Adaptation of Winter Crops for Summer Cultivation and Salinity Stresses in Mediterranean Region: Selection for Double-Cropping and Crop Rotation

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**ABSTRACT**

In countries poor in water as Jordan, the use of nonconventional water sources as saline water is gradually increasing in forages production. Objective of this research is to study the tolerance of winter crops for the dry summer cultivation and saline water irrigation and to select for double-cropping scheme and a variety of crop rotation. Three winter crops (barley, triticale and oat) were cultivated in winter and in summer of 2013 using saline water for irrigation. Crops completed growth and produced grains in the two seasons. Summer cultivation comparing to winter for the crops reduced average yield by 73.9 and 81% for the straw and grains, respectively. barley produced the highest dry straw yield (4.52 t ha\(^{-1}\)) representing 36.3% of the winter yield, and oat produced the highest grain yield (0.47 t ha\(^{-1}\)) representing 38.8% of the winter yield, whereas triticale produced poor straw and grains (9.5% and 10.3% of winter yield, respectively). Barley is saline and over season adapted for straw production followed by oat whereas triticale is susceptible. Production of barley straw as animal forage is proper for a second cropping in summer and in the crop rotation after legumes. Further evaluation of barley genotypes is vital to determine the stress tolerant and for high biomass production.

**INTRODUCTION**

Agriculture in Jordan employs about 122,000 workers and contributes 3% of GDP with income of 561 Million Jordan Dinar [10]. Animal production is one of the most important activities of the agricultural sector and its contribution to the total agriculture is 55%, with total income of 376 MJD. With the population increase, the demand on animal’s products increased, this is reflected by the increase in animals numbers. As a case study on cows, number of heads increase from 47,360 in 1995 to 67,590 head in 2011.

Forage shortage period extend from early summer to the end of winter, during this period farmers - basically- use the stored silage, grains and hay to feed their animals. Sustainable forage supply is crucial for animal sector in Jordan, and the market depends on the local production and on the import. The local production satisfies only 20% of needs and the quantities and cost of import forages increased from 256000 to 350000 ton and the cost from 42 to 148 million JD in the year 2000 and 2012, respectively. This is attributed to many reasons including the limit in fresh water and agriculture land for growing the forages.

The annual potential available ground and surface fresh water in Jordan is estimated to be 980 MCM, agriculture consumes about 70% of available fresh water [10]. Average rainfall estimated as 8 BCM the majority fall on arid lands. Other nonconventional water resources are available as the treated wastewater and saline water with annual discharge of 120 MCM and 46 MCM, respectively. On the other hand, available agricultural land is very limited in Jordan and restricted in about 8% of total area used to produce varied crops including the forages. Salinity is major environmental stress that limits agricultural production in different part of the world and it is affected the plant in different ways such as osmotic effects, specific-ion toxicity and/or nutritional disorders [12,15] Migrated saline lands prevailed in vast areas in Jordan, in which human food and animal feed deficits are at extremes. Saline water and soils resources are not fully used and limited for certain
robust crops. Moreover, numerous underground wells converted from fresh to saline as a result of over pumping, all last resources are not fully invested.

Interest in cultivating crops at varied season is old and practiced worldwide, for example Malmborn [8] in Sweden conducted an experiment on barley in the summer in 1956. In Germany summer cultivation of barley is practiced and the grain is sown in late May [16]. This research project aims to study the tolerance of winter crops for the dry summer cultivation and saline water irrigation and to select crops for double-cropping scheme and a variety of crop rotation. This information will contribute to local agricultural intensification through the use of available nonconventional water resources.

Methodology:

The study site is located at Al-Khaleediyah saline agronomy research station in center eastern Jordan during the growing season of 2013. The location has Mediterranean climate of mild rainy winters and dry hot summers [7]. The longer term rain average is 120 ml per year [9]. The soil type is soil is calcareous, pH 7.5, clay loam textured and salinity ranged from 9.44 and 21.7 dS m⁻¹ at depth of 0-15 cm and 15-30 cm, respectively.

Three winter crops were evaluated for the yield and yield components; barely (Hordeum vulgare L.) cultivar Rum (Jordan), triticale (X. triticeoscale Wittmack) cultivar Syria-1 (Syria) and Oat (Avena sativa L.) line F199084-d4 (Canada). Crops were grown during two seasons in 2013; winter (January) and summer (July) and harvested at maturity in June and November, respectively. Sowing was by hand in a 4 m² plots replicated 7 times for each crop and arranged in a one factor randomized complete block design. The trial lands were irrigated at total amounts of 400 mm distributed as three days interval at each sowing date. Irrigation water was from underground well with salinity of 5.6 and 8.1 dS m⁻¹ in the winter and summer, respectively. Weeds were removed manually whenever needed. A one m² quadrat was used to harvest the plants of central rows of each plot, cutting height was few centimeters above soil surface. During anthesis, plant height and number of tillers per plant were recorded then at the full maturity development, straw and grains yield and harvest index were determined.

Data for each trait were analyzed for a randomized complete block design (RCBD) according to procedure outlined by Steel and Torrie. Comparisons between means were made using least significant differences (LSD) at 0.05 probability level.

RESULTS AND DISCUSSIONS

Stress tolerance:

The winter crops were subjected to two types of stresses; the first was the out of season cultivation by growing the crops in the summer and the second was the salinity stress from the soil and the irrigation water. Crops were able to complete their life cycle and produced straw and grains (table 1 and 2). Straw and grain yield were influenced by the growing season and the crop type. The three crops produced lower yield in the summer in comparison with the regular winter growing season. Average percent decrease in the crop’s height, number of tiller per plant, straw yield and grain yield were 51.8%, 66.5%, 73.9% and 81.1%, respectively. In summer the dry weather hasten the crop maturity that reduced the straw and grain yield, also the increase in irrigation water salinity from 5.6 dS m⁻¹ in winter to 8.1 dS m⁻¹ in summer intensified the stress on the crops.

These results indicating that planting date for these winter crops is more flexible out of the winter season to include the summer, so they could be grown in double cropping systems and included in the crop rotation primarily when stress tolerant species alternatives are lack.

Crops tolerance:

Straw yield among the crops was not significantly different in the winter season, and triticale produced the highest straw yield (13.07 t ha⁻¹), whereas significantly triticale produced the lowest straw yield in summer (1.24 t ha⁻¹) and oat ranked the second (tables 1 and 2). On the contrary barley produced the highest straw yield (4.52 t ha⁻¹) among the other crops in summer, which represent 36.3% of the winter yield. In Germany, Bending et al., reported varied straw yield harvested from different barley genotypes grown in summer that ranged between 0.3 to 27 t ha⁻¹ with average of 8.1 t ha⁻¹. This indicated that barley is more adapted for fluctuated season’s conditions and salinity stresses in terms of straw production, however triticale found to be susceptible in this study.

Grain yield among the crops was not significantly different in the winter season and barley harvested the highest grain yield (2.26 t ha⁻¹), whereas barley was significantly the lowest grain producer in the summer (0.17 t ha⁻¹). On the contrary, oat significantly overcome barley and triticale and produced the highest grain yield (0.47 t ha⁻¹), however it representing 38.8% of the winter yield.

Harvest index:

The harvest index reflects the ability of the genotypes to partition its dry matter into seed and straw, and the ability to maintain the right balance between seed and straw yield. In the winter season the three crops were not
significantly different in term of harvest index, while in summer the highest harvest indices were obtained from the oat and triticale where as barley was the lowest (tables 1 and 2). Scientist revealed that crop yield is commonly proportional to total biomass production [13,7], in the case of barley this was right in the winter cultivation but this common proportion was not found in the summer cultivation despite of the greater amounts of straw production. Less straw yield was produced in summer by oat and triticale that produced the highest grain yield compared to barley that had higher straw yield. Similarly, Ishag revealed that faba bean plants grown at a lower level of inputs and had limited vegetative growth, always produced higher seed yield and harvest index.

Table 1: Yield and yield components of the crops grown in the winter season (2013).

<table>
<thead>
<tr>
<th>Crop (name)</th>
<th>Height (cm)</th>
<th>Tiller plant (no.)</th>
<th>Straw yield 1 ha⁻¹</th>
<th>Grain Yield 1 ha⁻¹</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triticale (Syria1)</td>
<td>117.20</td>
<td>19.67</td>
<td>15.07</td>
<td>2.06</td>
<td>0.16</td>
</tr>
<tr>
<td>Barley (Ram)</td>
<td>86.11</td>
<td>37.89</td>
<td>12.46</td>
<td>2.26</td>
<td>0.18</td>
</tr>
<tr>
<td>Oat (F199084-d4)</td>
<td>91.11</td>
<td>25.00</td>
<td>8.47</td>
<td>1.20</td>
<td>0.15</td>
</tr>
<tr>
<td>LSD*</td>
<td>13.37</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>CV %**</td>
<td>6.01</td>
<td>23.62</td>
<td>12.66</td>
<td>32.64</td>
<td>23.83</td>
</tr>
</tbody>
</table>

*Least significant difference
**Coefficient of variability

Table 1: Yield and yield components of the crops grown in the summer season (2013).

<table>
<thead>
<tr>
<th>Crop (name)</th>
<th>Height (cm)</th>
<th>Tiller plant (no.)</th>
<th>Straw yield 1 ha⁻¹</th>
<th>Grain Yield 1 ha⁻¹</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triticale (Syria1)</td>
<td>54.05</td>
<td>8.52</td>
<td>1.24</td>
<td>0.21</td>
<td>0.19</td>
</tr>
<tr>
<td>Barley (Ram)</td>
<td>37.02</td>
<td>8.59</td>
<td>4.52</td>
<td>0.17</td>
<td>0.04</td>
</tr>
<tr>
<td>Oat (F199084-d4)</td>
<td>50.00</td>
<td>8.67</td>
<td>2.75</td>
<td>0.47</td>
<td>0.21</td>
</tr>
<tr>
<td>LSD*</td>
<td>6.24</td>
<td>NS</td>
<td>1.33</td>
<td>0.18</td>
<td>NS</td>
</tr>
<tr>
<td>CV %**</td>
<td>11.35</td>
<td>28.04</td>
<td>40.09</td>
<td>53.58</td>
<td>76.00</td>
</tr>
</tbody>
</table>

*Least significant difference
**Coefficient of variability

Conclusion:
Among the three winter crops, the local barley cultivar “Rum” is the proper choice for a prolonged adaptation to fluctuations in the cultivation season and salinity level. Barley found to be fits into a double-cropping system and to be included in the crop rotations for straw production. Further evaluation of barley genotypes is vital to determine the stress tolerant and for high biomass production. More over evaluation of barley for crop cutting is needed along the year to maximize the forage production under the prevailed stress conditions.

REFERENCES
