FERTILITY AND MANAGEMENT PRACTICES TO CONTROL VERTICILLIUM WILT OF THE RUSSET BURBANK POTATO

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Abstract

Management practices for the suppression of Verticillium wilt of Russet Burbank potato include sanitation, use of optimum sprinkler-irrigation practices, soil solarization, and an adequate soil fertility program. Among all cultural factors considered, nitrogen (N) deficiency in potato tissue was most commonly associated with the severity of Verticillium wilt in Russet Burbank potato. Field studies have shown that increased N availability suppresses Verticillium incidence on cv Russet Burbank while having no effect on cv Norgold Russet. Studies from both greenhouse and field show that the colonization of *V. dahliae* in potato stem tissue is suppressed in cv Russet Burbank when the availability of Phosphorous (P) is increased to the optimum. Following one season of cropping with Russet Burbank potato, the treatment providing the optimal N availability also suppressed the increases of *V. dahliae* populations in the soil during the following year of consecutive cropping. Similarly, after two seasons of continuous potato cropping, treatments with optimal P had lower soil populations of *V. dahliae* in soil. Results show the suppression of Verticillium wilt with optimal fertility.

Verticillium wilt [caused by either *Verticillium dahliae* Kleb. (microsclerotial form) or *Verticillium albo-atrum* Reinke and Berthold (dark mycelial form)] is one of the most severe diseases of potato in the United States. Potato yields, tuber size, and specific gravity may be substantially reduced by this disease, depending on severity, time of occurrence, and growing season.

In Idaho and other arid growing regions of the United States, Verticillium wilt is caused by *Verticillium dahliae* Kleb. Idaho field studies involving cropping practices, soil fumigation treatments, solarization, and Verticillium-resistant potato clones all support the importance of *V. dahliae* upon potato yield. Data from these studies show that yield losses due to *V. dahliae* commonly approximate 5 to 12 metric T/ha (5, 6). Table 1 illustrates the effect of several cropping practices upon relative *V. dahliae* populations in soil with the effects upon both disease severity and potato yield. With continuous cropping of Russet Burbank, *V. dahliae* populations in soil

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TABLE 1.—*The effect of cropping practices upon soil-borne* V. dahliae *inoculum, Verticillium wilt incidence, and 1988 yields for Russet Burbank (cropped over all sites).*

Cropping histories of preceding 5 years 1983-1987	*V. dahliae* cfu/g soil 24 May	Wilt incidence in stems upper 15 cm 10 Aug	severe[1] 17 Aug	Yield metric T/ha Total	U.S.#1 113-284 g	Smooth >284 g
Russet Burbank	55 A[3]	67.0 A[3,4]	79.5 A[3,4]	24.8 A[3]	9.2 A[3]	1.7 A[3]
A66107-51[2]	23 B	29.0 C	44.5 B	28.1 A	9.3 A	2.2 A
Corn	6 C	12.0 D	13.0 C	42.8 B	20.1 B	10.0 B
Fallow	4 C	40.0 B	31.5 B	43.6 B	22.9 B	7.5 B

[1]Plants dead or nearly dead.
[2]Potato clone.
[3]Different letters denote significant differences to 0.05 P level.
[4]Analyses of variance based upon arcsin $\sqrt{\%}$ transformation values.

increased, and yields were reduced by 18 to 19 metric T/ha when compared to locations that had been allowed to remain either weed-free and fallow or where corn had been previously cropped. It was estimated that *V. dahliae* was influencing yield by about 10 to 12 metric T/ha based on a regression analysis of yield as a function of *V. dahliae* populations in soil. Similarly, when *V. dahliae* was suppressed by fumigation treatments involving mixtures of dichloropropene and picfume, yields more significantly increased by 6.5 to 12 metric T/ha (5). Although many factors may influence yields, clones with higher Verticillium resistance than Russet Burbank generally out-yield Russet Burbank. Figure 1 demonstrates the effect of solarization (a technique involving the laying of clear plastic on soil for the purpose of elevating soil temperatures to kill *V. dahliae*). When Verticillium was controlled in this manner (10), there was no significant yield difference between the Russet Burbank potato and the highly resistant A68113-4 clone. The A68113-4 clone grown in non-solarized soil out-yielded the Russet Burbank in non-solarized soil by 31 percent while the solarization treatment significantly increased yield for the Russet Burbank and A68113-4 clones by 46 and 18 percent, respectively. These yield responses were observed in a field where inoculum levels of *V. dahliae* were relatively low ($\sim$10 cfu/gm of soil). With these losses, the need to develop control procedures is great and to achieve this control the need also exists to accurately evaluate the effect of treatments upon *V. dahliae*. Our Idaho studies have routinely utilized such a procedure (9) in combination with comparisons of both disease severity and yield.

Compendio

Las prácticas de manejo para la eliminación de la marchitez por Verticillium de la papa Russet Burbank incluyen actividades sanitarias, uso

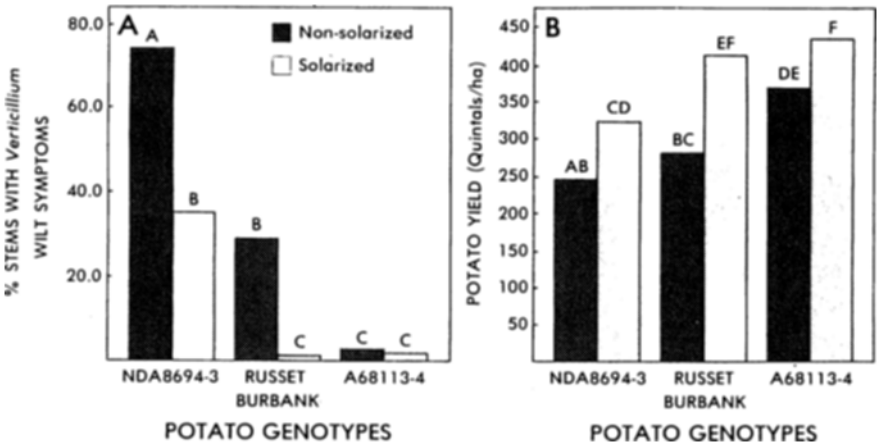

FIG. 1. (A) Differential suppression of Verticillium wilt following soil solarization by potato genotypes of differing resistance to *Verticillium dahliae* (NDA 8694-3 [Very susceptible], Russet Burbank [moderately resistant], A68113-4 [highly resistant]) (B) Differential yield responses of potato genotypes to solarization treatment. Different letters over bars denote significant differences at P=0.05 (adapted from Davis and Sorensen [10]).

de métodos óptimos de irrigación por aspersión, solarización del suelo, y un programa adecuado de fertilización. Se encontró que entre todos los factores culturales considerados, la deficiencia de nitrógeno (N) en los tejidos de la papa Russet Burbank estaba más comunmente asociada con la severidad de la enfermedad. Los estudios de campo han mostrado que un incremento de N elimina la incidencia del Verticillium sobre el cultivar Russet Burbank mientras que no tiene ningún efecto sobre el cultivar Norgold Russet. Estudios tanto de invernadero como de campo muestran que es posible eliminar la colonización de los tejidos de los tallos del cultivar Russet Burbank por *V. dahliae* cuando se incrementa fósforo (P) en cantidades óptimas. Después de una temporada de cultivo con papa Russet Burbank, el tratamiento que provee el óptimo de N eliminó también en el suelo los incrementos de las poblaciones de *V. dahliae* durante el siguiente año de cultivo consecutivo. Similarmente, después de dos temporadas de cultivo contínuo de papa, los tratamientos con cantidades óptimas de P tuvieron poblaciones más bajas de *V. dahliae* en el suelo. Los resultados muestran la eliminación de la marchitez por Verticillium cuando se optimiza la fertilidad del suelo.

Sanitation

Verticillium wilt is considered to be a single cycle disease because the pathogen usually fails to produce inoculum that is effective in the same year (20). Therefore, control measures that reduce the amount of initial inocu-

lum should effectively suppress this disease. The burning of potato vines (12) may be of value as a first line of defense against the increase of *V. dahliae* by delaying the buildup of soil-borne inoculum. Also, the use of Verticillium-free-seed may reduce the rate of inoculum increase. This is particularly true on "new" potato land and land that has been recently fumigated with an effective fungicide (*e.g.*, chloropicrin, metham-sodium).

Rotation

After several potato crops, the level of soil-borne inoculum is generally sufficient to cause severe wilt. This inoculum is long-lasting in soil. Even after allowing land to remain weed-free and fallow for five years, *V. dahliae* inoculum levels have not been shown to be significantly reduced (unpublished data). In "old" potato ground, the short rotation practices commonly used (two to three years) are ineffective in reducing inoculum levels (5). When land cropped for eight consecutive years with potatoes was compared with cropping treatments involving rotations including either corn or barley for two consecutive years between potato crops during the same eight-year period, the soil-borne *V. dahliae* populations were not significantly different (8). Similarly, Huisman and Ashworth (16) showed that rotations that included non-host crops had little effect on *V. dahliae* populations. The longevity of *V. dahliae* microsclerotia, and its wide host range, including many weed species severely diminishes the effectiveness of crop rotation in controlling this disease.

In contrast, crop rotation for suppression of *V. albo-atrum* has been effective. In England, where infested hop gardens were rotated to grass for a minimum of two years before being replanted with hops, *V. albo-atrum* was suppressed (21). Conceivably, the limited persistence of the resting hyphae of *V. albo-atrum* is a major factor in the reduction of inoculum by this method.

Disease Resistance

Due to the expense of soil fumigation and the limited success of crop rotation, resistance has been the traditional means for controlling Verticillium wilt diseases. A considerable portion of potato breeding efforts throughout the world has been directed towards the development of potato clones with high degrees of resistance. From these efforts a collection of germplasm has been obtained with genes for *V. dahliae* resistance. Extensive testing of these clones shows that true resistance to colonization of stem tissue by *V. dahliae* has been combined with desirable characteristics of vine and tuber that are similar to those of Russet Burbank. Among clones that have been found to possess a high degree of resistance are A66107-51(-51) and A68113-4 (-4). The rate of maturity (defined by vine growth/tuberization ratios) of

these two clones is similar to that of Russet Burbank (4) which results in a high yield potential with the resistance to Verticillium.

Although Russet Burbank lacks the high degree of Verticillium resistance as the -51 and -4 clones, it does possess a moderate degree of resistance. It is this resistance that very likely accounts for much of the success of Russet Burbank when grown under favorable cultural practices.

Although the genetics of Verticillium wilt resistance in potato has not been determined, it is believed to be polygenic (13). With this resistance, environmental factors may play a significant role (3). Thus, a manipulation of cultural practices may support the inherent, existing genetic resistance to Verticillium.

Verticillium Suppression in Russet Burbank Through Cultural Management

Several cultural factors influence the degree of colonization by *V. dahliae* in potato stems, but these cultural relationships may not necessarily be the same in every region and every year. Our studies in eastern Idaho, 1976, (7) showed the relationship of several cultural factors [electrical conductivity (mmhos/cm) of soil, NO_3-N, K and P in petioles] to account for 71% of the field variability related to colonization of *V. dahliae* in potato stem-tissue.

Studies (7) have also shown that Verticillium wilt is favored by furrow irrigation, when compared with sprinkler irrigation. These observations agree with previous reports (14, 18). Subirrigation has also been associated with Verticillium wilt of potato. In the Egin Bench area of Idaho, subirrigated fields had more Verticillium wilt than sprinkler irrigated fields.

As the season progresses (particularly beyond the "flowering stage"), the influence of moisture stress upon Verticillium-like symptoms may become pronounced (5) while early in the season (prior to flowering) this effect may not be evident (Table 2). Severe moisture stress (when moisture

TABLE 2.—*Effect of moisture stress on Verticillium wilt in Russet Burbank.*

Irrigation Treatment[1]	% Stems with Wilt[2] August 29
Normal irrigation	6.5 AB[3]
WP June 26-30[4]	1.5 A
WP July 21-25[4]	22.5 BC
WP Aug. 15-19[4]	43.5 C

[1]Sprinkler irrigated. Plots were maintained between 60 to 100% available soil moisture throughout the season. On dates indicated moisture was depleted to wilting point (WP).
[2]Percentage of stems showing symptoms typical of severe *V. dahliae* wilt (severe wilt = >75% of stem with severe wilt symptoms.). Wilt was related to presence of *V. dahliae* in stems.
[3]Different letters denote differences to .05P level (adapted from Davis [5]).

was reduced to wilting point for several days) early in the season appears to stunt growth, delay plant maturity, and suppress the degree of wilt.

Although the explanation for relationships between Verticillium wilt and methods of irrigation is not known, a relationship with N availability and distribution has been suggested (5). With furrow irrigation, N often accumulates within the upper 5.0 - 7.5 cm of the potato hill. In contrast, N will be more uniformly distributed throughout the soil with sprinkler irrigation. When N is less available to the plants' root systems because of leaching and poor distribution, disease incidence and severity may increase.

Pennypacker (19) states that much of the research into the effect of soil fertility on resistance to Verticillium wilt has been concentrated on the major elements (N, P and K). Among plant nutrients, nitrogen most commonly had the greatest effect upon the host-pathogen system.

Among all cultural factors considered, N availability has been most commonly associated with the severity of Verticillium wilt of potato in Idaho (6, 7). As the N availability increases, colonization of plant tissue by *V. dahliae* decreases. Verticillium wilt in Russet Burbank has been found to be most severe when N is deficient. As N availability approaches the optimum for highest yield, disease severity in Russet Burbank is generally less.

In contrast, this inverse relationship between available N and severity of Verticillium wilt has not been found with the Norgold Russet, which has a more determinant growth habit than Russet Burbank. These observations show a genotypic relationship associated with N response. Figure 2 illustrates the effect of several preplant nitrogen application rates on wilt incidence for both cv Russet Burbank and Norgold, respectively.

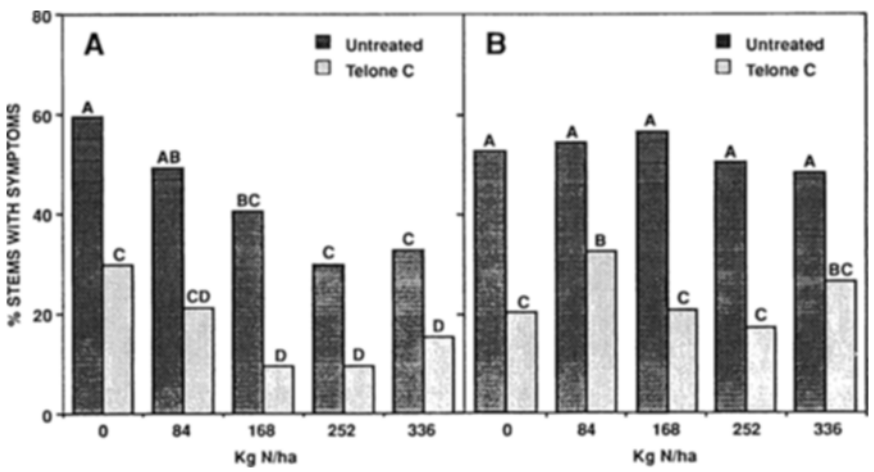

FIG. 2. Differential suppression of Verticillium wilt with Telone C soil fumigation (74% 1, 3-dichloropropene plus 17% chloropicrin applied at 296 L/ha) and nitrogen (side-dressed as NH_4NO_3) treatments in potato cultivars (A) Russet Burbank and (B) Norgold Russet. Different letters over bars denote significant differences at P=0.05 (adapted from Davis and Everson [7]).

Our field studies have also demonstrated significant effects of P levels upon disease suppression. As P concentrations in the soil increased to the optimum, the colonization of *V. dahliae* in potato stem-tissue decreased (Fig. 3). Similarly, our field and greenhouse studies (unpublished) also show that the incidence of Verticillium wilt is suppressed when P deficiencies are corrected.

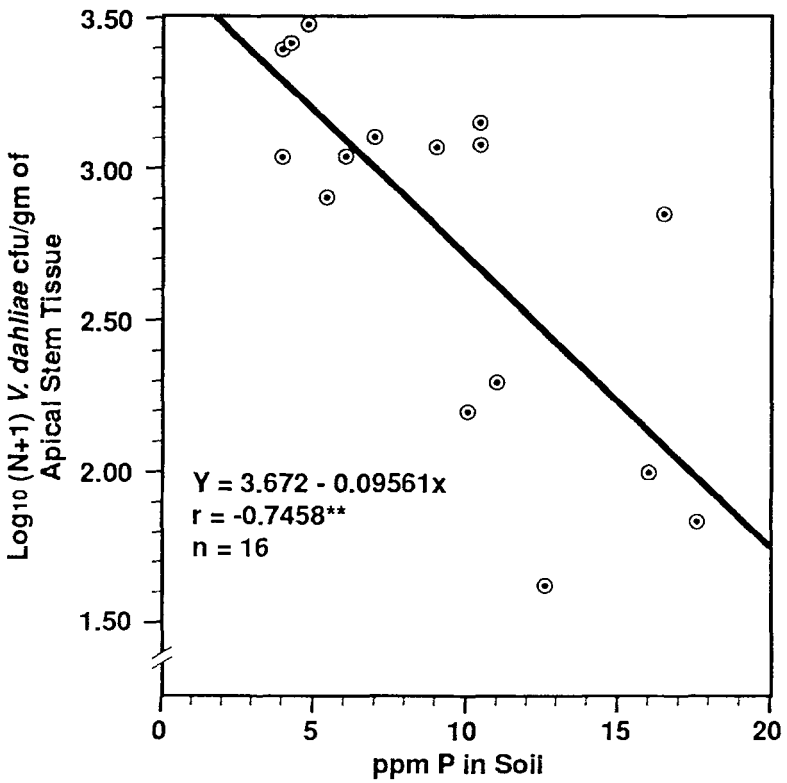

FIG. 3. Relationship of P in soil to *Verticillium dahliae* colonization in Russet Burbank stems (P concentrations determined in spring prior to planting and stems collected for *V. dahliae* colonizations at season-end in late August).

The effects of K on Verticillium have not been documented for potato. However, the effects of K upon Verticillium wilt have been reported for other crops. Marschner (17) reports the effect of K on resistance to Verticillium to be evident when the element is deficient in the soil. Hafez *et. al.* (15), noted that the addition of K to deficient soils not only reduced the incidence of wilt in cotton, but also decreased symptom severity. Similarly, Ashworth, *et. al.*, showed a similar relationship to Verticillium wilt of pistachio trees (1, 2).

The Effect of Optimal N and P on Wilt Suppression

Recent studies point to the importance of nutritional interactions upon Verticillium wilt of potato (11). An investigation involving three years of continuous cropping from 1984 to 1986 illustrates the importance of both N and P for the suppression of *V. dahliae* in both stem tissue and soil.

After one season of cropping (1985), the N treatment providing the best N nutrition (240 kg N/ha, split-applied) had significantly lower *V. dahliae* counts in soil than treatments providing less late-season N availability (0 kg N/ha and 240 kg/ha preplant) (Figure 4). Similarly, after two seasons of continuous cropping, treatments with higher P (120 to 240 kg/ha) had lower *V. dahliae* populations in soil compared to the treatment with no added P (6ppm of residual P in upper 30 cm of soil profile) (Figure 5). Although the explanation for these results is not known, it may be related to the influence of nutrients available to the host. Since infected stem-residue is the primary source for increases in soil-borne *V. dahliae*, soil-borne inoculum may be decreased with reduced colonization of the stems.

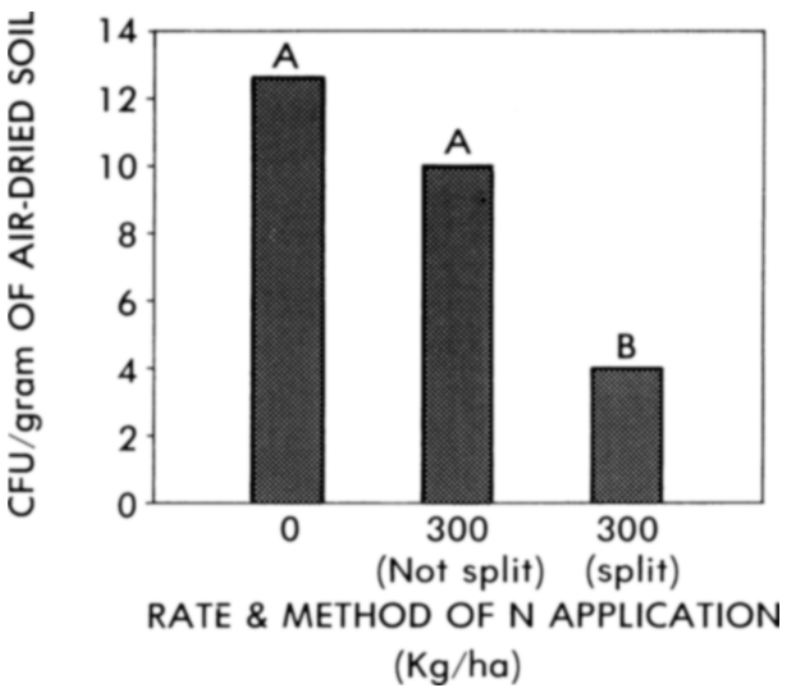

FIG. 4. Influence of N treatments on cfu of *Verticillium dahliae* in soil after one season of cropping (1985). The N treatment providing the best N availability late in season (300 kg N/ha, split applied) shows less soil-borne *V. dahliae* than treatments with less late-season N availability (0 kg N/ha and 300 kg/ha preplant). Different letters over bars denote significant differences at P=0.05 (soil collected in spring prior to planting in second year of continuous cropping).

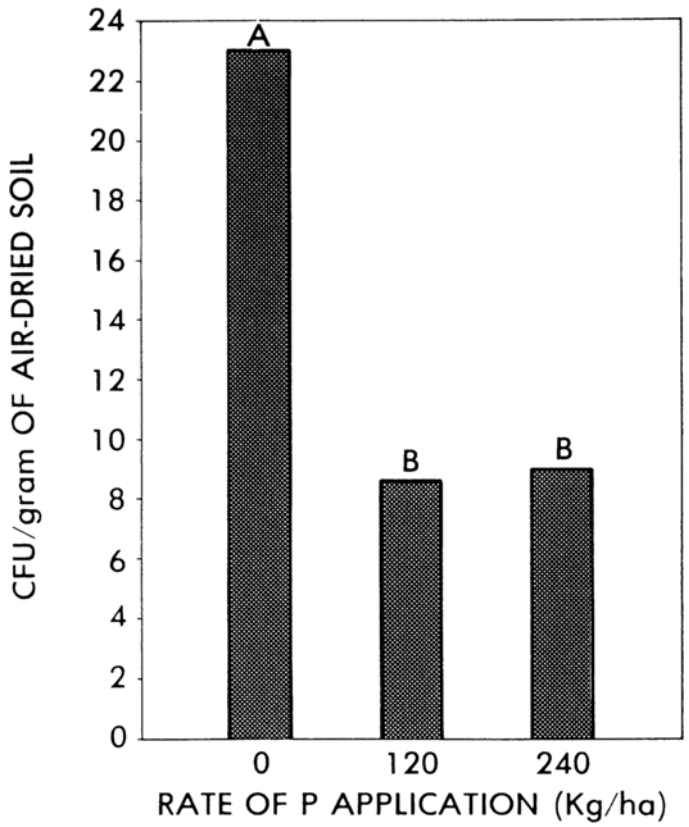

FIG. 5. Influence of P treatments on cfu of *Verticillium dahliae* in soil after two seasons of continuous cropping. Different letters over bars denote significant differences at P = 0.05 (soil sampled in spring prior to planting in third year of continuous cropping).

Table 3 shows the relationship of N and P fertilizer management to *V. dahliae* colonization in potato stem tissue. These results show a trend toward reduced *V. dahliae* colonization with improved N and P management. Yields were found to be consistently higher with the higher N and P treatments and with the split-application of N treatments.

Discussion

This paper emphasizes the importance of cultural management practices on the Verticillium wilt disease of the Russet Burbank potato. The use of optimal soil fertility combined with sprinkler irrigations may currently provide one of the most viable solutions to the management of this disease.

TABLE 3.—*The relation of N and P to* Verticillium dahliae *colonization in Russet Burbank stem tissue. (Aberdeen 18 Aug 1986).*

N kg/ha	Log (x+1) *V. dahliae* cfu/gm of apical stem tissue P(kg/ha) P_0	P_{120}	P_{240}	Means[1] Nitrogen
N_0	2.326	2.502	2.500	2.442
N_{240} (preplant)	2.236	2.438	1.257	1.977
N_{240} (split applied)	2.457	1.777	1.064	1.766
Means Phosphorus[2]	2.340	2.239	1.607	

[1]LSD between N means = 0.486 (P=0.05).
[2]LSD between P means = 0.361 (P=0.05) and 0.547 (P=0.01) (adapted from Davis *et. al.* [11]).

Although rotation practices are largely ineffective for the suppression of *V. dahliae*, the use of green manures and some soil amendments may provide fertile areas for future research. There is relatively little knowledge on the effects of these practices upon the ecology of soil-borne pathogens, including *Verticillium* spp. There also is little information about the effects of cropping practices upon nutrient availability as related to pathogenic expression. These relationships should be intensively investigated.

As the options for pesticide and fumigant use are withdrawn, we shall become increasingly dependent upon the use of non-pesticide methods for control of Verticillium wilt of potato. In addition to resistant varieties and solarization, the use of improved crop management practices should provide hope for the future.

Acknowledgments

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