Influence of Previous Crops on Rhizoctonia Root and Crown Rot of Sugar Beet

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ABSTRACT

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A field study was conducted to determine the effects of previous crops on Rhizoctonia root and crown rot development in the subsequent sugar beet crop. Alfalfa, cotton, sorghum, sunflower, or wheat, grown in monoculture for 2–3 yr, or fallow ground, preceded sugar beets grown in 1987 and 1988. Disease incidence in the sugar beet crop was monitored by bimonthly counts of dead plants in two 7.6-m lengths of row in each plot. At the end of the season in 1987, sugar beets following alfalfa had the highest incidence of disease, losing 47% of the stand to root rot. Sugar beets on sorghum and winter wheat ground followed with 41 and 38% stand losses, respectively. Sugar beets preceded by cotton, fallow, and sunflower all had significantly less disease, with 32, 22, and 21% losses, respectively. In 1988, results were similar. By season's end, sugar beets preceded by wheat, sorghum, or alfalfa had 84, 81, or 48% stand losses, respectively. Cotton, fallow, and sunflower were again best for preceding sugar beets, with 30, 22, and 19% stand losses, respectively. Root yield was negatively correlated ($P = 0.05$) with percent disease, $r = -0.96$ in 1987 and $r = -0.97$ in 1988. In both years, sugar beets grown on previously fallow ground had significantly greater root yields than all other treatments except sunflower. Root yields of sugar beets following winter wheat and sorghum were low. However, in both years percent sucrose was highest in sugar beets following wheat. No significant differences were found when sugar beets followed the other crops either year. Previous crops also affected residual soil NO_3-N. In general, residual soil NO_3-N was lower in alfalfa, sorghum, and winter wheat plots than in cotton, fallow, or sunflower plots, but differences were not always significant. Although previous crops affected yield and root disease development in the subsequent sugar beet crop, many interacting variables, such as disease × yield, NO_3-N × yield, and NO_3-N × disease complicated interpretation of results.

Each year, approximately 15,380 ha of sugar beets (*Beta vulgaris* L.) are grown in the Texas Panhandle. The long growing season and fertile soils provide a favorable environment for sugar beet culture, but the increasing occurrence of root diseases has caused many producers to either reduce or eliminate production of the crop.

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Root diseases primarily responsible for yield loss in the area include Rhizoctonia root and crown rot, Fusarium root rot, and Aphanomyces root rot, caused by *Rhizoctonia solani* Kühn (AC 2-2) (21,23,30), *Fusarium oxysporum* Schlechtend. f. sp. *betae* Snyd. & Hans. (12), and *Aphanomyces cochlioides* Drechs. (19), respectively. Often, all three pathogens are found in the same field; however, each pathogen causes a root disease with distinct diagnostic symptoms. Use of cultivars tolerant to a single pathogen is ineffective in keeping disease loss at an acceptable level. Because of the lack of effective chemical or genetic options for disease control, rotations of 3–5 yr out of sugar beets are a standard practice.

Crops grown during the interval between beets often include combinations of wheat (*Triticum aestivum* L.), corn (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), sunflower (*Helianthus giganteus* L.), alfalfa (*Medicago sativa* L.), cotton (*Gossypium hirsutum* L.), or soybean (*Glycine max* (L.) Merr.). Carrots (*Dacus carota* L.), onions (*Allium cepa* L.), and cabbage (*Brassica oleracea* L.) have also been used. No standardized cropping sequence has been developed, and minimal research addressing the effects of crop rotation on sugar beet disease development in the Texas Panhandle has been conducted.

In 1984, a research project was initiated to determine whether specific crops, typically grown in rotation with sugar beets, affect root rot development in the subsequent sugar beet crop. The large number of crops and possible combinations, however, warranted an unconventional approach. Instead of selecting specific crop combinations and sequences, individual crops were grown in monoculture before sugar beets were planted. The basic assumption was that the crop immediately preceding sugar beets exerted the major influence on the beet crop. Based on this assumption, the objective of this study was to determine how specific crops grown in monoculture for 2–3 yr affect disease development and yield in the subsequent sugar beet crop.

A preliminary report has been published (21).

MATERIALS AND METHODS

Site history. Studies were conducted in a field at the Texas Agricultural Experiment Station, Bushland, in a Pullman clay loam, with approximately 1.2% organic matter and a pH of 6.7. Sugar beets were first grown on the study area in 1973 with no apparent disease. When the next sugar beet crop was planted in 1977, it was watered heavily by furrow and sprinkler irrigation in an attempt to induce Cercospora leaf spot caused by *Cercospora beticola* (Sacc.). Rhizoctonia root and crown rot began to appear in mid-June, and by the end of the season approximately 20% of the crop was lost. Half of the field was planted to sugar beets a third time in 1982. Rhizoctonia crown and root rot was the only major disease that limited yield, and stand losses ranged from 11 to 27%. The other half of the field was planted to sugar beets in 1983, and severe Rhizoctonia root and crown rot and sporadic Fusarium root rot developed. Both areas were fallow without weed growth until rotation crops were first planted in the fall of 1984 (alfalfa and wheat) and spring of 1985 (sorghum, cotton, and sunflowers). Wheat was the primary rotation crop grown on the study area during the 1974–1981 period.

Rotation crops. Wheat, sorghum, cotton, alfalfa, and sunflower were grown in monoculture on 15- × 60-m plots, for 2–3 yr before sugar beets were planted in 1987 and 1988. Three replicate plantings of each crop and three fallow plots were arranged in a randomized complete block design. Crops were not irrigated or fertilized and, with the exception of wheat, were shredded before reaching maturity to reduce volunteer problems the following year. The fallow plots were almost totally weed free. Weed growth in the five rotation crops was minimal.

Sugar beet culture and disease detection. Sugar beet seed, cv. Mono-Hy Tx18, was planted at the rate of 1.7 kg of seed per hectare on half of each 15- × 60-m plot 16 April 1987 (following the 1982 beets) and on the other half 23 March 1988 (following the 1983 beets). The ground in each plot area was bedded on a 76-cm row spacing to provide 40 15-m rows per plot each year. Because of anticipated stand reductions due to root disease, no thinning was done. Soil samples were taken in all plots before planting to determine how previous crops had affected residual soil NO_3-N in the upper 1.2 m of the soil profile. Preplant applications of Phorate (1.1 kg a.i./ha) and Nortron (3.4 kg a.i./ha) were incorporated into the soil for insect and weed control, respectively. Plots were irrigated to promote seedling emergence.

Approximately 4 wk after seedling emergence, four-row subplots, 15 m in length, were marked in each of 4 and 6 main plots, in 1987 and 1988, respectively. Stand counts were made in each subplot. Half of the plots received irrigations every 2 wk and the others every 4–6 wk. The intent of the irrigation treatments was to establish "wet" and "dry" subplots for evaluating moisture effects on disease development.

To record treatment differences in disease development, stand counts were made in the center two rows of each subplot approximately every 2 wk. Plants that exhibited typical foliar symptoms diagnostic of Rhizoctonia root and crown rot (23), Fusarium root rot (12), or Aphanomyces root rot (19,23), were recorded as diseased and were pulled. All sugar beets that were pulled were inspected to verify that observed foliar symptoms were actually a result of root disease. Disease progression data were first analyzed using repeated measures analysis of variance (ANOVA) (11) to determine whether significant treatment × time interactions existed. If the interaction was detected, ANOVA for a randomized complete block design was then used to analyze treatment differences at each date.

At the end of the season, sugar beets in all subplots in each main plot were harvested with a commercial beet digger. Total root yield in kilograms per plot was recorded, and subsamples of representative roots were taken for sugar analysis (24). Differences in yield data and final disease were evaluated using ANOVA, and treatment means for each recorded variable were separated using Duncan's multiple range test.

RESULTS

The effect of previous crop on sugar beet emergence and initial stand was negligible. In 1987, sugar beet stands were slightly higher when following wheat than when following cotton or sorghum. In 1988, no differences were found in emergence or initial stand among treatments. Environmental conditions were favorable for sugar beet root rot development in 1987 and 1988. Although *A. cochlioides, F. oxysporum* f. sp. *betae*, and *R. solani* were all present, *R. solani* was the predominate pathogen and accounted for approximately 90% of all diseased roots. Frequent rains during both growing seasons minimized irrigation treatment differences. In both years, more disease developed in the wet subplots. Usually no irrigation × previous crop interaction existed, and data from all irrigation subplots within a main plot were grouped and analyzed as a single value.

Plants began to die in early June. Disease progression accelerated rapidly through July and began to taper off from mid-August to harvest in late September and early October (Fig. 1). Repeated measures ANOVA showed a highly significant ($P = 0.001$) interaction between time and treatment, indicating that "change in disease over time was not the same for each treatment, i.e., the disease progress curves were not equal" (11). Therefore, ANOVA was used to analyze disease data from each date.

In 1987, treatments for Rhizoctonia root rot differed from June until harvest. Throughout the entire season, sugar beets preceded by alfalfa, sorghum, and wheat had significantly more disease than those preceded by fallow or sunflower. Sugar beets following cotton had significantly less disease than those preceded by alfalfa or sorghum, but not wheat. At the end of the growing season in 1987, beets following alfalfa had the highest incidence of root rot, with a loss of 47%. Beets following sorghum and wheat had 41 and 38% stand losses, respectively. Sugar beets following cotton, fallow, and sunflower all had significantly less root rot, with 32, 22, and 21% losses, respectively. Differences among these three were not significant. In 1988, the rate of sugar beet root rot development was initially faster when beets followed wheat and sorghum, compared with that of beets following fallow, cotton, or sunflower. Sugar beets preceded by wheat and sorghum also had significantly more disease from day 188 through harvest. Beets following alfalfa had significantly less disease than those following wheat or sorghum over the same period, but significantly more than beets following cotton, sunflower, or fallow treatments. At the last stand count in late September, sugar beets preceded by wheat or sorghum had 84 and 81% stand losses, respectively. When beets followed alfalfa, 48% of the sugar beet stand was lost to root rot. Sugar beets following cotton, fallow, and sunflower had 30, 22, and 19% stand losses, respectively.

Root yield in each of the previous-crop treatments was highly and significantly correlated to percent disease, $r = 0.96$ in 1987 and $r = 0.97$ in 1988. All yields were quite low in 1987 because hail and strong winds early in the season greatly reduced stands (Table 1). Growth conditions were better in 1988, but an increase in disease severity, especially in the wheat and sorghum treatments, kept yields low. Sugar beets following alfalfa, cotton, fallow, and sunflower had approximately the same percentage of disease loss both years but higher root yields in 1988 (Table 2).

Residual soil nitrogen also had a relatively high correlation with root yield, $r = 0.83$ and $r = 0.78$ for the two years. In general, as nitrogen increased, yield increased. However, in both years, sugar beets following cotton, which had more residual nitrogen than sunflower, had lower root yields, although the differences were significant only in 1987.

Sucrose percentage, of all the measured variables, was least affected by previous crop. The only consistently significant response was a higher sucrose percentage in beets following wheat. Overall, sucrose percentage was higher in 1987 than in 1988.

DISCUSSION

The effects of previous crop treatments on disease development in this study were dramatic but difficult to interpret. Without question, sugar beets following winter wheat or sorghum always had more disease and lower root yields than sugar beets following either fallow or sunflower. However, numerous interacting factors, other than the direct effect of pathogens on sugar beets, could have given these results. These include, but are not limited to, effects of previous crop on beets, on residual nitrogen, or on pathogens, and nitrogen effects on beets and pathogens.

Crop rotation is a common practice for improving crop production and reducing disease incidence (2,27). Its use for disease management in such diverse crops as cotton (16), wheat (17), corn (27), and potatoes (4) indicates its general effectiveness in controlling a wide variety of foliar and soilborne plant pathogens. Crop rotation has been used in sugar beet culture for years, but the reasons for its use and the specifics of rotation have varied greatly among localities.

Numerous studies have been conducted to determine the best crops to rotate with sugar beet. Many of these have been agronomic in nature and made no mention of disease (5,26,31,32). Alfalfa and other legumes have often been suggested as good rotation crops because of their ability to supply nitrogen to the beet crop. Also, nitrogen distribution in the soil profile is much better for sugar beet production when beets follow deep-rooted crops such as alfalfa (32). Shallow rooting crops, which do little to remove deep NO_3-N, i.e., that below 120 cm, may actually "do more harm than good by removing shallow NO_3-N needed early by sugar beets to produce high root yields while leaving deep NO_3-N for late season uptake detrimental to sugar accumulation" (32). In this study, alfalfa did not add nitrogen to the soil but actually reduced the level of residual NO_3-N. This was not surprising and has been shown before in Pullman clay loam soils (32). In the Texas Panhandle sugar beet growing region, added nitrogen usually increases root yield but often decreases percent sucrose (31). A similar effect of nitrogen has also been shown with manure and fertilizer applications (5). In this study, the same general trend was observed. Previous treatments that resulted in high residual NO_3-N such as fallow, cotton, and sunflower gave comparatively high root yields, whereas growing wheat, sorghum, and alfalfa resulted in less residual nitrogen and lower sugar beet root yields. In addition, sugar beets following wheat had significantly higher sucrose percentages both years of the study. However, sucrose levels cannot be wholly attributed to residual soil NO_3-N because of the presence of root disease. Rush et al (20) showed a strong negative correlation between root rot severity and sucrose content in sugar beet samples and concluded that, in the presence of extensive disease, the severity of root rot related more to sugar content than to residual soil NO_3-N or other environmental or cultural effects.

Relatively few studies involving crop rotation and disease intensity in sugar beets have been conducted. Most have evaluated how specific crops and crop sequences affect Rhizoctonia root rot development (13,18,24). The basic idea has been to include crops that were not hosts to the pathogen, but in this regard, there has been much disagreement. Maxson (13) stated that small grains and corn were nonhosts and that alfalfa was host to *Rhizoctonia*, whereas Ruppel (18) suggested just the opposite. However, Ruppel also stated that, despite the fact that alfalfa appeared to be a nonhost to *Rhizoctonia*, root rot caused by this pathogen was often more severe following alfalfa than following wheat. In our study, more Rhizoctonia root rot occurred following alfalfa than wheat in 1987, but in 1988, more disease occurred when sugar beets followed wheat. Both these treatments resulted in more disease than when sugar beets followed fallow, sunflower, or cotton. No tests were conducted to determine whether the crops used in this study were susceptible to *R. solani*, but no symptoms of disease were apparent on any preceding crop. We agree with Ruppel's statement that "more than pathogen susceptibility must be

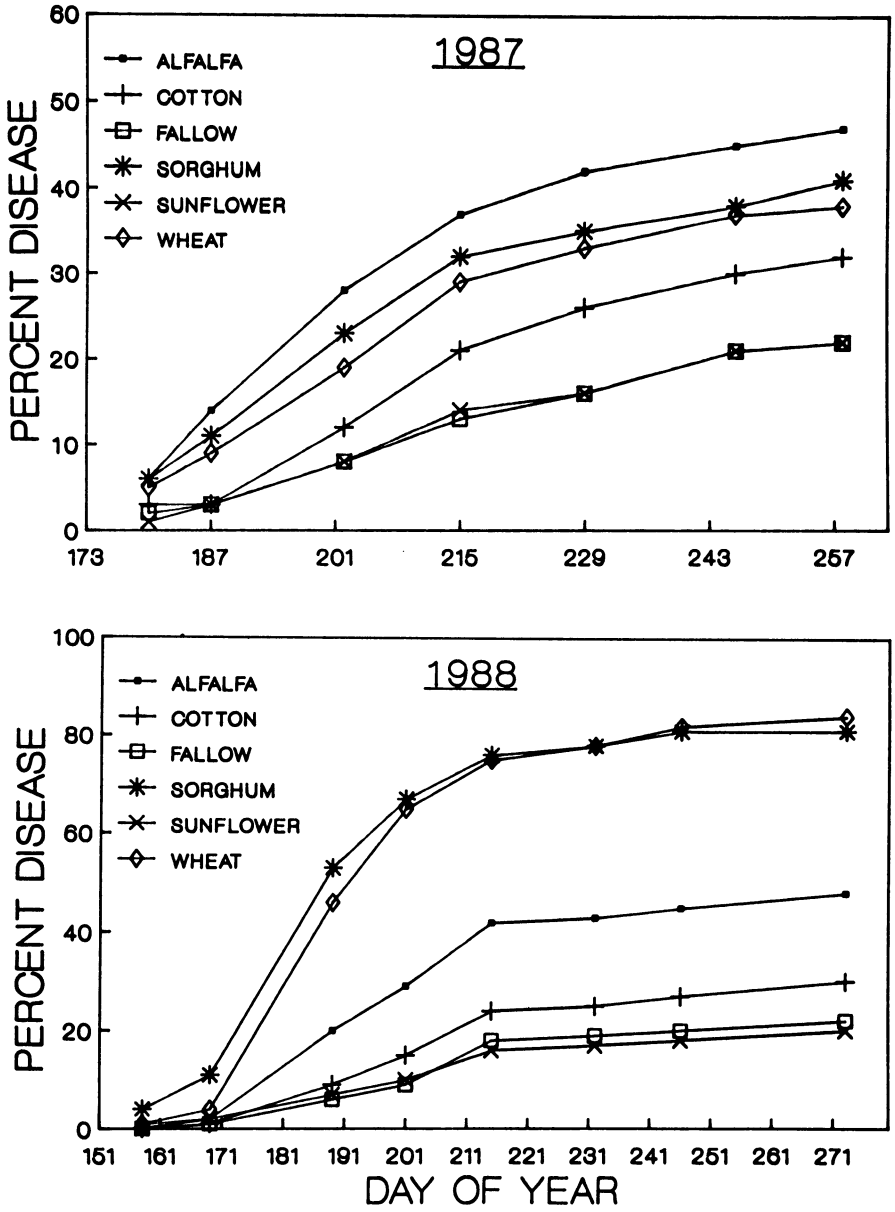

Fig. 1. Progress of Rhizoctonia root rot in 1987 and 1988 sugar beet crops following various crops grown in monoculture.

considered in selecting cropping sequences to control Rhizoctonia root rot in sugar beet" (18).

As an additional point, research results from Colorado, Montana, and North Dakota, with regard to cropping systems and Rhizoctonia root rot, may not be directly applicable to sugar beet culture in the Texas Panhandle. In many of the northern sugar beet growing states, and also in Colorado, *R. solani* does not persist in the soil at high levels from year to year (E. G. Ruppel, *personal communication*). Therefore, sugar beets are often grown every other year without excessive disease loss to Rhizoctonia root rot. However, in the sugar beet growing region of Texas, *R. solani* appears to be endemic, and high levels of Rhizoctonia root rot sometimes occur in first-year sugar beet plantings. In addition, the high levels of Rhizoctonia root rot recorded in this study indicate that the pathogen is capable of surviving relatively long rotations in the absence of sugar beets. These differences between the Texas Panhandle and other sugar beet growing regions help account for the results of this study, which are somewhat contrary to conventional wisdom, with regard to crops best suited for preceding sugar beets.

It is well documented that *R. solani* survives in saprophytically colonized crop residues (8,14,15,22). In this study, the high levels of residue incorporated into the soil in the wheat, sorghum, and alfalfa plots may have resulted in elevated pathogen populations. This could readily explain the increased disease incidence in those treatments. Saprophytic colonization of crop residues has been frequently cited as a means of survival for *R. solani* in the absence of a host crop (8,15). However, elevated populations of *R. solani* surviving in crop residues do not necessarily equate to increased disease severity in the next susceptible crop. Herr (8) found no differences in soil-dilution colony counts, on any of 30 different sampling dates, between "previously diseased areas or apparently healthy areas." He concluded that "initiation of disease patches in sugar beet fields was governed by factors other than inoculum density."

Many soil physical and environmental properties are involved in disease development. Increased residue levels may have affected disease incidence by creating a favorable environment for disease development. The incorporation of high levels of crop residue often results in cooler, wetter soils (28,29). These conditions have been reported to favor Rhizoctonia root rot in several crops (1,14).

A third possible explanation of how residues could affect disease development is by altering the nitrogen status of the soil. When high levels of organic matter are incorporated into a soil, available soil nitrogen is rapidly immobilized by soil microorganisms (3). A beet crop planted into a nitrogen-deficient soil would be less vigorous and more susceptible to infection by *R. solani* than beets growing in soil with adequate nitrogen for optimum growth (25). Although some researchers have indicated that nitrogen form or quantity in the soil can directly affect the pathogenicity or virulence of *Rhizoctonia* (1,9,10), others report that nitrogen has little direct affect on the pathogen (6,7). Hills and Axtell (9) reported that the amount of dry rot canker caused by *R. solani* in naturally infested soils was greater in unfertilized plots. Schuster and Harris (24) also reported that nitrogen fertilizer application decreased crown rot; however, this effect was only observed in short rotations. In two separate studies, Hecker and Ruppel found only minimal nitrogen effects on Rhizoctonia root rot of sugar beet (6,7). They concluded that although root rot may be slightly inhibited by nitrogen applications, the level of disease reduction was practically insignificant (6). They also suggested that there could possibly be nitrogen × genotype interactions under conditions of nitrogen deficiency (7) but that excessive nitrogen fertility would not control Rhizoctonia root rot.

In our study, no nitrogen fertilizer was added to any plots, and large differences in residual soil NO_3-N existed between the treatments. Earlier studies by Winter (31,32) showed that a minimum of 170 kg/ha of residual or fertilizer nitrogen was required for young sugar beets, to avoid early season nitrogen deficiency. In both years of this study, wheat, alfalfa, and sorghum had low levels of residual NO_3-N and high levels of Rhizoctonia root rot. The differences between these three treatments and fallow, sunflower, and cotton, with regard to residual NO_3-N and percent disease, were significant in 1988. Although residual NO_3-N and incidence of Rhizoctonia root rot appear to be strongly correlated, more research is required for verification of this relationship.

The causes for treatment differences in this study are unknown. In both years, sugar beets following fallow and sunflower treatments had low levels of disease, whereas beets preceded by wheat, sorghum, and alfalfa had high levels. Distinct treatment differences such as these are seldom observed in field studies involving cultural practices and soilborne pathogens. However, lack of definite conclusions concerning the reasons for the observed results indicates a need

Table 1. 1987 sugar beet root and sucrose yield, root rot incidence, and residual soil NO_3-N as affected by previous crops[v]

Previous crop[w]	Residual[x] NO_3-N (kg ha^{-1})	Disease[y] (%)	Root yield[z] (kg/plot)	Sucrose (%)
Alfalfa	172 d	47 a	38 e	10.8 bc
Sorghum	376 bc	41 ab	59 d	11.1 bc
Wheat	235 cd	38 ab	70 cd	12.1 a
Cotton	487 ab	32 bc	76 bc	10.9 bc
Fallow	566 a	22 c	104 a	10.7 c
Sunflower	410 abc	21 c	90 ab	11.4 b

[v] In each column, values followed by the same letter are not significantly different according to Duncan's test ($P = 0.05$).
[w] Previous crops were grown in monoculture for 2 yr preceding beets.
[x] Values represent total soluble NO_3-N in the upper 1.2 m of the soil profile.
[y] Values represent mean percent disease incidence due primarily to *Rhizoctonia solani* from 12 two-row subplots, 7.5 m each.
[z] Values represent kilograms of roots harvested from 12 four-row subplots, 15 m each. Two samples were taken from each subplot for sucrose analysis.

Table 2. 1988 sugar beet root and sucrose yield, root rot incidence, and residual soil NO_3-N as affected by previous crops[v]

Previous crop[w]	Residual[x] NO_3-N (kg ha^{-1})	Disease[y] (%)	Root yield[z] (kg/plot)	Sucrose (%)
Alfalfa	221 d	48 a	112 b	10.3 b
Sorghum	359 d	81 a	43 c	10.3 b
Wheat	148 e	84 a	42 c	11.4 a
Cotton	511 b	30 c	117 b	10.1 b
Fallow	718 a	22 cd	141 a	10.0 b
Sunflower	432 c	19 d	124 b	10.4 b

[v] In each column, values followed by the same letter are not significantly different according to Duncan's test ($P = 0.05$).
[w] Previous crops were grown in monoculture for 3 yr preceding the 1988 beet crop.
[x] Values represent total soluble NO_3-N in the upper 1.2 m of the soil profile.
[y] Values represent mean percent disease incidence due primarily to *Rhizoctonia solani* from 18 two-row subplots, 7.5 m each.
[z] Values represent kilograms of roots harvested from 18 four-row subplots, 15 m each. Two samples were taken from each subplot for sucrose analysis.

for additional studies. Profitable areas of investigation might include studies on in situ nitrogen × residue interactions or pathogen population dynamics as affected by type and quantity of crop residues.

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