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ORIGINAL ARTICLE / ORIGINALBEITRAG

Interactional Impacts of Drought and Weed Stresses on Nutritional Status of Seeds and Water Use Efficiency of Peanut Plants Grown in Arid Conditions

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Abstract

Globally, rationalizing and converting each drop of irrigation water into food is a crucial act in agricultural production, particularly with climatic change concerns. Thus, the current study seeks to find an integral practice between irrigation pattern and weed control for saving the irrigation water in peanut fields with improving the nutritional value of the seeds. In sandy loam soil, under two irrigation regimes (75 and 100% of crop evapotranspiration—ETc_{75} and ETc_{100}, respectively), the responses of peanut pod yield and quality (seed oil, N, P, and K contents) and water use efficiency to six weed control treatments (bentazon, clethodim, bentazon + hoeing once,clethodim + hoeing once, hoeing twice and unweeded) were evaluated. The obtained data of 2016 and 2017 seasons illustrated that whether using ETc_{75} or ETc_{100}, hoeing twice showed the highest efficiency of weed control in peanut. Reduction in yield was diminished from 15.1–16.9% in unweeded plots to 9.0–9.7% in weeded ones. Controlling weeds led to a decrease in their efficiency for exploiting the applied water. That decrease amounted to 64.4 and 64.3% reductions with ETc_{100} as well as 66.9 and 64.4% reductions with ETc_{75} in the 1st and 2nd seasons, respectively. Peanut plants consumed less water under ETc_{75} than ETc_{100} to produce one kilogram of pods by about 17.9% in weeded plots (mean of applied weeded treatments) as well as 10.1% in weedy conditions. Also, ETc_{75} plus weeded practices raised the benefit/cost by 52.3% compared to unweeded one. In conclusion, the interactional impact of irrigation and weed control proved that peanut plants can be irrigated as much as 75% of evapotranspiration under water shortage conditions with hoeing twice or herbicide use. Selecting the appropriate weed control practice is a vital act for water saving and keeping productivity, quality and returns of peanut cultivation in arid regions.

Keywords Arachis hypogaea · Water deficit · Peanut yield · NPK content · Weeds

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Wechselseitige Auswirkungen von Trockenheit und Unkrautstress auf den Nährstoffstatus der Samen und die Wassernutzungseffizienz von Erdnusspflanzen unter ariden Bedingungen

Zusammenfassung

Global gesehen ist die Rationalisierung und Umwandlung jedes Tropfens Bewässerungswasser in Nahrung ein entscheidender Akt in der landwirtschaftlichen Produktion, insbesondere im Hinblick auf den Klimawandel. Daher versucht die aktuelle Studie, eine integrale Praxis zwischen Bewässerungsmuster und Unkrautbekämpfung zu finden, um das Bewässerungswasser in Erdnussfeldern zu sparen und gleichzeitig den Nährwert der Samen zu verbessern. In sandigem Lehmboden wurden unter zwei Bewässerungsregimes (75 und 100 % der Evapotranspiration – ET_{c75} bzw. ET_{c100}) die Reaktionen von Erdnussertrag und -qualität (Samenöl-, N-, P- und K-Gehalt) sowie die Wassernutzungseffizienz auf sechs Unkrautbekämpfungsbehandlungen (Bentazon, Clethodim, Bentazon + einmaliges Hacken, Clethodim + einmaliges Hacken, zweimaliges Hacken und keine Behandlung/Kontrolle) bewertet. Die erhaltenen Daten aus den Saisons 2016 und 2017 zeigten, dass bei Erdnuss, egal ob mit ET_{c75} oder ET_{c100}, das zweimalige Hacken die höchste Effizienz der Unkrautbekämpfung zeigte. Die Ertragsminderung wurde von 15,1–16,9 % in den unbehandelten Parzellen auf 9,0–9,7 % in den behackten Parzellen verringert. Die Bekämpfung von Unkräutern führte zu einer Effizienzverringerung bezüglich der Ausnutzung des ausgebrachten Wassers. Diese Abnahme betrug 64,4 und 64,3 % bei ET_{c100} sowie 66,9 und 64,4 % bei ET_{c75} in der ersten bzw. zweiten Saison. Erdnusspflanzen verbrauchten unter ET_{c75} weniger Wasser als unter ET_{c100}, um ein Kilogramm Erdnusshülsen zu produzieren – die Differenz betrug 17,9 % in behandelten Parzellen (Mittelwert der angewendeten Unkrautbehandlungen) sowie 10,1 % bei der Kontrolle. Außerdem erhöhte ET_{c75} plus Unkrautbehandlung das Nutzen/Kosten-Verhältnis um 52,3 % im Vergleich zur Kontrolle. Zusammenfassend lässt sich sagen, dass die Wechselwirkung zwischen Bewässerung und Unkrautbekämpfung bewiesen hat, dass Erdnusspflanzen unter Bedingungen von Wasserknappheit mit zweimaligem Hacken oder Herbizideinsatz bis zu 75 % der Evapotranspiration bewässert werden können. Die Wahl der geeigneten Unkrautbekämpfungsmethode ist ein entscheidender Schritt, um Wasser zu sparen und die Produktivität, Qualität und Erträge des Erdnussanbaus in ariden Regionen zu erhalten.

Schlüsselwörter Arachis hypogaea · Wasserdefizit · Erdnussertrag · NPK-Gehalt · Unkraut

Introduction

Despite the favorable climatic conditions in African countries for peanut (*Arachis hypogaea*, L.) cultivations, the deficiency of water counted as a major obstacle in the mercantile production. Relative to world cultivation and production, the acreage in Africa reached about 47% with 27% production (FAO 2012). Peanut is considered as a monetary crop in arid and semiarid areas. Peanut seeds have desirable quality traits involving edible oil, protein and nutrients. The dominance of unsaturated fatty acids more than saturated ones gives peanut seeds comparative advantage (Sabate 2003). Moreover, since peanut is a nitrogen-fixer legume crop, it is essential to be one of the agroecosystem components for agricultural sustainability. Brooker et al. (2015) stated that legumes are known to provide multiple ecosystem services.

Due to the scarcity of water in the dry land areas with higher consumption in the agricultural sector than in other sectors, rationalization of water use is inevitable with enhancing water productivity. However, at dry environment in arid zones, water shortage as abiotic stress represents a great challenge for crop growth and development. Drought is the major environmental constraint to peanut, limiting productivity (Awal and Ikeda 2002). Counteractive impacts on peanut yield, yield attributes and seed quality due to reducing water supply have been reported (Aboelill et al. 2012; El-Boraie et al. 2009). In this context, Aydinsakir et al. (2016) recorded 81.0, 68.5, 28.5, 12.0% reductions in peanut seed yield owing to irrigation with 0, 25, 50 and 75% of crop evapotranspiration, respectively, compared to the recommended irrigation (100%). Noticeable reductions in peanut biomass yield and seed nutrient constituents were recorded because of the low water supply (Saudy and El-Metwally 2019). Furthermore, the least amount of water applied (40 mm) resulted in yield reductions by 76, 70 and 67% of the greatest amount of water applied (480 mm) for seed yield, pod yield and final biomass, respectively (Amiri et al. 2015). Moreover, Abou Kheira (2009) reported that regulating soil moisture status in the rhizosphere with daily assessment of crop evapotranspiration can be an effective pattern for valid irrigation scheme, chiefly in sandy soils, hence optimizing water and crop productivities.

Water consumption by unwanted plants, i.e. weeds, is one type of loss that contributes to the cost of weed control practices in agriculture (Norris 1996). Increasing water supply caused increase in dry weight of peanut weeds (Saudy et al. 2020). Thus, eliminating sources of water loss via weeds is becoming increasingly important in this regard. Herein, the presence of undesirable plants, i.e. weeds as biotic pressure, represents another restriction toward the crop productivity. Since weeds interfere with crop plants for land exploitation, water and nutrients, reduction in crop production is realized. In weed infestation conditions, yield of peanut reduction reached 30–40% (Clewis et al. 2007; Jhala et al. 2005; Saudy et al. 2020). Furthermore, transpiration requirements of weeds disturb not only the impact on the water requirements of the crop vegetation growth, but also the moisture-competitive relations between the cultivated crops and weed plants (Pivec and Brant 2009).

Despite the availability of some herbicides which can be used in controlling weeds in peanut fields, the herbicidal efficiency and nutrient uptake under low water supply require more investigations. Therefore, the following questions were asked for investigation and analysis: Do the efficiency of weed control practices against peanut weeds change under low water supply compared to normal condition? What are the modifications in nutritional value of peanut seeds and water use efficiency that may associate drought plus herbicide applications? Practically, could we gain applicable simple solutions for saving irrigation water in peanut fields using irrigation regimes combined with weed control practice?

Materials and Methods

Site Depiction

Over almost four months, May, June, July and August, during the seasons of 2016 and 2017, peanut plants were grown in field trial at the Experimental Research and Production Station, National Research Centre, Beheira governorate, Egypt (30°31′N, 30°18′E; 21 m a.s.l.). A representative composite soil sample (0–30 cm depth) was obtained before planting in each season and was analyzed according to Page et al. (1982), The analysis proved that the soil was sandy loam in texture and its initial physico-chemical and water status traits are tabled (Table 1). According to US Soil Taxonomy (Soil Survey Staff 1999), the soil is order Aridisol and suborder Durids. The study site belongs to the arid zone conditions without rainfall and dry-hot summer. Table 2 illustrates some meteorological data of the study area. The preceding cultivated crop was wheat in both seasons.

Table 1 Some initial physico-chemical and water status traits of the soil at the experimental research and production station, National Research Centre, Egypt (average of 2016 and 2017 seasons)

Trait	Value
Particle size distribution	
Sand, %	69.8
Silt, %	23.5
Clay, %	6.7
Texture class	Sandy loam
Bulk density, g cm^{-3}	1.59
Chemical analysis	
pH	7.72
EC, dS m^{-1}	0.23
Organic mater, %	0.14
Soil water status, θ_S % on weight basis	
Field capacity	12.2
Permanent wilting point	4.0
Available water	8.2

Table 2 Averages of monthly air temperature, wind speed, relative humidity and insolation incident of the experimental research and production station, National Research Centre, Egypt in 2016 and 2017 seasons

Month	Air temperature (°C)	Wind speed (m sec^{-1})	Relative humidity (%)	Insolation incident (MJ m^{-2} day^{-1})
2016				
May	24.7	4.27	38.9	26.5
June	27.6	4.69	40.2	29.3
July	28.6	4.32	45.8	29.2
August	29.5	4.14	46.8	27.4
2017				
May	24.5	3.88	39.0	27.5
June	26.6	4.69	45.0	24.9
July	28.7	4.28	43.5	29.3
August	31.6	4.24	43.6	27.0

Experimentation and Procedures

Two irrigation regimes (irrigation by 75 and 100% of crop evapotranspiration ETc, denoted ETc_{75} and ETc_{100}, respectively) in combination with six weed control treatments (bentazon, clethodim, bentazon + hoeing once, clethodim + hoeing once, hoeing twice and unweeded) were tested.

Irrigation water requirement was calculated by estimating daily reference evapotranspiration (ETo) developed by FAO using FAO Penman-Monteith equation (Allen et al. 1998) for growing season of peanut (Fig. 1). Consequently, crop evapotranspiration (ETc) was calculated using the Eq. 1 according to Doorenbos et al. (1977)

$$ETc = ETo \times Kc \tag{1}$$

Where:

ETc = Crop evapotranspiration (mm day^{-1}),
ETo = Reference evapotranspiration (mm day^{-1}),
Kc = Crop coefficient (0.60–1.15).

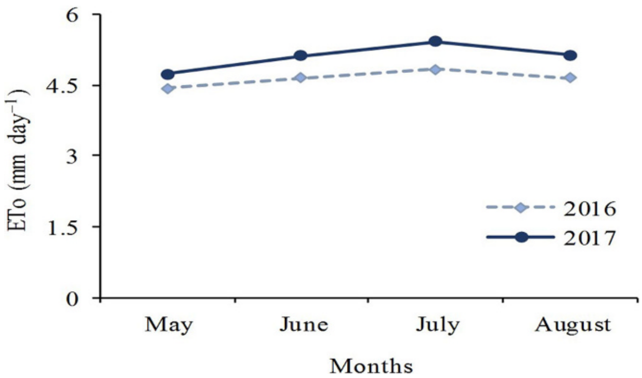

Fig. 1 Reference evapotranspiration (ETo) during 2016 and 2017 growing seasons of peanut at the experimental research & production station, National Research Centre, Egypt

Amount of irrigation requirement was computed according to Keller and Bliesner (1990) by the Eq. 2

$$IR = ETc \times LR \times 10/Ea \quad (2)$$

Where:

IR = Irrigation requirement (m^3 ha^{-1}),
LR = Leaching requirement (%), which was estimated using Eq. 3
Ea = Water application efficiency (85%).

$$LR = ECw/2Max\ ECe \quad (3)$$

Where: ECw and Max ECe are the electric conductivity of the irrigation water and the maximum electric conductivity of the soil saturation extract (dS m^{-1}), respectively.

Moreover, Fig. 2 illustrates the seasonal irrigation amounts applied for peanut based on irrigation treatments.

Plants were irrigated through trickle irrigation system had emitters spaced 30.0 cm apart with discharge of 2.0 L h^{-1}. Irrigation water was obtained from an irrigation channel passing through the experimental site, with pH 7.5, and EC 3.02 dS m^{-1}.

Each of bentazon {3–(1–methylethyl)–(1H)–2,1,3–benzothiadiazin–4(3H)–one 2,2–dioxide}, 1.25 L ha^{-1} and clethodim{ (E,E)–(6)–2–[1–[[(3–chloro–2–propenyl)oxy]imino]propyl]–5–[2–(ethylthio)propyl]–3–hydroxy–2–cyclohexen–1–one}, 0.625 L ha^{-1} were sprayed as post emergence herbicides 20 and 30 days after planting (DAP), respectively. A knapsack sprayer had one nozzle with 476 L water ha^{-1} as a solvent/carrier was used. Hoeing twice treatment was applied at 21 and 42 DAP. Also, hoeing once supplemented each herbicide was applied at 42 DAP.

The experiment was arranged in a strip-plot design with three replications, where irrigation regimes occupied the vertical plots as well as weed control treatments distributed in horizontal ones. The net plot size was 10.5 m^2; comprising five ridges, 3.5 m length and 0.6 m width. During land preparation, single superphosphate (15.5% P_2O_5), 350.0 kg ha^{-1} was incorporated. On May 1st and 5th in 2016 and 2017 seasons, respectively, peanut seeds (c.v. Giza 6) were inoculated with the specific *Rhizobium* strain and immediately sown (3–4 seeds per hill), 25 cm apart on both sides of the ridge. At 21 DAP plants were thinned to secure one plant per hill as well as 150.0 kg ha^{-1} of ammonium nitrate (33.5% N), was applied. Moreover, plants were received potassium 150.0 kg ha^{-1} sulphate (48.0% K_2O), at 35 DAP.

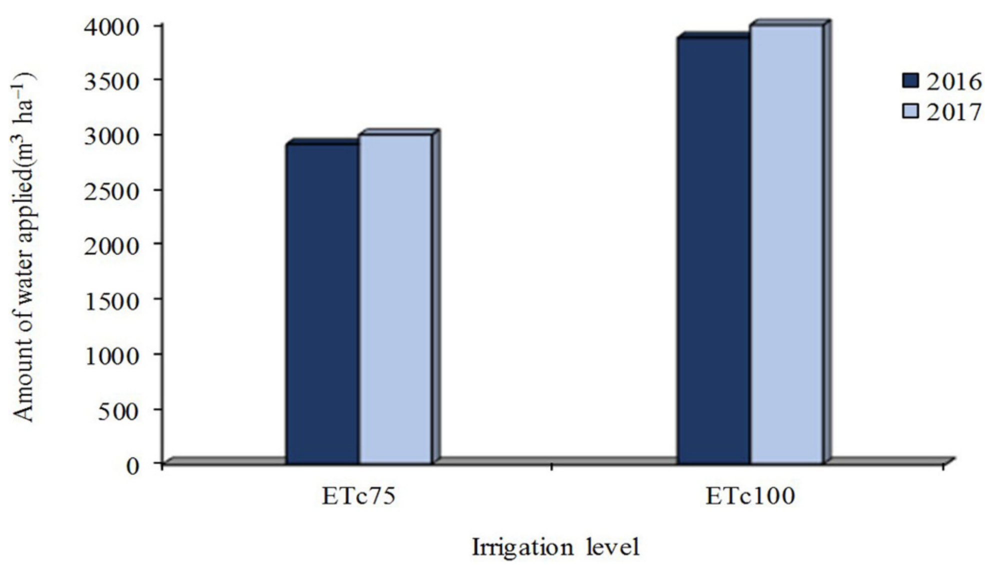

Fig. 2 Seasonal irrigation water amount under 75% (ETc_{75}) and 100% (ETc_{100}) of crop evapotranspiration for peanut in 2016 and 2017 seasons at the experimental research & production station, National Research Centre, Egypt

Sampling and Assessments

Weeds

The dominant floras at the experimental field were Common purslane (*Portulaca oleraceae*), Nalta jute (*Corchorus olitorius*) and Venice mallow (*Hibiscus trionum*) as broadleaved weeds. The major grassy weeds were Jungle rice (*Echinochloa colonum*) and Field Sandbur (*Cenchrus ciliaris*).

For measuring weed dry biomass expressed in total weed dry weight, weeds were hand pulled from one square meter of each plot at 90 DAP, air dried for 7 days, oven dried at 80 °C for 48 h and weight was recorded.

Peanut

Plants of the central three ridges were harvested on August 25 and 29 in the 1st and 2nd seasons, respectively to estimate seed yield ha^{-1} after peeling the pods. Moreover, oil percentage in seeds was measured by extraction using Soxhlet Apparatus with hexane as an organic solvent, according to AOAC (2012).

N, P and K in Peanut Seeds

At the Central Laboratory, Soil and Water Unit, Faculty of Agriculture, Ain Shams University, dried seed powders were digested by a mixture of H_2SO_4/H_2O_2 according to the method described by Page et al. (1982). Total nitrogen was determined using Kjeldahl method according to the procedure described by Chapman and Pratt (1961). Using Spectrophotometer, phosphorus content was determined according to Watanabe and Olsen (1965). Potassium content was estimated by Flame photometer as described by Chapman and Pratt (1961).

Water Use Efficiency

Based on the calculated gross irrigation water amounts for ETc_{75} and ETc_{100} in 2016 and 2017 seasons (Fig. 2), water use efficiency (WUE) for weed or crop was estimated according to Jensen (1983) (Eq. 4).

$$\mathrm{WUE} = \frac{\mathrm{Yield}^{*}\left(\mathrm{kg\,ha^{-1}}\right)}{\mathrm{Water\ applied}\left(m^{3}\mathrm{ha^{-1}}\right)}\left(\mathrm{kg}\,m^{-3}\right) \tag{4}$$

* Yield values expressed in dry weight for weeds biomass or peanut seed yield.

Data Analysis

A two-way analysis of variance (ANOVA) for data of the two seasons was undertaken (Casella 2008), using Costat software program, Version 6.303 (2004). Based on Duncan's multiple range test, means separation were performed only when the F-test indicated significant ($P < 0.05$) differences among the treatments.

Results

Since ANOVA detected the significant interaction effects between irrigation level and weed control on weed growth and peanut traits, only interaction will be elucidated and interpreted, while the main effects will be neglected.

Weed Biomass

Our findings reveal the significant effect of irrigation pattern × weed control treatment on weed biomass in 2016 and 2017 seasons (Table 3). Whether using ETc_{75} or ETc_{100}, hoeing twice recorded the highest efficiency for weed control in peanut. Moreover, bentazon + hoeing once or clethodim + hoeing once came in the second order in this respect. Contrariwise, in unweeded plots, weeds produced biomass with ETc_{100} greater than ETc_{75}. Weed biomass of

Table 3 Weed dry biomass (g m^{-2}) as affected by irrigation pattern plus weed control in peanut in 2016 and 2017 seasons

Variable	2016			2017		
	ETc_{75}	ETc_{100}	Mean	ETc_{75}	ETc_{100}	Mean
Bentazon	247.9 ± 4.6 cd	271.5 ± 7.8bc	259.7 ± 6.6B	248.2 ± 9.9d	256.2 ± 9.1 cd	252.2 ± 6.3B
Clethodim	235.0 ± 26.2d	277.8 ± 4.9b	256.4 ± 15.2B	260.3 ± 4.4 cd	271.9 ± 3.8c	266.1 ± 3.7B
Bentazon + hoeing once	115.0 ± 2.9e	118.6 ± 0.7e	116.8 ± 1.5C	105.5 ± 2.2f	115.7 ± 3.4ef	110.6 ± 2.9C
Clethodim + hoeing once	116.0 ± 4.7e	126.7 ± 1.6e	121.3 ± 3.2C	106.6 ± 5.3f	128.8 ± 5.1e	117.7 ± 5.9C
Hoeing twice	41.7 ± 2.1f	51.0 ± 1.3f	46.3 ± 2.3D	35.8 ± 2.5g	39.6 ± 1.0g	37.7 ± 1.4D
Unweeded	456.5 ± 5.6a	474.3 ± 12.7a	465.4 ± 7.4A	427.9 ± 12.4b	454.5 ± 10.6a	441.2 ± 9.4A
Mean	202.0 ± 32.8B	220.0 ± 34.1A	–	197.4 ± 31.7B	211.1 ± 32.9A	–

ETc_{75} and ETc_{100} are irrigation by 75 and 100% of crop evapotranspiration, respectively; Means followed by different letters in each column are significantly different ($P < 0.05$). Values are the mean of 3 replicates ± standard errors

each weed control treatment under ETc_{75} was as similar as ETc_{100}. However, in plots irrigated by ETc_{75}, clethodim in 2016 season and achieved the remarkable reduction in weed biomass compared to plots irrigated by ETc_{100}.

Peanut Yield and Oil Percentage

Hoeing twice or bentazon + hoeing once with ETc_{100} in both seasons and with ETc_{75} in the first season recorded the maximum increases in pod yield of peanut (Table 4). Such combinations were significantly equal ETc_{100} × clethodim + hoeing once treatment in pod yield.

As comparing to the standard practice, ETc_{100} × hoeing twice, lowering irrigation water by 25.0% (ETc_{75}) led to reductions in pod yield under different weed control treatments (Fig. 3). However, such reduction was diminished from 15.1–16.9% in unweeded plots to 9.0–9.7% in weeded ones in 2016 and 2017 seasons, respectively. In this regard, ETc_{75} × bentazon showed the least reduction, while ETc_{100} × unweeded caused the highest one.

As presented in Table 4, ANOVA showed significant response in peanut seed oil % to the interaction between irrigation and weed control. Under each of ETc_{75} or ETc_{100} in 2016 season as well as ETc_{100} in 2017 season, hoeing

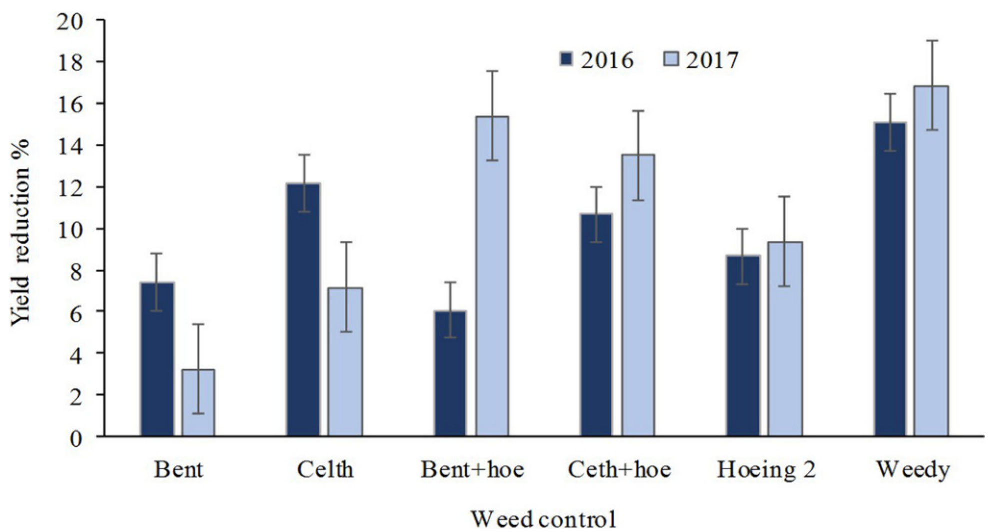

Fig. 3 Peanut yield reduction (%) owing to lowering irrigation amount by 25.0% under different weed control treatments in 2016 and 2017 seasons. Bent: Bentazon; Celth: clethodim; Bent + hoe: bentazon + hoeing once; Ceth + hoe: clethodim + hoeing once; Hoeing 2: hoeing twice; Weedy: unweeded

Table 4 Pod yield and seed oil content of peanut as affected by irrigation pattern plus weed control in 2016 and 2017 seasons

Variable	2016			2017		
	ETc_{75}	ETc_{100}	Mean	ETc_{75}	ETc_{100}	Mean
	Pod yield (t ha^{-1})					
Bentazon	4.86 ± 0.18cde	5.25 ± 0.24bcd	5.05 ± 0.16C	5.40 ± 0.17 cd	5.58 ± 0.20c	5.49 ± 0.12CD
Clethodim	4.62 ± 0.25de	5.26 ± 0.25bcd	4.94 ± 0.21C	5.06 ± 0.13d	5.45 ± 0.20 cd	5.26 ± 0.13D
Bentazon+hoeing once	5.57 ± 0.21abc	5.93 ± 0.11ab	5.75 ± 0.13AB	5.44 ± 0.14 cd	6.43 ± 0.04ab	5.94 ± 0.23B
Clethodim+hoeing once	5.28 ± 0.15bcd	5.91 ± 0.23ab	5.59 ± 0.18B	5.37 ± 0.14 cd	6.21 ± 0.04b	5.79 ± 0.20BC
Hoeing twice	5.80 ± 0.19ab	6.35 ± 0.24a	6.07 ± 0.18A	6.11 ± 0.06b	6.74 ± 0.13a	6.43 ± 0.15A
Unweeded	3.72 ± 0.21f	4.38 ± 0.14ef	4.05 ± 0.18D	3.65 ± 0.16f	4.39 ± 0.09e	4.02 ± 0.18E
Mean	4.97 ± 0.18B	5.51 ± 0.17A	–	5.17 ± 0.18B	5.80 ± 0.19A	–
	Oil %					
Bentazon	20.9 ± 0.40 cd	21.5 ± 0.33abc	21.2 ± 0.27AB	20.9 ± 0.35bc	21.5 ± 0.37abc	21.2 ± 0.26A
Clethodim	20.5 ± 0.24d	21.3 ± 0.23bcd	20.9 ± 0.23B	20.7 ± 0.33c	21.7 ± 0.12abc	21.2 ± 0.27A
Bentazon+hoeing once	21.7 ± 0.28abc	21.9 ± 0.44ab	21.8 ± 0.24AB	21.1 ± 0.25bc	22.2 ± 0.50ab	21.7 ± 0.35A
Clethodim+hoeing once	21.7 ± 0.23abc	21.6 ± 0.32abc	21.6 ± 0.17AB	21.0 ± 0.37bc	22.1 ± 0.58ab	21.6 ± 0.40A
Hoeing twice	21.8 ± 0.36abc	22.4 ± 0.30a	22.1 ± 0.24A	21.5 ± 0.30abc	22.6 ± 0.56a	22.1 ± 0.37A
Unweeded	18.4 ± 0.29e	18.8 ± 0.33e	18.6 ± 0.21C	18.3 ± 0.21d	19.1 ± 0.47d	18.8 ± 0.29B
Mean	20.8 ± 0.30A	21.3 ± 0.30A	–	20.6 ± 0.27A	21.6 ± 0.31A	–

ETc_{75} and ETc_{100} are irrigation by 75 and 100% of crop evapotranspiration, respectively; Means followed by different letters in each column are significantly different ($P < 0.05$). Values are the mean of 3 replicates ± standard errors

twice, bentazon + hoeing once and clethodim + hoeing were the distinctive practices for increasing oil %.

N, P and K in Peanut Seeds

The estimation of the nutritional value of peanut seeds clarified that N, P contents markedly influenced by irrigation level × weed control treatment, while K content did not affect (Table 5). In ETc_{100} plots, hoeing twice and bentazon + hoeing once (in both seasons) and clethodim + hoeing (in 2017 season) in addition to ETc_{75} × hoeing twice (in 2017 season) were the eminent combinations for enhancing seed N content. Moreover, controlling weed using each of hoeing twice, bentazon + hoeing once or clethodim + hoeing in plots irrigated by ETc_{100} achieved distinguished seed P content in both seasons.

Water Use Efficiency (WUE) of Weeds and Crop

Fig. 4 illustrates that weeds recorded the maximum WUE since they left free (unweeded). While controlling weeds led to decrease in their efficiency for exploiting irrigation water which amounted to 64.4 and 64.3% reductions with ETc_{100} as well as 66.9 and 64.4% reductions with ETc_{75} in the 1st and 2nd seasons, respectively, (percentages computed as averages of weeded treatments compared to unweeded one). The most weeded practice caused reduction in WUE of weed was hoeing twice, whether with using ETc_{75} or ETc_{100} in both seasons.

Except for each of bentazon and clethodim × ETc_{100} in 2016 season, all other combinations between irrigation level and weed control surpassed the counterpart unweeded for boosting peanut WUE (Fig. 5). In plots irrigated with ETc_{75}, hoeing twice in both seasons in addition to bentazon + hoeing once and clethodim + hoeing in the 1st season, the highest and significantly equaled values of peanut water use efficiency were achieved. The enhancements in peanut WUE reached 55.7, 49.7, and 41.7% with hoeing twice, bentazon + hoeing once and clethodim + hoeing, respectively, in the 1st season and 67.6% with hoeing twice in the 2nd one.

Table 5 Nitrogen, phosphorus, and potassium content in peanut seeds as affected by irrigation pattern plus weed control in 2016 and 2017 seasons

Variable	2016			2017		
	ETc_{75}	ETc_{100}	Mean	ETc_{75}	ETc_{100}	Mean
	Nitrogen (mg g^{-1})					
Bentazon	30.1 ± 0.05ef	31.2 ± 0.05de	30.6 ± 0.04D	31.5 ± 0.02e	36.5 ± 0.02bc	34.0 ± 0.11C
Clethodim	29.0 ± 0.06 fg	31.4 ± 0.02de	30.2 ± 0.06D	31.5 ± 0.02e	34.4 ± 0.02 cd	33.0 ± 0.06C
Bentazon + hoeing once	32.7 ± 0.01 cd	35.6 ± 0.08ab	34.1 ± 0.07B	35.3 ± 0.10 cd	37.8 ± 0.07ab	36.6 ± 0.08B
Clethodim + hoeing once	32.1 ± 0.02d	33.1 ± 0.05 cd	32.6 ± 0.03C	34.0 ± 0.05d	38.0 ± 0.05ab	36.0 ± 0.09B
Hoeing twice	34.5 ± 0.05bc	37.3 ± 0.07a	35.9 ± 0.07A	37.6 ± 0.04ab	39.2 ± 0.06a	38.4 ± 0.05A
Unweeded	25.4 ± 0.03h	27.2 ± 0.06g	26.3 ± 0.05E	27.0 ± 0.05f	30.7 ± 0.06e	28.9 ± 0.09D
Mean	30.6 ± 0.07B	32.6 ± 0.08A	–	32.8 ± 0.08B	36.1 ± 0.07A	–
	Phosphorus (mg g^{-1})					
Bentazon	5.2 ± 0.02de	5.9 ± 0.01bc	5.5 ± 0.02AB	5.4 ± 0.02de	5.9 ± 0.01bcd	5.6 ± 0.01BC
Clethodim	5.1 ± 0.02de	5.5 ± 0.02 cd	5.3 ± 0.01B	5.3 ± 0.01e	5.7 ± 0.01cde	5.5 ± 0.01C
Bentazon + hoeing once	5.6 ± 0.02 cd	6.3 ± 0.02ab	5.9 ± 0.02AB	5.7 ± 0.01cde	6.3 ± 0.02ab	6.0 ± 0.02A
Clethodim + hoeing once	5.3 ± 0.03 cd	6.0 ± 0.01abc	5.7 ± 0.02AB	5.6 ± 0.01cde	6.2 ± 0.01abc	5.9 ± 0.01AB
Hoeing twice	5.7 ± 0.02bcd	6.5 ± 0.01a	6.1 ± 0.02A	5.9 ± 0.01bcd	6.5 ± 0.02a	6.2 ± 0.02A
Unweeded	4.2 ± 0.01f	4.7 ± 0.01ef	4.4 ± 0.01C	4.3 ± 0.01f	4.7 ± 0.01f	4.5 ± 0.01D
Mean	5.2 ± 0.01B	5.8 ± 0.01A	–	5.4 ± 0.01B	5.9 ± 0.01A	–
	Potassium (mg g^{-1})					
Bentazon	22.7 ± 0.09a	23.3 ± 0.09a	23.0 ± 0.06A	24.2 ± 0.13a	24.3 ± 0.14a	24.3 ± 0.08A
Clethodim	22.2 ± 0.11a	23.0 ± 0.10a	22.6 ± 0.07A	23.1 ± 0.08a	23.7 ± 0.14a	23.4 ± 0.07A
Bentazon + hoeing once	23.5 ± 0.09a	24.4 ± 0.20a	24.0 ± 0.10A	24.5 ± 0.14a	25.5 ± 0.10a	25.1 ± 0.08A
Clethodim + hoeing once	23.2 ± 0.13a	23.7 ± 0.18a	23.4 ± 0.10A	24.0 ± 0.15a	23.4 ± 0.19a	23.7 ± 0.11A
Hoeing twice	24.3 ± 0.14a	24.2 ± 0.13a	24.3 ± 0.08A	25.5 ± 0.07a	25.6 ± 0.07a	25.5 ± 0.04A
Unweeded	22.2 ± 0.12a	23.3 ± 0.12a	22.7 ± 0.08A	23.3 ± 0.12a	23.0 ± 0.08a	23.1 ± 0.06A
Mean	23.0 ± 0.04A	23.6 ± 0.05A	–	24.1 ± 0.04A	24.3 ± 0.05A	–

ETc_{75} and ETc_{100} are irrigation by 75 and 100% of crop evapotranspiration, respectively; Means followed by different letters in each column are significantly different ($P < 0.05$). Values are the mean of 3 replicates ± standard errors

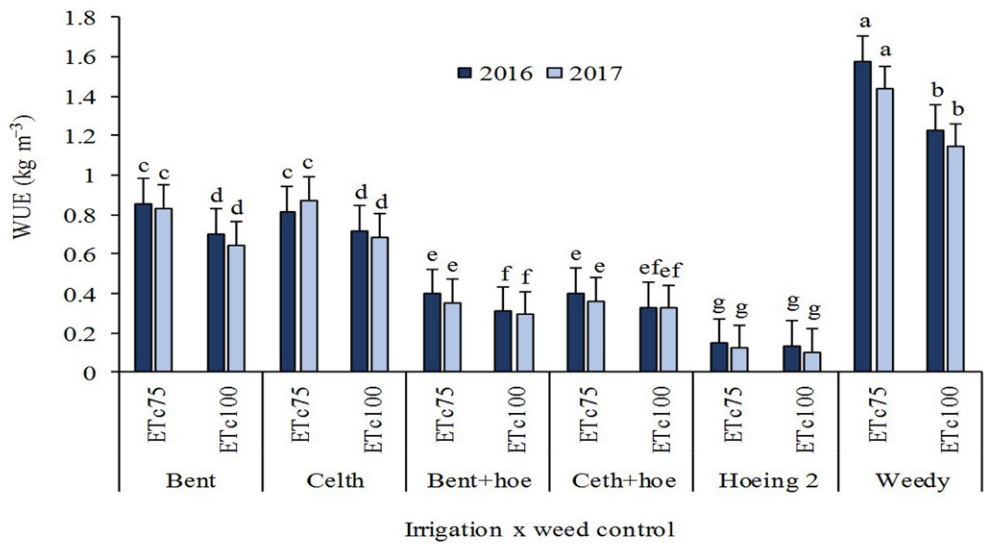

Fig. 4 Water use efficiency (WUE) of weeds associated peanut crop as affected by irrigation plus weed control in 2016 and 2017 seasons. ETc_{75} and ETc_{100} are irrigation by 75 and 100% of crop evapotranspiration, respectively. Vertical bars represent means of three replications ± SE (*P* ≤ *0.05*). Columns marked by different letters are significantly different. Bent: Bentazon; Celth: clethodim; Bent + hoe: bentazon + hoeing once; Ceth + hoe: clethodim + hoeing once; Hoeing 2: hoeing twice; Weedy: unweeded

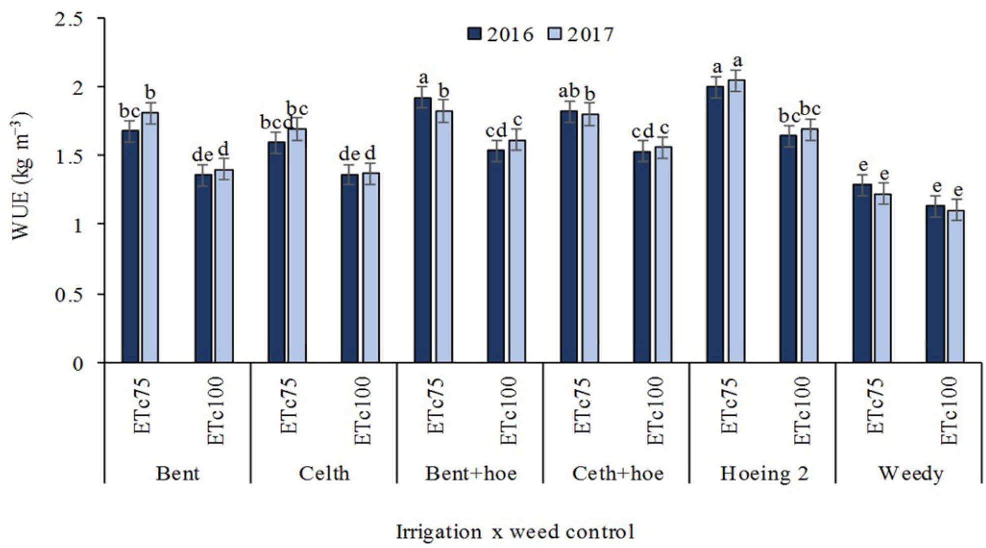

Fig. 5 Water use efficiency (WUE) of peanut crop as affected by irrigation plus weed control in 2016 and 2017 seasons. ETc_{75} and ETc_{100} are irrigation by 75 and 100% of crop evapotranspiration, respectively. Vertical bars represent means of three replications ± SE (*P* ≤ *0.05*). Columns marked by different letters are significantly different. Bent: Bentazon; Celth: clethodim; Bent + hoe: bentazon + hoeing once; Ceth + hoe: clethodim + hoeing once; Hoeing 2: hoeing twice; Weedy: unweeded

Consumed Water and Cost

By computing the consumed water amount needed for obtaining one unit of peanut pod ($m^3\ kg^{-1}$) as shown in Table 6 (an average of the two seasons), it could be deduced that peanut plants depleted less water under ETc_{75} than ETc_{100} to produce one kilogram pods by about 17.9% in weeded plots (mean of applied weeded treatments) as well as 10.1% in weedy conditions (unweeded). In weeded plots, water was largely utilized by peanut plants under ETc_{75} compared to ETc_{100}, since weeded practices saved the consumed water by 31.3 and 24.7%, respectively compared to the unweeded. On the other hand, the production costs of one kilogram were less with ETc_{75} compared to ETc_{100}, and consequently, the increases in benefit/cost reached 23.9 and 9.5% under weed free or weedy conditions, respectively. Moreover, in ETc_{75}, weeded practices improved the benefit/cost by 52.3% compared to the unweeded one.

Discussion

It is well known that drought is the biggest challenge for crop production. Low water supply caused serious reduction in yield productivity and quality of peanut (Aydinsakir et al. 2016; Saudy and El-Metwally 2019). Owing to drought, reductions in stomatal conductance, photosynthesis and transpiration rates were observed, and consequently CO_2 assimilation rates declined (Farooq et al. 2012). Deficit water caused reduction in leaf pigments and soluble sugars, hence dry matter accumulation and nutrient uptake decreased (Saudy and El-Metwally 2019). The significant reduction in relative water content of groundnut leaves positively correlated with soil water availability under different irrigation treatments (Kalariya et al. 2015). Also, water stress adversely affects the absorption and use of mineral nutrients shackling plant growth and production (Sun et al. 2012). Because of drought inhibited the nutrient

Table 6 Amount and cost of consumed water and benefit/cost per kilogram pod of peanut as affected by irrigation pattern plus weed control (an average of 2016 and 2017 seasons)

Treatment		Consumed water		Benefit/cost ($)
		Amount ($m^3\ kg^{-1}$)	Cost ($\$\ kg^{-1}$)	
Bentazon	ETc_{75}	0.57	0.022	63.6
	ETc_{100}	0.72	0.028	50.0
Clethodim	ETc_{75}	0.61	0.024	58.3
	ETc_{100}	0.73	0.029	48.3
Bentazon + hoeing once	ETc_{75}	0.53	0.021	66.7
	ETc_{100}	0.63	0.025	56.0
Clethodim + hoeing once	ETc_{75}	0.55	0.022	63.6
	ETc_{100}	0.65	0.026	53.8
Hoeing twice	ETc_{75}	0.49	0.019	73.7
	ETc_{100}	0.60	0.024	58.3
Average	ETc_{75}	0.55	0.021	66.7
	ETc_{100}	0.67	0.026	53.8
Unweeded	ETc_{75}	0.80	0.032	43.8
	ETc_{100}	0.89	0.035	40.0

Note: Cost of irrigation ($0.04 m^{-3}); price of pod yield ($1.40 kg^{-1}). ETc_{75} and ETc_{100} are irrigation by 75 and 100% of crop evapotranspiration, respectively

translocation from below-to aboveground tissues, plant nutrient uptake capacity was reduced (Sanaullah et al. 2012). Low water supplies reduced plant growth and development by influencing uptake, transport, and partitioning of nutrients (Gessler et al. 2017; Saudy et al. 2020). Accordingly, in crop production management, all sources of water lost should be avoided. The current study proved that the behavior of some weed control practices and their efficiency against peanut weeds changed under low water supply compared to normal condition. For instance, in plots irrigated by ETc_{75}, the reduction in weed biomass reached 15.4% with clethodim treatment in 2016 and 17.1% with clethodim + hoeing once treatment in 2017 compared to irrigation by ETc_{100} (Table 3). Moreover, weeded treatments lowered WUE of weeds either with ETc_{100} or ETc_{75} compared to unweeded (Fig. 4). On the contrary, evident increase in weed biomass was obtained in weedy plots irrigated by ETc_{100} compared to ETc_{75} due to water abundance. Thus, weeded treatments disserved weeds to absorb more water, saving it to crop plants. In this concern, hoeing twice after emergence as a mechanical practice minimizes weed competition and enables crop plants to utilize light, water, nutrients, CO_2, and other environmental resources. On the other site, application of tested herbicides plus hoeing once quenched the growth of weeds (Table 3), forbidding them to obtain more water and consequently reduced their WUE (Fig. 4). Herein, bentazon acts as a selective contact post-emergence herbicide which is absorbed through the leaves of broad-leaved weeds and disrupts the photosynthetic process and causes a depletion of the carbohydrate reserves as well as disruption to the integrity of the chloroplast membranes. Moreover, clethodim is a selective grass herbicide and absorbed mainly through the foliage inhibiting acetyl-coenzyme A carboxylase and consequently restraining lipids synthesis. Due to these modes of action of hoeing twice or herbicide plus hoeing once under lowering water supply, ETc_{75}, the amount of metabolites synthesized by peanut crop increased, enhancing plant growth, and consequently yield and its attributes and seed oil % (Table 4), seed N content (Table 5) and crop WUE (Fig. 5). The presence of weeds in groundnut reduced harvesting efficiency and increased yield losses up to 40% (Clewis et al. 2007; Saudy et al. 2020). Under water-stress conditions, weeds can diminish crop yields more than 50% due to moisture competition alone (Abouziena and Haggag 2016). While application of herbicides followed by one hand weeding can keep the weed density and dry weight below the economic threshold level and increase the yield and net return in groundnut (Priya et al. 2013).

Calculated data in Table 6 refers to the efficiency of peanut in exploiting each water unit under water stress, especially with eliminating weeds. Contrariwise, peanut plants consumed 45.5% with ETc_{75} and 32.8% with ETc_{100} in weedy treatment more than weeded ones. Such notices explain that weeded practice has a distinctive and crucial role in compensating the reduction in yield associated with lowering water supply, and consequently more income expressed in benefit/cost ration is realized. Herein, application of weeded practices, i.e., hoeing twice or herbicides supplemented by one hoe can keep the weed density and biomass below the economic threshold level and increase the productivity and net returns (Sardana et al. 2006; Walia et al. 2007).

Conclusion

Although irrigation by ETc_{75} caused reduction in economic yield, removing weeds associated peanut plants alleviated such impact. Applying appropriate practice of weed control, i.e., hoeing twice or herbicide plus hoeing once saved 25% of applied irrigation water and reduced weed growth with enhancing crop quality and WUE. Peanut can be irrigated as much as 75% of evapotranspiration under water shortage conditions with safe use of herbicide. Therefore, the selection of appropriate weed control method is a vital act for saving water and keeping productivity and quality. In weeded plots, water was largely utilized by peanut plants under ETc_{75} compared to ETc_{100}, since weeded practices saved the consumed water by 31.3 and 24.7%, respectively. The production cost of one kilogram with ETc_{75} was lesser than $ETc_{100,}$ and consequently, the increases in benefit/cost reached 23.9 and 9.5% under weed free and weedy conditions, respectively. Accordingly, reducing water supply could be used as a helpful tool for weed management programs in peanut fields for enhancing yield productivity and economic returns.

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Conflict of interest I.M. El-Metwally and H.S. Saudy declare that they have no competing interests.

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