

## AZSCHEd V2.0: CLIMATE-BASED IRRIGATION SCHEDULING IN ARIZONA

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### ABSTRACT

Timely information on crop water needs is essential for any effective irrigation scheduling strategy. Use of historical or average weather data may suffice in the short term, but often causes significant errors in crop water use estimates when used over long periods of time. AZSCHEd (AriZona Irrigation SCHEDuling) program utilizes real-time weather data from the AZMET (AriZona METeorological) database to estimate reference crop evapotranspiration ( $ET_o$ ). These data are then combined with crop coefficient data ( $K_c$ ) to estimate daily crop water use for 28 different crops grown in Arizona and the Southwest. AZSCHEd V1.0 is already available on the Internet and has been downloaded to over 300 users. This new version allows for the use of tree crops and incorporates many new features that can be used with drip and micro sprinkler systems. This paper discusses some of the new features and how the new V2.0 system operates.

### INTRODUCTION

Recent droughts in the Southwest have many agricultural producers thinking about their water use and ways to conserve water. In-field tools such as soil sampling, tensiometers and gypsum blocks serve a purpose, but quite often growers are too busy to make frequent visits to all of their fields. Other monitoring devices, such as Time Domain Reflectometry, capacitance probes and crop imaging often carry a hefty price tag. One alternative is computerized irrigation scheduling programs.

To help growers increase their water use efficiency, the University of Arizona's Department of Agricultural and Biosystems Engineering developed a computerized irrigation scheduling program called AZSCHEd (Fox et al., 1992; Martin, et al., 2003). AZSCHEd calculates the crop evapotranspiration ( $ET_c$ ) as the product of a crop coefficient ( $K_c$ ) and a reference evapotranspiration ( $ET_o$ ).  $ET_o$  is estimated from real time weather data using the modified Penman equation (Doorenbos and Pruitt, 1977). Crop coefficients are taken from 28 crop curves developed from existing water use data and normalized by heat units to account for climatic variability (Slack et al., 1996; Martin et al., 1996). AZSCHEd V1.18 system, originally developed in 1992 by Fox et al., is now a Windows-based program available for downloading on the Internet (Martin, et al., 2003). AZSCHEd V1.18 can only be run under Windows-based operating systems. These systems include Windows NT, Windows 98, or Windows XP. If real time weather is to be used, then an internet connection may be useful. It is recommended that the computer used to run the software have at least 20MB of free hard disk space for the program files and associated Visual Basic .DLL files.

With the success of the AZSCHEd V1.18, the developers began the design of AZSCHEd V2.0. Version 2.0 has new programming to accommodate tree crops and drip irrigation systems.

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## PROGRAM STRUCTURE

AZSCHED V2.0 is not available to the general public. However, AZSCHED V1.18 can be downloaded directly from the Internet at <http://ag.arizona.edu/crops/irrigation/irrigation.html>. In addition to the program itself, a Users Guide is downloaded. This handbook is available by clicking “Help” on the first screen of AZSCHED V1.18. From the main page of AZSCHED V2.0 (Fig. 1), Users can enter data, retrieve data and get a schedule of all the fields managed with AZSCHED. Below are detailed descriptions of AZSCHED V2.0

### Field Options

This is the portion of the programming where the majority of the user/program interface takes place. Choosing this option, the User is given five additional options plus a “Go Back” button to return to the main menu. A diagram of the screen is shown in Fig. 2.

#### *Field Display*

This option will display all of the fields currently being scheduled. The User can choose on how the fields are displays (i.e., according to planting date, crop type, next irrigation or field name). The total number of fields displayed on the screen at one time is determined by the User entered value from the “Configuration” option in the main menu. The fields are displayed in color according to their irrigation needs. Green fields are within the specified soil moisture, yellow fields are closing approaching irrigation or harvesting and red fields are in need of immediately attention.

#### *Field Selection*

In this option, the User can either select a field to be updated, create a new field, or select a field to be harvested/deleted. Harvested/deleted fields are removed for the field list but the data is saved. Thus, if the User wanted to review data from a field harvested several years ago, it would still be possible to go back and printout a summary/history of that field.

#### Creating a new field

The creation of a new field requires several inputs from the Users and it would be best to gather the information prior to initiating a field. The first screen asks for crop type and soil data format. Crop type is selected from a list. For the soil format, there are two choices: Fixed soil layers – Soil are defined by “fixed” layers of a certain thickness. For example, the soil can be defined every 6 inches... or every 12 inches. Or, the soil format can be defined as Variable soil layers – where each individual layer is defined. Thus, if the soil has about 3 inches of top soil, then 6 inches of clay, then 7 inches of sandy clay, etc., this option will allow the User to define the thickness of each individual layer.

Next, the User needs to input a field ID, planting date, a weather station nearest the field being scheduled, an irrigation efficiency and the maximum allowable deficiency (MAD). The MAD should be in percent and is the threshold of the percent of Plant Available Water (PAW) in the plant rootzone at which the User wants an irrigation to occur. The weather station selection is a list of AZMET (Arizona Meteorological Station) weather station locations. These stations collect hourly data on a variety of atmospheric conditions (Brown, 1998). However, if the User created a Custom Weather file, using weather data from a station not on the AZMET network, this station can be chosen here. Then, the program will also look first to this file for updated weather information. There is also a selection for soil, asking whether the User wants to enter new soil data, use soil data from an existing field or use soil data

from a harvested/deleted field. Then the User is given the option to alter the crop's maximum rooting depth.

If the crop to be scheduled is alfalfa, then there are two more entries. One is the Critical MAD and the other is the Field Drying Time. The Critical MAD is a depletion percentage that you never want the field to fall below. Quite often, the cutting date and the scheduled irrigation date conflict. Thus, the program may be calling for irrigation the day before a scheduled cut. In order to avoid this, the program will use the Critical Mad and the Field Drying Time. The default for the Field Drying Time is 7 days. This means that the field can be safely entered with machinery 7 days after an irrigation event. The program will calculate this and may ask for an irrigation earlier than the entered MAD to assure that the hay will be cut and removed before the soil water falls below the Critical MAD. Normally, the Critical MAD is set 5-10% higher than the MAD.

Finally, if the crop chosen is a tree crop, additional information on orchard geometry and the size of the tree is requested. First, the User is asked to enter ft/m between rows and between trees. Then the User is asked to enter the Effective Crop Canopy (ECC). The ECC is a method for helping to determine the age, size and thus water use of an orchard tree. When trees are young, their canopy size is limited and the amount of canopy coverage on the orchard floor is low. As the trees grow, they begin to cover more and more of the orchard floor. Once the ECC equals 70%, it is assumed that the trees are transpiring at their maximum (Sammis et al., 2005). The User can enter any number from 10-100%, although there is no adjustment once the ECC gets beyond 70%. However, lower numbers reduce the  $K_c$  and the root coverage of the crop by the ECC factor given in Equation 1:

$$\text{ECC Factor} = (-0.0001 * \text{ECC}^2 + 0.0221 * \text{ECC}) * 100 \quad (1)$$

Here, the ECC Factor will be used to reduce crop water use (via a reduction in  $K_c$ ) and reduce the actual soil volume available for water uptake. A diagram of the Input Screen for a tree crop for AZSCHED V2.0 is shown in Fig. 3.

Once this information is entered, the program will automatically check to see if there is weather data available for the field created. If not, a window will now pop up saying that weather data is required. The User can then either download data automatically from the Internet or use default data. The internet data will be automatically downloaded from the AZMET (the University of Arizona's weather station system; Brown, 1998) website and will download data from the weather station the User entered. The second option is to allow the program to use default weather data. The program automatically computes weather data for your station based on the average over many years. This data is not the best to use for scheduling since it uses averages.

### Soils Data

When initially setting up the field, the User had the option to either enter soil water data one of three methods: 1) Enter new data; 2) Use data from an existing field; or 3) Use data from a harvested/deleted field. If the User chose to enter new data, a soil screen will appear requesting information of the soil's available water holding capacity and the initial soil water content at planting. If options 2 or 3 were chosen, the User is given a list of existing or harvested/deleted fields to choose from. Once the soils data is entered, the program then predicts the next irrigation.

### *Field Options*

The *Field Options* pull-down menu allows the User to enter data throughout the season on water added to the field. It also allows the User to change certain parameters such as the MAD, irrigation efficiency or field depletion. The User can also get a quick view of the Field Summary and Field Details.

### *Field Reports*

This pull down menu has three options: 1) Print/Save/View irrigation schedule for all fields; 2) Print/Save/View the field report for the field selected; 3) Print the field report for a harvested/deleted field. The irrigation schedule gives a list of all fields presently being scheduled, their present soil water status and the predicted next irrigation date, along with irrigation amount. For alfalfa, the next predicted cutting data is also give.

The field report (Fig. 4) contains daily data on the selected field including the following (Text in **bold** is how the data is reported in the field report):

#### **Date**

**Day (DAP)** - days after planting

**Avail (in)** - available water in inches

**Depl (%)** – percent available water depletion

**GDD (F)** – growing degree days in Fahrenheit, for that day

**GDD (Cumm)** – cumulative growing degree days in Fahrenheit

**ETR (in)** – reference evapotranspiration ( $ET_o$ ) for that day, in inches

**ETR (Cumm)** – cumulative ETR

**Kc** – crop coefficient

**Kd** – soil dryness coefficient

**ETC (in/acre – gals/tree)** – crop  $ET_c^*$ . It is the  $ET_o$  times the  $K_c$  times the soil dryness factor, in inches

**ETC (Cumm)** – cumulative  $ET_c$

**Irr (in)** – irrigation amounts

**Rain (in)** – rainfall amounts

**Cut No.** – the number of the cut that was taken off a field (for hay only)

\* **Gallons** or liters per tree only for tree crops and only if selected by the User.

The final option is to print a field report of a harvested/delete field. This report is the same as previously described in the last paragraph. However, since these are harvested/deleted fields, only printed copies can be obtained.

### **Weather Data information section**

The “Weather Data” is chosen from the main menu and gives the User several options of adding or viewing weather data. If not previously done, the program will first prompt the User to choose a weather station. Then the User can choose from three pull down menu: 1) Add Weather Data; 2) View Weather Data 3) Custom Disk Weather Files (Fig. 5).

#### *Add Weather Data*

In this section the User can: 1) download data from AZMET; 2) enter/edit weather data; or 3) load default weather data. Downloading AZMET data allows the User to download weather data without having to have a field to schedule. This way, the User can view weather data from any available AZMET station. Option 2, enter or edit weather data, allows the User to enter weather data for any AZMET station. Caution must be used here because the entered data will be saved by the program and used to schedule

irrigations. This option should only be used when it is known that the weather data already saved by AZSCHEd is incorrect. Loading default weather data can be helpful if there is no Internet connection and the User wants to view historical averages.

#### *View Weather Data*

This selection allows the User to view the weather data from the selected station for years that have been downloaded, either directly in the menu or automatically through scheduling. The User also has the option of printing the weather data shown on the screen or printing the entire weather file.

#### *Custom Disk Weather Files*

This selection allows the User to create, update or delete a custom weather file. This is for User's outside of the AZMET weather network who may want to use AZSCHEd V2.0. Also, a page describing the format of weather files required by AZSCHEd is given.

### **Configuration section**

This section allows the User to change the date the program has set as today's date, set units to English or metric, and set field display – which allow the User to change the number of fields that are displayed on your computer screen when the Field Options > Field Displays menu choice is selected.

## **ESTIMATING CROP WATER USE**

AZSCHEd uses the “water-balance method” to estimate daily crop water use. In this approach, the soil is viewed as a water storage reservoir from which plants extract water. This water is then replaced by either irrigation or precipitation. In using this method, reliable information on the soil available water holding capacity (AWC) is essential. The AWC is generally defined as the amount of water retained in the soil between “field capacity” (FC) and the “permanent wilting point” (PWP).

Crop water use is estimated using a calculated reference crop evapotranspiration ( $ET_o$ ) data and a crop coefficient. The method used in AZSCHEd for estimating  $ET_o$  is the FAO Modified Penman equation (Doorenbos and Pruitt, 1977). This equation estimates the ET of a healthy, cool season grass, 8-15 cm in height maintained in a well watered environment. The Modified Penman equation requires daily information on max/min temperatures, max/min relative humidity, net radiation, wind speed and the day/night wind ratio. The equation, often referred to as the combination equation, has the form:

$$ET_o = c * [W * R_n + (1 - w) * f(u) * (e_a - e_d)] \quad (2)$$

Where c is an adjustment factor to compensate for the effect of day and night weather conditions; W is a temperature related weighing factor, f(u) is a wind function,  $R_n$  is the net radiation equivalent in mm/day and  $(e_a - e_d)$  is the vapor pressure deficit.

To estimate actual crop water use, AZSCHEd uses the  $ET_o$  data with crop coefficient values ( $K_c$ ), derived from several sources (Erie, et al., 1982; Sammis et al., 1985; Martin, et al., 1996). The crop coefficient is defined as:

$$K_c = \frac{ET_c}{ET_o} \quad (3)$$

Where  $ET_c$  is the actual crop evapotranspiration and  $ET_o$  is calculated as previously described.

A unique feature of AZSCHED program is the use of growing degree days (gdd) as the unit of time measurement. Growing degree days are often referred to as heat units or thermal time. In its simplest form, gdd are defined as:

$$gdd = T_{mean} - T_{base} \quad (4)$$

Where  $T_{mean}$  is the daily mean air temperature and  $T_{base}$  is the minimum daily mean air temperature required for crop growth. The value of  $T_{base}$  is unique to the crop. Equation 4 is only valid when  $T_{base} < T_{mean} < T_{max}$ . In areas such as Arizona, where summer temperatures often rise well above 100 °F, an upper threshold temperature similar to  $T_{base}$ , and referred to as  $T_{max}$  is required. If  $T_{mean} > T_{max}$ , then formula for computing gdd is:

$$gdd = T_{max} - T_{base} \quad (5)$$

Where  $T_{mean}$  is the daily mean air temperature and  $T_{max}$  is the maximum daily mean air temperature that once reached, no additional significant crop growth occurs. Snyder (1985) developed a method for calculating gdd for a variety of temperature scenarios. This method was used in the AZSCHED program to determine daily gdd accumulation.

## CONCLUSION

Over 300 copies of AZSCHED V1.18 have been downloaded from the University of Arizona website. It is hoped that this new version of AZSCHED will also be used so widely. With initial testing continuing this year, it is hoped that a Beta version will be available by the end 2005, with a public release by June of 2006.

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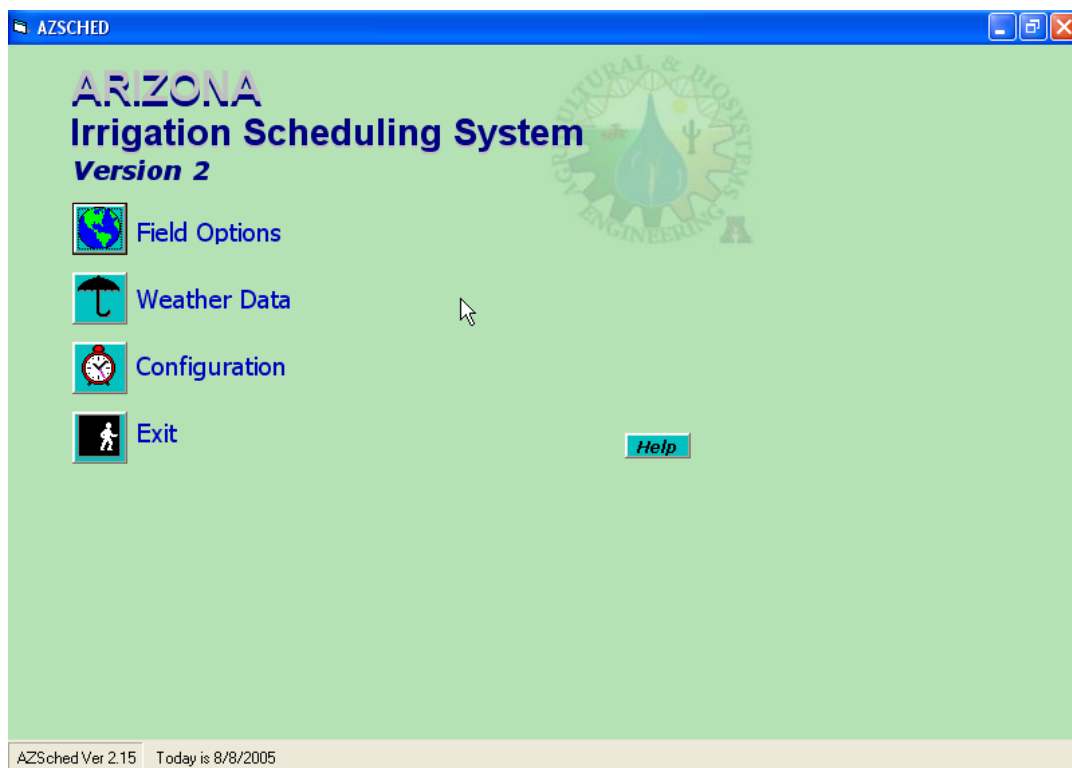


Figure 1. The main menu screen for the AZSCHEM Version 2 program.

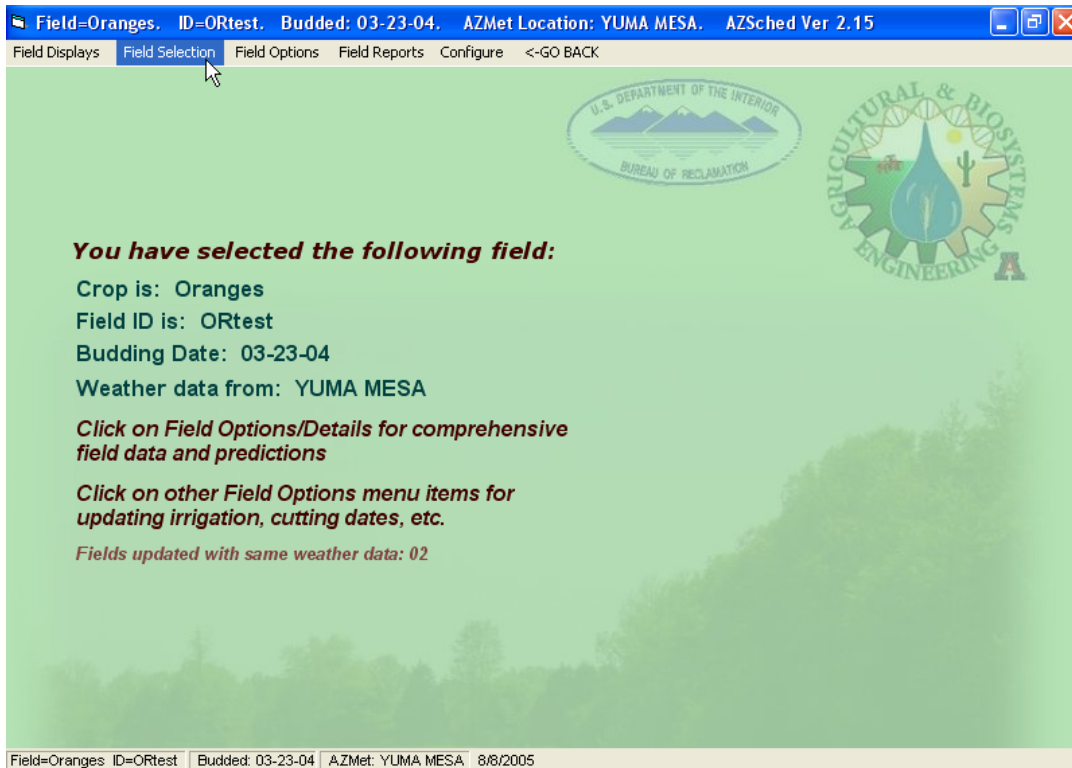


Figure 2. The Field Options screen from AZSCHED. This screen shows data from an orange test plot with a budding date of 3-23-04.

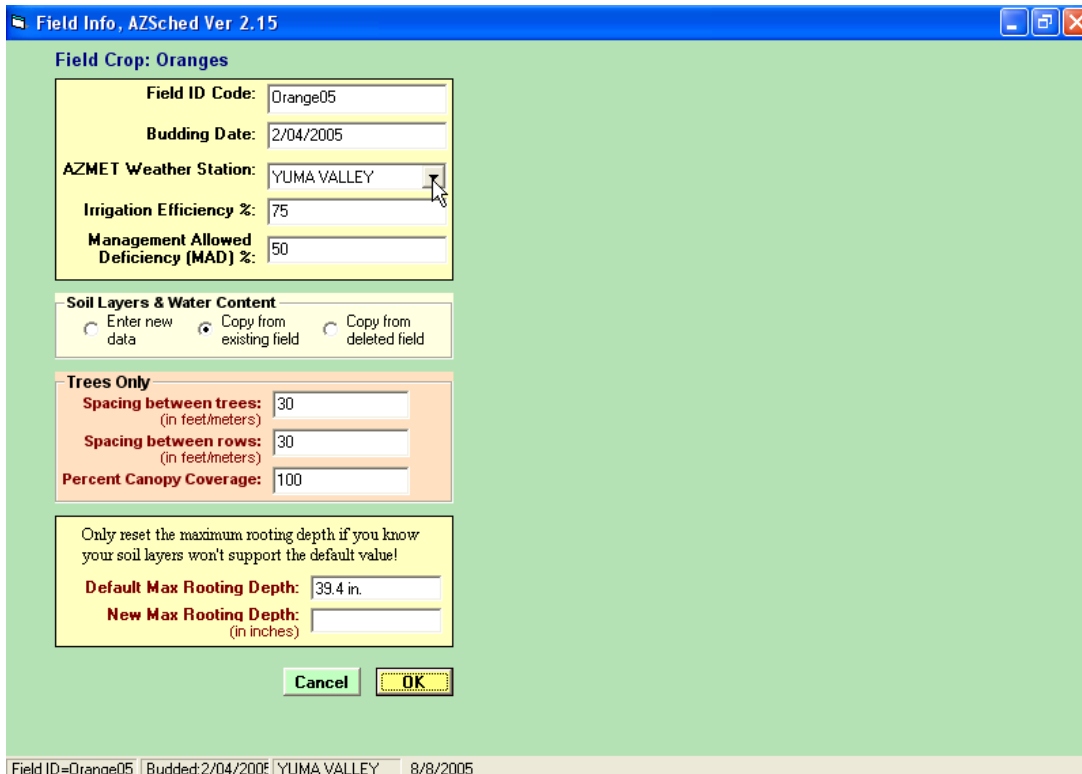


Figure 3. Field input screen for AZSCHED V2. This is for an orange crop.



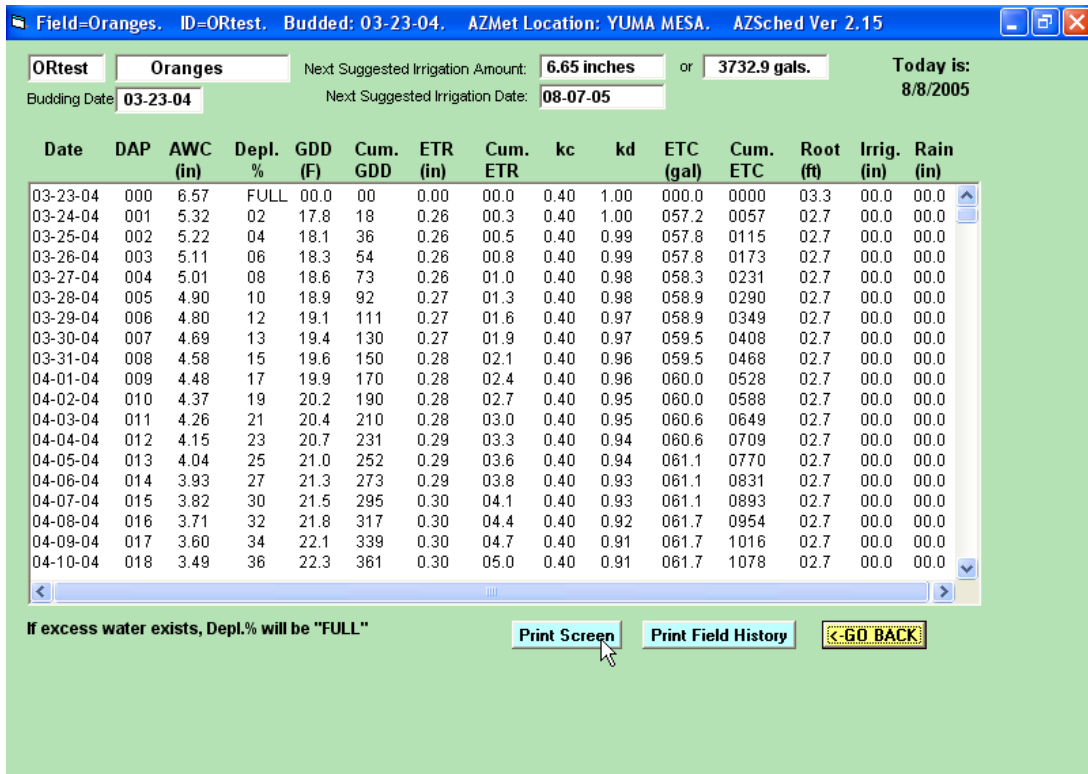


Figure 4. A sample of the Field Report from AZSCHED Version 2.



Figure 5. The Weather Menu from the AZSCHED V2 program.