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Assessment of the Soybean Yield Reduction due to Infection of Septoria Brown Spot, *Septoria glycines* Hemmi

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大豆 갈색무늬병에 依한 收量減少의 評價

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ABSTRACT

Septoria brown spot caused by *Septoria glycines* is one of the most serious fungal diseases in soybean. Average yield reduction of 3 varieties for two years was 16.1% by the septoria brown spot inoculation and 9.0% by the natural infection as compared to fungicide-sprayed plots. Number of pods per plant and seed weight were significantly reduced while plant height, number of branches and number of nodes per plant were not affected. Yield reduction was positively correlated to the septoria brown spot severity in all varieties examined. Correlation coefficient (r=0.38*) between yield reduction and area under the disease progress curve was higher than that (r=0.156) between yield reduction and Van der Plank's apparent infection rate. Potential effect of the septoria brown spot on the soybean yield reduction estimated with the area under the disease progress curve was expressed by the equation of $Y=4.38+0.05X$ (r=0.0696*, df=25).

INTRODUCTION

Several diseases of soybean have been documented o occur in Korea. Of these, septoria brown spot caused by *Septoria glycines* Hemmi is one of the most serious fungal diseases occurring in the soybean growing areas.

Septoria brown spot was first reported in 1915[5] and also in Korea by Nakata and Takimoto in 1934.[12] Then, the disease has been reported from almost all soybean growing regions in the world.[6,9,18] The disease develops on leaves throughout the growing season,[9,10] and sometimes occurs on stem and pods at maturing stage under warm, moist weather conditions.[13,18] Incidence of brown spot decreased in midsummer, but the disease reappeared actively ag ain in September.[6,18] Young and Ross[19] suggested that factors responsible for the lack of disease on upper leaves in the mid-summer might include resistant physiological phase of the plant other than unfavorable high temperature and lack of sufficient rainfall. There are reports on histolological study of brown spot[11] and physiological changes of host cells

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by the disease infection.[4]

Noticeable yield reductions caused by septoria brown spot epidemics have been reported. Yield losses ranging from 12% to 34% was caused by artificial inoculation with *S. glycines*, resulting mostly from reduction in seedsize.[9,13,14,19] No significant differences were observed for number of pods or number of seeds per pod. The yield losses varied among cultivars, locations, inoculation at different growth stages and natural infection.[19] This study was conducted to assess the yield reduction due to septoria brown spot epidemics in this country.

MATERIALS AND METHODS

Planting of soybean in field plots

Experiments were conducted in 1979 and 1980 at experiment farm of Korea Advanced Energy Research Institute, Gumgog, Gyeonggi Province. The soybean varieties planted for yield loss assessment were KEX-2, Clark and KAS 604-24, in which the former two varieties were yellow seed coat and the latter was green seed coat. Treatments were consisted of the plots inoculated with *Septoria glycines*, checks plots maintained under natural condition and controlled plots sprayed with 0.1% benlate methyl-1- (butyl carbamoyl-2-benzimidazole) carbamate once every other weeks from emergence to podding stages of growth. Each plot consisted of 5 rows spacing 75cm apart and 3m long with 10cm between seeds in a row, unless otherwise indicated. The experiment was conducted by the split block design with three replications.

Inoculation of *S.glycines*

Cultures of *S. glycines* grown on PDA for 2-3 weeks at 25°C were flooded with sterile distilled water, and the agar surface was slightly rubbed with painting brush to release the conidia, and then suspension was strained through three layers of cheesecloth. The conidial suspension was adjusted to about 10^5 conidia/ml before being applied. All plots were inoculated at V_4 stage with the aquous spore suspension mixed with 0.1% Tween 20 just before inoculation. Air compressor operated at $2kg/cm^2$ was used to spray evenly on upper and lower leaves with the suspension.

Measurement of yield reduction

Yield data were taken from the central three row: of each plot after two plants were removed tron both ends of each row. Harvested plants were driec for two days under the field conditions prior to hanc threshing. Soybean grains maintained 14% relativ humidity for yield measurement. Percent yield reduction was calculated as (Yield of sprayed plot-yielc of inoculated plot)/(yield of sprayed plot x 100).

Evaluation of brown spot severity

Disease observation was made four times (July 1, July 15, Aug. 13 and Sept. 7) from a week after inoculation in the field. Twenty plants selected at random in each plot were rated and averaged tc obtain the percent diseased leaf area for each plot. The severity of brown spot disease was calculated by using the method of Young and Ross[19] as follows: (% defoliation+% remaining leaves) x proportion of remaining leaf area diseased. Diseased leaf area was determined by using a modified Horsfall and Barrat scale.[8]

Soybean growth stage[2] was recorded on each disease rating date. The disease progress over time in each plot was estimated with logit transformation of brown spot severity. The regression coefficient of the logit on time was the same as Van der plank's apparent infection rate.[16] The area under the brown spot progress curve (AUEC) was calculated for each plot to express the severity of brown spot during the entire growth and to regress yield reduction on accumulative disease severity. AUEC was calculated by dividing the curves into segments corresponding to the time intervals when disease ratings were made. Each segment was thus represented by a trapezoid whose unequal heights were measured in terms of disease severity at times of observation. This relationship was expressed by the following formula: $AUEC=\sum_{i=1}^{k-1} (X_{i+1}+X_i)(t_{i+1}-t)/20$, in which $X=$ the severity of brown spot, $t=$the time of rating, $K=$ total number of observation.

Table 1. Effect of Septoria brown spot infection on agronomic traits of soybean in fungicide sprayed[a], inoculated[b] and check plots[c] of three soybean varieties in 1979 and 1980

ariety	Treat.	Plant height (cm)		No. of nodes		No. of branches		No. of pods		100-seed wgt. (g)	
		'79	'80	'79	'80	'79	'80	'79	'80	'79	'80
EX-2	Spray	51.2	51.0	15.2	14.3	5.3	5.1	46.5	45.9	30.1	29.0
	Check	52.1	52.2	14.2	14.2	4.9	4.3	44.3	40.9	28.6	28.7
	Inocul.	47.3	46.3	14.3	13.8	4.5	4.2	40.4	39.5	27.3	26.9
:lark	Sprak	65.3	66.2	18.5	18.7	2.9	2.9	47.9	51.8	14.9	14.4
	Check	66.7	67.5	17.5	18.6	2.9	2.7	45.1	45.9	14.5	13.8
	Inocul.	65.8	64.7	18.6	18.6	2.8	2.6	43.3	43.4	13.5	13.0
:AS 604-24	Sparay	63.4	63.2	15.7	15.7	3.7	3.8	68.1	75.5	14.1	14.3
	Check	60.8	59.2	15.7	15.8	3.8	3.6	64.1	63.0	13.7	13.8
	Inocul	58.7	58.5	15.6	15.6	3.1	3.1	63.2	60.9	13.4	13.4
'-value	Variety	65.43**	88,50**	29.45**	55.78**	52.42	43.58**	18,94**	28.33**	108.91**	68.0**
	Treat.	0.33	0.45	2.33	3.09	4.01	3.83	8.65	9.83*	10.07	25.34**

[a] Benlate 0.1% at every other weeks from the primary leaf stage until first flower appeared
[b] Conidial suspension (10^3/ml) treatment on 8 June 1979 at 2-3 trifoliolate leaf stage
[c] Natural infection

Table 2. Effects of Septoria brown spot infection on yield in three soybean varieties

Variety	Treat[a].	1979 Yield (Kg/ha)	1979 Yield reduction (%)	1980 Yield (Kg/hr)	1980 Yield reduction (%)	Average yield reduction (%)
KEX-2	Spray	2425.6	0	2097.6	0	0
	Check	2280.2	6.0	1842.4	13.5	9.7
	Inocul.	2064.2	14.9	1740.6	18.9	16.4
Clark	Spray	2232.6	0	1968.6	0	0
	Check	2114.2	6.1	1764.4	11.5	8.8
	Inoclu.	1896.8	15.8	1671.4	16.9	16.3
KAS 604-24	Spray	2089.4	0	1560.6	0	0
	Check	1975.8	5.4	1411.2	11.0	8.2
	Inocul.	1792.8	14.2	1327.8	17.3	15.7
F-value	Year (Y)	133.12**	Interaction:	YV	13.04*	
	Variety (V)	108.13**		YT	0.37	
	Treat. (T)	14.21**		YVT	0.24	

[a] Spray ; Benlate 0.1% at every other weeks from the primary leaf stage until first flower appeared
Check ; Natural infection
Inocul. ; Conidial suspension (10^3/ml) treatment at 2-3 trifoliolate leaf stage

RESULTS

Yield components of the three soybean varieties :rown each year of 1979 and 1980 at the Gumgog :xperiment farm are presented in Table 1. Responses of the varieties to septoria brown spot showed similar trends. Even though there was a little difference between two years. Number of pods per plant and seed weight were significantly reduced by the infection of septoria brown spot, however, other characters, such as plant height, number of branches

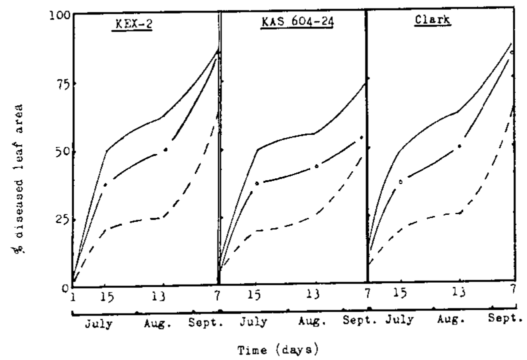


Fig. 1. Septoria brown spot severity in soybean varieties inoculated with *Septoria glycines* (——), sprayed with fungicide (······), and a check of natural infection (— • —)

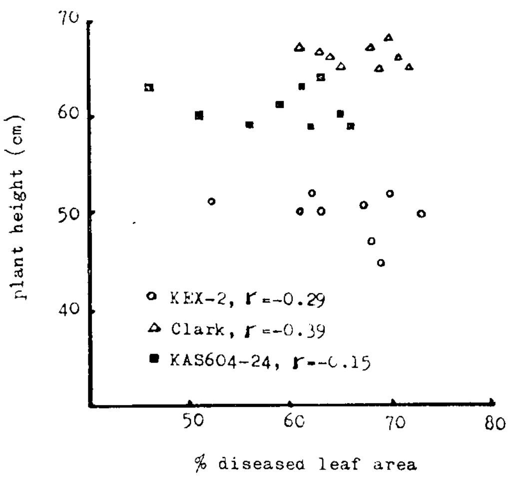


Fig. 2. Relationship between disease severity of Septoria brown spot and plant height in three soybean varieties

and number of nodes per plant were not affected. Seed weights considerably reduced to ca 5% in naturally infected plots (check) and ca 9% inoculated plots as compared to fungicide sprayed plots. There were significant difffrences in the seed weight and number of pods per plant between treatments and also between varieties.

Yields were signficantly reduced by the infection of Septoria brown spot (Table 2). In comparison of yields in fungicide-sprayed plots and inoculated plots in 1979, inoculated plots had yield reductions of 14.9% for KEX-2 15.8% for Clark and 14.2% for KAS 604-24, whereas 1980 inoculated plots had yield reductions of 18.7% for KEX-2, 10.9% fo Clark and 17.3% for KAS 604-24. For check plo in which natural infection occured, yield reductio were 6-13%, 6.11-11.5% and 5.4-11.0% for KEX-2 Clark and KAS 604-24, respectively, as compare to fungicide-sprayed plots. Yield reduction in chec plots was greater in 1980 than that of in 197 Average yield reducton of two years by the inocu ation was 16.1% as compared to those of fungicid sprayed plots. The development of the Septoria brow spot in the experimental plots during the grov ing season was similar trends in the three variet (Fig. 1). Brown spot appeared on the prima leaves about a month after seeding in the field, ar then rapidly increased leaf area. The disease grad ally increased as the time went by, but manifest less progress of the disease at the flowering stag (R_1) and at the beginning of pod filling stage (R^3) Symptoms progressed acropetally and more rapidl on older leaves than those of younger leaves.

Relationships between the the diseace severity an several agronomic characters of soybean were stud ied. Septoria brown spot affected plant height but i was not statistically significant (Fig. 2). The co relation coefficients (r) of the plant height to th disease severity were -0.39, -0.15 and -0.29 fo varieties Clark, KAS 604-24 and KEX-2, respective ly. Also, number of branches each plant wer

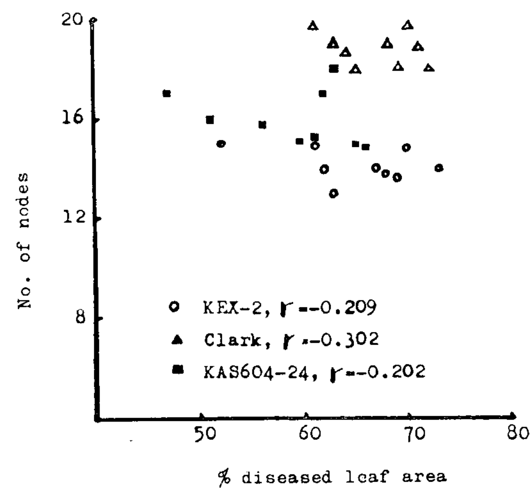
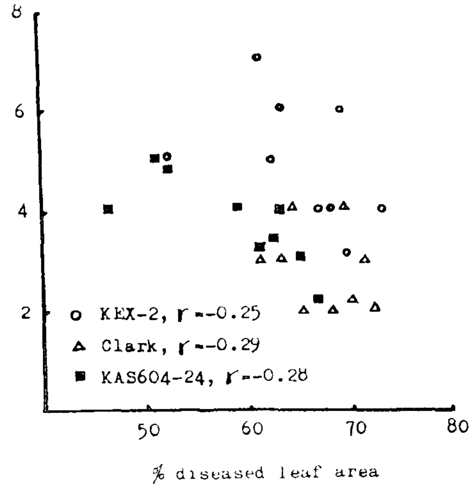


Fig. 3. Relationship between disease severity o Septoria brown spot and number of node per plant in three soybean varieties



ig. 4. Relationship between disease severity of Septoria brown spot and number of branches per plant in three soybean varieties

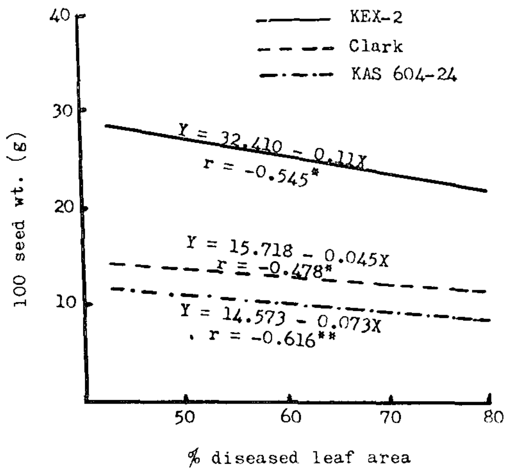
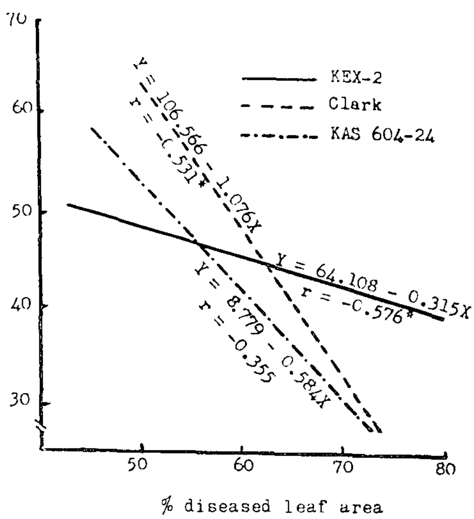


Fig. 6. Regression analysis between disease severity of Septoria brown spot and 100 seed weight in three soybean varieties



ig. 5. *Regression analysis between severity of* Septoria brown spot and number of pods per plant in three soybean varieties

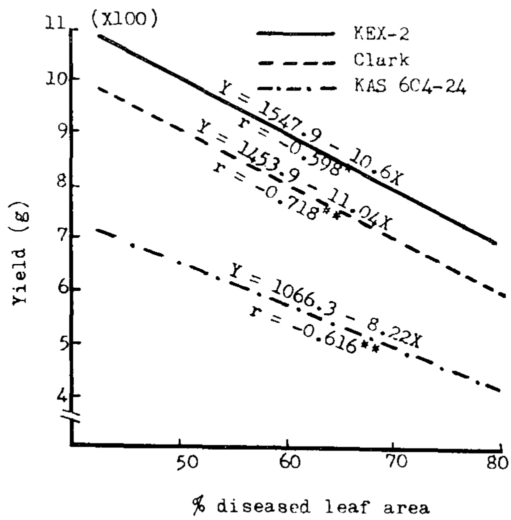


Fig. 7. Regression analysis between disease severity of Septoria brown spot and seed yield in three soybean varieties

iightly reduced by the increase of the disease sever- :y, but there was no significant correlation (Fig. 3 nd Fig. 4). However, most important yield compon- ents, such as number of pods per plant and seed /eight were negatively correlated with the Septoria rown spot severity (Fig. 5 and Fig. 6). The correla- *on cofficients (r)* were -0. 576 for variety, KEX-2 . 355 for variety, KAS604-24 -0. 531 for Clark ı number of pods per plant and -0. 545 for KEX-2, -0. 478 for Clark, -0. 616 for 604-24 in seed weights. Accordingly, yield reduction was highly correlated with the disease severity in all varieties. The linear regression cofficients were 10. 6, 11. 04 and 8. 22 for varieties KEX-2, Clark and KAS 604-24, respectively (Fig. 7). Table 3 shows the relation- ships between soybean yield and the severity of Septoria brown spot, as expressed by the Van der Plank's apparent infection rate (b) and AUBC

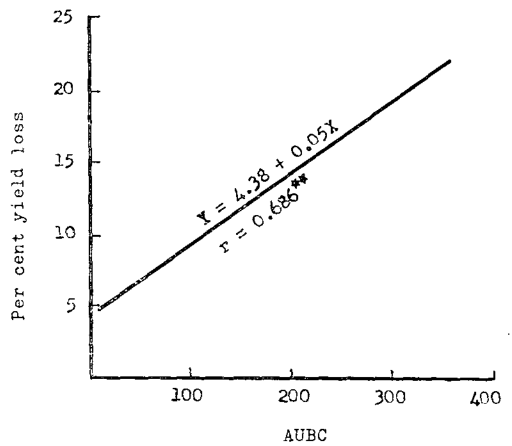


Fig. 8. Relationships between AUBC values and per cent yield loss by Septoria brown spot epidemics

values. Apparent infection rate, as expressed by regression coefficient was higher in all plots inoculated (b=0.0189 for Clark and 0.0174for KAS 604-24), than those of check plots or fungicide-sprayed plots. The AUBC value was significantly different among plots. The fungicide-sprayed plots showed AUBC values of 214.09 for the variety KEX-2, 220.65 for Clark and 180.65 for KA! 604.24. The AUBC values from the inoculate plots were significantly higher than those fro any other plots for each variety. Yield reducto was related to apparent infection rate of brow spot, but statistically not singificant. However, ther was higher correlation coefficient (r) between yiel reduction and AUBC value in all varieties. On thi account, the AUBC values were used to assess pot ential effect of brown spot on soybean yield. Sinc there was no significant difference among the regres sion coefficient for yield reductions, combined dat of the three varieties over year used to calculat linear regression equation for the estimation of yiel reduction based on AUBC values (Fig. 8). The equa tion was as follows: $Y=4.38+0.05X$ in which Y= percent predicted yield reduction, X=AUEC value $r=0.686^{**}$ ($P\leq 0.01$, df=25).

DISCUSSION

A considerable yield reduction due to infection of Septoria brown spot has been reported (9), but there was still a lack of informations of potential yield loss in this country. Results from both years

Table 3. Correlation between seed yield and infection rate and AUBC value of Septoria brown spot in three soybean varieties

Variety	Treat.	Yield(g)	b[a]	AUBC[b]
KEX-2	Inocul.	770.3	0.0189	426.49
	Check	821.2	0.0150	371.76
	Spray	948.8	0.0109	214.09
	LSD(0.5)	33.999	0.0013	2.291
Clark	Inocul.	735.7	0.0181	441.74
	Check	782.2	0.0165	373.91
	Spray	884.3	0.0092	220.65
	LSD(.05)	39.259	0.0006	9.165
KAS 604-24	Inocul.	563.9	0.074	399.45
	Check	605.1	0.060	329.45
	Spray	680.3	0.0003	180.65
	LSD(.05)	34.075	0.0013	4.069
	Correlaton to yield(r)	—	−0.156	−0.388*[c]

[a] The slope of the regression line which is the same as van der Plank's apparent infection rate
[b] Area under the brown spot disease curve
[c] Statistially significant at 5% level

1979 and 1980 indicated that yield losses caused by Septoria brown spot epidemics were very high. It was average 16.1% of all over the inoculated plots as compared to fungicide-sprayed plots, in which the reduction was supposed to zero.

There was a different yield reduction in plots with natural infection between 1979 and 1980. Possible explanations for less yield reduction in 1979 were that Septoria brown spot symptoms appeared afew days later than did in 1980 and that there was more disease in 1980 than that of in 1979 presumably because of the greater abundance of naturally occurring inoculum with a favorable weather conditons for the disease development. This indicates that more severe infection in some seasons may lead to even greater yield loss.

The yield loss occurred primarily through the reduction of seed weight (size) as one would be expected with a late-season foliar diseases. The reduction in seed size might be associated with decrease in chlorophyll contents of soybean leaves infected with *Septoria glycines*. According to MacNeil and Zalasky (11), soybean seeds can become detatched from pods when *S. glycines* invades the placentae and funiculi. This type of pod infection could also be responsible for reduction of seed weights. Yield reduction seemed to be significantly associated with the amounts of early defoliation in the present study. Leaf defoliation in turn was related to the level of Septoria brown spot infection. Other investigators (3, 15) reported soybean yield reduction by premature defoliation at the reproductive stage.

There were contradictory reports that bacterial blight resulted in considerable amounts of soybean yield by synergistic effect with Septoria brown spot (1) and some degree of antagonism between two pathogens (17). Actually no other foliar diseases capable of affecting soybean yield, however, were observed in all of the plots. Furthermore, it was likely that benlate treatment did not affect to yield potential in this experiment, as reported by Horn et al. (7). Consequently, yield loss should be concerned with disease complex. For assessment of yield reduction, disease components first must be studied separately from any interaction of fungicides, other diseases, insects and unusual physical conditions. Once a baseline for potential yield loss is determined for each pathogen, the effect of two or more pathogens on a host can be determined under different environmental conditions. Such research can provide realistic informations to aid in deciding what control measures shall be applied.

It was considered that relationship between the severity of brown spot with diseased leaf area and yield reduction in soybean could best be expressed by the regression of yield reduction on AUBC values. However, the regression equation exhibited some inability to account for the time of infection as related to yield reduction. Because, there were significant differences in yield reduction according to the time of infection and amounts of infection relative to the growth stage, even though the AUBC values are similar. In this regard. further study is needed to test and improve the simulation for the estimation of yield reduction.

적 요

2년간에 걸쳐 조사한 대두의 수량감소는 갈색무늬병을 접종한 경우 농약 살포구에 비해 15.7-16.4% 감소하였으며 자연감염의 경우에는 8.2-9.2%의 감소를 나타냈다. 갈색무늬병의 감염은 초장, 주당절수(株當節數), 주당분지수(分枝數)에는 큰 영향이 없었으나 주당협수(莢數)와 종실중(種實重)에는 현저한 감소 현상을 보였다. 대두의 수량감소율은 갈색무늬병의 이병율과 정(正)의 상관을 보였으며 그 상관도는 Van der Plank's infection rate (0.156) 보다는 병 진전국선면적(AUBC) 과의 상관도가 높았다($r=0.388^*$). 병진전곡선 면적으로 표시된 갈색무늬병의 감염율과 대두수량 감소율과의 관계는 $y=4.38+0.5X$ ($r=0.686^{**}$, df=25)으로 나타났다.

LITERATUSE CITED

1. Dunleavy, J.M., C.R. Weber and D.W. Chamberlain, 1960. A source of bacterial blight resist ance for soybeans.Proc. Iowa Acad. Sci. 67 : 120-125.
2. Fehr, W.R., C.E. Caviness, D.T. Burmood, and J.S. Pennington, 1971. Stage of development descriptions of soybeans, *Glycine max* (L) Merril

(Abstract) Crop sci. 119. 29-931.

3, Fehr, W.R., C.E. Cavinese and J.J. Vost, 1977. Response of indeterminate soybean cultivars to defoliation and half-plant cutt off. Crop Sci. 17: 913-917.

4. Fucikovsky, L.A., 1972. Pigments of soybean leaves infected by *Septoria glycines* and *Pseudomonas glycinea*. Trans. Brit. Mycol. Soc. 59 : 506-508.

5. Hemmi, T., 1915, A new brown spot disease of the leaf of *Glycine hispida* Maxim. caused by *Septoria glycines* sp. Sapporo Mat. Hist. Soc. Trans. 6 : 12-17.

6. Hemmi, T., 1940. Studies on septorioses of plants. VI. *Septoria glycines* Hemmi causing the brown spot disease of soybean. Mem. Coll. Agr. Kyoto Imp. Univ. 47 : 1-4.

7. Horn, N.L., G. Whitney and T. Fort. 1978. Yields and maturity of fungicide-sprayed and unsprayed disease free soybean plants. Plant Dis. Rep. 62 : 247-249.

8. Horsfall, J.G. and R.W. Barratt, 1945. An improved grading system for measuring plant diseases(Abstract). Phytopathology 35 : 655.

9. Lim, S.M., 1980. Brown spots severity and yield reduction in soybean. Phytopathology 70 : 974-977.

10. Lockwood, J.L., J.A. Percich and J.N.C. Maduewesi, 1977. Effect of leaf removal simulating pathogen-induced defoliation on soybean yields. Plant Dis. Rep.. 61 : 458-462.

11. MacNeil, C.H. and H. Zalasky, 1957. Histologic study of host-parasite relationship between *Septoria glycines* Hemmi and soybean leaves an pods. Can. J.Bot. 35 : 501-505.

12. Nakata, K. and K. Takimoto, 1934. A list o crop disases in Korea. Agr. Exptl. Govt. Centra Chosen Res. Rep. 15 : 1-146.

13. Pataky, J.K. and S.M. Lim, 1980. Effect o septoria brown spot on the yield components o soybeans. Plant Dis. 13 : 28-30.

14. Shaner. G. and R.E. Finnyey, 1977. The effec of nitrogen fertilization on the expression o slow-mildewing resistance in Knox wheat Phytopathology 67 : 1051-1056.

15. Turnipseed, S.G., 1972. Response of soybean to foliage losses in South Carolina. J. Econ. Entomol. 65 : 224-229.

16. Vander Plank, J.E., 1963. Plant diseases, epidemics and control. Academic press, New York.

17. Williams, D. J. and R.F. Nyvall, 1980. Lea infection and yield losses caused by brown spo and bacterial blight diseases of soybean. Phytopathology 70 : 900-902.

18. Wolf, F.A. and S.G. Lehman, 1926. Brown spot disease of soybean. J. Agric. Res. 33 : 365-374.

19. Young, L.D. and J.P. Ross, 1979. Brown spot development and yield response of soybean inoculated with *Septoria glycines* at various growth stages. Phytopathology 69 : 8-11.