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## KANSAS

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### *Elevated Carbon Dioxide: Soil and Plant Water Relations.*

M.B. Kirkham.

I have finished writing a book entitled ***Elevated Carbon Dioxide: Soil and Plant Water Relations***, now being considered for publication by Wiley-Blackwell. The book is developed from research that we in the Evapotranspiration Laboratory at Kansas State University did between 1984 and 1990 with field-grown sorghum, winter wheat, and rangeland plants under elevated carbon dioxide. Such experiments had not been done before in the semiarid Great Plains of the U.S. The rising levels of carbon dioxide in the atmosphere were of interest to the Department of Energy, which funded our work.

As the years have passed, the carbon dioxide levels in the atmosphere have increased, along with increasing interest concerning their effects. The carbon dioxide concentration in the atmosphere was first recorded by Charles D. Keeling (1928–2005) of the Scripps Institution of Oceanography, University of California, San Diego. He monitored it beginning in 1957 at Mauna Loa, Hawaii, and in Antarctica at the South Pole. In the 50-year period between 1958 and 2008, the carbon dioxide concentration in the atmosphere increased from 316 ppm to 385 ppm. Because no book documents soil- and plant-water relations under elevated carbon dioxide, I wrote this book to put the information in one source. It has been 26 years since we started our first experiments (1984–2010), so we can make some predictions, based on our early results, about how plants in the semiarid Great Plains of the U.S. are responding to elevated carbon dioxide, which has increased 55 ppm (from 330 ppm to 385 ppm) during this time.

Water and carbon dioxide are the two most important compounds affecting plant growth. In introductory botany textbooks, we have seen the familiar equation for photosynthesis, which shows carbon dioxide ($CO_2$) joining with water ($H_2O$), in the presence of light and chlorophyll, to form sugar ($C_6H_{12}O_6$) and oxygen ($O_2$), as follows:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$$

Life on earth would not be possible without photosynthesis. We survive because of the oxygen produced by photosynthesis, as well as the food (sugars) produced by photosynthesis. Therefore, it is of critical importance to look at the water relations of plants under elevated carbon dioxide.

The book is technical and is based on information from peer-reviewed journal articles. I have written the book as if I were speaking to my graduate students and is organized as follows. I start with an introductory chapter dealing with drought, because it is predicted that the central Great Plains, where Kansas is located, will become drier as the carbon dioxide concentration in the atmosphere increases. In this chapter, I give a preliminary overview of the three types of photosynthesis: C3, C4, and Crassulacean acid metabolism.

The book then takes the water from the soil through the plant and out into the atmosphere. This is the way that water moves through the soil–plant–atmosphere continuum. Four chapters deal with soil. After I discuss soil and elevated carbon dioxide, I move the water into the root. One chapter deals with elevated carbon dioxide and root growth. And the following chapter deals with the effects of elevated carbon dioxide on plant water potential, osmotic potential, and turgor potential. Then the next two chapters deal with stomata under elevated carbon dioxide. Next, I take the water out of the plant into the atmosphere and discuss the effects of elevated carbon dioxide on transpiration, evapotranspiration, and water use efficiency. One chapter compares C3 and C4 plants under elevated carbon dioxide and goes into detail about C4 photosynthesis, its advantage, and how it has evolved. One chapter deals with plant anatomy under elevated carbon dioxide focusing on xylem (including wood), because this is the tissue that carries water in plants. One chapter deals with phenology and how elevated carbon dioxide affects it. The final chapter deals with growth of many different kinds of plants under elevated carbon dioxide and well-watered conditions.

Here follows a brief summary of the effects of elevated carbon dioxide on soil and plant water relations. The key factor is stomatal closure under elevated carbon dioxide. Stomata are extremely sensitive to the concentration of carbon dioxide in the atmosphere and close when the concentration increases. For example, in our first study, with grain sorghum in 1984, we elevated the atmospheric carbon dioxide 155 ppm above ambient. During that season, the average stomatal resistance of the plants under the ambient concentration (330 ppm) was 0.86 s/cm, wereas under elevated concentration (485 ppm), the stomatal resistance was 0.97 s/cm, an increase of 13%. When the stomata close, transpiration and evapotranspiration are reduced, resulting in more water in the soil. Less water is needed to produce a certain amount of grain, so water use efficiency is increased under elevated carbon dioxide. With an increased soil water content under elevated carbon dioxide, the plants have more water for uptake, and this results in an increased (less negative) plant water potential. Even though stomata close, the elevated carbon dioxide still stimulates growth, and consequently yield is usually increased under elevated carbon dioxide. When drought occurs, the elevated carbon dioxide often compensates for reduction of growth due to the drought stress. In our three-year (1984–1987) experiment with winter wheat, the grain yield of wheat under drought (half field capacity) and elevated carbon dioxide (825 ppm) was the same as the grain yield of wheat under well-watered conditions (field capacity) and ambient carbon dioxide (340 ppm). The year-to-year increase in wheat yields that have been observed over the last 50 years may be related in part to the increased carbon dioxide concentration in the atmosphere.

## *News.*

Master's degree graduate student, Nicole A. Rud, graduated in December, 2009, and is now pursuing a Ph.D. at the University of Toledo in Ohio. Her results showed that one cause of the physiological disorder, edema, which occurs under greenhouse conditions, is a lack of ultra-violet light. When she added UV-B light back to tomato plants grown in a greenhouse (UV-B light is filtered out by the glass of the greenhouse), the plants developed no edema.

Ms. Kalaiyarasi Pidaran (kalai@ksu.edu), started work toward the master's degree in the autumn of 2009. She is working jointly under the direction of M.B. Kirkham and R.M. Aiken. She is studying growth of sorghum under different planting patterns (clumped versus a standard row spacing).

Ms. Rattiypaorn Jaidee, a Ph.D. student at the University of Khon Kaen in Khon Kaen, Thailand, spent six months (July–December, 2009) in the laboratory of M.B. Kirkham. She studied the effect of drought on the uptake of phosphorus by two cultivars of soybean, a traditional Thai cultivar and a commercially developed cultivar.

## *Publications.*

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## *Notice of release of KS11WGGRC52-J AND KS11WGGRC52-O leaf rust and stripe rust resistant hard red winter wheat germ plasms.*

The Agricultural Research Service, U.S. Department of Agriculture and the Kansas Agricultural Experiment Station announce the release of KS11WGGRC52-J AND KS11WGGRC52-O hard red winter wheat (*T. aestivum* L.) germ plasm with resistance to leaf rust and stripe rust for breeding and experimental purposes. Scientists participating in this development were Vasu Kuraparthy, Crop Science Department, North Carolina State University, Raleigh, NC 27695; Parveen Chunneja, Department of Genetics & Biotechnology, Punjab Agricultural University, Ludhiana, Punjab, India; Shilpa Sood, Crop Science Department, North Carolina State University, Raleigh, NC 27695; H.S. Dhaliwal, Biotechnology department, Indian Institute of Technology, Roorkee, Uttaranchal, India; Deven See, USDA–ARS Western Regional Small Grains Genotyping Laboratory, Washington State University, Pullman, WA 99164-6420; and Duane Wilson and B.S. Gill, Wheat Genetic and Genomic Resources Center, Department of Plant Pathology, Kansas State University, Manhattan, KS 66506.

KS11WGGRC52-J and KS11WGGRC52-O are derivatives of WL711 (TA5602) with the rust resistance genes *Lr57* and *Yr40* in the form of a wheat-goat grass (*Ae. geniculata*) recombinant chromosome T5DL·5DS-5M$^g$S(0.95). The recombinant chromosome consists of the long arm of wheat chromosome 5D, most of the short arm of 5D, and a small distal segment derived from the short arm of the *Ae. geniculata* chromosome 5M$^g$ harboring *Lr57* and *Yr40*. KS11WGGRC52-J is derived from the cross 'WL711 (T5DL·5DS-5M$^g$S(0.95)/3*Jagger'. KS11WGGRC52-O is derived from the cross 'WL711 (T5DL·5DS-5M$^g$S(0.95)/3*Overley'. The F4-derived families are homozygous for *Lr57* and *Yr40* but segregating for other traits.

Small quantities (3 grams) of seed of KS11WGGRC52-J and KS11WGGRC52-O are available upon written request. We request that the appropriate source be given when this germ plasm contributes to research or development of new cultivars. Seed stocks are maintained by the Wheat Genetic and Genomic Resources Center, Throckmorton Plant Sciences Center, Kansas State University, Manhattan, KS 66506. Genetic material of this release will be deposited in the National Plant Germplasm System where it will be available for research purposes, including the development of new cultivars.

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