Plant Response to Wind as Affected by Genetic Backgrounds in Rice Plants

Hiroshi SUGE and Hideo TOKAIRIN

(Institute for Agricultural Research, Tohoku University, Katahira, Sendai 980)

Received January 30, 1982

Mechanical or physical stimulus has been known to have an effect on plant growth and development as well as on plant morphogenesis^{4,5}). Such a stimulus may come from many sources to crop plants grown in fields. Undoubtedly, one of the most important sources is the wind. Those morphological changes, in turn, must contribute in some way to the production of crop plants under different environmental conditions¹¹). This communication represents plant response to wind as affected by genetic backgrounds.

Materials and Methods

Plant materials: *Oryza sativa* L cv. Ginbozu (normal) and Tan-ginbozu (dwarf), which differ each other only by one major gene for plant height as well as gibberellin production⁹), were used. Tan-ginbozu has been known as a spontaneous mutant derived from Ginbozu. All the plants were grown in water culture. The seeds were soaked in water for 2 days, and spread over the surface of the vinyl net fixed to a wooden frame floated on the water surface. Soon after the seedlings became at the 3 leaf stage, the uniform plants in height were selected to be grown in water culture. Three plants were placed in each hole of a plastic frame with 34 holes separated from one another at 2 cm distance. The plastic frame was supported over the nutrient solution in a plastic container. Adjustment of pH was done twice a week and the nutrient solution was renewed once a week according to the ordinary manual for water culture practices¹).

Those containers were placed in front of an electric fan at a certain distance for obtaining different wind speed. The electric

fan was run using a timer from 9 a.m. to 5 p.m. for 25 days. The growth stage of rice plants at the start of wind treatment is shown in Table 1.

Growth analysis: At the initial and final, leaf area (A_1 , A_2) were measured using a Hayashi denko area meter. Plant parts were dried at 80°C for 48 hr and weighed to provide the initial and final plant weight (w_1 , w_2 at t_1 , t_2). The relative growth rate (RGR) and net assimilation rate (NAR) were calculated as described previously¹³). The leaf area ratio (LAR) was obtained using the relationship, $RGR = NAR \times LAR$.

The leaf area of ten plants was estimated as the sum of all the leaf blades separated from leaf sheath at the connecting points of those organs.

Ethylene measurement: Ethylene production was examined with leaf discs obtained from leaves expanded during the wind treatment. Plants were subjected to wind treatment from 9 a.m. to 3 p.m. every day for 25 days. At 25th day, plant materials were sampled at 12 p.m. and leaf discs, 1 cm in diameter, were obtained using a corkborer and 3 discs were floated either on 2 ml water or 5×10^{-4} M solution of 1-aminocyclopropane-1-carboxylic acid (ACC), an ethylene precursor, in 30 ml Erlenmyer flasks which were fitted with vaccine caps, and the atmosphere was sampled through the cap with a gas-tight syringe. The flasks were incubated in an incubator at 25°C and about 3,000 lux.

The amount of ethylene was measured with a flame ionization gas chromatograph (Shimadzu model GC-4CMPF) equipped with activated alumina column at 50°C. The data presented in this report are the average of triplicates.

Gibberellin and nitrogen measurement: Gibberellin (GA) and nitrogen content were obtained using materials harvested at the end of 25 days wind treatment. Nitrogen content was also examined in the materials obtained from plants before wind treatment. GA and nitrogen measurements were done by the procedures described previously¹³).

Results

Plant exposed to the wind with higher wind speed for 25 days were shorter in plant height and less in leaf area than those not exposed to wind in Ginbozu, whereas no growth reduction was detected in Tan-ginbozu, both in the above measurement. In Tan-ginbozu, total leaf area was rather increased in the plants exposed to the wind probably due to the increase of stem number (Table 1, Fig. 1). Reflecting this, the NAR and RGR were decreased by the wind exposure in Ginbozu as shown in Fig. 2, while in Tan-ginbozu almost no change in the value of NAR was obtained as also shown in the same figure (Fig. 2).

The value of RGR was rather increased slightly in the wind speed of 2.5 m s^{-1} in Tan-ginbozu (Fig. 2). The value of LAR was also the highest at the wind speed of 2.5 m s^{-1} and then decreased as the speed grew higher although the value was still higher than that at the control even at the wind speed of 5.0 m s^{-1} in Tan-ginbozu.

Ethylene production from leaf discs was increased with the exposure to the wind in both varieties (Fig. 3). Tan-ginbozu evolved much ethylene per unit fresh weight than Ginbozu, however the order was reversed when the leaf discs were incubated with ACC, an ethylene precursor (Fig. 3).

GA activity was detected in the extract obtained from no wind control of Ginbozu, however, no GA activity was detected in the extracts obtained from wind treated plants of both Ginbozu and Tan-ginbozu as well as no wind control of Tan-ginbozu plants (Fig. 4).

Nitrogen content was increased with wind speed when presented in percent in both varieties although the values were decreased from the initial of wind treatment (Fig. 5).

However, the value tended to decline with increasing wind speed when presented in absolute content per plant in Ginbozu, whereas the value again increased in Tan-ginbozu. (Fig. 5).

Discussion

The effects of wind speeds on the dry matter production of crop plant species have been studied by the growth analysis method in several crop plants²). In several experiments, the RGR decreased with increasing wind speed, but in the others made in water culture, there was no effect and this showed that water stress was an important cause of reduced growth by the wind^{2,14}). However, in grasses, it was suggested that the wind could reduce growth even when the plants were not much water stressed. In *Festuca* and *Lolium*, increasing wind speed reduced the rate of leaf expansion, RGR and LAR but increased the NAR slightly⁸).

Previously, the authors found that wind treatment reduced both NAR and RGR in rice plants¹³). Almost the same results were obtained in the present experiment in nor-

Fig. 1. Growth of rice plants as affected by the wind treatment in Ginbozu (A) and Tan-ginbozu (B). From left to right, control, wind speed 2.5 m s^{-1} and 5.0 m s^{-1} , respectively. Photographs were taken 25 days after the start of the wind treatment.

Table 1. Plant response to wind as affected by genetic backgrounds of rice plants.

Variety	Wind speed (m sec ⁻¹)	Plant height (cm)	Number of stems	Number of leaves	Leaf area per plant (cm ²)
Ginbozu (Tall)	Initial	24.9±1.8	1.3±0.7	7.7±0.3	18.64
	0	41.2±2.7	2.1±1.0	9.9±0.2	46.21
	2.5	38.4±2.4	2.0±0.9	9.8±0.2	45.31
	5.0	36.4±1.2	1.7±1.0	9.7±0.3	40.51
Tan-ginbozu (Dwarf)	Initial	17.5±1.1	2.4±0.8	8.0±0.1	16.11
	0	25.5±0.9	3.0±0.7	10.1±0.2	42.34
	2.5	25.8±0.7	3.3±0.7	10.2±0.2	45.12
	5.5	26.2±1.0	3.4±0.6	10.1±0.2	43.77

Fig. 2. The NAR, RGR and LAR of rice plants as affected by the wind treatment. Explanations are in the text.

mal tall variety, Ginbozu, however, features are quite different in the dwarf variety Tan-ginbozu. Almost no changes were found in both of RGR and NAR even in plants received 25 days wind treatment and slight increase was detected in RGR when the wind speed was 2.5 m s⁻¹.

Speed of leaf expansion was not affected by wind treatment, however, total leaf area per plant was rather increased by the wind treatment in Tan-ginbozu probably due to the stimulated growth of tillers.

No GA activity was detected in wind treated plants of Ginbozu although plants without wind treatment showed the activity. This may indicate that mechanical stress interfere to the process of GA production. As the GA production has been considered to be restricted genetically in Tan-ginbozu⁹⁾,

no GA activity was found even in no wind control in the variety. Mechanical stress was found to reduce GA activity in *Phaseolus vulgaris*¹⁰⁾ and rice plants¹²⁾.

Ethylene production was greater in the leaf discs obtained from Tan-ginbozu than those from Ginbozu, notwithstanding the wind treatment. It is not certain whether the ability of ethylene evolution has some correlation to the dwarfness of the plant, the present results seem somewhat suggestive. The wind treatment increased ethylene evolution also notwithstanding the varieties. However, under the presence of exogenously applied ACC, an ethylene precursor, ethylene evolution was greater from discs obtained from Ginbozu than those from Tan-ginbozu.

It is well known that various kinds of

Fig. 3. Ethylene production from leaf discs obtained from leaves expanded during the wind treatment. Plants were subjected to wind treatment from 9 a.m. to 3 p.m. for 25 days. At the 25th day, leaves were sampled and discs obtained were enclosed in 30 ml Erlenmyer flasks. Other procedures for the ethylene measurement are in the text. G, T, 0 and 5 represent Ginbozu, Tan-ginbozu, 0 ms^{-1} and 5.0 ms^{-1} , respectively.

Fig. 4. Histograms showing GA activities in the extracts from control and wind treated rice plants. Dwarf rice seedlings, Tan-ginbozu, were used as test plants. The solvent system used was isopropylether: acetic acid (95: 5, v/v). Materials used were 50 g fresh weight.

stressing of plant tissues results in increased ethylene production. The biochemistry of ethylene formation in stressed tissues has

Fig. 5. Nitrogen content as affected by the wind treatment in rice plants. "Initial" indicated the nitrogen content before the wind treatment. T, G, B and S indicate Tan-ginbozu, Ginbozu, leaf blade and leaf sheath, respectively.

been studied in number of plant materials^{3,6,7,16}). Recent evidences indicated that stressing induces the synthesis of ACC synthase, which in turn causes accumulation of ACC and the onset of stress-ethylene production¹⁵). Thus, wind stress may also act at the step of ACC synthesis.

Tall Ginbozu was more susceptible to the wind to reduce plant height and dry matter production and this may also have some correlation with the loss of GA activity in stressed plants. As Ginbozu produced much amount of ethylene than Tan-ginbozu when sufficient level of ACC was present, this may also have some correlation to the reduction of growth in the stressed Ginbozu plants.

Summary

Plant response to wind as affected by genetic backgrounds in rice plants was examined with 2 varieties differ each other by only one major gene, tall Ginbozu and dwarf Tan-ginbozu. Growth analysis indicated that in Ginbozu RGR and NAR decreased with increasing wind speed, whereas almost no change was found in NAR and rather slight increase was found in RGR in plants received weak wind in Tan-ginbozu

(Table 1, Fig. 1 and 2).

GA activity was found to decrease in plants received wind treatment in Ginbozu although no GA activity was detected in Tan-ginbozu in which GA production is restricted genetically.

Ethylene evolution was increased in the plants received wind treatment in both the varieties. Tan-ginbozu evolved much ethylene per unit fresh weight than Ginbozu, however, the order was reversed when the leaf discs were incubated with ACC, an ethylene precursor (Figs. 3 and 4).

Nitrogen content was increased with wind speed when presented in percent in both the varieties. However, the value tended to decline with increasing wind speed when presented in absolute content per plant in Ginbozu, whereas the value again increased in Tan-ginbozu (Figs. 5).

Acknowledgement

We would like to thank Dr. H. Imaseki of Nagoya University for his kind gift of ACC. We also to thank Toyama Agricultural Experiment Station for the gift of rice seeds. The present work was supported partially by a research Grant-in-aid from the Ministry of Education, Science and Culture, Japan.

References

1. BABA, I. and Y. TAKAHASHI 1957. Solution culture. *In* Experimental manual for crop science. Eds. TOGARI, Y. et al. Nogyo-Gijutsu Kyokai, Tokyo. 155—185. (in Japanese).
2. GRACE, J. 1979. Plant response to wind. Academic Press, London. 1—204.
3. HOGSETT, W.E., R.M. RABA and D.T. TINGEY 1981. Biosynthesis of stress ethylene in soybean seedlings: similarities to endogenous ethylene biosynthesis. *Plant Physiol.* **53**: 307—314.
4. JAFFE, M.J. 1980. Morphogenetic response of plant to mechanical stimuli or stress. *Bio-Science* **30**: 239—243.
5. ——— and R. BIRO 1979. Thigmomorphogenesis: The effect of mechanical perturbation on the growth of plants, with special reference to anatomical changes, the role of ethylene, and interaction with other environmental stresses. *In* Stress physiology in crop plants. Eds. MUSSELL, H. and R.C. STAPLES. John Wiley and Sons, New York. 25—59.
6. KENDE, H. and T. BOLLER 1981. Wound ethylene and l-aminocyclopropane-l-carboxylate synthase in ripening tomato fruit. *Planta* **151**: 476—481.
7. KONZE, J.R. and G.M. KWIATKOWSKI 1981. Rapidly induced ethylene formation after wounding is controlled by the regulation of l-aminocyclopropane-l-carboxylic acid synthesis. *Planta* **151**: 327—330.
8. RUSSELL, G. and J. GRACE 1978. The effect of wind speed on the growth of grasses. *J. App. Ecol.* **16**: 507—514.
9. SUGE, H. 1978. The genetic control of gibberellin production in rice. *Jap. J. Genetics* **53**: 199—207.
10. ——— 1978. Growth and gibberellin production in *Phaseolus vulgaris* as affected by mechanical stress. *Plant and Cell Physiol.* **19**: 1557—1560.
11. ——— 1980. Dehydration and drought resistance in *Phaseolus vulgaris* as affected by mechanical stress. *Rep. Inst. Agric. Res. Tohoku Univ.* **31**: 1—10.
12. ——— 1980. Effect of physical stress on the gibberellin production of rice plants. Control mechanism of environmental stresses (5). *Japan. Jour. Crop Sci.* **49** Extra Issue **2**: 139—140. (in Japanese).
13. ——— and H. TOKAIRIN 1982. The effect of wind on the growth of rice and barley plants. *Rep. Inst. Agric. Res. Tohoku Univ.* **33**: 1—14.
14. WADSWORTH, R.M. 1960. The effect of artificial wind on the growth rate of plants in water culture. *Ann. Bot. N.S.* **24**: 200—211.
15. YANG, S.F. 1980. Regulation of ethylene biosynthesis. *Hort. Science* **15**: 238—243.
16. YU, Y.B. and S.F. YANG 1980. Biosynthesis of wound ethylene. *Plant Physiol.* **66**: 281—285.

〔和 文 摘 要〕

イネの風に対する反応に及ぼす遺伝的背景の影響

菅 洋・東海林英夫

(東北大学農学研究所)

イネの風に対する反応に及ぼす品種の遺伝的背景の影響を草丈（あるいはジベレリン生成）に関する主動因子一個のみによって異なる銀坊主（正常）と短銀坊主（矮性）を用いて調べた。

生長解析の結果、銀坊主では風速が強まるほど RGR, NAR, が減少したが、短銀坊主では NAR は風処理によってもほとんど変化せず、RGR は風が弱い時はわずかながらむしろ増加した。

銀坊主では、風にあてない標準区で GA 活性が検出されたが、風処理したものでは活性が検出されなかった。GA 生成が遺伝的に制限されている短銀坊主では風にあてないものでも GA 活性は検出されなかった。

葉からのエチレン生成は、両品種ともに風処理により増加した。品種間の比較では短銀坊主は銀坊主よりエチレン生成が多かった。しかし外から与えたエチレン前駆物質の ACC が存在すると、この順序は逆転し銀坊主の方がエチレン生成が多かった。

窒素含量は、相対的濃度（%）でみると両品種ともに風処理により増加したが、植物個体当たりの絶対含量でみると銀坊主では風処理により減少し、短銀坊主では増加した。