Pak. J. Bot., 18(1): 51–58, 1986.

EFFECT OF *DRECHSLERA SOROKINIANA* AND *FUSARIUM AVENACEUM* ON ROOT AND SHOOT YIELD, EVAPOTRANSPIRATION, AND STOMATAL RESISTANCE OF SIX WINTER WHEAT CULTIVARS GROWN UNDER SOIL MOISTURE STRESS CONDITIONS

C. IKECHUKWU UMECHURUBA[1], L.L. SINGLETON AND M.B. KIRKHAM[2]

Department of Plant Pathology,
Oklahoma State University, Stillwater 74078, U.S.A.

Abstract

A growth chamber study was conducted to determine the effects of *Fusarium avenaceum* and *Drechslera sorokiniana* each alone and the two pathogens together on yield, evapotranspiration and stomatal resistance of 6 hard, red, winter wheat cultivars (Payne, Triumph 64, Danne, Vona, Tam 101, and Newton) grown under soil moisture stress conditions. Under soil moisture stress conditions, the pathogens reduced forage and root yields in all the cultivars. Evapotranspiration rate did not differ significantly in any of the treatments of cultivars as compared to their controls. In general, the pathogens had no significant effect on stomatal resistance, but *F. avenaceum* alone seemed to cause an increase in stomatal resistance while *D. sorokiniana* alone and the two pathogens together caused a decrease in stomatal resistance. The cultivar, Payne, was consistently superior to the other cultivars in forage and root yields and also gave the lowest stomatal resistance while the cultivar, Newton, consistently gave the lowest yields and the highest stomatal resistance in all treatments. This indicates that Payne is more tolerant to the pathogens under soil moisture stress conditions than the other cultivars while Newton is less tolerant.

Introduction

Water stress can predispose plants toward greater susceptibility to plant diseases. Leophart & Stage (1971) attributed the origin and severity of pole blight disease of western white pines from 1916 to 1940 to the extended drought that occurred then in the United States of America. Couch & Bloom (1960) showed that water stress predisposed kent blue-grass to *Sclerotina homeocarpa.* Cook *et. al.* (1972) listed certain fungal pathogens that cause greater damage on their host plants in dry soils. Cook (1980) also reported that *Fusarium* foot rot in wheat is more severe in the Pacific Northwest when plants are predisposed to water stress.

In Oklahoma, it has been observed that common root rot of wheat is very severe in wheat fields in years of scattered and/or limited rainfall. This study was therefore undertaken to determine the effects of *Drechslera sorokiniana* (Sacc.), Shoem (*Heliminthosporium sativum*) and *Fusarium avenaceum* (Fr) Sacc. on root and shoot yields, eva-

Present Address: [1]Department of Botany, University of Port Harcourt, Port Harcourt, Nigeria.
[2]Evapotranspiration Laboratory, Kansas State University, Manhattan 66506, U.S.A.

potranspiration rate, and stomatal resistanc of six hard, red winter wheat cultivars grown under soil moisture stress conditons. A better understanding of wheat-water relations and the effects of soil-borne pathogens on stomatal closure and opening will be helpful in breeding wheat varieties that will be resistant to drought and diseases favored by dry soil conditons.

Materials and Methods

The study was conducted in a growth chamber at the Controlled Environmental Research Laboratory at Oklahoma State University, Stillwater, Oklahoma. Certified seeds of 6 hard, red, winter wheat cultivars: Payne, Triumph 64, Danne, Vona, Tam 101, and Newton, were used in the study. Lincoln fine sand (94.9% sand and 3.0% clay) treated with methyl bromide was thoroughly mixed with inoculum suspension of macroconidia of *F. avenaceum* and conidia of *D. sorokiniana* (each pathogen alone and the two together) for 30 minutes at the rate 250 spores per gm of soil in water sufficient to raise the water content of the soil to field capacity (7.5%). Infested soil was put into plastic pots (11.0 x 14.5 cm). A total of 96 pots were used in the experiment. Five seeds of each cultivar were planted per pot to a depth of 5.1 cm. Plants were thinned to 3 plants per pot 5 days after emergence. A split plot design with watering regimes as main plots, cultivars as subplots and inoculated versus uninoculated plants as subplots was used and each plot was completely randomized. Half of the plants were watered every 3 days with 50 ml of tap water and the other half with 100 ml of tap water every 7 days. Every pot ultimately received the same amount of water by the end of the experiment. Each pot stood in a plastic container (11.0 x 8.0 cm) into which water was added and allowed to rise into the pots by capillarity.

Plants were grown in a growth chamber. The growth chamber was maintained at 26°C day and 23°C night, and a 12 hour photoperiod from 0600 to 1800. Fluorescent and incandescent bulbs in the growth chamber supplied light at an intensity of 635 microeinsteins M^{-2} Sec^{-1} as measured by Lambda (Lincoln, Nebraska) Instrument L1–185 Quantum, Radiometer, Photometer, in the region of exposed leaves. The relative humidity was between 50-70%. Plants were fertilized with water soluble NPK fertilizer (15-30-15, 4g/liter) when they were four weeks old. The experiment was repeated three times.

The following measurements were taken to help determine the effects of the pathogens and soil-moisture stress on the wheat cultivars.

Three forage yields were taken when plants were 21, 42 and 63 days old. Leaves were clipped on a per pot basis from the base of the first leaf and weighed to obtain fresh weights. Roots were harvested when plants were 63 days old on a per pot basis.

The roots were thoroughly washed with tap water on a 2.0 mesh sieve to get rid of soil particles. Excess water was allowed to drain and then roots were blotted with tissues and weighed to obtain fresh weights. Leaves and roots were oven-dried for 24 h at 80°C and weighed to obtain dry weights.

Evapotranspiration rate was determined daily for 7 days when plants were in their third, sixth, and ninth week. Measurements were taken by weighing each pot before watering to the nearest 0.1 gm.

Stomatal resistance was measured on alternate days of the week, when plants were in their third, sixth and ninth week with a calibrated stomatal diffusion porometer Kanemasu (1969) (Model L1-65 and Sensor L1-20S, Lambda instrument Corps; Lincoln, Nebraska). The upper leaf surface of the second leaf from the bottom of the plant was measured.

Soil samples were taken on a per pot basis when plants were in their third, sixth, and ninth week with a sterile soil probe and put into small glass vials (14.5 x 45 mm, 1 Dram) sealed with plastic snap caps and taken to the laboratory to determine the soil water potential. A total of 96 samples were taken at each sampling period. Dew point readings were taken in microvolts, using the C-52 sample Chamber attached to HR-33T, Dew Point Microvoilmeter by Wescor, Inc. (Logan, Utah). The soil water potential in negative bars (–U) was calculated using the dew point method. Mean soil water potential in the 3- and 7- day watered pots were -21 and -45 bars ±5 at 26°C respectively. Very low soil water potential obtained indicates that the soil was quite dry.

Results and Discussion

Effects on Forage Yield: The difference in yield between the inoculated plants and the control was generally significant at P=0.01. level (Table 1). In 3-days watered plants, *F. avenaceum* alone caused the highest mean percentage yield reduction on Danne and Vona and the lowest percentage yield reduction on Payne and Tam 101, as compared to other cultivars. In 7-day watered plants, *F. avenaceum* alone caused the highest percentage yield reduction on Triumph 64 and Vona and the lowest percentage yield reduction on Payne and Newton, as compared to other cultivars. These results seem to suggest that Vona is the most susceptible cultivar and Payne the most resistant cultivar to *F. avenaceum.* Greater perecentage yield reduction were caused by *F. avenaceum* alone on all the cultivars in 7-day watered plants than in 3-day watered plants. This indicates, as reported in the literature (Cook, 1973; Wiese, 1977) that *F. avenaceum* is very aggressive under extreme soil moisture stress condition.

Table 1. Mean percentage yield reduction of Six Wheat cultivars inoculated with *Fusarium avenaceum* and *Drechstera sorokiniana* each alone and the two pathogens combined, and grown under two watering regimes.

	3-Day Watered Plants			7-Day Watered Plants		
Cultivar	F	D	F+D	F	D	F+D
Dry Forage:						
Payne	18.75	25.00*	25.00*	34.48**	37.93**	41.38**
Triumph 64	29.73**	32.43**	62.16*	61.29**	41.94**	58.94**
Danne	35.29**	44.12**	38.24**	43.83**	34.48**	34.48**
Vona	34.38**	37.50**	34.38**	61.71**	46.45**	64.29**
TAM 101	25.71*	48.57**	31.43**	53.57**	28.57**	21.43**
Newton	26.67*	50.00**	40.00**	43.33**	66.67**	57.14**
Dry Root:						
Payne	3.77	0.00	5.66	62.50	39.58	33.33
Triumph 64	31.82	22.73	63.64*	72.58*	30.65	66.13
Danne	58.11*	47.30	68.92*	44.23	32.69	51.92
Vona	68.00*	62.67*	21.33	87.10*	75.81*	72.58
TAM 101	19.51	82.93**	2.44	38.46	10.25	58.97
Newton	23.08	92.31**	51.28*	68.42*	92.98*	84.21*

F = *F. avenaceum* inoculated plants (250 macroconidia/g soil) means of three replicates
D = *D. sorokiniana* inoculated plants (250 conidia/g soil) mean of three replicates
* = significantly different from control at P = 0.05
** = significantly different from control at P = 0.01

In 3-day watered plants, *D. sorokiniana* alone caused the highest mean percentage yield reduction in Newton and Tam 101 and the lowest percentage yield reduction on Payne and Triumph 64, Newton and Danne and the lowest percentage yield reduction in Payne and Tam 101. The 7-day watered plants, both pathogens together caused the highest mean percentage yield reduction in Vona, Triumph 64 and Newton and the lowest percentage yield reduction in Tam 101, Danne and Payne. These results seem to suggest that Triumph 64 and Newton are the most susceptible cultivars to both pathogens put together and Payne and Tam 101 the most resistant cultivars. Effects of both pathogens on the cultivars in 3- and 7-day watered plants did not differ appreciably.

Overall means of cultivars over treatments showed that *D. sorokiniana* alone caused higher percentage yield reduction (39.5%) in the 3-day watered plants than *F. avenaceum* (28.4%). But in 7-day watered plants, *F. avenaceum* alone caused higher percentage yield reduction (49.7%) than *D. sorokiniana* 42.7%). These differences in disease severity between *F. avenaceum* and *D. sorokiniana* in host plants under different soil moisture content support reports in the literature (Dosdall, 1923) that *D. sorokiniana* aggressiveness increases at relatively high soil moisture while *F. avenaceum* aggressiveness increases under comparatively dry soil conditions (Cook, 1973; Wiese, 1977). Overall results also showed that Payne is the most resistant cultivar to the two pathogens while Newton is the most susceptible cultivar to the pathogens, under the conditions of this study.

Effects on Root Yield: Results obtained on root production agreed with results obtained on forage yield, in that Payne is the most resistant cultivar to the pathogens and Newton and Vone the most susceptible cultivars (Table 2). The pathogens' ability to destroy the cultivars' root systems obviously accounted for reduced plant vigor and low forage production, as compared to their controls. The pathogens limited the plants' ability to absorb water and nutrients for normal growth. In addition, moisture stress probably contributed in predisposing the plants to secondary infections by the pathogens. Thus, a wheat cultivar with a root system resistant to the pathogens and tolerant to drought like Payne, is desirable for wheat improvement programs in Oklahoma.

Table 2. Mean evapotranspiration rate (g/day) and mean stomatal resistance (see cm^{-1}) of six wheat cultivars inoculated with *Fusarium avenaceum* and *Dreschstera sorokiniana* each alone and the two pathogens combined, and grown under two watering regimes.

	3-Day Watered Plants				7-Day Watered Plants			
Cultivar	C	F	D	F+D	C	F	D	F+D
Payne	9.8	8.0	9.2	8.0	6.6	5.6	5.4	5.7
Triumph 64	8.5	8.5	7.6	8.4	6.5	6.4	5.4	5.4
Danna	8.5	8.5	8.4	8.1	6.3	6.2	5.4	5.6
Vona	8.9	8.8	8.0	8.2	6.4	6.3	5.7	5.7
TAM 101	9.4	8.1	9.2	7.8	6.2	5.2	5.3	5.3
Newton	9.8	8.0	8.2	7.6*	6.4	6.0	5.1	5.0
Payne	31.5	18.8	9.7*	11.9	22.0	26.9	32.9	23.6
Triumph 64	16.8	16.3	19.9	39.1*	28.0	27.0		25.6
Danne	22.9	36.1	17.4	23.1	27.6	19.4	28.6	29.3
Vona	19.8	28.4	10.4	15.2	32.2	36.8	17.5	28.5
TAM 101	20.3	21.1	42.7*	23.2	33.5	34.4	29.8	32.6
Newton	44.8	29.1	30.0	30.7	33.3	33.8	32.3	32.4

C = Control, mean of three replicates
F = *F. avenaceum* inoculated plants (250 macroconidia/g soil), mean of three replicates.
D = *D. sorokiniana* inoculated plants (250 conidia/g soil) mean of three replicates.
* = significantly different from control at P = 0.05.

Effects on Evapotranspiration Rate: Evaporation and transpiration from plant communities is frequently termed evapotranspiration (Kramer, 1969). The relative amount of water removed from soil by evaporation and transpiration is of great interest particularly in regions of limited rainfall because it can be used as a guide for irrigation (Kramer, 1969). As water potential decreases, (water stress increases) the stomata close and the rate of transpiration decreases.

Results presented in Table 2 showed that the pathogens and soil-moisture stress seemed to cause a decrease in evapotranspiration rate of the cultivars but the decrease was not significantly different from controls with the exception of Newton, which differed significantly from its control at $p = 0.05$ level. Evapotranspiration rate seemed to decrease with increase in soil-moisture stress.

Considering the six cultivars, the rate of evapotranspiration did not differ significantly with age of the plants. The reason for this is because evapotranspiration rates of the cultivars were measured when plants were in their third, sixth and ninth weeks. Forage was harvested when plants were 3, 6 and 9 weeks old and leaves allowed to regrow. Therefore, transpiration rates of the plants measured were from leaves of the same age (Kramer, 1969).

Effects on Stomatal Resistance: In general the pathogens had no significant effect on stomatal resistance as compared to controls (Table 2). But *F. avenaceum* alone seemed to cause an increase in stomatal resistance in 7-day watered plants, as compared to controls. The two pathogens together seemed to cause a decrease in stomatal resistance as compared to controls.

The results, therfore, obtained suggest the *F. avenaceum* alone caused the stomata to close and prevent water loss, while *D. sorokiniana* alone and both pathogens together, caused the stomata to open and much water was lost. Increase in stomatal resistance in plants inoculated with *F. avenaceum* alone seemed to indicate that the pathogen may have blocked the vascular system of the plants, thereby causing decrease in transpiration rate and increase in stomatal resistance. Duniway (1971) and Machardy *et al.*, (1976) reported that vascular wilt pathogens such as *Verticillium* and *Fusarium* species which are confined to the vascular system of host plants, generally cause decrease in transpiration rate and increase in stomatal resistance. Duniway (1971) found that the diffusive resistance of leaves to water-vapor loss in tomato plants infected with *F. oxysporum f.* sp. *radici – lycopersici* was a high as or higher than the resistance in healthy plants at a given leaf water potential.

The decrease in stomatal resistance of the plants inoculated with *D. sorokiniana* alone seemed to suggest that *D. sorokiniana* may have released a toxin which was carried up the shoot where it induced stomatal opening and thereby decreased stomatal resistance. *Helminthosporium sacchari,* the causal agent of 'eyespot' of sugarcane, is reported to release a diffusible toxin that causes appearance of a 'runner (Strobel, 1975). The toxin altered the membrane permeability causing increase in transpiration and decrease in stomatal resistance (Strobel, 1975). Turner (1972) and Turner & Graniti (1969) have shown that fusicoccin, victorin, and phytotoxins lower stomatal resistance in *Avena sativa.* Wheeler & Black (1963) also reported that some root pathogens such as *Heliminthosporium* species, which produce toxins that interfere with metabolism of host-plants, generally cause stomatal opening and decrease in stomatal resistance.

The decrease in stomatal resistance in plants inoculated with the two pathogens together may be more of the effects of *D. sorokiniana* than of *F. avenaceum* at this plant stage, because *D. sorokiniana* is normally the first fungus to enter roots before it is out competed by *Fusarium* species, as the plant growing season progress. Results also showed that stomatal resistance tends to increase with increases in water stress (Table 2).

Although not included in Table 2, Newton had the highest stomatal resistance in all treatments while Payne had the lowest stomatal resistance (33 sec. cm^{-1} for Newton versus 22 sec. cm^{-1} for Payne; highly significant at P = 0.01 level). This means that Payne has a better stomatal closure mechanism, which can prevent tissue desiccation under conditions of high internal water stress, than Newton. Newton's stomatal resistance was significantly different from those of Danne and Vona at P = 0.05 level but not significant from those of Tam 01 and Triumph 64.

Overall results of this study-consistently showed that Payne is the most resistant cultivar to the two pathogens under soil-moisture-stress conditions, whiel Newton is the most susceptible cultivar. Adjel (1978) reported in his study on the effects of soil-moisture-stress on some wheat cultivars that the Wheat cultivars, centruk and concho, have desirable adaptive characteristics for dry land areas. Comparative studies of the effects of the pathogens on Payne, Centurk, and Concho under soil-moisture-stress conditions may be a worthwhile screening program leading to development of resistant cultivars.

Acknowledgements

This research was supported by Oklahoma State University Presidential Challenge Grant and by Oklahoma Department of Agriculture Grant. We are grateful to Dr. C.C. Russel for his assistance and advice and to Dr. H.A. Melouk and Professors G.C. Clerk and F.A. Onofeghara for reviewing this manuscript.

References

Adjei, G.B. 1978. Plant water relation of six cultivars of winter wheat grown under moisture stress. Master's Thesis. Oklahoma State Univ. Stillwater, 59 pp.

Cook, R.J. 1973. Influence of low plant and soil water potentials on diseases caused by soil-borne diseases. *Phytopath*, 63, 451–458.

Cook, R.J. 1980. Fusarium foot rot of wheat and its control in the Pacific Northwest. *Plant Disease*, 64: 1061–1066.

Cook, R.J., R.I. Papendick, and D.M. Griffin, 1972. Growth of two root rot fungi as affected by Osmotic and matric water potentials. *Soil Sci. Soc. Am. Aproc.* 36: 78–82.

Couch, H.B. and J.R. Bloom, 1960. Influence of environment on diseases of turf-grass. II. Effect of nutrition, pH and soil moisture on Sclerotina dollar spot., *Phytopath*, 50: 761–763.

Dosdall, Louise. 1923. Factors influencing the pathogenicity of *Helminthosporium sativum. Minn. Agr. Exp. Sta. Tech. Bull.*, 17: 54 pp.

Duniway, J.M. 1971. Water relations of Fusarium wilt in tomato. *Physiol. Plant. Path.* 1: 537–546.

Kanemasu, E.T., G.W. Thurtell, and C.B. Tanner, 1969. Design, calibration, and field use of a stomatal diffusion prometer. *Plant. Physiol.* 44: 881–885.

Kramer, P.J. 1969. *Plant and Soil Water Relationships: A modern synthesis*. McGraw-Hill Book Company, New York, 482 pp.

Leophart, C.D. and A.R. Stage, 1971. Climate: A factor in the origin of the pole blight disease of *Pinus monticola* Dougl. *Ecology*, 52: 229–239.

Machardy, W.E., V. Busch and R. Hall, 1976. Verticillum wilt of *Chrysanthenum:* quantitative relationship between increased stomatal resistance and local vascular disfunction preceding wilt. *Canad. Jour. Bot.*, 54: 1023–1034.

Strobel, G.A. 1975. A mechanism of disease resistance in plants. *Scientific American*, 223: 80–88.

Turner, N.C. 1972. Stomatal behaviour of *Avena sativa* treated with two phytotoxins, victorin, and fusicoccin. *Amer. Jour. Bot.*, 59: 133–136.

Turner, N.C., and A. Graniti, 1969. Fusicoccin: a fungal toxim that opens stomata. *Nature* 223: 1070–1071.

Wheeler, H., and H.S. Black.1963. Effects of *Heiminthosporium victoriae* and victorin upon permeability. *Amer. Jour. Bot.*, 50: 686–693.

Wiese, M.V. 1977. *Compendium of Wheat Diseases*. Amer. Phytopath. Soc. St. Paul, U.S.A.

(Received for publication 25 April 1985)