Effects of different methods of magnesium sulphate application on qualitative and quantitative yield of lentil (*Lens culinaris* Medik.) cultivars under Khorramabad climatic conditions of Iran

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ABSTRACT

To study the effect of different methods of magnesium sulphate application and cultivar on the quantity and quality of lentil yield in Khorramabad climatic conditions, this experiment was carried out in factorial arrangement based on randomized complete block design with three replications at the College of Agriculture, Lorestan University (48º22′ E and 33º29′ N) in 2008. Different methods of magnesium sulphate application as the first factor (control, soil application method, foliar application, seed inoculation, foliar+soil application and foliar application + seed inoculation method) and cultivar as the second factor (Gachsaran cultivar and Filip-92-12L cultivar) were applied. The results showed that the highest grain and biological yield and plant height were obtained from fertilization with the soil application method. The highest percentage of crude seed protein was obtained from foliar application. Also, the highest 1000-seed weight, pod number per plant, plant height and seed magnesium percentage were all obtained from foliar+soil application treatment. However, the highest harvest index was obtained from the seed inoculation method. Grain yield showed a significant positive correlation with the pod number per plant and biological yield (P<0.01). Also, there was a significant positive correlation between crude seed protein percentage and seed magnesium percentage (P<0.01). Soil application method of magnesium sulphate on Filip-92-12L cultivar was suggested to obtain the highest grain yield, while foliar application and foliar+soil application methods on Filip-92-12L cultivar were suggested to gain the high seed magnesium and crude protein percentage.

Key words : Fertilizer application methods, lentil cultivar, magnesium sulphate

INTRODUCTION

Lentil (*Lens culinaris*), one of the earliest crops cultivated by human beings, originated from the fertile Crescent in the Near East at the dawn of agriculture and was consumed in different ways by the people living in these regions (Aghaee et al., 2004).

Having a high and cheap supply of protein, legumes, including lentil, are the main source of protein in countries with a lack of meat or low consumption of meat due to economical or religious reasons (Majnon-Hoseini, 1993). Lack of protein in people’s diet, especially in undeveloped countries, is a critical foodstuff problem in the world. Legumes, such as lentil (*Lens culinaris*), pea (*Cicer arietinum*) and broad bean (*Vicia faba*) have played an important role in people’s diet since antiquity; people know them as “poor people’s meat” and use them in their diet. Regarding its nutritional value, lentil, with 28.5% protein, is a good substitute for meat. Lentil’s supply of protein is the same as broad bean, more than pea, and approximately twice as much as wheat. Lentil is also rich in iron and other mineral nutrients. The higher mineral content in lentil is due to the plant’s ability to absorb the available mineral elements during growth and seed filling stages, more efficiently (Bagheri et al., 1997).

Evidently, what is now-a-days considered in the application of fertilizers in production programmes is conspicuously...
different from what it was in conventional fertilization programmes which only included limited types of fertilizers known as white and black fertilizers. When the absorption of nutritious elements through the roots in the soil is limited, foliar application method is applied. Limitation in absorption may be the result of plant or soil factors. The efficiency and yield of a nutrient unit in foliar method is more than that of soil application (Malakouti and Homaei, 2004). Deficiency of any one of the nutrient elements may limit plant growth and economic output (Marschner, 1995).

Magnesium is essential to metabolize calcium, vitamin C, phosphorus and potassium. Magnesium has an important role in changing blood sugar to energy and is known as an anti-stress substance. Besides increasing the yield, appropriate application of fertilizers containing magnesium in forage and other products which lack this substance can be effective in human and animal nutrition and health (Malakouti, 1999).

Lack of magnesium is found in most natural ranges and farms with acid soil, and in farming and gardening plantations with heavy fertilization and over irrigation (De Oliveira et al., 2000). Soil with less than 25-50 mg of exchangeable magnesium per kg of soil is magnesium deficient. Reportedly, the amount of exchangeable magnesium is normally 4-20% of soil cation exchange capacity (Bagheri et al., 1997). Magnesium percentage in magnesium sulphate fertilizer is approximately 9.6. Regarding its high solubility, it can be applied to the soil either by broadcasting or stripe rows with other fertilizers before planting (Malakouti, 1999).

Characteristics of the Cultivars

Regarding the resistance to insects, diseases, seed shattering, early ripening, 1000-seed weight, market acceptability, grain largeness, greenness, cooking quality and grain yield, Gachsaran cultivar (ILL 6212) is considered as the best improved cultivar of lentil in Iran. Its yield average is around 780 kg/ha in cold regions and 2274 kg/ha in tropical regions (Mahmudi and Sabaghpur, 2005). A research carried out over three years to study and choose rich productive cultivars which were allocated to different climates in the country, concluded that Gachsaran and Filip-92-12L cultivars were the best cultivars for dry farming. Furthermore, Filip cultivar was recommended as the best cultivar for spring
planting in the cold western regions of the country (Kanuni et al., 2005).

**Magnesium Sulphate Application Methods**

**Soil application method**: Mineral magnesium sulphate fertilizer containing 9.6% of magnesium was applied in this method. The recommended amount of magnesium to compensate for magnesium deficiency in different crops was reported as 100 kg/ha (Salardini, 1995; Malakouti, 1999). In soil application method the same amount of fertilizer was applied along with other basal fertilizer at the time of preparing the seed bed before planting the seeds (Malakouti and Homaei, 2004).

**Foliar application method**: Foliar application can be applied to quickly remove the magnesium deficiency (Salardini, 1995; Malakouti, 1999). In foliar application method the same amount of fertilizer (100 kg/ha) with 3/1000 ratios (solution) was applied in three stages: one month after planting followed by every 20 days intervals (two intervals in this case) until the complete removal of all the signs of magnesium deficiency (Malakouti, 1999; Malakouti and Tehrani, 2005).

**Seed inoculation method**: In this method, the seeds were inoculated with magnesium sulfate 2-3% before being planted. Three kg of pure magnesium (28.8 kg sulphate magnesium) was applied to each 100 kg seed. The required seed of 58 g for each plot was put in a polyethylene bag and 30 ml of sugar solution (20%) was added and then the bag was shaken vigorously for 30 sec with a shaker to make all the seeds evenly sticky. Then, the proper amount of magnesium sulphate fertilizer was added to the sticky seeds. Seeds were shaken for 45 sec to make sure that all the seeds were evenly covered by fertilizer. The seeds covered with fertilizer were spilled on a piece of clean aluminum sheet and left in shadow to dry. Finally, the seeds were quickly planted.

**Soil+foliar application and seed inoculation+foliar application methods**: These methods are combinations of the three primary application methods. In these combined application methods, half of the specified amount of fertilizer was applied by foliar application and the other half either by soil application or seed inoculation methods.

A sampling area of 1 m² of each plot was harvested (border effects were excluded) to estimate the seed yield, biological yield and harvest index. Also, five plants were randomly selected from each plot at the end of the season, to measure the height, pod number and 1000-seed weight to determine grain yield components. The lentil crude protein content was measured using the Bradford method. Magnesium percentage was determined by atomic absorption spectrophotometer. Finally, the data were analyzed by MSTATC software and the means were compared by using Duncan's multiple range tests at 0.05 level and the graphs were drawn using Microsoft Office Excel.

**RESULTS AND DISCUSSION**

The analysis of variance of the data showed that there was a significant difference between the cultivars with regard to plant height, 1000-seed weight, however, seed yield, pod number per plant, biological yield, harvest index, seed protein and magnesium content were significantly (P<0.05) affected by fertilizer application methods (Table 1).

**Pod Number/Plant**

The significant interaction effect of fertilizer application method and cultivar indicated that the pod number per plant was significantly lower in seed inoculation treatment in both cultivars and in control treatment for Gachsaran cultivar (Fig. 1). Soil+foliar application on Filip-92-12L cultivar with 45.59 pods/plant had the highest, and seed inoculation treatment of the same cultivar with 26.78 pods had the lowest pod number per plant among different experimental treatments. Applying a mixture of micro elements and magnesium in beans also increased pod number in the plant (Ziolek et al., 1992). Pod number is the most important yield component in lentil and has an important effect on lentil seed yield. In other words, as the photosynthetic organs grow, more photosynthetic materials are consumed to increase the seed and pod number per plant.
1000-seed weight is a significant component of seed yield. Maximum 1000-seed weight was 53.09 g in seed inoculation and foliar treatment on Filip-92-12L cultivar and minimum 1000-seed weight was 41.88 g in seed inoculation of Gachsaran cultivar (Fig. 2). It seems that by applying magnesium sulphate fertilizer, nitrogen efficiency increases (Sreemannarayana et al., 1998; Choudhury and Khanif, 2001) which results in the growth of shoots and therefore increases inter-plant competition. Therefore, the seeds share (physiological sink) of photosynthetic elements becomes smaller and 1000-seed weight does not increase much. As a result of photosynthetic organ growth, most photosynthetic elements are consumed to increase seed yield and pod number and therefore do not increase the yield through 1000-seed weight (Salehi et al., 2007).

Plant Height

Plant height in seed inoculation and control treatment of both cultivars was less than the other treatments. Maximum plant height of 31.18 cm was achieved in soil+foliar application treatment on Filip-92-12L cultivar which was significantly more than plant height in the other treatments. Minimum plant height of 23.28 cm was observed in the control

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**Table 1. Results of variance analysis of studied characteristics in experimenting on the effects of magnesium sulphate and cultivar on lentil qualitative and quantitative yield**

<table>
<thead>
<tr>
<th>Variation source</th>
<th>d. f.</th>
<th>Plant height</th>
<th>Seed yield</th>
<th>Pods/plant</th>
<th>1000-seed weight</th>
<th>Seed magnesium</th>
<th>Seed protein percentage</th>
<th>Biological yield</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>2</td>
<td>2.957</td>
<td>1060.285</td>
<td>17.350</td>
<td>3.76</td>
<td>53.424</td>
<td>0.834</td>
<td>3486.35</td>
<td>3.051</td>
</tr>
<tr>
<td>Cultivar (A)</td>
<td>1</td>
<td>32.852**</td>
<td>31.847**</td>
<td>3.881**</td>
<td>111.267*</td>
<td>46.922**</td>
<td>0.321**</td>
<td>996.455**</td>
<td>0.009</td>
</tr>
<tr>
<td>Methods of fertilizer application (B)</td>
<td>5</td>
<td>21.366**</td>
<td>5912.25**</td>
<td>267.11**</td>
<td>54.464**</td>
<td>169.768**</td>
<td>2.259**</td>
<td>150381.591**</td>
<td>21.079**</td>
</tr>
<tr>
<td>Interaction A × B</td>
<td>5</td>
<td>7.216**</td>
<td>278.277**</td>
<td>18.669**</td>
<td>23.185**</td>
<td>10.08**</td>
<td>0.334**</td>
<td>6723.665**</td>
<td>1.480**</td>
</tr>
<tr>
<td>Error</td>
<td>22</td>
<td>7.023</td>
<td>1457.375</td>
<td>37.787</td>
<td>21.166</td>
<td>16.513</td>
<td>0.819</td>
<td>28622.7</td>
<td>3.365</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. V. (%)</td>
<td></td>
<td>10.05</td>
<td>9.42</td>
<td>16.19</td>
<td>10.38</td>
<td>3.11</td>
<td>3.43</td>
<td>13.59</td>
<td>5.57</td>
</tr>
</tbody>
</table>

* , ** Significant at P=0.05 and P=0.01 level, respectively.
NS : Not Significant.

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**Fig. 1. Comparison of mean of interaction effects of different magnesium sulphate fertilizer application methods and cultivars on pod number per plant.**

**Fig. 2. Comparison of mean of interaction effects of the different magnesium sulphate fertilizer application methods and the cultivar for 1000-seed weight.**
Environmental factors significantly affect lentil plant height. Not only the final height but also plant height in all the growth stages is influenced by environment and genotype. Before giving a large share of photosynthetic materials to the seeds, lentil tries as much as possible to produce an appropriate vegetative structure. This is important not only for receiving more solar radiation and controlling weeds, but also for providing enough space for inflorescence and increasing the yield potential (Bagheri et al., 1997). Researchers found that there was a direct relation between the concentration of magnesium, nitrogen, calcium and phosphorus in the leaves and root and rhizobium formation and nodulation intensity in legumes (Walker et al., 1989; Huang et al., 1990). It seems that magnesium sulphate fertilizer increases nitrogen absorption by root and therefore increases nitrogen efficiency resulting in an increase in plant height and the growth of shoots (Sreemannarayana et al. 1998; Choudhury and Khanif, 2001).

**Biological Yield and Harvest Index**

Maximum biological yield of 1495 kg/ha was achieved in the soil application treatment on Filip-92-12L cultivar which was significantly superior to the other treatments. Minimum biological yield of 1046 kg/ha was observed in seed inoculation treatment of Filip-92-12L cultivar (Fig. 4). The maximum harvest index of 35.3% was in seed inoculation of Gachsaran cultivar which was significantly superior to the other treatments (Fig. 5). Minimum harvest index of 30.25% was obtained in soil application treatment on Filip-92-12L cultivar.

Plant height is an important indicator in determining the yield, especially the dry
matter of the crops. In other words, the higher the plant height, the more the biological yield. Root growth is also an important factor in increasing the profile area of the soil used by the plants which lead to increasing the absorption of the soil elements. These are all important factors in increasing the dry matter and biological yield. In this experiment, fertilizer application increased both seed and biological yield but there was a negative correlation between different fertilizer application methods and harvest index which can be attributed to a more accumulative process of biological yield (denominator of the harvest index formula) compared to seed yield (numerator of the harvest index formula).

**Seed Yield**

Seed yield in soil application treatment on Filip-92-12L cultivar, with a seed yield of 450.9 kg/ha, was significantly more than the seed inoculation treatment of both cultivars and the control treatment of Gachsaran cultivar (Fig. 6). The results of this experiment are in accordance with the results of researches on pea. It seems that magnesium increases the number of rhizobium nodes in pea root and therefore increases nitrogen fixation and seed yield (Sandor et al., 2004). Studying nutritional elements in sunflower, Sreemannarayana et al. (1998) reported that magnesium increased nitrogen absorption and therefore increased the yield. Ghaderi and Malakouti (2000) stated that soil application was the most effective and economic method to increase wheat grain yield. Balali et al. (2001) also proved that if the fertilization objective is to increase seed yield, soil application of magnesium sulphate is the most effective method. Seed yield increase can be the result of either the magnesium sulphate fertilizer ability to increase the magnesium supply for plant growth to appropriate level, or the fertilizer effect on soil micro-organisms (Fajemilehin et al., 2008). Researchers also reported that foliar application of magnesium sulphate on pea significantly increased vegetative growth and seed yield (Takacs-Hajus and Kiss, 2004). However, soil application method has greater effect on seed yield compared to foliar application. Foliar method is not sufficient for fertilization (nourishment) because the leaf area is too small, and absorption is mostly done through the sub-surface of the leaves (stomata are mostly on the sub-surface) (Zarinkafsh, 1992). Although foliar method is very common and can be helpful to solve the nutrient deficiency, but absorption of nutritional elements as ion is limited to the sub-surface of the leaves. Therefore, plants cannot satisfy all their needs just through this method. So, in most of the cases, foliar method is applied as a complementary method to soil application. However, the efficiency of nutrient unit applied as solution on the plant is more than the efficiency of the same amount applied through the soil.

**Seed Magnesium Content**

The maximum amount of seed magnesium was 1397 ppm in soil+foliar application treatment in Gachsaran cultivar and the minimum amount of seed magnesium content was in seed inoculation treatment in Filip-92-12L cultivar (Fig. 7). The results of the experiment conclude that a high concentration of magnesium and other essential micro elements necessary for human and animal health could be achieved by soil+foliar application method (Ghaderi and Malakouti, 2000; Balali et al., 2001). Ghaderi and Malakouti (2000) proved that magnesium concentration in wheat seed increased by
applying sulphate magnesium. The maximum concentration of magnesium in dry-farming wheat seed was achieved by the soil application and soil+foliar application methods. In soil conditions of Iran, the foliar application of magnesium is more appropriate because of its fast resolve of nutrient deficiency, facility of application, decreasing the toxicity from the accumulation of the element in the soil, and preventing fixation by other ions in the soil. When a plant lacks an element, absorption is much more effective in application of that element through the foliar method (Malakouti and Tehrani, 2005). An important factor contributing in low yield and quality of products in dry and semi-arid regions is the low efficiency of nutrient elements absorption through the soil. In dry and semi-arid regions, due to low moisture content in the topsoil during the growing season, the existing roots either dry out or cannot absorb the nutrient elements properly. This is even more important and evident in dry-farming system. Therefore, to increase the yield and quality of products in dry and semi-arid regions, the foliar application of fertilizer has superiority over other methods (Malakouti and Tehrani, 2005).

Due to the competition between reproductive organs and roots for carbohydrates consumption, root activity and therefore absorption of nutrient elements are decreased in the reproductive stage. In this stage, supplying the nutrient elements as foliar application decreases this competition (Malakouti and Tehrani, 2005).

**Seed Protein Percentage**

The maximum seed protein percentage of 27.37 was obtained from foliar application treatment on Filip-92-12L cultivar. The minimum seed protein percentage of 25.3 was observed in the control treatment in Gachsaran cultivar (Fig. 8). These results correspond to similar results achieved by Ghaderi and Malakouti (2000) reporting an increment in protein percentage of wheat by magnesium sulphate application in dry farming and irrigated systems. However, in his experiment the maximum protein percentage was achieved in dry farming wheat by soil+foliar application method, while the foliar method came in second. Seed inoculation by magnesium sulphate increases the seed protein percentage (Malakouti, 1999; Malakouti and Tehrani, 2005). An increase in seed protein percentage can be the result of the formation of mineral elements from MgSO$_4\cdot$7H$_2$O by the micro-organisms in the soil and also increased absorption and activity of magnesium and sulfur in the plant which play an important role in protein synthesis (Fajemilehin et al., 2008). Many experiments carried out on protein synthesis showed that magnesium ion strengthened the connection of amino acids to tRNA and separated the
polypeptide chain from rhizobium. The amount of protein often decreases with magnesium deficiency. This shows that magnesium has a positive effect on protein synthesis and its deficiency suppresses the enzyme synthesis (Malakouti and Homaei, 2004). The seed protein supply is also under the influence of environmental conditions such as rain, the intensity of light, the length of the day, the length of the growing season, temperature and agronomic factors such as plant density, weeds and soil fertility (Wang and Duan, 2006).

The foliar method is applied when the absorption of nutritious elements through the roots in the soil is limited. Limitation in absorption may be the result of plant or soil factors. The efficiency of nutrient unit in the foliar method is higher than its efficiency in soil application (Malakouti and Homaei, 2004).

The results showed that lentil positively responded to magnesium sulphate fertilizer application. Therefore, the application of fertilizers containing magnesium is beneficial to yield and seed protein content of lentil. According to the results gained in this research Gachsaran and Filip-92-12L cultivars did not differ in the amount of seed protein and magnesium. The maximum amount of seed protein was observed in the foliar application method which did not show a significant difference to soil+foliar application and seed inoculation+foliar (Duncan, $\alpha=0.05$).

### Correlations between Seed Yield and Yield Attributes

To determine the correlation between the seed yield and the measured attributes, correlation coefficients were calculated (Table 2). The results showed that pod number per plant and biological yield had a positive and significant ($P<0.01$) correlation with seed yield. There was a linear correlation between biological yield and the seed yield. Seed yield is a major component of biological yield. So, the increment of both seed and biological yields by magnesium sulfate application can well explain the positive and significant correlation between them (Table 2).

<table>
<thead>
<tr>
<th>Character</th>
<th>Plant height</th>
<th>Seed yield</th>
<th>Pods/plant</th>
<th>1000-seed weight</th>
<th>Biological yield</th>
<th>Harvest index</th>
<th>Seed protein percentage</th>
<th>Seed magnesium percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height</td>
<td>1</td>
<td>0.297</td>
<td>0.294</td>
<td>0.197</td>
<td>0.311</td>
<td>-0.297</td>
<td>0.246</td>
<td>0.35*</td>
</tr>
<tr>
<td>Seed yield</td>
<td>0.297</td>
<td>1</td>
<td>0.722**</td>
<td>0.172</td>
<td>0.948**</td>
<td>-0.754**</td>
<td>-0.075</td>
<td>0.178</td>
</tr>
<tr>
<td>Pods/plant</td>
<td>0.294</td>
<td>0.722**</td>
<td>1</td>
<td>0.335*</td>
<td>0.721**</td>
<td>-0.633**</td>
<td>0.294</td>
<td>0.459**</td>
</tr>
<tr>
<td>1000-seed weight</td>
<td>0.197</td>
<td>0.172</td>
<td>0.335*</td>
<td>1</td>
<td>0.184</td>
<td>-0.237</td>
<td>0.041</td>
<td>0.286</td>
</tr>
<tr>
<td>Biological yield</td>
<td>0.311</td>
<td>0.948**</td>
<td>0.721**</td>
<td>0.184</td>
<td>1</td>
<td>-0.914**</td>
<td>0.021</td>
<td>0.239</td>
</tr>
<tr>
<td>Harvest index</td>
<td>0.297</td>
<td>-0.754**</td>
<td>-0.633**</td>
<td>-0.237</td>
<td>-0.914**</td>
<td>1</td>
<td>-1.046</td>
<td>-0.36*</td>
</tr>
<tr>
<td>Seed protein percentage</td>
<td>0.246</td>
<td>-0.075</td>
<td>0.294</td>
<td>0.041</td>
<td>0.021</td>
<td>-0.146</td>
<td>1</td>
<td>0.455**</td>
</tr>
<tr>
<td>Seed magnesium percentage</td>
<td>0.35*</td>
<td>0.178</td>
<td>0.459**</td>
<td>0.286</td>
<td>0.239</td>
<td>-0.36*</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

No positive and significant relation between 1000-seed weight and lentil seed yield was observed. Also, no correlation was perceived between seed magnesium content and seed yield, there was a direct and significant ($P<0.01$) correlation between the amount of seed magnesium and protein content. Magnesium plays an important role in protein synthesis. There was a positive and significant ($P<0.01$) correlation between the amount of seed protein and seed magnesium. There is usually an adverse relation between the amount of seed protein and seed yield. Although this relation is adverse and mostly not strong, but significant yield increase in recent years is accompanied with a decrease in the amount of seed protein which is usually as a result of breeding the cultivars that have a low protein percentage compared to other cultivars. This adverse relation could be explained by more seed yield through more carbohydrate synthesis or better translocation of carbohydrate in newly bred cultivars.

### REFERENCES


