Agricultural Water Management 96 (2009) 1409–1420

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

# Macromanagement of deficit-irrigated peanut with sprinkler irrigation

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ARTICLE INFO

*Article history:*
Received 13 August 2008
Accepted 3 May 2009
Available online 2 June 2009

*Keywords:*
Crop coefficient ($K_c$)
Evapotranspiration (ET)
Groundnut
Water stress
Water use
Water use efficiency
Water productivity
Yield response factor (ky)

ABSTRACT

Precision irrigation management and scheduling, as well as developing site- and cultivar-specific crop coefficient ($K_c$), and yield response factor to water deficit (ky) are very important parameters for efficient use of limited water resources. This study investigated the effect of deficit irrigation, applied at different growth stages of peanut with sprinkler irrigation in sandy soil, on field peanut evapotranspiration (ETc), yield and yield components, and water use efficiencies (IWUE and WUE). Also, yield response factor to water deficit (ky), and site- and cultivar-specific $K_c$ were developed. Four treatments were imposed to deficit irrigation during late vegetative and early flowering, late flowering and early pegging, pegging, and pod formation growth stages of peanut, and compared with full irrigation in the course of the season (control). A soil water balance equation was used to estimate crop evapotranspiration (ETc). The results revealed that maximum seasonal ETc was 488 mm recorded with full irrigation treatment. The maximum value of $K_c$ (0.96) occurred at the fifth week after sowing, this value was less than the generic values listed in FAO-33 and -56 (1.03 and 1.15), respectively. Dry kernels yield among treatments differed by 41.4%. Deficit irrigation significantly affected yields, where kernels yield decreased by 28, 39, 36, and 41% in deficit-irrigated late vegetative and early flowering, late flowering and early pegging, pegging, and pod formation growth stages, respectively, compared with full irrigation treatment. Peanut yields increased linearly with seasonal ETc ($R^2$ = 0.94) and ETc/ETp ($R^2$ = 0.92) (ETp = ETc with no water stress). The yield response factor (ky), which indicates the relative reduction in yield to relative reduction in ETc, averaged 2.9, was higher than the 0.7 value reported by Doorenbos and Kassam [Doorenbos, J., Kassam, A.H., 1979. Yield response to water. FAO Irrigation and Drainage Paper 33, Rome, Italy, 193 pp.], the high ky value reflects the great sensitivity of peanut (cv. Giza 5) to water deficit. WUE values varied considerably with deficit irrigation treatments, averaging 6.1 and 4.5 kg ha$^{-1}$ mm$^{-1}$ (dry-mass basis) for pods and kernels, respectively. Differences in WUE between the driest and wettest treatment were 31.3 and 31.3% for pods and kernels, respectively. Deficit irrigation treatments, however, impacted IWUE much more than WUE. Differences in IWUE between the driest and wettest treatment were 33.9 and 33.9% for pods and kernels, respectively. The results revealed that better management of available soil water in the root zone in the course of the season, as well as daily and seasonal accurate estimation of ETc can be an effective way for best irrigation scheduling and water allocation, maximizing yield, and optimizing economic return.



## 1. Introduction

Peanut is an important legume cash crop for the farmers in arid and semi-arid regions and its seeds contain high amounts of edible oil (43–55%), protein (25–28%), and minerals (2.5%). As a result of the continuous population explosion and the increasing standard of living, the demand on agricultural productivity and water resources is sharply increasing. Improper irrigation management not only causes variation in crop yield but also wastes scarce and valuable water resources. Deficit irrigation as an agricultural water management system is an effective way for managing water shortages. Better management of deficit irrigation requires a proper understanding of the effect of irrigation water on crop growth and yield under different growing conditions. Abundant soil moisture is required for normal development of peanut at all stages of growth. However, under limited availability of water, scheduling of irrigation at the critical stages or eliminating the least productive irrigations could increase crop productivity and water use efficiencies of peanut.

The variation of deficit irrigation timing and amount along the growing season at different growth stages might increase peanut yield, because it results in a change in the distribution of dry matter

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doi:10.1016/j.agwat.2009.05.002

between vegetative and reproductive organs (Ong, 1984). Sensitivity of pod development to moisture stress is related to the physiological stage when stress occurs (Rao et al., 1985; Singh et al., 1986; Stirling et al., 1989). Optimum productivity of peanut requires adequate water during all stages of its physiological maturity (Rao et al., 1988; Meisner and Karnok, 1992; Reddy and Reddy, 1993), but there are some critical points in its growth stages (flowering and pod filling) that are very sensitive to soil water availability compared with early vegetative and late maturity (Doorenbos and Kassam, 1979; Howell et al., 1980; Black et al., 1985; Ike, 1986; Patel and Golakiya, 1988; Stirling et al., 1989; Wright et al., 1991; Jain et al., 1997; Reddy et al., 2003). Insufficient water during these critical points reduces kernel yield substantially and fails to maximize water use (Pallas et al., 1979; Ike, 1986; Boote and Ketring, 1990; Meisner and Karnok, 1992; Metochis, 1993; Reddy et al., 2003).

Peanut is a crop whose drought resistance is due to its ability to maintain a viable root system during water stress. Water stress stimulates the growth of peanut roots into deeper soil. Peanut roots can effectively extract soil water to depths of at least 180 cm in fine sandy soils (Lenka and Mishra, 1973; Allen et al., 1976; Narasimham et al., 1977; Pandey et al., 1984; Simmonds and Ong, 1987; Devries et al., 1989; Sabale and Khuse, 1989; Sanders et al., 1993). Peanut cultivars subjected to soil moisture stress during the early vegetative phase resulted in an increase of individual seed weight. On the contrary, water stress at pod initiation and pod development stages reduced the suitability of seeds for planting (Nautiyal et al., 1991). Water deficit imposed during the vegetative stage of peanut achieved greater final yields and increased field water use efficiency and dry matter production, including economic yield (Ong, 1984; Nautiyal et al., 2000).

The start of flowering is not delayed by drought stress (Boote and Ketring, 1990). The pre-flowering phase is less sensitive to moisture stress than the flowering phase. Greater synchrony of pod set in moderately stressed plants during the pre-flowering phase resulted in greater proportion of mature pods at final harvest (Kulkarni et al., 1988; Rao et al., 1988). Some research reported that flowering stage is the most sensitive stage to water availability, where water stress during flowering would restrict root and canopy growth and affect the dry weight root to canopy ratio, as well as their growth rate (Yao et al., 2003). The rate of flower production is reduced by drought stress during flowering but the total number of flowers per plant is not affected due to an increase in the duration of flowering (Gowda and Hegde, 1986; Janamatti et al., 1986; Meisner and Karnok, 1992). When stress is imposed during 30–45 d after sowing the first flush of flowers do not form pegs during that time, however, flowers produced after re-watering compensated for this loss (Gowda and Hegde, 1986). A significant burst in flowering after alleviation of stress is a unique feature in the pattern of flowering under moisture stress, particularly when drought is imposed just prior to reproductive development (Janamatti et al., 1986). Reducing irrigation by 44% from early flowering to early pods formation decreased yield by 61% compared with full irrigation (Rao et al., 1985).

Conversely, several reports indicated that the pod development phase is the most sensitive period to water deficit (Patel and Golakiya, 1988; Stirling et al., 1989; Meisner and Karnok, 1992; Ramachandrappa et al., 1992). Yield reductions are greatest with stress imposed during the period between pegging and pod development and lowest with stress imposed from pod development to maturation (Patel and Golakiya, 1988). Irrigation timing affects pod yield mainly by influencing the duration of pod production. Naveen et al. (1992) found that water stress imposed during the flowering and pegging stages produced the greatest reductions in pod yield followed by water stress at the early- and late-pod stages. The deviation is probably due to the shorter duration of flowering. Reproductive growth stage is less affected than the vegetative growth stage. Applying mild water stress during reproductive stage enhanced peg and pod production. Mild water stress increased the ratio of pod to shoot weight. This ratio can be greatly increased when adequate water is supplied to relieve a mild stress (Ong, 1984).

Sprinkler irrigation systems with low irrigation frequencies of 3 d increased pod yield of peanut (ranged from 602 to 651 g $m^{-2}$) and WUEs due to decreasing water losses during the irrigation season (Plaut and Ben-Hur, 2005). They also stated that total water applied to peanut crop ranged from 575 to 648 mm. As reviewed by Ahmad (1999) the total water requirements of peanut may range from 500 to 700 mm throughout the growing season. Better management of water resources can be achieved by developing site- and cultivar-specific $K_c$ and estimation of phenological parameters. Comprehensive knowledge (Macromanagement) of actual evapotranspiration, crop coefficient ($K_c$), crop water requirements, and critical crop growth stages are very important for optimizing crop water use and maximizing crop yield (Elliott et al., 1988; Jain et al., 1997; Bandyopadhyay et al., 2005; Suleiman et al., 2007). Generic $K_c$ values for a number of crops grown under different climatic conditions were listed in FAO-33 (Doorenbos and Kassam, 1979) and FAO-56 (Allen et al., 1998). These $K_c$ values were developed from unknown resources, indicating only the climate, cropping season and height of the crop, without considering the cultivar specifications. Rarely an attempt was made to estimate site- and cultivar-specific $K_c$s under given climatic conditions. Local or regional calibration of FAO $K_c$ curve is strongly recommended for achieving the accuracy of irrigation scheduling and water allocation (Farahani et al., 2008).

The objectives of this study were: (1) to identify which growth stage of peanut (late vegetative and early flowering, late flowering and early pegging, pegging, and pod formation) is most tolerant to water stress; (2) to derive the $K_c$ value and the yield response factor (ky) for peanut from the water use data under the actual growing conditions for irrigation planning and management at a regional level; (3) to develop crop response functions to irrigation; (4) to study how deficit irrigation imposed at different growth stages of peanut with sprinkler irrigation affected the soil water distribution pattern, seasonal evapotranspiration, yield and yield components, and water use efficiencies of peanut in the arid climate of east Delta, Egypt; and (5) to improve traditional irrigation strategies for peanut.

## 2. Materials and methods

### 2.1. Site description

Field experiment was conducted during the 2006 growing season. The experiment was located at the Enshas Experiment Station, Water Management Research Institute, National Water Research Center, in East Nile Delta, Sharkiya governorate, Egypt. The experimental site had the following characteristics: (longitude 31.35°E, latitude 30.24°N and altitude 25.5 m). The soil texture is sandy with field capacity of 8.04%; wilting point 3.7%, soil bulk density of 1.49 g $cm^{-3}$ and infiltration rate 12.47 cm $h^{-1}$. The irrigation water source was surface water (Al-Esmaliya Canal). The quality of the irrigation water was good and would not be expected to affect the results of the study. The chemical analyses of the irrigation water and soil physical and chemical properties are presented for informational purposes (Tables 1–3).

### 2.2. Experimental design

The field experiment was conducted using a randomized complete block design with five irrigation treatments (T1–T5) and