary for crop growth was maintained throughout the growing period. Butachlor at 3 Kg/10a was applied at 5 days after transplanting for weed control. Other cultural practices, such as insect and disease control, were done optimum. The plot drained for 1 week before harvest. Harvesting was done when more than 90% of the spikelets ripened.

Grains were harvested in 5m^2 harvest areas that were free from border effects. Grain yield was computed at 14% moisture. Four places, covering 0.08m^2, were selected for plant sampling at harvest. Internode length, leaf area, stem and leaf dry weight, bending index, degree of lodging and nutrient composition were then measured. Chlorophyll content was determined by using laboratory manual for physiological studies of rice. The oxidizing activity of intact rice roots (about 1g of fresh root weight) immersed into 25 ml of 20ppm α-naphthylamine(α-NA) solution for 10 minutes to exclude initial absorption of α-NA by roots. The intact roots were transferred into another 25ml of 20ppm α-NA solution which was maintained at the low temperatures. After 3 hours of incubation, the roots were removed from α-NA solution, 2ml of the α-NA sample solution was pipetted and reacted with 10ml of 0.1% sulfanilic acid (in 3% acetic acid) and then combined with 2ml of 50ppm $NaNO_2$ for 10 minutes. The solution was then diluted to 25ml with distilled water and the absorbance of the colored solution was determined at 530nm wavelength by using a spectrophotometer(Model Hitachi 100-40).

Results and Discussions

1. Effect of plant growth regulators applied at 15 days after transplanting under low temperature

Plant characteristics

Low temperature treatment for 10 days reduced plant height on 25 days after transplanted, which was significantly lower than plant height under normal temperature (Table 1). However, plant growth regulator treatment, especially ABA treatment, regardless of concentration finally showed higher plant height than did the other growth regulators. The difference of plant height could diminish at heading stage between low temperature treatment and untreatment. No explanation can be given for the increase in plant height with growth regulators compared with the untreated. But ABA application remarkably prevented water loss. Besides, its direct effect on the water status, the ABA protects the membrane system against chilling induced by activation and degradation(Flores et al., 1988), the other studies on growth regulators, auxin increased 3′, 5′-cyclic AMP content in the tissue of higher plant which diminished the chilling injury with hardly any growth inhibition (Koichi and Shimizu, 1977). Present results indi-

Table 1. Effect of different growth regulators applied at 15 DAT on the plant height under low temperature.

Treatment	Concentration (Mole)	Plant height (cm)			
		Day after treatment (DAT)			
		0	10	30	60
ABA	10^{-4} M	23.4	29.0	47.5	91.2
ABA	10^{-5} M	23.2	26.2	48.1	91.2
BA	10^{-4} M	22.8	26.7	46.3	90.3
BA	10^{-5} M	23.1	26.2	46.2	92.6
TIBA	10^{-4} M	23.5	26.3	44.6	89.8
TIBA	10^{-5} M	23.7	27.2	48.4	93.9
Control		22.9	23.7	45.8	92.1
Normal temperature		23.2	37.9	47.5	92.1

cated that low temperature stress could decrease tillering differentiation at 15 DAT. The tiller number could be increased by applied abscisic acid (ABA) at a concentrations of 10^{-4}M and 10^{-5}M under low temperature for 10 days. (Table 2). However, tiller number, unlike plant height, did not recover up to harvesting time. This can be explained by the fact that the tillering period was shortened by the optimal temperature for tillering differentiation, hence, the final tiller number did not changes in later stage with rising temperture. This is not agree with Oda and Honda(1963) and Matsushima et al.(1964) reported that tiller number increased proportionally to temperature decrease.

Table 2. Effect of different growth regulators applied at 15 DAT on the number of tiller under low temperature.

Treatment	Concentration (M)	Tiller number (no./hill)			
		Day after treatment (DAT)			
		0	10	30	60
ABA	10^{-4} M	6.2	9.5	13.4	14.5
ABA	10^{-5} M	6.5	9.5	13.5	14.2
BA	10^{-4} M	6.0	8.7	11.6	13.6
BA	10^{-5} M	6.4	8.2	12.4	13.9
TIBA	10^{-4} M	6.0	8.9	12.6	13.7
TIBA	10^{-5} M	6.1	8.1	13.1	13.6
Control		6.3	7.4	11.4	12.9
Normal temperature		6.4	8.2	14.3	16.2

Dry matter production

The effect of low temperature resulted in reduction of dry matter in the shoot(Fig. 1). This may be the result of consumption of nonstructural carbohydrates and proteins without replacement since photosynthesis is impaired by the low temperature. Each concentration of ABA showed higher dry matter production than that of other growth regulators treatment during the 10-day low temperature stress. However, all of the growth regulators treatment could minimize dry matter reduction. This result agrees with Dai(1983) that the dry matter production of rice seedling would stop or decrease at the time when rice plant is exposed to low temperature stresses.

Chlorophyll content

Chlorophyll content could be enhanced by growth regulators under low temperature condition. The low temperature treatment for 10 days decreased chlorophyll content by more than 17% in comparison with the control plot (Fig. 2). Smaller amount of chlorophyll could result in lower photosynthetic rate, consequently, lower dry matter production. BA at concentration of 10^{-4}M and TIBA at concentration of 10^{-5}M had much higher chlorophyll than that with a low temperature treatment for 10 days. The difference in chlorophyll content of any of the growth regulator treatments at different concentration was not significant. This study agrees with Kanoe and Park, that the yellowing of rice leaves were caused by a decrease in chlorophyll content and an increase in the ratio of yellowish/greenish pigment by low temperature. The most efficiency and sensitive parameter for selecting cold-tolerant rice varieties at seedling stage is chlorophyll content because the first plant processes limited by chilling temperature is photosynthesis (Powals, 1984).

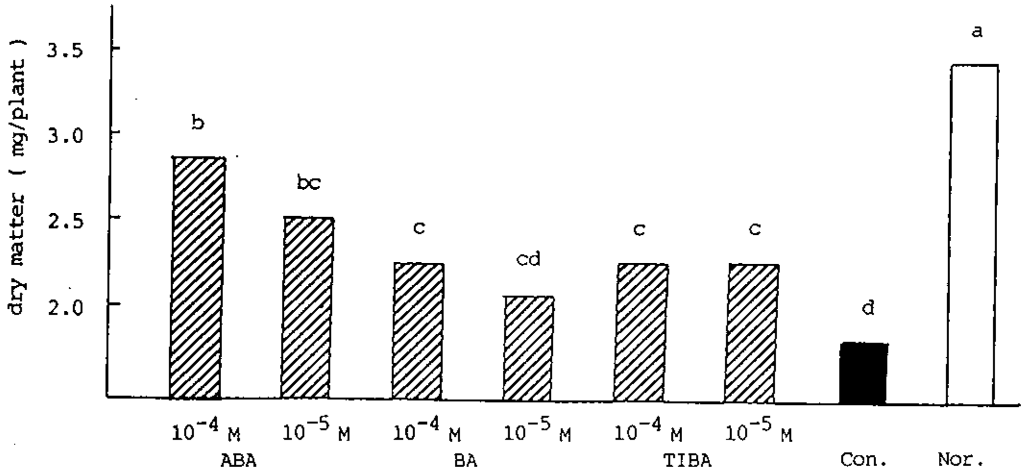

Fig. 1. Effect of different growth regulators applied at 15 DAT on dry matter under low temperature.

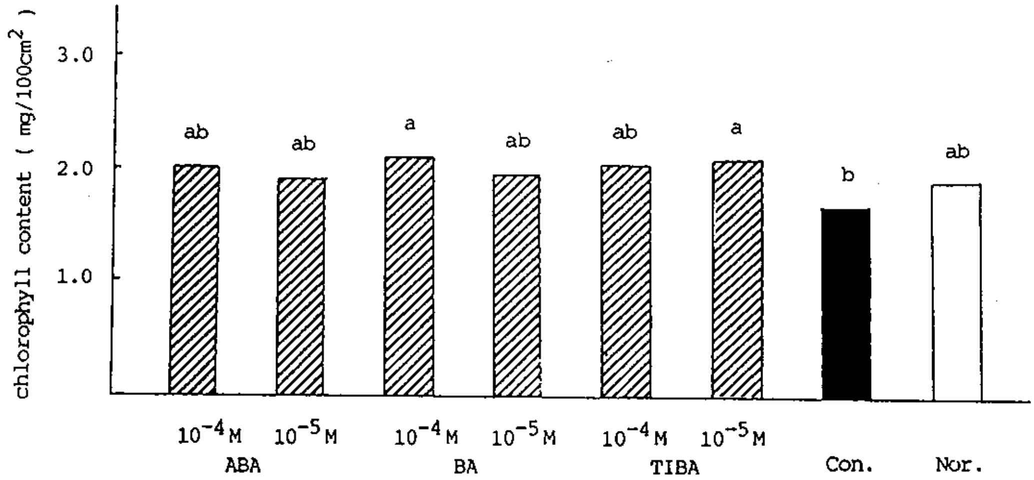

Fig. 2. Effect of different growth regulators on chlorophyll content under low temperature.

The oxidizing activity of roots

The low temperature stress greatly affected the activity of root system. The oxidizing activity of the roots decreased sharply to 52.2(mg/NA/g root/hr) after 10 days under low temperature condition. On the other hand, ABA at concentration of 10^{-4}M and TIBA at concentration of 10^{-4} M highly attain oxidizing activity of roots (Fig. 3). There was a difference in root activity between growth regulator treatments and control under low temperature condition for 10 days. Results of this study appeared to agree with previously reported work (Matsunaka, 1960., Ando et al 1983., and Dai 1985.). Rice seedling root grows favorably at 19℃-35℃ with optimum at 25℃-28℃. It is severely inhibited by temperature below 16℃(Nagai and mutsushita, 1963). It is possible that in rice roots, low temperature stress either reduce the synthesis of many normal proteins or synthesize some new sets of chilling shock proteins to minimize response to low temperature stress. The low temperature damage to rice plant is a consequence of a lack of root water absorption and resultant leaf desiccation. The physiological effect of the applied ABA analog in preventing chilling injury and this increasing cold tolerance seems to involve several mechanisms. Most important seems to be its water-conserving effect. Fig. 4 shows stomata behaviour when ABA applied at 15 DAT of rice under low temperature. ABA treatment had an effect on stomatal closure, whereas no treatment kept stomata open. This result agrees with Ludewig et al. that chilling-induced water loss due to inability of the stomates to close, and perhaps also due to increased resistance of the root to water. This view is based on the observation that water potential decreases during the chilling treatment of rice and that appling ABA analog prevents this chilling-induced water deficit (Flores et al., 1990).

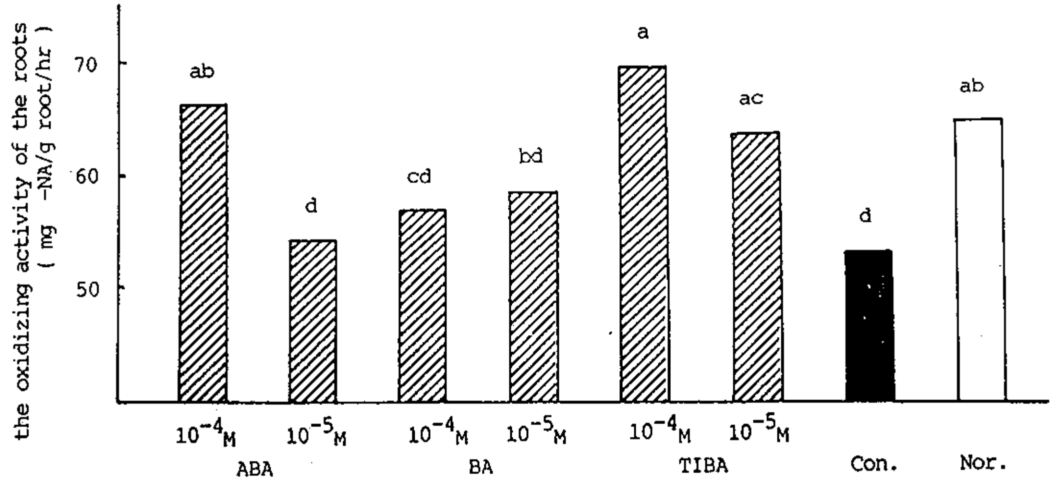

Fig. 3. Effect of different growth regulators on the oxidizing activity of the roots under low temperature.

Yield component

The panicle numbers were not affected by the different plant growth regulators under low temperature (Table 3). On the other hand, low temperature treatments without appling growth regulators decreased on panicle number. Compared with other treatments, application of TIBA at concentration of 10^{-5}M showed highest panicle number among the treatments. This result was similar to that of Yamada et al.(1962) that the growth retardant TIBA, which is capable of counteracting the action of auxin, promotes tillering. Tillering in rice plants can be controlled by auxin or anti-auxins. Ishizuka et al.(1962) reported that low temperature at 13℃ strongly inhibited the carbohydrate and salt translocation into the growing organs resulting in decreased panicle number at tillering stage. The growth regulators generally did not have a significant effect on spikelet number. However, the lowest spikelet number was found in control plants among the treatments. The growth regulators generally did not have a significant effect on spikelet number and 1000-grains weight. However, the lowest spikelet number and 1000-grains weight were recorded in control plots among the treatments. The growth regulators gave a higher filled spikelet percentage than did the control, but they had no significant effect on filled spikelet percentage. Findings collaborate with report of Matsushima(1964) that at early growth

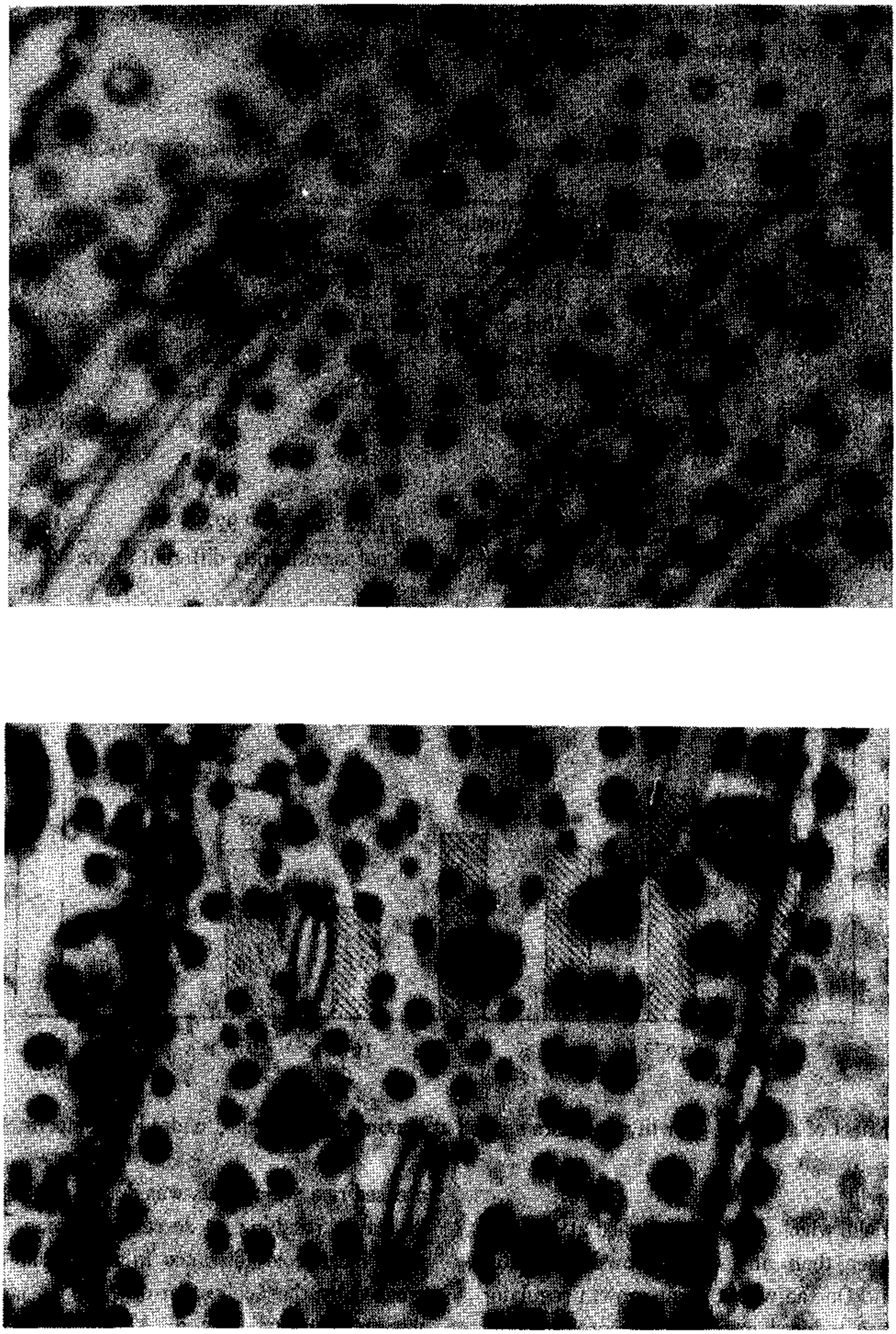

Fig. 4. Up : A stomata on the higher leaf surface at 15 DAT of rice (X800).
Low : A stomata on the higher leaf surface of rice when ABA applied with 10^{-4}M concentration at 15 DAT. (X800).

stages, the water temperature affects yield by affecting the panicle number per plant, spikelet number per panicle, and the percentage of ripened spikelets.

Table 3. Effect of different growth regulators applied at 15 DAT on yield component under low temperature.

Treatment	Concentration (M)	Panicle number (no./plant)	Spikelet number (no./plant)	Filled spikelet (%)	1,000 grains weight(g)
ABA	10^{-4} M	13.5 ab	87.1 a	89.5 a	24.1 a
ABA	10^{-5} M	13.6 ab	87.8 a	90.2 a	20.9 a
BA	10^{-4} M	12.9 ab	91.4 a	88.2 a	20.5 a
BA	10^{-5} M	12.6 ab	85.2 ab	89.1 a	20.7 a
TIBA	10^{-4} M	13.6 ab	88.8 a	88.7 a	20.4 a
TIBA	10^{-5} M	14.7 a	88.1 a	89.3 a	20.8 a
Control		12.2 b	84.8 b	82.4 b	19.7 a
Normal temperature		14.6 a	91.3 a	92.3 a	21.8 a

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

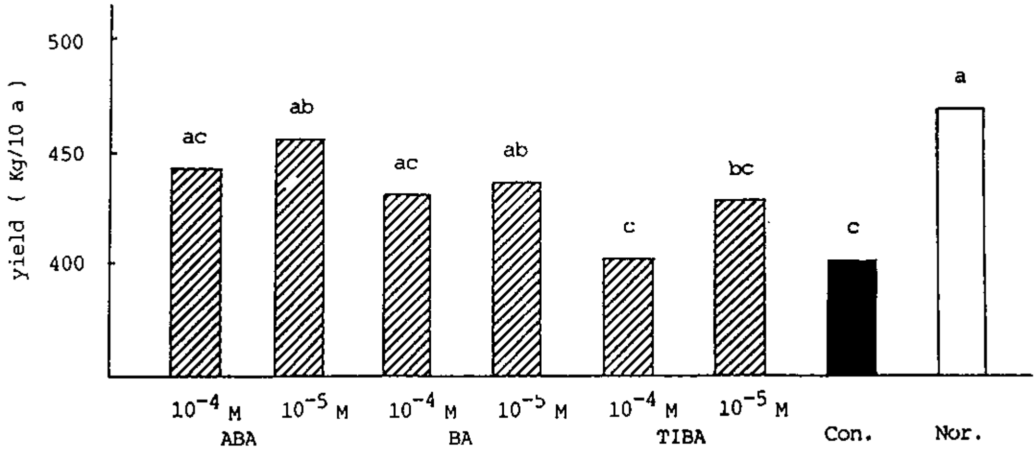

Fig. 5. Effect of different growth regulators applied at booting stage on yield under low temperature.

Grain yield

Grain yield, which ABA was applied at 15 DAT was higher than any other growth regulator treatment. On the whole, plant growth regulator treatments reduced grain yields more than did plant in control plots(Fig. 5). However, differences were not significant among growth regulator treatments. Lian(1972) postulated that decreased rice grain yields was due to discoloration of leaves resulting in decreased photosynthetic rate. Since cold tolerance in rice could be increased by the application of ABA to increase the endogeneous level of ABA, selection and breeding for “high ABA plants” may be a promising way to increase cold tolerance in rice. But no information is available as to whether this has been tried.

2. Effect of plant growth regulators applied at booting stage on rice growth under low temperature

Plant characteristics

Different concentrations of growth regulator application gave significant differences in culm length at harvest(Table 4). The highest culm length was recorded in normal temperature plots. No difference was observed in BA treatments, regardless of concentration. However, culm length significantly decreased in ABA and TIBA treatments. Suzuki et al.(1981) measured the levels of endogeneous GA_1 and GA_{19} in rice shoots at various stages of internode elongation and found decreasing values from maximum tillering stage to heading. Probably, both ABA and TIBA inhibited gibberellic acid biosynthesis at booting stage, accounting for the significant reduction in culm length. Tiller number did not vary (Table 4). No significant differences in tiller number occurred with growth regulators applied at different concentrations at booting stage. However, Nakuta and Nakai(1977) who reported that application of growth retardant B_9 to rice leaves at transplanting inhibits leaf emergence rate and promotes tiller growth.

Table. 4. Effect of different growth regulators applied at booting stage on culm length and tiller number under low temperature.

Treatment	Concentration (Mole)	Culm length(cm)	Tiller number(no/hill)
ABA	10^{-4}	77.5 c	12.8a
ABA	10^{-5}	78.2 bc	13.2a
BA	10^{-4}	79,7a-c	12.8a
BA	10^{-5}	79.7a-c	12.4a
TIBA	10^{-4}	76.9 c	12.4a
TIBA	10^{-5}	82.3ab	12.7a
Control		78.9 bc	12.4a
Normal temperature		83.6a	13.0a

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

Yield component

The growth regulators generally did not have a significant effect on panicle length, regardless of treatments, among the growth regulators treatment, BA applied at 10^{-5}M concenration gave the highest panicle length. For low temperature treatment at booting stage 10^{-4}M concentration of BA application significantly decreased panicle length (Table 5). Generally, low temperature treatment reduced spikelet numbers. although growth regulator application at booting stage did not affect spikelet number with BA with 10^{-4}M was highest and lowest with TIBA application (Table 5). The 1000 grain weight did not significantly differ among treatments(Table 5). trends were similiar for growth regulator applied at early and rooting stage. The low temperature treatment at panicle initiation gave a lower percentage of filled spikelets than did the normal temperature treatment(Table 5). Although growth regulators significantly affected the percentage of filled spikelets. However, no significant difference was observed on the same trait among the different concentrations of the three growth regulators applicating. Sterility is caused by low temperature at the meiotic stage resulting in unfertilization at anthesis. Several development steps are involved between the cause and the effect microspore growth, dehiscence of anthers, pollen mitosis, pollen growth dihiscence of anthers, pollen shedding on stigma, pollen tube elongation and fertilization. Ito et al.(1970) made precise observations at anthesis on the definite location of spikelets at meiotic stage. Injuries observed were arranged in developmental order than anther. Also, other researchers found that the main cause of sterility was pollen immaturity which at heading time was quantitatively manifested by low respiration.

Table 5. Effect of different growth regulators applied at booting stage under low temperature.

Treatment	Concentration (Mole)	Panicle length (cm)	Spikelet number (no/panicle)	Weight (g/1,000 grains)	Filled spikelet percentage (%)
ABA	10^{-4}M	19.0ab	94.3bc	20.8a	82.8cd
ABA	10^{-5}M	19.2ab	98.0bc	21.8a	88.1 b
BA	10^{-4}M	19.0ab	92.3bc	21.5a	87.1 b
BA	10^{-5}M	20.1 b	102.2ab	21.5a	92.4 a
TIBA	10^{-4}M	19.4ab	88.2bc	21.0a	81.2 d
TIBA	10^{-5}M	19.5 a	91.3bc	21.6a	86.0bc
Control		18.2 b	84.7 c	21.0a	79.1 d
Normal temp.		20.4ab	110.3a	21.2a	93.6 a

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

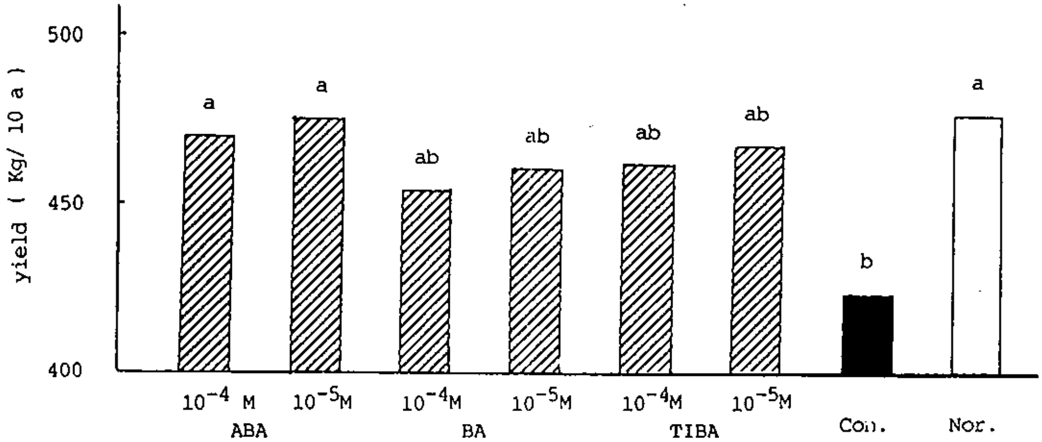

Fig. 6. Effect of different growth regulators applied at 15 DAT on yield under low temperature.

Grain yield

Grain yield of low temperature treatment at panicle initiation was significantly influenced by application of growth regulators. Grain yields varied from 409 to 454 kg/ha (Fig.6). This was due to shortened panicle length and low filled spikelet percentage. However, TIBA treatment at panicle initiation gave no significant differences in grain yield occurred low temperature treatment without growth regulator application. Lee et al. reported that during the early reproductive stage, the degeneration of spikelets and rachis-branchs occurred, whereas at the meiosis stage there is increased sterility owing to poor development of pollen and shortened panicle length. Therefore, grain yield decreased under low temperature stress.

摘　　要

本 實驗은 벼에 있어서 冷害로 因하여 每年 막대한 收穫量의 減少를 生育時期別 生長調節劑 處理에 의한 栽培的 方法을 통하여 그 被害를 減少시키고, 生長調節劑에 대한 벼의 生理學的 活動과 農業的 特性, 收量構成要素, 根活力, Chlorophyll 含量 等의 變化를 통하여 收穫量에 關係하는 要素를 糾明하고, 벼 栽培 方法에 있어서 基礎 資料로써 利用하고자 實施하여 얻은 實驗結果는 다음과 같다.

低溫조건하에서 處理된 모든 生長調節劑는 濃度에 관계없이 草長, 分蘖등의 벼 生育遲延을 다소 輕減시켰으며, 特히 ABA는 濃度에 關係없이 草長, 分蘖數등에 있어서 다른 生長調節劑보다 그 效果가 두드러진 것을 알 수 있었다. 低溫 條件下에서의 chlorophyll含量은 無處理區에 비하여 減少되나 植物生長調節劑를 處理함으로써 Chlorophyll含量이 增加되었고, 또한 根活力도 chlorophyll含量과 같은 傾向을 나타내었다. 生育 初期의 生長 調節劑의 處理는 水量 構成要素의 減少를 輕減시켜 주었으며, 이는 收量에 直接 影響을 미쳐 冷害로 因한 收量減少를 輕減시켰으며, 特히 Abscissic acid處理의 效果는 뚜렷하게 나타났다. 그러나 低溫下에서 수잉기때 生長調節劑 處理는 營養生長에 별다른 效果를 나타내지 않았으나 收量構成要素에는 다소 影響을 미쳐 收量에 關與하는 것으로 나타났다. 低溫條件下에서의 生長調節劑의 處理는 處理時期에 따라 다소 差異가 있지만 收量損失 輕減에 크게 影響을 미친 것으로 思料된다.

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