Experimental wheat area of CIMMYT near the town of Ciudad Obregon, Mexico.

Wheat response to drought

Robert E. Sojka □ Lewis H. Stolzy

Measurement of drought sensitivity helps evaluate wheat cultivars for bad as well as good conditions.

One of the greatest limitations on wheat production worldwide is inadequacy of available water. Therefore, it is important to know how the crop is physiologically affected by drought and which cultivars produce best under stress. Such information is also useful in selecting and evaluating cultivars in wheat breeding programs.

Cultivars developed under optimum irrigation regimes often do not produce the best yields under water stress. Where water is limited (because of low rainfall or insufficient water for irrigation), it is just as important to know the relative yield loss specific cultivars may suffer in a drought as it is to know optimum yield levels that might be expected under ideal conditions.

Field experiments on wheat stress physiology and yield interrelationships were conducted for two years by scientists from the University of California, Riverside, in cooperation with Centro Internacional de Mejoramento de Maíz y Trigo (International Maize and Wheat Improvement Center or CIMMYT). The work was done in the Mexican Sonoran Desert at the Centro Investigaciones Agricolas Noroeste (CIANO) field station of the Instituto de Investigaciones Agricoles, Secretaria de Agricultura, Mexico, near the town of Ciudad Obregon.

Numerous soil and plant water status measurements were made to characterize the severity of the treatments imposed. Of special interest were measurements of xylem pressure potentials (Ψ_x) for plant water status, soil water content, and, of course, yield. Twelve bread wheat and durum wheat cultivars were examined, along with two triticales. Of these twelve, three—Cocorit 71, Yecora 70, and Gabo—were observed more intensively

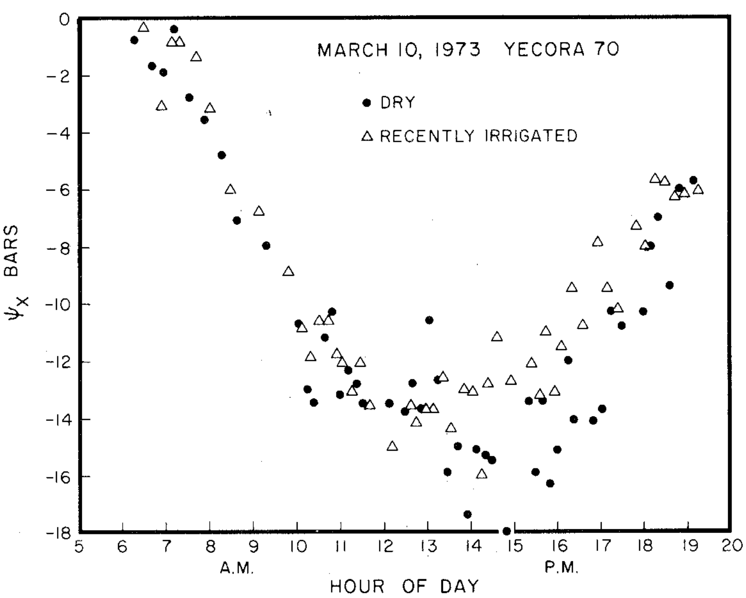


Fig. 1. Typical xylem pressure potential (Ψ_x) daily response pattern for wheat.

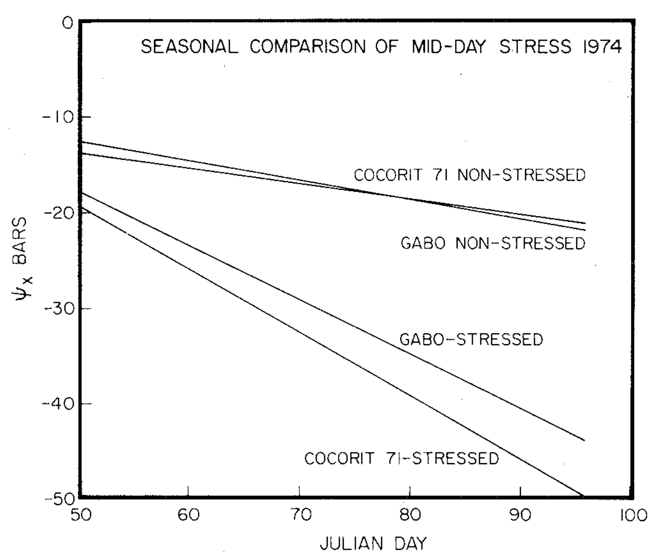


Fig. 2. Observations during growing season compare relative stress of a given cultivar under uniform soil-water regimes.

sterile, moist cotton swab and then using this swab to inoculate plates of BS medium. Following the first winter dormancy, the pathogen could no longer be recovered from any of the 20 cankers, which appeared hardened and dry. *Alternaria* spp. were recovered from all these year-old cankers, and *Rhizopus stolonifer* was recovered from 17 of the 20.

The disease cycle summarizing results of our study (see drawing) shows only infested dormant buds and catkins as overwintering sites for pv. *juglandis* on walnuts. Further research is needed to determine if other sites on the trees are suitable for epiphytic survival of the pathogen. Our studies, however, failed to substantiate the role of twig cankers in the survival of blight bacteria through the winter dormancy of walnuts.

Control

The vast majority of published information on walnut blight deals primarily with the use of various copper compounds and spray schedules developed for disease control. The program recommended for blight control consists of at least one spray during catkin elongation and two to three sprays during pistillate bloom. This program does not provide reliable, consistent blight control. In dry years, nut blight losses can usually be held below 10 percent with two to three copper sprays. In rainy years, it is difficult, if not impossible, to keep nut blight below 30 percent regardless of the spray schedule or copper formulation used.

Our epidemiological studies suggested that reducing overwintering populations of blight inoculum might improve control. Field experiments were established to evaluate the effectiveness of dormant sprays. In one replicated field plot, single branches were sprayed to runoff with various copper compounds and an experimental antibiotic one week before bud break. Two weeks later, foliage samples were collected, and populations of pv. *juglandis* on leaves emerging from treated buds were determined. Populations of the pathogen were significantly lower on new growth in all five treatments than in treated controls (table 2). However, even with $CuSO^4 \bullet H_2O$, the most effective treatment, the mean population per shoot was 1.86×10^5 CFU.

In a second series of field plots, one or two dormant-season sprays were applied in conjunction with standard bloom-period sprays. For two consecutive years, addition of dormant sprays failed to show a statistically significant improvement in nut blight control when compared with bloom sprays alone. Dormant-season copper sprays appeared to reduce the number of surface-infested buds (table 3), but these reductions were not sufficient to have any effect on the overall progress of the epidemic and subsequent crop loss.

TABLE 1. Recovery of *Xanthomonas campestris* pv. *juglandis* from Dormant and Developing Walnut Buds and Catkins

Variety	County	Date sampled	Blooming habit*	Infested on surface: Buds†	Infested on surface: Catkins
				%	%
Ashley	Butte	June	Early	90	90
Ashley	Butte	Feb	Early	45	35
Ashley	Glenn	Oct	Early	73	20
Ashley	Tehama	March	Early	73	—
Eureka	Contra Costa	Oct	Early	10	20
Eureka	Tulare	Oct	Early	20	0
Franquette	Butte	April	Late	0	0
Franquette	Contra Costa	April	Late	33	16.6
Hartley	Butte	April	Middle	0	0
Hartley	Contra Costa	April	Middle	13	21
Marchette	Tulare	Nov	Middle	63	18
Payne	Contra Costa	Dec	Early	95	95
Payne	Contra Costa	Aug	Early	80	70
Payne	Contra Costa	March	Early	45	55
Serr	Contra Costa	Sept	Early	20	0
Serr	Tulare	Sept	Early	5	0

*Blooming habits were based on leafing dates; early, March 15; middle, April 1; and late, after April 15.
†On the basis of a paired t-test, buds were infested significantly more often than catkins.

TABLE 2. Populations of *Xanthomonas campestris* pv. *juglandis* on Young 'Ashley' Walnut Shoots* Following Dormant-season Application of Three Bactericides

Treatments†	Mean shoot population ($\times 10^5$)‡
$CuSO_4 \bullet 5H_2O$) (25% Cu, 10 g/liter)	1.86 a
A-16886-b (100 ppm)§	4.43 a
A-16886-b (200 ppm)	9.03 a
Tribasic $CuSO_4$ (53% Cu, 5 g/liter)	23.33 a
Untreated	1,110.62 b

*Shoot = all new growth that emerged from an individual bud, including leaves, stems, nutlets, and developing buds and catkins.
†All treatments were applied on March 18, 1980, with a pressurized garden sprayer.
‡Means were based on isolations from five shoots per replication, each treatment replicated seven times in a randomized complete block design. Values followed by the same letter are not significantly different ($P = 0.05$), LSD = 767.05.
§Experimental bactericide provided by Eli Lilly Inc.

TABLE 3. Effect of Dormant-season Copper (Kocide) Sprays on Surface Bud Infestation and Nut Blight on 'Marchette' Walnut

Treatments*	Bud infestation after dormant sprays (Winter 1978)†	Nut blight at harvest‡: 1978	Nut blight at harvest‡: 1979
	%	%	%
2 dormant	58	22.4 a	ND§
1 dormant & 3 bloom	56	10.6 b	11.8 a
2 dormant & 3 bloom	66	21.6 b	ND
3 bloom	ND	12.2 b	12.9 a
Unsprayed	84	29.0 a	42.5 b

*Single tree treatments were replicated five times in a randomized complete block design. All Kocide treatments were applied to run off at 0.481 kg per 100 liters with a hand-gun sprayer.
†10 buds from each replication of treated and control trees were assayed for infestation seven days after the last dormant spray was applied January 27, 1978.
‡Values in column followed by the same letter are not signicantly different ($P = 0.05$).
§ND = not done.

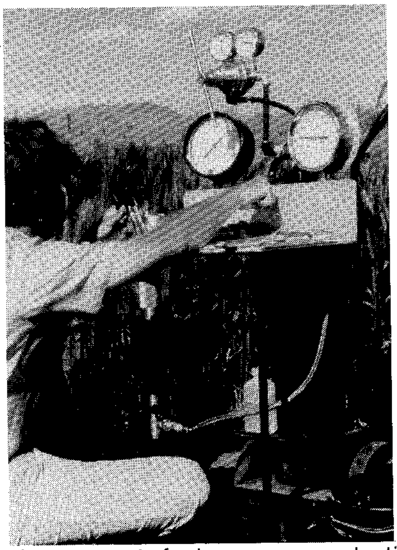
Preventing bud and catkin infestation with multiple protective copper sprays would be an approach to reducing the amount of overwintering inoculum. However, this type of program is not yet economically feasible.

Copper materials do not effectively penetrate walnut buds and catkins and, therefore, cannot eradicate blight bacteria from these overwintering sites. Thus the inoculum within these structures escapes the effects of topically applied copper sprays and can, under favorable environmental conditions, multiply and infect host tissues. Until bactericides with eradicative or systemic activities are developed walnut blight will continue to be a difficult disease to control.

Edward N. Mulrean, formerly Research Associate, University of California, Berkeley, is Extension Specialist, Plant Pathology, University of Arizona, Phoenix, and Milton N. Schroth is Professor, Department of Plant Pathology, University of California, Berkeley.

The authors express their appreciation to Ross Sanborn, Steve Sibbett, Bill Olson, and Larry Fitch, Farm Advisors, Contra Costa, Tulare, Butte, and Glenn counties, respectively; Dr. Beth Teviotdale, Extension Specialist, Plant Pathology, Parlier; and Janet Barton, Research Assistant, U.C., Berkeley.

because of their expected range of response under stress. Interestingly, cultivars in any given stress treatment did not differ markedly in water use, but well-irrigated controls required about 2½ times as much water as did plants in any of the stressed treatments. Soil water regimes were nearly identical for all the cultivars in any given stress treatment.



Measurement of xylem pressure potentials of wheat varieties by Robert Sojka.

(Xylem pressure potential, or plant water potential, is a measure of the energy status of water in the conductive xylem tissue of plants, as determined in a pressure chamber. If a plant is neither gaining nor losing water due to environmental forces, the water potential is zero. If the plant is in equilibrium with environmental forces that would cause a net loss of water, the water potential is negative, or less than zero. When soil is dry and the plant is actively transpiring water to a dry atmosphere, the degree to which the plant is stressed is indicated by how negative its water potential becomes. When two plants in the same environment have different water potentials, the plant with the less negative potential has some mechanism for resisting stress.)

It was determined that daily stress patterns (fig. 1) could be expressed statistically as three linear phases of Ψ_x response. In the morning Ψ_x began to drop (become more stressed) until about 10:00 a.m. After 11:00 a.m. Ψ_x ceased to drop, stabilizing until about 4:00 p.m., after which stress relief was evident and Ψ_x began to rise. The stable response period from 11:00 a.m. to 4:00 p.m. each day was long enough to allow numerous replicated observations of treatment and cultivar responses. These responses have been compared to evaluate the relative influence of stress on each cultivar over the treatment range.

As the season progressed, the daily responses during the stable midday periods resulted in relationships like those shown in figure 2. These types of data were used to show differences in the effect of soil water regime on development of physiological stress in the cultivars. For example, Cocorit 71 encountered much greater stress than Gabo in the second season of the study.

As each day passed, daily responses reflected the increased severity of stress in the nonirrigated treatments. Eventually, a point was reached when Ψ_x did not return to near zero values before dawn as was observed in figure 1. Instead, the plants were forced to enter succeeding daily cycles without full recovery. Thus, recovery (or presunrise) Ψ_x showed increased stress as the season progressed (fig. 3). Again, Cocorit 71 was the most stressed variety in the predawn comparison. Seasonal rankings of Ψ_x response paralleled the percent yield loss among cultivars. In general, the greater percentage of yield losses occurred in cultivars that suffered the lowest seasonal Ψ_x.

A final and perhaps most significant finding was the degree of sensitivity of wheat yield to full presunrise recovery of Ψ_x. When presunrise recovery values fell to -7 bars, the yield loss, when compared with controls, was about 80 percent (fig. 4). As presunrise Ψ_x continued to fall to nearly -40 bars, only an additional 20 percent yield loss occurred. This finding underscores the importance of at least a brief period of recovery of Ψ_x to near zero each morning. Plants thus regain full cell turgor, which allows for cell growth and expansion and ultimately attainment of full crop yield potential.

These data indicate that plant water status measurements have a genuinely important role in evaluation of wheat cultivars for response to drought.

Robert E. Sojka, formerly Research Assistant, is now Research Agronomist, Science and Education Administration, Agricultural Research, U.S. Department of Agriculture, Florence, South Carolina, and Lewis H. Stolzy is Professor of Soil Physics, Department of Soils and Environmental Sciences, University of California, Riverside. *The generous cooperation of CIMMYT and energetic participation of Dr. R.A. Fischer in this experiment are gratefully acknowledged. This work was funded in part by Rockefeller Foundation Grant #RF-72035 to the Department of Soil Science and Agricultural Engineering, University of California, Riverside.*

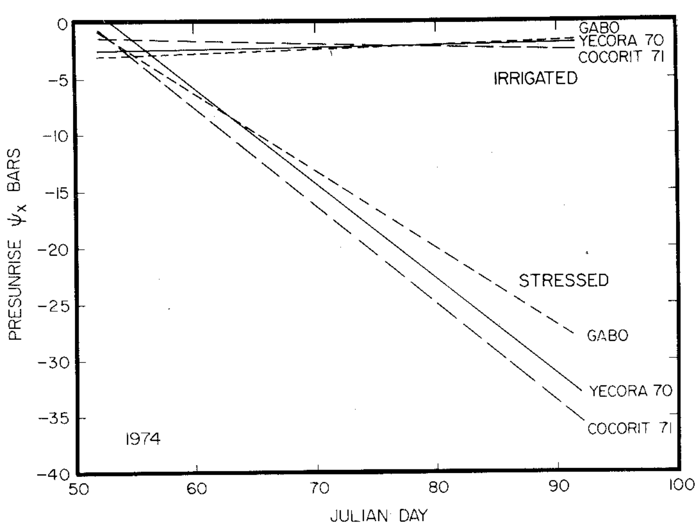


Fig. 3. By dawn, irrigated wheat recovered from previous day's stress; nonirrigated wheat had increasingly lower water potentials.

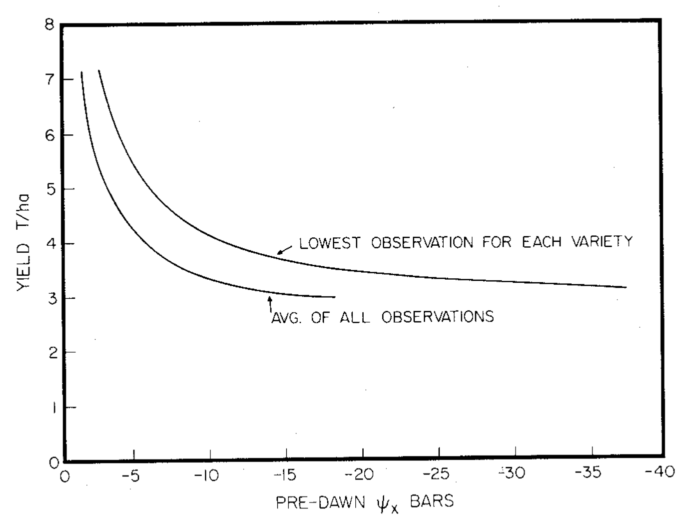


Fig. 4. Yields were highly sensitive to pre-dawn water potential; the first increments of stress took the greatest toll.