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FOLIAR ZINC AND SOIL APPLIED MOLYBDENUM OPTIMIZE YIELD AND DRY MATTER PARTITIONING OF LENTIL

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ABSTRACT. A field experiment on the effect of zinc and molybdenum application on the yield of lentil was carried out at The University of Agriculture Peshawar during the Rabi season of 2021. The experiment was carried out in a randomised complete block design with three replications. Four levels of molybdenum (0, 1, 2 and 3 kg ha^{-1}) and 0.5% zinc foliar spray at different intervals of lentil crop (control, 50 days after sowing, 100 days after sowing, 50 days after sowing + 100 days after sowing) were tested in the experiment. The results revealed that 3 kg ha^{-1} of molybdenum enhanced plant height (55 cm), nodules $plant^{-1}$ (25), branches $plant^{-1}$ (7), days to flowering (107) and maturity (159), dry matter of leaves at the flowering stage (64 g m^{-2}), dry matter of leaves at the maturity stage (113 g m^{-2}), dry matter of branches at the physiological maturity stage (304 g m^{-2}), dry matter of pods at the maturity stage (439 g m^{-2}), pods $plant^{-1}$ (92), seeds pod^{-1} (2.0), 1000-seed weight (31 g), biological yield (3207 kg ha^{-1}), and seed yield (1002 kg ha^{-1}). Zinc foliar spray (0.5%) at 50 days after sowing + 100 days after sowing of lentil crop improved the dry matter of leaves at the flowering stage (62 g m^{-2}), days to first flowering (109), days to physiological maturity (157), dry matter of leaves at the physiological maturity stage (111 g m^{-2}), dry matter of pods at the physiological maturity stage (435 g m^{-2}), pods $plant^{-1}$ (91), 1000 seed weight (32 g), biological yield (3236 kg ha^{-1}) and seed yield (1026 kg ha^{-1}). Lastly, scatterplots revealed a significant correlation of grain and biological yield with their components. It is concluded that molybdenum application at a rate of 3 kg ha^{-1} and 0.5% zinc foliar spray at 50 days after sowing + 100 days after sowing of the lentil crop increased seed yield and is thus recommended for the Peshawar region.

Keywords: correlation; cropping system; fertilisation; *Lens culinaris* L.

INTRODUCTION

Lentil (*Lens culinaris* L.) is a significant winter crop belonging to the Leguminosae family, known for its drought resistance and suitability for Mediterranean environments (Liber *et al.,* 2021). It thrives in a variety of soils, with sandy-loam soil being optimal for growth and yield. Historically, Asia has been the primary region for lentil cultivation, contributing 85% of the global area and 75% of production (Anik *et al.,* 2017).

In Pakistan, lentil cultivation covers approximately 6500 hectares, yielding approximately 4900 tonnes (MNFS&R, 2023). Lentil cultivation proves beneficial for soil fertility enhancement through crop rotation, positively impacting soil's physical, chemical and biological properties (Yadav *et al.,* 2007). By establishing a symbiotic relationship with rhizobia, lentils contribute to improved nitrogen conditions and crop productivity (Ahmed *et al*., 2008). Beyond human consumption, lentil plants provide valuable fodder for livestock (Vision *et al*., 2014). Challenges in lentil production in Pakistan stem from traditional practices, lack of certified seed, shifting cultivation to other crops, weed and disease issues, high fertiliser costs, and grower unawareness, collectively contributing to decreased production. Notably, adopting a balanced micronutrient application, which is crucial for fixing atmospheric nitrogen, can significantly enhance lentil yields (Singh and Bhatt, 2013). Zinc (Zn) and molybdenum (Mo) play crucial roles in enhancing legume productivity (Bakry *et al.,* 2012). Mo, an essential micronutrient for plant growth, is vital for nitrogenase enzymes and impacts nitrate reductase activation (Bhuiyan *et al.,* 2008). The Mo required by rhizobia for nitrogen fixation is significantly higher than that required for protein formation (Alam *et al.,* 2015). Ascorbic acid biosynthesis, flower and pod retention in pulses, and involvement in carbohydrate metabolism highlight Mo's diverse roles (Banerjee *et al.,* 2019; Khan *et al*., 2014; Malik *et al*., 2015). Mo deficiency leads to reduced nitrogen fixation, hindering vegetative growth and yield (Hamlin, 2007). As an essential micronutrient, Zn influences pollen grain development and enzymatic activity, affecting carbohydrate distribution in plant leaves (Valenciano *et al.,* 2011). Zn's physiological function in plants involves acting as a metal constituent in enzymes and a co-factor in enzymatic reactions, with excess accumulation impacting growth processes (Stoyanova and Doncheva, 2002). Zn deficiency reduces auxin levels and inefficient water utilisation, thus decreasing crop yield (Khan *et al.,* 2004; Liscum and Reed, 2002). Factors such as high phosphorus, pH, lime and clay contribute to Zn deficiency, while foliar application facilitates Zn movement within plants (Marschner, 2011; Phuphong *et al.,* 2020). Foliar Zn application, especially post-flowering, enhances the grain Zn content. Zn deficiency is a global concern, particularly in calcareous soils with high pH, low organic matter and sandy texture (Mahmood *et al.,* 2019). This study aimed to determine the optimal combination of Mo and Zn for improving lentil performance, recognising their importance in boosting productivity.

MATERIALS AND METHODS

Experimental site and design

The experiment was conducted at the Agronomy Research Farm, the University of Agriculture Peshawar, Pakistan, during the Rabi season of 2021.

The site was placed at 34.01 N latitude and 71.35 E longitude with an elevation of 350 m above sea level. The soil of the farm is clay loam in texture, alkaline (pH 8.2) and calcareous in nature.

Planting material, design and fertiliser application

Lentil variety Markaz-09 was used for the experiment. Four levels of Mo (0, 1, 2 and 3 kg ha^{-1}) and Zn foliar sprays at a 0.5% rate at different intervals (control, 50 days after sowing, 100 days after sowing, 50 days after sowing + 100 days after sowing) were tested.

The study was employed in a randomised complete block design (RCBD) with three replications. The unit plot size was 3 m × 2.4 m, comprising 6 rows with a row-to-row distance of 40 cm. The sources of Zn and Mo were zinc sulphate and sodium molybdate. The seed rate of lentil was 25 kg ha^{-1}, which was inoculated with 1 kg *Rhizobium leguminacere* inoculum ha^{-1} before sowing. Elemental Mo of 1, 2 and 3 kg ha^{-1} was applied as 1.54, 3.09 and 4.63 g of sodium molybdate per plot, respectively.

For the 0.5% Zn spray, 6.17 g of zinc sulphate dissolved in 500 mL of water was applied per plot. In the case of the S4 level, 0.25% Zn was applied 50 days after sowing, and the remaining 0.25% Zn was sprayed 100 days after sowing to complete the 0.5% dose. A starter dose of nitrogen (25 kg ha^{-1}) was applied using a urea fertiliser at the sowing time.

Procedure for data recording

Various agronomic parameters were assessed in the lentil experiment. The number of days to emergence was recorded from sowing until 50% emergence was achieved. Emergence m^{-2} was calculated by counting the number of seedlings in a 1-m row at three random positions in each plot and converting them to square metres. Nodule counts per plant were determined before the flower initiation stage.

The number of days to the first flowering were noted, representing the time from sowing to the appearance of the first flower in each plot. Dry matter was measured at the flowering and physiological maturity stages, involving the separation and weighing of leaves, branches and pods. The number of branches per plant were counted in 10 randomly selected plants. Plant height was measured for 10 randomly selected plants in each experimental unit.

The number of days to physiological maturity were calculated based on the period from sowing to pod blackening. The number of pods per plant, seeds per pod, and 1000-seed weight were determined. Biological yield and seed yield were recorded by harvesting the four central rows in each unit, and the harvest index was calculated as the ratio of seed yield to biological yield multiplied by 100.

Statistical analysis

Analysis of variance test suitable for RCBD was used for statistically analysed data. For significant F-values, the LSD test was used for mean comparison at the 0.05 level of probability (Steel and Torrie, 1984).

Table 1 – Pre sowing physiochemical properties of experimental soil

Properties	Unit	Value
pH	--	7.8
Electric conductivity	dS m^{-1}	0.70
Carbon content	%	0.24
Total Nitrogen Content	%	0.03
Extractable N	mg kg^{-1}	17.62
Extractable P	mg kg^{-1}	4.58
Extractable K	mg kg^{-1}	64.24
Organic Matter	%	0.41
Texture	--	silt loam
Bulk Density	g cm^3	1.47
Moisture content	%	9.03

RESULTS

Crop phenology

The number of days to lentil emergence was not significantly affected by Mo fertilisation. However, the number of days to first flowering and the number of days to physiological maturity were significantly influenced by Zn and Mo levels, but their interaction was not significant (*Table 2*). The most days to flowering (112 days) were observed in control plots, followed by 50 days after sowing (111 days), while the least days to flowering (109 days) occurred when Zn was sprayed 50 days after sowing + 100 days after sowing.

In the case of Mo application, the most days to first flowering (113 days) were recorded in the control plots, and the least (107 days) were noted in plots receiving 3 kg Mo ha^{-1}. The most days to physiological maturity (165 days) were recorded in the control plots, followed by Zn foliar spray at 50 days after sowing (161 days), while the least (157 days) occurred when Zn was sprayed at 50 days after sowing + 100 days after sowing. In terms of Mo levels, the most days to physiological maturity (162 days) were recorded in the control plots, and the least (159 days) were noted in plots receiving 3 kg Mo ha^{-1}.

Statistical analysis of the data demonstrated a significant effect of Zn and Mo application on the number of nodules per plant. The interaction between the number of branches per plant and plant height was not significant (*Table 2*).

The application of Zn foliar spray at 50 days after sowing resulted in the most nodules per plant (22), which was statistically similar (21) to the application at 50 days after sowing + 100 days after sowing. Conversely, the control plots exhibited the least nodules per plant (17). Regarding Mo levels, the most nodules per plant (25) were recorded with the application of 3 kg Mo ha^{-1}, followed by 2 kg Mo ha^{-1} (20), as compared to the control (16).

The number of branches per plant displayed a significant increase with Zn foliar spray at 100 days after sowing, resulting in the most branches per plant (8), followed by Zn application at 50 days after sowing + 100 days after sowing (7) in comparison to the control. Among Mo levels, more branches per plant (7) were recorded with the application of 3 kg Mo ha^{-1}, while less (6) were observed in the control plots.

Table 2 – Phenology and growth attributes of lentil as influenced by foliar zinc and molybdenum application

Treatments	Days to emergence	Days to flowering	Days to maturity	Nodules plant^{-1}	Branches plant^{-1}	Plant height (cm)
			Zinc foliar spray (0.5%)			
Control	x	112^{a}	165^{a}	17^{c}	4^{d}	46^{d}
50 days after sowing	x	111^{ab}	161^{b}	22^{a}	6^{c}	49^{c}
100 days after sowing	x	110^{bc}	159^{b}	19^{b}	8^{a}	58^{a}
50 days after sowing+100 days after sowing	x	109^{c}	157^{c}	21^{a}	7^{b}	53^{b}
$LSD_{(0.05)}$	x	2	2	1.5	1	2
			Molybdenum levels (kg ha^{-1})			
0	13	113^{a}	162^{a}	16^{c}	6^{b}	49^{c}
1	12	111^{ab}	161^{ab}	18^{c}	6^{b}	50^{bc}
2	13	110^{b}	160^{ab}	20^{b}	6^{b}	52^{b}
3	13	107^{c}	159^{b}	25^{a}	7^{a}	55^{a}
$LSD_{(0.05)}$	x	2	2	1.5	1	2
Zn×Mo interaction	ns	ns	ns	ns	ns	ns

Using the LSD test, means of the same category separated by different letters vary significantly ($P \leq 0.05$)

Plant height was also influenced by Zn and Mo fertilisation. Taller plants (58 cm) were observed with Zn sprayed at 100 days after sowing, followed by Zn applied at 50 days after sowing + 100 days after sowing (53 cm), in comparison with shorter plants observed in the control (46 cm). Among Mo levels, taller plants (55 cm) were observed with the application of 3 kg Mo ha^{-1}, followed by 2 kg Mo ha^{-1} (52 cm), while the control plots displayed shorter plants (49 cm) (*Table 2*).

Yield and yield-related traits in lentil

The most pods per plant (91) were observed when Zn was applied at 50 days after sowing + 100 days after sowing, while the least (86) were noted in the control plots. Regarding Mo levels, a higher number of pods per plant (92) were recorded in plots treated with 3 kg Mo ha^{-1}, whereas the least (85) were observed in the control plots. For seeds per pod, Mo fertilisation increased the number of pods per plant, with higher Mo levels. Plots treated with 3 kg Mo ha^{-1} produced more seeds per pod (2), followed by 2 kg Mo ha^{-1}, while control plots exhibited fewer seeds per pod (1).

The highest 1000-seed weight (32 g) was obtained when Zn was applied at 50 days after sowing + 100 days after sowing, followed by 100 days after sowing (31 g), while the lowest (26 g) was observed in the control plots. Among Mo levels, a higher 1000-seed weight (31 g) was recorded in plots treated with 3 kg Mo ha^{-1}, followed by 2 kg Mo ha^{-1} (29 g), which were statistically similar to the control plots (*Table 3*). Biological yield and seed yield of lentil were significantly affected by Mo and Zn fertilisation, while the interactive effect (Zn × Mo) was non-significant (*Table 3*). The highest biological yield (3236 kg ha^{-1}) was obtained when Zn was applied at 50 days after sowing + 100 days after sowing, while the lowest (3046 kg ha^{-1}) was observed in the control plots. Similarly, in terms of Mo levels, a higher biological yield (3207 kg ha^{-1}) was noted in plots treated with 3 kg Mo ha^{-1}, followed by 2 kg Mo ha^{-1} (3124 kg ha^{-1}), while a lower yield (3030 kg ha^{-1}) was observed in the control plots. For seed yield, the maximum (1026 kg ha^{-1}) was obtained when Zn was applied at 50 days after sowing + 100 days after sowing, followed by 100 days after sowing (929 kg ha^{-1}), while the minimum (869 kg ha^{-1}) was recorded in the control plots. Among Mo levels, a higher seed yield (1002 kg ha^{-1}) was noted in plots treated with 3 kg Mo ha^{-1}, followed by 2 kg Mo ha^{-1} (945 kg ha^{-1}), while the lowest (865 kg ha^{-1}) was obtained in the control plots. Lastly, the highest harvest index (31.7%) was achieved with Zn application at 50 days after sowing + 100 days after sowing, followed by Zn application at 100 days after sowing (30.4%), while the lowest harvest index (28.6%) was observed in the control plots. Regarding Mo levels, a higher harvest index (31.3%) was recorded in plots treated with 3 kg Mo ha^{-1}, followed by 2 kg Mo ha^{-1} (30.4%), while the lowest harvest index (28.8%) was noted in the control plots.

Dry matter partitioning at different growth stages

The dry matter of branches, leaves and pods was influenced by Zn and Mo fertilisation at different growth stages, with a non-significant interaction of Zn and Mo observed for all traits (*Table 4*). The highest dry matter of branches at the flowering stage (164 g m^{-2}) was recorded with 0.5% Zn foliar spray at 50 days after sowing + 100 days after sowing, followed by Zn application at 100 days after sowing (161 g m^{-2}) compared to the minimum observed in the control (159 g m^{-2}).

Table 3 – Yield and related traits in lentil as influenced by foliar zinc and molybdenum application

Treatments	Pods plant^{-1}	Seeds pod^{-1}	1000-seed weight (g)	Biological yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)
			Zinc foliar spray (0.5%)			
Control	86^{b}	1	26^{d}	3046^{b}	869^{d}	28.6^{c}
50 days after sowing	87^{b}	2	29^{c}	3077^{b}	895^{c}	29.4^{bc}
100 days after sowing	88^{b}	2	31^{b}	3092^{b}	929^{b}	30.4^{b}
50 days after sowing+100 days after sowing	91^{a}	2	32^{a}	3236^{a}	1026^{a}	31.7^{a}
$LSD_{(0.05)}$	2	ns	1	61	23	1
			Molybdenum levels (kg ha^{-1})			
0	85^{c}	1^{c}	29^{b}	3030^{c}	865^{d}	28.8^{c}
1	86^{c}	1.6^{bc}	29^{b}	3090^{bc}	906^{c}	29.5^{bc}
2	89^{b}	1.9^{ab}	29^{b}	3124^{b}	945^{b}	30.4^{ab}
3	92^{a}	2.0^{a}	31^{a}	3207^{a}	1002^{a}	31.3^{a}
$LSD_{(0.05)}$	2	0.4	1	61	23	1
Zn×Mo interaction	ns	ns	ns	ns	ns	ns

Using the LSD test, means of the same category separated by different letters vary significantly ($P \leq 0.05$)

Table 4 – Dry matter partitioning of lentil at various growth stages as influenced by foliar zinc and molybdenum application

Treatments	DM of Branches (g m^{-2}) at the flowering	DM of leaves (g m^{-2}) at the flowering	DM of branches (g m^{-2}) at maturity	DM of leaves (g m^{-2}) at maturity	DM of pods (g m^{-2}) at maturity
Zinc foliar spray (0.5%)					
Control	159^{b}	57^{b}	291^{b}	105^{c}	427^{b}
50 days after sowing	159^{b}	59^{b}	294^{b}	108^{b}	430^{ab}
100 days after sowing	161^{ab}	60^{ab}	301^{a}	109^{ab}	432^{ab}
50 days after sowing+100 days after sowing	164^{a}	62^{a}	298^{ab}	111^{a}	435^{a}
LSD$_{(0.05)}$	4	3	7	3	11
Molybdenum levels (kg ha^{-1})					
0	155^{c}	55^{c}	289^{c}	104^{c}	424^{c}
1	158^{c}	58^{b}	292^{bc}	107^{c}	429^{bc}
2	167^{a}	62^{a}	297^{b}	110^{b}	433^{b}
3	163^{b}	64^{a}	304^{a}	113^{a}	439^{a}
LSD$_{(0.05)}$	4	3	7	3	11
Zn×Mo interaction	ns	ns	ns	ns	ns

Using the LSD test, means of the same category separated by different letters vary significantly (P ≤ 0.05)

Concerning Mo levels, plots treated with 2 kg Mo ha^{-1} exhibited more branch dry matter at the flowering stage (167 g m^{-2}), while the control plots showed the least (155 g m^{-2}).

The highest leaf dry matter at the flowering stage (62 g m^{-2}) was recorded with Zn foliar spray at 50 days after sowing + 100 days after sowing, followed by 100 days after sowing with Zn foliar spray. The least dry matter (57 g m^{-2}) was noted in the control plots. For Mo levels, the highest leaf dry matter at the flowering stage (64 g m^{-2}) was recorded with 3 kg Mo ha^{-1} and was statistically similar to plots treated with 2 kg Mo ha^{-1} (62 g m^{-2}), while the lowest (55 g m^{-2}) was observed in the control plots. At maturity, the dry matter of branches (301 g m^{-2}) was highest when Zn was sprayed on foliage at 100 days after sowing, while the least (291 g m^{-2}) was recorded in control plots. Among Mo levels, the highest dry matter of branches at the physiological maturity stage (304 g m^{-2}) was noted in plots treated with 3 kg Mo ha^{-1}, while the least (289 g m^{-2}) was observed in the control plots. Additionally, the highest leaf dry matter at the maturity stage (111 g m^{-2}) was recorded with 0.5% Zn foliar spray at 50 days after sowing + 100 days after sowing, and the least dry matter (105 g m^{-2}) was noted in the control plots. For Mo levels, the highest leaf dry matter at the physiological maturity stage (113 g m^{-2}) was observed with 3 kg Mo ha^{-1}, while the lowest (104 g m^{-2}) was noted in the control plots. Lastly, the highest pod dry matter at the maturity stage (435 g m^{-2}) was obtained when Zn was foliar sprayed at 50 days after sowing + 100 days after sowing, while the least (427 g m^{-2}) was noticed in the control plots. Among Mo levels, a higher pod dry matter at the physiological maturity stage (439 g m^{-2}) was observed in plots treated with 3 kg Mo ha^{-1}, followed by 2 kg Mo ha^{-1} (433 g m^{-2}), while the least (424 g m^{-2}) was recorded in the control plots.

Correlation between seed and biological yield and their components

Seed yield of lentil was significantly influenced by pods $plants^{-1}$ and 1000-seed weight when treated with different Zn and Mo concentrations, as shown by the correlation analysis (*Figure 1*).

The coefficient of regression (R^2) in scatter plots revealed a strong correlation between pods $plants^{-1}$ (0.90) and 1000-seed weight (0.67) that showed moderate association with seed yield (a and b).

Similarly, the biological yield of lentil was highly associated with DM of branches and leaves at maturity when subjected to various levels of Zn and Mo.

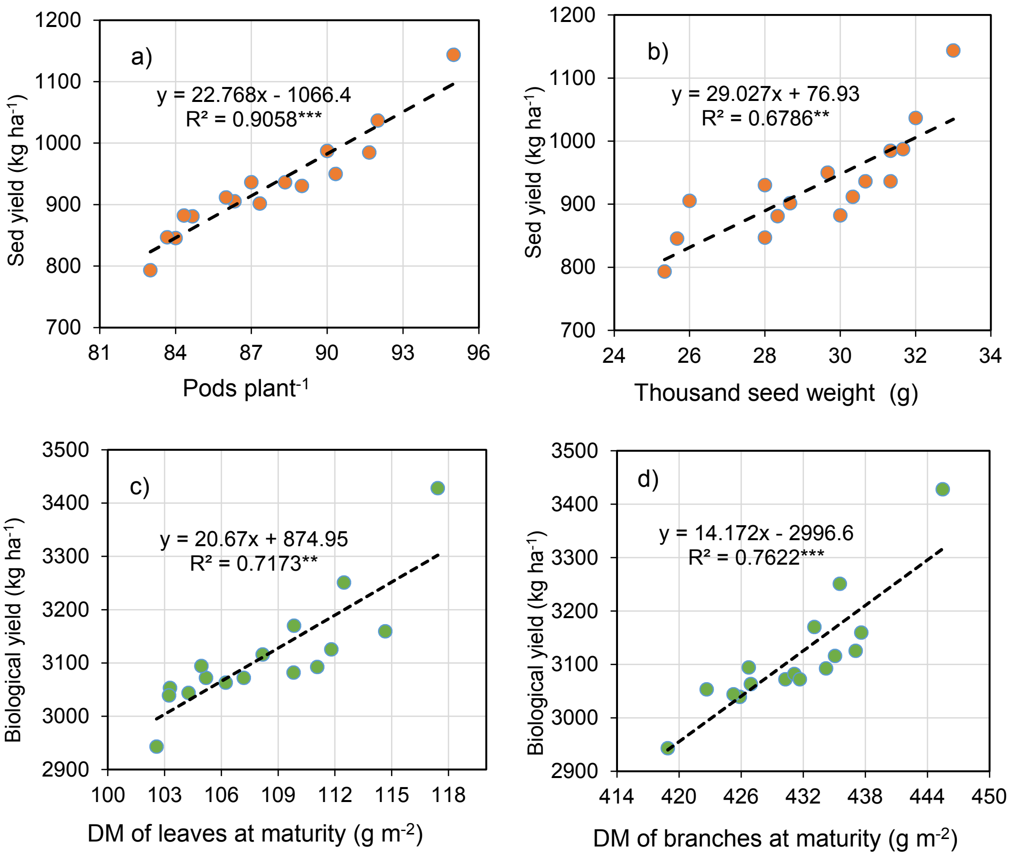

Figure 1 – Relationship between grain yield and its components (a and b) and biological yield and its components (c and d)

The coefficient of variance was slightly higher for leaf DM (0.76) compared to branch DM at maturity (0.71), showing that biological yield was a bit more dependent on leaf DM than branch DM at the time of maturity (c and d).

DISCUSSION

Mo application did not significantly impact the days to emergence of lentil crops, suggesting that stored seed food is sufficient for promoting germination. This aligns with the findings of Khan *et al.* (2017), who emphasised that the seed endosperm provides ample nutrients for seedling emergence. Zn and Mo applications positively affected the days to flowering and maturity of lentil. Plots treated with Zn foliar spray 50 days after sowing + 100 days after sowing exhibited early flowering, consistent with the findings of Hafeez *et al.* (2013), indicating that Zn limitation delays crop maturity. Zn plays a crucial role in pollination by aiding pollen tube formation. Mo application at 3 kg ha^{-1} resulted in early flowering, which aligns with the findings of Nautiyal *et al.* (2004), who observed that Mo deficiency hinders flower emergence. These results agree with Bejandi *et al.* (2012), indicating that Mo application promotes more flowers with a reduced time to flowering. Nodules play a vital role in legume crops by facilitating nitrogen fixation through nitrogen-fixing bacteria, making nitrogen available for plant utilisation. The mean values indicate that foliar Zn application at 50 days after sowing resulted in the maximum number of nodules plant^{-1}, while lower numbers were observed in the control plots. This agrees with Singh and Bhatt (2013), who noted that Zn application increased nodules and enhanced plant growth. Among the different Mo levels, higher nodules were recorded in plots fertilised with 3 kg Mo ha^{-1}, consistent with Oguz (2004), who demonstrated that increasing the Mo concentration led to more nodules in chickpea, possibly due to the role of Mo in nitrogen fixation in rhizobia. Branches plant^{-1} were significantly influenced by Zn and Mo application, with Zn foliar application at 100 days after sowing resulting in more branches, as also shown by Somani (2008). For Mo, more branches plant^{-1} were obtained from plots treated with 3 kg Mo ha^{-1}, consistent with findings by Togay *et al.* (2008) on Mo's positive impact on yield-related characteristics. Plant height (cm) was significantly affected by Zn and Mo application, with taller plants produced by Zn application at 100 days after sowing, in line with Pal *et al.* (2019). Mo application at 3 kg Mo ha^{-1} resulted in taller plants, as observed by Dharvendra *et al.* (2017).

The experimental results revealed more pods per plant in plots treated with Zn foliar spray at 50 days after sowing + 100 days after sowing. This aligns with Ali *et al.* (2017), who reported an increase in the number of pods per plant with a higher Zn concentration. Regarding Mo, a greater number of pods per plant were recorded in plots treated with 3 kg Mo ha^{-1}, consistent with the findings by Dharvendra *et al.* (2017), indicating that the increased Mo concentration resulted in more pods per plant. Data on seeds per pod were significantly affected by Mo and not significantly affected by Zn application. The mean values demonstrated that Mo application at a rate of 3 kg ha^{-1} maintained more seeds per pod, while lower seeds per pod were produced in the control plots.

Seed yield and biological yield were positively influenced by Zn and Mo application. A higher biological yield was recorded in plots where foliar Zn spray was applied at 50 days after sowing + 100 days after sowing, while lower biological yield was obtained from the control plots. Similarly, a greater seed yield was obtained from plots treated with foliar Zn spray at 50 days after sowing + 100 days after sowing, while a lower seed yield was recorded in the control plots. These results align with Nasar and Shah (2017), who reported a higher grain yield (1756 kg ha^{-1}) and biological yield (4860 kg ha^{-1}) compared to control plots (1293 and 4163 kg ha^{-1}, respectively). Regarding Mo, the highest biological output was noted in plots fertilised with 3 kg Mo ha^{-1}, while the least was obtained from control plots. The highest seed yield was received from plots treated with 3 kg Mo ha^{-1}, and a lower seed yield was noted in the control plots.

These findings are consistent with Singh and Bhatt (2013), who observed that Zn foliar application at a rate of 0.4% produced the maximum seed yield, and Shil *et al.* (2007) stated that the application of 1.5 kg Mo ha^{-1} resulted in a higher seed yield. Furthermore, a higher harvest index was recorded in plots where Zn foliar spray was applied at 50 days after sowing + 100 days after sowing, while a lower harvest index was obtained from the control plots. This is in line with the findings of Swargiary *et al.* (2021), who recorded the maximum harvest index in plots fertilised with 8 kg ha^{-1} Zn. In the case of Mo, a higher harvest index percentage was noted in plots fertilised with 3 kg Mo ha^{-1}, while the lowest was obtained from the control plots. These results are in accordance with the findings of Nasar and Shah (2017), who reported that foliar Mo application produced a higher harvest index than other treatments.

Branch and leaf dry matter at the flowering stage were positively affected by Zn and Mo application. Based on the mean data, the dry matter of both components was greater at the flowering stage when Zn foliar spray was done at 50 days after sowing + 100 days after sowing. These findings agree with those of Thamke (2017), who stated that increasing the Zn concentration produced more dry matter in pigeon pea crops. In the case of Mo, a higher dry matter at the flowering stage was recorded from 3 kg Mo ha^{-1}. These conclusions are similar to Datta *et al.* (2011), who concluded that the Mo application had a pronounced effect on growth along with a higher dry matter accumulation in Bengal gram.

Significant effects of Zn and Mo application on the dry matter of leaves, branches and pods at physiological maturity were observed, while their combination yielded non-significant results. The mean data indicate a higher dry matter content at the physiological maturity stage in plots where Zn foliar spray was applied 50 days after sowing + 100 days after sowing. These findings align with the positive impact of Zn foliar spray on dry matter production reported by Pal *et al.* (2019) and Haider *et al.* (2018), who observed an increased mung bean yield with Zn foliar application. Regarding Mo, higher dry matter at physiological maturity was recorded in plots treated with 3 kg Mo ha^{-1}, followed by 2 kg Mo ha^{-1}. These results are in accordance with Togay *et al.* (2008), who concluded that Mo application had a significant effect on dry matter in lentil, with an increasing Mo range from 0 to 6 g kg^{-1} seed.

Finally, correlation scatter plots demonstrated that seed yield was influenced by both the number of pods per plant and the 1000-seed weight. This is attributed to the fact that a higher pod count enhances the potential for seed production, and a greater seed weight contributes to the overall yield. Comparable findings have also been documented by Vaishali and Kumar (2018) and Quddus *et al.* (2021). Similarly, the biological yield revealed a strong connection with dry matter. Multiple studies affirm a positive correlation between dry matter and biological yield in lentils. Chauhan and Singh (2001) identified positive links between seed yield and secondary branches, plant spread, fruiting nodes, and total biological yield. Mekonnen (2014) and Xavier and Germida (2002) further supported these findings, showing strong positive correlations with various yield-related factors.

CONCLUSIONS AND RECOMMENDATIONS

The application of 0.5% Zn foliar spray at 50 days after sowing + 100 days after sowing resulted in a better dry matter and seed yield of lentil. Mo application at a rate of 3 kg ha^{-1} demonstrated positive effects on the yield and yield components of lentil. Therefore, application of 3 kg ha^{-1} of Mo and 0.5% Zn foliar is recommended at 50 days after sowing + 100 days after sowing to achieve maximum productivity in lentil. The selected levels of Mo and Zn application suggest that further research should be conducted with higher levels of those nutrients to explore their impact on lentil productivity.

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REFERENCES

Ahmed, Z.I.; Ansar, M.; Tariq, M.; Anjum, M.S. Effect of different rhizobium inoculation methods on performance of lentil in Pothowar Region. *International Journal of agriculture and biology.* **2008**, 10, 118-129.

Alam, F.; Kim, T.Y.; Kim, S.Y.; Alam, S.S.; Pramanik, P.; Kim, P.J.; Lee, Y.B. Effect of molybdenum on nodulation, plant yield and nitrogen uptake in hairy vetch (Vicia villosa Roth). *Soil Science and plant nutrition.* **2015**, 61, 664-675. https://doi.org/10.1080/00380768.2015.1030690

Ali, A.; Ahmad, B.; Hussain, I.; Ali, A.; Shah, F.A. *Effect of phosphorus and zinc on yield of lentil.* Pure Applied Biology. **2017**, 6, 1397-1402. http://dx.doi.org/10.19045/bspab.2017.600150

Anik, A.R.; Rahman, S.; Sarker, J.R. Agricultural productivity growth and the role of capital in South Asia (1980–2013). *Sustainability.* **2017**, 3, 470. https://doi.org/10.3390/su9030470

Bakry, B.A.; Tawfik, M.M.; Mekki, B.B.; Zeidan, M.S. Yield and yield components of three flax cultivars (Linum usitatissimum L.) in response to foliar application with Zn, Mn and Fe under newly reclaimed sandy soil conditions. *American-Eurasian Journal of Agricultural & Environmental Sciences.* **2012**, 12, 1075-1080.

Banerjee, P.; Visha Kumari, V.; Nath, R.; Bandyopadhyay, P. Seed priming and foliar nutrition studies on relay grass pea after winter rice in lower Gangetic plain. *Journal of Crop and Weed.* **2019**, 15, 72-78. https://dx.doi.org/10.22271/09746315.2019.v15.i3.1240

Bejandi, T.K.; Sharifii, R.S; Sedghi, M.; Navar, A. Effects of plant density, Rhizobium inoculation and microelements on nodulation, chlorophyll content and yield of chickpea (Cicer arietinum L). *Annals of Biological Resource.* **2012**, 3, 951-958.

Bhuiyan, M.M.H.; Rahman, M.M.; Afroze, F.; Sutradhar, G.N.C.; Bhuiyan, M.S.I. Effect of phosphorus, molybdenum and rhizobium inoculation on growth and nodulation of mungbean. *Journal of soil and plant nutrition.* **2008**, 2, 25-30.

Chauhan, M.P.; Singh, I.S. Relationship between seed yield and its component characters in lentil (Lens culinaris medik.). *Legume Research.* **2001**, 24, 278-280.

Datta, J.K.; Kundu, A.; Hossein, S.D.; Banerjee, A; Mondal, N.K. Studies on the impact of micronutrient (molybdenum) on germination, seedling growth and physiology of Bengal gram (Cicer arietinum) under laboratory condition. *Asian Journal of Crop Science.* **2011**, 3, 55-67. https://doi.org/10.3923/ajcs.2011.55.67

Dharvendra, S.; Archana, K.; Sukhvir, S. Effect of phosphorus and molybdenum nutrition on yield and nutrient uptake in lentil (Lens culinaris L.). *Annals of Plant and Soil Research*. **2017**, 19, 37-41.

Hafeez, B.; Khanif, Y.M.; Saleem, M. Role of zinc in plant nutrition. *American Journal of Experimental Agriculture.* **2013**, 3, 374-379. https://doi.org/10.9734/AJEA/2013/2746

Haider, M.U.; Farooq, M.; Nawaz, A.; Hussain, M. Foliage applied zinc ensures better growth, yield and grain biofortification of mungbean. *International Journal of Agriculture and Biology.* **2018**, 20, 2817-2822. http://dx.doi.org/10.17957/IJAB/15.0840

Hamlin, R.L. Molybdenum. In *Handbook of plant nutrition*, 1st Edition, A.V. Barker and D. Pilbeam, Boca Raton, Florida, U.S.A., 2006, 375-395.

Khan, H.R.; Mc Donald, G.K.; Rengel, Z. Zinc fertilization and water stress affects plant water relations, stomatal conductance and osmotic adjustment in chickpea (Cicer arietinum L). *Plant and Soil.* **2004**, 267, 271-284. https://doi.org/10.1007/s11104-005-0120-7

Khan, N.; Tariq, M.; Ullah, K.; Muhammad, D.; Khan, I.; Rahatullah, K.; Ahmed, N.; Ahmed, S. The effect of molybdenum and iron on nodulation, nitrogen fixation and yield of chickpea genotypes (Cicer arietinum L). *IOSR Journal of*

Agriculture and vetarnity Science. **2014**, 7, 63-79.

Liscum, E.; Reed, J.W. Genetics of AUX/IAA and ARF action in plant growth and development. *Plant Molecular Biology.* **2002**, 49, 387-400. https://doi.org/10.1023/A:1015255030047

Liber, M.; Duarte, I.; Maia, A.T; Oliveira, H.R. The history of lentil (Lens culinaris subsp. culinaris) domestication and spread as revealed by genotyping-by-sequencing of wild and landrace accessions. *Frontiers in Plant Science.* **2021**, 12, 628439. https://doi.org/10.3389/fpls.2021.628439

Mahmood, I.A.; Imran, M.; Sarwar, M.; Khan, M.; Sarwar, M.A.; Ahmed, S.; Malik, S.R. Growth and yield of lentil (Lens esculenta l.) influenced by Zn application with PGPR inoculation under rain-fed conditions. *Pakistan Journal of Agriculture Research.* **2019**, 32, 435-440. https://doi.org/10.17582/journal.pjar/2019/32.3.435.440

Malik, K.; Kumar, S.; Singh, K.P. Effect of zinc on growth and yield of mungbean (Vigna radiate L.). *Advance Research Journal Crop Improvement.* **2015**, 6, 59-65.

Marschner, H. *Marschner's mineral nutrition of higher plants*, 3rd edition. Petra Marschner, Elsevier Academic Press, Amsterdam, Netherlands, 2011.

Mekonnen, F.; Mekbib, F.; Kumar, S.; Ahmed, S.; Sharma, T.R. Correlation and path coefficient analysis of seed yield and yield components in lentil (Lens culinaris medik.) genotype in Ethiopia. *African journal of plant science.* **2014**, 8, 507-520. https://doi.org/10.5897/AJPS2014.1183

MNFS&R. Agriculture Statistics of Pakistan. Ministry of National Food Security and Research, Islamabad, Pakistan. https://mnfsr.gov.pk/Publications (accessed on 23rd December 2023)

Nasar, J.; Shah, Z. Effect of iron and molybdenum on yield and nodulation of lentil. *ARPN Journal of Agricultural and Biologycal Science.* **2017**, 12.

Nautiyal, N.; Singh, S.; Chatterjee, C. Seed reserves of chickpea in relation to molybdenum supply. *Journal of Science Food and Agriculture.* **2004**, 85, 860-864. https://doi.org/10.1002/jsfa.1929

Oguz, F. Effects of different levels molybdenum application on the yield and some yield components in Chickpea varieties on dry and irrigation conditions. 2004, M.Sc. Thesis, Yuzuncu Yıl University Van. Turkey.

Pal, P.; Mondal, S.; Samanta, P. Effect of zinc foliar application on seed yield of Lentil (Lens culinaris Medikus) and its yielding components. *Current Journal of Applied science and technology.* **2019**, 33, 1-6. https://doi.org/10.9734/cjast/2019/v33i230060

Phuphong, P.; Cakmak, I.; Yazici, A.; Rerkasem, B.; Promuthai, C. Shoot and root growth of rice seedlings as affected by soil and foliar zinc applications. *Journal of Plant Nutrition.* **2020**, 43, 1259-1267. https://doi.org/10.1080/01904167.2020.1730900

Quddus, M.A.; Hossain, M.A.; Naser, H.; M., Anwar, B.; Sattar, M.A.; Mazed, H.K. Assessment of Potassium Element on Lentil (Lens culinaris Medic) Agronomy and Nutrient Use Efficiency in Calcareous Soils. *Journal of Energy and Natural Resources.* **2019**, 8,116-126 https://doi.org/10.11648/j.jenr.20190803.13

Shil, S.; Noor, Hossain, M.A. Effects of boron and molybdenum on the yield of Chickpea. *Journal of Agriculture and*

Rural development. **2007**, 5, 17-24. https://doi.org/10.3329/jard.v5i1.1452

Singh, A.K.; Bhatt, B.P. Effects of foliar application of zinc on growth and seed yield of late-sown lentil. *Indian Journal of Agriculture Science*. **2013**, 83, 622-626. https://epubs.icar.org.in/index.php/IJAgS/article/view/30355

Somani, L. *Micronutrients for soil and plant health, 2nd edition*. Agrotech Publishing Academy, Udaipur-313002, India, 2008, 14-74.

Steel, R.G.D; Torrie, J.H. *Principles and procedures of statistics: A biometrical approach*, 2nd edition. McGraw-Hill, New York, U.S.A, 1984.

Stoyanova, Z.; Doncheva, S. The effect of zinc supply and succinate treatment on plant growth and mineral uptake in pea plant. *Brazilian Journal of Plant Physiology*. **2002**, 14, 111-116. https://doi.org/10.1590/S1677-04202002000200005

Swargiary, S.; Umesha C.; Nihal D. Influence of spacing and zinc levels on growth and yield of Lentil (Lens culinaris). *Biological Forum - An International Journal*. **2021**, 13, 114-117.

Togay, Y.; Togay N.; Dogan, Y. Research on the effect of phosphorus and molybdenum applications on the yield and yield parameters in lentil (Lens Culinaris Medic). *African journal of biotechnology*. **2008**, 7, 1256-60.

Vaishali, G.; Kumar, B. Association of Seed Yield and Yield Contributing Characters of Lentil (Lens culinaris Medik) Grown under Moisture Stress Condition. *International Journal of Current Microbiology and Applied Sciences*. **2018**, 7, 3171-3175.

Valenciano, J.B.; Boto, J.A.; Marcelo, V. Chickpea (Cicer arietinum L.) response to zinc, boron and molybdenum application under field conditions. *New Zealand Journal of Crop and Horticultural Science*. **2011**, 39, 217-229. https://doi.org/10.1080/01140671.2011.577079

Xavier, L.J.C.; Germida, J.J. Response of lentil under controlled conditions to co-inoculation with arbuscular mycorrhizal fungi and rhizobia varying in efficacy. *Soil Biology and Biochemistry*. **2002**, 34, 181-188. https://doi.org/10.1016/S0038-0717(01)00165-1

Yadav, S.S.; McNeil, D.L.; Stevenson, P.C. Lentil, an ancient crop for modern times. Springer, Netherlands, 2007. http://dx.doi.org/10.1007/978-1-4020-6313-8

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