Characteristics and influencing factors of crop coefficient for drip-irrigated cotton under plastic-mulched condition in arid environment

Zhipin Ai, Yonghui Yang, Qinxue Wang, Kiril Manevski, Quan Wang, Qiuli Hu, Deni Eer and Jiusheng Wang

Abstract
Crop coefficient ($K_c$) is a very useful and widely used variable in evapotranspiration estimation in cropland. Traditional methods in calculating $K_c$ are based on field water balance, which is limited by long measurement interval and small study area. In addition, there is the need for $K_c$ under new agronomy practice such as plastic mulching and drip irrigation in arid environments. This study calculated and analyzed $K_c$ of a drip-irrigated and plastic-mulched cotton field in Aksu Oasis of the arid Tarim River Basin, China, and its relationships with several crop-, soil- and management variables such as relative growth days (RGD), leaf area index (LAI), extractable soil water (ESW), and irrigation, based on two years’ observations. The results showed that daily $K_c$ varied within the range of 0.08–1.28, with an average of 0.54 for the entire cotton growth season, in 2013 and 2014. Compared to non-mulched condition already published, the $K_c$ of mulched cotton for the entire growth season decreased by 16 to 39% on average, partly due to arid advection. This study provided up-to-date and detailed information on cotton crop coefficient under plastic mulching and drip irrigation conditions in arid environment, and it is useful for improved management of agricultural water resources.

Key words: Arid advection, Bowen ratio, Cotton growth, Eddy covariance

1. Introduction
According to the United Nations World Water Assessment Programme (2015), agriculture by 2050 will need to produce 60% more food globally, and 100% more in developing countries. The sector needs to increase its water use efficiency by reducing water losses and, most importantly, increase crop productivity with respect to water. The semi-arid and arid agricultural regions are particularly important due to the contrasting conditions of high water demand and low water availability. This suggests an inevitable need for conserving water by improving irrigation management via accurate estimation of crop water requirement, i.e., evapotranspiration (Grassini et al., 2011).

Actual crop evapotranspiration ($ET_c$) can be directly measured with weighing or burrowed zero-tension lysimeters and eddy covariance towers. Lysimeter studies involving the water balance are restricted by long measurement intervals and small study areas (Rana and Katerji, 2000), whereas studies with eddy covariance are overall complex and expensive (Vásquez et al., 2015). The FAO recommended calculation of $ET_c$ is relatively simple method that combines reference evapotranspiration ($ET_0$) and crop coefficient ($K_c$) (Allen et al., 1998). $ET_c$ can be readily obtained by the FAO Penman-Monteith equation using standard meteorological data. On the other hand, $K_c$ is often adopted from previous studies or from generalized $K_c$ curves (Farahani et al., 2008). However, the use of standard or generalized $K_c$ values under non-standard pedo-climatic and management conditions, i.e., conditions significantly different from those of standard/ generalized $K_c$ determination, can lead to significant errors in the calculation of $ET_c$ (Shukla et al., 2013). Therefore, it is important to have reliable estimation of $K_c$ and $ET_c$, especially in arid environments with water-saving managements, in order to facilitate sustainable water management.

Cotton is the major cash crop in Aksu Oasis of the Tarim River Basin (TRB), an arid region in Northwest China with...
global importance for cotton production. Almost 50% of the total cotton in the TRB is produced in the Aksu Oasis. While annual precipitation amounts only 50 mm on average, nearly all croplands are irrigated and account for over 97% of total water use in the oasis (Zhang et al., 2012a). With the expansion of the oasis and the exploitation of the groundwater in recent years, the use and allocation of water resources are now critical elements of the water resources management in the region (Han et al., 2015). Therefore, a comprehensive understanding of $K_c$ for cotton will not only optimize the amounts of irrigation water, but will also support the government in the a priori information decision making.

Most studies on $K_c$ for cotton in Aksu Oasis have considered flood or furrow irrigation without plastic mulching (Liu, 1998). Over the years, however, these systems have been replaced by drip irrigation and plastic mulching (Zhong et al., 2009). Plastic mulching is a dominant water conservation technique in arid and semiarid regions in China and worldwide. It involves an application of a continuous and impervious sheet of polyethylene film that covers the lengths of the field rows (Kasirajan and Ngouajio, 2012). Accurate information on the seasonal dynamics of $K_c$ for cotton under plastic mulching and associated influencing factors such as fraction of mulch cover, plant row spacing, irrigation scheme and overall growth condition are very limited (Zhou et al., 2012).

The objective of this study is to determine the daily dynamics of $K_c$ of cotton in an arid region in China for two full seasons in order to: 1) capture the seasonal dynamics in $K_c$ for drip-irrigated and plastic-mulched cotton fields, 2) determine the differences in $K_c$ of cotton between plastic mulch and non-plastic mulch condition, and 3) analyze the key factors influencing $K_c$ such as relative growth days, leaf area index, extractable soil water, and irrigation.

2. Materials and Methods

2.1 Study site and hydrometeorological conditions

This study was conducted at the Soil and Water Conservation Monitoring Station (81°11' E, 40°37' N, 1013 m above sea level) in Aksu Oasis near Aler City, TRB during the cotton growing season.
season in 2013 and 2014. The climate is typical temperate desert with average annual sunshine of 2892 h, average annual cumulated daily temperature (higher than 10°C) of 4081°C, average annual precipitation of 50 mm, and average annual pan evaporation of 1987 mm. Air temperature, relative humidity, and wind speed were measured at 2.0 m above the ground surface using standard automatic instruments in a self-build meteorology station. The daily variations of mean air temperature, humidity, wind speed, and precipitation are plotted in Fig. 1. The mean daily values of air temperature, humidity and wind speed for 2013 and 2014 were, respectively, 21.4 and 20.4°C, 48.8 and 46.4%, and 2.6 and 2.6 m s⁻¹. Total precipitation during the growing season in 2013 and 2014 was, respectively, 72.6 and 30.3 mm, deviating from the long-term (1961–2007) mean annual precipitation of 49.5 mm obtained from Aler Soil and Water Conservation Monitoring Station. The soil texture in the region is mainly sandy loam, with an average bulk density of 1.58 g cm⁻³ in the top 1.6 m profile.

2.2 Crop development, plastic mulching and agronomic management

Cotton (Gossypium hirsutum L., Xinluzhong-37) was planted in early April in 2013 and 2014 in a narrow row with a width of 10 cm, as illustrated on Fig. 2. The distance between two narrow rows was 60 cm. A drip tape was placed in the center of each of two narrow row in east-west direction. The two narrow rows (including the drip tape) were covered with a transparent polyethylene plastic film and tightly pegged into the soil at the edges. The width of the transparent polyethylene plastic film was 110 cm. The width of pure bare soil between two successive plastic films was 50 cm. Thus, the area under plastic mulching accounted for almost 70% of the total cotton field. In order to ensure that the study was consistent with the local farming conditions, the cotton field was fertilized, irrigated, and managed in accordance with the local practices. LAI was directly measured by taking statistically significant sample of foliage from cotton canopy at seedling stage and indirectly measured every 10 days by hand-held LAI-2000 Plant Canopy Analyzer (LI-COR Inc., USA) at other growth stages.

2.3 Eddy covariance measurements

An eddy covariance system, oriented toward the direction of the prevailing winds (northeast), was installed in the center of a large cotton field (520 m × 225 m) to measure latent heat flux and sensible heat flux. The area surrounding the study site was flat and composed of homogeneous cotton fields, assuring large fetch for the measurements. The eddy covariance system consisted of a 3D sonic anemometer (CSAT3, Campbell Scientific Inc., USA) and an open-path infrared gas analyzer (LI-7500, LI-Cor Inc., USA). The sensors were installed at 3.0 m above the ground surface, i.e., about 2.2 m above the highest cotton canopy. The three orthogonal wind components and vapor concentration were sampled at a frequency of 10 Hz. The monitored results were averaged at 30 min intervals and post-processed in Eddypro 5.1.1 software (LI-COR) for quality control, including specific corrections and steps, as described in Ai and Yang (2016).

2.4 Irrigation and soil moisture

The cotton field was irrigated in accordance with the local practice, which corresponds to about 10-day interval and adjustment to soil moisture and precipitation water contents. The irrigation time in 2013 was 20 and 21 June, 1, 11, 18 and 25 July, 2, 8, 12 and 24 August and 9 September, with respective amounts of 63, 42, 48, 48, 49, 50, 50, 20, 48, 22 and 18 mm, whereas in 2014 irrigation time was 26 June, 6, 15 and 23 July, 3, 11, 18 and 24 August and 5 September and respective amounts of 30, 48, 48, 44, 40, 48, 48 and 48 mm. Before and after irrigation or precipitation, soil moisture was regularly measured at 10, 20, 30, 50, 70, 90, 110, 130, 150 and 160 cm soil depths with three neutron probe (503DR hydroprobe, CPN International Inc., USA) installed in the centers of the narrow and wide row and in bare soil between two successive plastic films. The probes were placed through PPR (polypropylene) access tubes following their calibration by the oven-dried method.

2.5 Data analysis and calculations

Kc was calculated according to the following equation:

\[ K_c = \frac{ET_c}{ET_{oa}} \]  

(1)

where \( ET_c \) is actual crop evapotranspiration (mm) obtained by eddy covariance measurements, and \( ET_{oa} \) is reference evapotranspiration (mm) estimated by the FAO Penman-Monteith equation (Allen et al., 1998):

\[ ET_{oa} = \frac{0.408\Delta(R_n - G) + \gamma}{\Delta + \gamma(1 + 0.3\hbar_2)} \left(\frac{900}{T + 273}\right) \left(\varepsilon_s - \varepsilon_a\right) \]  

(2)

where \( \Delta \) is slope vapor pressure curve (kPa°C⁻¹); \( R_n \) is net radiation at crop surface (MJ m⁻² day⁻¹); \( G \) is soil heat flux density (MJ m⁻² day⁻¹); \( \gamma \) is psychrometric constant (kPa°C⁻¹); \( T \) is mean daily air temperature at 2 m height (°C); \( \varepsilon_s \) is saturation vapor pressure (kPa); \( \varepsilon_a \) is actual vapor pressure (kPa); and \( \hbar_2 \) is wind speed at 2 m height (m s⁻¹). Mean daily \( K_c \) for each growth stage was calculated by the average of daily \( K_c \) during each growth stage that

![Fig. 2. Schematic representation of cotton plants spacing and row spacing according to the local agronomic practices in Aksu Oasis of Tarim River Basin, Northwest China. The unit of the number in the figure is centimeter.](image-url)
described in Table 1.

The $K_c$ curve was estimated on a daily scale as a function of relative growth days (RGD) i.e. normalized growing days (equals to the ratio of the day after emergency to the total days during a whole growth season) where “1” represents the last day in a growth season. The number of total days is 186 and 181 in 2013 and 2014, respectively. A piecewise third-degree polynomial regression equation was fitted to the $K_c$ as follow:

$$K_c = a_1 \cdot RGD^1 + a_2 \cdot RGD^2 + a_3 \cdot RGD + a_4$$

where $a_1$, $a_2$, $a_3$, and $a_4$ are the fitted regression coefficients.

Two indices of LAI and extractable soil water (ESW) were used to analyze the driving factors affecting $K_c$, where ESW was calculated as:

$$ESW = \frac{\theta_f - \theta_w}{\theta_f - \theta_G}$$

where $\theta_f$ is soil water content in the cotton root zone, $\theta_w$ is the wilting point, and $\theta_G$ is the filled capacity, the unit is in volumetric (m$^3$ m$^{-3}$).

2.6 Statistical analysis

Performance of the models was evaluated for key residuals using root-mean square error (RMSE), and for correlation and efficiency using the coefficient of determination ($R^2$) and the NasheSutcliffe Model Efficiency (NSME) between modeled ($M_j$) and observed ($O_j$) values of $K_c$ (Bennet et al., 2013). The model performance is optimum at low RMSE and high $R^2$ and NSME values, though these indices are sensitive to extreme values and should be interpreted with caution.

3. Results and Discussion

3.1 $K_c$ dynamics and effect of plastic mulching

The growth stages of plastic-mulched cotton for the two-year study period are presented in Table 1, whereas the daily dynamics of $K_c$ during its growth stages are plotted in Fig. 3. $K_c$ was low and relatively stable during the juvenile seedling stage, after which it rapidly increased during squaring stage; daily $K_c$ values remained high during flowering and boll-setting stage, thereafter decreasing at boll opening stage. The mean daily $K_c$ for the aforementioned four growth stages was 0.25/0.21, 0.54/0.45, 0.90/0.82, and 0.58/0.54 in 2013/2014. These values corroborate well the results of Yang et al. (2016), who found $K_c$ of 0.23, 0.88, and 0.44 during initial, middle, and late growth season, respectively, of a three-year plastic-mulched cotton in similar study area in China. Furthermore, comparison of cotton $K_c$ obtained in this study under plastic mulch with literature values obtained for cotton without mulch is given in Table 2. There was a notable reduction in cotton $K_c$ under plastic mulch conditions compared to no mulch conditions, which can be mainly attributed to the high mulch fraction of almost 70% used in the present study. The lower values for plastic-mulched cotton $K_c$ were particularly evident during the initial- and development stages, with respective of reductions 47 and 35 for the two development stages, compared to no mulched cotton. For the entire growth period, the reduction in $K_c$ under plastic mulch conditions ranged from 16 to 39, with an average of about 27%, compared to

| Growth stage                          | Training period       | Testing period       |
|---------------------------------------|-----------------------|----------------------|
| Sowing to emergence                   | April 4 to April 15   | April 8 to April 23  |
| Seedling                             | April 16 to May 21    | April 24 to May 30   |
| Squaring                             | May 22 to June 21     | May 31 to June 25    |
| Flowering and boll-setting            | June 22 to September 2| June 26 to September 5|
| Boll opening                          | September 3 to October 18 | September 6 to October 21 |

![Fig. 3. Variations in daily crop coefficient ($K_c$) of cotton under plastic mulch conditions in Aksu Oasis of Tarim River Basin, Northwest China at different growth stages in 2013 and 2014.](image-url)
no mulch conditions. Although the reported effects of mulching (with plastic or straw) on water utilization are often contradictory, likely due to differences in weather-, soil-, crop characteristics and water and fertilizer inputs (Zhang et al., 2017), literature reviews clearly indicate that mulching significantly improves the agro-hydrological performance, primarily yields and water use efficiency (yield per unit water) for many crops, compared with no-mulching (Qin et al., 2015). Compared to no mulching, the effect of plastic mulching on evapotranspiration and associated $K_c$ values is expected to diminish as the plant grows due to canopy cover of the soil, which decreases the amplitudes of soil heat flux and soil temperature (Zhang et al., 2017; Farahani et al., 2008). In the early growth stages, however, plant transpiration and soil evaporation under mulching do not attain saturation of intercepted sunlight and the magnitude and variation of $K_c$ are lower. Therefore, using $K_c$ growth stages, plant transpiration and soil evaporation may contain uncertainties due to differences in climatic and management condition. It is noted that the $K_c$ comparison presented in Table 2 reported by no mulching studies may overestimate evapotranspiration for any day during the growth stage in TRB or other regions under the same or comparable hydrometeorological and management conditions.

3.2 Variation of $K_c$ with RGD

A piecewise dual polynomial model for the rising and the fall- ing trends of the $K_c$ curve was fitted to the data for 2013 and the equations for the two main RGD stages are presented in Table 3. Furthermore, the model was validated using the $K_c$ data for 2014 and the fit between modelled and measured values is shown in Fig. 4 with associated model performance indicators given in Table 4. It can be deducted from these results that the model had an acceptable statistical performance, with significantly high values of $R^2$ and NSME and low values of RMSE, despite the slight tendency for overestimation of $K_c$, probably due to cooler weather conditions in 2014 (Fig. 1) that also affected crop growth and lowered slightly the $K_c$ values (Fig. 3). Nevertheless, the regressions reliably reflect the daily $K_c$ patterns of the plastic mulched cotton by depicting an increasing trend from initial to early development season, followed by a gradual decrease in $K_c$ from mid- to the end of late season. Reddy (2015) used similar approach to model $K_c$ in function of days after sowing and found good model performance for castor and maize in India. Thus, the proposed models can be useful for estimation of cotton evapotranspiration for any day during the growth stage in TRB or other regions under the same or comparable hydrometeorological and management conditions.

### Table 2. Comparison of cotton crop coefficient ($K_c$) values under plastic mulch condition in this study and under non-plastic mulch condition reported by other studies.

| Cotton $K_c$ | Growth stage | Initial | Development | Mid-season | Late-season | Average |
|--------------|--------------|---------|-------------|------------|-------------|---------|
| This study   |              | 0.23    | 0.49        | 0.86       | 0.56        | 0.54    |
| Allen et al. (1998) | | 0.35    | 0.66        | 1.15 – 1.20| 0.50 – 0.70 | 0.67 – 0.73 |
| Farahani et al. (2008) | | 0.29    | None        | 1.05       | 0.66        | 0.67    |
| Mohan and Arumugam (1994) | | 0.46    | 0.7         | 1.01       | 0.39        | 0.64    |
| Bezerra et al. (2012) | | 0.75    | None        | 1.09       | 0.8         | 0.88    |
| Ko et al. (2009) | | 0.43    | 0.94        | 1.24       | 0.58        | 0.8     |
| Karam et al. (2006) | | 0.58    | None        | 1.1        | 0.83        | 0.84    |

### Table 3. Polynomial regression models for crop coefficient ($K_c$) of cotton under plastic mulch conditions in Aksu Oasis of the Tarim River Basin, Northwest China, under two different relative growth day (RGD) periods.

| Relative growth period | Regression equation |
|------------------------|---------------------|
| 0 < RGD ≤ 0.6          | $K_c = -21.346RGD^3 + 19.261RGD^2 - 2.9885RGD + 0.3285$ |
| 0.6 < RGD ≤ 1          | $K_c = -1.6519RGD^3 - 2.4627RGD^2 + 5.6725RGD - 1.3268$ |
significantly increase $K_c$ (Allen et al., 1998; Ding et al., 2015).

Soil water content is an important factor influencing $K_c$. In the present study, a linear and significant ($P<0.05$) correlation was found between $K_c$ and extractable soil water (ESW) in the root zone (0–100 cm), expressed as $K_c = 2.39 \times \text{ESW} - 0.30$ for ESW < 0.5 (Fig. 5); for ESW > 0.5, $K_c$ was nearly constant and insignificantly ($P>0.05$) correlated to ESW according to the relation $K_c = 0.42 \times \text{ESW} + 0.54$. This suggested that ESW of 0.5 can be adopted as a critical value when evaluating the influences of extractable soil water on cotton $K_c$. A possible reason is that the crop would be under water stress condition and $K_c$ would therefore increase with the increase of ESW when ESW is less than 0.5 (Ding et al., 2015).

Zhang et al. (2012b) pointed on soil water content at 10 cm soil depth, rather than biological factors such as LAI, as the driving factor of $K_c$ in desert steppe conditions. It was noted in this study, however, that both LAI and extractable soil water were the main driving factors of $K_c$. And the critical values of 3.0 in LAI and 0.5 for extractable soil water were detected, which was similar to the results of Ding et al. (2015). The above-mentioned equations could be useful in analyzing or estimating cotton $K_c$ independently on LAI or ESW alone.

### 3.4 Effect of irrigation on $K_c$

The effect of irrigation on $K_c$ for plastic mulched cotton, expressed by $K_c$ values before and after irrigation events are presented in Table 5. It can be seen from the table that $K_c$ generally increased after irrigation, and the increase was, on average, 0.22 corresponding to 29.4. This finding suggests that irrigation has a significant effect on $K_c$ of plastic mulched cotton under arid conditions. Similar results of crop coefficient increase due to irrigation have been observed by Li et al. (2008) and Ding et al. (2015). The main reason could be the increase of latent heat flux after irrigation. The effect of arid advection after irrigation probably also contributes to the increase of $K_c$. In order to investigate advection effect on $K_c$ in more detail, Bowen

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**Table 4.** Statistical analysis of the crop coefficient ($K_c$) models for cotton under plastic mulch conditions in Aksu Oasis of the Tarim River Basin, Northwest China.

| Indicators             | Training period | Testing period |
|------------------------|-----------------|----------------|
| Slope of the scatter plot | 0.9999          | 0.9276         |
| $R^2$                  | 0.82            | 0.69           |
| RMSE                   | 0.13            | 0.17           |
| NSME(%)                | 91.32           | 86.29          |
| $P$                    | $<0.01$         | $<0.01$        |

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**Fig. 4.** Scatter plots of daily observed versus model-estimated crop coefficient ($K_c$) of cotton under plastic mulch conditions in Aksu Oasis of Tarim River Basin, Northwest China.

**Fig. 5.** Relationships between crop coefficient ($K_c$) and leaf area index (LAI) and extractable soil water (ESW) for cotton under plastic mulch conditions in Aksu Oasis of Tarim River Basin, Northwest China.
ration, i.e., the ratio of the sensible to the latent heat flux, was calculated for a single irrigation event on 11 July 2013 (Fig. 6). Bowen ratio of less than zero indicates that sensible heat advection has taken place because the sensible heat is negative and the latent heat is higher than the available energy under such condition (Gavilán and Berengena, 2007). From Fig. 6, it can be seen that the Bowen ratio indeed decreased to less than zero after irrigation, indicating that advection occurred and provided additional energy for evapotranspiration, and hence increased $K_c$. The decrease of the Bowen ratio was due to the increase of near-surface soil moisture and latent heat flux. For example, soil volumetric water content at 10 cm increased from 0.1 m$^3$ m$^{-3}$ (one day before irrigation) to 0.19 m$^3$ m$^{-3}$ (two day after irrigation). The negative Bowen ratio was due to the negative sensible heat advection from the surrounding dry land. Similar findings have also been reported by Lei and Yang (2010). Therefore, advection should be considered by further studies in the estimation of evapotranspiration for irrigated and plastic mulched croplands under arid climate. The use of the difference between potential evapotranspiration and available energy, as conducted by Yang et al. (2013), may be one kind of method to address such issue.

4. Conclusion

This study determined the values and characteristics of $K_c$ and related driving factors in cotton fields under plastic mulch conditions in Aksu Oasis, TRB, China, using the eddy covariance method to calculate actual evapotranspiration. Compared with traditional method based on water balance, eddy covariance is more reliable for calculation of actual evapotranspiration due to shorter measurement intervals and larger study area. The $K_c$ for plastic mulched cotton in Aksu Oasis, TRB, varied within a range of 0.08–1.28, with an average value of 0.54 for the entire growth season. Compared to non-plastic mulch condition, $K_c$ of cotton under plastic mulch had a substantial decrease of 47% and 35%, for initial and developmental stage, respectively, whereas $K_c$ values during mid- and late season were less different. Thereafter, a piecewise defined $K_c$ model in function of relative growth days was developed and validated based on the eddy covariance measurements. The proposed model is useful for estimation of cotton evapotranspiration during its growth under the same or comparable hydrometeorological and management conditions.

Table 5. Effect of irrigation on crop coefficient ($K_c$) of cotton under plastic mulch conditions in Aksu Oasis of the Tarim River Basin, Northwest China. “I” denotes irrigation day, “1BI” denotes 1 day before irrigation, and “1AI”, “2AI”, and “3AI” denote 1, 2, and 3 days after irrigation, respectively. “none” denotes no $K_c$ values due to the failure of eddy covariance observation.

| Irrigation time (year/month/day) | $K_c$  
|---------------------------------|-------|
|                                 | 1BI   | I     | 1AI   | 2AI   | 3AI   |
| 2013/06/10                      | 0.44  | 0.48  | 0.59  | 0.54  | 0.66  |
| 2013/06/21                      | 0.98  | 0.96  | 1.05  | 0.85  | 1.10  |
| 2013/07/01                      | 0.93  | 0.67  | 0.90  | 0.99  | 0.70  |
| 2013/07/11                      | 0.90  | 0.92  | 1.06  | 1.18  | 1.12  |
| 2013/07/18                      | 1.06  | 0.92  | 1.15  | 0.91  | 0.92  |
| 2013/07/25                      | 1.16  | 0.87  | 1.21  | 0.95  | 0.72  |
| 2013/08/02                      | 0.90  | 0.90  | 0.98  | 0.93  | 0.91  |
| 2013/08/12                      | 0.70  | none  | 0.91  | none  | none  |
| 2013/08/24                      | 0.73  | 0.76  | 0.90  | none  | none  |
| 2013/09/09                      | 0.73  | 0.82  | 0.92  | 0.83  | 0.87  |
| 2014/06/26                      | 0.50  | 0.58  | 0.70  | 0.67  | 0.72  |
| 2014/07/06                      | 0.77  | 0.63  | 0.66  | 0.87  | 0.61  |
| 2014/07/15                      | 0.68  | 0.71  | 0.88  | none  | 0.77  |
| 2014/08/24                      | 1.13  | 0.97  | 1.07  | 1.28  | 0.59  |
| 2014/09/05                      | 0.90  | 0.71  | 0.94  | 1.02  | 0.91  |

Fig. 6. Daytime variation in half-hourly Bowen ratio values for cotton after irrigation under plastic mulch conditions in Aksu Oasis of Tarim River Basin, Northwest China. “I” denotes irrigation day (11 July 2013), “1AI”, “2AI”, and “3AI” denote 1, 2, and 3 days after irrigation, and “1BI”, “2BI” denote 1 and 2 days before irrigation, respectively.
conditions. Additional analysis showed that LAI and extractable soil water are important factors influencing $K_c$, and near-maximum $K_c$ was reached at critical values of 3.0 for LAI and 0.5 for extractable soil water. In addition, irrigation notably increased $K_c$, i.e., about 29% on average, partly due to advective heat fluxes.

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