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EFFECT OF MOLYBDENUM AND POTASSIUM APPLICATION ON NODULATION, GROWTH AND YIELD OF LENTIL (*LENS CULINARIS MEDIC*)

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Abstract

Two experiments were accomplished at Agriculture College farms (Duhok) and in pots during the winter growing season 2011-2012, to investigate the response of local lentil in terms of growth, yield and nodulation to different application methods and concentrations of molybdenum and potassium fertilizer. Both experiments were arranged in Randomized Complete Block Design (RCBD) with three replications and included three factors (Molybdenum application methods; soaking or spraying; Mo-concentrations; 0, 5, 10, and 15 ppm and Potassium fertilizer rates; 0, and 160 kg. ha^{-1}).The results for field experiment indicated that most of the studied traits excluding plant height were not affected significantly by each of molybdenum application methods (Moa) or concentrations (Moc) and potassium fertilizer. Moa interaction with K was significant for number of pods (NPP), number of seeds (NSP) per plant and final seed yield per hectare (SYH). The final grain yield was positively correlated with each of number of pods per plant, number of seeds per plant and weight of grains. Regarding pot experiment, the foliar spraying of Mo produced higher seeds per plant (9.34).While seed soaking in Mo solution was superior in number of nodules per plant (179.4); 5 ppm of Mo was superior and recorded higher number of branches (2.665) as compared to control unit or other treatments followed by 15 ppm (2.552). The effect of K or its interactions with each of Moa and Moc was not significant on all studied traits in these experiments. While, the second order interaction of the three factors was significant for the number of pods, number of seeds per plant, seed yield, and 1000 grain weight.The results of field experiment were not encouraged concerning the single application of molybdenum or potassium fertilizers on the performance of lentil crop; hence they are not recommended in similar environments. In pots, foliar application of Mo can increase the seed yield while seed soaking is recommended in unfertile soil due to the increasing of nodules in roots.

Key words: Lentil, Molybdenum, Potassium, Nodulation.

Introduction

Lentil is one of the oldest domesticated crops which back to about 8500 years ago (Togay *et al*., 2008). It is considered one of the most important pulse legumes that are grown widely in Iraq and Iraqi Kurdistan region that consider the main source of easily digestible protein, which complements the staple bread and rice diet in the region. The seed protein content is varied between 22-25% (Singh, 2001). Also, it has a positive contribution for increasing the soil fertility due to the high number of effective nodules in their root that supply nitrogen into the soil (Omer, 2009).

Molybdenum which is an important microelement for chemical reactions in plant, is commonly used for seed priming (treatment) which is more effective than soil or foliar applications (Mahler, 2005) and Hernandez *et al.* (2009); they also reported that the high levels of Mo in the soil may be harmful; although low quantities of seed treatment by Mo (0.03 pound per acre) are useful for plant growth, in Idaho soils having about 0.5 ppm Mo. Therefore, only about 0.2 to 5 ppm of Mo is needed for plants. Similarly, Togay *et al*. (2008), Glubaiak (2008), Zakikhani *et al.* (2014) and Togay *et al.* (2015) found that the Mo and other fertilizer applications depend on the soil moisture and pH. Contrarily, Bambara & Ndakidemi (2010) demonstrated that the Mo is less available in acidic soil and foliar application can overcome this problem. Although foliar application of Mo is beneficial, but the seed and soil applications remain effective for longer period under normal conditions.

Vieiraa *et al.* (1998) investigated that foliar application of molybdenum (Mo) on common bean after 25 days of plant emergence decreased nodule number per plant, while after 45 days the nodule weight was increased; they suggested that the Mo maintains nodules effective for longer period, which mean increasing nitrogen fixation. Similarly, Hamayun *et al*. (2011) found effective foliar application of NPK fertilizer in lentil. El-Hersh *et al.* (2011) illustrated that soaking lentil seeds in 2 and 5 ppm Mo solution before sowing induced nodulation and also enhanced some of the growth traits such as plant height as well as final seed yield. However, Kaiser *et al.* (2005) suggested that Mo deficiency is rare in most of agricultural cropping areas which is mostly dependent on soil pH, moisture and organic matter; therefore, not always Mo application increases the plant productivity.

Regarding potassium fertilizers, Srinivasarao *et al.* (2003) concluded that potassium application increase the pulses pest resistance and improve the seed yield and quality; the status of potassium in soils depends on soil texture, nutrient, and agricultural practices. In intensive cropping systems, considerable amount of potassium is depleted that need to be addressed. Increasing of the legumes yield and yield components (number of branches, pods and seeds) by potassium fertilizer has been reported by numerous researchers. Jahan *et al.* (2009) stated that the yield of lentil varieties increased when the rates of potassium fertilization were increased in Bangladesh; the highest seed yield (2.16 t. ha^{-1}) was found at 35 kg K ha^{-1}compared to zero, 15, 25, and 45 kg.ha^{-1} treatments. While the plant dry weight was not affected; they also stated that the highest number of nodules per plant was obtained when potassium fertilizer was applied at a rate of 15 kg.ha^{-1} compared to control or high levels of potassium. Also, El-Bramawy & Shaban (2010) noticed significant increases for the most of growth and yield characters of broadbean crop by the application of potassium fertilizer. Sahgal & Johri (2003) and Prevost & Antoun (2006) stated that *Rhizobium leguminosarum by Viceae* is the nodulating Rhizobial species for lentil crop. Omer (2009) reported that lentil can be used in crop rotations as it produced 130.44 nodules per plant in a pot study which surpassed both chickpea and broadbean.

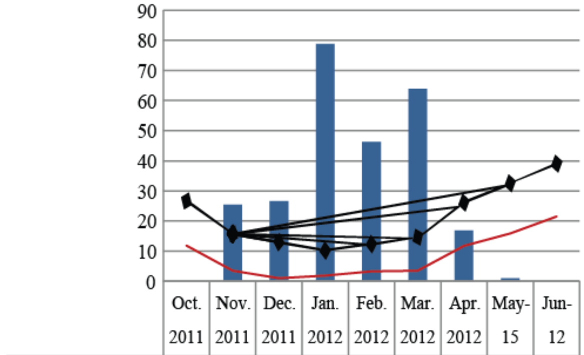
Due to the favorable environment conditions (climate and soil) for lentil production in Iraqi Kurdistan, it can be sown successfully in the region; while the average yields of lentil is still inferior compared to the leading world countries. This can attributed to the traditional application of fertilizers without emphasizing on new yield improvement practices. Therefore, instead of seeking for other options, use of balanced fertilizer application can overcome the issue of poor yields. Build on this idea, this study was suggested to investigate the response of local lentil in terms of growth, yield and nodulation to the different applications of molybdenum and potassium fertilizer.

Materials and Methods

A local lentil (*Lens culinaris* Medic.) with seed index (1000 seeds equal to 32.23 g) and 100% germination was grown in in a field and pot experiments conducted at the College of Agriculture, University of Duhok during the growing season 2011/12. Both experiments were arranged in Randomized Complete Block Design (RCBD) with three replications and included three factors (Molybdenum application methods; soaking or spraying; Mo concentrations; 0, 5, 10, and 15 ppm and Potassium fertilizer rates; 0, and 160 kg. ha^{-1}). Similarly, they were applied in a pot experiment for nodules and other related traits. Plot area was 2 * 1m and pot dimensions 25 * 20 cm with about 8-10 kg soil capacity. Climatic data were collected from the meteorological station at the experimental site (Fig. 1).

The seeds were sown manually (broadcasting) at a rate of 20 $kg.d^{-1}$ (equivalent to 80 $kg.ha^{-1}$) in the field experiment. For pots, ten seeds were sown and then thinned to 5 after field emergence. Seeds were soaked in Molybdenum concentrations (0, 5, 10, and 15 ppm) for 24 hours prior to sowing; the same concentrations were sprayed on the plants before flowering stage; Potassium applied as K_2SO_4 at rate of 40 $kg.d^{-1}$ (160 $kg.ha^{-1}$) at the day of sowing. The soil for the experiments site characterized by 7.49 pH; $1.7gm/cm^3$ bulk density; 34.83% porosity and 0.30 ds/m Ec (Omer *et al.*, 2013).The data were statistically analyzed using GenStat program (Anon., 2011). Least Significant Difference (LSD) test was used for means separation using alpha level of 0.05, and for discussion of the results under probability level of 0.05.

Grassy weeds were controlled by using of Pantera (Quizalofop-p-tefuril) herbicide 40EC during the last week of March while other broad leaf weeds were controlled by hand hoeing. The pots were irrigated whenever required (1.5 lt per pot at intervals). Five plants and soil samples were taken from both trials for nodules counts and the crop was harvested at the $15^{th}$of May, 2012. Plant height, number of branches, plant seed yield, number of pods and seeds per plant, weight of 1000 seeds, number of $nodules.plant^{-1}$, dry weight of roots including nodule per plant, were recorded for each experiment. Pots were washed under tap water; nodules number and weight were recorded.



	Oct. 2011	Nov. 2011	Dec. 2011	Jan. 2012	Feb. 2012	Mar. 2012	Apr. 2012	May-15	Jun-12
Rainfall (mm)	0	25.4	26.6	78.8	46.2	63.9	16.8	1	0
Max. Tem (C)	26.6	15.7	13.0	10.2	12.4	14.6	26.1	32.5	39.1
Min. Tem(C)	11.8	3.5	1.0	1.9	3.2	3.5	11.8	15.8	21.5

Fig. 1. Walter Climate diagram of the trials site, College of Agriculture meteorological station.

Results and Discussions

Field trial: Analysis of variance (ANOVA) for the effect of Mo application methods (Moa), Mo concentration (Moc), potassium fertilizer application and their interactions are display in tables (1) and (2). In respect to Moa, most of the studied traits were not significant excluding plant height (*P=0.002*). Spraying of Mo recorded higher plant height (23.85) as compared to seed priming treatment (soaking). Meanwhile, all studied traits were not affected significantly by Moc or potassium fertilizer application.

As for the interactions (Table 2), Moa interaction with K was significant for each of number of pods (NPP), number of seeds (NSP) per plant and final seed yield per hectare (SYH); while the other interactions were not different significantly; for the three mentioned traits, spraying of Mo with zero K surpassed other interactions and produced 7.98 pods, 9.72 seeds per plant and 682 $Kg.ha^{-1}$ respectively. Also, the interaction of seed soaking of Mo with 160 $Kg.ha^{-1}$ potassium applications for the same traits (NNP, NSP, and SYH) significantly produced highest values. Under the current conditions of this study, it seems that there is adequate amounts of Mo in the soil of experiment site or due to the drought season; 258.7 annual rainfall (Fig. 1) particularly at the reproductive stage in April and May which contributed negatively on the soil moisture content that lead to the decrease the effect of fertilizers or any other chemical application and therefore, the single effect for both of Mo or K was remarkably not significant. These results are in a harmony with those of Mahler (2005), Kaiser *et al.* (2005), Togay *et al*. (2008) and Zakikhani *et al.* (2014). In the same direction, Weir (1984) and Hernandez *et al.* (2009) explained that molybdenum is required in a very small amount; about 50 g per hectare or 1-2 ppm. Kg^{-1} soil will be sufficient for most of green plants. Therefore, deficiency of Mo in soils is very rare as compared to other nutrients. On the other hand, it was hypothesized that the response of plant growth to the foliar application of Mo is more pronounced in low soil pH condition than in natural or high levels of pH soils (Glubiak, 20018) and this is the case in Iraqi soils (Omer *et al.*, 2013).

Table 1. Analysis of variance and mean values for NPP, NSP, SYP, SYH, TGW, PH, AGBP for lentil crop in the field experiment.

Source of variance[1]	NPP[1] (n)	NSP (n)	SYP (g)	SYH (kg)	TGW (g)	PH (cm)	NBP (n)	AGBP (g)
	Probability of significance							
Mo application (Moa)	0.252	0.365	0.259	0.945	0.941	0.002	0.923	0.193
Mo conc. (Moc)	0.941	0.887	0.454	0.631	0.880	0.238	0.653	0.464
K	0.178	0.235	0.444	0.126	0.586	0.765	0.771	0.625
Moa*Moc	0.244	0.640	0.448	0.847	0.729	0.556	0.370	0.665
Moa*K	<.001	0.001	0.678	<.001	0.165	0.857	0.498	0.190
Moc*K	0.098	0.256	0.273	0.162	0.461	0.138	0.501	0.923
Moa*Moc*K	0.645	0.629	0.316	0.568	0.534	0.472	0.177	0.736
Residual D.F	30	30	30	30	30	30	30	30
	Effect of Mo application methods							
Soaking	6.15	7.65	0.212	540	27.79	22.47	2.175	0.363
Spraying	6.65	8.23	0.357	543	27.86	23.85	2.183	0.412
LSD[1]	0.872	1.283	0.2580	99.0	1.971	0.845	0.1735	0.0748
	Effect of Mo concentration levels							
0 ppm	6.41	7.98	0.207	539	28.16	23.57	2.183	0.416
5 ppm	6.41	7.93	0.225	543	27.80	22.45	2.133	0.396
10 ppm	6.57	8.27	0.243	588	28.16	23.17	2.133	0.338
15 ppm	6.20	7.57	0.463	497	27.19	23.47	2.267	0.401
LSD	1.233	1.814	0.3649	140.0	2.788	1.195	0.2454	0.1058
	Effect of Potassium fertilizer							
Zero $kg.ha^{-1}$	6.69	8.32	0.235	580	27.56	23.22	2.192	0.379
160 $kg.ha^{-1}$	6.10	7.56	0.333	503	28.09	23.10	2.167	0.397
LSD	0.872	1.283	0.2580	99.0	1.971	0.845	0.1735	0.0748

Moa, Molybdenum application methods; Moc, Molybdenum concentration; K, Potassium; NPP, Number of pods per plant; NSP, Seeds per plant; SYP, Seed yield per plant, SYH, Seed yield per hectare; TGW, 1000 grain weight; PH, Plant height; NBP, Number of branches per plant; AGBP, Above ground biomass per plant; LSD, Least significant differences

Table 2. The interaction of Molybdenum and potassium fertilizer application on NPP, NSP, and SYH for lentil crop in the field experiment.

#	NPP* (n)		NSP (n)		SYH ($Kg.ha^{-1}$)	
Mo Application	Zero K	160 $kg. ha^{-1}$K	Zero K	160 $kg. ha^{-1}$K	Zero K	160 $kg. ha^{-1}$K
Seed soaking in Mo	5.40	6.90	6.92	8.38	478	602
Spraying of Mo	7.98	5.31	9.72	6.74	682	405
LSD	1.233		1.814		140	

***NPP; Number of pods, NSP; Number of seeds per plant, SYH; Seed yield per hectare

Table 3. Simple correlation coefficient among some studied traits of the field experiment.

SYH[1]	SYH	NPP	NSP	TGW	NBP	AGBP	PH
NPP	0.4478**						
NSP	0.8645**	0.3941**					
TGW	0.5072**	0.083ns	0.3537*				
NBP	-0.215ns	0.0955ns	-0.265ns	-0.222ns			
AGBP	-0.095ns	-0.075ns	-0.033ns	-0.092ns	0.0557ns		
PH	0.101ns	0.1602ns	0.13ns	-0.079ns	0.1707ns	0.4226**	
SYP	0.1072ns	0.006ns	0.0681ns	0.2376ns	0.1543ns	0.0065ns	0.1263ns

[1]SYH, Seed yield per hectare; NPP, Number of pods per plant; NSP, Number of seeds per plant; TGW, 1000 grain weight; NBP, Number of branches per plant; AGBP, Above ground biomass per plant; PH, Plant height; SYP, Seed yield per plant

Table 4. Analysis of variance and mean values for number of pods, number of seeds, seed yield per plant, 1000 grain weight, plant height, number of nodules, and root dry weight.

Source of variance[1]	NPP[1] (n)	NSP (n)	SYP (g)	TGW (g)	PH (cm)	NBP (n)	NNP (n)	RDW (g)
	Probability of significance							
Moa	0.081	0.040	0.706	0.104	0.781	0.862	0.047	0.356
Moc	0.716	0.509	0.783	0.972	0.344	0.006	0.710	0.962
K	0.613	0.194	0.084	0.436	0.276	0.701	0.330	0.133
Moa*Moc	0.566	0.237	0.299	0.082	0.272	0.247	0.168	0.867
Moa*K	0.233	0.293	0.601	0.118	0.329	0.213	0.356	0.845
Moc*K	0.337	0.172	0.337	0.202	0.451	0.209	0.130	0.939
Moa*Moc*K	0.022	0.026	0.038	0.035	0.372	0.938	0.103	0.384
Residual D.F	28	28	30	29	30	30	30	30
	Effect of Mo application methods							
Soaking	6.04	7.86	0.264	33.86	17.00	2.358	179.4	0.242
Spraying	7.04	9.34	0.275	31.37	17.23	2.380	157.8	0.213
LSD[1]	1.124	1.40	0.058	3.029	1.698	0.256	21.27	0.0636
	Effect of Mo concentration levels							
0 ppm	6.29	8.37	0.264	32.86	17.47	2.136	171.3	0.239
5 ppm	7.08	9.49	0.291	33.0	16.86	2.665	175.9	0.216
10 ppm	6.31	8.42	0.272	32.16	16.02	2.123	159.1	0.230
15 ppm	6.48	8.12	0.250	32.39	18.12	2.552	167.9	0.225
LSD	1.589	1.98	0.082	4.284	2.401	0.362	30.08	0.090
	Effect of Potassium fertilizer							
Zero kg.ha^{-1}	6.40	8.14	0.244	33.20	17.58	2.393	173.7	0.204
160 kg.ha^{-1}	6.68	9.05	0.295	32.03	16.65	2.345	163.4	0.252
LSD	1.124	1.40	0.058	3.029	1.698	0.256	21.27	0.0636

[1]Moa, Molybdenum application; Moc, Molybdenum concentration; P, Potassium; NPP, Number of pods per plant; NSP, Seeds per plant; SYP, Seed yield per plant, TGW, 1000 grain weight; PH, Plant height; NBP, Number of branches per plant; NNP, Number of nodules per plant; RDW, Root dry weight including nodules

Table 5. The interaction effect of Mo application, concentration and potassium fertilizer application on seed yield, number of pods and number of seeds per plant in the pot experiment.

Traits		SYP (g)		NPP (n)		NSP (n)	
Mo Application[1]	Moc	Zero K	160 kg. ha $^{-1}$K	Zero K	160 kg. ha $^{-1}$K	Zero K	160 kg. ha $^{-1}$K
Seed soaking in Mo	0	0.243	0.36	4.33	8.4	5.7	12
	5	0.273	0.297	5.93	6.3	7.27	8.9
	10	0.173	0.29	4.47	6.67	6.9	8.03
	15	0.293	0.18	7.53	4.7	8.3	5.8
Spraying of Mo	0	0.25	0.203	7.47	4.97	9.17	6.6
	5	0.177	0.417	7.12	8.97	9	12.8
	10	0.317	0.307	7.43	6.67	9.4	9.33
	15	0.223	0.303	6.9	6.77	9.43	8.97
LSD		0.1640		3.179		3.96	

[1]Mo; molybdenum, Moc; molybdenum concentration, K; potassium fertilizer, SYP, seed yield per plant, NPP; number of pods per plant, NSP; number of seeds per plant

A positive correlation between seed yield and each number of pods per plant (*r=0.4478***), number of seeds per plant (*r=0.8645***) and thousand grain weight (*r=5072***) was estimated (Table 3). Also, significant correlation (*r=0.4226***) was found between above ground biomass and plant height.

Pot experiment: Table (4) shows the analysis of variance (ANOVA) for the effect of Mo Application methods (Moa), Mo concentration (Moc), potassium fertilizer application (K) and their interactions on the traits studied in the pots experiment.

Molybdenum application treatment was significant on the number of seeds (*P=0.04*) and number of nodules per plant (*P=0.047*).The foliar spraying of Mo produced higher seeds (9.34 seeds.plant^{-1}) while seed soaking in Mo solution significantly surpassed Mo spraying in number of nodules (179.4 nodules.plant^{-1}). Molybdenum molecules contribute positively to release the enzyme which help for the fixation of nitrogen (nitrogenase), Togay *et al.* (2015) reported that the bacterium which is responsible for nitrogen fixation needs a molybdenum molecules in legume crops. In Regards to the molybdenum concentrations (Moc), only the number of branches per plant (NBP) was highly affected (*P=0.006*); 5 ppm of Mo was superior and recorded higher number of branches per plant (175.9) as compared to control unit or other treatments followed by 15 ppm (2.552) concentration.

The effect of potassium application or its interactions with each of Moa and Moc was not significant on all studied traits in this experiment. On the other hand, the second order interaction of Moa*Moc*K was significant for the number of pods, number of seeds per plant, seed yield, and 1000 grain weight (Table 5). The interaction of Moa spraying*Moc, 5 ppm* 160 $kg.ha^{-1}$ K significantly produced highest amount of seed yield per plant (0.417 $g.plant^{-1}$) followed by the interaction of Mo soaking* Moc, 0 ppm* $160.ha^{-1}$ K with 0.360 $g.plant^{-1}$. The same interactions were superior for both number of pods (8.97 and 8.40 $pods.plant^{-1}$) and number of seeds per plant (12.80 and 12.00) respectively. These findings clearly confirm the significant correlation of seed yield per plant with each of number of pods and seeds in pots experiment.

The results of the two experiments (field and pots) were concord in respect to the single application of molybdenum or potassium fertilizers on the growth and yield of lentil; hence they are not recommended to be applied in similar environments. The interaction of Moa with potassium and second order interaction for each of the Moa and/or Moc, with potassium were found to be effective for improving the yield of lentil which can be suggested to lentil growers. Furthermore, further studies are recommended in various environments to confirm these findings. However, these results can be interpreted with the explanations of Kaiser *et al*. (2005) and Bambara & Ndakidemi (2010).

It can be concluded that under the conditions of this study, the individual application of potassium fertilizer is not useful for the performance of lentil crop. On the other hand, it increased the lentil yield and yield components when applied along with Molybdenum fertilizer. Although the Mo application were not significant in the field experiment, but in pots, the foliar application of Mo significantly improved the seed yield, and seed soaking enhanced the nodulations. Hence, Mo application is recommended in unfertile soils to increase nodules in roots and consequently increasing soil fertility through enhancing the nitrogen fixation process. Also, further studies in different soils and climates are recommended to support the obtained results and provide adequate recommendations about K and Mo application.

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