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Effect of Root Amount on Wind Damage in Rice

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ABSTRACT : Foehn damage on rice plant is one of the important abiotic stresses in eastern costal area of Korea. To know the relationship between foehn impact and morphological traits of rice, wind tunnel method was used with 106 rice cultivars. Less influencing traits on foehn were short panicle, large panicle number per hill, thin panicle neck, and the flag leaf of narrow, short and thick. Leaf pubescence reduced the impact on foehn. 'Naepungbyeo' belong-ed to foehn tolerant varietal group, while 'Ansanbyeo' belonged to the opposite group. Three levels of root cutting treatment with two rice cultivars were conducted to evaluate the foehn impact using wind tunnel. The severity of wind damages was followed the sigmoidal curve duration of wind tunnel treatment were prolonged. Different responses of root cutting to wind tunnel treatment could be used to evaluate the severity of the foehn impact. 'Naepungbyeo' was one of the less implausible cultivars on foehn. 'Nae-pungbyeo' showed tolerant response to wind under 21% root removing treat-ment(20 cm root cutting), however 'Ansanbyeo' was wilted under the same treatment. In case of 35% root removing treatment(10 cm root cutting), both rice cultivars failed to alive against foehn wind.

Keywords **:** foehn, wind damage, white head, rice (*Oryza sativa* L.)

When air flows downhill from a high elevation, its temperature is raised by adiabatic compression. Foehn winds, the warm and dry winds, are katabatic winds caused by adiabatic heating of air as it descends on the lee sides of mountains. In case of Korea, these phenomena appear frequently in east part of mountain range following the typhoon. Most of Typhoon such as Irving (1979), Agnes (1983), Ellis (1983), Vera (1986) and Janis (1996) accompanied by 4.0 to 8.5 m/sec of wind velocity, and low humidity less than 60% with high temperature in the east coastal and southen area of Korea were inducing the foehn phenomenon (Choi, 1981; Kang *et al.*, 1987; Kang, 1989). Although foehn impact on rice plant is not frequently occurred, once it happened, the casualty is so serious to farmer's field. The symptoms of wind damage are leaf fracture, lodging, white head on panicle and whole plant's perishing from wilting. Among these symptoms, white head on panicle and discolored brownish grain bring out sterility and poor filling of grain following yield loss and quality deterioration(Choi, 1981 ; Kim *et al.*, 1983; Kim *et al.*, 1986; Lee *et al.*, 1998). Foehn phenomenon and rice damage by it was also reported at Hokuriku district in Japan (Muramatsu, 1976).

Foehn damage on farmer's rice field arose on the weather conditions which were between 4 and 8.5m/sec in wind velocity, over 26 in air-temperature and between 42% and 67% in relative humidity. In the case of artificial treatment using wind tunnel, damage was induced on the condition of 30°C of temperature, 50% of relative humidity and 4m/sec of wind velocity for three or four hours at night time. (Uehara & Samoto, 1979). The most sensitive growth stage to foehn is four to seven days after heading date(Kim *et al,* 1983, Muramatsu & Kamota, 1981) or three to four days after heading date. (Uehara & Samoto, 1979). The results of those studies showed that foehn is most dangerous to rice plant just after the panicle is fully emerged. The most efficient condition for inducing foehn damage at heading stage was pre-treatment of rice plant by showering water just before foehn treatment, and wind tunnel treatment on mid night(Uehara & Samoto, 1979).

Sensitivity of rice plant to foehn was affected by fertilizer levels, the higher level of nitrogen fertilizer was applied, the more frequently white heads appeared. Calcium silicate had no protective effect to foehn damage in rice plant(Uehara & Samoto, 1979). The poor root activity also made rice plant sensitive to wind damage(Choi & Park, 1981). Wind damages of plant leaf blade and panicle were positively correlated with the traits such as the number of silicified cell, stomatal aperture and rate of moisture lose(Imai et al., 1979 ; Yang *et al.*, 1988). Dripping wet (*drp*) leaf, hairy glume (*Hg*) and glabrous leaf and hull (*gl*) were also highly related to foehn damage (Lee *et al.*, 2000). The varietal difference has been found in tolerance level to foehn. Tolerant rice cultivars had high stomatal resistance, low transpiration rate, small status, short planicle length, small number of grain per panicle, short flag leaf length and thin neck node of panicle(Uehara & Samoto, 1979; Lim *et al.*, 1988; Kim, 1991). Among the Korean rice commercial cultivars, 'Seoanbyeo', 'Yeongdeogbyeo', 'Janganbyeo', 'Hwashinbyeo' and 'Nae-

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pungbyeo', were tolerant to wind tunnel treatment while 'Daeribbyeo 1', 'Nonganbyeo', 'Milyang 23' and 'Bonggangbyeo' were susceptible (Lee *et al.*, 1998). This study was carried out to investigate the effects of root cutting on foehn damage and varietal different response against root cutting.

MATERIALS AND METHODS

Relationship Between Foehn Tolerance and Morphological Traits on Rice

To know the relationship between foehn tolerance and morphological rice traits, we used 106 rice cultivars. Seeds were pregerminated for 48 hr in tap water in the dark at 30°C. Treated rice seeds was sown in a seedling tray after germinate. Thirty days after sowing, seedlings were transplanted with one plant per pot into a pot(15cm diameter and 25 cm high) at May 25, 1999. Fertilizer was applied as 11-6.4-7.8 kg/10a of N-P_2O_5-K_2. Other cultural practices were conducted according to standard cultural methods developed by National Yeongnam Agricultural Experiment Station. Artificial foehn treatment was conducted for six hours using wind tunnel with the rice plant which was three or five days after heading date. The rice materials were pre-treated in condition of high humidity in dark room for twelve hours to make it easy to be sensitive at wind tunnel treatment. Wind tunnel treatment was conducted at night time for the same reason. The setting of wind tunnel condition was 30±1°C temperature, 50±5% of relative humidity and 7m/sec of wind velocity, and the other condition in wind tunnel was showed at Table 1. White head on panicle, discolored brownish grain and reduction ratio of grain filling were investigated between plants treated in wind tunnel and those of control to evaluate foehn tolerance of rice. Foehn damage degrees were also evaluated on a scale of 1 to 9 (1= tolerant to foehn as less than 20% of white head on rice panicle and 9 =susceptible as higher than 80% of them). Morphological rice traits such as panicle length, panicle number per hill, thickness of panicle neck, leaf pubescence, flag leaf length, flag leaf width and flag leaf thickness were also evaluated to know the relationship of foehn tolerance.

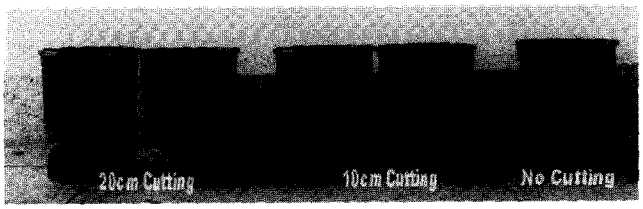

Fig. 1. Pots preparation for three type of root cutting(0 cm, 10 cm and 20 cm from top of pot) treatment before rice transplanting.

Effects of rice root cutting on foehn damage

Two japonica rice cultivars, 'Naepungbyeo' and 'Ansanbyeo' which are tolerent and susceptable, respectively (Lee *et al.*, 1998) were used to investigate the effects of root cutting on foehn damage and varietal different response against root cutting. Pots were prepared horizontally divided in two part with three different depth from top of them, and they were put together with tape to cut off rice root without any damage before wind tunnel treatment. The three different cutting depths from top of pots were 0 cm, 10 cm and 20 cm respectively(Fig. 1). Other cultural practices and wind tunnel treatment were same as previous experiment. Before wind tunnel treatment, pots which had been bound with tape were unbound, and then roots were cut off with two parts before rebounding pots. The traits, which were measured in previous study were also considered including root dry matter.

RESULTS AND DISCUSSION

Relationship between foehn tolerance and morphological traits on rice

Among 106 rice cultivars, eighteen cultivars including 'Naepungbyeo', 'Haepyeongbyeo', 'Chucheongbyeo' and 'Cheongmyeongbyeo' belong to tolerant group, and twelve cultivars such as 'Hwaseongbyeo', 'Ilpumbyeo' and 'Juanbyeo' were susceptible group in artifical wind tunnel treatment(data not shown). Foehn damages of tolerant group of rice cultivars were less than those of susceptible group based on white head ratio of rice panicle, discolored brownish grain and reduction ratio of grain filling as compared

Table 1. The measured wind tunnel air condition at Foehn treatment.

Treatment time (hr)	Air temperature (°C)	Relative humidity (%)	Air velocity (m/sec)	E-e†	Q‡	ΣQ
6	30	52.6	7.0	15.1	39.9	240

†*E-e*: vapor pressure deficit(mmHg), E is saturated vapour pressure(mmHg) and e is vapour pressure(mmHg).

‡*Q* : vaporization ability(mmHg · m · sec^{-1})=$(E\text{-}e)\sqrt{U}$, U is air velocity(m/sec).

Table 2. Mean values of foehn tolerance and panicle related traits of rice cultivars classified by foehn tolerance level.

Foehn tolerance	No. of cultivars	White head ratio	discolored brownish grain ratio	reduction ratio of grain filling	Panicle number	Panicle length	No. of grain per panicle	Panicle neck thickness
Tolerant (1-3)†	18	31.0	23.6	24.6	11.5	18.7	88.6	1.37
Moderate (4-6)	76	55.8	38.7	39.9	10.7	19.1	91.2	1.45
Susceptible (7-9)	12	76.3	71.8	76.3	9.7	19.9	89.2	1.48

†Foehn damage degrees described as materials and methods.

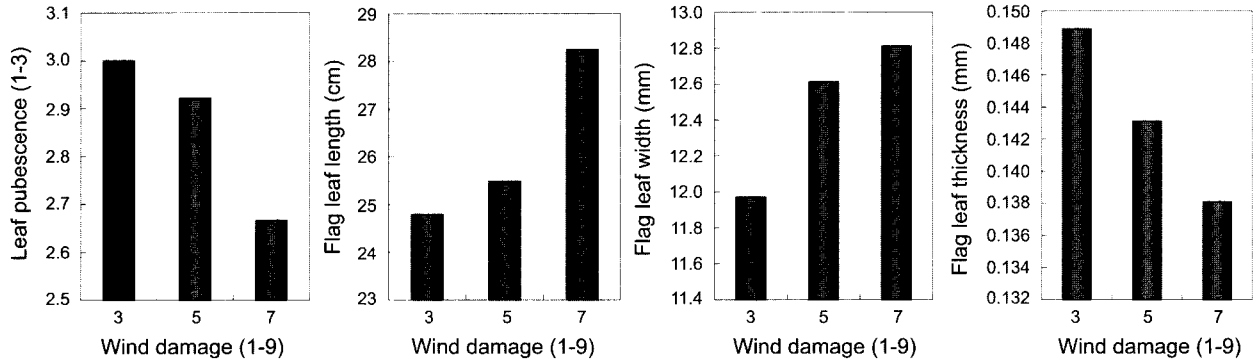

Fig. 2. The relationship between leaf morphological traits and foehn damage degree on mean value of classified by foehn tolerance among 106 cultivars after wind tunnel treatment.

between plants of wind tunnel treatment and those of control after wind tunnel treatment. When panicle morphological traits of rice were also evaluated to investigate relationship of foehn tolerance. Foehn tolerant rice cultivars had relatively shorter panicle, larger panicle number and thinner panicle neck than susceptible rice cultivars. There was not any tendency in grain number per panicle (Table 2). In case of relationship between leaf morphological traits and foehn damage severity, it was estimated that rice cultivars possessing narrow, short and thick flag leaf tended to foehn tolerance. Leaf pubescence also positively affected to foehn tolerance(Fig. 2).

This study showed that foehn tolerant cultivars tend to have large number of panicle per hill, short panicle, thin panicle neck, and short, narrow and thick flag leaf with hair. This kind of traits of foehn tolerant cultivars may not aid water absorption from soil but protect water loss against blowing foehn which is warm and dry wind to maintain water balance in rice plant. These results were similar to reports of other researcher. Foehn tolerant rice cultivars had high stomatal resistance, low transpiration rate, small status, short planicle length, small number of grain per panicle, short flag leaf length and thin neck node of panicle(Uehara & Samoto, 1979 ; Lim *et al.*, 1988 ; Kim, 1991). Imai *et al.*, (1979) reported that water saturation deficit percentage was high in the plant which had long leaf blades. Foehn tolerant Korean rice commercial cultivars were 'Seoanbyeo', 'Yeongdeogbyeo', 'Janganbyeo', 'Hwashinbyeo' and Naepungbyeo', while susceptible cultivars were 'Daeribbyeo 1', 'Nonganbyeo', 'Milyang 23' and 'Bonggangbyeo' (Lee *et al.*, 1998).

Effects of Rice Root Cutting on Foehn Damage

To evaluate the effects of root amount on foehn damage, two rice cultivars, 'Naepungbyeo' and 'Ansanbyeo' were used. Root cuttings for the maintenance of root amount were conducted before wind tunnel treatment as 0cm, 10cm and 20cm respectively. Remaining root weight indexes from upper part of plant after three kinds of root cutting treatments were approximately 100% (no cutting), 71% (20 cm cutting) and 65% (10 cm cutting), respectively in both cultivars, although 'Ansanbyeo' had slightly larger amount of root dry weight than those of 'Naepungbyeo' (Table 3). Wind damages of two rice cultivars with three different root cutting depth were increased as sigmoidal curve by the wind tunnel treatment time passed. Wind damage represented by white head reached plateu with in 150 minutes of wind tunnel treatment. The more rice root were cut from plant, the higher wind damage occurred (Fig. 3). 'Ansanbyeo' showed more dramatic foehn response than 'Naepungbyeo' in root

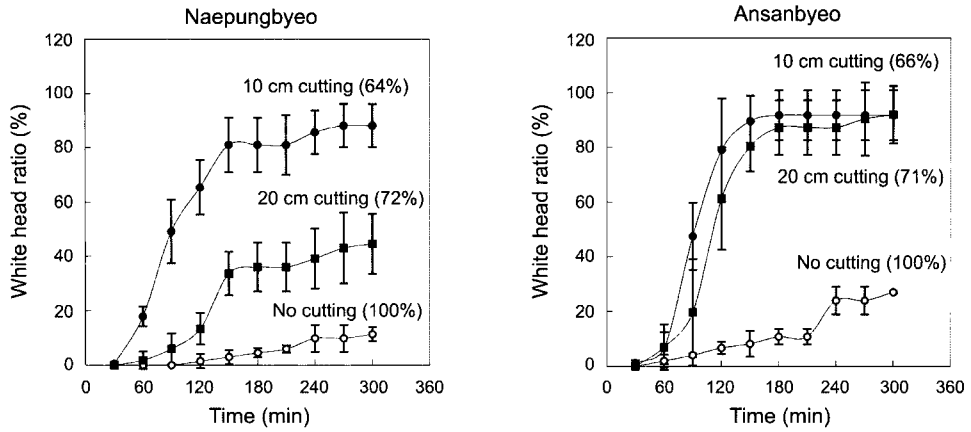

Fig. 3. Changes of white head ratio of two rice cultivars, 'Naepungbyeo' and 'Ansanbyeo', according to different root cutting depth from top of pot during wind tunnel treatment. The numbers between parenthesis are Remaining root weight indexes against root cutting.

Table 3. Foehn damages of two rice cultivars after wind tunnel treatment by different root cutting depth from top of pot .

Traits	Naepungbyeo			Ansanbyeo		
	Nocutting	20 cm cutting	10 cm cutting	No cutting	20 cm cutting	10 cm cutting
Root dry weight (g/hill)†	4.19	3.01	2.67	4.79	3.40	3.18
Root dry weight index‡	100	72	64	100	71	66
White head ratio (%)	11.4[a]	44.6[b]	88.1[c]	21.1[a]	91.7[b]	91.9[b]
Discolored brownish grain ratio (%)	33.1[a]	42.4[b]	49.9[c]	17.9[a]	75.1[b]	75.4[b]
Reduction ratio of grain filling (%)	35.3[a]	39.5[b]	45.7[c]	19.7[a]	78.6[b]	79.5[b]

†Root dry weight of remained root from upper part of plant after cutting root from top of pot with different depth, 0 cm, 20 cm and 10 cm respectively.
‡Root dry weight index=(dry weight of remained root×100)/(total root dry weight including cut root)
§Mean separation within a same raw of a cultivar by Duncan's multiple range test at the 5% level with each cultivars.

Table 4. Mean values of foehn tolerance related traits of two rice cultivars, 'Naepungbyeo' and 'Ansanbyeo'.

Traits	Naepungbyeo	Ansanbyeo	T-test
Panicle length (cm)	17.5	20.1	**
Panicle neck thickness (mm)	1.23	1.32	*
Flag leaf length (cm)	22.1	26.1	**
Flag leaf width (mm)	11.9	13.5	**
Flag leaf thickness (mm)	0.14	0.15	ns

cutting treatment. When 10 cm from top of pot was cut, white head ratios were around 90% in two rice cultivars, while those of 20 cm were differently shown as 45% in 'Naepungbyeo' and 92% in 'Ansanbyeo'. There were similar response in discolored brownish grain ratio and reduction ratio of grain filling (Table 3).

When morpholgical traits related to foehn tolerance were also evaluated, every morphological traits was significantly different in two rice cultivars except flag leaf thickness (Table 4). 'Naepungbyeo' had short panicle, thin panicle neck, and short and narrow flag leaf compare to 'Ansanbyeo'. According to previous study, foehn tolerant cultivars normally have large number of panicle per hill, short panicle, thin panicle neck, and the flag leaf of short, narrow and thick characteristics with pubescence. Other researchers also reported similar results that foehn tolerant rice cultivars had small status, short planicle length, small number of grain per panicle, short flag leaf length and thin neck node of panicle (Uehara & Samoto, 1979; Lim *et al.*, 1988; Kim, 1991). Therefore the traits of 'Naepungbyeo' became tolerant against foehn wind, although 'Ansanbyeo' had larger amount of root dry weight than those of 'Naepungbyeo'.

Different response of root cutting between two cultivars to wind tunnel treatment indicated that there were foehn tolerant cultivars. 'Naepungbyeo' showed tolerant traits to foehn wind under 20 cm root cutting treatment, however 'Ansanbyeo' was wilted in the same treatment. These results mean that foehn tolerant mechanism of 'Naepungbyeo' may not be maintained by water absorption from soil but protect themselves from water loss against foehn wind to maintain water balance in rice plant. So called 'Naepungbyeo' was belonging to water saver compared to 'Aansanbeo'.

REFERENCES

Choi, S. J. 1981. Effects of strong wind at heading stage on glume development and yield components of rice. Korean J. Crop Sci. 26(3) : 219-225.

Choi, S. J. and R. K. Park 1981. Studies on causes and phases of wind damage at heading stage of rice. Ph. D Choi HO. 61th birthday festschrift : 207-212.

Imai, H., S. Ishihara and S. Hayashi 1979. Ripening damage and moisture depression f rice plats under the foehn climatic conditions. Bull. Toyama Agric. Exp. Stn. 10 : 17-25.

Kang, Y. S., E. S. Yang, M. H. Nam, and Y. T. Jung 1987. Studies on the occurring phenomenon of saline wind & reduction of damages on rice plant in the southern coastal area of Korea. 1. The occurring mechanism & damages of saline wind to rice plant. Res. Rept. RDA(PM & U). 29(1) : 71-75.

Kang, Y. S. 1989. Wind and flooding damages of rice plants in Korea. Korean J. Crop Sci(DP. 1) : 45-65.

Kim, C. R. 1991. Growth of rice crop and its wind damage in the eastern costal area of Korea. Thesis for D. Ph. Degree.

Kim, C. Y., S. T. Park, J. S. Lee, and R. K. Park 1983. Survey on the climatic conditions and wind influence for the rice production in eastern costal area. Res. Rept. ORD 25(C) : 124-133.

Kim, C. Y., S. T. Park, and S. J. Lim 1986. Climatic condition in middle part of east coastal area and wind damage of rice plant. Res. Rept. RDA(Crops) 28(1) : 48-54.

Lee, J. S., K. Y. Lee, D. K. Shin, S. C. Kim, H. S. Suh, and Y. J. Oh 1998. Dry wind damage of rice plant at different growth stages. RDA. J. Crop Sci. 40(2) : 14-18.

Lee, J. S., H. S. Suh, H. Y. Kim, S. J. Lim, J. K. Chang, B. G. Oh, and S. C. Kim. 2000. Morpho-physiological characteristics associated with tolerance to dry wind in rice. Korean J. Breed. 32(2) : 139-141.

Muramatsu, K. 1976. The occurrence and damage to paddy-field rice by foehn in the Hokuriku district, Japan. Bull. Hokuriku Natl. Agri. Exp. Stn. 19 : 25-43.

Muramatsu, K. and T. Kamota 1981. Damage of paddy rice plant[*Oryza sativa*] caused by foehn. Bull. Hokuriku Natl. Agri. Exp. Stn. 23 : 19-56.

Uehara, Y. and S. Samoto 1979. A testing method for foehn tolerance in rice plant. Bull. Hokuriku Natl. Agri. Exp. Stn. 22 : 89-100.

Yang, E. S., Y. S. Kang, Y. T. Jung, and G. S. Chung 1988. Ecophysiological Characteristics of rice leaves and wind damage by Typhoon. Korean J. Crop Sci. 33(2) : 201-204.