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Drip irrigated Barley (*Hordeum vulgare* L.) in arid regions of South Tunisia: Plant Growth and Yield Parameters

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ABSTRACT

Historically relegated to the status of "poor man's bread" barley is one of widely cultivated crops in arid regions of south Tunisia for its grain and biomass used as an animal feed and other various purposes. Barley is incorporated into many types of home recipes. Harsh climate and frequent droughts are the great challenge for cereals production so farmers must supply irrigation in order to improve yields. Traditional irrigation techniques are widely used despite their low efficiency. Conversion to drip is encouraged by public services as a measure to save water resources, boost yields and as an adaptation measure to climate change that will cause more pressure on available water resources .The present paper presents results for drip irrigated barley in arid climate of South Tunisia. The study was undertaken at research farm of Institute of Arid Regions in Medenine and tried to replicate current farmer's practices with the aim to facilitate their conversion to drip irrigation. For full drip irrigated barley (100% irrigation water requirements), following crop variables were recorded according to standard agronomic procedures as described in Daur et al. (2011): Plant height (m); Ears number by square meter at harvest; Number of grains per ear; 1000 grain weight (g); Biological yield ($kg.m^{-2}$); Grain yield at harvest ($g.m^{-2}$). Grain yield was 360.75g m^{-2} which corresponds to 3.61 ton $ha^{-1}$and Biological yield was 1.014 kg m^{-2} for a total water amount of 225 mm. These values far exceed those obtained in rainfed agriculture.

Introduction

As many countries of Mediterranean basin, water is a scarce source in Tunisia because of harsh climate and frequent droughts. Competition for this source between agricultural, industrial and urban consumers increases continually (Romagny et al., 2004). The arid climate requires that cultivated crops be irrigated. Under these conditions of scarcity, crop production must be maintained at expense of minimum inputs but aiming at achieving maximum incomes. As irrigated agriculture is dominated by traditional methods of surface irrigation (Thabet, 1997), drip irrigation is considered as one of the most effective methods to supply water to crops (Sermet et al., 2005). It can result in water saving if good management procedures are applied (Ünlü et al., 2006). As it was one of the most important food grains from ancient times until the beginning of the twentieth century, current practices in the arid regions of Tunisia give to barely (*Hordeum vulgare* L.) an important place in winter annual crops rotations (Nagaz et al., 2010). Millet (*Pennisetum glaucum*) is cultivated as a summer crop. These two cereals are characterized by short cycle and high economic value. Barely cycle coincides with the rainy season but great variability in rainfall due to climate change has made so difficult to grow it and must be irrigated. Barley is considered as one of more tolerant crops to salinity. It is cultivated around shallow wells of the region that most part has a TDS around 5 g/L. Largest used irrigation systems for barely are basin and border irrigation, they need important volumes of water due to their low efficiency because of leveling difficulties and high sand fraction of soil that promotes seepage losses. Conversion to drip irrigation is a national strategy to save water in order to extend irrigated areas. Nevertheless, this technique relatively recent is widely used for row crops and fruit tree but not for cereals and some other field crops. The aim of this paper is to study possibility and yield of drip irrigated barley in arid climate of south Tunisia

Materials and Methods

Experimental Site and Layout

Experiment was carried out at research farm of Arid Regions Institute (IRA), Tunisia, (33°3′ N, 10°3′ E), with 100m altitude. Climate is typically Mediterranean with dry and hot summer and irregularly distributed precipitations throughout the year. Principles weather parameters are included in Table1

Soil at experimental farm is loamy sand and almost flat. Before seeding, it was ploughed; levelled and 40 units per hectare of K_2O and P_2O_5 were applied as basic fertilizer. For nitrogen (ammonitrate 33.5%) 60 units were applied at seed emergence, 70 units at the beginning of heading and 70 units late heading. Soil texture of trial plots is dominated by sand that exceeds 80%.

Experimental layout is shown in figure1. It is a small plot of 120 m^2 area divided into 10 small strips of 1meter wide on12 meters length each one and drip irrigated from a shallow well. Measurements have been taken in strips 2, 5 and 9 which represent the head, the middle and the end of the plot in order to see both spatial variability and avoid side effects. Strips dimensions are those most frequently encountered in smallholder farming in the region. Each strip is equipped with two laterals in low density polyethylene plastics pipes of 16 mm diameter for drippers. The spacing between the lateral lines was 0.5 m and drippers were mounted on lateral lines at 0.5 m spacing. Chosen strips for this trial were considered as three replications (R1, R2 and R3). Sowing was done by broadcast seeding method as in smallholder farming in the region with a rate of 12grams by square meter on November 26th 2012.

Irrigation water was pumped from the shallow well at a pressure of 10 m achieved by discharge controlling valve. Principles irrigation water characteristics are:

pH = 7.9;
SAR = 10.8;
Electrical Conductivity (EC) = 4.6 dS/m.

Crop Water Requirements

Water requirement (ETc) values are useful for effective planning of irrigation scheduling. ETc values were obtained by using ETo and Kc values according to Doorenbos and Pruit (1977) and Allen et al. (1998) procedures. Crop evapotranspiration (ETc) is linked to reference evapotranspiration (ETo) by kc factor which increases with crop growing season by The following equation:

$$ETc = Kc \times ETo \quad (1)$$

Based on Kc values, entire cropping period is divided into four growth stages: initial, development, mid and maturity. Barley crop growing periods were considered 120 days divided into 15days, 25days, 50days and 30days respectively for growing stages in climatic conditions of study area.

For different crop stages of Barley (local landrace: Ardaoui), Kc values are respectively: 0.3; 0.7; 1.15 and 0.4.

Irrigation Scheduling

Calculations performed according equation (1) lead to irrigation scheduling calendar shown in Table 2.

Used drippers flow in the experiment was four liters per hour ($4L.h^{-1}$).One liter delivered by the dripper corresponds to 4mm amount of water at the field since each drip irrigates an area of 50cm x 50cm.

Results and Discussion

As strip areas are very small most of the measures were performed exhaustively. For the number of grains per ear, five ears were collected at each strip at head, middle and the end. Presented data correspond to the average in each strip.

Table 1 Local weather parameters

Month	Rainfall(mean) (mm/month)	Rain (days/month)	Mean temp (°C)	RH (%)	Sunshine (% of Hrs)	WS (m/s)	Penman-Monteith ETo (mm/day)
Jan	17	3.60	11.80	64.00	69.00	3.80	2.31
Feb	18	2.90	13.40	62.00	71.00	3.90	2.98
Mar	29	3.70	15.40	62.00	69.00	4.10	3.76
Apr	15	2.80	18.40	62.00	70.00	4.40	4.79
May	6	2.10	22.00	63.00	73.00	4.30	5.73
Jun	2	1.10	25.70	63.00	76.00	4.10	6.57
Jul	0.3	0.40	27.90	60.00	85.00	3.80	7.25
Aug	1	0.50	28.70	63.00	85.00	3.70	6.76
Sep	8	1.80	26.30	65.00	75.00	3.70	5.33
Oct	21	3.30	22.30	64.00	73.00	3.50	3.99
Nov	18	3.70	16.80	63.00	72.00	3.30	2.80
Dec	17	3.70	12.80	66.00	69.00	3.70	2.19

Table 2 Irrigation scheduling calendar

Stage	1	2	3	4
Length (days)	15	25	50	30
Kc	0.3	0.7	1.15	0.4
ETc (mm)	10	35	137	44
Irrigations	2	3	8	3
Irrigation rate (mm)	5	12	16	15

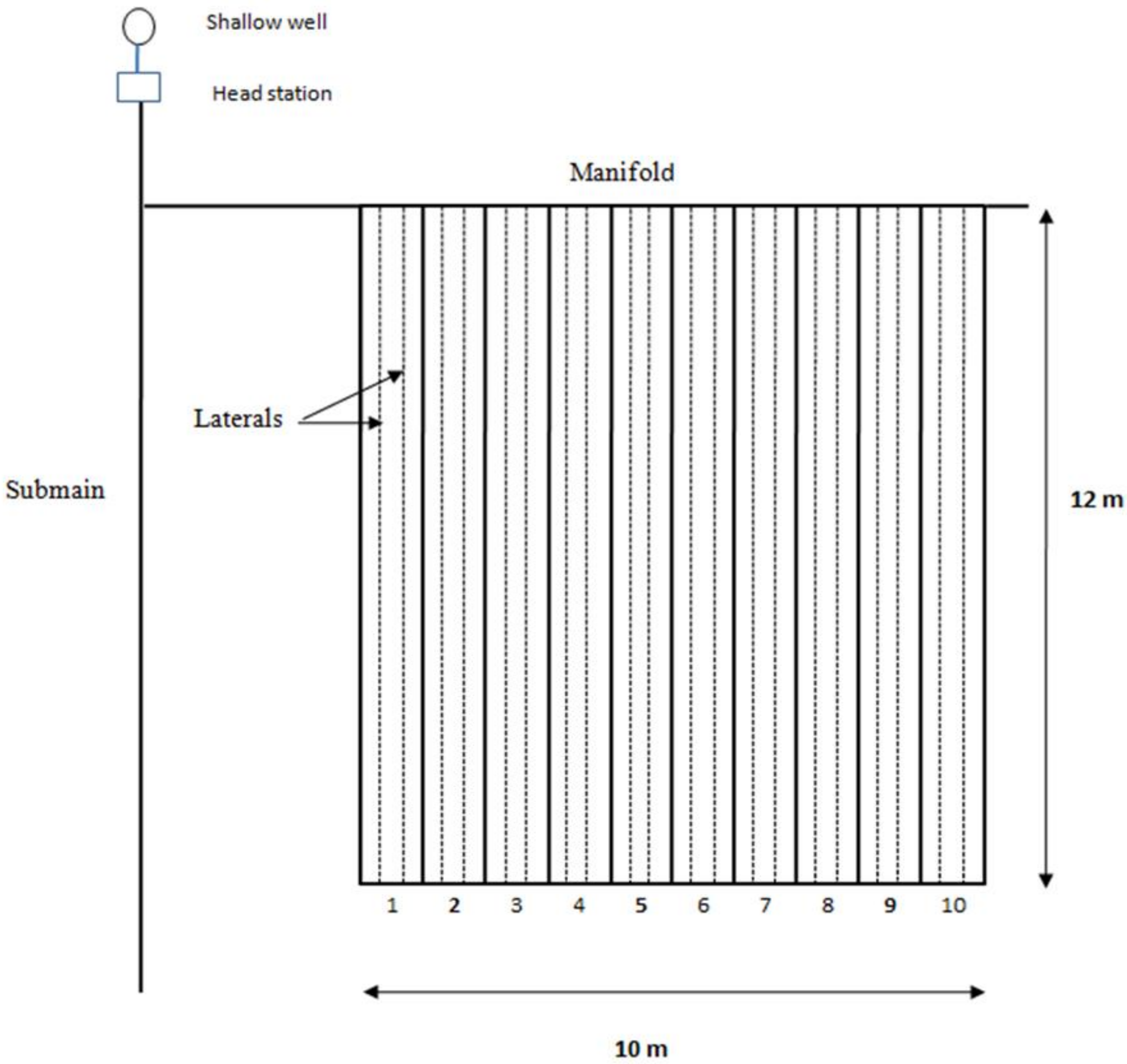

Figure 1 experimental layout components

Plant Height (m)

Plant height depends on both varieties, water availability, mineral and organic fertilization. Height directly affects biological yield. At harvest, plants height measured between 0.98m and 1.14m as shown in figure 2 whereas it was 32.8 and 45.6 for Almarshadi and Ismail (2014).

In varietal study of 13 genotypes of barley in Algeria, Souilah (2012) has obtained heights from 0.81m to 1.11m which agree obtained results. This factor boost biological yield which is an important factor for making some handicraft products and construction of groves shade for animals.

Ears Number/m^2

The number of ears directly affects yield. More is the number of ears per square meter important more is the yield because for cereals, yield is usually expressed as a product of grains number by grain mass. Results at harvest are shown in figure 3. Average number of ears for all replications is 357.3 ears m^{-2}. Khlouj (2011) has recorded a number of 380.85 ears m^{-2}. Souilah (2012) reported a number of ears per square meter from 102.88 to 344.65. However, this number depends on seedling density and other environmental factors. Sampling method can affect this number, in our case, measurements were made on complete strip while many others are based on plots of one square meter considered as representative for all field.

Grains Number per Ear

This factor is an important component of yield. As it was not possible to measure it exhaustively, measurements have been carried out on a sample of five ears taken at the head, the middle and the end of each strip. Measurements average is presented in figure 4. For Souilah study (2012) the number of grains per ear varied from 23.2 to 40.60. However, this number depends on many factors such as water, fertilizing, sowing date ... etc. Productivity depends not only on grain number but also on grain weight. We note that there is no significant difference between different values. However, these values may be influenced by the choice of the experimenter and the variability in the field.

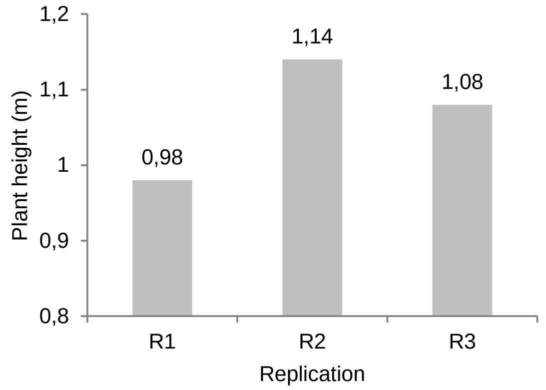

Figure 2 Plant height

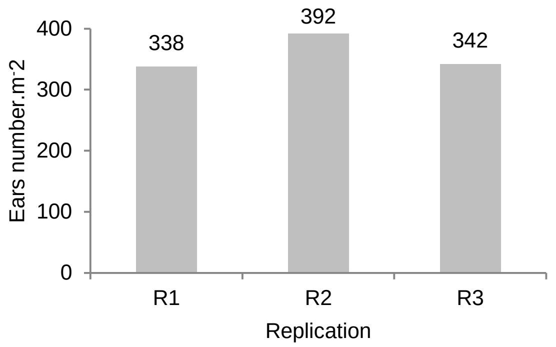

Figure 3 Ears number per square meter

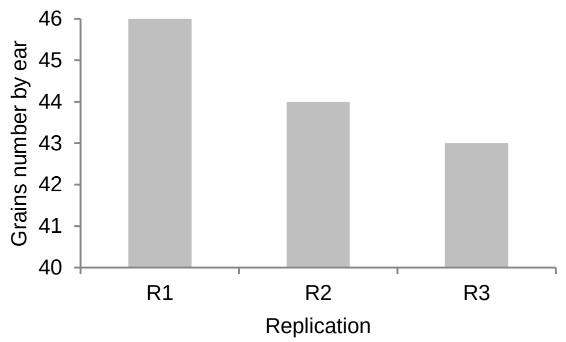

Figure 4 Grain number per ear at harvest

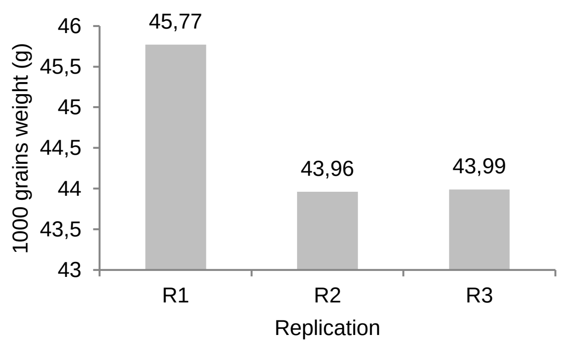

Figure 5 1000grains weight at harvest

1000 Grains Weight (g)

In cereals, 1000-grain weight (g) is a parameter which describes the ability of the accumulation of reserve substances in optimum conditions. Grain filling is done primarily by the recently photosynthesized assimilates. This parameter can be influenced by weather conditions. Knowing the mass of 1000 grains of a cereal sample provides to farmers important information for more accurately calculation of seeds doses needed to meet desired yield. Results of 1000-grain weight at harvest for different replications are shown in figure 5. However, these values may be influenced by the choice of the experimenter and the variability in the field.

Almarshadi and Ismail (2014) given a 1000 grains weight around 34g, for Khlouj (2011) that weight was 52g. Souilah (2012) indicates in her study values of 1000 grains weight going from 34.8 to 61 g. Banga and al (2012) indicates values from 37 to 42g for a study undertaken in north Tunisia. Ouji (2010) in the same region obtained values from 36.4 to 48.4g as weight of 1000 grains. These results are near from those obtained in our experiment undertaken in other arid part of the country. In France, ″C.R.E.A.B″ (2008) values of 1000 gains weight go from 43.2 to 52.9 g. This parameter is influenced by many factors as other yield parameters.

Grain Yield (g. m^{-2})

As for all crops, barley yield depends on inputs (water, fertilizers) but also on environmental conditions as tillage and weeding. Results of grain yield in figure 6 expressed in gr.m^{-2} revealed the same trend as in biological yield. Converted to tons per hectare, mean of this yield corresponds to 3.61 ton ha^{-1}. For the Almarshadi and Ismail (2014), grain yield was 3.235 ton ha^{-1} for full irrigated barley. Khlouj (2011) obtained a yield of 3.224 ton ha^{-1} for barley irrigated with salt water in the same geographical area. All these values exceed those of rainfed barley yield which varies from 0.4 to 1.5 T/ha depending on rainfall and its distribution during crop stages (Bachta, 2011).

Biological Yield (kg. m^{-2})

Biological yield which is a very important factor is shown in figure 7. Grains serve for nutrition of both human and livestock. During drought periods, straws are very useful in smallholder farming systems for small ruminant's nutrition. Straws are also used by farmers to make huts for shading in rural areas and rangelands.

Difference in biological yield between different replications is not very important. Seeding and fertilizers applications had done by hand; they can be with other environmental factors a source of this little non-uniformity. Almarshadi and Ismail (2014) obtained a biological yield of 0.62kg per square meter for full irrigated barley in conditions of Arabia Saudi. To compare variability of different parameters, coefficient of variation (CV) was used.This coefficient represents the ratio of the standard deviation to the mean is a useful statistic for comparing the degree of variation from one data series to another. It is expressed as following:

$$CV = \frac{\text{Standard Deviation}}{\text{Average}} \quad (2)$$

It is usually expressed in %. Applied to data of different replications, results are reported in Table 3.

Table 3 Coefficient of variation (CV) of different measured parameters

Data series	CV (%)
Grain number per ear at harvest	3.4
Ears number per square meter at harvest	8.4
Grain yield at harvest	9.4
Biological yield at harvest	11.2
1000-grain weight at harvest	3.9
Plant height	7.5

Excepted Biological yield at harvest, all other values are in a range less than10%. According to Martin and Gendron (2004) a coefficient of variation between 0.0% and 16.0% indicate a little variation in the sample; between 16.0% and 33.3%, the change is significant; finally, beyond 33.3% variation is very high. This shows that obtained results in different replications are homogeneous.

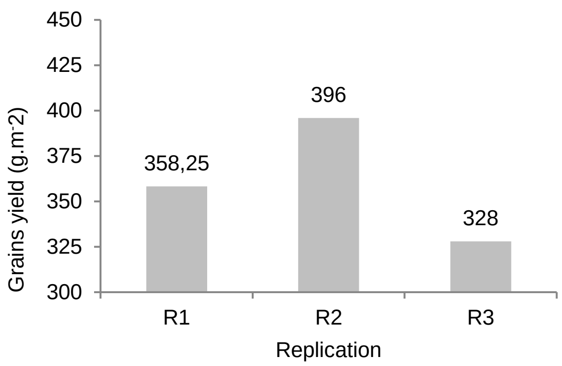

Figure 6 Grain yield at harvest

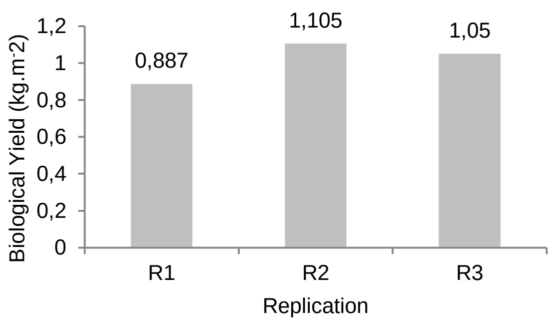

Figure 7 Biological yield at harvest

Conclusions

The water resources scarcity in Tunisia will be even more pronounced in the coming years which will be affected by climate change, so it is necessary to develop methods and forms of adaptations in future planning and management of water resources. This effort must be linked to the role of scientific research and its multidisciplinary input.

With drip irrigation, generally, only a portion of irrigated area is wetted (cases of row crops and trees). In case of field crops, the network must be relatively dense for covering all plants and this leads to large quantities of water to meet crop needs .Lines spacing can be optimized according to the moistened strip created with each line. Thabet (2008) showed that for a similar soil, this strip ranges from 70 to 80cm for drippers flowing 4 liters per hour.

As in this arid climate, barley is generally grown in small areas under rained conditions or with supplemental irrigation; so it will be possible to apply deficit irrigation in the form of Regulated Deficit Irrigation "RDI" or "PRD" 'Partial Rooting Drying (FAO,2002) as this species is known for its tolerance to drought . In all these cases, ratio yields/used water must be optimized for a good water resources management. Drip irrigation also allows reduction in labor and a good uniformity repartition of fertilizers for maximum farmers' profit.

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