Squeezing more crop from every drop

By Don Comis, Agricultural Research Service, USDA

Agricultural Research Service scientists at Fort Collins, Colorado, are helping to usher farmers worldwide into an age of increasingly limited water supplies for irrigation.

Says Laj Ahuja, research leader of the Agricultural Systems Research Unit, "Making the best use of irrigation water is extremely important to balancing the needs of the farm sector and a growing human population.

With the increasing complexities of modern agriculture due to environmental concerns and more frequent droughts, we need to optimise the use of limited water, as well as nitrogen and other inputs, for varying weather conditions."

International collaboration to save water and nitrogen

Ahuja has been involved in a series of three studies with computer models backed by field experiments in areas of increasingly limited and erratic rainfall and irrigation water: Two studies were in wheat-corn double-cropping systems in the North China Plain area, and one was in northeastern Colorado corn fields in the US Great Plains.

The studies were geared towards determining when and how much to irrigate so water and nitrogen could be saved while optimising yields. The computer models used long-term local weather data to provide recommendations for optimal water and nitrogen use in each area.

Ahuja and colleagues focused on irrigations triggered either by growth stages or by declining levels of soil moisture. Soil probes were used to detect soil moisture levels.

For the North China Plain studies, Ahuja and Fort Collins colleagues teamed up with Quanxiao Fang at China's Qingdao Agricultural University and the Chinese Academy of Sciences. In a study using four irrigation levels based on the Fort Collins crop-growth-stage method, the scientists found that with limited irrigation, it was best to skip the traditional preplanting irrigation for wheat.

Crop simulations in China relied on local weather data from 1961 to 1999. The simulations showed that there would still be adequate water in the wheat fields from heavy rains the previous corn season.

"We also found it best to use 80 per cent of the water for the two critical wheat growth stages and only 20 per cent at corn planting," Ahuja says. This promises the highest yields, the best water-use efficiency, and the least water drainage overall for the two crops.

The critical growth stages for wheat are stem extension and booting. Booting is when the wheat head is about to emerge from the top leaf sheath of the stem.

The stem-extension stage is crucial because that is when the last leaf emerges, the one that contributes most nutrients to the developing grains that eventually contribute to yield.

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ARS agricultural engineers Tim Green (left), Walter Bausch (centre), and Laj Ahuja adjust the height of solar radiation instruments to one metre above the corn canopy. Wind is measured at two metres. (PHOTO: Stephen Ausmus)

ARS agricultural engineers Walter Bausch (foreground), Gerald Buchleiter (right), and Laj Ahuja evaluate the distinct differences in wheat growth at full irrigation (right side) and 40 per cent of full irrigation. (PHOTO: Stephen Ausmus)

◁13…MORE CROP PER DROP

Irrigate later, fertilise less

The scientists also found that North China Plain farmers can delay their first irrigations until the water in the top 45 cm (18 inches) of soil is 50 per cent depleted. And when they do irrigate, it's best to recharge or refill the land only partly, to no more than 70 per cent capacity.

Ahuja and colleagues came up with these findings by combining the ARS Root Zone Water Quality Model (RZWQM) with the Decision Support System for Agrotechnology Transfer (DSSAT) crop-growth modules. This produced a hybrid model, named RZWQM2.

They then did two years of field experiments with four irrigation levels, in China, based on crop growth stages. They used the data to calibrate the hybrid model.

Ahuja says, "While the combination of models has been used in other experiments to test alternative water- and nitrogen-management practices, this is the first time the models have been used to evaluate crop responses to lack of water across critical crop-growth stages and the first to use long-term weather data."

In a second study in the North China Plain, Ahuja and colleagues did two years of field experiments with four different nitrogen fertiliser levels. They used the results to validate RZWQM2.

The long-term simulation with 38 years of weather data showed that North China Plain farmers should apply no more than 200 kg per hectare (180 lbs/acre) of nitrogen fertiliser to get the best yields for winter wheat followed by corn.

Those farmers usually use about 300 kg per hectare (270 lbs/acre).

The model results indicate that cutting back nitrogen fertiliser use by one-third would reduce nitrate leaching by 60 per cent without affecting crop yields.

Weather records back to 1912

In Colorado, ARS researchers from Fort Collins and Akron used the DSSAT model to look at corn produced either with or without irrigation. They used local historical weather records from 1912 through 2005. Their field data came from eight years of experiments.

The results were similar to those in China in terms of favouring crop-growth stages with irrigation water:

- When simulated irrigation water supplies were limited, it was best for yields, water-use efficiency, and minimising nitrogen losses when 20 per cent of the water was used during the vegetative stage of development and 80 per cent was used for the critical flowering and grain-filling stage.
- At the higher irrigation levels, they found it is best in northeastern Colorado to begin the reproductive-stage irrigation on June 22, when tassels initiate but before pollen is shed.
- With very limited water, the simulations showed that farmers would do best to fully irrigate only half a field.
- And farmers could also wait until the plant-available water in the top 45 cm (18 inches) of soil is depleted by 20 to 40 per cent before starting irrigations, depending on soil type.

Crop models aid farmer tech transfer

"Crop-simulation models enable faster and cheaper transfer of technology from research labs and experiment stations to farmers' fields," says Ahuja. He believes that computer models coupled with field experiments are an excellent tool for making the best use of limited water.

"The concepts developed in these studies can potentially be adapted to other locations, climates, and crops. But site-specific recommendations need to be developed for each soil-climate zone using models validated by local experiments. And we will have to do studies based on the various technologies available for triggering irrigations."

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