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Effects of Soil Disinfection, Fungicide Application, and Narrow Ridge Cultivation on Development of Ginger Rhizome Rot Caused by *Pythium myriotylum* in Fields

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*Pythium myriotyrum*에 의한 생강뿌리썩음병의 포장내 발병진전에 미치는 토양소독, 살균제 시용, 좁은 이랑재배 효과

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ABSTRACT: Effects of soil disinfection, fungicide application, and narrow ridge cultivation on ginger rhizome rot development were examined in two naturally-infested fields at Seosan, Choongnam province. Soil disinfection treatments were assigned to main plots, and fungicide and ridge treatments to sub-plots in a split plot design with three replications. The rhizome rot started in late July, and progressed rapidly until late September with the peak incidence in mid-August to early September. Soil disinfection by dazomet application showed the most prominent inhibition effects in both fields, where the disease was reduced by the treatment from 17.5% to 4.8% in one field, and from 51.0% to 2.2% in the other field. Three to five applications of fungicide metalaxyl-copper during the growing season inhibited the disease by 89.7% in one field, but less effectively in the other field. Narrow ridge cultivation reduced the disease effectively by 78.1% and 63.9%, compared to the unridged control plots in each field, respectively. Germination rate of seed-rhizomes and growth of ginger plants were similar between treatments, except when the plots received improper aeration after applying dazomet, and then the germination rate was significantly reduced. The greatest yields were obtained in the disinfected plots, regardless of rhizome rot incidence, except one control plot with very little disease. Ginger yield was negatively correlated with disease severity. However, the yield of ridge plots averaged 58~59% compared to those of the unridged plots, due mainly to the half planting rate of the ridge plots. In spatial progress, the disease in the disinfected plots started from a single focus of the inoculum, and spread into the adjacent areas only, whereas in the untreated plots, the disease started from many foci that were distributed over the plot, and rapidly progressed to make an epidemic during the season. The soil density of *P. myriotylum* in the disinfected plots was not changed or, if not, increased slightly during the season. However, in the untreated plots it increased rapidly to reach the density 3 to 5 times greater by the end of the season.

Key words: **ginger, *Zingiber officinale*, rhizome rot, *Pythium myriotyrum*, soil disinfection, chemical control, cultural control, soilborne disease.**

Rhizome rot of ginger caused by *Pythium myriotylum* has been a major limiting factor for ginger production in Korea (2) and in other countries (1, 5, 9). Incidence of the disease ranged 0% to 98% depending on the field and averaged 18.1% in major production areas in 1995 (2). The pathogen attacks mainly underground rhizomes and basal stems resulting in blight of the whole plants with mummified rhizomes at end of the season. Since the pathogen is soilborne in nature, continuous planting of ginger which is commonly practiced in major production areas has been considered as a factor for buildup of the inoculum in soil (3, 7).

Although incidence pattern of the disease differed with area and year, the disease occurs very severely, and often devastates ginger fields, particularly in the year of extremely hot summer and much precipitation in July and August. Control of the disease heavily depends on fungicide spray (8), but has been known to be ineffective

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(2). Consequently, development of effective control measures has been an urgent task for the stable production of ginger.

Studies on the control of ginger rhizome rot disease in Korea have been mostly carried out on fungicide screening in a greenhouse in small scale pot-experiments (10), and thus their results were of little value for practical application in fields. Further, little research effort has been made on ecology of soil inocula. Since inocula of the disease dispersed by soil water, ridge cultivation might be effective for reducing the disease due to better drainage, compared to the conventional unridged cultivation. This possibility has never been examined.

The present study was carried out to examine effects of soil disinfection, fungicide application, and ridge cultivation on ginger rhizome rot development. This study is a part of the researches which have been initiated to develop effective control measures against ginger rhizome rot. Research results on the survey of incidence (2), etiology (4) and ecology of the disease (3) have been published.

MATERIALS AND METHODS

Cultural practices and treatment in field experiments. A ginger cultivar; Seosan-jaerae susceptible to rhizome rot was used throughout the study. The experiment was conducted at two commercial fields located at Inji-myon and Buseok-myon in Seosan-city, Choongnam province in 1996. Cultivation of ginger including planting, fertilization, water management and other cultural methods was followed by the standard method commonly practised in Seosan area. Seed rhizomes which had been disinfected previously by soaking in the suspension of fungicide benlate-T (200x dilution) for 4 hr were planted April 24, 1996. A split plot design was employed in the experiment by assigning soil disinfection treatment as main plots, and the ridge cultivation and fungicide application treatments as subplots. The experimental field, 46 m long and 39 m wide, was first divided into two main plots where one half was received soil disinfection treatment. Then, ridge and fungicide application treatments were assigned as subplot to each main plot with three replications. Each subplot consisted of three small plots, 9.6 m long, 1.2 m wide, 0.6 m apart, which has 27- to 30-planting rows each, except for ridge treatment. The ridge plots consisted of only 13 to 15 planting rows, that is, one half of the planting rates of other treatments. A ridge was made by combining two planting rows. Soil disinfection was achieved by fumigation with dazomet 98% G, at the labeled rate on Mar 28, 1996. Fumigated fields were aerated three times at three-day intervals from 12 days after its application. Seed rhizomes were then planted after germination tests with radish seeds to make sure proper aeration in the fumigated soil. The plots with fungicide application were received three times of foliar sprays of metalaxyl-copper 50% WP at the labeled rate at 15 to 20 days intervals beginning end of July, when the disease was first observed.

Assessment of temporal and spatial disease progress. Rhizome rot incidence was examined for all plants in the plots. Plant with typical yellowing symptom was considered as the diseased. Location of the diseased plants in the plots was recorded at each time of disease assessment to examine the pattern of spatial spread in each plot. Disease incidence was examined from early July to mid-October at 6 to 14 day intervals.

Monitoring pathogen population in filed plots. Five to 10 g of soil was sampled from 25 different spots randomly selected in each plot on Jun 17, Jul 16 and Sep 16. Enumeration of *P. myriotylum* density has been done by using the selective medium (6). Twenty five soil samples were thoroughly mixed before taking 1 g sample soil. The soil sample was put on the selected medium of *P. myriotylum* in a 9 cm diam. petri dish, and distributed evenly on the surface of the medium after adding 10 ml of sterile water. The dishes were incubated at 35C for 18 hr, and then washed the soil off under a tab water. Number of colonies appeared on the medium surface was counted. Each soil sample was replicated 5 times for enumeration.

Examination of ginger growth and yield. Germination rate of seed rhizome was examined for all plots on Jul 24, 1996. Height of the germinated ginger plants was measured based on 20 plants randomly selected in each plot on Aug 17. Each plot was harvested on Oct 31, and ginger yield per 10a was calculated in each treatment. In order to examine the relationship between rhizome rot incidence and ginger yield, the yield in each subplot was plotted against the disease incidence in each field, and a linear regression was obtained between two variables. Significance of the regression model and R-square in each model was assessed with a regression analysis.

Data analysis. The data were analyzed using Statistical Analysis System (SAS). The significance of main plot and subplot effects and their interactions for germination rate, plant height, rhizome rot incidence and yield was examined using a standard analysis of variance technique for split-plot design. In the presence of significant factor effects, least significant difference (LSD) test was then employed to compare the treatment means.

RESULTS

Temporal progress of rhizome rot. There were major differences in rhizome rot development between the disinfected and the undisinfected plots in both fields (Fig. 1 and 2). Disease progressed rapidly in the undisinfected plots except for ridge and fungicide treatments in field at Inji, but was greatly reduced in the fumigated plots regardless of treatment and field location. Time of initial incidence of the disease varied from Jul 24 to Jul 30, 1996, depending upon the treatments. Final disease severity for the plots of untreated control, ridge and fungicide spray treatments in the undisinfected plots at Buseok averaged 69.9%, 25.2% and 58.0%, respectively, but those in the fumigated plots were less than 6% (Fig. 2). In Inji field, the corresponding final disease severity in the unfumigated plots was 39.8%, 8.8% and 4.1%, respectively, but those in the fumigated plots were 10.3% 3.1% and 1.1%, respectively (Fig. 1). Treatment effects within the main plot were significant in both fields. Disease was developed slowly for ridge and fungicide treatments. However, disease control efficacy by fungicide spray was reduced in Buseok, where the disease occurred more severely than in Inji.

Spatial progress of rhizome rot. Spatial spread of rhizome rot differed greatly between the disinfected and the undisinfected plots (Figs. 3-5). In the disinfect-

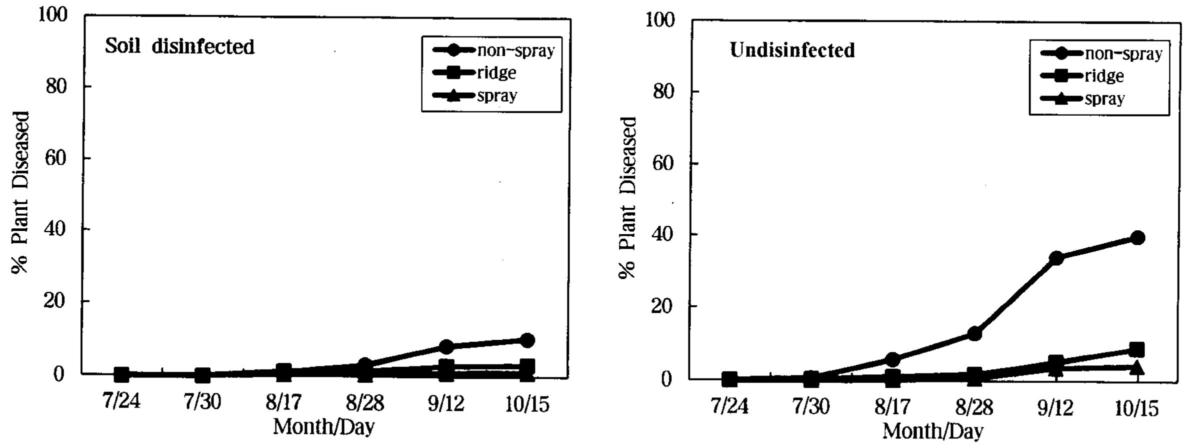

Fig. 1. Disease progress of ginger rhizome rot as influenced by soil disinfection with dazomet, fungicide spray with metalaxyl-copper and ridge cultivation in field at Inji-myon, Seosan city, Choongnam province in 1996.

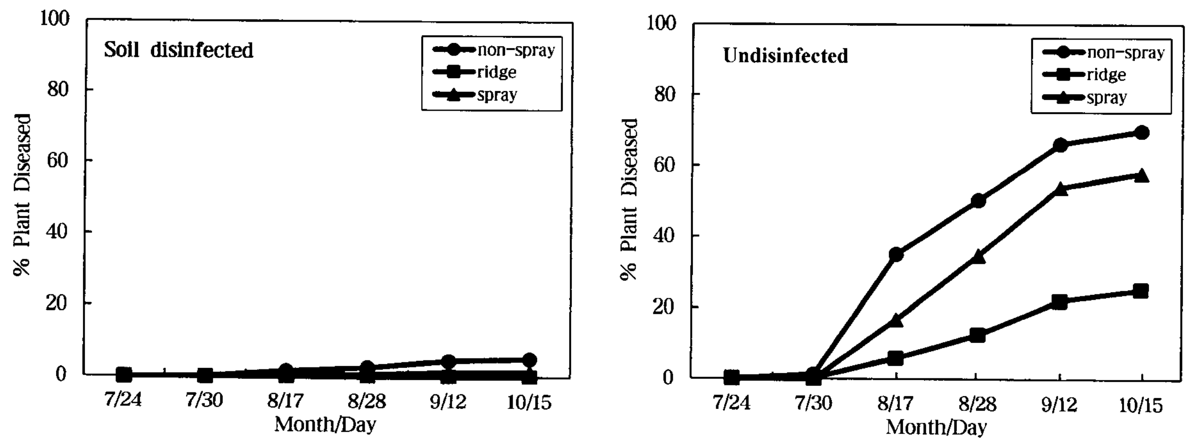

Fig. 2. Disease progress of ginger rhizome rot as influenced by soil disinfection with dazomet, fungicide spray with metalaxyl-copper and ridge cultivation in field at Buseok-myon, Seosan city, Choongnam province in 1996.

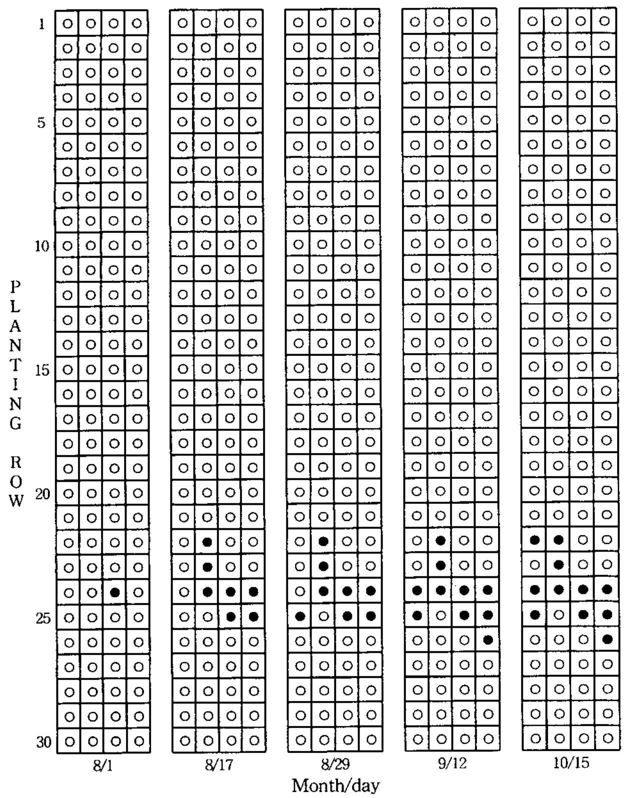

Fig. 3. A typical spatial progress of ginger rhizome rot in the plot received soil disinfection treatment without fungicide spray in field at Buseok-myon, Seosan city, Choongnam province in 1996. Open circles and closed circles mean healthy plants and diseased plants, respectively.

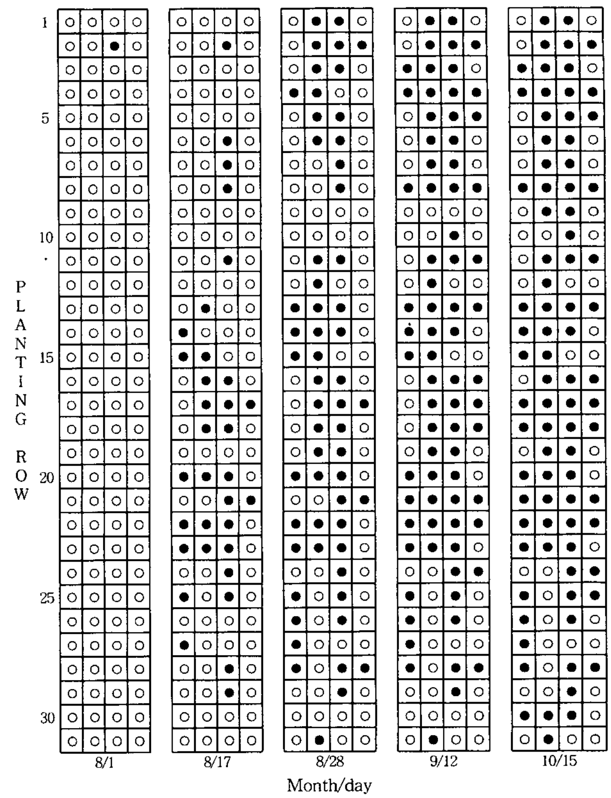

Fig. 4. A typical spatial progress of ginger rhizome rot in the plot of untreated control in field at Buseok-myon, Seosan city, Choongnam province in 1996. Open circles and closed circles mean healthy plants and diseased plants, respectively.

ed plots, pattern of the disease spread was limited to adjacent area of the initial disease focus, despite absence of fungicide spray (Fig. 3). In contrast, disease in the undisinfected plots spread fast to adjacent areas, and distributed more or less uniformly over the plots at end of the season (Fig. 4). Disease spread pattern in the undisinfected plots with fungicide spray was somewhat similar to that without fungicide spray. However, rate of the spread was much slower (Fig. 5).

Pathogen density in soil. Density of *P. myriotylum* in the disinfected plots was greatly reduced to 0 to 12 cfu/g soil, compared to the undisinfected plots with 23 to 103 cfu/g soil (Fig. 6). Pathogen density in the undisinfected plots increased rapidly in both fields as the season progressed, whereas the density in the disinfected plots remained unchanged or slightly increased at end of the season in Inji field.

Growth of ginger plants and yield. Germination rate of seed rhizomes in disinfected plots was similar to or higher than that of the undisinfected except for Inji field where the damage occurred due to the insufficient aeration after soil fumigation (Table 1). Germination rate in ridge plots in the undisinfected field was 95~96% and did not differ with other treatments. Plant height of ginger in the mid-growth stage did not vary between treatments in both experimental fields.

Ginger yields generally reflected rhizome rot incidence in corresponding plots. Ginger yields were much greater in the disinfected plots than in undisinfected plots, due mainly to the differences in rhizome rot incidence, especially at Buseok, where rhizome rot occurred more severely. However, yield differences in the disinfected and undisinfected plots were reduced in Inji field, despite appreciable differences in rhizome rot incidence between the two treatments, because of the poor ginger germination in the disinfected plots. Yields in ridged plots were about one half of the other plots because of the half planting rate. Yields in the disinfected plots with fungicide application did not differ from those without fungicide application.

Relationship between yield and rhizome rot severity.

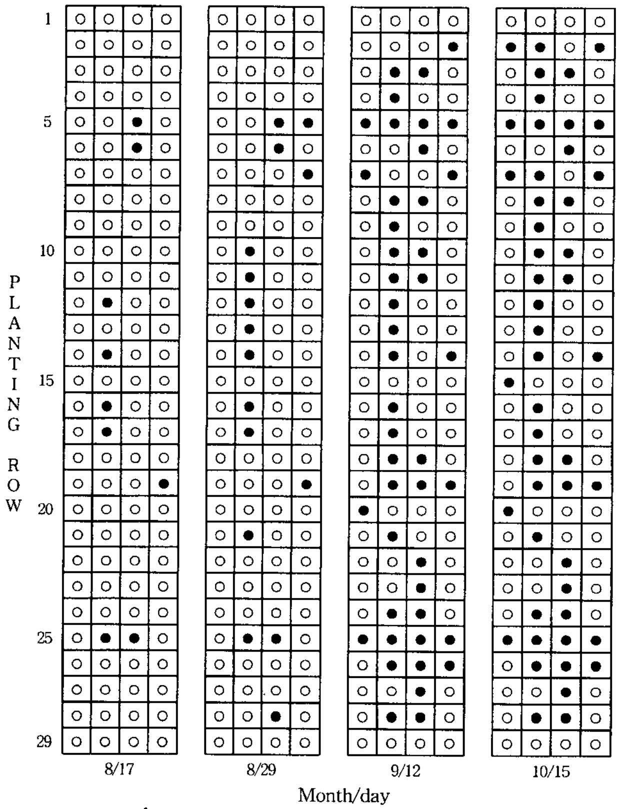

Fig. 5. A typical spatial progress of ginger rhizome rot in the undisinfected plots with fungicide spray in field at Buseok-myon, Seosan city, Choongnam province in 1996. Open circles and closed circles mean healthy plants and diseased plants, respectively.

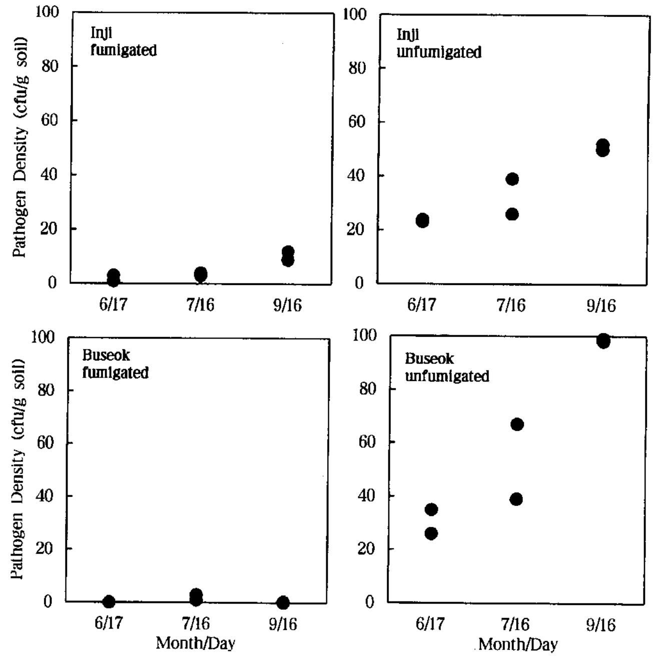

Fig. 6. Change of density of *Pythium myriotylum* in field plots of Inji (upper) and Buseok (bottom) treated with soil fumigation (left) and untreated control (right) in Seosan city, Choongnam province in 1996.

Significant negative linear relationships were found between yield and rhizome rot severity in both experimental fields (Fig. 7). Coefficients of determination (R square) of the relationships when disease severity was used as an independent variable were 0.83 and 0.53 for Buseok and Inji fields, respectively. Regression equation was Y=2099.5-91.1X for Buseok, and Y=1965.5-33.1X for Inji, where Y=yield and X=rhizome rot severity. Goodness of fit of the linear model for Inji field was reduced due mainly to the large variations occurred in yields influenced by germination rate rather than disease severity.

DISCUSSION

In this study, soil disinfection by dazomet fumiga-

Table 1. Effects of soil disinfection, fungicide application, and narrow ridge cultivation on ginger growth and yield in fields at Inji-myon and Buseok-myon in Seosan city, Choongnam province in 1996

Field location	Treatment	Germination rate (%)		Plant height[a] (cm)		Yield (kg/10a)	
		SD[b]	ND	SD	ND	SD	ND
Inji	Ridge	86	96	37	38	543	770
	Fungicide application	75	90	40	1	1,321	1,079
	Untreated check	75	89	41	0	1,406	1,540
	Average	78.6	91.6	39.2	9.5	1,112	1,129
Buseok	Ridge	100	95	37	36	954	329
	Fungicide application	98	98	38	40	1,656	256
	Untreated check	99	86	37	35	1,616	315
	Average	99.1	93.2	37.5	37.0	1,408	299

[a] Plant height was measured on August 17, 1996.
[b] SD : Soil disinfection by fumigation with dazomet, ND : no disinfection.

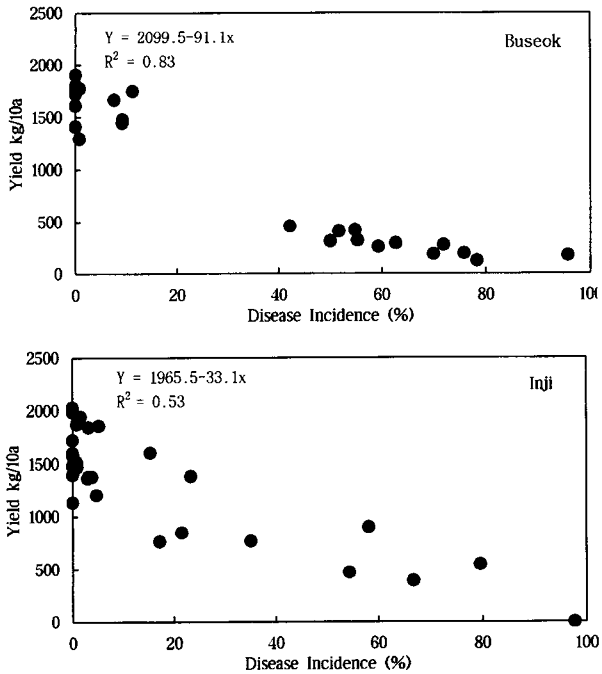

Fig. 7. relationship between rhizome rot incidence and yield of ginger plants in flied plots of Buseok-myon (upper) and Inji-myon (bottom) in Seosan-city, Choongnam province in 1996.

tion was very effective for reducing rhizome rot incidence in ginger fields. However, many problems exist for its practical use, for instances, high cost for soil fumigation, and the complexity of fumigation methods. Accordingly, development of simple and cheap method of soil fumigation has become one of the most urgent tasks. One of other important problems of soil fumigation is that the fumigated fields has to be protected from re-introduction of the pathogen during growth period. This is obviously difficult in practice, and because of this reason, soil fumigation often failed to control the diseases. In addition, influence of soil fumigation on growth of ginger plant and soil microflora, and yield has to be clarified prior to use of soil fumigation as a popularized method of soil disinfection. More researches are needed in these areas.

Soil aeration has to be done sufficiently after soil fumigation. Otherwise, seed germination is damaged by toxic gas residue remained in soil as observed in Inji field plots. Although three times of soil aeration were done in both fields, Inji fields resulted in poor aeration, compared to Buseok. This seemed to be due mainly to the excessive soil water in Inji field plots because of poor drainage at the time of soil fumigation. A germination test with radish seeds after three times of soil aeration revealed poor aeration at Inji, despite seed rhizomes had to be planted for other reasons.

In this study, spatial spread of the disease in the disinfected plots was limited to the area adjacent to initial inoculum focus, and hardly distributed over the whole areas of the plots unlike those in the undisinfected plots even under favorable weather conditions and without fungicide applications. The exact reason for this phenomenon remained unexamined. However, it might occur from changes in microbial population in field soil by fumigation.

In the fumigated plots in Inji field, pathogen population tended to increase as season progressed, whereas it remained low in Buseok field. It is not clear to demonstrate whether the increased pathogen population and subsequent lower disease control effects observed in the fumigated plots in Inji field came from incomplete soil fumigation due to poor aeration or from re-introduction of the pathogen by contamination after fumigation.

Ridge cultivation was found to be effective for reducing rhizome rot incidence. Increased disease control effects by ridge cultivation might come from both good drainage due to ridges and slower spread of the disease due to more space between ginger plants. Although ridge cultivation was effective for reducing disease incidence, ginger yield, however, was too low for practical use because of half planting rate in the same acreage as standard cultivation. Therefore, narrower ridge than used in this study could be considered to increase yield.

Control efficacy of fungicide application was found to be effective in the Inji field where the disease occurred mildly, whereas it was ineffective in Buseok field where the disease occurred very severely. This indicates that three times of foliar applications of metalaxyl as currently recommended might not be sufficient for the control of the disease in severely diseased fields as seen in Buseok. Since rhizome rot is soilborne in nature and infectious period of the disease is rather longer from early July to late September, compared to other diseases, in fields where the disease continued to occur severely until late season, one or two additional fungicide applications might be needed to control late infections.

요 약

생강뿌리썩음병의 발병 진전에 미치는 토양소독, 살균

제 살포, 좁은 이랑재배의 효과를 충남 서산의 두 자연감염 농가포장에서 시험하였다. 토양소독 처리를 주구로, 살균제 살포와 이랑재배 처리를 세구로 하여 분할구배치 3반복으로 시험을 수행하였다. 생강뿌리썩음병은 7월 하순부터 발생하기 시작하여 9월 하순까지 급격히 진전하였으며 최대 발생시기는 8월 중순부터 9월 초순까지의 기간이었다. 다조메 입제 처리에 의한 토양소독은 두 포장 모두 그 방제효과가 탁월하였으며 뿌리썩음병의 발병주율을 한 포장에서는 무처리구의 17.5%에 비하여 4.8%로 그리고 다른 한 포장에서는 51.0% 비해 2.2%로 낮추었다. 생육기 동안 메타실동 살균제의 3~4회 살포에 의하여 한 포장에서는 병 발생이 89.7% 감소한 반면에 다른 한 포장에서는 그 발병 억제효과가 낮았다. 좁은 이랑재배시 병 발생은 무처리에 비하여 양 포장에서 각각 78.1%와 63.9%가 감소하였다. 종강의 발아율과 발아후 생강의 생육정도는 다조메 시용후 가스를 충분히 휘발하지 않아 발아장해를 받은 몇몇 토양소독구를 제외하고는 처리간에 큰 차이가 없었다. 생강 수량은 발병이 극히 적었던 한 시험구를 제외하고는 시험구내 뿌리썩음병의 발병정도와 상관없이 토양소독구에서 가장 많았다. 생강 수량은 병 발생정도와 부의 상관이 있었다. 이랑재배구는 단위면적당 파종량이 비이랑재배구에 비하여 1/2수준이었으므로 생강 수량도 비이랑재배구의 58~59%에 불과하였다. 뿌리썩음병의 공간적 확산형태를 보면 토양소독구에서는 병의 발생이 시험구내 단일 전염원에서 시작되어 생육후기까지 그 근처의 생강에만 극히 제한적으로 발생하는 것에 비하여 무처리구에서는 시험구 전체에 걸쳐 퍼져있는 여러 전염원에서 발생이 시작되어 생육후기까지 극격히 주위로 확산하여 대발생을 초래하였다. 토양소독구의 토양내 *P. myriotylum*의 밀도는 생육기 동안 변화가 없거나 약간 증가하는데 그쳤으나 무처리구에서는 그 밀도가 생육초기에 비하여 3~5배 증가하였다.

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