Australian Journal of Crop Science AJCS

AJCS 12(06):975-979 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.06.PNE1075

Effects of soil type and rainwater harvesting treatments in the growth, productivity and morphological trains of barley plants cultivated in semi-arid environment

Abdel Rahman Al-Tawaha[1], Abdel Razzaq Al-Tawaha[2], Mohammad Alu'datt[3], Abdul Latief Al-Ghzawi[4], Mohammad Wedyan[4], Sa'doon A. Al-Obaidy[5], Ezz Al-Dein Al-Ramamneh[6]

[1]Department of Biological sciences, Al-Hussein bin Talal University, Maan, Jordan
[2]Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[3]Faculty of Agriculture, Jordan University of Science and Technology, P.O. Box 3030, Irbid, Jordan
[4]Department of Biology and Biotechnology, Faculty of Science, the Hashemite University, Zarqa, Jordan
[5]Department of mathematics, Al-Hussein bin Talal University, Maan, Jordan
[6]Department of Agricultural Sciences, AL-Shouback University College, Al-Balqa Applied University, AL-Shouback, Maan, Jordan

***Corresponding author: abdel-al-tawaha@ahu.edu.jo**

Abstract

Field experiments were conducted in the years 2013/2014 with two soil types from northern part of Jordan. The soil types that were chosen for the study were yellow Mediterranean sandy loam soil (site A) and red Mediterranean silt loam soil (site B). At both sites, a control (untreated soil) and experimental soil (hoops method of rainwater harvesting) was used. Our results indicated that barley plants which were grown in red Mediterranean silt loam soil had higher grain yield, increased number of spikes per plant, high amount of grains per spike, 1000-grain weight, increased plant height and higher spike length than those plants grown at yellow Mediterranean sandy loam soil. On the other hand, barley plants which were grown under water harvesting treatment gave the best results compared to those plants which were grown without water harvesting treatment.

Keywords: barley; rainwater; soil type; Jordan.
Abbreviations: RWH: rain water harvesting

Introduction

Barley (*Hordeum vulgare* L.), an important winter crop, is cultivated under dry land conditions in northern Jordan, west Asia and Africa where inadequate rainfall limits the production (Tawaha et al., 2003). Badia, a region named so in Jordan since 90% of its total land area receives only less than 150 mm rainfall. It is better to produce barley than other crops such as wheat and oats under drought and cold conditions (Chapman and Carter, 1976). Barley is the fourth most important crop in the world as it is used as feed, food and as malt-based food products (Al-Jamali et al., 2002; Al-Tawaha and Turk, 2002; Al-Tawaha et al., 2002; Turk and Tawaha, 2003; Al-Tawaha et al., 2003).

The low productivity of barley in Jordan is due to various reasons such as wide seasonal variation, low rainfall, poor soil moisture, availability of weak soil nutrients, lack of weed control and low yield potential genotypes (Turk and Tawaha, 2001; Al-Tawaha and Turk, 2002; Al-Tawaha et al., 2002; Turk and Tawaha, 2003; Al-Tawaha et al., 2003). Previous research has documented the phenomenon of decreasing barley and other cereal crops yields under conditions of poor water supply (Turk and Al-Tawaha, 2002; Turk et al., 2003; Abebe et al., 2005; Nikus et al., 2005; Mesfine et al., 2005; Al-Tawaha et al., 2005; Al-Ajlouni et al., 2009; Al-Tawaha et al., 2010; Al-Tawaha and Al-Ghzawi, 2013; Al-Tawaha et al., 2017; Abu Obaid et al., 2017).

Drought negatively impact on grain yield by affecting the yield components such as number of spike per plant, number of grain per spike, 1000 grain weight (Ajalli and Salehi, 2012; Hossain et al., 2012; Beigzadeh et al., 2013; Francia et al., 2013; Haddadin, 2015; Al-Tawaha et al., 2017; Abu Obaid et al., 2017)

In Mediterranean region the drought has always been considered as a key issue that restricts barley growth and yield especially in the early stages of the growth where drought decrease the number of branches per plant, Also during the reproductive stage of barley, it reduces potential grain number per unit area and decrease fertilization rate (Turk and Al-Tawaha, 2002; Nikus et al., 2005; Al-Tawaha et al., 2005; Al-Tawaha and Al-Ghzawi, 2013; Hossain et al., 2012).

Being an essential element of life for human beings, animals and plants, water and the water resources need to be preserved especially in arid and semi-arid areas. In dry areas, Rain Water Harvesting (RWH) can reduce risk as well as increase yields.

The philosophy behind RWH is to preserve soil moisture, to minimize agricultural soil erosion, to contribute significantly to the reclamation of sloping lands by reducing the deterioration of their natural properties, to reduce the flow of surface water and to increase the soil water content in cultivated lands (Boers and Ben Asher, 1982).

Various forms of Rain Water Harvesting (RWH) have been used from known time. For example, in the Middle East, Rain water was harvested by diverting the 'Wadi' flow (spate flow from normally dry water courses) onto agricultural fields. Other examples include Negev desert (Evenari et al., 1971), desert areas of Arizona and Northwest Mexico (Zaunderer and Hutchinson, 1988). It is a well-known fact that soil plays a significant role in barley production in terms of water productivity. Many studies suggest that soil texture can impact the water capacity available in soil (Meng et al., 1987; Bell and van Keulen, 1995; Saxton and Rawls, 1986). Usually clay soil is rich in organic matter and nutrients than sandy soils. The purpose of this investigation to identify strategies that will allow the production of barley under semi-arid conditions and to determine the effects of soil types and rain water harvesting on barley growth and watershed stability.

Results and Discussion

The data collected for all characters were subjected to statistical analysis of variance to detect significant differences among treatments (i.e., soil type and rainwater harvesting treatments). The main effects were considered in the absence of significant interactions between soil type and rainwater harvesting treatments.

Effects of soil type and rainwater harvesting on grain yield

Grain yield was significantly affected by both features such as soil type and rainwater harvesting treatments. Barley plants produced in the red Mediterranean silt loam soil had higher grain yield than those grown at yellow Mediterranean sandy loam soil. The higher grain yield might be due to the reason that there exists favorable moisture as well as long life span of plants in the red Mediterranean silt loam soil than yellow Mediterranean sandy loam soil.

On the other hand, the other possible reasons for high barely grain yield in red Mediterranean silt loam soil could presumably because of late heading dates, long spike length, increased number of spikelet per spike, high number of grains per spike and increased main spike grain yield. Further, prior to planting, when the yellow Mediterranean sandy loam soil was tested for its nutrient contents, our data indicated the soil had very low nitrogen, phosphorus, potassium, organic carbon compared to red Mediterranean silt loam soil (Table 1). Barley plants grown under rain water harvesting treatment gave the best grain yields compared to its counterparts i.e., those grown without water harvesting treatment. Our data proves that barley plants grown under water harvesting treatment produced more tillers and consequently more fertile spikes and grains compared to the barley plants grown without rain water harvesting treatment.

Water is one of the most important factors affecting the growth of barley plant. It is known that the barley plants which are grown under RWH treatment were supplied with high quantity of water compared to the plants which were grown without RWH treatment. Water harvesting, especially in the dry and semi-dry areas, stores the rain water in soil as much as possible and reduce the flow of excess water. Adding to that, RWH reduces the soil from getting drifted. Sinebo (2002) reported that barley grain yield can be expressed as a function of spike per plant, grains per spike, and 1000-grain weight, which together raised as yield components. On the other hand, Kozak and Mądry (2006) reported that difference in yield components resulting from environmental and management factors affects variation in crop yield.

Effects of soil type and rainwater harvesting on spikes-per-plant

Spikes-per-plant were significantly affected by both features such as soil type and RWH treatments. Barley plants which were grown in red Mediterranean silt loam soil had more number of spikes-per-plant than those that were grown in yellow Mediterranean sandy loam soil. Brown (1999) reported that soil texture, one of the soil characteristics, is one of the main issues that impact many other properties of great significance towards land use and land management.

In general, red Mediterranean silt loam soils are rich in nutrients, moisture, and humus, and in addition possess superior drainage properties coupled with infiltration of water and air compared to yellow Mediterranean sandy loam soil. Bulman and Smith (1993) found that the increase in the number of spikes-per-plant with increasing nitrogen levels in the soil could be endorsed to the well-accepted role of nitrogen in speeding up the vegetative growth of plants. Barley plants which were grown under RWH treatments gave best spike-per-plant results compared to the barley plants which were grown without RWH treatment (Table 3).

Effects of soil type and rainwater harvesting on grains-per-spike

Soil type also significantly affected the grains-per-spike (Table 2). Grain-per-spike in red Mediterranean silt loam soil was 41.5% higher than yellow Mediterranean sandy loam soil (Table 2). This result had to be attributed to the different levels of nitrogen, phosphorus, potassium and organic carbon present in both the sites. Al-Tawaha et al. (2005) reported that the deficiency of nitrogen and phosphorus are the key factors behind the tremendous decrease in grain-per-spike and yield of barely.

Barley plants which are grown under RWH treatment gave the best grains-per-spike results compared to the barley plants which were grown without RWH treatment. It is thus proved that water is one of the most important factors that can affect the productivity of agricultural crops such as barley. Water is also the first determinant of extent of agricultural progress, especially under dry and semi-arid conditions where water scarcity is common.

Table 1. Summary of main and interactive effects on yield, yield components and morphological traits for barley plant.

	Site affect(SA)	Rainwater harvesting (RH)	Interaction (RH x SA).
Grain Yield	*	*	NS
Spikes per plant	*	*	NS
Grains per Spike	*	*	NS
1000-Grain Weight	*	*	NS
Plant Height (cm)	*	*	NS
Spike Length (Cm)	*	*	NS
Days To 50 % Heading	*	*	NS

NS, * and ** indicate non-significant, significant at P ≤ 0.05 level of probability, respectively.

Table 2. Grain yield, spike per plant, number of grains per spike, 1000-grain weight, Plant height, spike length, and days to 50 % heading as affected by soil type

Parameters	Soil type		
	Silt loam soil	Sandy loam soil	LSD
Grain Yield (kg/ha)	1750	1550	55
Spikes per plant	2	1	0.6
Grains per spike	37.5	26.5	2.1
1000-grain weight	42.5	31.5	1.5
Plant height (cm)	110	95	3.3
Spike length (cm)	5.5	8.0	2.3
Days to 50 % heading	91.5	82.5	4.0

LSD indicates least significant difference between means at P ≤ 0.05.

Table 3. Grain yield, spike per plant, number of grains per spike, 1000-grain weight, Plant height, spike length, and days to 50 % heading as affected by water harvesting treatments.

Parameters	Water harvesting treatments		
	Plot with water harvesting	Plot without Water harvesting	LSD
Grain yield (kg/ha)	1900	1400	56
Spikes per plant	2	1	0.8
Grains per spike	39	25	2.5
1000-grain weight	44	30	1.8
Plant height (cm)	120	85	3.9
Spike length (cm)	8.5	5.0	2.9
Days to 50 % heading	90	84	4.6

LSD indicates least significant difference between means at P ≤ 0.05.

Effects of soil type and rainwater harvesting on 1000-grain weight

1000-grain weight was significantly affected by both features such as soil type and RWH treatments. Barley plants which were grown in red Mediterranean silt loam soil had high levels of 1000-grain weight than those grown at yellow Mediterranean sandy loam soil. 1000-grain weight in red Mediterranean silt loam soil was 35% higher than yellow Mediterranean sandy loam soil (Table 2). Al-Tawaha et al. (2005) reported that both nitrogen and phosphorous might positively influence the 1000-grain weight i.e., biomass production of plants. Barley plants grown under RWH treatment had most 1000-grain weights compared to the plants grown without RWH treatment.

Effects of soil type and rainwater harvesting on plant height (cm)

Plant height was significantly affected by both features such as soil type and RWH treatments. Barley plants that were grown in red Mediterranean silt loam soil were taller than those grown at yellow Mediterranean sandy loam soil. The plant height in red Mediterranean silt loam soil was 16% higher than in yellow Mediterranean sandy loam soil (Table 2). The increase in plant height in silt loam soil might be due to the presence of abundant nutrients and moisture levels than sandy loam soil. Barley plants grown under RWH treatment were taller compared to the barley plants grown without RWH treatment.

Effects of soil type and rainwater harvesting on spike length (cm)

Spike length was significantly affected by both features such as soil type and RWH treatments. The barley plants that were grown in red Mediterranean silt loam soil had higher spike length than those grown at yellow Mediterranean sandy loam soil. The spike length in red Mediterranean silt loam soil was 45% higher than in yellow Mediterranean sandy loam soil (Table 2). The barley plants which were grown under RWH treatment gave the best spike length compared to the barley plants grown without water harvesting treatment.

The days to 50% heading was significantly affected by both features such as soil type and RWH treatments. The barley plants grown in yellow Mediterranean sandy loam soil flowered and reached physiological maturity earlier than those grown in red Mediterranean silt loam soil. White and Izquierdo (1991) reported that a number of breeding approaches to increase the yield assume that the yield potentials can be enhanced by increasing the size of photosynthetic source and lengthening the growth span. Some study results (Gifford and Evans, 1981) clarified that the life of plant canopies when extended, leads to improved yields. On the other hand, the barley plants grown in water harvesting treatments flowered and reached physiological maturity earlier than those without water harvesting treatment.

Materials and Methods

Site description and treatments

Field experiments were conducted in 2013/2014 using two different soil types in northern part of Jordan. The soil types chosen for the study were yellow Mediterranean sandy loam soil (site A) and red Mediterranean silt loam soil (site B). The climate in both sites was classified as Mediterranean, described as mild rainy winter and dry hot summer (Loss and Siddique, 1994). In both sites, all plots were hand-weeded as needed throughout the growing season.

The hoops method of rainwater harvesting was deployed (Biswas and Mandal, 2014) This method is suitable for pasture production particularly in dry areas. These are raised earthen structures (bunds), constructed as semi-circles, on gently sloping land. In this technique, the tips of the bunds or hoops are made to point up the slope and are on the same level with contour line. The hoops capture rainwater that runs down the slope. In this technique, starting from contour line, hoe was used to dig the soil in a shallow and semi-circle manner throwing the soil on the lower side (downhill slope). The hoop was 40 cm high in the middle which gradually decreased in height and reached ground level at the tip.

The distance between two hoops in a row was 50 cm. Further, our experiment included untreated soil without 'soil hoops technique' (non-treated control). The plot area was 2 x 2 m. The local six row barley cultivar (*Hordeum vulgare* L. cv. Rum) was sown on 1 November 2013 ⁄ 2014 at a rate of 90 kg ha^{-1}.

Measured variables

The grain yield (kg ha^{-1}), spikes per plant, grains per spike, 1000-grain weight, plant height (cm), spike length (cm), and days to 50% heading (day) were measured.

Experimental design and Statistical analyses

The experiments were laid out in a randomized block design with three replications. The analysis of variance (ANOVA) and mean separation were performed using MSTAT-C, a computer statistical program as described for a split-block design by Steel and Torrie (1980). The means were compared using Least Significant Difference test (LSD) at 0.05 probability level.

Conclusion

The study results indicate that red soils are rich in nutrients than yellow soil. This difference in nutrient availability is reflected in plant components specifically and in yields generally. The plants grow in the red soil show better productivity than those growing in the yellow soils. On the other hand, plants that have grown under RWH treatment performed better than the plants which were grown without RWH treatment. Thus it is concluded that the availability of adequate water and nutrients in the soil are the most important determinants in barley yield.

Acknowledgement

The authors acknowledge the support from Al-Hussein bin Talal University, Jordan

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