Influence of Soil Moisture on Root Rot and Wilt of Chickpea

M. A. BHATTI, Department of Plant Pathology, Washington State University, Pullman 99164, and JOHN M. KRAFT, Supervisory Research Plant Pathologist, Vegetable and Forage Crops Production, Agricultural Research Service, U.S. Department of Agriculture, Rt. 2, Box 2953A, Prosser, WA 99350

ABSTRACT

Bhatti, M. A., and Kraft, J. M. 1992. Influence of soil moisture on root rot and wilt of chickpea. Plant Dis. 76:1259-1262.

This study was conducted to determine the effects of soil moisture on wilt and root rot of chickpea (*Cicer arietinum*), caused by *Fusarium oxysporum* f. sp. *ciceri, F. solani* f. sp. *pisi, Pythium ultimum*, and *Thielaviopsis basicola*. Three soil matric potential regimes (high = −40 to −20 kPa, medium = −260 to −40 kPa, low = −1,060 to −260 kPa) were used. Wilt and root rot increased with decreased soil matric potential, as did rhizosphere populations of each pathogen when present in soil alone or in various pathogen combinations. Chickpeas grown in soil infested with equal inoculum densities of two pathogens usually had as much or more disease as plants grown in soil infested with a single pathogen. However, wilt severity was significantly less when plants were grown in soil infested with *F. o. ciceri* and *P. ultimum* than with either pathogen alone. Rhizosphere populations of *F. o. ciceri* were higher than populations of other pathogens at the conclusion of each test.

Several soilborne fungal pathogens cause root rot and wilt of chickpea (*Cicer arietinum* L.) and may seriously limit production (23). In the United States, chickpea wilt, caused by *Fusarium oxysporum* Schlechtend.:Fr. f. sp. *ciceri* (Padwick) Matuo & K. Sato, and root rot, caused by *Fusarium solani* (Mart.) Sacc. f. sp. *pisi* (F. R. Jones) W. C. Snyder & H. N. Hans., *Pythium ultimum* Trow, and *Thielaviopsis basicola* (Berk. & Broome) Ferraris (=*Chalara elegans* Nag Raj & Kendrick) are reported to cause serious problems in chickpea production (3,4,14,16,29,30). Root rot and wilt of chickpea has also been reported in India and Spain (12,22, 23,28). With the exception of *F. o. ciceri*, the other root pathogens listed above are also important pathogens of peas (*Pisum sativum* L.).

Chickpeas are now being grown in the Pacific Northwest of United States in the same areas where root diseases of peas have become severe. Average annual rainfall in this area is 45–70 cm, and soil moisture can often be limiting or excessive during the growing season. Previous research has demonstrated that the combined effects of *P. ultimum* and *F. solani* f. sp. *pisi* on pea root rot severity were additive at any soil moisture and temperature tested (5,18). However, there are no reports on the effects of soil moisture on chickpea plants exposed to combinations of wilt and root rot fungi.

The present study was undertaken to determine the effects of soil matric potential on the severity of wilt and root rot of chickpeas grown in soil infested with each pathogen alone or in combination with other pathogens.

MATERIALS AND METHODS

The isolate of *F. o. ciceri* was obtained from W. J. Kaiser, USDA-ARS, Washington State University, Pullman. The isolates of *F. s. pisi, P. ultimum*, and *T. basicola* were available in our laboratory. All isolates were pathogenic on chickpea and were maintained in soil tubes stored in the refrigerator at 4 C (27).

A Moxee silt loam soil (39% sand, 57% silt, and 3.6% clay) with a pH of 6.9, which had been passed through a screen, air-dried, and stored at room temperature, was used for this study. Because *Rhizoctonia solani* Kühn was detected in this soil, it was autoclaved at 121 C for 6 hr before use. The moisture-characteristic curve of this soil was determined by the pressure-membrane procedure (25) and is presented in Figure 1. Matric potentials were determined by using the moisture curve and relating percentage of moisture (determined by gravimetric analysis) to water potential (11).

Separate batches of soil were individually infested with *F. o. ciceri, F. s. pisi*, and *T. basicola* at an inoculum rate of 2,000 propagules per gram of soil and with *P. ultimum* at 200 propagules per gram according to procedures previously described (17). Each pathogen-infested soil was mixed proportionately to obtain test soils with the four pathogens in all possible combinations and with equal number of pathogen propagules. For example, the combination of *F. o. ciceri, F. s. pisi*, and *T. basicola* had approximately 666 propagules of each pathogen per gram of soil. Pathogen-free soil was used for the uninoculated control.

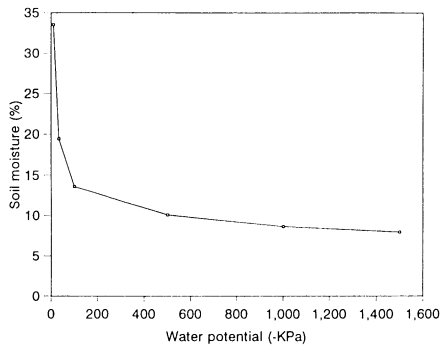

Fig. 1. Moisture characteristics of Moxee test soil as determined by the pressure-plate procedure (28).

Cooperative investigations of the ARS, USDA, and the Washington State University Agricultural Research Center, Prosser. Plant Pathology PPNS 0098, College of Agriculture and Home Economics Research Center, Washington State University, Pullman 99164.

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products that may also be suitable. This article reports the results of research only.

Accepted for publication 28 July 1992.

About 650 g of each test soil was placed in plastic pots 11.4 cm in diameter. Five surface-disinfested seeds (soaked in 0.1% sodium hypochlorite for 1 min) of the chickpea cultivar JG-62 were planted in each of three replicate pots. An additional replication of each treatment was used for estimation of plant weight for maintenance and adjustment of each soil matric potential. Filtered water (0.45 $\nu\mu$) was added to all pots to adjust the soil matric potential to −260, −40, and −20 kPa. Clay saucers were placed under each pot to retain excess water. The weight of soil plus plastic pot at each matric potential was recorded for each replication per treatment. Pots were weighed daily with filtered water to maintain the average ranges of soil matric potentials (high = −40 to −20 kPa, medium = −260 to −40 kPa, and low = −1,060 to −260 kPa) by bringing the pot to original weight and matric potential plus estimated plant weight. Plants from an additional replication were dug every fourth day to estimate plant weight in each treatment.

The experiment was run twice with three replications per treatment, using a split plot experimental design with fungal pathogens as whole plot and soil matric potential as subplot. These experiments were conducted under greenhouse conditions with natural sunlight and a temperature range of 22–25 ± 3 C. At 30 days after planting, each experiment was harvested, roots were removed carefully, and rhizosphere soil was collected from each root system (17,18), which was stored at 4 C until used for dilutions. Roots were washed, and fresh weights of roots and tops were determined. Plants were scored for wilt and root rot severity. Severity of wilt and root rot was determined for individual plants when harvested at 30 days after planting. Wilt and root rot severity was determined by using a 1–9 scale: odd numbers 1 = a healthy plant; 3 = very few wilted leaves or light discoloration of roots, with no more than 10% of root system covered with necrotic lesions; 5 = approximately 20% of leaves and branches wilted or 25% of the root and hypocotyl with lesions, tissues are firm; 7 = approximately 50% of leaves and branches wilted, with chlorosis and stunted plants, or approximately 50% of root system and hypocotyl with lesions, with roots softened and reduced in number; and 9 = severe stunting and wilting, often resulting in death or severe root and hypocotyl decay, and severe root reduction, resulting in death of plant. Even numbers (2, 4, 6, and 8) were assigned to plants whose symptoms were between two odd-number rating scales. Reisolation of the fungal pathogens from seedlings was done on relative selective media (19,21,26).

Populations of fungal pathogens in rhizosphere soil were determined by using selective media for the genus *Fusarium* (21) and for *P. ultimum* (19) and *T. basicola* (26). Hartley's test of homogeneity of variances (10) was performed to determine whether the results of two experiments could be combined. A split plot analysis was then performed with the MSTAT statistical package (20).

RESULTS

Because variances of the two experiments were homogeneous according to Hartley's test of homogeneity of variances (10), the results of the two experiments were combined. Plants grown in pathogen-free soil were significantly taller and had greater root and shoot weights at the low and medium soil matric potentials than at the high matric potentials. Chickpea biomass was significantly reduced, because of the presence of wilt and root rot pathogens alone or in combination (Table 1).

The interaction between pathogens and soil matric potential was significant ($P = 0.05$). Chickpea plants grown in soil infested with one or more root rot pathogens and maintained at the low soil matric potential generally had higher disease scores than those exposed to the high soil matric potential (Table 2). *F. s. pisi* caused the most severe root rot at the low soil matric potential. Necrotic lesions above the soil line caused by *F. s. pisi* appeared about 10 days earlier than disease symptoms caused by any other pathogen or combination of pathogens.

Chickpea plants grown in soil infested with a combination of *F. s. pisi* and *T. basicola* had more root disease than when grown in soil infested with either pathogen alone at the medium or high soil matric potential ranges. However, at the low soil matric potential, disease severity caused by *F. s. pisi* alone or in combination with *T. basicola* was not statistically different ($P > 0.05$). Plants grown in soil infested with a combination of *F. s. pisi* and *P. ultimum* exhibited significantly ($P = 0.05$) more root rot than plants grown in soil infested with *P. ultimum* alone at all moisture regimes (Table 2). However, plants grown in soil infested with the combination of *F. s. pisi* and *P. ultimum* did not exhibit more root rot at the medium and high matric potentials than plants grown in soil infested with *F. s. pisi* alone.

Plants grown in soil infested with a mixture of *F. s. pisi* and *F. o. ciceri* were more diseased at the medium soil matric potential range than those grown in soil infested with either pathogen alone (Table 2). Plants were less diseased and had greater root and shoot weight when grown in soil infested with *F. o. ciceri* and *P. ultimum* than when grown in soil infested only with *F. o. ciceri* at all soil water potentials (Table 2).

Chickpea plants grown in soil infested with a combination of *F. oxysporum, F. solani*, and *T. basicola* were more diseased than those grown in soil infested only with *F. oxysporum* at all soil water matric potentials (Table 2). Plants grown in soil infested with a combination of all four fungal pathogens exhibited severe wilt and root rot symptoms at all soil water potentials. Increased disease severity was accompanied by reduced root and shoot weight (Table 1).

Pathogen populations increased in the rhizosphere as the soil matric potential decreased (Fig. 2). *F. o. ciceri* increased more in rhizosphere than any other

Table 1. Effect of wilt and root rot pathogens, alone and in combination, on root and shoot weights[x] of chickpeas (cv. JG-62) grown in soil of different matric potentials

	Root weight (g)			Shoot weight (g)		
	Soil matric potential (−kPa)			Soil matric potential (−kPa)		
Pathogen(s)[y]	40–20	260–40	1,060–260	40–20	260–40	1,060–260
FOC	1.6 d[z]	1.4 e	0.9 h	1.3 e–h	1.0 hij	0.8 ijk
FSP	0.4 lm	0.9 h	0.5 kl	0.5 k	1.3 e–h	0.6 jk
PU	1.7 d	2.0 c	1.3 ef	1.5 d–g	1.8 bcd	1.2 f–i
TB	0.5 kl	0.7 ij	0.8 hi	1.8 bcd	1.9 bcd	1.2 f–i
FOC + FSP	0.7 ij	0.9 h	0.9 h	1.9 bcd	1.7 b–e	1.3 e–h
FOC + TB	0.8 hi	0.9 h	0.8 hi	1.8 bcd	1.6 c–f	1.1 ghi
FOC + PU	2.3 b	1.7 d	1.1 g	2.0 bc	2.1 b	1.2 f–i
FSP + PU	1.9 c	1.3 ef	0.9 h	2.0 bc	2.0 bc	1.1 ghi
PU + TB	0.7 ij	0.9 h	0.9 h	1.7 b–e	1.9 bcd	1.2 f–i
FSP + TB	0.3 m	0.4 lm	0.6 jk	0.6 jk	0.9 h–k	1.0 hij
FOC + TB + PU	0.8 hi	0.9 h	0.8 hi	1.5 d–g	1.5 d–g	0.9 h–k
FOC + FSP + TB	0.4 lm	0.9 h	0.9 h	1.6 c–f	1.9 bcd	1.3 e–h
FOC + FSP + TB	1.4 e	1.2 fg	0.8 hi	1.9 bcd	1.5 d–g	1.2 f–i
FSP + PU + TB	0.7 ij	0.7 ij	0.7 ij	1.6 c–f	1.5 d–g	0.9 h–k
FOC + FSP + TB + PU	0.8 hi	0.7 ij	0.8 hi	1.7 b–e	1.6 c–f	1.2 f–i
Control	2.8 a	2.2 b	1.3 ef	3.3 a	3.0 a	1.5 d–g
		LSD = 0.102			LSD = 0.409	

[x]Data is an average of two experiments, three replications per experiment, and five plants per replication.

[y]FOC = *Fusarium oxysporum* f. sp. *ciceri*, FSP = *F. solani* f. sp. *pisi*, PU = *Pythium ultimum*, and TB = *Thielaviopsis basicola*.

[z]Means within rows and columns followed by same letter are not significantly different, according to Fisher's protected LSD test ($P = 0.05$).

pathogen or combination of root rot pathogens at all soil matric potentials. The rhizosphere populations of both *Fusarium* species increased when *T. basicola* was also present. The disease severity rating was also high with these combinations. Rhizosphere population of *F. solani* and *T. basicola* was similar at low and medium matric potential. However, the population of *T. basicola* dropped drastically (93%) at high soil matric potential, whereas *F. solani* dropped only 25% (Fig. 2). The combination of pathogens did not cause any inhibition in the growth of either pathogen in the rhizosphere.

DISCUSSION

The deficit soil moisture (high soil matric potential) was generally detrimental to both plant growth and pathogen activity regardless of whether pathogens were alone or in combination (Table 1). The effects of the combination of *F. o. ciceri, F. s. pisi*, and *T. basicola* on chickpea wilt or root rot severity were generally additive (Table 2). Wilt symptoms were not suppressed when chickpea plants were grown in soil infested with a combination of *F. o. ciceri* and *F. s. pisi. F. s. pisi* was reported to suppress pea wilt caused by race 1 when a race 1-susceptible cultivar was inoculated simultaneously with both pathogens (6). At harvest, each pathogen was successfully isolated from diseased chickpea seedlings grown in all combination treatments. It appears that once each pathogen has invaded a chickpea root, each can perhaps act independently, resulting in an additive disease expression more severe than that produced by one pathogen alone. These results are in agreement with Worf and Hagedorn (31), who reported similar interactions between *F. o.* f. sp. *pisi* and *F. s. pisi* on peas. The primary site of infection for *F. s. pisi* is the cotyledonary attachment area (18). If the root tip is the infection site of *F. o. ciceri* (17,24), then neither *F. s. pisi* nor *T. basicola*, which are root cortex invaders, would be expected to antagonize or compete with the wilt fungus.

Wilt symptoms were suppressed when chickpeas were grown in soil infested with both *F. o. ciceri* and *P. ultimum* (Table 2). Perhaps the shared infection site may be responsible for suppression of wilt pathogen. *P. ultimum* attacks and destroys juvenile root tissue (tap and lateral root apices), which are the infection sites for the wilt pathogen (24). Similar results were found when a susceptible pea cultivar was grown in soil infested with *F. o. pisi* and *P. ultimum* (17). Typical symptoms of root tip pruning caused by *P. ultimum* were masked in the presence of *F. s. pisi* or *T. basicola*.

The increased soil moisture increased the severity of wilt and root rot of chickpea caused by any or all of the four fungi tested. These findings agree with previous work that reported that less wilt of chickpeas (7,8,13) or root rot of peas (9,15) occurred with low soil moisture levels than at moderate to high soil moisture levels. Rhizosphere populations of the wilt and root rot pathogens also increased with an increase in soil water contents (Fig. 2). Increased chlamydospore germination and resultant increased inoculum levels in the rhizosphere can help to explain why wilt and root rot were most severe in the infested soil at high moisture contents. The reduced activity of fungal pathogens in the dry soil may be due to poor propagule germination caused by less root exudate (9,15). Saturated soil can cause anaerobic or near-anaerobic conditions, which are injurious to roots and can predispose them to root disease (1).

The authors have frequently recovered *T. basicola, F. s. pisi*, and *P. ultimum* from the diseased roots of peas and chickpea in the field. The isolation of each pathogen from chickpea seedlings

Table 2. Effect of wilt and root rot pathogens, alone and in combination, on disease severity of chickpea at different soil matric potentials

Pathogen(s)[y]	Soil matric potential (−kPa) 40–20	260–40	1,060–260
FOC	7.5 e–h[z]	6.6 ijk	2.8 uv
FSP	8.4 a–d	6.5 ijk	5.2 mn
PU	5.0 mno	3.9 q–t	2.3 v
TB	7.2 f–i	6.0 kl	4.3 o–s
FOC + FSP	8.2 b–e	7.8 def	4.7 m–p
FOC + PU	4.4 o–r	3.6 st	3.2 tu
FOC + TB	8.4 a–d	7.9 c–f	5.4 lm
FSP + TB	9.0 a	8.6 abc	6.2 jk
PU + TB	7.9 c–f	7.4 fgh	4.6 n–q
FOC + FSP + PU	8.4 a–d	7.8 def	4.6 n–q
FOC + FSP + TB	8.9 ab	7.9 c–f	6.0 kl
FOC + PU + TB	6.9 hij	5.3 lmn	3.8 rst
FSP + PU	7.0 ghi	6.0 kl	4.0 p–s
FSP + TB + PU	8.9 ab	6.9 hij	5.2 mn
FOC + FSP + PU + TB	8.6 abc	7.7 d–g	5.3 lmn
Control	1.0 w	1.2 w	1.08 w
LSD = 0.759			

[y] FOC = *Fusarium oxysporum* f. sp. *ciceri*, FSP = *F. solani* f. sp. *pisi*, PU = *Pythium ultimum*, and TB = *Thielaviopsis basicola*.

[z] Means within rows and columns followed by same letter are not significantly different, according to Fisher's protected LSD test ($P = 0.05$).

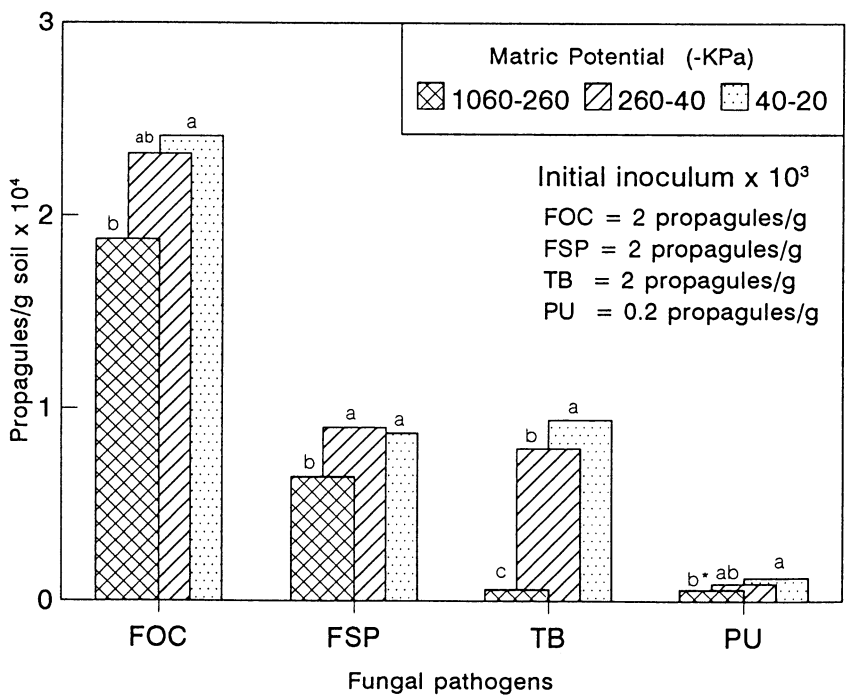

Fig. 2. Rhizosphere population of wilt and root rot pathogens of chickpea after 30 days in previously infested soil maintained at different soil matric potentials. FOC = *Fusarium oxysporum* f. sp. *ciceri*, FSP = *F. solani* f. sp. *pisi*, PU = *Pythium ultimum*, TB = *Thielaviopsis basicola*.

grown in different combination treatments of these interaction studies clearly indicate that these fungi are important components of the fungal complex associated with root rot of peas and chickpeas in eastern Washington and northern Idaho. *T. basicola* has been previously reported as causing root rot of beans (5) and peas and chickpea (2–4), but this is the first report of *T. basicola* interactions with other soilborne pathogens of chickpea.

Rhizosphere population studies (Fig. 2) indicated that *F. o. ciceri* was the most prolific pathogen, either alone or in combination with root rot pathogens. This fungus is a known common soil inhabitant and facultative saprophyte. The population of wilt and root rot pathogens was significantly higher at the medium and high soil matric potential. Worf and Hagedorn (31) reported similar results with pea wilt and root rot fusaria. This data suggests that *F. o. ciceri* has the capacity to rapidly increase inoculum levels in fields in which a susceptible cultivar is planted once the inoculum is introduced.

Previous reports have suggested that interactions between several fungal pathogens of chickpeas may occur and influence the incidence and severity of disease (28). The research reported here demonstrates that Fusarium wilt and root rot of chickpea is more severe with high soil moisture levels, and that in some instances more disease results from a combination of pathogen infections. *F. s. pisi* and *T. basicola* were found to be severe pathogens of chickpeas with high soil moisture levels.

Many fields in which chickpeas are grown in the Pacific Northwest drain slowly and could be ideal for chickpea diseases to be severe. Results from this pathogen interaction and soil moisture study indicate that any breeding program for developing chickpea cultivars for the Pacific Northwest should include resistance to *F. s. pisi* and *T. basicola* as a primary objective.

LITERATURE CITED

1. Allmaras, R. R., Kraft, J. M., and Miller, D. E. 1988. Effects of soil compaction and incorporated crop residue on root health. Annu. Rev. Phytopathol. 26:219-243.
2. Blume, M. C., and Harman, G. E. 1979. *Thielaviopsis basicola*: A component of the pea root rot complex in New York State. Phytopathology 69:785-788.
3. Bowden, R. L., Wiese, M. V., Crock, J. E., and Auld, D. L. 1985. Root-rot of chickpeas and lentils caused by *Thielaviopsls basicola*. Plant Dis. 69:1089-1091.
4. Buddenhagen, I. W., Workneh, F., and Bosque-Perez, N. 1988. Chickpea improvement and chickpea diseases in California. Int Chickpea Newsl. 9:9-10.
5. Burke, D. W., and Kraft, J. M. 1974. Response of beans and peas to root pathogens accumulated during monoculture of each crop species. Phytopathology 64:546-549.
6. Buxton, E. W., and Perry, D. A. 1959. Pathogenic interactions between *Fusarium oxysporum* and *Fusarium solani* on peas. Trans. Br. Mycol. Soc. 42:378-387.
7. Chauhan, S. K. 1963. Incidence of Fusarium wilt of gram (*Cicer arietinum* L.) in relation to soil moisture. Agra Univ. J. Res. Sci. 12:271-274.
8. Chauhan, S. K. 1963. Influence of different soil moistures on the incidence of Fusarium wilt of gram (*Cicer arietinum* L.) Proc. Indian Acad. Sci. Sect. B. 33:552-554.
9. Cook, R. J., and Flentje, N. T. 1967. Chlamydospore gemination and germling survival of *Fusarium solani* f. sp. *pisi* in soil as affected by soil water and pea exudation. Phytopathology 57:178-182.
10. Dawdy, S., and Wearden, S. 1982. Statistics For Research. John Wiley & Sons, New York.
11. Glinski, J., and Lipiec, J. 1990. Soil Physical Conditions and Plant Roots. CRC Press, Boca Raton, FL. 250 pp.
12. Grewal, J. S., Pal, M., and Kulshrestha, D. D. 1974. Fungi associated with gram wilt. Indian J. Genet. Plant Breed. 34:242-246.
13. Gupta, O., Kotasthane, S. R., and Khare, M. N. 1987. Factors influencing epidemiology of vascular wilt of chickpea. Proc. Nat. Acad. Sci. India Sect. B. 57(1):86-91.
14. Kaiser, W. J. and Hannan, R. M. 1983. Etiology and control of seed decay and preemergence damping-off of chickpea by *Pythium ultimum*. Plant Dis. 67:77-81.
15. Kerr, A. 1964. The influence of soil moisture on infection of peas by *Pythium ultimum*. Austr. J. Biol. Sci. 17:676-685.
16. Kraft, J. M. 1969. Chickpea, a new host of *Fusarium solani* f. sp. *pisi*. Plant Dis. Rep. 53:110-111.
17. Kraft, J. M. 1978. Effects of root rot pathogens on Fusarium wilt of peas. Plant Dis. Rep. 62:216-221.
18. Kraft, J. M., and Roberts, D. D. 1969. Influence of soil water and temperature on the pea root rot complex caused *Pythium ultimum* and *Fusarium solani* f. sp. *pisi*. Phytopathology 59:149-152.
19. Mircetich, S. M. 1971. The role of *Pythium* in feeder roots of diseased and symptomless peach trees and in orchard soils in peach tree decline. Phytopathology 61:357-360.
20. MSTAT. 1989. A microcomputer program for the design, management, and analysis of agronomic research experiments. Michigan State University, East Lansing.
21. Nash, S. M., and Snyder, W. C. 1962. Quantitative estimations by plate counts of propagules of the bean root rot *Fusarium* in field soils. Phytopathology 52:567-572.
22. Nene, Y. L. 1987. Chickpea diseases and their control. Pages 233-270 in: The Chickpea. M. C. Saxena, and K. B. Singh, eds. CABI, Wallingford, Oxon, U.K.
23. Nene, Y. L., Sheila, V. K., and Sharma, S. B. 1984. A world list of chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanas can* L.) Millsp. pathogens. ICRISAT Pulse Pathol. Prog. Rep. 32. 19 pp.
24. Nyvall, R. F., and Haglund, W. A. 1972. Sites of infection of *Fusarium oxysporum* f. sp. *pisi*, race 5 on peas. Phytopathology 62:1419-1424.
25. Richards, L. A. 1947. Pressure membrane apparatus construction and use. Agric. Eng. 28:416-418.
26. Specht, L. P., and Griffin, G. J. 1985. A selective medium for enumerating low populations of *Thielaviopsis basicola* in tobacco field soils. Can. J. Plant Pathol. 7:438-441.
27. Toussoun, T. A., and Nelson, P. E. 1976. *Fusarium*: A pictorial guide to the identification of *Fusarium* species, 2nd ed. Pennsylvania State University Press, University Park.
28. Trapero-Casas, A., and Jimenez-Díaz, R. M. 1985. Fungal wilt and root rot diseases of chickpea in southern Spain. Phytopathology 75:1146-1151.
29. Trapero-Casas, A., Kaiser, W. J., and Ingram, D. M. 1990. Control of Pythium seed rot and preemergence damping-off of chickpea in the U.S. Pacific Northwest and Spain. Plant Dis. 74:563-569.
30. Westerlund, F. V., Jr., Campbell, R. N., and Kimble, K. A. 1974. Fungal root rot and wilt of chickpea in California. Phytopathology 64:432-436.
31. Worf, C. L., and Hagedorn, D. J. 1962. Interaction of two fusaria in soil and associated host responses. Phytopathology 52:1126-1132.