Identifying Drought Tolerant Cotton Cultivars Using Spectral Reflectance and Canopy Temperature

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Introduction

Water plays a vital role in crop growth and development. Recent concerns associated with climate change effects on crop growth and yield have been increasing worldwide. Adoption of drought tolerant cultivars is one of the adaptation strategies to tackle climate change and water shortage problems. Cotton (Gossypium hirsutum L.) is a drought tolerant crop. However, severe water stress during the growing season could result in devastating impacts on lint yield and quality. Planting drought tolerant cultivars of cotton could significantly improve water use efficiency in regions with water shortage.

The objectives of this research are: 1) test the response of four cotton cultivars to different irrigation regimes in the Texas Rolling Plains and 2) determine the best adapted cotton cultivar to deficit-irrigation and semi-arid conditions using spectral reflectance and canopy temperature measurements.

Methodology

A field study was conducted at the Texas AgriLife Research Station near Chillicothe, TX in 2012 and 2013.

- Split-Split plot design with three replications
- Main Plot treatments: Irrigation (90%ET, 45%RT, dryland, and ET replacement based on a remote sensing strategy)
- Sub-plot treatments: Tillage (conventional and minimum)
- Sub-Sub-plot treatments: Cultivars (FiberMax9170 (FM9170), Deltapine1044 (DP1044), Pytogen375 (PHY375), and Phytogen499 (PHY499).
- Subsurface drip irrigation
- Planting date: 23 May (2012 ,13)
- Soil type: Abilene clay loam
- Plots: 50ft x 8 rows; Row spacing: 1m

Measurements:

- Plant height
- Leaf area index (LAI) using a LAI-2200 plant canopy analyzer (LI-COR Inc., Lincoln, NE).
- Remote sensing data was collected using a CropScan 16 channel multispectral radiometer
- Canopy temperature using a hand-held infrared thermometer (IRtec MicroRay HVAC, Langhorne, PA).
- We calculated the following vegetation indices:
  - Normalized difference vegetation index (NDVI)
    NDVI= (810-665)/(810+665)
  - Normalized difference water index (NDWI)
    NDWI = (831-1160)/(831+1160)
  - Normalized water index (NWI)
    NWI = (940-831)/(940+831)

The Crop water stress index (CWSI) was calculated as:

CWSI = (Tc-Ta)-(Tc-Ta)ll/(Tc-Ta)ul-(Tc-Ta)ll

where Tc is the canopy temperature (°C), Ta is the air temperature(°C). ll and ul refer to lower and upper limits, respectively.

Results

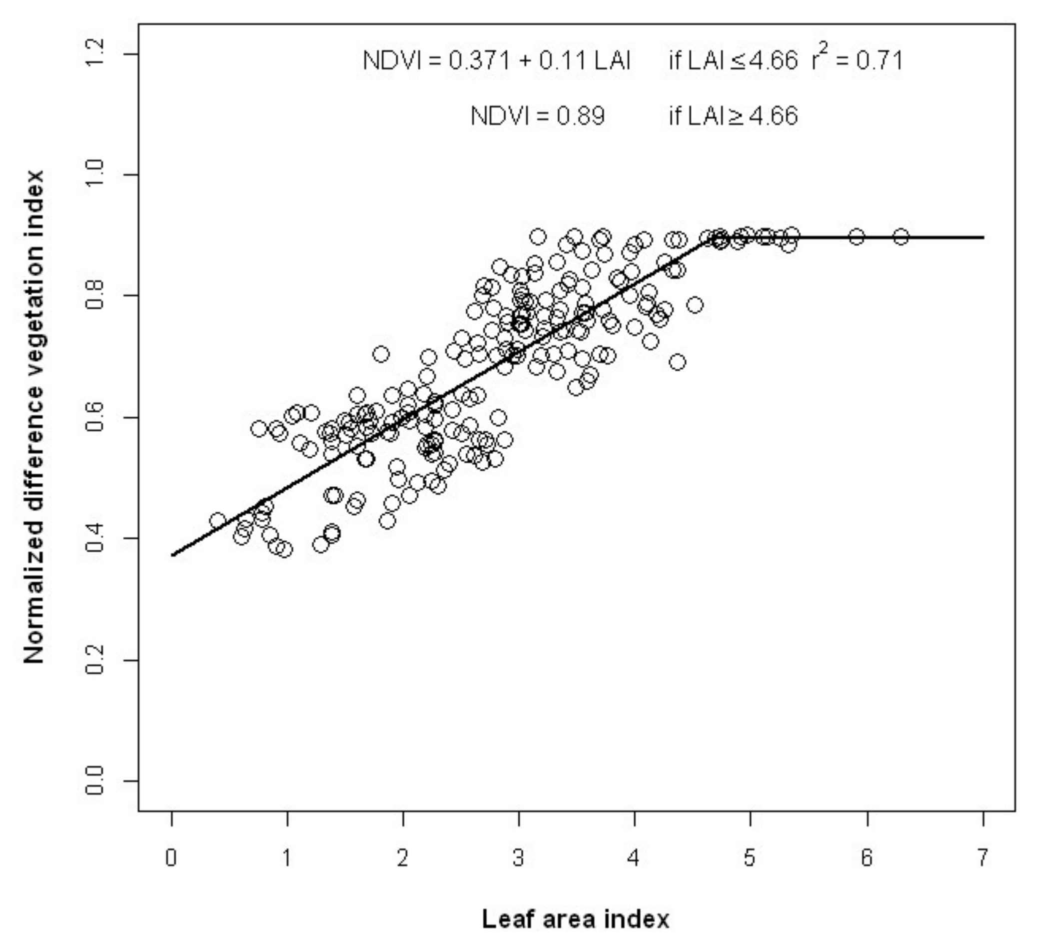

Fig.1. Relationship between leaf area index (LAI) and normalized difference vegetation index (NDVI).

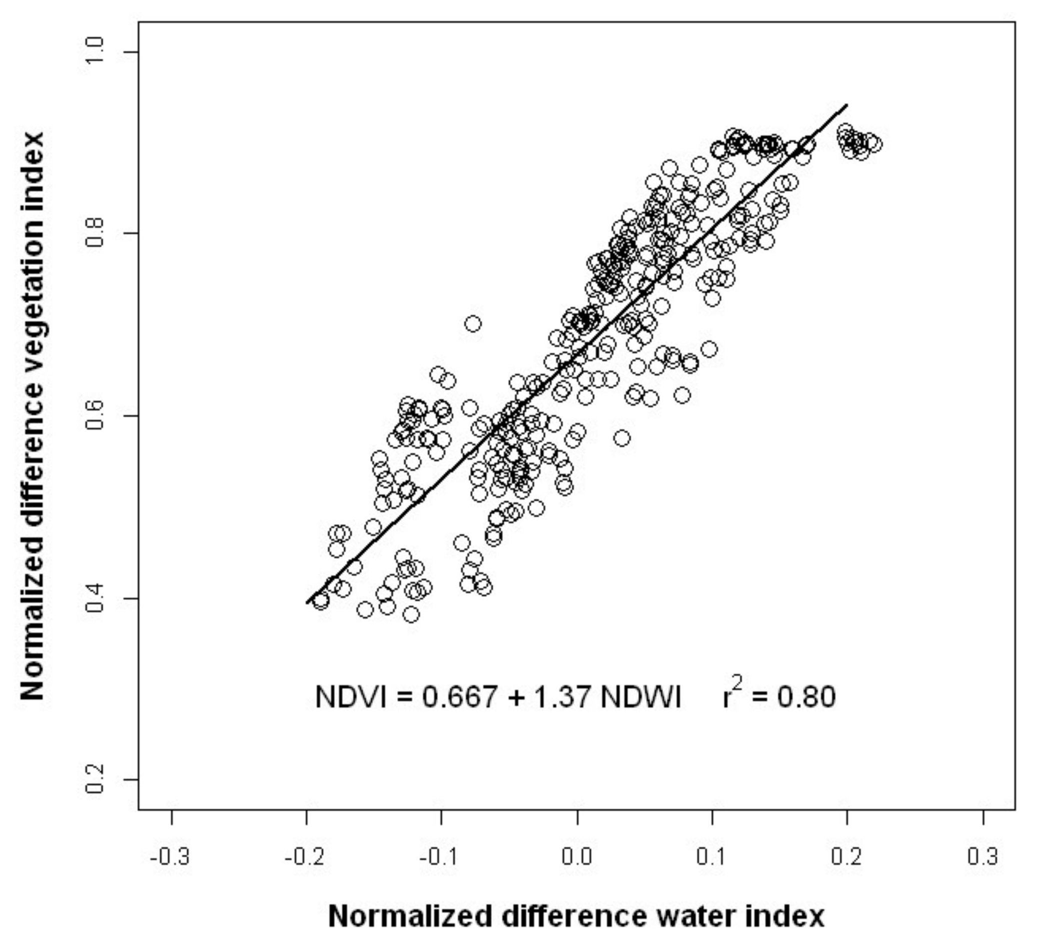

Fig.2. Relationship between normalized difference water index and normalized difference vegetation index.

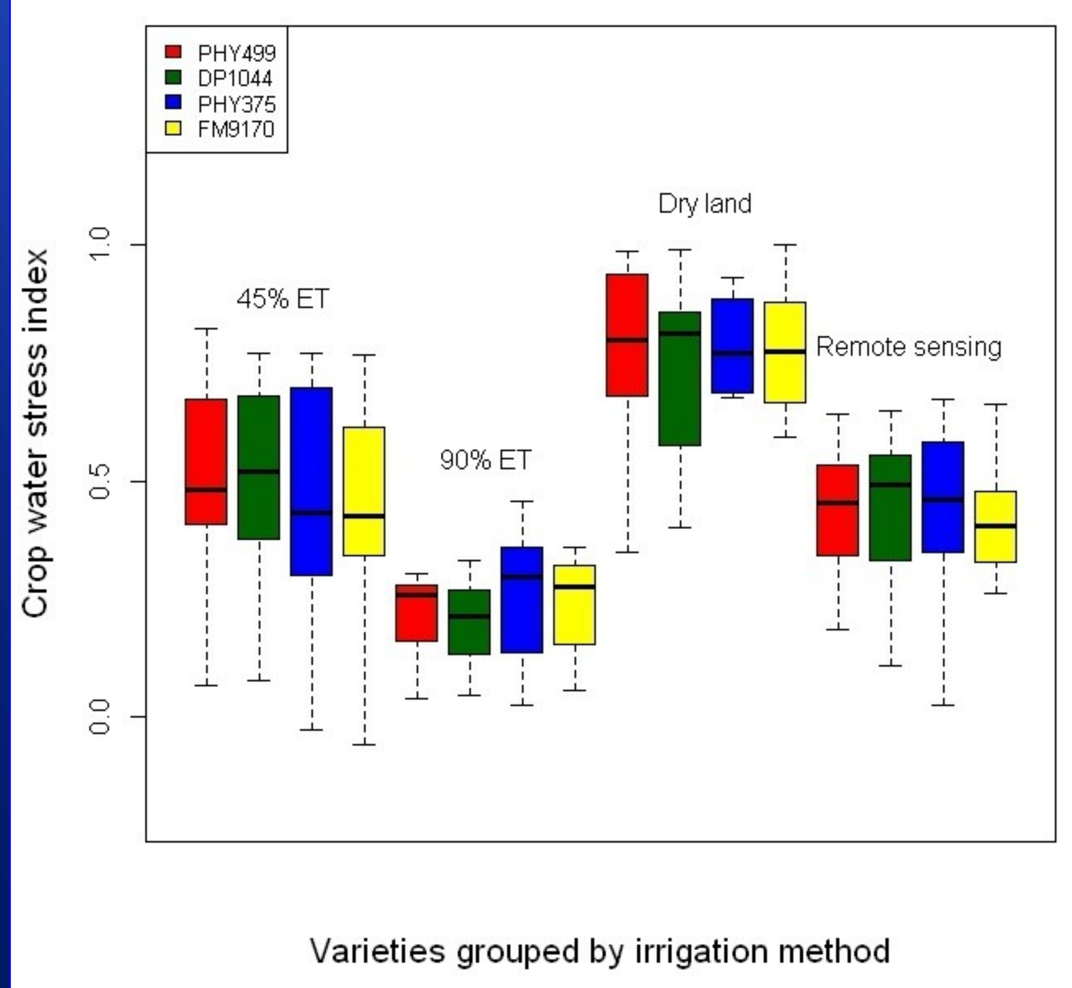

Fig.3. Crop water stress index of cultivars by irrigation method.

- NDVI showed a strong relationship with LAI (r^2=0.71) (Fig. 1).
- As LAI increased, NDVI increased linearly and reached a maximum value of 0.89 when LAI was 4.66. NDVI was insensitive to LAI development beyond this point.
- NDWI had a strong correlation with NDVI (Fig. 2) showing a positive linear relationship (r^2=0.80).
- CWSI varied significantly among irrigation treatments (Fig. 3)
- Figure 4 shows the relationship between NDWI and CWSI at different irrigation regimes. Dryland had the highest CWSI and the lowest NDWI values, but the relationship between both indices was weak. At high irrigation level, there was a strong negative linear relationship between NDWI and CWSI (Fig. 4).
- NDWI showed significant differences between irrigation regimes, but did not show cultivar variations within each irrigation regime (Fig. 5). The box-and-whisker plot shows that all cultivars had similar data distribution.
- NWI showed significant differences between irrigation regimes. The NWI indicated that DP1044 and PHY375 had the highest water content under dryland conditions (Fig. 6).

Summary

- The indices NDWI, NWI, and CWSI have the potential for screening drought tolerant cotton cultivars.
- Compared to NWI, NDWI was less sensitive to irrigation regimes.
- Among the four varieties tested at the Texas Rolling Plains, DP1044 and PHY375 showed greater drought tolerance.
- Further investigation will be required to link NWI, NDVI, and CWSI to canopy water status.
- Ongoing work: We are currently analyzing lint yield and quality data from the study.

Acknowledgement

Funding for this study was provided by Cotton Inc. We also thank all current and former employees at Chillicothe Experiment Station and cropping systems research team at Texas AgriLife Research-Vernon for their help with project implementation and data collection.

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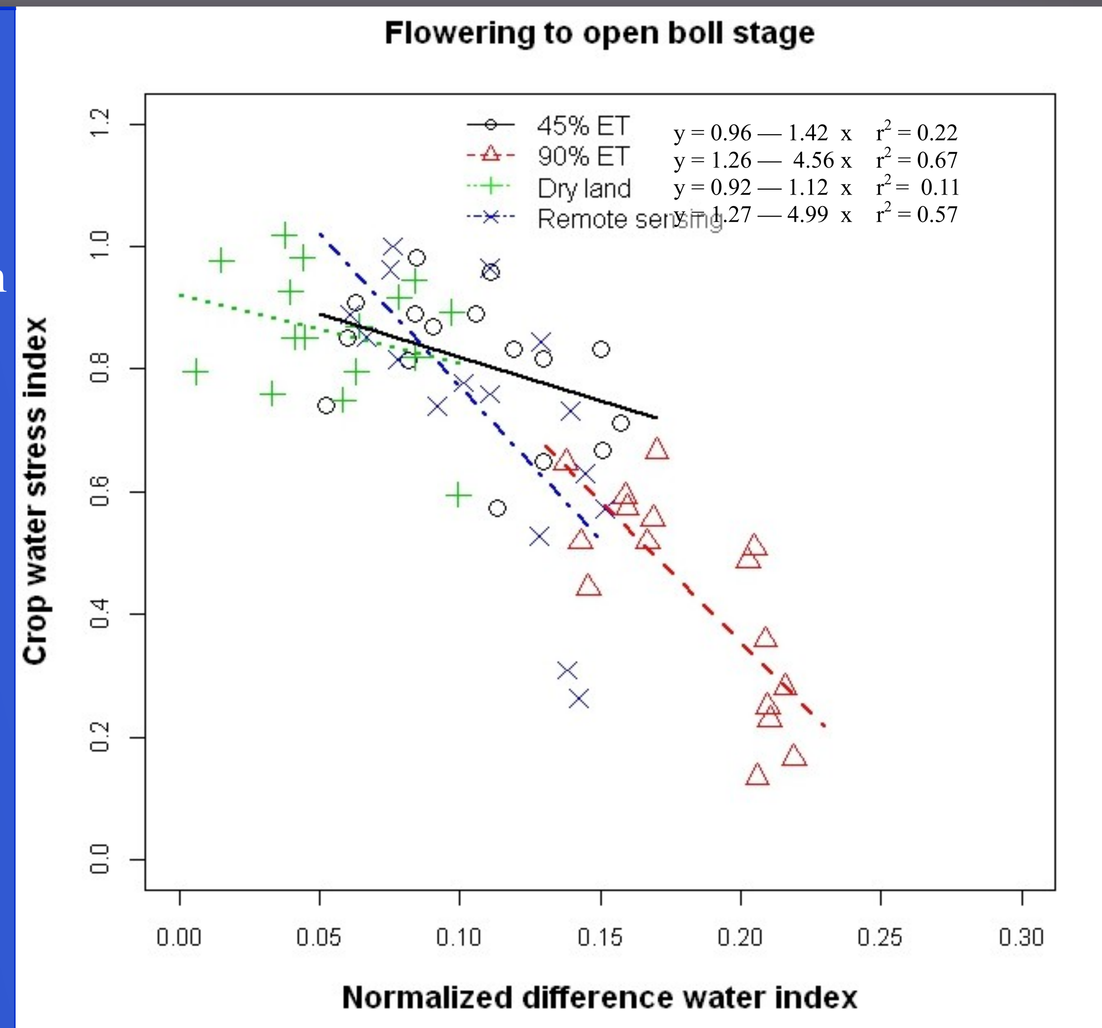

Fig.4. Relationship between normalized difference water index and crop water stress index for different irrigation methods.

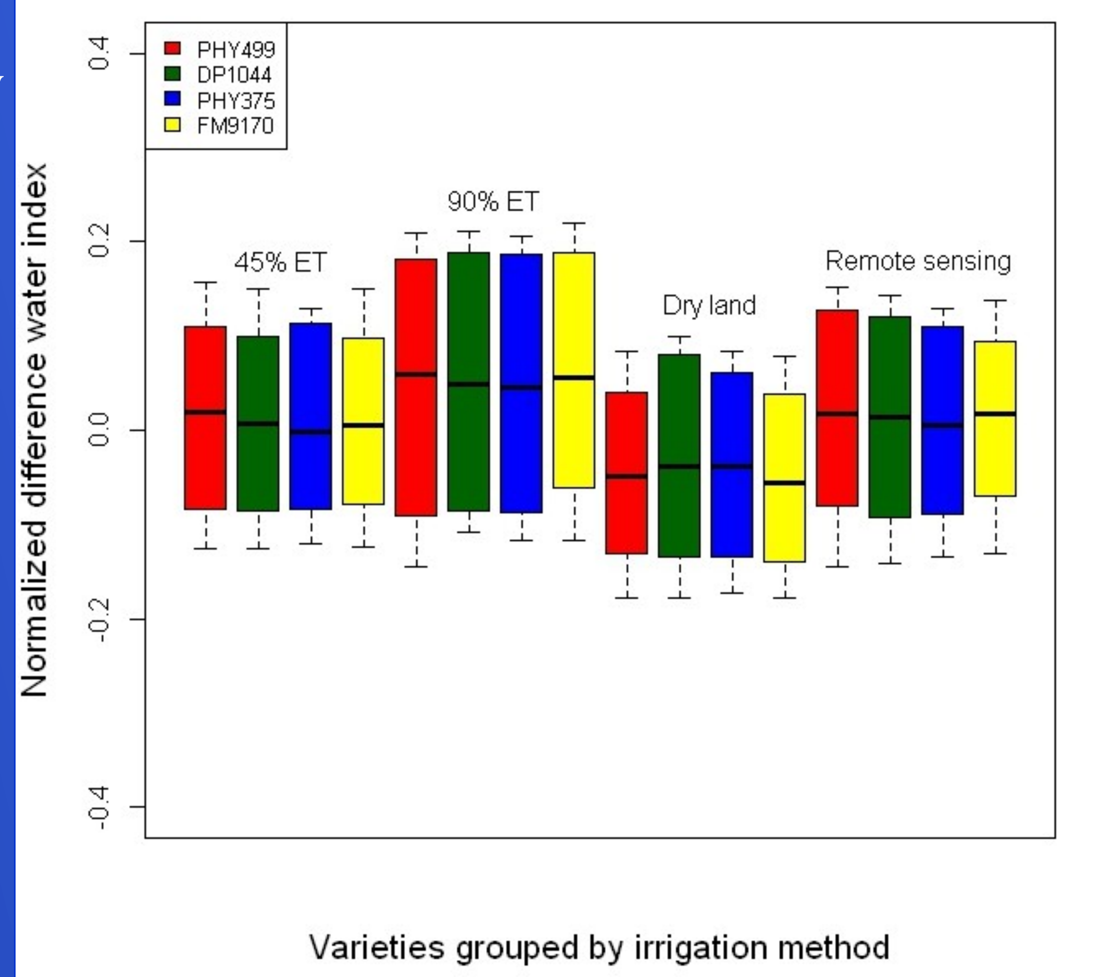

Fig.5. Normalized difference water index of four cotton cultivars grouped by irrigation methods.

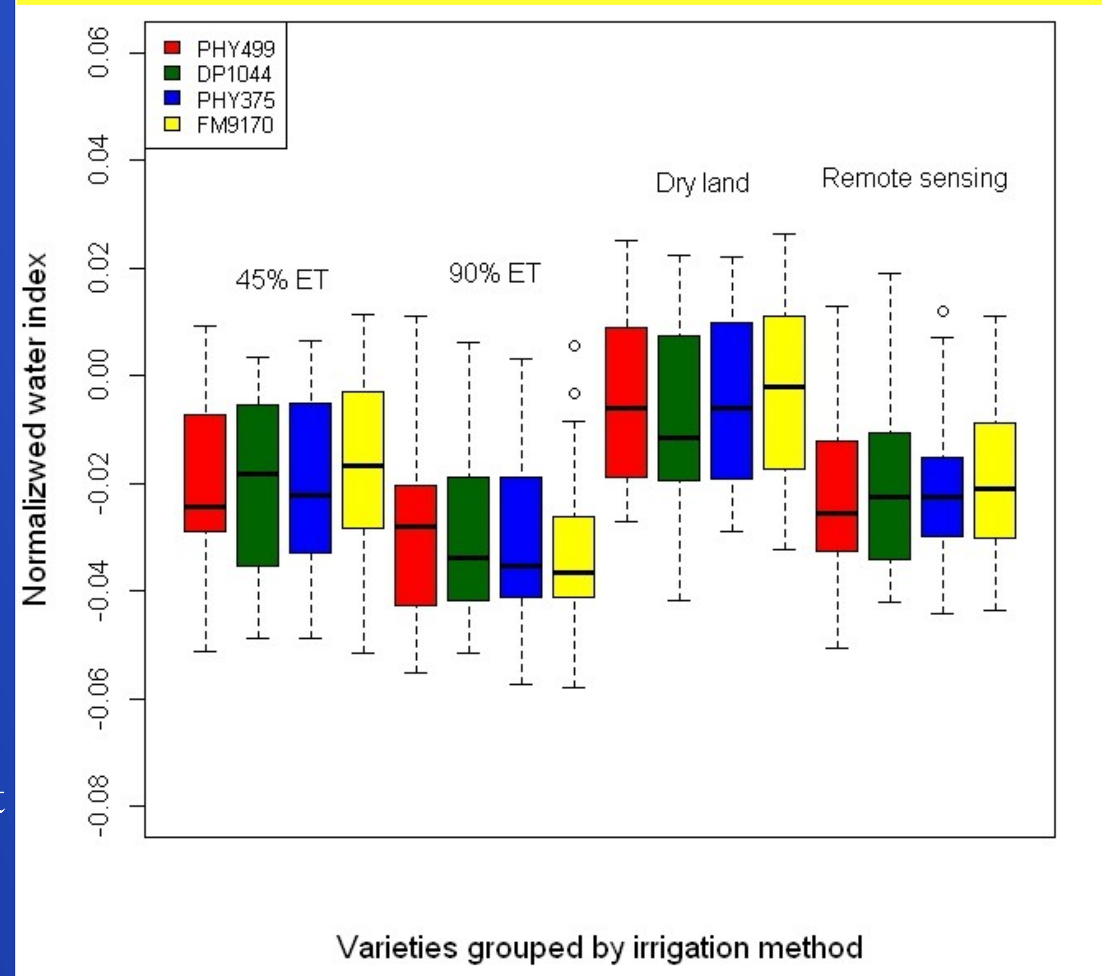

Fig.6. Normalized water index of four cotton cultivars grouped by irrigation method.