Effect of plastic film mulching on evapotranspiration and water use efficiency of a rainfed spring maize cropping system on the Loess Plateau

Fengxue Gu, Xiang Gao, Weiping Hao, Xurong Mei

Institute of Environment and Sustainable Development in Agriculture,
Chinese Academy of Agricultural Sciences

content

- Introduction
- Methodology
- Results and discussion
- Summary of conclusion

Introduction

- Plastic film mulching (PFM) as an agricultural cultivation technique is widely used in China and rapidly developing. In 2008, the covering area of ground film had already ranked the first in the world, was 15.613 million hm^2 accounting for about 13% of national arable land (Yan et al., 2010)

- PFM led to increases in the crop yield and net income, therefore, PFM plays an important role in guaranteeing food security and improving living conditions of farmers in China.

Introduction

- The Loess Plateau is a typical continental monsoon climate, more than 60% of the precipitation falls from June to September as rain (Li and Xiao, 1992). Drought and low air temperature during April-June often restrict spring maize production. PFM can solve the problem of spring maize growth in early stage very well and is widely used on the Loess Plateau.

- Evapotranspiration (ET), grain yield (GY) and water use efficiency (WUE) were affected by agricultural strategies and measures. Then, what effects of plastic film mulching are?

Introduction

Objectives:

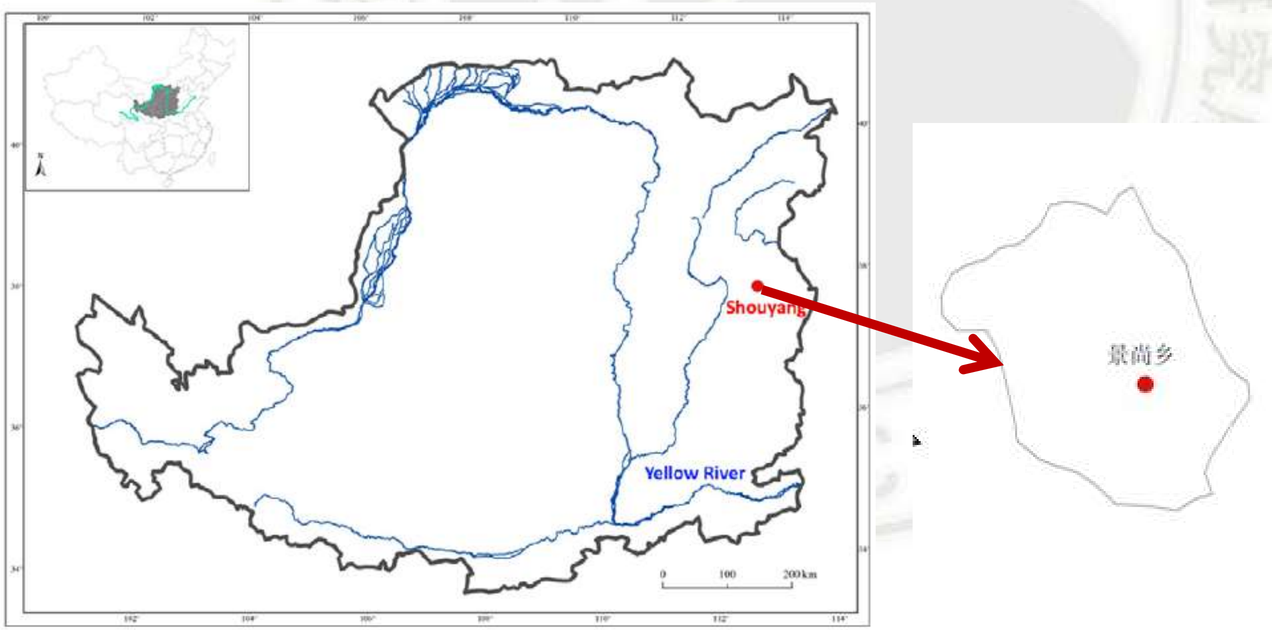
(1) To characterize the differences of ET and WUE between conventional flat cultivation (CFC) and PFM cropping systems ;

(2) To investigate the effect of plastic film mulching on ET and WUE in rainfed spring maize cropping system and its mechanisms.

Methodology

Site description:

- The study was conducted at the Shouyang Scientific Observing and Experimental Station of Dry land Agriculture and Agro-environment, Ministry of Agriculture, P. R. China, located in Shanxi province (N 37° 45′, E113° 12′) on the eastern Loess Plateau.
- The region is characterized by a semi-arid continental temperate monsoon climate, with prolonged cold, dry winters and strong daily and seasonal temperature variations.



Methodology

Site description:

- Mean annual precipitation is 474.5mm, with over 70% occurring from July-September; mean annual temperature is 8.2℃ and the mean annual frost free period is 150 days.

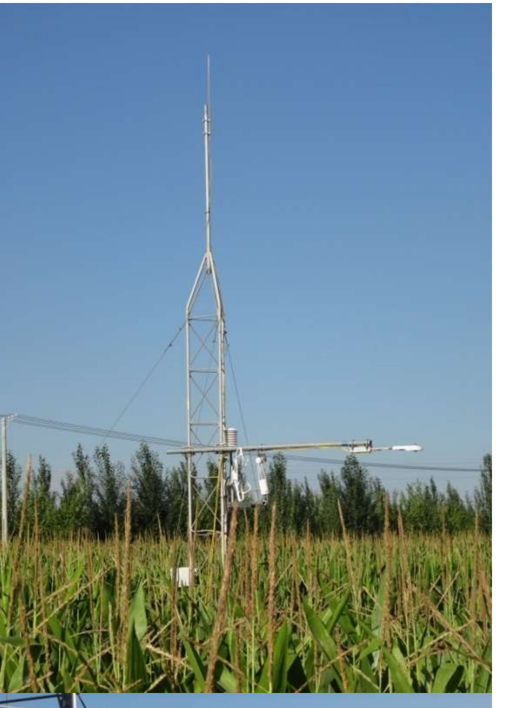
- Spring maize was grown with row spacing of 50 cm and planting spacing of 30 cm in the CFC and PFM study areas, and film mulching degree was 70% in both years. Sowing before or after 1 May and harvesting at early November with straw returning. The plastic film was a kind of transparent polyethylene film with a thickness of 8 µm.

Methodology

Eddy covariance measurements:

Two open-path eddy covariance systems were installed in each middle spring maize field, with a fetch length of ~140 m in the prevailing wind. Instrument height was adjusted to maintain a relative height of ~1.3 m above crop canopy (Zhang et al., 2008; Li et al., 2009).

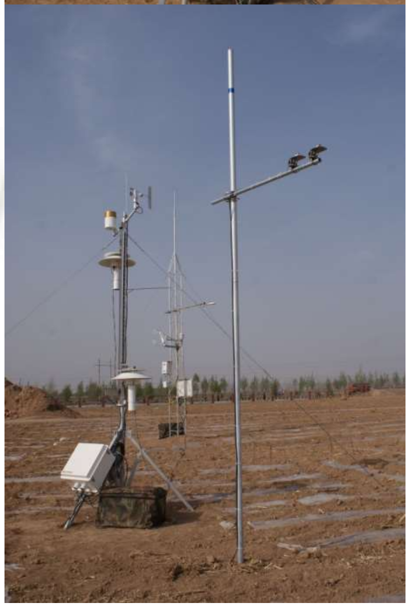
Each eddy covariance instrument consisted of a three-dimensional sonic anamometer (CSATS3, Campbell Scientific Inc., Logan, UT, USA) and an open-path infrared gas analyzer (LI-7500, Li-COR Inc., Lincoln, NE, USA). Data were recorded at a frequency of 10 Hz on a data logger (CR5000, Campbell Scientific Inc.), block-averaged at 30min intervals for analysis and archiving, and stored on a 2 GB compact flash card.



Methodology

Other measurements:

Item	Sensor	Item	Sensor
Air temperature	(HMP45C, Vaisala Co., Ltd., Helsinki, Finland	**soil temperature**	TCAV, Campbell Scientific, USA
Relative humidity		**soil heat flux**	HFP01SC, Hukseflux, Netherlands
rain	TE525, Texas Electronics Inc.,Dallas, TX, USA	**solar total radiation**	LI200X, Li-COR, USA
PAR	LI190SB, Li-COR Inc.		
Soil moisture	EnviroSmart, Sentek Pty. Ltd., Stepney, SA, Australia	**net radiometer**	CNR4, Kipp & Zonen, Netherlands



During the growing season, seven spring maize plants were randomly selected every 6–10 days for manual measurement of green leaf length and maximum width, and green leaf area index (**GLAI**) was calculated according to McKee (1964).

Methodology

Data calculation :

EddyPro software (https://www.licor.com/env/products/eddy_covariance/software.html) was used to calibrate and quality control the 10-Hz flux data from the eddy covariance system; the software output 30-min data. According to the wind direction and a footprint analysis provided by the software, if > 70% of the 30-min flux footprint overlapped in the area of interest, the data were used for further analysis; otherwise, the data were rejected. The data gaps of turbulent fluxes due to instrument malfunction or quality control procedures reported by the published studies (Zhou et al., 2009b; Li et al., 2008), were divided into short gaps (≤2h) and long gaps (＞2h). The former was filled by liner interpolation, and the later based on the mean diurnal variation (MDV) method described by Falge et al. (2001).

Reference crop evapotranspiration ET_0 (mm d^{-1}) was calculated each day using the FAO Penman-Monteith equation according to Allen et al. (1998), specific as follows:

$$ET_0 = \frac{0.408\,\Delta(R_n - G) + 900\,u_2\gamma(e_s - e_a)/(T + 273.3)}{\Delta + \gamma(1 + 0.34u_2)}$$

WUE was calculated as the ratio of GY to ET.

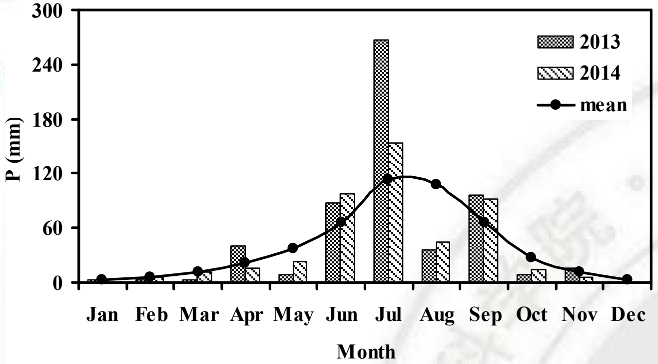
$$WUE = \frac{GY}{ET}$$

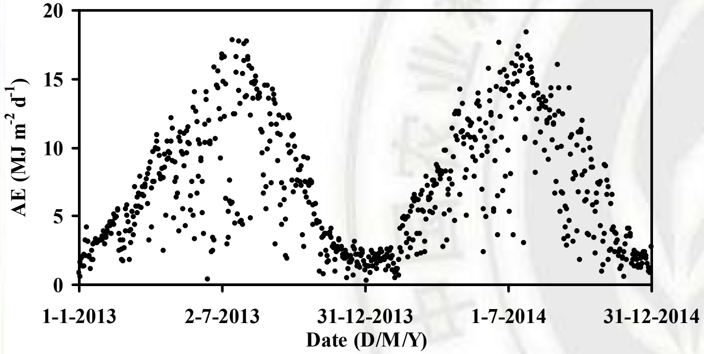
Water balance (WB) is the residue of precipitation (PRE) minus ET.

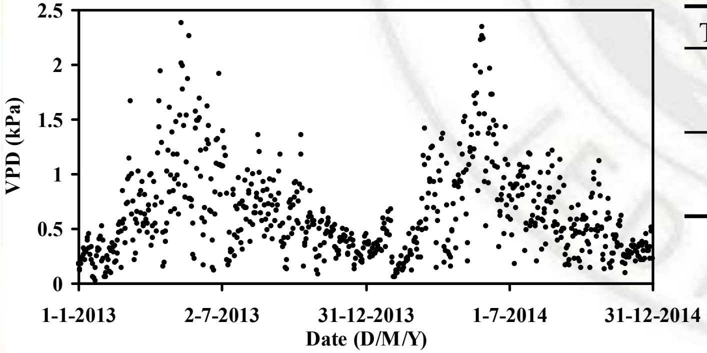
$$WB = PRE - ET$$

Results and discussion

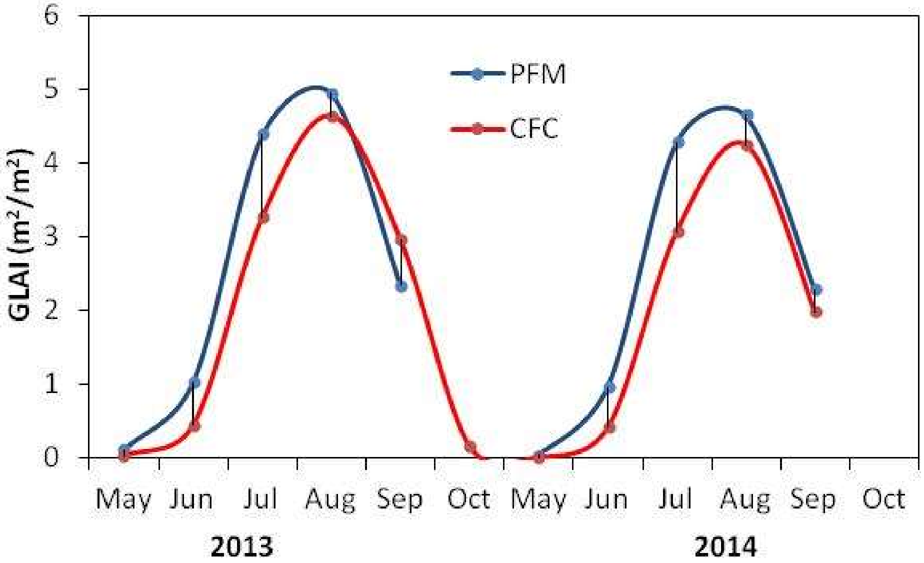
Abiotic factors and GLAI







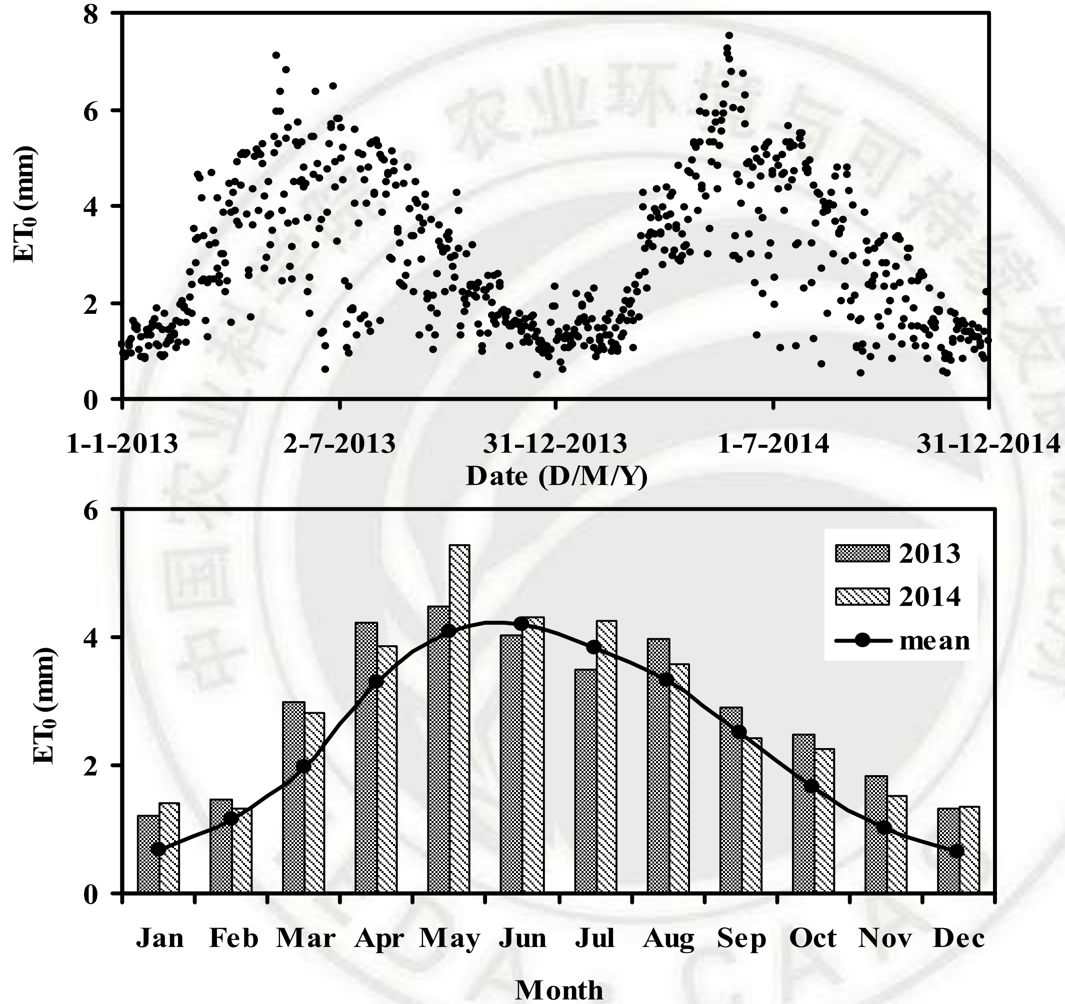
mean represents the average for 1967-2014



Treatment	Year	Planting Date	Seeding Date	Dead Date	Duration
PFM	2013	Apr 28	May 5	Oct 2	157
	2014	May 4	May 11	Oct 1	150
CFC	2013	Apr 28	May 8	Oct 10	165
	2014	May 1	May 11	Oct 1	154

Results and discussion

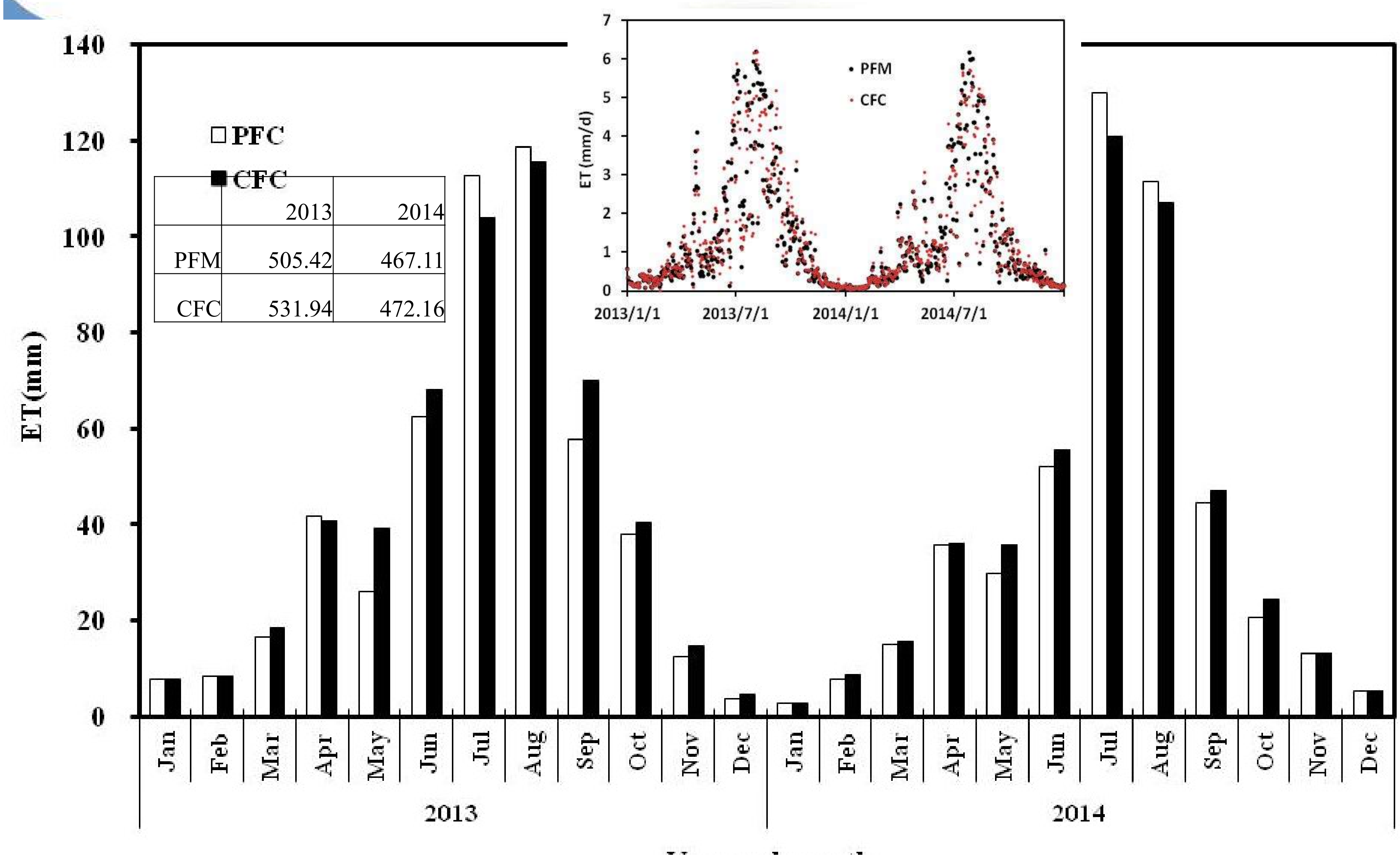
Daily and monthly ET_0



Seasonal variation of (a) daily ET_0 and (b) monthly average ET_0 in 2013 and 2014 (mean represents the average for 1981-2014).

Results and discussion

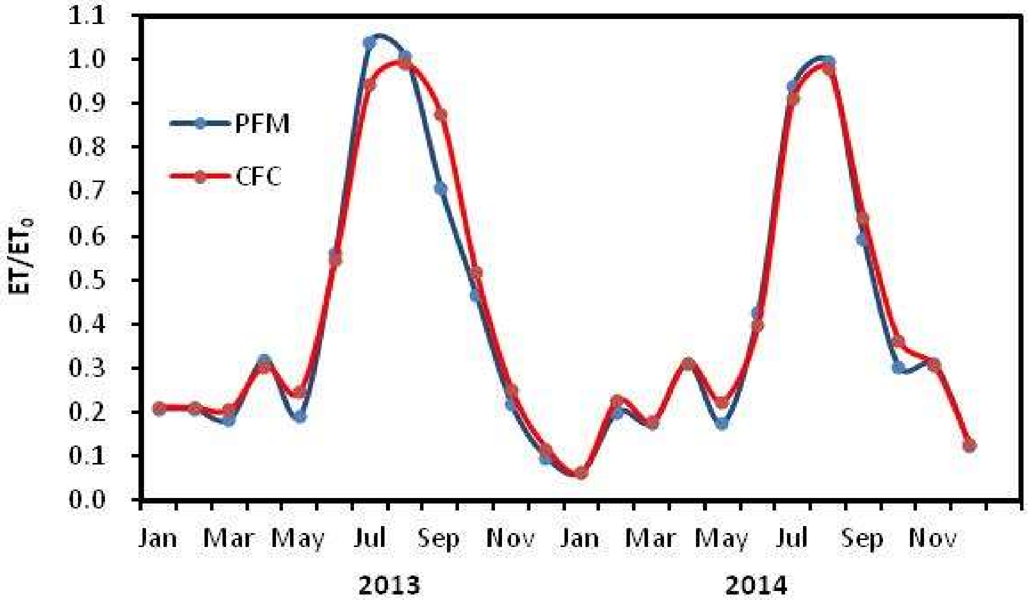
Daily and monthly ET



	2013	2014
PFM	505.42	467.11
CFC	531.94	472.16

Results and discussion

ET/ET_0, Water balance, grain yield and water use efficiency



Treatment	GY (t hm^{-2})		WUE (kg hm^{-2} mm^{-1})	
	2013	2014	2013	2014
PFM	12.52[a]	11.54[a]	24.04[a]	24.68[a]
CFC	11.39[b]	10.66[b]	21.34[b]	22.80[b]

Treatment	Month	2013	2014
	Jan	-4.85	-2.60
	Feb	-4.88	-1.52
	Mar	-13.00	-3.84
	Apr	-1.10	-20.25
	May	-17.17	-6.74
	Jun	25.39	46.01
	Jul	154.77	24.29
	Aug	-82.24	-66.73
	Sep	38.90	47.01
	Oct	-29.80	-6.73
	Nov	2.77	-6.75
	Dec	-3.81	-5.26
PFC	Total	64.98	-3.13
	Jan	-5.04	-2.71
	Feb	-4.86	-2.52
	Mar	-14.99	-4.48
	Apr	-0.25	-20.59
	May	-30.31	-12.72
	Jun	19.75	42.28
	Jul	163.42	33.39
	Aug	-79.06	-62.49
	Sep	26.56	44.31
	Oct	-32.52	-10.39
	Nov	0.91	-6.86
	Dec	-4.69	-5.38
CFC	Total	38.92	-8.17

Results and discussion

Effects of plastic film mulching

- PFM could obviously improve soil water content and temperature in early growth stage of spring maize.

- PFM promotes growth and development of spring maize, and shortens the growth duration (early germination, rapid growth and premature induced by PFM).

- PFM decreases soil evaporation evidently, as it prevents water exchange between the soil and air during early growth stage. However, PFM increases the crop transpiration because of the stimulation of crop growth. In total, PFM decreases the ET of spring maize cropping system compared with CFC.

Summary of conclusion

- PFM could significantly promote growth and development of spring maize and reduce soil evaporation in growth season.

- Monthly ET and ET/ET_0 in PFM treatment was lower in early (May) and later (September) stage and higher in middle stage (June, July and August).

- PFM decreased ET, and significantly improved GY and WUE of spring maize

Thanks for your attention!