Transactions of the Nebraska Academy of Sciences and Affiliated Societies

Nebraska Academy of Sciences

1981

Influence of Windbreak-Shelter on Light Interception, Stomatal Conductance, and CO_2-Exchange Rate of Soybeans, *Glycine max* (Linnaeus) Merrill

S. N. Ogbuehi
University of Nebraska-Lincoln

J. R. Brandle
University of Nebraska-Lincoln

Ogbuehi, S. N. and Brandle, J. R., "Influence of Windbreak-Shelter on Light Interception, Stomatal Conductance, and CO_2-Exchange Rate of Soybeans, *Glycine max* (Linnaeus) Merrill" (1981). *Transactions of the Nebraska Academy of Sciences and Affiliated Societies*. 266.
https://digitalcommons.unl.edu/tnas/266

1981. *Transactions of the Nebraska Academy of Sciences,* IX:49-53.

INFLUENCE OF WINDBREAK-SHELTER ON LIGHT INTERCEPTION, STOMATAL CONDUCTANCE, AND CO_2-EXCHANGE RATE OF SOYBEANS, *Glycine max* (Linnaeus) Merrill*

S. N. Ogbuehi and J. R. Brandle

Department of Forestry, Fisheries and Wildlife
University of Nebraska-Lincoln
Lincoln, Nebraska 68583

Interception of photosynthetically active radiation, CO_2-exchange rate, stomatal conductance, and leaf water potential of windbreak-sheltered and exposed soybeans were studied in the field. Within-canopy profiles of photosynthetically active radiation measured after canopy closure indicated deeper light penetration into the canopy of sheltered soybeans. Consequently, plants in shelter had higher CO_2-exchange rates and greater stomatal conductance at equivalent relative canopy heights in comparison with unsheltered plants. Since no vertical gradient of leaf water potential was observed in the canopy in either treatment, gradients of CO_2-exchange rate and stomatal conductance were solely responses to light. Mean CO_2-exchange rates of top, fully expanded, canopy leaves of six soybean cultivars tested were significantly greater for sheltered plants. This was a consequence of greater leaf water potential and stomatal conductance. Selection of soybean cultivars on the basis of these physiological responses to shelter should lead to increased exploitation of the windbreak microclimate for soybean production.

† † †

INTRODUCTION

Light interception, stomatal conductance, and CO_2-exchange rate (CER) are important to plant growth. The only published report of comparative light interception measurements in sheltered and exposed soybeans was by Ogbuehi and Brandle (1979). These authors evaluated vertical light profiles in the canopy of "Wayne" soybeans and observed deeper light penetration into the canopy of the soybeans in shelter. They attributed this to greater spatial separation of leaves within the canopy of the sheltered plants.

An increase in plant growth due to shelter implies an increase in seasonal net photosynthesis (Miller, Rosenberg, and Bagley, 1973). Only few measurements of daytime CER in sheltered and exposed plants have been made, and no consistent difference between treatments was reported (Brown and Rosenberg, 1972; Skidmore, Hagen, Naylor, and Teare, 1974). The study reported here was designed to determine the influence of shelter microclimate on soybean light interception, stomatal conductance, and CER. Such information will lead to the identification of the factors contributing to increased growth and yield of sheltered soybeans.

MATERIALS AND METHODS

Cultivars, Site, and Plots

Seven soybean cultivars (Bonus, Corsoy, Cutler, Wayne, Wells, Woodworth, and Elf) were seeded on May 19, 1979, under windbreak-sheltered and exposed conditions. The study was carried out at the University of Nebraska-Lincoln Field Laboratory, Mead, Nebraska (41° 29′ N; 96° 30′ W; 354 m above mean sea level). Plant rows, 92 cm apart, were oriented in a north-south direction. A system of east-west oriented shelterbelts (6 m high, and about 60% dense) established in 1964 for windbreak research provided shelter from wind. Each windbreak consisted of two rows of green ash (*Fraxinus pennsylvanica* Linnaeus), Austrian pine (*Pinus nigra* Arnold), and eastern redcedar (*Juniperus virginiana* Linnaeus). The prevailing winds in Nebraska during the summer months are mainly from the south. Experimental plots (9 x 10 m) were in a randomized block design with four replications.

Experiments with "Wayne" Soybeans

Leaf water potential (Ψ_L) of the middle leaflet of top, fully expanded, trifoliates was measured one day each week

---

*Published with the approval of the Director as Paper No. 6025, Journal Series, Nebraska Agricultural Experiment Station.

(1300–1400 hr) beginning at growth stage V2 (Hanway and Thompson, 1971). After canopy closure, changes in photosynthetically active radiation (PAR), Ψ_L, leaf diffusive resistance (R_L), and CER were established for leaves at different canopy heights, on July 31 and August 31 (1300–1400 hr). Canopy closure occurred in sheltered and exposed plots about July 15 and July 22, respectively. Measurements of PAR were made using the Line Quantum Sensor, Model LI-191S (Lambda Instr. Corp.). This sensor gives the average PAR value over a distance of 1 m. Carbon dioxide exchange rate was determined under essentially ambient conditions using the gas sampling and analysis methods of Sullivan, Clegg, and Bennett (1976) and Clegg, Sullivan, and Easton (1978). Measurements were made with a single-leaf Plexiglas chamber (14 x 14 x 15 cm). Gas flow rate through the infra-red gas analyzer (Model 225 MKII, Analytical Dev. Co. Ltd., Britain) was 0.5 l/min. Leaf water potential was measured with a pressure chamber (Scholander, Hammel, Bradstreet, and Hemmingen, 1965); and stomatal diffusive resistance with Model LI-20S diffusive resistance sensor (Lambda Instr. Corp.). Stomatal conductance (C) was calculated as follows:

$$C = 1/Rad + 1/Rab$$

where Rad and Rab are adaxial and abaxial leaf diffusive resistance, respectively. During sampling, measurements of CER, Ψ_L, and R_L were made on the center leaflet of four randomly selected, attached leaves at each height of measurement. All measurements were made at four randomly selected locations in each treatment.

Starting at growth stage V2, estimates of plant height and dry matter production were made weekly. During sampling, plants were cut at ground level from four randomly selected, meter-length row segments within each plot. The samples were taken to the laboratory and oven-dried to constant weight at 70 C. At maturity, bean yield estimations were made on plants clipped from sixteen 2.5 m^2 plot areas in each treatment.

Experiments with "Bonus," "Corsoy," "Wells," "Woodworth," and "Elf" Soybeans

Daytime CER of top, fully expanded, canopy leaves of these cultivars were measured between 1000 and 1200 hours on July 30 and 31; August 3, 20, 22, and 31; and September 7. The diurnal trends of CER, Ψ_L, and R_L were measured every hour between 1000 and 1700 hours, on August 21. Measurement techniques used were the same as described for "Wayne" above.

RESULTS AND DISCUSSION

Experiments with "Wayne"

Data on PAR gradients in the canopy (Table I) showed

TABLE I. Photosynthetically active radiation (PAR), stomatal conductance (C), and CO_2-exchange rate (CER) at various canopy heights in sheltered and exposed soybeans.

Date	Relative height in canopy*	PAR		C		CER	
		Exposed	Sheltered	Exposed	Sheltered	Exposed	Sheltered
	%	μE/m²/sec		cm/sec		mg/dm²/hr	
July 31	100	1496.8a[†]	1496.8a	0.18a	0.20b	38.58a	42.69b
	70	299.4a	568.8b	0.15a	0.18b	20.38a	32.52b
	40	149.7a	299.4b	0.12a	0.16b	3.78a	9.17b
	10	90.0a	164.6b	0.08a	0.09a	2.20a	3.90b
	Ave.	509.0a	632.4b	0.13a	0.16b	16.24a	22.07b
August 31	100	1433.1a	1433.1a	0.16a	0.18b	26.66a	30.14b
	70	258.0a	401.3b	0.13a	0.15b	20.22a	25.02b
	40	215.0a	286.6b	0.10a	0.12b	3.12a	12.55b
	10	57.3a	114.6b	0.08a	0.10b	0.75a	2.46b
	Ave.	490.9a	558.9b	0.12a	0.14b	12.94a	17.54b

*Height of measurement as percentage of canopy height.

[†] Means in rows under PAR, C, or CER followed by different letters are significantly different at the 5% level using LSD.

that sheltered plants had a better canopy light climate than those in exposed plots. At equivalent relative canopy heights, plants in shelter had a significantly greater PAR. This is in agreement with the data of Ogbuehi and Brandle (1979). Previous studies have established that restriction of light penetration to lower canopy strata in soybeans is a serious limitation to bean yield (Johnson, Pendleton, Peters, and Hicks, 1969). On this basis, the significant increase in plant growth (Table II) and end-of-season bean yield in sheltered plots obtained in this study can partly be accounted for by the better canopy light climate. Bean yield was 1815 and 1436 kg/ha in sheltered and exposed plots, respectively. Carbon dioxide exchange rates and stomatal conductance of leaves at equivalent relative canopy heights were significantly greater in shelter and reflected the differences between treatments in within-canopy PAR, and in plant water stress (Table I; Fig. 1). Since no vertical gradient of Ψ_L was obtained within the canopy, the gradients of CER and stomatal conductance were solely a response to light.

Experiments with "Bonus," "Corsoy," "Cutler," "Wells," "Woodworth," and "Elf" Soybeans

Trends in CER of the cultivars between July 31 and September 7 are illustrated in Figure 2 and indicate significant differences between treatments. Carbon dioxide exchange rate was higher in shelter for most of the daily measurements. The data of Figure 2 are summarized in Table III to highlight mean differences between cultivars and between treatments. For each cultivar, mean CER was significantly higher ($p = 0.05$) in shelter. Researchers have not always obtained higher CER in shelter. Brown and Rosenberg (1972), and Miller, Rosenberg, and Bagley (1973), did not find any significant effect of shelter on CO_2-flux rates over sugar beets and soybeans, respectively. Skidmore, Hagen, Naylor, and Teare (1974) obtained an equal or a significantly higher CER in sheltered winter wheat when plant water stress was high; but on days when water stress was low, differences between treatments were not significant. Differences in the results obtained by different authors may reflect differences in measurement techniques, as well as variability of the windbreak microclimate with location and season. Contrary to the general trend, all cultivars had a significantly greater CER in exposed than in sheltered plots on August 22 (Fig. 2). This occurrence is difficult to explain because Ψ_L was greater in shelter on that day (Fig. 1).

A typical example of the diurnal trends in the CER of the cultivars is depicted for August 21 in Figure 3. These trends reflect the diurnal changes in Ψ_L and stomatal conductance, as illustrated for "Bonus" in Figure 4. Mean differences between cultivars and between treatments in Ψ_L, CER, and stomatal conductance on August 21 were statistically significant ($p = 0.05$).

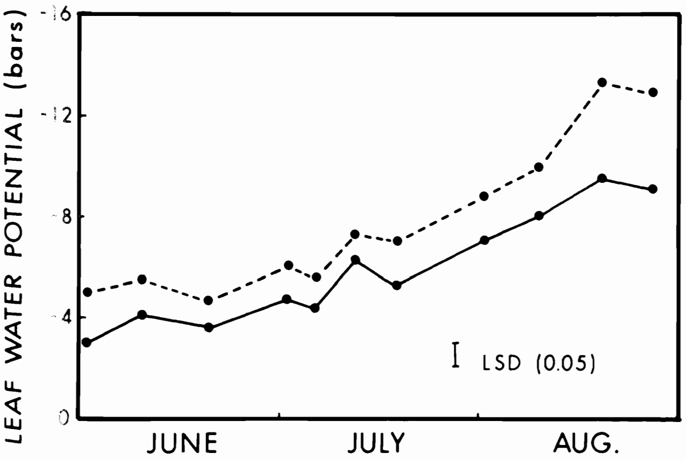

FIGURE 1. Seasonal trend of leaf water potential in sheltered (solid line) and exposed (broken line) "Wayne" soybeans during 1979 growing season.

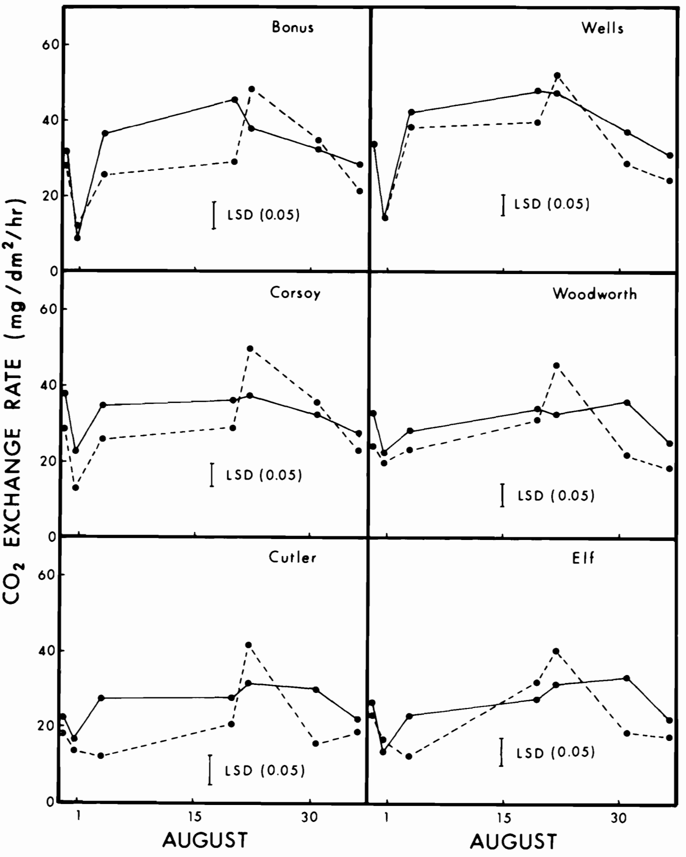

FIGURE 2. Seasonal trend of CO_2-exchange rates for six soybean cultivars in sheltered (solid line) and exposed (broken line) plots during 1979 growing season.

TABLE II. Mean monthly plant height (cm) and dry matter (g/m^2) production in sheltered and exposed soybeans.

	Plant height		Plant dry matter	
Month	Exposed	Sheltered	Exposed	Sheltered
June	10.9a*	11.7a	20.8a	24.0a
July	31.9a	38.6b	214.4a	251.0b
August	73.0a	90.3b	543.8a	568.3b
Average	38.6a	46.9b	259.7a	281.1b

*Means in rows under plant height or dry matter followed by different letters are significantly different at the 5% level using LSD.

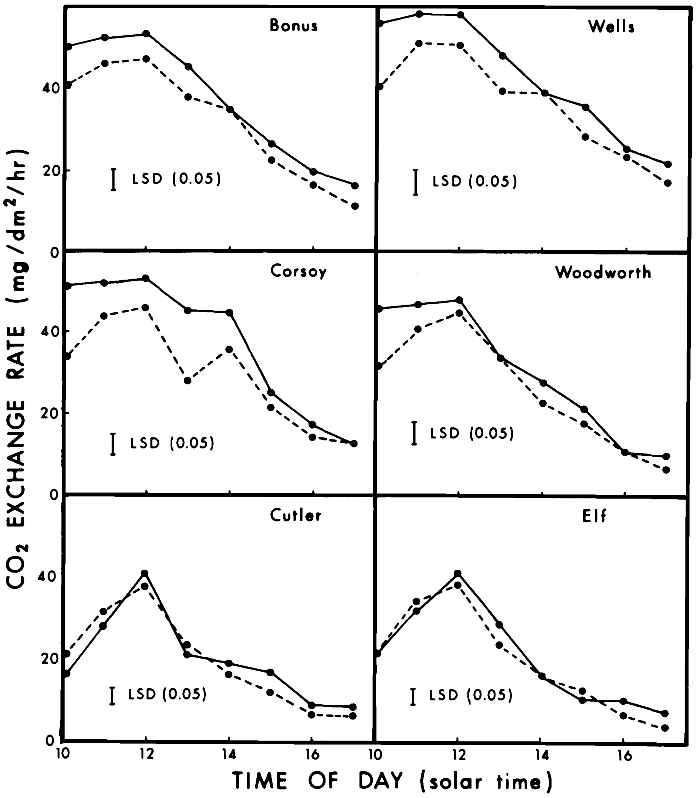

FIGURE 3. Diurnal trend of CO_2-exchange rates of top, fully expanded, canopy leaves of soybean cultivars in sheltered (solid line) and exposed (broken line) plots on August 21, 1979.

TABLE III. Mean CO_2-exchange rate ($mg/dm^2/hr$) of soybeans in windbreak-sheltered and exposed plots.

	Mean CO_2-exchange rate	
Variety	Exposed	Sheltered
Bonus	28.4a*	31.4b
Corsoy	27.5a	31.9b
Cutler	19.7a	24.8b
Wells	32.6a	35.4b
Woodworth	25.7a	29.5b
Elf	22.2a	24.1b

*Means in rows followed by different letters are significantly different at the 5% level using LSD.

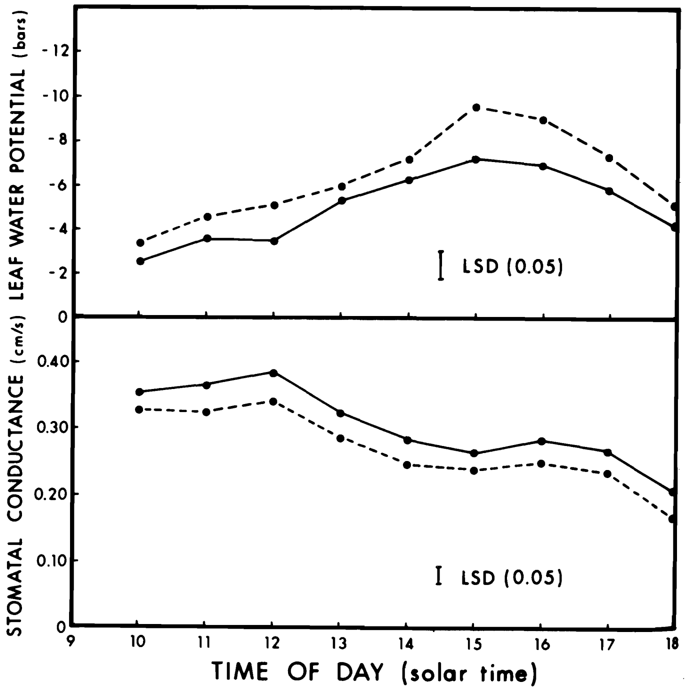

FIGURE 4. Diurnal trends of leaf water potential and stomatal conductance of sheltered (solid line) and exposed (broken line) "Bonus" soybeans on August 21, 1979.

In the study reported here, CER of top, fully expanded, canopy leaves varied between 4 and 58 mg/dm^2/hr. Cultivar differences in CER of top canopy leaves of soybeans have been estimated to range from 8 to 65 mg/dm^2/hr (Curtis, Ogren, and Hageman, 1969; Dornhoff and Shibbles, 1970). These differences have been ascribed to the differences between cultivars in stomatal and mesophyll resistance to CO_2 diffusion (Dornhoff and Shibbles, 1970), and in photorespiration (El-Sharkawy and Hesketh, 1965).

The results of this study clearly established greater CER in sheltered than in exposed soybean plants. This was a consequence of greater Ψ_L, stomatal conductance, and better canopy light climate. Cultivar selection on the basis of the above responses to shelter should lead to increased exploitation of the benefits of the windbreak microclimate for soybean production.

REFERENCES

Brown, K. W., and N. J. Rosenberg. 1972. Shelter effects on microclimate, growth and water use by irrigated sugar beets in the Great Plains. *Agricultural Meteorology,* 9(3/4):241-263.

Clegg, M. D., C. Y. Sullivan, and J. D. Eastin. 1978. A sensitive technique for the rapid measurement of carbon dioxide concentration. *Plant Physiology,* 62(6):924-926.

Curtis, P. E., W. L. Ogren, and R. H. Hageman. 1969. Variety effects in soybean photosynthesis and photorespiration. *Crop Science,* 9(3):323-327.

Dornhoff, G. M., and R. M. Shibbles. 1970. Varietal differences in net photosynthesis of soybean leaves. *Crop Science,* 10(1):42-45.

El-Sharkawy, M., and J. Hesketh. 1965. Photosynthesis among species in relation to characteristics of leaf anatomy and CO_2 diffusion resistance. *Crop Science,* 5(6):517-521.

Hanway, J. J., and H. E. Thompson. 1971. How a soybean plant develops. *Iowa State University of Science and Technology Special Report,* 53:1-17.

Johnson, T. J., J. W. Pendleton, D. B. Peters, and D. R. Hicks. 1969. Influence of supplemental light on apparent photosynthesis, yield and yield components of soybeans (*Glycine max* L.). *Crop Science,* 9(5):577-581.

Miller, D. R., N. J. Rosenberg, and W. T. Bagley. 1973. Soybean water use in the shelter of a slat-fence windbreak. *Agricultural Meteorology,* 11(3):405-418.

Ogbuehi, S. N., and J. R. Brandle. 1979. Windbreak effects on soybean growth, canopy structure and light relations. *Agronomy Abstracts,* 1979:14.

Scholander, P. F., H. T. Hammell, E. D. Bradstreet, and E. A. Hemmingsen. 1965. Sap pressure in vascular plants. *Science,* 148(3668):339-346.

Skidmore, E. L., L. J. Hagen, D. G. Naylor, and I. D. Teare. 1974. Winter wheat response to barrier-induced microclimate. *Agronomy Journal,* 66(4):501-505.

Sullivan, C. Y., M. D. Clegg, and J. M. Bennett. 1976. A new portable method for measuring photosynthesis. *Agronomy Abstracts,* 1976:77.