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EFFECT OF IMPOSED WATER STRESS AT CERTAIN GROWTH STAGES ON GROWTH AND YIELD OF BARLEY GROWN UNDER DIFFERENT PLANTING PATTERNS

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Abstract

A field experiment was conducted to investigate the effects of water stress on spring barley *Hordeum vulgare* L. which was planted with different patterns. A six rows barley (cv. Iba. 99) was grown with four planting patterns as main plots (broadcasting, drilling, broadcasting with ridge and drilling on raised – bed. Sub – plots were assigned for four watering treatments *e.g.* frequent irrigation after depletion 50% of available water as control (S_0), skipping irrigation at tillering (S_1), at booting (S_2) and at grain filling (S_3) stages.

The results revealed that S_1 and S_2 caused a reduction in the number of tillers (by12% and 2%), plant height (15% and 2%), flag leaf area (12% and 1%), dry weight of the flag leaf (10% and 4%) spike weight, (8% and 1%), root dry weight (14% and 6%) and chlorophyll content of flag leaf (4% and 7%) at two stages (tillering and booting), respectively. These reduction were reflected reduced of biological yield and grain yield components. Grain weight was decreased only in S_3 treatment (grain filling) by 21% compared to the control (S_0).

Key words : Water stress, barely, growth stages, planting pattern, grain yield.

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops grown in Iraq for dual purposes forage and grains.

Iraq is dominated by arid to semi – arid continental climate with limited supply of water resources for agriculture and / or because of increasing municipal and industrial demand for water in addition to the climatic changes.

Therefore, water deficit stress may occur at any stage of plant development as a result of fluctuation in water quantity throughout growth season of the crops which causes variations in barely yield (Jamieson *et al*., 1995).

The water soil deficit not only affects the morphology of plant, but also severly modifies their metabolism (Hasio, 1973).

The extent of modification depend upon duration , intensity and development phase of the growth cycle where imposed water stress causes significant differences in the yield components (Foster, 2004; Szira *et al*., 2008 and Rajala *et al*., 2011). When water deficit occurs during early vegetative stages (tillering and jointing), reduction in yield is mainly due to the decline in the number of ears per plants (Elhawary and Samia, 2011; Mollah and Paul, 2011 and Thameur *et al*., 2012). Water deficit during the rapid spike – growth phase from booting to anthesis reduces grain set and number of grain bearing tillers (Cooper *et al*., 1994; Christen *et al*., 1995; Foullcas *et al*., 2007 and Rajala *et al*., 2011).

Terminal drought during the grain filling period is known to reduce single grain weight (Jamieson, 1995; Voltas *et al*., 1999; Sanchez *et al*., 2002; Garciada moral *et al*., 2003; Gonzalez *et al*., 2007; Samarah *et al*., 2009 and Alireza and Yazdachi, 2012).

Therefore, growers of barely must have prior knowledge of crop yield as response to the water stress at different growth stages of barley plant and some measures are needed to avoid high yield reduction with

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increase the efficiency of water use that available when deficit irrigation by eliminating irrigations practice that have little impact on yield (Kirda, 2010). This interacts with other practices. Therefore, we need to make rational and economic use of water management practices to improve barely growth under water stress conditions (Meti *et al*., 2004). Among many factors of plant production is the pattern of planting.

Bed planting systems have been used in cultivation for centuries. The origin of raised – bed cultivation has traditionally been associated with water management issues to more efficient supply of irrigation water in high production system (Sayer, 2006) via improvement of distribution of soil moisture, nitrogen management and soil aeration in the root zone of the plant on the ridge of the furrow or raised – bed (Ali and Aljubori, 2010). This play a vital role in improving growth of plant under water stress.

The aim of the current study was to investigate the effects of water stress imposed at different growth stages of barely grown under different planting patterns on phenology growth, grain yield, yield components and water use efficiency.

Materials and Methods

Experimental site

The experiment was carried out on a silt 10am (34% clay, 48.4 silt and 17.6% sand, at the experimental farm of the Agricultural Extension Center, Ministry of agriculture, Iraq (32^0 31' N, 44^0 18' E) during 2011 – 2012 season. The soil contained 400.6, 73.3, 12.8 and 276.0 mg kg^{-1} of organic matter, available N, P and K, respectively; the bulk density, pH and EC were 1.24 Mg M^{-3}, 7.10 and 3.00 dsm^1, respectively. The annual mean precipitation and annual mean temperature were 10 mm, and $15C^0$, respectively with maximum daily air temperature of -2.6^{0}C (January) and 36^{0}C (April).

The water content at field capacity and wilting point at 0 – 0.4 m were 0.3998 and 0.1868 cm^3, respectively.

The field was prepared by the local standard procedure that followed by farmers. The total dose of P (160 $kgha^{-1}$) of Diamino phosphate (18 : 46 : 6) with half dose remaining nitrogen (50 $kgha^{-1}$) was applied at sowing date and remaining nitrogen (50 $kg.ha^{-1}$) was applied at the beginning of elongation stage.

The experiment was arranged as spilt blocks in a randomized complete block design (RCBD) with three replications comprising four planting patterns (occupied the blocks) namely, broadcasting the seed and buried them in the soil using spring harrow, drilling (uniform row 10 cm, which were irrigated with flate basin, ridge the seed were broadcasted and furrowing the soil with 0.30 m spacing) and rasied –bed (4 rows on the bed with 0.2 m spacing and 0.40 between beds). The sub-plots (area was 3m × 4m) consisted of four water stress treatments imposed at certain developmental growth stages , in which one irrigated was skipped at some of growth stages as well as following; full irrigation (irrigation every 50% depletion of available water) as a control (S_0), skipping for 22 days at tillering (S_1), 13 days at booting (S_2) and 33 days at grain filling (S_3). Spring barely (Iba – 99 cuiltivar) was sown on 15th November 2011 at a seed rate of 160 $kgha^{-1}$. All cultural practices were done according to the conventional practices followed by farmer at the central region of Iraq.

Experimental Irrigation Units

Irrigation was applied seven time at the growing season using a surface irrigation system , through line pipe provided with gages meter for measuring water applied for S_0 treatment and six time for S_1, S_2, and S_3.

Soil content at 0 – 0.4 m depth with measured by the gravimetric method for each sown plot, shortly after harvest and just before and after irrigation numbers. Soil moisture measured by gravimetric methods (weight basis) was converted into proportion by multiplying with bulk density. Irrigation intervals were assessed when readily available water of soil was depleted to 50% in root zone (0 – 0.4 m).

The amount of irrigation water that added to each experimental unit at each irrigation events was calculated as following by using this equation (Reddy, 2007).

$$W = a.pd\ (\%\ Pw_{f.c.} - Pw_w) / 100 \times D \quad (1)$$

Where,

W = the water must be added to the experimental units (m^3)

a = the irrigation area (m^2)

pd = the bulk density (Mgm^3)

$Pw_{f.c.}$ and Pw_w = the percentage moisture of soil at field capacity and wilting point, respectively.

D = the depth of irrigation soil.

The plants were subjected to the water stress in S_1, S_2 and S_3 treatments according to the Zadoks (Zadoks *et al*., 1974) by skipping irrigation at Z20, Z41 and Z70 for S_1, S_2 and S_3, respectively.

The actual crop evaporanspiration during each irrigation interval was estimated by soil water balance equation as described in details by Huang *et al.* (2005).

$$ET = \pm \Delta S + (P + I + C) - (RO + DP) \quad (2)$$

Where,

ΔS = the change in the soil water storage before sowing and after harvest measured in the soil profile (mm)

P = the precipitation (mm)

I = the irrigation (mm)

C = the upward flow into the soil profile (mm)

RO = the surface runoff each plot (mm)

DP = the deep percolation out of the soil profile.

The soil water stroge was equal before sowing and after harvest P was less than 10mm therefore, it was negligible water.

At the equal of about 2m below the surface according to the piezometer installed in the field. So the uprising into soil profile was negligible. Surface runoff was assumed to be zero because water application was controlled, deep percolation was assumed to be zero because irrigation was in field capacity limit, regarding the information mentioned above Eq. (2) reduced to following from :

$$ET = I \quad (3)$$

Measurements

At the appearance of the anther from spike, fifteen plants were randomly selected from all the plots and then the chlorophyll content of flag leaf was measured by using a chlorophyll meter (CHOROPHYLL METER) SPAD. 502 plus. KONIKA MINOLTA SENSING. INC. Flag leaf area (FLA) was measured by following the methods suggested using the standard formula (Reberston and Guinta, 1994).

$$FLA = Lenghth_{max} . Width_{max} . 0.75$$

The dry weight of flag leaves, stems and spikes were determined following oven – drying for 48 h. at 70^0C.

At harvest time data were recorded for plant height, tillers per^{-2} m, spike per m^{-2} and grain per spike and then by using equal meter in each sub plot at harvest to determine the biological yield (tha^{-1}), 1000 grain weight (gm), grain yield (t.ha^{-1}), harvest index and water use efficiency, which was also calculated based on grain production (WUE_g) kg per hectare for each m^3 of water supplied during the growing season. Root dry weight was measured after uproot a cylinder (0.40 m length and 0.30 diameter) washed with tap water and then oven dried to determine root weight. The root deep density was measured according to Manske technique (Manske *et al.*, 2001).

Data were analysed by using analysis of variance method and the significant differences were tested by least significant differences (LSD) when $P > 0.05$. All statistical analysis was performed using the SAS programs (SAS Institute, 1999).

Results

Shoot growth

Imposing water stress during vegetative stages (tillering and booting) significantly reduced the flag leaf area chlorophyll content and dry weight ($P \leq 0.05$) (tables 1 and 2). The reduction percentages in flag leaf area , chlorophyll content and dry weight were 12%, 10% and 4%, respectively due to the water stress imposed at tillering (S_1) and 1%, 4% and 7% at booting (S_2) compared with control (S_0). There was no effect of imposed water stress at grain filling (S_3) because the measurements was achieved before this treatment applied.

Recorded flag leaf area, chlorophyll content and dry weight values were significantly higher under raised – bed method (tables 1 and 2) compared with others (Ridge, Drilling and Broadcasting). Under raised – bed, the averages of area, chlorophyll content and dry weight were 35.03 cm^3, 0.86 gm and 53.83 followed by ridge (33.03 cm^3, 0.83 gm and 45.60), respectively. There was no interaction between stress treatments and planting patterns.

Both water stress treatments (S_1 and S_2) reduced total biomass accumulation per plant at anthesis (tables 1 and 2). Biomass accumulation was reduced by 19% for S_1 than control (S_0). Lower plant biomass in S_1 was associated with reduced biomass accumulation of stems (Table 1) and leaves (data not shown). The accumulation of biomass in S_2 and S_3 treatments was not affected.

Also plant height and number of tillers were significantly reduced and on average, plant height and number of tillers for those plant subjected to water stress were reduced by 15%, 12% in S_1 and S_2 by 2% and 2% respectively compared with the control plant (S_0).

The biomass accumulation, plant height and number of tillers were affected by planting pattern (tables 3 and 4). The averages of biomass accumulation, plant height and number of tiller in raised bed pattern were 968.50 gm.m^{-2} , 121.9 cm and 6.19.67 m^{-2} followed by ridge and drilling methods.

The results indicated that there was not interaction between planting patterns and water stress treatments for plant height and number of tillers (table 4).

Imposed water stress at grain filling stage (S_3) caused a reduction in the grain filling duration by 6 days than

Table 1 : Mean values of flag leaf area, chlorophyll content and dry weight, stems and spike and duration of grain filling as affected by water stress and planting pattern in 2011 – 2012.

Treatment	Flag leaf area (cm^2)	Chlorophyll content (Spad)	Dry weight of			Duration of grain filling (day)
			Flag leaf (gm)	Stems (gmm^{-2})	Spike (gm)	
S_0	32.27	47.50	0.80	553.40	5.15	27.25
S_1	28.52	45.44	0.73	425.10	4.74	27.58
S_2	31.61	44.28	0.77	538.30	5.10	27.25
S_3	32.51	47.37	0.81	519.20	5.16	21.25
$LSD_{(0.05)}$	0.28	0.31	0.01	7.48	0.04	0.60
Broadcasting	27.33	42.04	0.69	458.60	4.57	22.08
Drilling	30.13	43.11	0.73	488.60	4.63	22.42
Ridge	33.03	45.60	0.83	500.20	5.17	27.00
Rasied – bed	35.06	53.83	0.84	589.10	5.79	31.67
$LSD_{(0.05)}$	0.96	1.19	0.02	12.45	0.04	2.11

S_0 = well watered (control) S_1 = water stress at tillering S_2 = water stress at booting
S_3 = water stress at grain filling LSD = least significant differences.

Table 2 : Mean values of flag leaf area , chlorophyll content and dry weight and dry weight of stems and spike and duration of grain filling as affected by water stress and planting patterns in 2011 – 2012.

Treatment		Flag leaf area (cm^2)	Chlorophyll content (spad)	Dry weight of			Duration of grain filling (day)
				Flag leaf (gm)	Stems (gm m^{-2})	Spike (gm)	
	Water stress						
Planting pattern							
Broadcasting	S_0	28.33	43.23	0.72	505.30	4.66	23.67
	S_1	24.83	41.17	0.63	379.30	4.30	23.67
	S_2	27.73	40.31	0.68	490.20	4.62	22.33
	S_3	28.43	43.46	0.72	458.30	4.70	18.67
Drilling	S_0	30.20	44.40	0.74	527.50	4.74	23.67
	S_1	26.53	42.50	0.68	406.00	4.34	24.00
	S_2	29.63	41.22	0.72	511.00	4.67	23.00
	S_3	29.86	44.33	0.76	509.70	4.76	19.00
Ridge	S_0	34.16	46.96	0.86	540.90	5.31	28.33
	S_1	30.33	45.03	0.78	417.30	4.85	28.67
	S_2	33.53	43.96	0.83	533.80	5.23	29.00
	S_3	34.10	46.46	0.85	508.70	5.28	22.00
Rasied – bed	S_0	36.40	55.40	0.89	640.00	5.90	33.33
$LSD_{(0.05)}$	S_1	32.40	53.05	0.81	497.70	5.46	34.00
	S_2	35.56	51.65	0.86	618.20	5.88	34.00
	S_3	35.86	55.23	0.86	600.30	5.91	25.33
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	2.21

S_0 = well watered (control), S_1 = water stress at tillering, S_2 = water stress at booting, S_3 = water stress at grain filling, LSD = least significant differences at P > 0.05, NS = no- significant differences at P≥0.05

Table 3 : Mean values of plant height, number of tillers, dry matter weight of plant, root weight, deep root density and biological yield as affected by water stress and planting patterns in 2011 – 2012.

Treatment	Plant height (cm^2)	Number of tillers (m^2)	Dry matter of		Deep root density (cm)	Biological yield ($t\ ha^{-1}$)
			Plants ($gm\ m^{-2}$)	Root (gm)		
S_0	115.90	559.25	873.33	103.53	18.88	15.54
S_1	98.80	490.33	708.83	89.23	24.55	12.52
S_2	113.60	546.42	872.58	100.5	22.20	14.73
S_3	115.50	559.42	874.00	102.93	18.88	14.38
$LSD_{(0.05)}$	0.90	4.41	3.81	0.80	0.59	0.15
Broadcasting	99.20	491.50	756.00	86.20	18.00	12.32
Drilling	102.80	514.42	792.17	91.53	19.00	12.92
Ridge	120.00	529.83	812.08	105.10	21.75	14.71
Rasied – bed	121.90	916.67	968.50	110.50	25.30	17.76
$LSD_{(0.05)}$	3.00	7.90	13.85	0.20	0.58	0.15

S_0 = well watered (control) S_1 = water stress at tillering
S_2 = water stress at booting S_3 = water stress at grain filling.
LSD = least significant differences P≥0.05

Table 4 : Mean values of plant weight , no. of tillers, dry matter weight, root weight , deep root density and biological yield as affected by water stress and planting pattern in 2011 – 2012.

Treatment		Plant weight (gm)	Number of tillers (m^2)	Dry weight of		Deep root density (cm)	Biological yield ($t\ ha^{-1}$)
				Plants ($gm\ m^{-2}$)	Root (gm)		
	Water stress						
Planting pattern							
Broadcasting	S_0	104.00	512.00	793.30	90.40	16.00	13.55
	S_1	87.30	447.00	643.67	79.00	22.00	10.64
	S_2	101.60	497.30	792.33	86.40	18.00	12.77
	S_3	104.00	509.60	795.00	89.00	16.00	12.34
Drilling	S_0	107.00	537.00	832.67	95.70	17.00	14.02
	S_1	92.30	466.00	671.33	83.60	23.60	11.28
	S_2	104.60	518.60	832.34	92.60	20.30	13.31
	S_3	107.30	539.00	832.33	94.20	16.50	13.08
Ridge	S_0	125.30	547.00	851.33	110.00	20.00	15.36
	S_1	107.30	484.00	694.33	95.30	24.00	12.47
	S_2	123.00	542.30	850.67	104.80	23.50	14.58
	S_3	124.30	546.00	852.00	110.30	20.00	14.25
Rasied – bed	S_0	127.30	644.00	1016.33	118.00	22.50	19.25
	S_1	108.30	564.00	826.00	99.00	28.70	15.68
	S_2	125.30	627.00	1015.00	106.80	27.00	18.27
	S_3	126.60	643.00	1016.67	118.20	23.00	17.87
$LSD_{(0.05)}$		NS	NS	14.45	1.40	1.12	0.29

S_0 = well watered (control), S_1 = water stress at tillering, S_2 = water stress at booting, S_3 = water stress at grain filling, LSD = least significant differences P≥0.05, NS = No Significant different.

Table 5 : Mean values of spike no., number of grain per spike, grain weight, grain yield, biological yield, harvest index and water use efficiency as affected by water stress and planting patterns in 2011 – 2012.

Treatment	No. of spike per (m^2)	Number of grain per spike	1000 grain weight (gm)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index	Water use efficiency (K gm^{-3})
S_0	456.10	37.25	33.91	5.84	15.54	37.15	1.73
S_1	406.30	33.91	34.25	4.78	12.52	37.77	1.64
S_2	447.60	32.91	34.25	5.12	14.73	34.29	1.77
S_3	455.00	37.33	26.98	4.63	14.38	31.93	1.59
$LSD_{(0.05)}$	5.00	0.44	0.11	0.08	0.15	0.42	0.02
Broadcasting	406.60	35.00	31.10	4.08	12.32	33.15	1.19
Drilling	409.90	35.66	31.19	4.22	12.92	32.72	1.41
Ridge	437.70	37.00	33.24	5.14	14.17	36.30	1.91
Rasied – bed	510.90	41.66	33.86	6.92	17.76	38.96	2.22
$LSD_{(0.05)}$	10.50	0.56	0.65	0.15	0.15	0.71	0.05

S_0 = well watered (control) S_1 = water stress at tillering, S_3 = water stress at grain filling
S_2 = water stress at booting, LSD = least significant differences at $p < 0.05$

control (S_0). The grain filling period was not affected by water stress at tillering and booting stages.

There was interaction between water stress treatments and planting patterns for days to the grain filling period. Rasid – bed had longest grain filling period (34 days) at S_1 and S_2, composed with the broadcasting method which had the shortest (18.67 day) at S_3 (table 1).

Root growth

Water stress significantly increased the depth of root density (tables 3 and 4). Imposing water either at tillering or booting stages had effect on depth of root density and dry weight.

Water stress caused an increase in depth of root density by 30 and 18% for S_1 and S_2 compared with S_0 where water stress caused reduction in root dry weight by 14% and 60% for S_1 and S_2, respectively compared with S_0.

Rasied – bed planting method recorded the highest values of root density depth (25.30 cm) and root dry weight (110.4 gm). However, the broadcasting had the lowest (18.00 cm and 86.2 gm). Rasied – bed at S_1 recorded the highest values of root density deapth (28.70 cm), while Rasied – bed gave the highest value of root dry weight (118.2 gm) at S_3 with no difference with S_0 (table 6).

Yield and yield components

The number of spike per m^2 was decreased under water stress imposed at tillering S_1 and S_2 by 11% and 2%, respectively compared with S_0 which gave 456.1m^{-2} (tables 5 and 6). For planting patterns, the number of spike m^{-2} was generally greater in raised – bed (tables 5 and 6) than others patterns, ridge (437.7), drilling (409.9) and broadcasting (406.6) spike.m^{-2}. There was no interaction between water stress treatments and planting patterns (table 6).

Number of grain per spike

The effects of water stress treatments were significant for grain number per spike (tables 5 and 6). Imposing water stress at tillering stage (S_1) or booting (S_2) reduced the number of grain per spike by 9 and 12%, respectively compared with control S_0. The average number of grain per spike of S_0, S_1, S_2 and S_3 were 37.25, 33.91, 32.91 and 37.33 grain/spike^{-1}, respectively.

Higher values of number of grain per spike were obtained in rasied – bed pattern (40 – 16) grain/spike^{-1} where the broadcasting had the lowest (32.50). There was no interaction between water stress and planting patterns.

Thousand Grain Weight (TGA)

Imposing water stress at grain filling stage (S_3) reduced the TGA by 20% than control (tables 5 and 6) where S_3 gave the lowest value (26.98 gm) while S_1 and S_2 had the highest (34.25 gm) with an increase by 1% than S_0.

TGA in raised – bed pattern was (33.36 gm), (33.24 gm), (31.91 gm), (31.10 gm) in ridge, drilling, respectively. There was significant interaction between water stress treatments and planting patterns (table 6). The raised – bed under S_1 gave the highest value of TGA (36.00 gm) with no different between raised – bed under S_2 and S_0. Broadcasting under S_3 gave the lowest value (25.90 gm).

Table 6 : Mean values of no. of spike, number of grain per spike, grain weight , grain yield, biological yield harvest index and water use efficiency as affected by water stress and planting patterns 2011 – 2012.

Treatment		No. of spikes (m^2)	Number of grains per spike	1000 grain weight (gm m^2)	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index	Water use efficiency (Kg m^{-3})
Planting pattern	Water stress							
Broadcasting	S_0	421.30	34.30	32.60	4.72	13.55	34.70	1.23
	S_1	373.00	30.60	32.90	3.75	10.64	35.20	1.14
	S_2	410.70	30.00	32.90	4.05	12.77	31.70	1.24
	S_3	421.70	35.00	25.90	3.81	12.34	30.90	1.16
Drilling	S_0	425.70	34.60	32.60	4.81	14.02	34.30	1.44
	S_1	377.30	32.00	32.90	3.97	11.28	35.10	1.37
	S_2	414.30	30.60	33.00	4.18	13.31	31.40	1.47
	S_3	422.30	35.60	26.10	3.93	13.08	30.00	1.37
Ridge	S_0	451.70	37.60	34.80	5.92	15.36	38.50	1.98
	S_1	403.70	34.30	35.10	4.87	12.47	38.90	1.87
	S_2	443.70	33.00	35.20	5.14	14.58	35.20	1.99
	S_3	452.00	37.00	27.70	4.63	14.25	32.50	1.79
Rasied – bed	S_0	526.00	42.30	35.50	7.90	19.25	41.00	2.27
	S_1	471.30	38.60	36.00	6.55	15.68	41.70	2.18
	S_2	522.00	38.00	35.80	7.11	18.27	38.80	2.38
	S_3	524.00	41.60	28.10	6.13	17.87	34.20	2.05
$LSD_{(0.05)}$		NS	NS	0.66	0.19	0.29	0.95	0.06

S_0 = well watered (control) , S_1 = water stress at tillering , S_3 = water stress at grain filling
S_2 = water stress at booting , LSD = least significant differences at P < 0.05 NS = No significant different

Grain yield

The effect of water stress was significant for grain yield ($P \leq 0.05$) (tables 5 and 6). As water stress imposed at tillering (S_1), booting (S_2) and grain filling (S_3), grain yield was decreased for all planting patterns.

Water stress at grain filling , tillering and booting reduced yield by 21%, 18% and 21%, respectively compared with control (S_0).

For the planting pattern (tables 5 and 6) rasied – bed had the highest grain yield under all the water stress treatments. There were 7.90, 6.55, 7.11 and 6.13 t.ha^{-1} under S_0, S_1, S_2 and S_3, respectively. Broadcasting had the lowest grain yield under S_1 treatment (3.75 t.ha^{-1}).

Harvest index

Water stress treatments (S2) and (S3) reduced harvest index by 8% and 14%, respectively compared with (S0), while water stress at (S1) increased harvest index by 2% compared with S0 (tables 5 and 6). Rasied – bed had the highest harvest index (38.96), which was increased by 17%, 14% and 7% than broadcasting , drilling and ridge, respectively (tables 5 and 6). The Rasied – bed under S1 treatment had the highest harvest index (41.73) whereas the drilling under S3 treatment had the lowest (30.03).

Water use efficiency

Water use efficiency was the highest for S_2 (1.77 kg.m^{-3}) compared with S_0 (1.73 kg.m^{-3}). The water use efficiency for S_1 and S_2 was 1.64 and 1.59 kg.m^{-3}, respectively.

The highest water use efficiency was obtained from rasied – bed (2.22 kg.m^{-3}), whereas broadcasting had the lowest (1.19 kg.m^{-3}).

Discussion

Water stress at vegetative stages (S_1 and S_2) reduced plant growth substantially resulting in limited source and sink capacity. Leaf area and chlorophyll content were decreased and then the photosynthetic capacity resulted in reduction in dry weight of leaf stem and root (tables 1 and 2). This may be due to the closure of stomata (Losch *et al.*, 1992; Sanchez *et al.*, 2002; Sayed, 2003), the reduction of CO_2 diffusion (Earl, 2003), chlorophyll content (Sairam *et al.*, 1997; Chandresekar *et al.*, 2000) and relative water content (Szira *et al.*, 2008; Thameur *et al*., 2012). Water stress at intermediate and late growth stages may accelerate senescence of leaf, causing decrease of the leaf area and its dry weight (Sanchez – Diaz *et al.*, 2002; Bahrani *et al.*, 2011) conducted that the highest decrease which occur in chlorophyll content when barely imposed to water stress at the onest of elongation (GS Z 13) followed by booting (GS Z 43) and early grain filling stages (GS Z 70). This would reduced the amount of net assimilation and the accumulation of carbohydrate.

Roots are in direct contact with soil and the first part of the plant to sense water deprivation. The length, volume and cell wall chemistry of root are modified during prolonged water stress (Sharp *et al.*, 2004; Ober and Sharp, 2007). Water stress also disrupts metabolic processes involved in CO_2 assimilation and the combined effects of stomatal clouser and metabolic important ultimately decrease rates of biomass accumulation and then remobilization to the root causing reduction of dry weight.

The reduction in plant height with water stress (tables 3 and 4) could be attributed to lower gross photosynthetic rate due to the decrease of expantion , elongation and division of leaf cells as a result of low water potential , the light interception and conversion efficiency to chemical energy was decreased (Hopkins, 1997; Taiz and Zeiger, 2002).

Tillering is usually affected by water stress (tables 3 and 4). This was expected since leaf elongation is the first and most sensitive process by water deficits and consequently leaf appearance too. This is in turn, decreases the number of potential sites for tillering (Assuero *et al.*, 2006).

Cone *et al*. (1995) reported that not only maximum tillers number strongly reduced by water deficit but also initiation of tillering was inhibited until water reapplied . The water stress tented to increase the phyllocrone which correlated with tillering (Cone *et al.*, 1995; Mosaad *et al*., 1995).

These results are in agreement with other studies that reported the water stress before anthesis stages reduced number of tillers (Evadic *et al.*, 2000; Anjume *et al*., 2003; Rajala *et al.*, 2011; Thameur *et al*., 2012).

The reduction in number of spike of S_1 and S_2 treatments (tables 5 and 6) was due to the reduction in number of tillers (tables 3 and 4). Researches had attributed the reduction in number of spike per plant under drought stress to the increase in the number of steriles and the decrease in the number of fertile (tillers) in barely (Mogensen, 1992; Sanchez *et al.*, 2002; Samarah, 2004; Samarah *et al.*, 2009).

Crop management, particularly soil moisture and nutrition can significantly influence grains per spike and spike per.m^{-2} , which altogather determine the number pf grain per.m^2. In barely, grain yield is more strongly related to grain number than grain size. Therefore, early management is essential to optimize tiller production and survival, which particularly important and the maximum number of grains in barely determined of spiklet initiations at flag leaf emergency from Z30 to Z37 (Clive and Geoff, 2006). The reduction of grain number in S_1 and S_2 treatments was attributed to the reduction in spike weight at anthesis (tables 1 and 2), which was correlated with number of grain per spike (Fisher, 1985) and floret abortion prior to anthesis in most cases (Rajala *et al.*, 2011).

The coincide water stress with floret initiation decreased the primordial per shoot apex that the initiates floret, number of tillers and third level in the flowering stage caused reduction in number of grain per spike. This results were similar to the studies that report water stress at tillering , elongation and spikeing to reduce the number of grain per spike (Krcek *et al*., 2008; Arisnabarreta and Miralles, 2008).

The grain weight reduction (tables 5 and 6) could be attributed to the shorter grain filling duration under water stress at grain filling stage (tables 1 and 2), which led to lower accumulation of dry matter in the growing grains (Agueda, 1999; Sanchez *et al.*, 2002; Garicadel Moral *et al.*, 2003; Samarah *et al.*, 2009) or as a results of the reduction in the rate and duration in the accumulated starch in the endosperm (Brooks *et al.*, 1982). Samarah (2004) reported that the development grain from plants grown under water stress had lower grain weight and faster loss of grain moisture content than those from the well – watered plants.

The lower grain yield of S_1, S_2 and S_3 compared with S_0 was due to lower grain weight in S_3 and number of spike and grain per spike in S_1 and S_2 (tables 5 and 6).

The pervious studies shows that there was relationship between crop ability to maintenance grain filling period and a appositive correlation with grain yield under drought stress conditions (Ganzolez , 2007). Grain yield reduction in small grain under drought stress is likely due to the ovary abortion or pollen sterility. Praba *et al.* (2009) reported that positive correlated with grain filling duration (R^2 = 0.08). Water deficit at the grain filling period induced early senescence , reduced photosynthesis and shortened the grain filling period (Inoue *et al.*, 2004; Waines, 2006).

The increase of harvest index in S_1 (tables 5 and 6) due to the stress caused reduction in accumulation of dry matter as a result of decreased weight of the leaf , stem and spike (tables 1 and 2) and when repeating the watering this treatment improved remobilization of dry matter to the grain the weight of grain increased (Ehabaie, 1995). On other hand, water stress then at S_2 and S_3 caused reduction the grain number in S_2 and grain weight in S_3 (tables 5 and 6).

Water use efficiency increased in S_2 treatment (tables 5 and 6), this may be due to the reduction in grain number which compensated by increase grain weight later or the number of grain limited before the plants imposed to stress (grain site limited from tillering to elongation). The reduction of water use efficiency of S_3 due to high reduction in grain weight (tables 5 and 6). The previous study reported that water stress at early stages, can make precosity while at late stages there was no chance for compensation (Zhao *et al.*, 2010).

Planting Patterns had a significant effect on yield component (tables 5 and 6) and growth parameters (tables 1, 2, 3 and 4). The increase of grain yield for rasied – bed pattern was due to the increase in yield grain components such as number of spike, number of grain and grain weight (tables 5 and 6), the increase of yield components was due to the improved root environment via improvement of soil moisture, nutrients uptake and soil aeration in the root zone of the plant on the bed (Sayer, 2006; Fahong *et al.*, 2011).

The efficiency of photosynthesis increased and then dry matter accumulation compared with the conventional methods (broadcasting and drilling). This results are supported by other studies where rasied – bed pattern improved the growth and grain yield of wheat (Sayer and Moreno, 2004; Mehrver and Hormoz, 2006; Ghane *et al.*, 2009; Jamshidi and Tayari, 2011).

The increase of grain yield for Rasied – bed improved the harvest index and water use efficiency (tables 5 and 6). This was due to the highest dry matter accumulation and remobilization efficiency to the grain, therefore grains weight was increased (tables 5 and 6). These results were supported by other studies (Xu *et al.*, 2009; Kilic, 2009; Jamshidi and Tayaril, 2011). They reported that increased harvest index for rasied – bed was due to the decreased, lodging of plant and increased grain filling duration.

Conclusion

In the light of aforementioned results, it can be concluded that water stress at grain filling and tillering more sensitive to water stress causing ahighest reduction in grain yield and WUE. The rasied - bed pattern was optimal for growth, yield and WUE. There was a significant interaction between stress and planting treatment, Rasied – bed gave a highest mean of grain filling duration, root weight, root deep density, biological yield, 1000 grain weight, grain yield, harvest index and WUE under all the planting patterns.

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