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Studies on Physiological Reactions of Soybean Cultivars Tolerant and Susceptible to Rust (*Phakopsora pachyrhizi* Syd.)

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大豆 녹병에 對한 耐病性 및 罹病性 品種의 生理的 反應

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ABSTRACT

The physiological reaction of two soybean (*Glycine max* (L.) Merrill) cultivars tolerant and susceptible to rust (*Phakopsora pachyrhizi* Syd.) was studied at the AVRDC in Taiwan, ROC.

The rust epidemic on the susceptible cultivar began earlier and progressed more rapidly than on the tolerant cultivar. The defoliation by rust infection increased rapidly after the latter half of pod filling. The reduction of LAI by rust in the susceptible cultivar occurred earlier than in the tolerant cultivar. The differences in the chlorophyll content between the rust-free and rust-infected plants was 2.04% in the tolerant, and 16.43% in the susceptible cultivar. The shoot dry weight increased at each growth stage in the fungicide protected plots, but decreased in the non-fungicide protected plots after the R6 growth stage onward and the tendency to decrease was more severe in the susceptible than in the tolerant cultivar. The pod and seed dry weight of the susceptible cultivar in the fungicide-protected plot increased dramatically from the R6 growth stage, but in the non-fungicide plot, there was almost no increase in pod and seed dry weight from R6 growth stage, due to rust. The number of empty pods and imperfect grains were increased by rust infection, but the protein content was not afftected. There were reductions of oil content, seed length, seed width, seed thickness, pod thickness, number of pods and seeds, 100 seed weight, and yield due to rust infection. The yield losses by rust infection were 22.3%in the tolerant and 68.7% in the susceptible cultivar.

INTRODUCTION

At present, about 90% of the world's output of soybean (*Glycine max* (L.) Merr.) is produced in three countries; the USA, Brazil, and China. Recently many countries, particularly in tropical and sub-tropical regions, have tried to cultivate soybean as a new crop.[1]

Soybean rust, caused by *Phakopsora pachyrhizi* Syd., is the most serious soybean disease in southeast Asia and Australia, and is a potential threat in the other soybean production areas.[20] Yield reductions caused by this disease have been reported to range from 10 to 80% in field plantings over different seasons and locations, and more than 90% in greenhouse experiments.[2, 10, 11, 12, 16, 19, 21, 22] But in Korea, soybean rust is not a major problem

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with the soybean cultivation because it usually occurs in mid-September.[4)]

Soybean rust reduces yield due to premature defoliation and decreasing the number of pods and seeds per plant and 100 seed weight. It also lowers the seed quality.[16)]

Plant leaves lightly infected with rust show increased respiration during the flecking period when symptoms are first apparent[14)], and respiration rises to the highest rates when the rust fungus is sporulating.[5,6)] However, heavy infections of rust reduce the chlorophyll content and the rate of photosynthesis of infected leaves.[3,13)]

The objectives of this study were a) to see the difference between rust infection on tolerant and susceptible soybean cultivars, b) to evaluate the effect of rust on tolerant and susceptible soybean cultivars by measuring leaf area index (LAI), chlorophyll content, dry weight, grain/stem ratio, yield, and yield components.

MATERIALS AND METHODS

This experiment was done at the AVRDC, Taiwan, ROC. Two soybean cultivars were used in this experiment. One, SRE-B-15A is tolerant and the other, Taita Kaohsiung No. 5 (TK#5) is susceptible to rust. Soybean seeds were planted in the field on Feb. 24, 1986. Each experimental plot was 6 x 7m, with 1m between cultivars and 6m between the fungicide and non-fungicide plots including a 2m wide border of corn. Plant spacing was 10cm between hills within rows, 1 plant per hill and 50cm between rows (equivalent to 200,000 plants/ha).

The experiment was conducted using a split-plot design with three replications which consisted of a main plot receiving non-fungicide and fungicide application, and a sub-plot containing the two cultivars. Non-fungicide plots were inoculated with rust spore suspension at a concentration of about 20,000 spores per ml on April 8, 11, 17, 23, 25, and 28 by using the same method as Yeh, et al.[22)] Fungicide plots were sprayed with Dithane M-45 at the rate of 1:400 at fortnightly intervals from March 21 to May 30. A fertilizer mixture of 40kg N + 60kg P_2O_5 + 80kg K_2O per hectare was applied over the experimental field as basal fertilizer, and 20kg N per hectare was applied at flowering as a side dressing. All plots were irrigated with furrow irrigation on March 7, April 7, 22, 28, May 1, and 5. Also all non-fungicide plots were sprayed with water on May 1 and 5 for development of the rust disease.[2,15,18)]

All data were gathered from 10 plants of each experimental plot and evaluation date. The data for measuring rust severity, number of defoliate nodes, leaf area per plant, and shoot dry weight per plant were collected at the R2, R4, R5, R6 and R7 growth stages as evaluated according to the methodology of Fehr and Caviness.[7)] The data of grain/stem ratio, number of pods and seeds per plant, pod size and seed size, protein and oil content, and yield components were collected at the R7 growth stage. Rust severity was evaluated according to the Horsfall-Barrat rating system.[9)] The data of chlorophyll content were gathered from three leaflets of the middle part of each plant from the 10 plants per plot at the R6 growth stage. Yield was evaluated from a 2 x 6m area of the central portion of each experimental plot and calculated at 13 percent seed moisture content.

RESULTS AND DISCUSSION

1. Characteristics of two soybean cultivars

Characteristics of SRE-B-15A and TK #5 used in this experiment are shown in Table 1. The growth habits of SRE-B-15A and TK #5 were indeterminate and determinate type, respectively. SRE-B-15A had more number of main stem nodes, longer stem length, and darker green leaf color than TK #5. Flowering and maturity date of SRE-B-15A were earlier than TK #5, and yield and yield components of the two cultivars were similar to each other.

2. Rust epidemic of two soybean cultivars

Rust epidemic of the two soybean cultivars in

Table 1. The characteristics of SRE-B-15A and TK #5. z)

Cultivars	Growth habit	Leaf color	FD y)	MD y)	Stem length (cm)	Branches per plant	Main stem nodes	Pods per plant	Seeds per plant	100 seed wt. (g)	Yield per plant (g)
SRE-B-15A	Indet.	Dark green	Apr. 9	Jun. 6	88	3.3	17.1	55.9	105.9	20.4	18.9
TK #5	Det.	Green	Apr. 14	Jun. 7	57	3.1	12.5	56.1	109.8	19.9	18.3

z) Planting date: Feb. 24, 1986. Spacing: 50x10cm, 1 plant per hill.
y) FD: Flowering date, MD: Maturity date.

each growth stage are shown in Fig. 1. In this year, comparing to normal years, it was late in rust development because the relative humidity was not continuously high enough to induce the epidemics of rust. It was reported that the moderate temperature for rust development is 17-26°C and 6 hours of the dew period is the minimum necessary to permit infection.[2, 15, 18] In the fungicide plots, rust did not occur in all growth stages. In the case of the non-fungicide plots, SRE-B-15A, the tolerant cultivar, was infected with rust sometime between the R5 and R6 growth stages, and rust progress was very slow. On the other hand TK #5, the susceptible cultivar, was infected with rust between the R4 and R5 growth stages and the rust progressed rapidly during R5-R6 growth stages. As a result of this, at the R6 growth stage of TK #5, about 50 percent of leaves still attached to the plants were covered with rust causing the leaf color to change to yellow and an increased rate of defoliation. In another experiment, it was observed that the tolerant cultivar is less infected with rust in early stage, and even though it is infected in early stage, the progress of rust development is slow.[17]

The percentage of defoliated nodes/total nodes of the main stem per plant at each growth stage is shown in Fig. 2. Until the R5 and R6 growth stages for TK #5 and SRE-B-15A, respectively, defoliation follows a normal physiological pattern. From these points on, the contribution of rust infection to defoliation can be clearly seen as the curves rise dramatically in the non-fungicide plots. The rust development of SRE-B-15A at R6 growth stage had no affect on defoliation. Even though the rust was severe in the non-fungicide plot of TK #5 at the R6, defoliation was not severe compared to the fungicide plot. Defoliation at the R7 growth stage was also affected by physiological defoliation due to maturation. However, the difference in defoliation in the cultivars and fungicide treatment was clear.

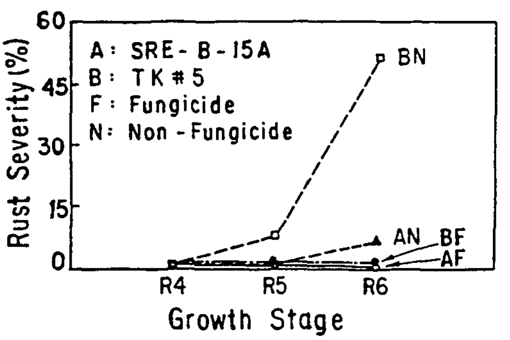

Fig. 1. Varietal difference of rust epidemic at different stages of soybean development and fungicide treatment.

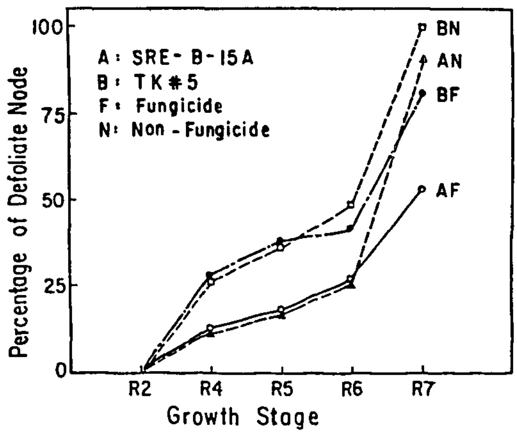

Fig. 2. Varietal difference of percentage of defoliate node at different stages of soybean under condition of fungicide and non-fungicide treatments.

3. Effect of rust on LAI, chlorophyll content, dry weight and grain/stem ratio.

Leaf area index in each growth stage is shown in Fig. 3. In all experimental plots, LAI, after increasing rapidly to the R4 growth stage, almost was not changed during the R4-R5 in the non-fungicide protected plot of TK #5, and during the R4-R6 in the fungicide protected plot of both cultivars and in the non-fungicide portected plot of SRE-B-15A. After these stages, LAI decreased rapidly. Considering defoliation, the leaf area of new and elongated leaves was greater than the area of the fallen leaves during the R2-R4 growth stages, since LAI increased from R2-R4 for both cultivars.

Chlorophyll content at the R6 growth stage is shown in Table 2. The difference of chlorophyll content between fungicide and non-fungicide treatments in SRE-B-15A, the tolerant cultivar, was 2.04%, but it was 16.43% in TK #5, the susceptible cultivar. In the fungicide plot, chlorophyll content of SRE-B-15A was higher than that of TK #5 and those leaf colors were dark green and green, respectively.

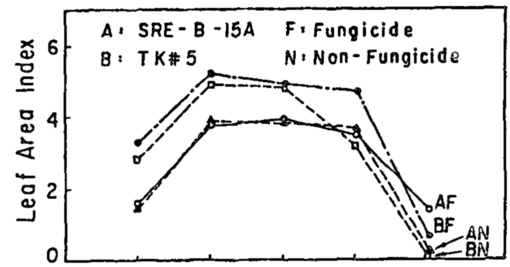

Fig. 3. Varietal difference of leaf area index at different stages of soybean under condition of fungicide and non-fungicide treatments.

Table 2. Effect of rust on chlorophyll content of two soybean cultivars[z)]

Cultivars	Fungicide (mg/dm^2)	Non-fungicide (mg/dm^2)	Difference (%)
SRE-B-15A	4.902	4.802	2.04
TK #5	4.754	3.973	16.43

[z)]Data for R6 growth stage.

Shoot dry weight, and pod and seed dry weight in each growth stage are shown in Fig. 4 and 5. The shoot dry weight in this experiment seems to be affected by the LAI, chlorophyll content, and the pod and seed dry weight. In the non-fungicide protected plots, the rate of shoot dry weight accumulation of TK #5 and SRE-B-15A decreased after the R5 and R6 growth stages, respectively. However, in the fungicide plots, this parameter increased at all growth stages. These changes in shoot dry weight were the result of increasing pod and seed dry weight due to pod filling, and decreasing LAI by defoliation, and a decrease of photosynthesis by reduction of chlorophyll content.

The difference in the pod and seed dry weight

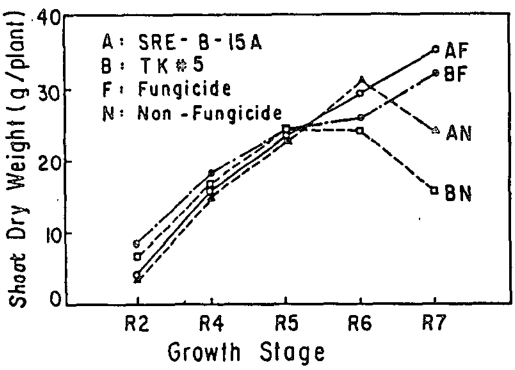

Fig. 4. Varietal difference of shoot dry weight at different stages of soybean development and fungicide treatment.

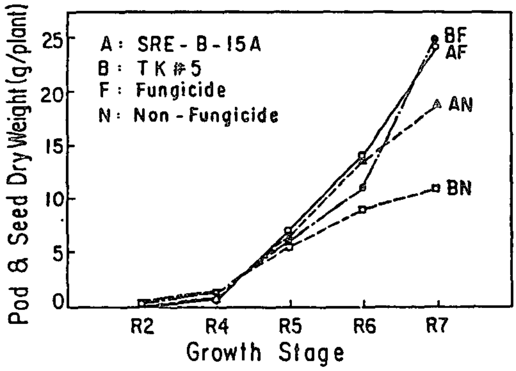

Fig. 5. Varietal difference of pod and seed dry weight at different stages of soybean development and fungicide treatment.

between the fungicide and non-fungicide protected plots of TK #5 was very clear (Fig. 5). The rate of pod filling in the non-fungicide plot slowed from the R5 growth stage, and it almost ceased after the R6, whereas in the fungicide protected plot pod filling continued until R7. As the result of this, the pod and seed dry weight of TK #5 in the non-fungicide protected plot was about 50% that of the fungicide protected plot. In SRE-B-15A cultivar, pod and seed dry weight of the fungicide treatment plot was increased continuously with largeness from R4 to R7, but the tendency of increase of it in the non-fungicide treatment became dull from R6.

Grain/stem ratio at the R7 growth stage is shown in Table 3. The difference between the grain/stem ratio in the fungicide and non-fungicide protected plots of cultivars SRE-B-15A and TK #5 were 9.32% and 59.99%, respectively. There was no difference in the dry weight of stem between the fungicide and non-fungicide protected plots until pod setting time, because the rust occurred generally after flowering. TK #5 in the non-fungicide protected plot seemed to almost cease photosynthetic activity and to stop pod filling after the R6 due to rust infection. It is reported that one half of the total nitrogen in the soybean plants was translocated to the grains in the latter half of the pod filling period.[8)]

4. Effect of rust on pod and seed size, protein and oil content, and empty pod/total pod ratio.

The effect of rust on pod and seed size at the R7 growth stage is shown in Table 4. The differences in the pod length and pod width between the fungicide and non-fungicide protected plots were not significant. However, there were significant differences between the two fungicide treatments for the pod thickness, seed length, seed width, and seed thickness. These data show that the rust affects the development of seeds. The pod thickness was affected by seed development which was affected by rust. However, pod length and width were not affected by rust infection because the pods had almost finished their elongation and width growth by 20 days after flowering.

The effect of rust on the protein and oil content of SRE-B-15A and TK #5 at the R7 growth stage is shown in Table 5. There was no significant

Table 3. Effect of rust on grain/stem ratio of two soybean cultivars[z)].

Cultivars	Fungicide	Non-fungicide	Difference (%)
SRE-B-15A	2.79	2.53	9.32
TK #5	3.07	1.23	59.99

[z)] Data for R7 growth stage.

Table 4. Effect of rust on pod and seed size of two soybean cultivars.[z)]

Pod and seed characters	SRE-B-15A			TK #5		
	Fungicide	Non-fungicide	Difference (%)	Fungicide	Non-fungicide	Difference (%)
Pod length (cm)	3.41	3.45	1.17	4.42	4.45	0.68
Pod width (cm)	1.09	1.07	1.83	1.16	1.14	1.72
Pod thickness (mm)	7.90	7.06	10.63	6.53	5.01	23.28
Seed length (mm)	8.19	7.81	4.64	8.83	7.52	14.84
Seed width (mm)	6.61	6.37	3.63	7.11	6.12	13.92
Seed thickness (mm)	6.01	5.76	5.57	5.25	3.80	27.62

[z)]Data for R7 growth stage.

Table 5. Effect of rust on protein and oil content of two soybean cultivars.[z)]

Cultivars	Protein			Oil		
	Fungicide	Non-fungicide	Difference (%)	Fungicide	Non-fungicide	Difference (%)
SRE-B-15A	43.2	43.8	1.4	22.9	22.7	0.9
TK #5	43.2	43.7	1.2	22.4	19.3	13.8

[z)]Data for R7 growth stage.

Table 6. Effect of rust on empty pod/total pod ratio per plant of two soybean cultivars.[z)]

Cultivars	Fungicide	Non-fungicide
	----- % ------	
SRE-B-15A	0.7	1.8
TK #5	0.9	12.6

[z)]Data for R7 growth stage.

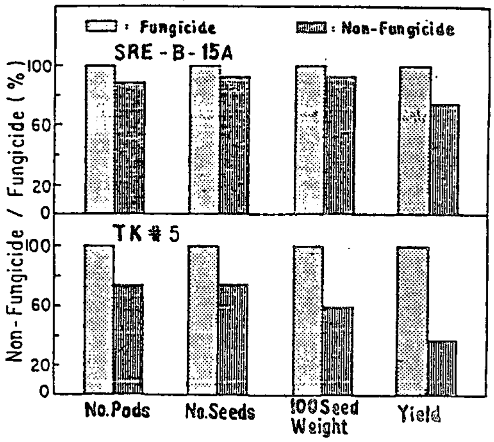

Fig. 6. Varietal difference of yield and yield components between fungicide and non-fungicide treatment of two soybean cultivars.

difference in the protein content between the fungicide and non-fungicide protected plots. However, in the oil content, there were significant differences in the fungicide treatments, in the cultivars, and in the interaction.

The empty pod/total pod ratio per plant at the R7 growth stage is shown in Table 6. The empty pod/total pod ratios of the two cultivars in the fungicide protected plot were almost the same. However, in the non-fungicide protected plot, the empty pod/total pod ratio of SRE-B-15A was 1.8, and for TK #5 it was 12.6. According to the results of analysis of variance, there were significant differences in the fungicide treatment, in the cultivars, and in the interaction.

5. Yield and yield components affected by the rust

The differences in the yield and yield components between the fungicide and non-fungicide protected plots of the two soybean cultivars are shown in Figure 6. In this experiment, the number of pods and seeds per plant, 100 seed weight, and yield of SRE-B-15A, the tolerant cultivar, were reduced by the rust infection in the non-fungicide protected plot by 9.8%, 7.1%, 7.4%, and 22.3%, respectively. However, in the case of TK #5, the susceptible cultivar, these yield components were reduced by the rust infection by 27.1%, 26.1%, 40.5%, and 68.7%, respectively. The rust infection caused to reduce the number of pods and seeds per plant, 100 seed weight, and yield, which agrees with the findings of other researchers.[11, 16)]

摘　　要

熱帶 및 亞熱帶地域의 大豆栽培에서 收量을 激減시키고 있는 콩녹병에 對한 耐病性品種과 罹病性品種을 供試하여, 本 病害의 進展過程과 生理的 및 收量關聯形質에 미치는 影響을 檢討한바 그 結果를 要約하면 다음과 같다.

1. 罹病性品種은 耐病性品種에 比하여 病의 早期感染 및 進展이 빨랐으며, 녹병에 依한 落葉은 콩 꼬투리가 半 程度 登熟된 後부터 急激히 增加하였다.

2. LAI의 減少는 罹病性品種이 耐病性品種에 比하여 빨랐으며, 健全個體와 녹병 罹病個體間의 葉綠素 含量의 差異는 耐病性品種에서 2.04%, 罹病性品種에서 16.43%의 差異가 있었다.

3. 地上部 乾物重은 녹병無發病區(殺菌劑 處理區)에서는 繼續 增加하였으나, 녹병發病區에서는 R_6 生育段階 以後부터 減少하였고, 減少程度는 罹病性品種이 耐病性品種에 比하여 더 컸다.

4. 莢과 種實의 乾物重은 罹病性品種의 녹병無發病區에서는 R_6生育段階 以後에 急激히 增加하였으나, 녹병發病區에서는 아주 緩慢하게 增加하였고, 耐病性品種에서는 녹병의 影響을 적게 받아 녹병發病區에서도 繼續 큰 幅으로 增加하였다.

5. 녹병은 不完全粒과 빈 꼬투리 數를 增加시키고, 種實의 Oil含量 및 길이, 폭, 두께를 減少시키며, 莢數, 粒數, 百粒重을 減少시켜 收量을 激減시키지만 蛋白質 含量에는 影響을 미치지 않았다.

6. 收量에 對한 녹병의 影響은 耐病性品種에서 22.3%, 罹病性品種에서 68.7%의 收量減少가 있었다.

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