Effect of Pulverization Tools and Deficit Irrigation Treatments on Water Use Efficiency and Yield of Barley

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Abstract

Under limited water resources in arid and semi-arid environments, the great challenge of developing agriculture is to increase water use efficiency. For that field experiment have been conducted during autumn season of 2011-2012 at the experimental farm, Department of Agricultural Machines Science, College of Agriculture –University of Baghdad. A field study have been carried out to determine the effect of pulverization tools and irrigation scheduling on growth parameters and Water Use Efficiency (WUE) of barley crop for optimum production. Pulverization tools treatments are (rotivator, disk harrow and spring cultivator). Deficit irrigation including omitting two irrigation at growth stage (T_1), flowering stage (T_2) and growth grain stage (T_3), as well as the full irrigation treatment (control) (T_0). Irrigation is applied at 55% depletion of available water. Plant growth parameter of barley is significantly affected by the different irrigation treatments and pulverization tools. The mean values of the pulverization tools shows that the plant height (cm) decreased from 86 to 79 and 76, No. of spike/ m^2 from 582 to 569 and 530, biological yield (t/ha) from 16.64 to 16.13 and 14.72 and the grain yield (t/ha) from 5.36 to 4.81 and 4.22 at spring cultivator, disk harrow and rotivator, respectively. The deficit-irrigated treatments required less water than the control-irrigated treatments,have been recorded 320 – 369 mm and 373 – 411 mm, respectively. The mean ET_a measured during the season is 370 mm for spring cultivator and 391, 400 mm for the disk harrow and rotivator, respectively. The highest actual evapotranspiration is measured for the rotivator + control irrigation treatment (438 mm), while the lowest value have been recorded 347 for spring cultivator + deficit irrigation (T_3). The water use efficiency of all the treatment ranges from 0.94 to 1.53 kg m^{-3} while the irrigation water uses efficiency ranges from 1.01 to 1.66 kg m^{-3}.

Key Wards : Pulverization Tools , Deficit Irrigation , Water Use Efficiency , Barley .

INTRODUCTION

Soil water is the major limiting factor in dry land crop production in different region of Iraq. Water-use efficiency is an important concept for understanding soil–crop systems and designing practices for water conservation. Efficient use of water by irrigation is becoming increasingly important, may contribute substantially to the best use of water for agriculture and improving irrigation efficiency. The effect of water deficit on yield during different period of growth crops is greater under conditions of high temperature and low humidity. Controlled irrigation is essential for high yields because the crop is sensitive to both over and under irrigation (*Al-Harbi et al., 2008*).

Also, for reducing irrigation water use, it is necessary to examine the possibility for further reducing irrigation applied by optimizing the irrigation scheduling. The stated improvement in both grain and straw production was associated with many factors such as improved cultivars and production practices. According to the experiment of *Rahman and Islam (2004)* they found that the amount of water applied at each, irrigation and how often a soil should be irrigated depend on several factors such as the degree of soil water deficit before irrigation, soil types, crops and climatic conditions.

Tillage generally improves soil conditions for plant growth, especially under the circumstances where the soil presents zones of high strength and compaction. However, tillage may also exert adverse effect on soil conditions when it is performed in less than adequate soil moisture, or when inadequate tillage implements are used. Tillage and pulverization tools were an indirect effect on soil water content during the growth cycle of plant, particularly areas with an Iraq climate. The rotivator, disk harrow and spring cultivator are a valuable implement. Since farming in Iraq is carried on under so many different climate, altitude and moisture the farmer should make use then intelligently.

Barley (*Hordeum vulgare* L.) is the most widely grown cereal crop in Iraq and other west Asian countries. The barley-based farming system exists in wide areas along the dry margins (200-300 mm annual rainfall) in cultivation in Syria, Jordan and Iraq (*Jaradat and Haddad, 1994*). Lack of soil moisture was identified as the major factor limiting crop growth and production under rained condition (*Matar, 1977*). Therefore, the present study was focused on evaluation of the effect of irrigation scheduling as well as pulverization tools on growth parameters and water use efficiency of Barely in the middle region of Iraq.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm, Department of Agricultural Machines Science, College of Agriculture of Abu-Graib- Baghdad-Iraq (33º 20´ N, 44º 12´ E; elev. 34.1 m) during Autumn season 2011-2012. The soil texture was clay loam with pH= 7.8, EC = 4.8 $dS.m^{-1}$, FC = 32%, PWP = 16.5% and bulk density = 1.45 g cm^{-3}. Experiment was laid out in randomized complete block design with three replications. Conventional primary tillage equipment with moldboard ploughs with depth 25 cm were used for all fields. Pulverization tools treatments were kept as main plots and deficit irrigation treatments as sub plots. Pulverization tools treatments were (rotivator, disk harrow and spring cultivator). Deficit irrigation including omitting two irrigation at growth stage (T_1), flowering stage (T_2) and growth grain stage (T_3), as well as the full irrigation treatment (control) (T_0). Irrigation was imposed at 55% depletion of available water. Season length and seasonal weather parameters in Abu-Graib- Baghdad are included in Table (1).

Table 1. Monthly temperature (maximum, minimum and mean), relative humidity and total amount of rainfall, mm. in the period from November to May during 2011/2012 season

Month	Month length (days)	Mean Temperature (^{0}C)		Mean R.H (%)	Total amount of rainfall (mm)	ET_0 Penman-Montieth (mm)
		Maximum	Minimum			
29-31 Nov./2011	30	21.25	6.82	51.61	0.9	5.76
December/2011	31	17.81	2.91	58.16	6.4	47.3
January/2012	31	16.91	3.15	65.06	4.1	45.0
February/2012	29	18.48	5.55	50.74	7.5	69.3
March/2012	31	22.49	7.51	38.59	1.8	81.31
April/2012	30	32.83	16.54	32.19	6.5	123.36
1 to 15 May/2012	15	38.05	22.09	24.55	0.0	98.34
Total					27.2	470.37

Irrigation system was surface flow irrigation through line pipe provided with meter gages for measuring water applied. The total soil water, calculated between field capacity and wilting point for an assumed *Horidium vulagri* L. root extracting depth from 0.15 to o.45 m.

Seeds of *Horidium vulagri* L. was sown at a rate of 120 kg/ha, with recommended dose of 200 kg/ha phosphorus fertilizer was applied as a form of calcium super phosphate. Recommended rate of nitrogen (200 kg N/ha) was applied as a form of urea in two split equal doses (at sowing, beginning of flowering stage). Planting took place on 29th November, 2011 harvesting date 9th of May 2012. Each experimental unit consisted of 14 rows 4 meters in length within 25 cm; total plot area was 16 m^2. All plots were irrigated with river water an ECi = 1.1 dS.m^{-1}. Irrigation were scheduled when soil water content in the root zone was depleted by the crop to specific fraction of available water (irrigation was applied at 55% depletion of available water). The soil depth of the effective root zone is increased from 0.15 m at planting to 0.45 m in flowering and beginning grain stages. At harvest time, two central rows in each plot were harvested to determining grain yield and then; grain yield per hectare was calculated. Sub sample of 10 plants was taken from each plot to measuring plant height in cm, No. of spike (m^2) spike length (cm) biological yield (t/ha) and grain yield (t/ha).

The sum of differences in soil water and applied irrigation water plus rainfall were calculated as ET_a using water balance equation, assuming negligible deep percolation, groundwater contribution and runoff ($ET = P + I - D \pm \Delta W$). Where P is the rainfall (mm); I is the irrigation applied to individual plots (mm); D is the deep percolation; and ΔW is the change in water storage of the soil profile (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was ignored.

Reference evapotranspiration ET_0 was calculated using Penman-Montieth modified equation (*Allen et al., 1998*). Water – Use Efficiency (WUE) and Irrigation Water – Use Efficiency (IWUE) were calculated as fallows:

$$WUE = \frac{Yield\ (kg)}{ET_a\ (m^3)}$$

$$IWUE = \frac{Yield(kg)}{Total\ \ water\ \ applied(m^3)}$$

Analysis of variance (ANOVA) was conducted to evaluate the effects of the treatments on the yield and water use efficiency. Least significant differences method (L.S.D) was used to differentiate means at the 0.05 level *(SAS, 2002).*

RESULTS AND DISCUSSION

Growth, Yield and its components

Different plant growth and yield parameters such as plant height (cm), No. of spike/ m^2, biological yield (t/ha) and grain yield (t/ha) of barley crop were significantly affected by different pulverization tools treatments during the crop season (Table 2). There was no significant difference in spike length among the treatments. The mean values of the pulverization tools show that the plant height (cm) decreased from 86 to 79 and 76, No. of spike/ m^2 from 582 to 569 and 530, biological yield (t/ha) from 16.64 to 16.13 and 14.72 and the grain yield (t/ha) from 5.36 to 4.81 and 4.22 at spring cultivator, disk harrow and rotivator, respectively. The reason for this is due to disking caused an increase in bulk density and decrease in mean weight diameter and saturated hydraulic conductivity. The highest values of MWD and HC were found in spring cultivator record 0.665, 0.987, 0.765 mm and 5.234, 8.675, 7.625 cm/hr in begging, middle and ending of plant growth stage compared with disk harrow recording 0.512, 0.723, 0.611 mm and 4.355, 6.003, 5.641 cm/hr and rotivator 0.431, 0.523, 0.321 mm and 4.122, 5.110, 3.762 cm/hr. The reason of disking may impact negatively on the growth and production characteristics, such as the spread and growth of roots. And the differences in crop response occur through pulverization tools effects on soil physical, chemical and biological processes and occurrence of crop diseases and may also differ among crop and soil (*Chang and Lindwall, 1979; Karlen, 1990*).

The values of all the plant growth parameters were not significant among the various deficit irrigation treatments (growth stage T_1, and growth grain stage T_3) compared with the irrigation treatment (control) T_0, but for the flowering stage T_2 decreasing in this parameters.

Table 2. Effects of pulverization tools and deficit irrigation on Barley yield and yield components

Pulverization Tools	Treatment	Plant Height (cm)	No. of Spike (m^2)	Spike Length (cm)	Biological yield (t/ha)	Grain yield (t/ha)
Rotivator	T_0	78	550	5.5	16.10	4.75
	T_1	78	538	5.5	14.87	4.36
	T_2	70	500	5.3	13.00	3.64
	T_3	77	532	5.4	14.89	4.13
Mean		76	530	5.4	14.72	4.22
Disk harrow	T_0	81	600	5.8	18.00	5.25
	T_1	80	575	5.8	16.26	5.00
	T_2	74	530	5.5	14.15	4.10
	T_3	80	571	5.7	16.11	4.88
Mean		79	569	5.7	16.13	4.81
Spring cultivator	T_0	89	602	5.9	18.23	5.85
	T_1	86	588	5.9	16.89	5.72
	T_2	82	552	5.7	14.67	4.55
	T_3	86	584	5.8	16.77	5.32
Mean		86	582	5.8	16.64	5.36
LSD (0.05)		1.2	9.2	ns	0.54	0.51

Actual evapotranspiration (ET)

Data on the amounts of applied irrigation water and measured actual evapotranspiration for all treatments during the growing period are presented in Table 3. The number of irrigation events varied from 7 to 9 for deficit and control irrigation, respectively. As expected, the deficit-irrigated treatments required less water than the control-irrigated treatments, recorded 320 – 369 mm and 373 – 411 mm, respectively. The actual ET_a under different pulverization tools are also presented in Table 3. The mean ET_a measured during the season was 370 mm for spring cultivator and 391, 400 mm for disk harrow and rotivator, respectively. The highest actual evapotranspiration was measured for the rotivator + control irrigation treatment (438 mm), while the lowest value recorded 347 for spring cultivator + deficit irrigation (T_3). Pulverization tools modify soil structure by changing its physical properties such as soil moisture content, soil bulk density and saturated hydraulic conductivity. The pulverization tool (rotivator) produces a finer and loose soil structure as compared to spring cultivator and disk harrow, which leaves the soil intact. This difference results in a change of number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water, agricultural chemicals and crop growth. This in turn changes in soil penetration resistance affects the plant population density, root distribution and crop yield. Early research reports that seasonal Barley ET ranged from 390 to 430 mm for different climatic and environmental conditions for optimum yield in arid and semi-arid region (*Shone and Flood, 1988 and Janieson et al., 2005*).

Result in Table 2 and 3 showed the period at the flowering stage is most sensitive to deficit irrigation and soil water depletion in the root zone. Water shortage during the flowering stage reduces the number of grain and yield total. The net saving in irrigation water with irrigation scheduling average between 11.39 to 13.40 % when compared with full irrigation treatment (control) (Table 3).

Table 3. Effects of pulverization tools and irrigation in actual evapotranspiration, water use efficiency (WUE) and irrigation water use efficiency (IWUE) in season growth

Pulverization Tools	Treatment	Number of irrigation	Irrigation (mm)	Rain fall (mm)	Actual evapotranspiration (mm)	IWUE CWP_{Irr}	TWUE CWP $_{ETa}$	Irrigation water saving (%)
Rotivator	T_0	9	411	27.2	438	1.16	1.08	-
	T_1	7	369	27.2	396	1.18	1.10	10.22
	T_2	7	360	27.2	387	1.01	0.94	12.41
	T_3	7	353	27.2	380	1.17	1.09	14.11
Mean			373	27.2	400	1.13	1.06	12.25
Disk harrow	T_0	9	398	27.2	425	1.32	1.24	-
	T_1	7	359	27.2	386	1.39	1.30	9.79
	T_2	7	353	27.2	380	1.16	1.08	11.31
	T_3	7	346	27.2	373	1.41	1.31	13.07
Mean			364	27.2	391	1.32	1.23	11.39
Spring cultivator	T_0	9	373	27.2	400	1.57	1.46	-
	T_1	7	349	27.2	376	1.64	1.52	13.5
	T_2	7	332	27.2	359	1.37	1.27	11.42
	T_3	7	320	27.2	347	1.66	1.53	15.27
Mean			343	27.2	370	1.56	1.45	13.40
LSD (0.05)						0.15	0.12	

Water Use Efficiency

Data on irrigation water use efficiency (IWUE) and water use efficiency (WUE) for all treatments are presented in Table 3. The rotivator pulverization used the higher amounts of water than spring cultivator and disk harrow. IWUE of spring cultivator treatments were higher and differed from rotivator and disk harrow treatments in the growth season ($P < 0.05$). However, the IWUE did differ ($P<0.05$) for deficit irrigation and pulverization tools interactions. The spring cultivator treatments produced higher WUE in comparison to rotivator and disk harrow in all treatments in growth season ($P < 0.05$). The water use efficiency of all the treatment ranges from 0.94 to 1.53 kg m^{-3} while the irrigation water uses efficiency ranges from 1.01 to 1.66 kg m^{-3}. It can also be deduced from the results of the percentage difference in water use efficiency compared between pulverization tools. Also the deficit irrigation except the flowering stage, an increase in IWUE and WUE compared full irrigation record an increase in WUE from 1.08 to 1.10; 1.09 in rotivator tool and from 1.24 to 1.30; 1.31 in disk harrow and from 1.46 to 1.52; 1.53 kg m^{-3} with spring cultivator in T_0, T_1 and T_3, respectively.

ET_o calculated from Penman-Monteith modified equation totaled 470 mm which are close to the ETa (387mm) proved the validity of this equation for estimating the water requirements of barley within the context of the region.

CONCLUSION

Conventional primary tillage equipment with moldboard plough + spring cultivator (pulverization tools) is the best tillage system was found to be more appropriate and profitable treatment in improving grain yield of Barley as compared to other pulverization tools treatments. It will be successful under a wide range of soil conditions especially on medium and fine texture.

The study suggests that Barley farmers better can used deficit irrigation in different stage of barley growth except the flowering stage.

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تأثير معدات التنعيم ومعاملات الري الناقص في كفاءة الاستهلاك المائي وحاصل الشعير

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الخلاصة

في إطار الموارد المائية المحدودة في البيئات القاحلة وشبه القاحلة، والتحدي الكبير المتمثل في الزراعة النامية لزيادة كفاءة استخدام المياه، فقد أجريت تجربة حقلية خلال الموسم الخريفي 2011-2012 في حقل قسم المكائن والآلات الزراعية- كلية الزراعة- جامعة بغداد. وقد أجريت دراسة حقلية لتحديد تأثير معدات التنعيم وجدولة الري على صفات النمو وكفاءة استخدام المياه (WUE) من محصول الشعير للحصول على الإنتاج الأمثل. وتضمنت معدات التنعيم (rotivator, disk harrow and spring cultivator)، اما معاملات الري الناقص (الري غير الكامل) فتضمنت حذف ريتين في مرحلة النمو (T1)، ومرحلة الإزهار (T2) وتكوين الحبوب (T3)، فضلا" عن معاملة الري الكامل (المقارنة) (T0)، تم تطبيق الري عند استنفاد 55٪ من الماء الجاهز. وكان تأثير ادوات التنعيم والري الناقص معنويا في صفات نمو وحاصل الشعير. إذ تبين أن اطوال النبات (سم) انخفضت من 86 حتى 79 و 76، عدد السنابل /م^2 من 582 إلى 569 و 530 والحاصل البيولوجي (طن / هكتار) 16.64 حتى 16.13 14.72 وحاصل الحبوب (طن / هكتار) من 5.36 الى 4.81 و 4.22 في معاملة المنعمة spring cultivator، disk harrow وrotivator ، على التوالي. إما معاملات الري غير الكامل فقد سجلت كميات مياه ري اقل مقارنة بمعاملة الري الكامل، اذ سجلت 320 - 369 ملم و373 - 411 مم، على التوالي. وكان اعلى استهلاك مائي في معاملة الري الكامل + أداة التنعيم rotivator (438 ملم)، في حين سجلت أقل قيمة للاستهلاك المائي عند معاملة الري الناقص وأداة التنعيم spring cultivator (347 ملم).تراوحت كفاءة استخدام المياه لجميع المعاملات بين 0.94 الى 1.53 كغم.م$^{-3}$ وكفاءة مياه الري بين 1.01-1.66 كغم.م$^{-3}$.

الكلمات المفتاحية : معدات التنعيم ، الري الناقص ، كفاءة الاستهلاك المائي ، الشعير