EFFECT OF IRRIGATION MANAGEMENT ON CROP PRODUCTION FOR A DROUGHT-TOLERANT GENOTYPE OF BARLEY

Hokam, E. M.\textsuperscript{a} and I. H. El-Sheikh \textsuperscript{b}

\textsuperscript{a} Soil and Water Dept., Faculty of Agriculture, Suez-Canal Uni., Egypt
\textsuperscript{b} Agricultural Engineering Dept., Faculty of Agriculture, Suez-Canal Uni., Egypt

ABSTRACT

The effect of sprinkler irrigation management on barley yield, soil moisture distribution and water use efficiency was studied under field conditions. A field experiment was conducted in 2005/2006 growing season in sandy loam soil, at Wadii-Ghepeen (Bani-Waleid Governorate, Libya). A drought-tolerant genotype of barley (\textit{Hordeum vulgare} L.: AKSAD 67) was irrigated by semi-portable sprinkler irrigation system with a local well-water (electrical conductivity of 2.7 dS m\textsuperscript{-1}). The experiment included two factors: The first factor was two levels of sprinkler distance: 12 and 6 m, and the second factor was two levels of working hours: 2 and 3 h. The control treatment was that recommended in the region (i. e. 12 m sprinkler distance and 5 working hours). So, the experiment consisted of five treatments, namely: 12 m × 3 h.; 6 m × 3 h.; 12 m × 2 h.; 6 m × 2 h. and 12 m × 5 h., labeled as A, B, C, D and Co, respectively.

To evaluate the performance of the sprinkler system and yield response to different treatments, many field measurements were achieved: local rainfall; sprinkler discharge (under working pressure of 2 bar); uniformity coefficient; total dry matter; grain yield and water use efficiency. Also, change of soil moisture contents; seed germination percent and crude protein were determined.

The main results can be summarized as follows: in general, the results indicated that both total dry and grain yields were increased as irrigation water amount decreased. The lowest water amount was consumed under C treatment, therefore, appeared the highest water use efficiency. The statistic analysis shown that, there was no significant effect between sprinkler distances, while significant and high significant effect were found in both working hours and the interaction of sprinkler distance and working hours, respectively.

The results indicate that maximum uniformity coefficient was found under 6 m treatments (i. e. B and D treatments). Germination test showed that, there was no observed effect as difference among all treatments. Following of soil moisture changes after irrigation, indicated that, it is not necessary to bring up soil moisture content to 100% of soil field capacity, while 50% of soil field capacity was found to be optimum amount for high yield production. Such irrigation water quality can be safely used, where the precipitation can prevent salt accumulation hazard.

Keywords: Sprinkler irrigation; Barley; Water use efficiency; Soil moisture distribution

INTRODUCTION

Barley is an important food crop for irrigated regions in the world. Its growth and production may be limited by the applied amount of irrigation water. Both over-irrigation and under-irrigation has a significant effect either on yield quantity or quality. Fox \textit{et al.} (2006) reported that, the genetic effect
on grain size of barley was greater than environmental effect despite some sites suffering terminal moisture stress. By partitioning all variance components, and thereby having more robust estimates of genetic differences, plant breeders can have greater confidence in selecting barley genotypes which maintains a large stable grain size across a range of environmental. In this investigation a drought resistance genotype of barley (i.e. AKSAD 67) has been cultivated to study its response to different irrigation managements. Thomson, et al. (1993) studied the morphological characteristics and chemical composition of barley straw fractions from several genotypes over a range of watering levels. They found that, the nutritive value of cereal straws from different genotypes are often complicated by the difference in plant height which is affected by genotype and the amount of rainfall. The range of water levels was obtained by using sprinklers to apply various levels of water in addition to normal rainfall. On the other hand, Sahnoune et al. (2004) found that the effect of low and moderate water deficit (75% and 50% of soil field capacity) was slight, while the impact of severe water treatment (25% of soil field capacity) was strongly marked on seminal root length and root-to-shoot dry matters’ ratio.

As reported by Jamieson et al. (1995), final biomass was sensitive to drought timing and, in particular, was more sensitive to maximum potential soil moisture deficit for the early than the later drought treatments. Similar results have been found by Macnicol et al. (2002), who studied the effect of heat and water stresses on barley plants. The results showed that, the water stress at mid grain-fill led to decreased grain and increased malt extract.

The effect of supplemental irrigation and irrigation practices on soil water storage and barley crop yield were studied by Abu-Awwad (1998). The obtained results showed that, the differences in stored water had a significant effect on grain and straw yields of barley. The improvement is coming from the increased water storage associated with furrows. He recommended, since irrigation water is very limited if available, farmers are encouraged to form such furrows for reducing runoff from rainfall thereby increasing the amount of water available for forage and field crop production. In the current study, the amount of the local rainfall has been measured in the field, to detect the contribution of rainfall in irrigation water requirements.

The effect of salinity on barley was investigated by Hussain et al. (1997), who studied the effect of saline water on growth parameters of six barley (Hordeum vulgare L.) cultivars in a pot experiment. Their results showed that, growth parameters decreased with irrigation water having EC of 9.26 dS m$^{-1}$. Plant height and total number of plant tillers were decreased significantly with increasing irrigation-water salinity. Green matter and dry matter yields were decreased significantly with increasing irrigation water salinity. In conclusion, they found a lot of potential for a reasonable production of barley as forage crop with irrigation water having salinity up to 9.26 dS m$^{-1}$ provided 15% extra water above crop-water requirement is applied as leaching requirements to control soil salinity. Well irrigation water used in this study had electrical conductivity of 2.7 dS/m, therefore, such effects and problems can be avoided, but salt accumulation in soil was expected. According to Hoffman and Jobes (1983), the barley irrigated each
day with small quantities of water have an electrical conductivity of 2.3 dS m$^{-1}$, could be grown successfully.

The effect of sprinkler irrigation uniformity on crop yield is an important consideration for the design of sprinkler irrigation system. A model that relates yield response to evapotranspiration deficits at special growth stages to evaluate the impacts of uniformity on crop yield can be developed from a crop water production function. A simulation results of the model, which designed by Li (1998) showed that crop yield was increased with increasing uniformity. He found that, the optimum irrigation amount depends on irrigation uniformity and on economic factors, decreasing with the uniformity but increasing with the ratio of product price to water cost. The optimum uniformity was increased with an increase of irrigation amount expressed by a ratio between gross and required irrigation amount, but approximated 90% when the ratio exceeded 0.85. The results obtained from the field experiments, demonstrated that, the relationship between spatial distribution of soil moisture and sprinkler application uniformity, where the water in the soil was more uniformly distributed than that measured for the application at the soil surface.

The areal distributions of soil water content under varying uniformities of sprinkler water application were observed on two different soil types. To quantify the relationship between the subsurface distribution of soil moisture and water application on the ground surface, field experimental results showed evidence of the importance of redistribution of the unevenly applied surface water. The water within the soil is more uniformly distributed than that applied through a sprinkler irrigation system. The extent of water redistribution within the soil profile depends mainly on the uniformity of initial soil water content and the total applied water, Li and Kawano (1996).

According to Li and Rao (2002), the determination of target uniformity for sprinkler irrigation system should consider the impacts of nonuniformity of water and fertilizers on crop yield. In their field experiment, irrigation water and fertilizers were applied through a solid set sprinkler system. The results showed that the uniformity of fertilizer applied was increased with sprinkler water uniformity. The obtained results demonstrated that the uniformity of sprinkler-applied water and fertilizers has insignificant effect on yield for the studied uniformity range. The current standard for sprinkler uniformity (for example, the target CU is equal to or higher than 75% in China) is high enough for obtaining a reasonable crop yield in dry sub-humid regions.

**MATERIALS AND METHODS**

**Field experiment layout**

A sprinkler irrigation system (Semi-Portable System) was installed in a special farm of 2100 m$^2$ at Bani Waleid Locality (semi-arid climate, in which the precipitation rate reached 165 mm season$^{-1}$), Libya. A drought-tolerant genotype of barley (*Hordeum vulgare* L.: AKSAD 67) was cultivated in sandy loam soil has electrical conductivity of (soil past extraction) of 1.6 dS m$^{-1}$. The crop was irrigated by semi-portable sprinkler irrigation system with riser height of 0.7 m. The water available for irrigation was local well water its
salinity reaches 2.7 dS m$^{-1}$. The working pressure during irrigations processes has been kept constant at 2 bar. The fertilization was done as followed in the region (i.e. 25 kg N ha$^{-1}$), and applied at the beginning of grain filling. Barley was seeded on November 1, 2005 and the crop was harvested on the first week of April, 2006.

The total experimental area was 2100 m$^2$, divided into four different treatments, each one equaled to 525 m$^2$. The treatments consisted of two different sprinkler spacings (6 and 12 m) and two different working hours (2 and 3 hours). All treatments were labeled A, B, C and D, and expressed as following:

A = 12 m sprinkler space X 3 working hours  
B = 6 m sprinkler space X 3 working hours  
C = 12 m sprinkler space X 2 working hours  
D = 6 m sprinkler space X 2 working hours

The actual irrigation practice applied in the field (i.e. recommended in the region) was considered as the control treatment: 12 m sprinkler space X 5 working hours, and labeled as Co.

Some measurements for the soil and irrigation system have been achieved either in the filed or in laboratory, as shown in table 1.

### Table 1: Measurements achieved for the soil and irrigation system.

<table>
<thead>
<tr>
<th>Soil measurements (in upper 30 cm)</th>
<th>Irrigation system measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil bulk density, 1.57 g cm$^{-3}$</td>
<td>Uniformity Coefficient of Christian</td>
</tr>
<tr>
<td>Soil field capacity, 31.9 % volumetric</td>
<td>(catch cans 2 m separated)</td>
</tr>
<tr>
<td>Saturation hydraulic conductivity, 0.65 m$^3$ d$^{-1}$</td>
<td>Sprinkler flow rate, 0.7 m$^3$ h$^{-1}$</td>
</tr>
<tr>
<td>Soil texture, sandy loam: 73 % sand, 12 % silt and 15 % clay</td>
<td>Working pressure, 2 bar</td>
</tr>
<tr>
<td></td>
<td>Diameter of wetting cycle was 14 m, in average</td>
</tr>
</tbody>
</table>

Total dry matter, grain yield, weight of 1000 grains, germination percent and nitrogen content in grains have been used to evaluate the performance of the different irrigation managements. The statistical analysis for total dry yield and grain yield was performed based on split plot design, in which the control treatment (as a recommended practice in the region) was associated with both sprinkler distances.

### RESULTS AND DISCUSSION

The irrigation network could be evaluated through some parameters, namely: Applied water amounts; soil moisture distribution; uniformity coefficient; water use efficiency; total dry yield; weight of 1000 grains; grain yield and germination test.

**Applied irrigation water and water use efficiency**

Amount of irrigation water for each treatment was estimated based on nozzle discharge, working hours, number of irrigations and wetted diameter. The results listed in Table 2 shown that excess irrigation water was recorded at B treatment (2475 m$^3$ water ha$^{-1}$ season$^{-1}$ resulted in 4905 kg ha$^{-1}$ total dry yield). The lowest amount was found at C treatment (800 m$^3$ water ha$^{-1}$ resulted in 6062 kg ha$^{-1}$ total dry yield).
Table 2: Applied water amount, AWA in m³ ha⁻¹; total dry yield, TDY in kg ha⁻¹; grain yield, GY in kg ha⁻¹ and water use efficiency, WUE in kg m⁻³.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>AWA</th>
<th>TDY</th>
<th>GY</th>
<th>WUE of TDY</th>
<th>WUE of GY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1200</td>
<td>5373</td>
<td>2470</td>
<td>4.48</td>
<td>2.00</td>
</tr>
<tr>
<td>B</td>
<td>2475</td>
<td>4905</td>
<td>1647</td>
<td>2.00</td>
<td>0.70</td>
</tr>
<tr>
<td>C</td>
<td>800</td>
<td>6062</td>
<td>2427</td>
<td>7.60</td>
<td>3.00</td>
</tr>
<tr>
<td>D</td>
<td>1650</td>
<td>8394</td>
<td>3250</td>
<td>5.10</td>
<td>2.00</td>
</tr>
<tr>
<td>Co</td>
<td>2000</td>
<td>3306</td>
<td>1452</td>
<td>1.65</td>
<td>0.73</td>
</tr>
</tbody>
</table>

In general, under C treatment comparative to B treatment, 1675 m³ of irrigation water can be saved from one hectare each season, in spite of both total dry yield and grain yield were more at C treatment than B treatment. Water use efficiency, WUE, was calculated for both total dry yield and grain yield as shown in table 2. The obtained data indicated that, the highest WUE was found at C treatment, 7.6 and 3.0 kg ha⁻¹ for both total dry yield and grain yield, respectively. On the other hand, the lowest WUE value was found at Co treatment, 1.65 and 0.73 for total dry yield and grain yield, respectively. According to these results, the irrigation management could be recommended based on WUE values as following: C (12 m X 2 h) > D (6 m X 2 h) > A (12 m X 3 h) > B (6 m X 3 h) > Co (12 m X 5 h).

Total dry yield and grain yield

Data listed in table 2 shown that total dry yield ranged from 8394 kg ha⁻¹ (D treatment) to 3306 kg ha⁻¹ (Co treatment). The total dry yield for all treatment were in order of D > C > A > B > Co. Likewise, results of grain yield ranged from 3250 kg ha⁻¹ to 1452 kg ha⁻¹ at D and Co treatments, respectively. Grain yield values for all treatments were in a similar order as following: D > A > C > B > Co. Generally, the higher applied water amount the smaller grain yield and total dry yield. These results indicated that the variation in applied water amounts had a great effect on both grain and total dry yield, a similar results were found by Thomson et al. (1993) and Abu Awaad (1998).

Table 3 gives the results of statistic analysis for all treatments. The results emphasized some different management treatments caused significant responses of the investigated barley genotype for both total dry yield and grain yield. Working hours and sprinkler distance interaction had high significant influence on both measured variables, while working hours treatment had a significant effect on both variable. On the other hand, sprinkler distance treatments were not significant for both variables, where the results show that the variation in sprinkler distance under the same working hours had no significant effect on the measured variables. From Table 3, the studied working hours and sprinkler distances interaction can be ranked according to their significance as following: a > b > c.
Table 3: Performance of barley genotype (AKSAD 67) for total dry yield and grain yield

<table>
<thead>
<tr>
<th>Sprinkler Distance</th>
<th>Working hours</th>
<th>Main Working hours</th>
<th>Main</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 h</td>
<td>3 h</td>
<td>2 h</td>
</tr>
<tr>
<td>12 m</td>
<td>3306</td>
<td>5373</td>
<td>6062</td>
</tr>
<tr>
<td>6 m</td>
<td>3306</td>
<td>4905</td>
<td>8394</td>
</tr>
<tr>
<td>Main</td>
<td>3306</td>
<td>5139</td>
<td>7228</td>
</tr>
</tbody>
</table>

L. S. D. distance = NS  
L. S. D. working hours = 751.1  
L. S. D. Distance × working hours = 1064.2  

Weight of 1000 grain, germination test and crude protein

Weight of 1000 grain, germination test and crude protein % are listed in Table 4. The data show, that the lowest weight of 1000 grain (i.e. 28.3 g) was found at Co treatment. Such trend was also recorded for total dry yield and grain yield listed in Table 2. These results may be explained by the relative low uniformity coefficient at this treatment, in addition to excessive application of irrigation water. Data of germination test revealed that physiological property may did not judge by water stress. The obtained data show that germination percent values were closed each to other although the observed variation among the applied water amounts. For all treatments the values ranged from 90 % to 99 % at A and D treatments, respectively. These results are agree with that found by Fox et al. (2006), they reported that genetic effect on grain size was greater than environmental effects despite some sites suffering moisture stress.

Table 4: Weight of 1000 grain in g; germination test in % and crude protein in %.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of 1000 grain</td>
<td>38.3</td>
<td>40.7</td>
<td>36.7</td>
<td>36.7</td>
<td>28.3</td>
</tr>
<tr>
<td>Germination test</td>
<td>99</td>
<td>95</td>
<td>94</td>
<td>90</td>
<td>96</td>
</tr>
<tr>
<td>Crude protein</td>
<td>7.6</td>
<td>7.4</td>
<td>7.4</td>
<td>8.6</td>
<td>6.3</td>
</tr>
</tbody>
</table>

The crude protein percent was calculated according to Rau and Johnson (1999), where nitrogen percent was multiplied by 5.7. The obtained data showed that excess irrigation water did not increase the quality of grain, the lowest value (i.e. 6.3 %) was found at Co treatment that received 2000 m³ ha⁻¹ water. On the other hand, the relative high values at A, C and D treatments, lead to conclusion that, for quality point of view relatively more water stress seems to be favourable.

Soil moisture distribution

Monitoring the change in soil water contents was done in upper 30 cm of soil profile (two months before harvest), where plant roots are diffused. Soil samples were collected just through the next ten days after irrigation, and
the moisture content was gravimetric determined. Figure 1 illustrates the change in soil water contents for during the ten days period. Due to the differences in sprinkler distances, therefore, different applied water amounts, changes in soil moisture distribution became clear. It is important to note that, the first value of soil water content (i.e. one day after irrigation) at B and D treatments was close to soil field capacity (31.9 %, lab. determined), reached 32.5 % and 29.5 % for B and D treatments, respectively, Figure 1. The results indicated that, the difference between sprinkler distances may have had the main effect on soil moisture distribution although the applied water amounts varied strongly from 1650 m$^3$ ha$^{-1}$ to 2475 m$^3$ ha$^{-1}$ for D and B treatments, respectively. On the other hand, soil moisture contents at the same time reached 17.5 % and 14 % (i.e. about 50 % of soil field capacity), at A and C treatments, respectively. So, under such field conditions the irrigation management can be achieved to keep the root zone wetted up to 50 % of soil field capacity. A similar result was reported by Sahnoune et al. (2004), they stated that the impact of severe water treatment (25 % of soil field capacity) was strongly marked on barley growing, while the effect of low and moderate water deficit (75 % and 50 % of soil field capacity) was slight.

The irrigation with such well water (i.e. 2.7 dS m$^{-1}$) should be lead to larger salt accumulation in the root zone. Finally determination of soil salinity for all treatments indicated that soil salinity in the root zone, 30 cm depth, was decreased from 1.5 dS m$^{-1}$ at the beginning of season to 0.6 dS m$^{-1}$ at the end. This result may be explained because leaching effect resulted from the relative high precipitation (i.e. 165 mm season$^{-1}$) during the growing season. Evidently, this water quality can be used safely for irrigation under such field conditions without salinity hazard.

**Uniformity coefficient**

Typically, the higher the distance between sprinklers the smaller the water depth between sprinklers, therefore, the smaller water quantity stored in soil with poor wetting pattern. To inssure optimum uniformity coefficient, UC, is one of the most important factor for such aim. Uniformity coefficient of Cherestian, UCC, was used to estimate the uniformity coefficient of the irrigation system for both 6 m and 12 m distances with discharge rate of 0.7 m$^3$ h$^{-1}$ and working pressure of 2 bar. The obtained results indicated that maximum uniformity (92.7 %) can be found at 6 m treatment, while reached 78.6 % under 12 m treatment. As shown in figure 1, the high water content closed to soil field capacity at D treatment may be related to its maximum uniformity coefficient. Likewise and as reported by Li (1998), crop yield and water use efficiency increased with increasing uniformity coefficient. The results shown that water contents within the soil was uniformity distributed either at UC of 92.7 % or 78.6 %. According to Li and Kawano (1996) and Li and Rao (2002), both high values of UC may be resulted from a high uniformity of initial soil water contents.
Figure 1: Soil moisture distribution at 30 cm soil depth
Conclusion
Sprinkler irrigation management affected the total dry yield; grain yield uniformity coefficient and water use efficiency. Under the different irrigation treatments, applied water amounts ranged from 800 m$^3$ ha$^{-1}$ to 2475 m$^3$ ha$^{-1}$, resulted in total dry yield of 6062 kg ha$^{-1}$ to 4950 kg ha$^{-1}$, respectively. So, for high water use efficiency it is not necessary soil water content at root zone to 100 % of soil field capacity, as water content of 50 % of soil field capacity seemed to be satisfied. The sprinkler distance of 6 m was associated with high applied water amount, high uniformity coefficient and high soil water content.

Drought tolerant barley genotype (AKSAD 67) seems to be stable across a range of different irrigation managements. Furthermore, water use efficiency was enhanced under water stress conditions (i.e. 800 m$^3$ ha$^{-1}$). Such quality of applied well-water (2.7 dS m$^{-1}$) can be used safely for irrigation without salinity hazard; because of failed precipitation can prevents salt accumulation in the upper part of soil.

ACKNOWLEDGEMENTS
Authors would like to acknowledge the 7 October University in Libya for providing facilities and Prof. Dr. Abdel-Mmoulttelb, H. from Suez-Canal University for his advice.

REFERENCES
Hokam, E. M. and I. H. El-Sheikh


تأثير إدارة الري بالرش على إنتاج أحد أصناف الشعير المتحملة للجفاف

عثمان محمد حكام* و إسلام حسن الشيخ*

كلية الزراعة (قسم الأراضي والمياه) جامعة قناة السويس، جمهورية مصر العربية

(*) كلية الزراعة (قسم الهندسة الزراعية) جامعة قناة السويس، جمهورية مصر العربية

يشمل هذا البحث تقدير أداء أحد أنظمة الري بالرش (ري بالرش النصففنقفا بفابلرأ الفدرار)
رذذلك لأختيام أفضط مار الوصمة للري في المنطقة. وقد تم تقدير جودة حقلية بناءً على معدل معدل حقلية ونسبة الإصابات والتصاص المائي.

جرت المحاكى بتقديم موديل الكهروضلاحي له 2.7 ديم. الماء لسنتين، بدأ الحصاد في الأبري 2007 إلتملت التسربة على أربع مفاملات مختالة نتسفت مفب مفاملتيب للم فافة بفيب الرلالفات (7 متفر ر 25 (م) إلتملتی الفاعات االتلفغا 5 و3 ففاعات) لتفاقد الفائدة. أظهرت التسربة الفائدة في ضغط التلغي طرا فترات الري عند 5000 بار.

و على المستوى الحيلى فقد تم تمتاز إيواد إضافة المياء لفري المضافة في مفاملات متغيرة مدف في ألقام الحبرأ، و ذلك لابد من توظيف المياء المتاصلا للري، ديفاء المياء الفري المضافة و ذلك لابد من توظيف المياء المتاصلا للري، ديفاء المياء المضافة، و ذلك لابد من توظيف المياء المتاصلا للري، ديفاء المياء المضافة، و ذلك لابد من توظيف المياء المتاصلا للري، ديفاء المياء المضافة، و ذلك لابد من توظيف المياء المتاصلا للري، ديفاء المياء المضافة، و ذلك لابد من توظيف المياء المتاصلا للري، ديفاء المياء المضافة.