Using the CROPGRO Model for Predicting Water Balance, Evapotranspiration and Water Use Efficiency of Spring Safflower

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Introduction

- Water deficit is a major limiting factor of crop productivity in the semi-arid Southern High Plains (SHP) of New Mexico and Texas.
- Inclusion of drought tolerant, low input crops such as safflower (*Carthamus tinctorius* L.) is one of the strategies to extend the life of fast declining Ogallala Aquifer in the SHP.
- Crop modeling is a viable option to simulate safflower water footprints in different climatic scenarios to assess its feasibility in optimization of water use in the SHP.
- These efforts could be helpful to open opportunities for removing genetic and management barriers to safflower becoming an attractive crop option in water-limiting environments.

Objective

- To calibrate the CROPGRO model for improved ability to simulate water balance, evapotranspiration (ET) and water use efficiency (WUE) of spring safflower.

Materials and Methods

- **Location :** Agricultural Science Center, Clovis, NM (2013 and 2014).
- **Experimental design : Split Plot**
- **Treatments :**
  - **Main plot : Irrigation treatments (4)**
    - Fully Irrigated (FI)
    - Stress at vegetative stage (VS)
    - Stress at reproductive stage (RS)
    - Dryland (DL)
  - **Sub-plot : Cultivars (3)**
    - PI8311, 99OL and Nutrisaff
- **Replications :** 4

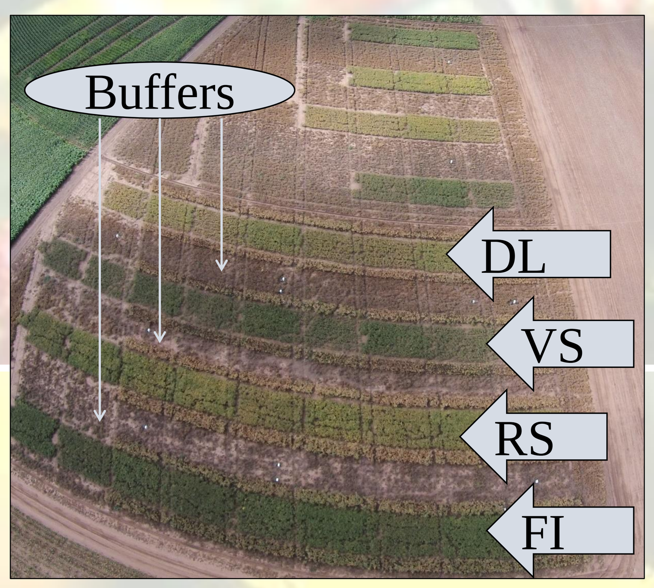

Fig.1. Physical layout of the trial in 2014 during reproductive stage (aerial shot).

- **Data collection:** Volumetric soil water content (neutron gauge).
- **ET = RF+I+SD+R+D**, where RF is rainfall (mm), I is irrigation (mm), SD is the difference in soil water content between planting and post-harvest (mm), R is runoff (mm), and D is drainage (mm) below root zone.
- **WUE = Y/ET**, where Y is seed yield (kg ha^{-1}) and ET (mm).

Fig.2. Measuring soil water content with neutron probe.

- **The CROPGRO model** template was adapted to safflower.
- The crop specific values and relationships were updated in the model template from the literature.
- Additional parameters of species, ecotype, and cultivar files were optimized based on **Bayesian optimization** relative to collected data.
- The observed data from PI8311 cultivar were used to calibrate the model, and the data from 99OL and Nutrisaff cultivars were used to evaluate the model.
- The values of lower limit (SLLL; permanent wilting point), drained upper limit (SDUL; field capacity), and root growth factor (SRGF) were manually adjusted with considerable iterations to match the simulated water use results with the observed results.
- Simulations were performed with the calibrated model to compare with observed data from the field experiments conducted at Clovis, NM.
- **Statistical evaluation:**
  - The Willmott Agreement Index (d): The index varies between 0 and 1, with a value of 1 indicating perfect agreement between predicted and observed data.
  - Root mean square error (RMSE).

Results

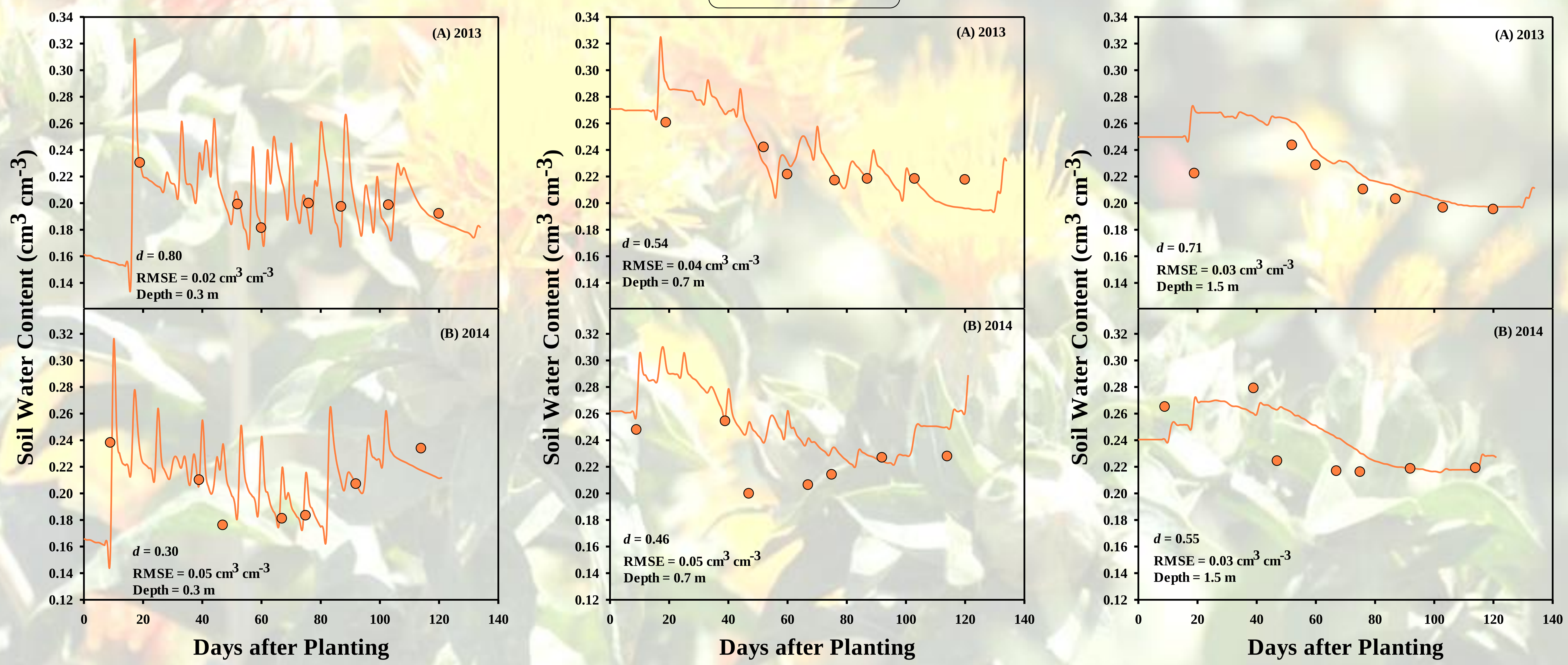

Fig. 3. Simulated (lines) vs. observed (symbols) soil water content of safflower cultivar PI8311 at 0.3 m (left), 0.7 m (middle), and 1.5 m (right) soil depths averaged over four irrigation treatments at Clovis, NM in (A) 2013 and (B) 2014.

Table 1. Comparison between observed (Obs.) and simulated (Sim.) seed yield, evapotranspiration (ET), and water use efficiency (WUE) of safflower cultivar PI8311 under four irrigation treatments averaged over 2 years, and root mean square error (RMSE).

	Yield (kg ha^{-1})			ET (mm)			WUE (kg ha^{-1} mm^{-1})		
Irrigation§	Obs.	Sim.	RMSE	Obs.	Sim.	RMSE	Obs.	Sim.	RMSE
FI	2507	2411	377	500	427	73	5.1	5.7	0.6
RS	2053	2072	79	379	386	16	5.5	5.5	0.0
VS	1718	2055	337	377	372	13	4.6	5.6	1.0
DL	1331	1320	48	257	291	34	5.3	4.6	0.7
Average	1902	1964	210	378	369	34	5.1	5.3	0.6

Irrigation§: FI, fully irrigated; RS, stress at reproductive stage; VS, stress at vegetative stage; DL, dryland.

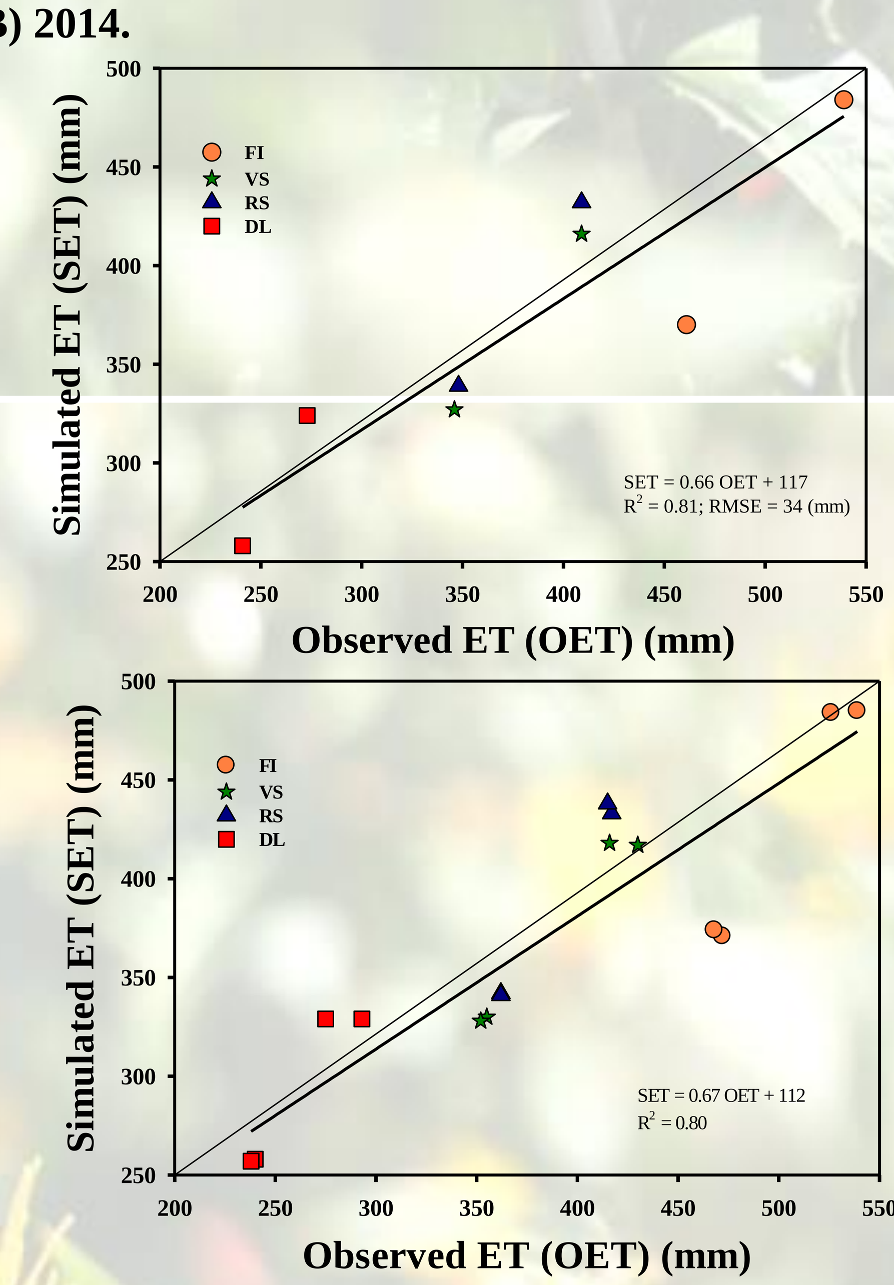

Fig. 4. Simulated vs. observed evapotranspiration (ET) of safflower cultivar PI8311 (top), and cultivars 99OL and Nutrisaff (bottom) during 2013 and 2014 at Clovis, NM. The thin line represents 1:1 line.

Results

- At 0.3 m soil depth, the average observed and simulated water content values were 0.20 and 0.19 cm^3 cm^{-3} in 2013 (Fig. 3A; left), and 0.20 and 0.21 cm^3 cm^{-3} in 2014 (Fig. 3B; left), respectively
- At 0.7 m soil depth, the average values for observed and simulated water contents were 0.23 and 0.23 cm^3 cm^{-3} in 2013 (Fig. 3A; middle), and 0.23 and 0.25 cm^3 cm^{-3} in 2014 (Fig. 3B; middle), respectively.
- At 1.5 m soil depth, The average observed and simulated soil water content values were 0.21 and 0.23 cm^3 cm^{-3} in 2013 (Fig. 3A; right), and 0.23 and 0.24 cm^3 cm^{-3} in 2014 (Fig. 3B; right), respectively.
- The seed yield was also well predicted by the model with average simulated yield of 1964 kg ha^{-1} compared to observed yield of 1902 kg ha^{-1} with RMSE of 210 kg ha^{-1} (Table 1).
- The average observed ET was 378 mm compared to simulated ET of 369 mm with RMSE of 34 mm (Table 1).
- A strong relationship was observed between observed and simulated ET with R^2 = 81 (Fig. 4; top)
- The observed WUE values were fairly close to the calculated values from the model simulations with average RMSE of 0.6 kg ha^{-1} mm^{-1} (Table 1).
- The model was evaluated using independent data and a strong linear relationship was obtained between observed ET and simulated ET of 99OL and Nutrisaff cultivars with R^2 = 0.80 (Fig. 4; bottom).

Conclusions

- Average simulated water content was close to observed water content.
- The resulting water balance in the model led to excellent simulations of ET and WUE of safflower.
- The satisfactory performance of the model for an independent data demonstrate that the CROPGRO model is capable of predicting water use of spring safflower.
- However, site-specific calibrations based on weather, especially soil and rooting inputs are needed in different regions

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