The impact of foliage fertilization of iron and molybdenum on yield, N uptake and root nodulation of lentil (Lens Culinaris Medic) crop

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Received: 06-10-2018 Accepted: 11-07-2019 DOI: 10.18805/IJARe.A-392

ABSTRACT
A field experiment was established to study the impact of foliage fertilization of microelements (Fe and Mo) on lentil at the Agricultural Research Farm Mingora, Swat, Pakistan in 2016-17. All the treatments were assigned in random block design. The results showed that iron (Fe) and molybdenum (Mo) significantly improved the yield and quality of lentil crop. Based on the obtained results, the majority of the parameters increased with the combined application of Fe and Mo. The combined application of Fe and Mo at 500 and 100 g ha\(^{-1}\) produced the maximum yield (1361 kg ha\(^{-1}\)), biological yield (3126 kg ha\(^{-1}\)), 1000 grain weight (56.62 g), protein percent (30 %), N uptake (65.32 kg ha\(^{-1}\)), Fe (48.33 mg/g) and Mo (5.07 mg/g) concentration. Results further revealed that Mo at the rate of 100 g ha\(^{-1}\) significantly enhanced the number of nodules (9.13 plant\(^{-1}\)) and active nodules (8.03 plant\(^{-1}\)). These results suggested that Fe and Mo in optimal amount solely or as a blend considerably improve the growth, yield and quality of lentil crop and is therefore recommended for the better production of lentil crop in the agro-climatic condition of Swat valley.

Key words: Calcareous, Iron, Molybdenum, Nodules, Swat.

INTRODUCTION
Lentil (Lens culinaris Medic) belongs to family Leguminosaeis originated from South Western Asia also known as poor man meat because of its rich nutrient content (Rozan et al. 2001). It is commonly eaten as dhal in socio-economic groups in South-East Asia (Bhatti 1988). Lentil flour can be used in bakeries and in other foods for softness (Williams and Singh 1988). In Asia, legumes are eaten as a major food, side dish or in salads and can also be used as alternate of meat in vegetarian diets. Compared to wheat straw lentil straw is rich in protein, Ca and P (Zeidan et al. 2006). Lentil is helpful for soil health because of its N fixing ability which can recover the N content and yield of the crop (Khan et al. 2014). Approximately, 85% of N requirement of lentil can be obtained from atmospheric nitrogen fixation during symbiotic relationship with microbes which increased the yield up to 2 ton ha\(^{-1}\) (Bisen et al. 1980).

Pakistan produced 9.7 thousand tones lentil with an average yield of 54.1 kg ha\(^{-1}\)from 19.6 thousand hectares area (GOP 2013). The lentil cultivation is decreasing in the country due to growing population, diseases attack and weeds infestation.

Micronutrients are essential elements required by plants in small amount but their unavailability causes abnormality in plants for example Iron (Fe) involve in the breaking down of hormone and other chemical reactions taking place in plants (Kerkeb and Connolly 2006). Iron deficiency causing reduction in crops yield including lentil which is a common nutritional disorder (Erskine et al. 1993) varied between 18 and 25% among different crops. Plants low Fe\(^{2+}\) content indicates soil iron deficiency (Sakal et al. 1984). Iron helps to activate the plant enzymatic activities like nitrogenase, leghemoglobin and ferrodoxin production. Iron deficiency causes decrease in nodules formation, nitrogenase activity resulting in low N content in plants (Togay 2015).

Molybdenum (Mo) is an essential element in two enzymes that convert nitrate into nitrite (a toxic form of nitrogen) and then into ammonia before it is used to synthesize amino acids within the plants. It also needed by N\(_2\) fixating bacteria in leguminous plants. Acidic soil are mostly Mo deficient, plant grows on such may have low N fixation ability which can be accelerate through Mo fertilization (Mandai et al. 1998). Molybdenum deficient plants have low chlorophyll content which causes abnormality in plant chloroplast. Molybdenum increases the photosynthetic activities in plants through which plant can prepare their food easily and grow healthy. Iron and Mo

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application can improve the nitrogenase enzyme activity which is closely associated with plant growth and yield performance. Previously research has found positive impact of Fe and Mo on different legumes (El-Tantawy and Nawar 2013, Khan et al. 2014, Togay et al. 2015). Regarding the activities and different significant studies of Fe and Mo in legumes crop, we conducted a field experiment to study the effect of these elements on lentil crop with objective of determining the effect of Fe and Mo on yield attributes of lentil, to investigate the growth parameters of lentil with Fe and Mo application and to examine the lentil quality under Fe and Mo fertilization.

**MATERIALS AND METHODS**

The current work was conducted to study the effect of Fe and Mo on lentil at Agriculture Research Farm, Mingora, Swat during 2016-2017. Swat is located at 34.3° and 35.53° latitude north and 71.50° and 72.50° longitude East, 873 to 2300 m above sea level with annual rainfall 737.3 to 1200 mm, average temperature from 11.25 to 25.68°C and humidity 24 to 68 % (Metrological reports ARI Migora Swat, Pakistan). Mansehra-89 lentil variety was grown on 12 m²(4 m x 3 m) area in completely randomized block design with nine (9) treatments and repeated thrice. Row to row and plant to plant distance were kept 20 and 30 cm respectively. The nodules soil was silt loam (sand 3.2%, clay 26.8%, silt 70 %), non-saline, pH (6.5), Electrical conductivity 0.167 m.mohs cm⁻¹, lime content 2.6 %, non calcareous, organic matter 1.2 %, medium in Mehlich-3 P, total N 0.03 %, marginal in Fe 1.0 -1.3 ppm and low at Mo 0.4 ppm. The blanket dose of NPK (20-60-60 kg ha⁻¹) was applied before sowing. Micronutrients (Fe and Mo) were applied as a foliar spray alone and in combination in two splits at early 3-4 leaves stage and flowering stage at the rate of 100 and 500 Fe g ha⁻¹ (ferrous sulfate 20.5% Fe) and molybdenum (ammonium molybdate 54% Mo) 50 and 100 g ha⁻¹. The treatments were arranged as T1 (Control), T2 (Fe (100 g ha⁻¹), T3 (Fe 500 g ha⁻¹), T4 (Mo 50 g ha⁻¹), T5 (Mo 100 g ha⁻¹), T6 (T2+T4), T7 (T2+T5), T8 (T3+T4) and T9 (T3+T5). The physio-chemical properties of the soil were tested before sowing according to the standard procedure like soil texture (Koehler et al. 1984), pH (Rhoades 1996), lime content (Ryan and Rashid 2006), organic matter (Nelson and Sommers 1996), electrical conductivity (McLean 1982) and soil N (Bremner 1996).

**Statistical analysis:** Data were analyzed using statistical software (statistix, 8.1) and graphs were designed using graph pad Prism 7.1. Means were compared by LSD test (P≤0.05) (Jan et al. 2009).

**RESULTS AND DISCUSSION**

**Grain yield and biological yield (kg ha⁻¹):** It can be seen from Table 1 that iron and molybdenum had a significant effect on lentil yield (Fig 1). The maximum grain yield 1361 kg ha⁻¹ was obtained from the plots where iron and molybdenum were sprayed in a combination at Fe 500 and Mo 100 g ha⁻¹, whereas the lowest 1203.7 kg ha⁻¹ was recorded in control treatment. The highest biological yield 3126 kg ha⁻¹ was produced by the plots treated with Fe 500 + Mo 100 g ha⁻¹, as compared to control. These results indicated that Fe and Mo improved the yield attributes of lentil crops because iron and molybdenum are key components of nitrate reductase, nitrogenease, photosynthetic activities, legohomoglobin which improve the nutritional value of the crop resulting in better yield production. Similar results were also found by (Togay et al. 2015) who reported that Fe and Mo application at optimum level increased the grain and biological yield of lentil crop.

**1000 seeds weight:** Data regarding 1000 seeds weight showed that iron and molybdenum significantly enhanced the 1000 seeds weight of lentil crop (Table 1 and Fig 1). The highest 1000 seeds weight 54.62 g was produced by the treatment where iron at 500 and Mo at 100 g ha⁻¹ applied in combination and the lowest produced by control treatment. Our results were in agreement with those of (Khan et al. 2014) who reported that Fe at 2 kg ha⁻¹ and Mo at 0.5 kg ha⁻¹ progressively improved the seed yield of chickpea plant.

**Numbers of nodules and active nodules per plant:** Data recorded on numbers of nodules and active nodules per plant are presented in Table 1 (Fig 1). Results demonstrated that both Fe and Mo significantly increased the nodules number and active nodules per plant. The more nodules number (9.12 plant⁻¹) and active nodules (8.03 plant⁻¹) were produced by the treatment treated with Mo at100 g ha⁻¹, which were
Table 1: The yield, N uptake and root nodulation of lentil as affected by foliar application of iron and molybdenum.

| Treatments | Grain yield (kg ha⁻¹) | Biological yield (kg ha⁻¹) | 1000 grain weight (g) | No. of nodules plant⁻¹ | No. of active nodules plant⁻¹ | Protein content (%) | N uptake (kg ha⁻¹) | Fe (mg/g) | Mo (mg/g) |
|------------|-----------------------|---------------------------|----------------------|------------------------|----------------------------|---------------------|-------------------|-----------|-----------|
| 1          | 1203.7 d              | 3053 f                    | 48.1c                | 4.08 e                 | 2.33 f                     | 21.0 e              | 40.4 f            | 42.1 f    | 2.14 g    |
| 2          | 1295.7 c              | 3072.7de                  | 50.8 bc              | 5.6 d                  | 3.33 e                     | 23.7 d              | 49.1 e            | 45.5 d    | 3.14 f    |
| 3          | 1336.7 b              | 3079 d                    | 51.1 bc              | 6 d                    | 4.44 d                     | 24.8 cd             | 52.7 de           | 46.5 c    | 3.07 e    |
| 4          | 1275 e                | 3066.3 e                  | 50.5 bc              | 7.7 c                  | 6 c                        | 25.0 cd             | 51 e              | 43.2 e    | 4.15 d    |
| 5          | 1321.7 b              | 3071de                    | 51.2 abc             | 9.13 a                 | 8.03 a                     | 25.1 cd             | 53.1de            | 45.7 d    | 4.3 ed     |
| 6          | 1338 ab               | 3091.7 c                  | 51.4 abc             | 8.15 bc                | 7.04 b                     | 26.7 bc             | 57.2 cd           | 46.6 c    | 4.4 bc     |
| 7          | 1340 ab               | 3092.3 c                  | 51.8 ab              | 8.34 b                 | 7.33 b                     | 27.2 b              | 58.4 bc           | 46.9 bc    | 4.51 b     |
| 8          | 1353.3 a              | 3106 b                    | 53.4 ab              | 9.04 a                 | 7.53 ab                    | 28.7 ab             | 62.2 ab           | 47 b      | 4.87 a     |
| 9          | 1361 a                | 3126.3 a                  | 54.6 a               | 9.12 a                 | 8.03 a                     | 30.0 a              | 65.5 a            | 48.3 a    | 5.07 a     |

LSD 23.345
CV 1.03

Mean in the table with different alphabets are significantly different at LSD (P ≤ 0.05).

**Fig 1:** The Fig represents the yield and quality parameters of lentil under Fe and Mo foliar applications. The bar in the column graph shows the STD values and the treatments indicates T1 (Control), T2 Fe (100 g ha⁻¹), T3 (Fe 500 g ha⁻¹), T4 (Mo 50 g ha⁻¹), T5 (Mo 100 g ha⁻¹), T6 (T2+ T4), T7 (T2 + T5), T8 (T3 +T4) and T9 (T3 + T5).

- **Protein content (%):** Protein content presented in Table 1 shows that iron and molybdenum significantly affected protein content (Fig 1). Highest protein content (30.0 %) was produced by the plants treated with combined iron and molybdenum application at 500 and 100 g ha⁻¹, whilst the minimum (21.0 %) was recorded in control plots. (Togay et al. 2015) found that iron and molybdenum significantly improved the protein content of lentil crop.

- **Nitrogen uptake (kg ha⁻¹):** The data obtained on lentil N uptake is presented in Table 1 (Fig 1). Significant differences were observed among different treatments. The N uptake (65.32 kg ha⁻¹) increased when plants fertilized together with Fe at 500 + Mo at 100 g ha⁻¹. It might happen because iron and molybdenum both involve in nitrogenase enzyme responsible for N fixation in legumes crops. These elements help in fixing more atmospheric nitrogen resulting in more N content and uptake by plants. Previously (Khan et al. 2014) reported that iron and molybdenum application increased the N concentration which improved the N uptake in plant and thus enhanced the yield of chickpea plant.
also found for molybdenum content. The maximum Mo content (5.07 mg g⁻¹) was produced by combined Fe and Mo application at 500 and 100 g ha⁻¹ and minimum (2.14 mg g⁻¹) by control plants. The increasing concentration of nutrients in lentil might be due to the optimistic interaction of iron with molybdenum within the legumes crops (Togay et al. 2015).

CONCLUSION

It is concluded from the current results that iron and molybdenum significantly improved yield, nutrient uptake and root nodules in lentil crop as compared to control. The best results were obtained from the plots where Fe and Mo were applied in combination, suggesting that micronutrients applied in a mixture are more suitable for better crop performance. However more research is required to explore the micronutrients effect on different legumes crops.

ACKNOWLEDGMENT

The authors are thankful to senior research scientist Dr. Roshan Ali (ARL, Swat) and Professor Dr. Zhair Shah for always concern about the experiment. Authors are also thankful to friends, family for their moral support.

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