Water Currents

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Dear Reader:

Breeding plants for drought tolerance is a very important activity in Texas. Of all the major agricultural states, Texas can expect to have bigger shifts than any other state in cropping practices in the next 20 years. These changes are due to the decline in available irrigation water. The impact they will have on production depends to a great extent on the kinds of plants bred to offset the lack of water.

Scientists working on drought tolerance are prevalent within The Texas Agricultural Experiment Station (TAES). They work primarily with wheat, cotton, and grain sorghum. These important crops to Texas agriculture are noted for their ability to grow under adverse moisture conditions.

Shifts in crop production to those parts of the state with enough rainfall to produce crops without irrigation is becoming increasingly important as energy costs increase and water availability decreases. To many of us in agricultural research, it appears that agriculture in the rainfed areas of the state having more than 25 or 30 inches of rainfall will become more intensive in the future.

In addition to the breeding of plants for drought tolerance, agronomic production practices are also important. It is well known, for example, that sorghum following sorghum yields less than sorghum grown on land following any one of a number of other crops.

A production agronomy team recently assembled in the Department of Soil and Crop Sciences, Texas A&M University, has as one of its primary objectives to design cropping systems which more adequately use the soil and water resources of each unit of land. The team will concentrate on that part of Texas having 25 or more annual inches of rainfall.

Drought tolerance in crops is very important for the well-being of Texas agriculture in the years ahead. The TAES plant breeding, plant physiology, tissue culture, and production agronomy areas are geared to provide information for agricultural producers here in Texas.

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Sorghum for Texas

What causes one plant to survive and produce during a dry season while another plant withers and dies?

This question is a common one asked by Texas Agricultural Experiment Station scientists. Their answers to the question of drought tolerance have helped increase and stabilize dryland crop production in Texas and have reduced the water requirements of irrigated crops.

Reducing the effects of drought on crop yield continues as a major research commitment of The Texas Agricultural Experiment Station, the agricultural research arm of the Texas A&M University System. Efforts to improve the drought tolerance of grain sorghum currently underway in various scientific disciplines and research centers across the state is a good example of this commitment.

Sorghum improvement is already one of the research agency's most impressive success stories. As much as 75 percent of all the sorghum breeding material used by private plant breeders in the world today contains germplasm derived directly from lines developed in the TAES sorghum improvement program.

Significant breakthroughs by TAES research in the past provide current Texas sorghum growers shorter, earlier maturing, and more disease and insect resistant plants. TAES research has also developed the technology required to handle, store, process and use the grain produced.

Because of breeding improvements, dryland yields of sorghum in Texas have doubled since the 1950's. Continued improvement in yields, according to TAES plant breeder Fred Miller, is possible through the addition of new lines from the Sorghum Conversion Program. The program, a joint venture by The Texas Agricultural Experiment Station and the U.S. Department of Agriculture, converts tropical sorghum varieties from all over the world to varieties able to produce acceptable yields in Texas' temperate climate.

Miller and TAES scientists Darrell Rosenow, Wayne Jordan, and Roberta Smith all have research projects designed to offer sorghum growers in Texas a better chance in seasons of below average rainfall. Their research projects and locations show the diversity in scientific methods and study environments of the many TAES researchers working on drought tolerant sorghum.

RATING PLANTS

Rosenow, a crop scientist stationed at the TAES research center in Lubbock, works in areas where dry summers are all too familiar. He studies the effect of water stress on different grain sorghum varieties planted in TAES research fields near Lubbock, Halfway, Big Spring, and Chillicothe.

In order to study sorghum response to moisture stress, Rosenow manipulates the amount of moisture his test plants receive at different stages of growth. He and Charles Wendt, TAES soil scientist at the Lubbock research center, block rainfall from test plots with rainfall shelters and irrigate plots at specific growth stages of development.

Rosenow and Wendt have identified two distinct responses in moisture stressed sorghum plants. They base responses on the stage of growth when stress occurs. One response occurs during the pre-flowering stage while the other is after flowering during grain development. So far, no sorghum lines tested have shown good tolerance to stress at both stages of growth.

Rosenow judges drought tolerance by visually rating sorghum plants growing in test fields. He has developed a rating system to describe how a plant reacts to moisture stress at different stages of maturity. During the pre- flowering stage, Rosenow gives a "one" to a plant showing no leaf stress symptoms such as rolling, excessive erectness, bleaching, or burning. He rates a plant a "five" if it is dead or near death. For stress response at the post- flowering stage, he rates a plant "one" if it is completely green and "five" if it has died prematurely.

Rosenow has found many more lines possessing good pre-flowering tolerance than good post-flowering tolerance. He has crossed lines with the two types of drought tolerance and is attempting to develop sorghum lines that can tolerate moisture stress before flowering as well as during grain development.

EXPLAINING WHY

Jordan, a crop physiologist, concentrates his research efforts on explaining why sorghum varieties react differently to moisture stress. Working in greenhouses and in test plots at the TAES Blackland Research Center near Temple, Jordan looks at characteristics of sorghum plants such as root systems and leaf structure. He evaluates how these characteristics might help a grain sorghum plant cope with limited water situations.

These characteristics help a plant tolerate drought in one of three ways, according to Jordan. They help a plant avoid stress times, extract water from the soil, or retain moisture.

A sorghum plant can avoid periods of water stress by maturing before the hottest, driest time of the summer. Fast maturing plants generally have more moisture available in the soil profile during the growing season. They also tend to lose less moisture to the atmosphere because of cooler, shorter days and shorter growing time.

Jordan also looks for differences in sorghum root systems which influence a plant's ability to withstand periods of low rainfall. He has found that an increased rooting density at deeper levels allows a plant to extract greater quantities of water from the soil.

Jordan's research also includes physical characteristics of sorghum leaves and how they affect the way a plant responds to drought. He studies the thickness of a natural layer of wax on sorghum leaves to determine its effect on the amount of moisture the plant loses to the atmosphere. Leaves growing at an upright angle, he feels, may reduce moisture loss compared with leaves more exposed to sunlight and heat. He evaluates the leaf temperature or the leaf resistance to drying as other ways to determine a sorghum variety's response to drought.

Jordan works closely with Fred Miller, located in College Station. Miller has found that sorghum varieties with solutes such as sugar or amino acids in the plant tissues are more drought tolerant than varieties without these solutes. He is currently investigating the possibility that the presence of sugar in the sorghum stem and roots could increase a plant's ability to extract moisture from the soil.

"Our goal," explains Jordan, "is to help sorghum breeders make use of some of the nonvisible plant traits which may increase drought tolerance."

TEST TUBE GARDEN

Roberta Smith, plant physiologist, studies tiny sorghum plants in a laboratory on the Texas A&M University campus at College Station. She carefully monitors light, temperature, and humidity in her test tube garden.

Smith's research is in tissue culture - a technique where plant parts are isolated in sterile test tubes and encouraged to form new plants.

To begin a cultured sorghum plant, Smith cuts a sorghum seed so that it will form a callus, a wound response tissue, as the seed germinates. She removes the callus from the seed and places the callus in a test tube containing a liquid medium. Filter paper holds the callus above the medium, but allows it to draw nourishment from the precisely mixed medium containing nutrients, hormones, and vitamins.

After one or two months of growth, the callus may be divided and placed in several test tubes. These tubes contain a different type of medium, a gelled formula specially mixed with plant hormones to encourage formation of new plants.

If the callus part develops into a plant with visible roots and leaves, Smith moves it into a tube with potting soil (vermiculite) to gain strength. She then transplants it into a pot to mature and produce seed in a greenhouse.

A plant Smith cultures from the callus may or may not show differences from the parent plant. Her research is to determine if plants grown from the callus differ from the original seed-derived plants and, if so, how this difference can improve the drought resistance of present sorghum varieties.

One of the promising aspects of culturing plants from tissue, according to Smith, is the possibility of screening plants for such things as disease resistance and stress tolerance. This screening could take place in the laboratory instead of the greenhouse or test field and could significantly reduce costs and years of screening time.

Smith is quick to point out, however, that techniques and applications are not yet fully understood in this rapidly developing field of research. She does hope, however, to be able to answer some of the questions concerning the use of tissue culture in breeding sorghum for drought tolerance.

SORGHUM POWER

Although the sorghum improvement program conducted by The Texas Agricultural Experiment Station is in many stages of development and in many specialized areas, it remains a well coordinated effort. TAES scientists such as Miller, Rosenow, Jordan, and Smith work with sorghum in very different ways, but strive toward a common goal: to offer Texas sorghum producers plants more tolerant of Texas' undependable rainfall.

The full potential of sorghum in Texas, according to TAES researchers, is yet to be developed. Demand for the grain used as both human and livestock food in most parts of the world will certainly increase in the future. Sorghum is also a potential source of energy, building materials, and paper products.

A relatively drought tolerant crop, sorghum is already the number one grain crop in the state. As TAES researchers improve its ability to produce in seasons of below average rainfall, sorghum will surely grow in popularity with Texas producers.

Consider the Cowpea

Farmers tired of pouring water on thirsty crops might do well to consider the cowpea.

Creighton Miller, vegetable breeder and interim head of the Horticultural Sciences Department at Texas A&M University, predicts cowpeas will become a more attractive alternative for Texas producers as water for irrigation declines in availability and increases in cost. His arguments for the cowpea are convincing.

Cowpeas need little or no irrigation to produce a successful crop in most years even in areas with as little as 20 inches average annual rainfall. Miller has found some cowpea varieties which can produce with as little as two inches of rainfall during the growing season if preplant soil moisture is adequate.

Cowpeas convert nitrogen from the atmosphere for their own use so they require little additional fertilizer. This economic benefit of cowpeas is sure to increase because of energy costs involved in producing synthetic fertilizers.

Cowpeas produce in poor soil. They also add valuable nitrogen to fields where they are plowed into the soil as a green manure.

Cowpeas provide an important source of protein in many developing nations of the world and are a potential export commodity for the U.S.

Cowpeas are easily digested. Native Texans know them as black-eyed, crowder, or cream peas and eat them with cornbread.

Cowpeas are an inexpensive, nutritious livestock feed.

Of the 40,000 acres of cowpeas planted in Texas each year, according to Miller, 65 percent are grown for human consumption. Only 10 percent are harvested as green shelled peas while 55 percent are harvested as dry cowpeas. The remaining 35 percent are plowed back into the soil as soil builder.

Miller explains that production of cowpeas has declined in Texas since 1936 when over one million acres were planted. Improved forages and other legumes such as soybeans have replaced cowpeas, but these species require more water and fertilizer - both high energy users - than do cowpeas. Miller feels that the cowpea may regain some of its former popularity as water supplies in the state decline and as energy costs increase.

Miller conducts research as part of a joint TAES-U.S. Agency for International Development program to identify cowpea varieties with exceptional ability to produce during dry seasons. He points out that even though the cowpea is considered a drought tolerant species, cowpea varieties differ in their response to water stress. Miller hopes that this finding will provide information for breeding cowpea varieties with superior drought resistant qualities.

He has plenty of varieties from which to choose. There are 8,000 different varieties of cowpeas identified and collected at the International Institute of Tropical Agriculture in Nigeria.

Miller bases his research on a rather simple definition of drought resistance. "You can go in and use a lot of fancy instruments to describe drought resistance mechanisms - and we do," says Miller. "But the ultimate test to see if a plant is drought resistant is whether the plant will or will not produce either seed or biomass under drought conditions." He uses two criteria to identify a drought resistant cowpea variety: (1) production with less than optimal available moisture and (2) difference between dryland and irrigated yields.

An important aspect of Miller's study is to determine how drought resistance affects the plant's ability to fix nitrogen. The cowpea plant naturally forms nodules on roots in which atmospheric nitrogen is changed into a form that the plant can use.

He looks for cowpea varieties with superior drought resistance and also with superior nitrogen fixing potential. It is important to a plant breeding program, he says, to understand the relationship between a plant's ability to resist drought stress and its ability to fix and assimilate nitrogen.

As do so many TAES projects, Miller's research serves as a training ground for TAMU graduate students learning to conduct plant research. David Walker is a graduate student of horticulture currently working under Miller's direction. Walker, who is from Munday, Texas, began his interest in plants and in research as a high school student working summers in the TAES test fields around the Munday vegetable research center.

Miller and Walker, along with a second graduate student Doug Smallwood, have evaluated cowpea plants in irrigated plots, in powdery dry research fields near Lubbock, in greenhouses on the TAMU campus, in plastic growth pouches, and in test plots at College Station covered with a plastic sheet to keep rainfall from reaching plant roots.

Smallwood studies the response of cowpeas grown with limited moisture over 24-hour periods and over entire growing seasons.

Walker, as part of his graduate program, has measured the difference in weight of plants grown under irrigation and other plants of the same variety grown with only natural rainfall. He found that some of the varieties planted on irrigated and dryland test plots at the TAES Lubbock research center differed by as much as 94 percent between the irrigated and non-irrigated plants.

From this evaluation, Walker identified 14 varieties which seemed most drought resistant and 16 cowpea varieties most likely to wither and die during a dry period. To check his findings, Walker planted the 30 varieties he identified as the best and the worst drought resistant cowpeas this spring. He now protects these plants from rainfall and carefully monitors the moisture the plants receive. This fall, Walker will report his findings which he hopes will not only earn him a PhD degree from Texas A&M University, but will also help plant breeders develop a cowpea plant able to produce in the driest of Texas summers.

Miller will direct other graduate students and will continue his TAES research on cowpeas. His research goal is to develop cowpea varieties as a stable crop for Texas producers in areas where annual rainfall cannot support more traditional crops and where there is no longer a cheap source of irrigation water.

Ripples & Waves

Plant breeding to reduce the risks in dryland or limited irrigation production is a major research objective of The Texas Agricultural Experiment Station. Scientists at research centers throughout Texas search for plants able to produce in spite of Texas' undependable rainfall. The following are examples of current or completed projects.

Stephen Winter looks for ways to evaluate crops for drought resistance at the Bushland center. He also studies soil water extraction and seedling root growth rates of sugar beets, wheat, and soybeans.

L. S. Bird, in the plant sciences department on the Texas A&M University campus, works to adapt cotton to resist environmental stresses including lack of adequate moisture.

A special TAES study conducted in cooperation with the Volcani Ctr., Bet Dagan, Israel, and the U.S. Department of Agriculture, helps evaluate the use of aerial infrared photography to detect drought stressed crops.

Charles Wendt's research at Lubbock looks at grain sorghum, cotton, and millet to determine if differences exist between species in the amount of water a plant can extract from the soil.

Even in Beaumont, where the average rainfall is 56 inches, TAES researchers are concerned with production during periods drier than normal. J. W. Stansel studies the effects of drought on rice and Glenn Bowers looks at breeding soybeans for drought tolerance at the Beaumont research center.

TAES scientist James Read studies tall fescue grass in the forage improvement program at the Dallas research center. Tall fescue is a popular cool season perennial grass in Texas, but currently it lacks drought and heat tolerance.

Cotton improvement is the research focus of John Gannaway at Lubbock. He hopes to find ways to improve insect resistance, disease resistance, and fiber quality of cotton grown under limited irrigation or dryland conditions.

TAES plant breeder Ken Porter studies ways to improve yields of small grains such as wheat, barley, and oats under dryland conditions at the Bushland research center.

C. J. Gerard, soil physicist at the TAES Chillicothe-Vernon research center, screens sorghum and wheat varieties for drought tolerance. Using a sprinkler irrigation system, he applies graduated amounts of water to each test variety in order to compare performances under different moisture levels.