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Effect of Inabenfide and Nitrogen Top-Dressing on Ethylene Evolution and Lodging in Rice

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窒素追肥와 生長調整劑 Inabenfide 處理가 벼 倒伏 및 에틸렌 發生에 미치는 影響

李 相 哲*·田 邊 猛**

ABSTRACT : This experiment was carried out in the green house at Tokyo University of Agriculture in 1992 to investigate the relationship between lodging resistances and specific morphological characters and to examine the effects of nitrogen top-dressing and growth retardant on changes of the endogenous ethylene content in rice plant.

Inabenfide did not affect significantly yield, yield component, chlorophyll content, and CO_2 assimilation but, decreasing plant height when growth regulators were applied at booting stage, decreasing internode elongation, and increasing culm thickness and diameter of the third and fourth internode. While, nitrogen top-dressing usually showed to effect increasing vegetative growth such as plant height, tiller number, and morphological characteristics but, were not significantly affected the chlorophyll content and CO_2 assimilation.

Ethylene evolution was dramatically changed with nitrogen top-dressing and growth retardant. Application of Inabenfide at 15 days before heading inhibited ethylene evolution in the all nitrogen levels. Higher nitrogen top-dressing showed higher ethylene evolution than that of low nitrogen level. High positive correlation was detected between nitrogen application and ethylene evolution.

Key word : Lodging, Ethylene, Inabenfide, Top-dressing, Rice

Lodging, especially at intermediate stages of the growth and development, arrests dry matter synthesis, uptake, and assimilation of nutrient, thus significantly reduced yield.

There are some methods which 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 planting of varieties with different lodging resistance. Biside, fertilizer management as expecially nitrogen is also important factor causing lodging.

Lodging resistance is not only directly pro-

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portional to the amount of N fertilizer but also affected by timing and method of N fertilizer application.

Generally, top-dressing of N fertilizer decreases lodging resistance, however, top- dressing at 20 days before heading improved the rice plants to reduce lodging susceptability and increase panicle weight and grain yield[7]. We have now considered another method utilizing the plant growth regulators against lodging which could be very effective because lodging is mainly due to internode elongation. Lee and De Datta(1987)[4] found that growth regulators significantly reduced lodging in rice plants, when plant growth regulators were applied at booting stage, by decreasing internode elongation and increasing vascular bundles, the thickness and diameter of third and fourth internodes. However, the application of plant growth regulators for reducing loging in rice still remains some limitation to further increasing yield, quality, and decreasing production costs.

Ethylene plays an important role in internode elongation, ear development, and senescence of rice plant. However, endogenous changes in rice plants by ethylene application have not known well.

This experiment was carried out to identify the change in the endogenous ethylene levels under different nitrogen levels and growth retardant and to understand the relationship between lodging resistance and specific morphological charaters, and the effects of nitrogen top-dressing and plant growth retardant on the level of endogenous ethylene in rice plant.

Material and Methods

The experiment was conducted in green house at Tokyo University of Agriculture with 3 replications of a split-plot design. The growth regulator was the main plot, and the nitrogen levels was sub-plot.

Forty five-day-old rice seedling were transplanted to 1/2,000a Wagner pot. Urea as nitrogen, superphosphate as P, and potassium chloride as K were applied with 6Kg of each as basal and 3 Kg/10a of urea as top-dressing at tillering stage. Top-dressing at panicle initiation was applied with two levels of nitrogen ; 4 and 8 Kg/10a. The growth regulator, Inabenfide(3 Kg/10a), was applied at booting stage.

Other cutural practices were well maintained according to standard cultural practices.

Internode length was measured before harvest from the neck of the panicle to the fourth internode of main stem. Diameter of culm and culm thickness were determined by dial caripers(Peacock). Bending strength was measured with spring scale and expressed in gram by using breaking resistance guage (Kindai Model EO-3).

Chlorophyll content was measured by SPAD-501(Minolta). Photosynthetic rate of top leaf was determined by measuring CO_2 concentration with infrared gas analyzer(Fugi Model ZRC) under light condition at 25℃. The sampling of gas for ethylene determination was taken out from upper four leaves. In order to release ethylene, 1 ml of distilled water was transferred into 20 ml test tube and this tube incubated at five hours at dark condition. One ml of the gas sample was withdrawn with the syringe and injected into the gas chromatographic apparatus.

Ethylene was determined by gas chromatography, with a flame ionized detector(Shimazu model GC-14B), using a glass column(3

mm×2 m) with porapak Q(50/80 mesh). The flow rate of carrier gas(nitrogen) was 100ml/min. And the oven temperature was maintained at 80℃.

Results and Discussion

Ethylene evolution

Ethylene evolution was dramatically changed by both nitrogen and growth retardant application at 10 days and 20 days after heading (Table 1).

There were significant differences in ethylene evolution after heading according to different levels of nitrogen and Inabenfide application. The highest ethylene evolution was recorded in high levels of nitrogen application at twenty days after heading(0.904 nl/g F.W. /5 hrs) without growth retardant application. Generally, ethylene evolving was higher in the control without growth retardant application than in growth retardant treatment at fifteen days before heading.

High positive correlation was detected between nitrogen application and ethylene evolution. This similar trend was observed in all treatments regardless of growth retardant applicating. However, this results do not agree with earlier explanations of Lee and Ota(1980)[5] that the reduced ethylene evolving from leaves under high nitrogen condition may play an important role to explain growth promotion by nitrogen supply in plant.

Table 1. Ethylene evolution(nl/g F.W. /5hrs.) at 10 and 20 days after rice heading according to inabenfide and nitrogen levels

Inabenfide	Nitrogen	Ethylene evolution after heading	
(Kg/10a)	(Kg/10a)	10 days	20 days
0	0	0.572 bc	0.642 b
3	0	0.363 d	0.319 d
0	4	0.673 bc	0.830 a
3	4	0.408 d	0.500 bc
0	8	0.731 a	0.904 a
3	8	0.482 cd	0.467 cd

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

Generally, ethylene evolution was higher at twenty days after heading in all treatments. Michiyama and Saka(1991)[6] reported that the highest ethylene concentration was observed at the heading and anthesis stage but ethylene was hardly detected in the leaf at fourteen days after heading.

Vegetative characteristics

The plant growth retardant reduced plant height in all treatments. Plant height did not increased after Inabenfide application so that it probably lead to less lodging. However, plant height in control increased until twenty days after treatment(Fig. 1).

Increasing the nitrogen fertilizer level from 0 to 8 Kg/10a was slightly increased in plant height.

Tiller number slightly differed by the nitrogen application level but not by the growth

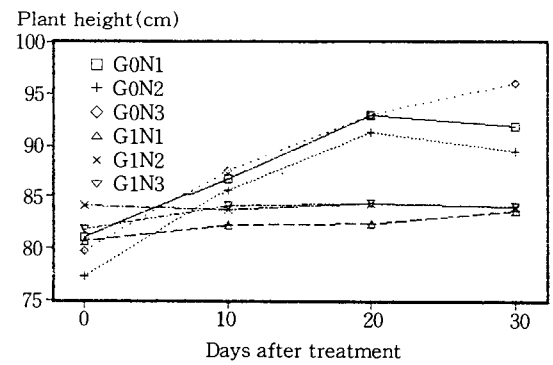

Fig. 1. Changes in plant height of rice during thirty days after treatments according to Inabenfide and nitrogen application.
G0 : Untreated G1 : Inabenfide
N1 : 0(Kg/10a) N2 : 4 N3 : 8

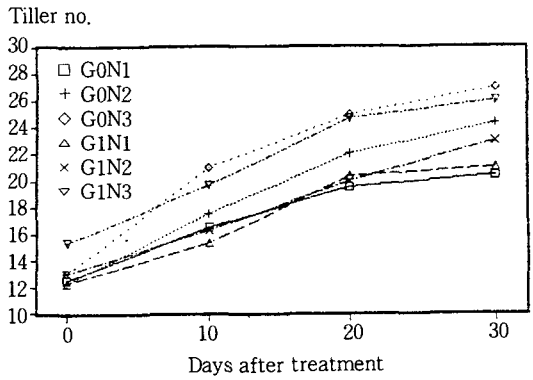

Fig. 2. Changes in tiller number of rice during thirty days after treatments according to Inabenfide and nitrogen application.
G0 : Untreated G1 : Inabenfide
N1 : 0(Kg /10a) N2 : 4 N3 : 8

retardant treatment. Tiller numbers continuously increased during 30 days after treatments(Fig. 2). This was different tendency with the changes in plant height. Lee and De Datta(1987)[4] also reported same results in a paddy field experiment that foliar spraying of PP-333 and Hoe 78784 at booting stage affected in reducing plant height but not in tillering number compared with the control.

Plant height largely affects to lodging by its contributions to top weight and distance from the panicle to root system.

Findings by some workers regarding the association of plant height with lodging were often in contrast. However, most researchers concluded that the lodging seemed to be governed by culm characteristics such as shortness, stiffness, stem diameter, nutrient content and so on. Suzuki et al(1981)[9] measured the levels of endogenous GA_1 and GA_{19} in the shoots of rice at various stages of internode elongation and found decreasing values from maximum tillering stage to heading. Inabenfide probably inhibited gibberellic acid biosynthesis, which might be reduced in plant height. Plant height and straw strength does not necessarily correlated with lodging but short plants have an advantage in lodging tolerance over the tall ones.

Chlorophyll content and CO_2 assimilation

The chlorophyll content increased by 10 days after Inabenfide application and after then it was not changed with growing(Fig. 3).

There was not significantly differences in CO_2 assimilation rate by Inabenfide and nitro-

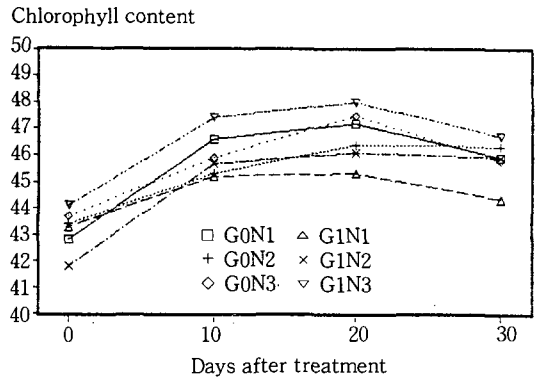

Fig. 3. Changes in chlorophyll content of rice during thirty days after treatments according to Inabenfide and nitrogen application.
G0 : Untreated G1 : Inabenfide
N1 : 0(Kg /10a) N2 : 4 N3 : 8

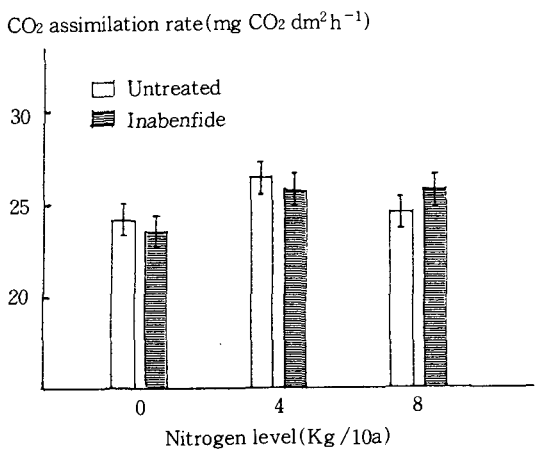

Fig. 4. CO_2 assimilation rate of rice at different levels of nitrogen application and Inabenfide treatment.

gen treatments(Fig. 4).

Generally, growth retardant had no significant effect on the vegetative growth except the plant height. This would be one of reason why there were not any differences in chlorophyll content and CO_2 assimilation rate by the treatments.

Bending strength

Bending strength was affected by growth regulator and nitrogen application. Inabenbfide greatly increased the bending strength of the rice variety regardless of nitrogen application. Low-nitrogen applying(4 Kg/10a) increased the bending strength however high nitrogen application(8 Kg/10a) slightly decreased the breaking strength of basal internodes regardless of Inabenfide treatment at booting stage(Table 2). Kohli(1984)[3] reported that the period from 45 to 30 days before heading was responsive to lodging prevention by PP-333, but because of close association between adverse effects on grain yield and the treatment at this time, attention has recently focused on the period from 20 to 10 days before heading. Therefore, Inabenfide application in this experiment was carried out at booting stage, fifteen days before heading.

All treatments did not show any indications of lodging but bending strength became significantly higher by growth regulator treatment accompanied by decreased culm length regardless of nitrogen application. Inabenfide have been found to be very effective in reducing culm length and preventing lodging, but it was not used generally because of accompanying yield reduction.

Table 2. Breaking strength of 3rd and 4th internode of rice plant according to inabenfide and nitrogen levels

Inabenfide (Kg/10a)	Nitrogen (Kg/10a)	Breaking Strength(g) 3rd Internode	4th Internode
0	0	343 cd	410 c
3	0	420 ab	466 b
0	4	345 c	442 bc
3	4	475 a	523 a
0	8	300 d	422 bc
3	8	388 bc	455 bc

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

The results of this experiment indicated that growth regulator application at booting stage decresed in culm length without grain yield reductions. According to the Takaya and Miyasaka(1983)[10], the top-dressing of nitrogen at full heading stage delayed the senescence of lower leaves and leaf sheath.

High nitrogen application resulted in weak straw, particularly in tall varieties and it led to lodging at the lower internode. Moreover, the cross section of the pith cavity and the total number of air spaces increased with N application, reducing the total tissue area and thickness of schlenchyma layer.

Morphological characteristics

Increasing N level from 0 to 8 Kg/10a slightly increased the length of the first to fourth internode and reduced in Inabenfide treatment(Fig. 5).

Reduced internode length resulted in great breaking strength of culms, and internode length might be useful indicating character of lodging. Since breaking occurs at the lower internodes, the length, thickness and stiffness of the lower internode is important factor to determine lodging resistance.

The average thickness of third internode varied from 0.52, 0.57mm and significantly differed among treatments. The fourth internode was thicker than the 3rd internode(Table 3).

The excess N application slightly decreased the thickness of third and fourth internode.

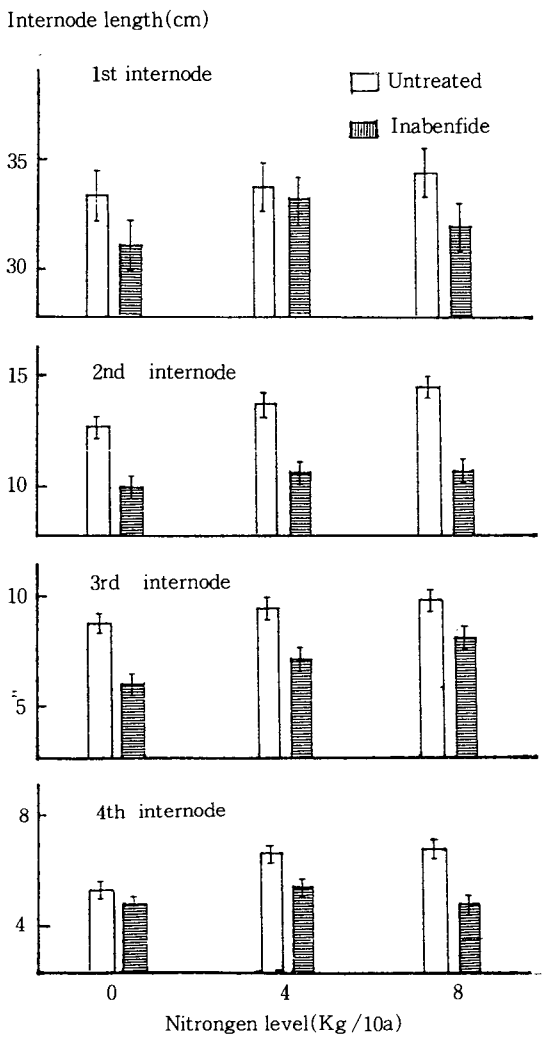

Fig. 5. Internode length of rice at different level of nitrogen application and Inabenfide treatment.

However, proper nitrogen application increased the thickness of fourth internode.

Inabenfide generally increased the thickness of stem in all treatments and especially increased the thickness of third internode by low nitrogen application at booting stage but not in higher nitrogen levels(8 Kg/10a)

The thickness of stem was considered as one of the morphological characteristics of the leaf sheath since it was earlier suggested that the thickness of leaf sheath concerned with the lodging resistance of the internode[2].

It is difficult to explain the increase in thickness of culm by Inabenfide application resulted in lodging resistance. However, Seko(1962)[8] observed that in lodging susceptible plants, the lower internode were long and slender, culm wall was thin, weight per unit length of culm was small, development of culm mechanical tissues was inferior and breaking strength of the first to the third internode was small.

Culm diameter is one of the important factors for lodging, the width of the cross section and the flattening of 3rd and 4th internodes have a close relation to lodging. The results were similar as thickness tendency. Stem diameter slightly increased when growth retardant applied at booting stage, probably indicating the increased breaking re-

Table 3. Effect of growth regulator and nitrogen levels on diameter and thickness of third and fourth internode of rice

Inabenfide (Kg/10a)	Nigrogen (Kg/10a)	Third internode		Fourth internode	
		Diameter (mm)	Thickness of stem wall (mm)	Diameter (mm)	Thickness of stem wall (mm)
0	0	2.98 b	0.52 c	3.12 c	0.57 c
3	0	2.99 b	0.55 ab	3.18 bc	0.62 ab
0	4	2.99 b	0.54 bc	3.19 bc	0.60 bc
3	4	3.17 a	0.57 a	3.44 a	0.66 a
0	8	3.03 ab	0.54 bc	3.22 ab	0.57 c
3	8	3.03 ab	0.54 bc	3.30 ab	0.63 a

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

sistance. The lower internodes were usually getting shorter and larger, culm was thicker and weight per unit length of culm was large in short plant. However, no explanation can be given for the increase in the thickness of stem wall and the diameter of culm with Inabenfide application. Mimoto et al(1970)[7] reported that there was a negative correlation between lodging and breaking strength of the third or fourth internode. Our experiment pointed out the positive association between breaking strength of the third internode and its diameter. Hitaka(1969)[1] suggested that lodging could be reduced by decreasing plant height, enlarging the diameter and cross section of culms and stimulating the development of schlerenchyma tissues and vascular bundles in culm.

The culm diameter of tested variety was larger in the plot of 4 Kg/10a N application compared with 0 and 8 Kg/10a of nitrogen applications.

High-N application did not increased the diameter of culm. The diameter was larger in fourth internode compared with the third internode in all treatments.

These results agreed with the fact that excess N application decreases stem thickness and makes leaves heavier[11].

Yield and yield components

The growth regulator generally did not have an effect on ripening ratio at the same level of nitrogen application. There was not significantly difference in filled grain ratio between 4 Kg/10a nitrogen application and untreated but it was significantly low in high-N application(8 Kg/10a) plot. Panicle length ranged from 18 to 19 cm and shortened slightly by Inabenfide application. Inabenfide application slightly decreased the spikelete number at the same level of nitrogen application(Table 4.)

Grain yield was not significantly different among the treatments. But Inabenfide(8 Kg/10a) applied at booting stage slightly decreased grain yield due to reduced panicle length and spikelets per hill. Grain yield was increased with nitrogen application, but not significantly different among the nitrogen treatments(Fig. 6).

Table 4. Effect of growth regulator and nitrogen levels on yield component of rice

Inabenfide (Kg/10a)	Nitrogen (Kg/10a)	Spikelet number (no./hill)	Ripening ratio	Panicle length (cm)
0	0	93 ab	92.7 a	18.5 ab
3	0	87 b	93.2 a	17.2 c
0	4	100 a	90.6 ab	18.2 b
3	4	95 ab	93.0 a	18.2 b
0	8	99 a	90.1 ab	19.2 a
3	8	93 ab	88.8 b	18.4 b

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

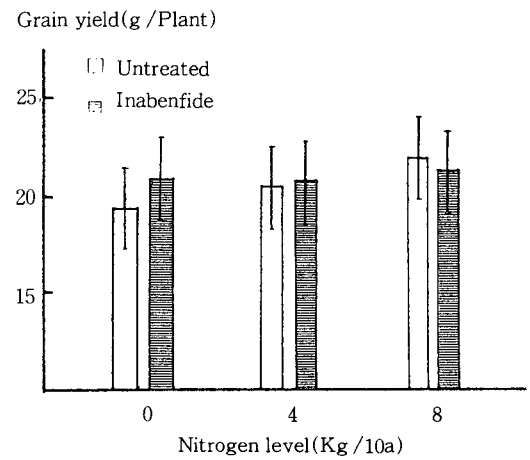

Fig. 6. Grain yield of rice at different level of nitrogen application and Inabenfide treatment.

摘 要

本 實驗은 1992年 日本 東京農業大學 溫室에서

窒素 追肥와 生長抑制劑 處理가 벼의 生育과 倒伏 形質에 미치는 形態學的 特性과의 關係를 調査함과 同時에 耐生 에틸렌 發生에 미치는 影響을 究明하기 위하여 實驗을 遂行한바 아래와 같은 結果를 얻었다.

1. 植物生長抑制劑인 Inabenfide는 草長은 減少시켰지만, 收量構成要素, 葉綠素 含量, CO_2 同化量 및 分蘖에는 變化가 없었다.
2. Inabenfide를 穗孕期에 處理하였을 때 節間 伸長을 減少시켰으나, 세번째와 네번째의 節間 直徑과 줄기의 두께를 增加시켰다.
3. 窒素追肥는 대체로 草長과 CO_2 同化量에는 뚜렷하게 影響을 나타내지 않았다.
4. 에틸렌 發生은 生長抑制劑에 對하여 많은 變化를 보여 주었으며 Inabenfide를 出穗 15日 前에 處理하였을때 에틸렌 發生은 無處理區보다 낮게 나타났다.
5. 窒素 追肥量에 따른 에틸렌 發生은 追肥量이 많을 때 發生量이 높았으며 窒素 追肥와 에틸렌 發生 사이에는 높은 相關關係가 있는 것으로 나타났다.

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