A study of the Effects of supplemental irrigation and fertilizing on yield and yield components of lentil cv. Bilesavar

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ABSTRACT

Maximizing water productivity, and net yield per unit of land, is a good strategy for farming systems. Therefore a field experiment was designed to determine the effect of different fertilizers treatments on yield and some agronomic traits of lentil (Lens culinaris Medic) under different supplementary irrigation regimes which is one of the most essential practices in dry farming crop management in a completely randomized block design using split plots in four replications. Main plots consist of two irrigation levels including supplemental irrigation and dry farming. Secondary plots consist of four levels of fertilizers including control, phosphorous fertilizer, 50% phosphorous + Azotobacter and Azotobacter biofertilizer. Results showed that use of combined biologic and chemical fertilizers under drought stress conditions increased lentil yield. The effects of irrigation system on studied traits were not significant which could be attributed to high precipitation (about 442 mm) during experiment period. Generally, it can be stated that using of Azotobacter had significant effects on studied traits and as a result of nitrogen fixation by this bacteria. Therefore, from viewpoint of decreasing use of chemical fertilizers, 50% phosphorous fertilizer along with biofertilizer and supplementary irrigation at flowering stage and pods filling could be recommended for lentil.

Key words: Supplemental irrigation, biofertilizer, Azotobacter, yield, lentil.

INTRODUCTION

There are about 60 domesticated grain legume species in the world (Hedley, 2001). Lentil (Lens culinaris Medic) is an annual legume best adapted to cool climate conditions and is traditionally grown as a rain fed crop in the Middle East. Lentil seed is a rich source of protein (up to 28%) in human diets in arid and semi-arid areas of West Asia (Sarker et al., 2003). While there are benefits to growing lentil, such as atmospheric nitrogen (N) fixation, this crop is poorly competitive with weeds due to its small stature and slow growth early in the season (McMaurry, 2007) or restricted by water deficit (Lal et al., 1988).

The impact of climate change in the next few decades will increase risks of wheat production under dry-land conditions (Miranzadeh et al., 2011). To cope with the limitation of water and the high demand for food crop production, improving crop water productivity will be a major solution to the current problems (Zhang et al., 2003). Lentil water requirement mainly depends on stored water of soil, amount of precipitations in previous years and soil depth and texture (Tiwari and Vyas, 1994). Water shortage during seed filling stage decreases number of pods per plant and number of seeds per pods results in seed yield reduction in lentil (Lal et al., 1988). Under dry lands condition, supplementary irrigation could significantly
problems can be solved by the use of supplementary irrigation. Increasing seed and biological yield through supplementary irrigation has been reported by many researchers (Zhang et al., 2000).

Khorgami et al. (2012) showed that supplementary irrigation especially at 50% flowering stage significantly had a positive effect on most of assessed traits. The highest seed yield was obtained by dry farming with supplementary irrigation at 50% flowering stage by average of 1895.3 kg ha⁻¹. The excessive use of chemical fertilizers has generated several environmental problems. Changes in the soil pH, soil acidifications and lower humic acid contents are some key problems of overuse of synthetic fertilizers (Suthar, 2009). Some of these problems can be solved by the use of bio fertilizers such as Azotobacter sp. which are natural, beneficial and ecologically friendly (Hargreaves et al., 2008; Lazzano et al., 2009). The application of bio fertilizers has been recognized as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, and increasing crop yields (Azarmi et al., 2008; Hargreaves et al., 2008). Because of avoidance of environmental problems, human health, and more crop production to meet the increasing need of world population, integrated nutrient management by the combination of chemical and bio fertilizers may be a useful way as mentioned by Ayoola et al. (2007).

Azotobacter is a free-living nitrogen-fixing bacterium which is used as a biofertilizer in the cultivation of most crops. In the local soils, Azotobacter fixes annually about 60–90 kg N/ha and it may be used in crop production as a substitute for a portion of mineral nitrogen fertilizers (Hajnal et al., 2004). Inoculation with Azotobacter can increase the yield by 5-28% (Kennedy et al., 2004). The increase is a result of BNF, as well as the production of antibacterial and antifungal compounds, growth regulators and siderophore (Pandey and Kumar, 1989).

Optimum amounts of nutrients are required for obtaining high grain yields of lentil. Therefore this study was conducted to determine the effect of different fertilizers treatments on yield and some agronomic traits of lentil (Lens culinaris Medic) under different supplementary irrigation regimes which is one of the most essential practices in dry farming crop management.

METHODS AND MATERIALS

In order to compare the effects of phosphorous fertilizer, Azotobacter biofertilizer and their combination under dry farming and supplemental irrigation conditions on yield and yield components of lentil cv. Bilesavar. A field experiment was conducted during 2013-2014 cropping year in Khorram Abad town, Iran. The area is located in 33°29’ N latitude and 48°18’ E longitude. The area elevation is 1175 m from sea level and mean annual precipitation and temperature is 520 mm and 17.5°C, respectively. The area annual length of drought period is five months. The experiment was a complete randomized block design using split plots in four replications. Studied factors consisted of two irrigation levels including supplemental irrigation (I₁) and dry farming (I₂) as main plots and four fertilizing systems including control (F₁), 100% phosphorous fertilizer (F₂), 50% phosphorous fertilizer+ Azotobacter inoculation (F₃) and Azotobacter inoculation (F₄) as secondary plots.

In order to sow seeds, along with each sowing line, a 5 cm-depth rip was created throughout the sowing lines and triple super phosphate (TSP) were simultaneously added to soil along with sowing (03.12.2013). In order to apply Azotobacter treatments, seeds were soaked by Azotobacter suspension and then placed in cracks. Primary efficient precipitation occurred on a day after sowing (04.12.2013). With regards to supplemental irrigation, supplemental irrigation was conducted at three steps: first irrigation on 25.04.2014, second irrigation on 05.05.2014 and third one on 16.05.2014. Plants were harvested on 24.05.2014 and following traits were measured as methods in literatures: plant height, productive pods number/m², grain number/m², 100-grains weight, grain yield, grain protein percent and protein yield.

A compound soil sample (0-30 cm depth) were prepared and analyzed for some of chemical properties by conventional methods (Sparks, 1996) with results presented in Table 1. Soil texture was clayey loam.

RESULTS AND DISCUSSION

Table 2 shows the results of analysis of variance of the effects of supplemental irrigation, fertilizers levels and their interactions on yield and yield components of lentil.

Productive pod number per square meter

Results showed that the effects of fertilizer on productive pod number were significant (Table 2, P<0.01). Results of mean comparisons showed that there was considerable differences between different fertilizer types, so that 50% phosphorous+ Azotobacter treatment (F₄) has the greatest number of productive pods (3860.5 pod per m²) and the lowest pods number observed in control (2452.3 pod per m²) which had no significant differences with other two treatments (F₂ and F₄) (Figure 1). This increase in pods number (by 57% compared to control) represents the positive effect of phosphorus fertilizer on flowers and grain’s number compared to no application of chemical fertilizers (Zafar et al., 2003). There were no significant differences between supplemental irrigation and its interactions with fertilizer types, but irrigation increased...
Table 1. Chemical properties of soil before applying treatments.

<table>
<thead>
<tr>
<th>Texture</th>
<th>pH</th>
<th>EC (dS/m)</th>
<th>O.C (%)</th>
<th>N (%)</th>
<th>P (ppm)</th>
<th>K (ppm)</th>
<th>Mn (ppm)</th>
<th>Fe (ppm)</th>
<th>Zn (ppm)</th>
<th>B (ppm)</th>
<th>Cu (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCS</td>
<td>7.7</td>
<td>0.58</td>
<td>1.05</td>
<td>0.14</td>
<td>7.6</td>
<td>320</td>
<td>2.7</td>
<td>3.7</td>
<td>0.5</td>
<td>0.15</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Using SAS (Ver. 9.1) data were subjected to analysis of variance. Mean comparisons were calculated using LSD test, at the probability level of 5 percent by MSTAT-C software.

Table 2. Results of analysis of variance of the effects of supplemental irrigation, fertilizer types and their interactions on yield and yield components of lentil.

<table>
<thead>
<tr>
<th>SOV</th>
<th>DF</th>
<th>Productive pods/m²</th>
<th>Single seed pods No./m²</th>
<th>Two-seed pods No./m²</th>
<th>Biologic yield</th>
<th>Grain yield</th>
<th>100-grain weight</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>3</td>
<td>1042447.6ns</td>
<td>991766.6ns</td>
<td>1716.6ns</td>
<td>1598790.3ns</td>
<td>470130.5ns</td>
<td>0.103ns</td>
<td>133.4ns</td>
</tr>
<tr>
<td>Supplemental irrigation (I)</td>
<td>1</td>
<td>1077879ns</td>
<td>919368ns</td>
<td>630ns</td>
<td>2156272.8ns</td>
<td>422432.9ns</td>
<td>0.195ns</td>
<td>64.07ns</td>
</tr>
<tr>
<td>Fertilizer F</td>
<td>3</td>
<td>3567713.9**</td>
<td>2754896**</td>
<td>61970.6**</td>
<td>1915397*</td>
<td>194135.5**</td>
<td>0.04ns</td>
<td>28.04*</td>
</tr>
<tr>
<td>I × F</td>
<td>3</td>
<td>1016492.4ns</td>
<td>1018530.7*</td>
<td>249.3*</td>
<td>1129116.1*</td>
<td>20763.2*</td>
<td>0.1*</td>
<td>12.67*</td>
</tr>
<tr>
<td>error</td>
<td>18</td>
<td>494426.04</td>
<td>490983</td>
<td>2267.32</td>
<td>789929.6</td>
<td>34708.3</td>
<td>0.02</td>
<td>9.59</td>
</tr>
</tbody>
</table>

ns: not significant, * and ** significant at 5 and 1% probability level, respectively.

Figure 1. Mean comparisons of the effects fertilizer types on number of productive pods in lentil. Means having similar letters in each row have no significant difference at 5% probability level according to LSD test.

this trait by 13% compared to control. Increasing in phosphorus would increase availability of nutrients and consequently increase in pod numbers per area unit and there is a regulation system by which allowed available nutrients for developments of pods in plant and grains in pods (Zafar et al., 2003). This result is inconsistent with that of Singh (2005) who reported that there was no significant difference between pod yield of non-inoculated and inoculated soybean seeds with B. japonicum. While, Rashid et al. (1999) stated that Rhizobium inoculation + 20 kg N ha⁻¹ significantly increased pod yield.

Number of pods having single- and two seeds per plant

Results showed that supplemental irrigation significantly
affected these traits and increased single-seed and two-seed pods per plant by 13 and 14%, respectively, while the effect of fertilizer types was significant (Table 2). Highest single-seed pods number per plant (3523) obtained in F3 treatments which increased by 52% compared to control (2313) (Table 3). Similarly, highest number of two-seed pods per plant observed in same treatment (3523) which increased by 42% compared to control (1392) (Table 3). The enhancing effect of seed inoculation with N₂-fixing bacteria on the growth and yield of wheat was reported by many researchers (Bhattari and Hess, 1993; Ozturk et al., 2003). This improvement may be attributed to the high nitrogen uptake by the inoculated plants and the ability of bacterial strains to produce growth promoting substances (Haathela et al., 1988). A. chroococcum inoculation increased the yield of seed in the variant without urea application (Milosevic et al., 2012).

### Biological yield and harvest index

Biological yield is an important variable in improving cropping which represents plant ability to produce during growing season. Results showed that supplemental irrigation had no significant effect on both parameters. However, fertilizer type and its interactions with irrigation significantly affected biological yield and harvest index (P<0.05, Table 2). In spite of non-significant effect of irrigation, supplemental irrigation increased biological yield and harvest index by 13 and 21% compared to control (data not shown). Mean comparison results showed that highest biological yield obtained in F3 treatment (4927.5 kg/ha) (50% phosphorous chemical fertilizer +Azotobacter) in comparison with control (3892.5 kg/ha) indicated 27% increase (Table 3). Based on mean comparison results, F3 treatment had highest harvest index (16.92%) while control had the lowest one (12.53%) representing 9% increase compared to control (Table 3). In experiment conducting year, precipitation amount was high with proper distribution which caused non-significant differences in studied traits and in fertilizer treatments due to improved photosynthesis and better plant growth, treatments caused increase in biomass and consequently biological yield.

Inoculation with Azotobacter may significantly affect plant germination and growth, i.e., it may indirectly affect the yield. The application of microorganisms increased the availability of nutrients, which had a positive impact on yield parameters (Milosevic et al., 2012).

### 100-grain weight and Grain yield

Analysis of variance showed that there was considerably significant difference between different fertilizer types (Table 2, P<0.01), so highest grain yield (847.4 kg/ha) was associated with F3 treatment and the lowest amount is related to control (479.9 kg/ha) which indicates 77% increase due to application of combination of P fertilizer and bio fertilizer (Figure 2). Also results showed that interactions of fertilizer types and irrigation significantly affected grain yield (P<0.05, Table 2) and highest grain

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**Table 3.** Mean comparisons of the effects of fertilizer types and its interactions with supplemental irrigation on some of yield components of lentil (ILL6037) plant.

<table>
<thead>
<tr>
<th>Fertilizer Type (F)</th>
<th>Single-seed pod number/plant</th>
<th>two-seed pod number/plant</th>
<th>Biological yield (kg/ha)</th>
<th>Harvest index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>2313&lt;sup&gt;b&lt;/sup&gt;</td>
<td>193.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3893&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>F2</td>
<td>2262&lt;sup&gt;b&lt;/sup&gt;</td>
<td>205.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3953&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>F3</td>
<td>3523&lt;sup&gt;a&lt;/sup&gt;</td>
<td>337.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4298&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>F4</td>
<td>2562&lt;sup&gt;b&lt;/sup&gt;</td>
<td>165.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4008&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>13.9&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>I × F</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I&lt;sub&gt;1&lt;/sub&gt;F&lt;sub&gt;1&lt;/sub&gt;</td>
<td>2150&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>160&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>4623.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>12.2&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;1&lt;/sub&gt;F&lt;sub&gt;2&lt;/sub&gt;</td>
<td>2416&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>217.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3866.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>16.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;1&lt;/sub&gt;F&lt;sub&gt;3&lt;/sub&gt;</td>
<td>3542&lt;sup&gt;a&lt;/sup&gt;</td>
<td>345&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4931.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;1&lt;/sub&gt;F&lt;sub&gt;4&lt;/sub&gt;</td>
<td>3230&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>181.3&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>4396.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>15.7&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;2&lt;/sub&gt;F&lt;sub&gt;1&lt;/sub&gt;</td>
<td>2476&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>118.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3161.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;2&lt;/sub&gt;F&lt;sub&gt;2&lt;/sub&gt;</td>
<td>2108&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>193&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>4038.3&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>13.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;2&lt;/sub&gt;F&lt;sub&gt;3&lt;/sub&gt;</td>
<td>3504&lt;sup&gt;a&lt;/sup&gt;</td>
<td>330&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4923.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;2&lt;/sub&gt;F&lt;sub&gt;4&lt;/sub&gt;</td>
<td>1894&lt;sup&gt;c&lt;/sup&gt;</td>
<td>150&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3618&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>12.2&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means having similar letters in each row have no significant difference at 5% probability level according to LSD test.
yield obtained in supplemental irrigation and $F_3$ fertilizer combination treatment (Figure 2).

Results showed that there were no significant differences between irrigation levels as well as fertilizer type in terms of 100-grain yield. Nevertheless, interactions between supplemental irrigation and fertilizer type significantly affected 100-grain weight of lentil ($P<0.05$, Table 1), so highest grain yield obtained in $F_4$ bio fertilizer and $F_2$ phosphorous fertilizer (5.6 g) at supplemental irrigation level (Figure 3).

The positive influence of inoculation on seed yield and seed mass in lentil was partly due to the inoculation promoting nodule formation (Gan et al., 2005). Qureshi et al. (2009) showed that inoculation with M. ciceri or A. chroococcum significantly enhanced plant biomass and grain yield, but the response was more pronounced with co-inoculation. According to Govedarcia et al. (2004), inoculation of wheat seed with diazotrophs increased the 1000-seed weight from 2 to 14% under conditions of a greenhouse.

**Conclusion**

Results showed that a combination of biologic and chemical fertilizers under drought stress conditions increased lentil yield. Non-significant effects of supplemental irrigation levels on studied traits could be attributed to high precipitation (about 442 mm) during experiment period. Generally, it can be stated that using *Azotobacter* had significant effects on studied traits and as a result of nitrogen fixation by this bacteria. Nutrients uptake
increased in the plant which eventually resulted in increased in grain yield. The effect of seed inoculation with Azotobacter biofertilizer compared to control (without any fertilizer) represents superiority of Azotobacter + 50% phosphorous fertilizer combination treatment. Therefore, from decreasing use of chemical fertilizers standpoint, 50% phosphorous fertilizer along with biofertilizer and supplementary irrigation at flowering stage and pods filling could be recommended for lentil.

REFERENCES


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