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Yield, Nodulation, Nitrogen Uptake, and Powdery Mildew Disease by Pea (*Pisum sativum* L.) as Influenced by Applied Molybdenum and Iron

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This was an investigation of powdery mildew disease in peas to test a hypothesis formulated on the probability of change in nitrogen fixation and nodulation due to applied molybdenum and iron. The objective of this field experiment was to work out the effect of various concentrations of molybdenum and iron on the productivity, modulation, and nitrogen absorption of pea plants (*Pisum sativum* L.) under two varieties namely Medawar-I and Zeena Park-I situated at Agriculture Research Station Swabi during the years 2011 and 2012. Initial rates of 25 N, 60 P_2O_5, and 60 K_2O were applied randomly within full blocks with split-plot designs and replication. According to the results, the greatest yield and yield metrics, nodule counts, and nitrogen absorption were noted in the treatment plots when Fe 2.0 and Mo 0.50 kg ha^{-1} were administered concurrently for both kinds. Compared to the Zeena Park-I variety of pea, the Metawar-I variety showed much higher grain output, nodulation, and nitrogen uptake. This difference may have resulted from the variety with optimal treatments showed better performance. Instead of the plant's ability to generate maximal modulation and uptake of nitrogen, the Medawar-I variety efficiently utilized applied nutrients for improved productivity. This difference may have resulted from the plant's ability to generate maximal modulation and uptake of nitrogen. Further, there was correlation made in the present study regarding the number of nodules and the nitrogen content of the two types of plants. During the experiment, it was proven that these two variables were directly proportional the rate at which the number of nodules that were produced increased as well as the rate of nitrogen accumulation in the plants. The fact that N concentration increases in a manner analogous to that of Fe concentration in plant leaves suggests that Fe was crucial to the pea crop. Deposition of nitrogen. The current research indicates that sufficient levels of iron and molybdenum are crucial for obtaining the highest possible yield, nodules, and nitrogen absorption in leguminous crops.
Keywords: *Pisum sativum* L., molybdenum, iron, yield and nodulation, powdery mildew disease, nitrogen uptake, nitrogen fixation.

INTRODUCTION

Globally, peas (*Pisum sativum* L.) are farmed for their grains and fresh vegetables. After common beans and soybeans, peas are the third-largest crop of legume grains worldwide (Vaughan et al., 2005). The species is produced to produce split peas and other dry peas, as well as fresh, frozen, or canned vegetables. However, from the perspective of genetics and nutritional management, more concerted and sustained efforts are required to enhance peas. The quality and productivity of the pea cultivars grown by Pakistani vegetable producers are not comparable to those grown in developed nations (Khokhar et al., 1988). Legumes, such as peas, are legume crops that fix nitrogen in their root nodules. This process is dependent on several variables, including molybdenum and iron nutrition, which are essential for the symbiotic nitrogen fixation of legumes. Many living organisms, including plants, require molybdenum, a trace element found in soil. Molybdenum serves as a co-factor for various plant enzymes involved in reduction and oxidation processes, like other essential metals necessary for plant growth (Mendel & Hansch, 2002). Being an essential part of

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the enzymes nitrate reductase and nitrogenase, it helps plants absorb nitrogen by reducing inorganic nitrate, converting N_2 to NH_3, and promoting nodulation. Molybdenum is essential for nitrogen fixation in legumes, according to Meagher et al. (1991) and Brkic et al. (2004). Furthermore, plants that form symbiotic relationships with nitrogen-fixing bacteria, such as Rhizobium, require molybdenum. Ascorbic acid synthesis and iron bioavailability are processes in which it participates as an enzyme component of specific nitrogenase enzymes found in bacteria (Katyal & Randhawa, 1983). Although the molybdenum itself does not exhibit biological activity, it is primarily found as a critical component of an organic protein complex called the molybdenum co-factor (Moco). Moco binds to molybdoenzymes, which are required for various biological processes in prokaryotes, plants, and mammals (Williams & Silva, 2002). Research indicates that molybdenum is essential for nitrogenizing and nitrate reeducates enzyme activity in plants (Westermann, 2005). Pea productivity is significantly impacted by various fungal infections, including powdery mildew (PM), which is predominantly caused by species of the genus Erysiphe (order Erysiphales, family Erysiphaceae). Although the order Erysiphales encompasses around 400 species and approximately 19-22 recognized taxa, The Erysiphe genus can be the largest, and most pathogenic species are part of this genital. These obligate bio trophic parasites infect approximately 10,000 species of angiosperms which include grains, pulses, fruits, vegetables and ornamental crops. Most of these fungal species are host-specific, in that they infect plants preferentially, and this implies that there is a specific pathogenesis-related (PR) gene. In plants, this condition can be easily diagnosed by the emergence of white to grey, powdery-like structures grown on different parts of vegetable crops such as peas as well as identification of the organisms liable for such disease.

Similarly, iron is important for the prothectic group (haem or haemin) in several enzyme systems. The respiratory metabolism of live cells within the hemoglobin is controlled by cytochromes. The essential roles that Fe plays in all aspects of plant metabolism are highlighted by its participation in photosynthesis, NO_2 and SO_4^{-2} reduction, and N_2 assimilation. The iron enzyme ferredoxin controls oxidation-reduction processes. Chlorophyll is produced in part by iron, and iron-sensitive crops growing on calcareous soils can easily be identified as having iron chlorosis. Numerous enzymes involved in energy transmission, nitrogen reduction and fixation, and lignin production also include iron. Although iron is not a component of chlorophyll, it is necessary for its production. Accordingly, plants with low iron levels are chlorotic (Katyal & Randhawa, 1983) and lack chlorophyll. Because of insufficient chlorophyll levels, yellow leaves are the primary sign of iron deficiency. In interveinal tissues, leaf yellowing initially manifests itself on the younger top leaves. When leaves are severely iron deficient, they turn yellow or nearly white; when they die, they turn brown.

The enzyme nitrogenase, which is crucial for biological nitrogen fixation, relies on molybdenum as a key microelement. The Fe protein, which comprises iron and protein, and the Mo-Fe protein, which comprises molybdenum, iron, and protein, are the two components that make nitrogenize, as stated by Brkic et al. (2004). The same holds for crops that are symbiotic to Rhizobium bacteria. These crops need larger amounts of molybdenum. According to Kim et al. (1992), nitrogenase is a two-component complex enzyme. One component contains iron and molybdenum, while the other component contains simply iron. The reduction of N_2 and H_2 requires both components and can be used up to 28 moles of ATP every mole of N_2 is reduced. Molybdenum is an essential component of the nitrogenize enzyme, which is essential for efficient N_2 fixation in the legume-Rhizobium symbiosis. Additionally, Meagher et al. (1991) highlighted the importance of iron in the N_2-fixation process.

The production of grain legumes, particularly pea crops, is often hindered by the limited availability of molybdenum and iron in calcareous-alkaline soils. Since the efficiency of N_2-fixation is influenced by molybdenum and iron deficiencies in natural conditions in leguminous crops such as peas is not clearly understood, a field study was carried out in a field plot at the Agricultural Research Station in Sawabi. The experiment was on the premise of the general hypothesis that both molybdenum and iron applications affect nodulation with a resultant effect on nitrogen fixation on pea crops. The objectives of this experiment were to 1) ascertain how applied iron and molybdenum affect various pea crop types, yields and yield components, 2) investigate how applied iron and molybdenum affect pea variety root nodulation, and 3) determine how applied iron and molybdenum affect pea types 'and powdery mildew disease's ability to absorb nitrogen.

MATERIALS AND METHODS

***Experimental description*:** In November 2011, a field experiment was carried out at the Agricultural Research Station, Swabi, to investigate the impact of iron and molybdenum on the N-Fixation of two pea varieties, namely Metewar-I and Zena Park-I. Three replications of the split-plot layout and randomized full-block design were used to sow the pea seeds. A 15 m2 plot was maintained. Every plot had three rows with a row-to-row spacing of thirty centimeters and a plant-to-plant spacing of twenty centimeters. Different concentrations of iron (0, 2, and 5 kg ha^{-1}) and molybdenum (0, 0.25, and 0.5) were applied as sodium molybdate and iron sulfate, respectively. Before planting, a base dosage of 25 N, 60 P_2O_5, and 60 K_2O kg ha^{-1} was administered in the form of potassium sulfate, urea, and single super phosphate. Before applying fertilizer, a composite soil sample was taken to assess the test soil's intended nutritional status as well as its physico-chemical properties. Every cultural custom was followed when it was necessary. During field and lab research, the following parameters' data were noted:

- Days to flowering
- Days of seedling emergence
- Number of nodules plant^{-1}
- Number of pods plant^{-1}
- Number of seeds pod^{-1}
- 100 seeds plot^{-1}
- Seed yield plot^{-1} and powdery mildew disease
- N uptake by plant
- Fe uptake by plant

Table 1. Treatments layout in the field.

Treatments	Fe (kg ha^{-1})	Mo (kg ha^{-1})
T1	0	0
T2	0	0.25
T3	0	0.5
T4	2	0
T5	2	0.25
T6	2	0.5
T7	5	0
T8	5	0.25
T9	5	0.5

***Estimation of N-fixation*:** After counting the nodules and oven-drying the plant materials at 65 degrees Celsius, they were weighed, and their N content was measured. The equation of Mary et al. (1995) was used to determine the amount of N-fixed and the % of N obtained from biological fixation.

***Leaf analysis*:** Fully formed leaves from each treatment plot of randomly chosen plants were harvested at the blooming stage to measure the concentrations of elements N, Mo, and Fe. After being cleaned with distilled water and wiped with tissue paper, fresh leaves were allowed to air dry in the shade. After 48 hours at 700C in the oven, the samples were dried to a consistent weight. The leaves were first diced using a small grinder, and then they were subjected to a technique for wet acid digestion (Benton et al., 1991).

***N concentration*:** Mulvaney (1996) describes the use of the micro Kjeldhal equipment to measure the total-N content in leaves. After it cooled, a combination of 1.1 g of K_2SO_4, $CuSO_4$, and Se in a ratio of 100:10:1 was added to 0.2 g of plant leaf material for digestion. The next step was to use 3 mL of concentrated H_2SO_4 to digest the sample. The digest was then distilled using an indicator solution that consisted of 5 mL of boric acid and 20 mL of 40% NaOH. The liquid underwent titration with 0.005 M HCl.

$$\text{Total N (\%)} = \frac{(\text{Sample} - \text{Blank}) \times 0.005 \times 0.014 \times 100 \times 100}{\text{Weight of plant sample} \times 20}$$

Fe concentration: Using an atomic absorption spectrophotometer, the content of iron in pea leaves in the digested sample was measured (Perkin Elmer 2380) Nitric acid and perchloric acid were used to digest a 0.25 g sample in accordance with Walsh & Beaton's (1977).

Statistical analysis: ANOVA was used to do the statistical analysis of the data, and the LSD-test of significance was used to quantify the treatment differences. Furthermore, the link between fixed-N in plants, Mo-Fe levels in plants, and N absorption by plant leaves and nodules in roots was determined using multiple regression models (Steel et al., 1997).

RESULTS AND DISCUSSION

A field experiment on yield, nodulation, and nitrogen uptake by peas (*Pisum sativum* L.) as influenced by applied molybdenum and iron was carried out under agro-climatic conditions of Swabi during the season of 2011-2012. The test verities were Metawar-I and Zeena Park-I. The experimental soil's physico-chemical properties (Table 2) reveal that it had a loamy sand texture, was moderately calcareous, non-saline by nature, had a low organic matter content, and was slightly deficient in accessible nitrogen, but had appropriate amounts of soluble Fe, the values as reported by Katyal & Randhawa (1983).

Table 2. Physico-chemical characteristics of the experimental soil.

Properties	Units	Values
Sand	%	76.21
Silt	%	21.42
Clay	%	2.37
Textural class	-	Loamy sand
$pH_{s\ (1:5)}$	-	6.86
$EC_{s\ (1:5)}$	dSm^{-1}	0.11
Lime	%	8.13
Organic matter	%	0.78
Total mineral nitrogen (NH_4+NO_3-N)	%	0.75
Iron	µg kg^{-1}	108.0

***Days to emergence*:** The yield and nutrient absorption by the plant are directly impacted by seed emergence. Table 4.2a contains information on the number of days till germination from the date of sowing. Metawar-I took the longest (8.7 days) compared to Zeena Park-I, and this variation is most likely caused by genetic factors or the effects of the climate, such as constant rainfall on crop types, rather than a nutritional issue with the seed. However, it took longer for both pea kinds to emerge in the treatment plot without any molybdenum supplied.

Table 3. Application of iron and molybdenum and its impact on the number of days till pea emergence (*P. sativum* L.) crop.

Varieties	Mo (kg ha^{-1})	Fe (kg ha^{-1}) 0	2	5	Mean
Meta war-I	0	8.00	8.33	8.67	8.33
	0.25	8.67	7.67	8.00	8.11
	0.5	8.67	8.67	8.33	8.56
Zeena park-I	0	8.67	7.67	8.33	8.22
	0.25	8.00	7.33	7.67	7.67
	0.5	8.67	7.67	8.00	8.11
	0	8.33	8.00	8.50	8.28
	0.25	8.33	7.50	7.83	7.89
	0.5	8.67	8.17	8.17	8.33
Meta war-I		8.44	8.22	8.33	8.33
Zeena park-I		8.44	7.56	8.00	8.00
Mean		8.44	7.89	8.17	

LSD value of P< 0.05 for varieties = 0.28

Nenova (2006) found that the development rate and physiological components were affected by varying iron levels, which ranged from toxicity to total deficiency. Data on seedling emergence was obtained following four days of seeding. Environmental variables such as continuous rain and lack of sunlight during the experiment caused a delay in emergence.

Results showed that the emergence percentage increased from 5 to 9 days due to the application of iron and molybdenum, but 7 and 9 days showed statistical significance while the remaining days such as 5, 6 and 8 revealed a non-significant effect on emergence due to Fe and Mo application (Table 4). The data on days to emergence revealed that the emergence rate in the Fe and Mo plots was superior to the plots that did not receive any Fe and Mo fertilizer, as seen in Figure 1. Moreover, there was a significant difference recorded between the varieties, the variety Metawar-I emergence percentage was more as compared to Zena park-I, and similar results were found by Tahir et al. (2007).

***Days to flowering*:** Table 5 contains the statistics about the number of days till blossoming. The number of days to blooming differed greatly between the iron and molybdenum treatments, according to the results. When Fe 2 and Mo 0.25 kg ha^{-1} were administered, the smallest number of days until flowering (73 days) was observed, whereas the greatest number of days (78 days) was recorded in the control group. Furthermore, there were statistically no variations in the number of days till blooming amongst pea kinds. The more current study by Tahir et al. (2011) supports these findings. The results also showed that the absence of molybdenum shortened the number of days needed for pea crop blossoming in treatment plots when it was not administered. Nautiyal et al. (2005) and Truong et al. (1993) both observed similar observations. They noted that pollen grain viability and formation are known to be disrupted by reduced molybdenum availability. In the end, there were less blooms overall, both in terms of quantity and size, and as a result, there were fewer seeds produced. Additionally, the results demonstrated that there was no statistically significant varietal variation in the number of days till blooming. In general, the variety Metawar-I took longer than Zeena Park-I to blossom, which might be because of genetic differences rather than crop-related effects from nutrition or weather. Additionally, flowering has a direct impact on plant output and nutrient absorption. Following 68 days of seeding, the blooming data were recorded. Table 5 shows that the percentage of flowering days increased from 68 to 73 days after iron and molybdenum application; however, there was no statistical significance on days 68, 70, and 73, and a significant effect on emergence on days 69, 71, and 72. Figure 1 shows that compared to plots that did not receive fertilizer, plants that were treated with iron and molybdenum had substantially increased emergence rates (days to flowering data). Comparable results were found by Truong & Duthion (1993).

Table 4. Effect of iron and molybdenum application on the % seedling emergence of pea (*P. sativum* L.) Crop.

Verities	Treatments Fe (kgha^{-1})	Mo	D5	D6	D7	D8	D9
Metawar-I	0	0	24.7	42.3	65.3	79.0	88.0
		0.25	21.0	41.0	67.7	78.0	89.3
		0.5	23.3	45.7	68.0	82.0	89.3
	2	0	24.7	39.7	69.0	79.3	87.7
		0.25	37.5	51.5	69.0	84.5	88.0
		0.5	24.3	43.7	68.3	79.3	90.0
	5	0	24.0	42.7	70.0	80.0	87.0
		0.25	22.7	43.3	66.3	77.0	87.7
		0.5	24.0	43.3	70.0	81.3	89.7
Zeena park-I	0	0	28.0	47.0	72.7	71.7	82.7
		0.25	25.7	48.0	70.3	75.3	89.7
		0.5	30.0	46.7	70.0	74.0	88.7
	2	0	26.3	49.0	71.3	73.7	87.7
		0.25	28.7	48.7	65.3	76.0	86.3
		0.5	27.3	48.7	69.7	76.7	89.7
	5	0	27.0	48.0	73.3	74.0	88.0
		0.25	26.7	49.3	67.7	74.3	87.3
		0.5	27.3	49.7	72.0	77.3	89.3
LSD (P<0.05)			NS	NS	2.25	NS	2.03
% CV			15.47	11.99	9.19	6.27	0.26

NS= Non-significant

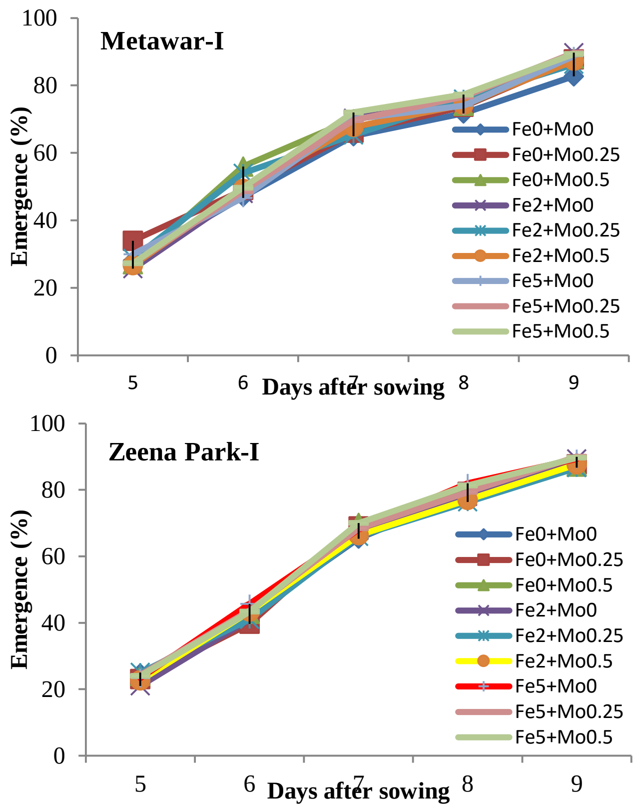

Figure 1. Effect of applied molybdenum and iron on the % seedling emergence of pea (*P. sativum* L.).

Table 5. Effect of iron and molybdenum application on the days to flowering of pea.

Varieties	Mo (kg ha^{-1})	Fe (kg ha^{-1}) 0	2	5	Mean
Meta war-I	0	78.00	75.00	76.00	76.33
	0.25	75.00	73.00	74.33	74.11
	0.5	75.67	75.00	76.67	75.78
Zeena park-I	0	75.33	74.33	74.67	74.78
	0.25	74.67	73.00	73.67	73.78
	0.5	75.33	73.33	75.00	74.56
	0	76.67	74.67	75.33	75.56a
	0.25	74.83	73.00	74.00	73.94b
	0.5	75.50	74.17	75.83	75.17ab
Meta war-I		76.22	74.33	75.67	75.41
Zeena park-I		8.44	75.11	73.56	74.44
Mean		8.44	75.67a	73.94b	75.06ab

LSD value of P< 0.05 for Fe = 0.90; LSD value of P< 0.05 for Mo = 6.52

Pods per plant: The information on plant-1's number of pods is shown in Table 9. The quantity of pods per plant varied significantly amongst the different iron-molybdenum treatments, according to the results. On the other hand, less pods plant^{-1} (12.7) and (7) were noted in control, while more pods (26.5) and (9.6) were discovered in the treatment plot, where Fe 2 and Mo 0.25 kg ha^{-1} were treated for both kinds. Applied Mo had a highly significant effect on pod plant^{-1} as reported by Wazir (2018) who also productivity noted. The results showed that Metawar-I, a more prolific variety,

Table 6. Effect of iron and molybdenum on the days to flowering of pea (*Pisum sativum* L.) crop.

Verities	Treatments Fe (kgha^{-1})	Mo	D68	D69	D70	D71	D72	D73
Metawar-I	0	0	14.7	28.0	39.0	56.0	65.7	88.0
		0.25	16.3	27.0	37.0	55.7	68.7	87.3
		0.5	17.0	27.0	37.0	55.3	66.7	87.7
	2	0	15.3	26.7	36.7	54.7	68.7	89.3
		0.25	25.0	37.5	50.0	81.0	73.0	89.5
		0.5	16.0	26.7	35.7	55.0	68.0	85.7
	5	0	15.7	26.7	39.7	55.3	67.7	87.0
		0.25	16.0	27.0	35.7	56.7	66.3	87.7
		0.5	16.3	28.0	38.3	57.7	68.3	87.0
Zeena park-I	0	0	18.0	28.0	39.0	57.0	71.0	78.0
		0.25	15.7	27.0	41.7	56.3	66.0	81.7
		0.5	17.7	27.0	44.0	54.7	68.7	80.3
	2	0	15.7	26.7	48.3	53.3	68.3	79.0
		0.25	14.3	25.0	48.0	55.0	77.0	81.3
		0.5	16.0	26.7	49.0	56.0	74.7	81.7
	5	0	16.0	26.7	43.0	56.7	64.0	80.3
		0.25	16.0	27.0	45.3	56.3	69.7	80.7
		0.5	17.0	28.0	42.7	58.3	72.0	79.3
LSD (P<0.05)			NS	1.66	NS	1.87	3.23	NS
% CV			16.81	7.88	6.37	4.87	2.90	3.09

NS = Non-significant

produced a bigger yield under experimental circumstances, as it performed better in terms of pods plant^{-1} compared to Zeena park-I.

Table 7. Effect of iron and molybdenum application on pods plant^{-1} of pea (*Pisum sativum* L.) crop.

Varieties	Mo (kg ha^{-1})	Fe (kg ha^{-1}) 0	2	5	Mean
Meta war-I	0	12.67	17.00	15.67	15.11
	0.25	14.00	17.67	17.33	16.33
	0.5	16.00	16.33	17.00	16.44
Zeena park-I	0	7.00	8.67	8.67	8.11
	0.25	8.33	9.67	9.33	9.11
	0.5	8.00	9.00	9.00	8.67
	0	9.83	12.83	12.17	11.61
	0.25	11.17	13.67	13.33	12.72
	0.5	12.00	12.67	13.00	12.56
Meta war-I		14.22	17.00	16.67	15.96
Zeena park-I		8.44	7.78	9.11	9.00
Mean		8.44	11.00b	13.06a	12.83a

LSD value of $P< 0.05$ for Fe = 1.22; LSD value of $P< 0.05$ for varieties = 0.48

***Seeds pod^{-1} powdery mildew disease*:** Table 8 provides information regarding the number of seeds per pod. The number of seeds per pod changes drastically when treated with iron and molybdenum. However, when both pea varieties were treated with Fe 2 and Mo 0.25 kg ha^{-1}, the treatment plot showed an increase in seeds per pod, whereas the control plot showed a decrease.

Table 8. Effect of iron and molybdenum application on seeds pod^{-1} of pea (*Pisum sativum* L.) crop.

Varieties	Mo (kg ha^{-1})	Fe (kg ha^{-1}) 0	2	5	Mean
Meta war-I	0	6.33	7.67	7.33	7.11
	0.25	7.33	8.67	5.33	7.11
	0.5	8.00	8.00	8.00	8.00
Zeena park-I	0	5.33	7.00	7.33	6.56
	0.25	7.33	9.00	8.33	8.22
	0.5	7.33	8.67	8.00	8.00
	0	5.83	7.33	7.33	6.83b
	0.25	7.33	8.83	6.83	7.67ab
	0.5	7.67	8.33	8.00	8.00a
Meta war-I		7.22	8.11	6.89	7.41
Zeena park-I		8.44	6.67	8.22	7.89
Mean		8.44	6.94b	8.17ab	7.39b

LSD value of $P< 0.05$ for Fe = 0.93; LSD value of $P< 0.05$ for Mo = 5.94

The current results clearly show that both kinds require a normal level of Fe and Mo to increase the number of seeds pod$^{-1.}$ Additionally, the results demonstrated that there is no significant difference between the kinds concerning seeds pod^{-1}, suggesting that the pea crops nourished with Fe and Mo were similarly affected. Additionally, the data corroborated the results of Tahir et al. (2011).

***100 seeds weight*:** Hundred-grain weight is a measure that indicates the extent of seed development out of which grain yield of the crop can be predicted. Data analysis indicated that various Fe and Mo concentrations did not significantly affect the 100-grain weight (Table 9). The mean values of the data showed that the higher grain weight 117g, and 92. 6g were obtained from a treatment plot whose seeds were sown in a treatment plot containing Fe 2 and Mo 0. In the corresponding treatments, 25 kg ha^{-1} was applied, while a lighter grain of = 103. 3g, and = 85. 3 g were harvested for the two varieties of pea crops in the control. These outcomes revealed that either nil or excess Fe and Mo lowered the 100-grain weight compared with those plots that received the standard amount of Fe and Mo. From all the plots it is also clear that not all could have big variations in the 100-grains weight. Previous research by Nautiyal & Chatterjee (2005), who noted that leguminous plants are very sensitive to Mo impacts, but that too much Mo may hinder growth and reduce crop seed output, supports our findings. The Metawar-I variety of peas often had heavier seeds than the Zeena park-I type, according to the results. This phenomenon is explained by the genetic makeup of the various pea kinds.

Table 9. Effect of iron and molybdenum application on 100 seeds weight of pea (*Pisum sativum* L.) crop.

Varieties	Mo (kg ha^{-1})	Fe (kg ha^{-1}) 0	2	5	Mean
Meta war-I	0	103.33	108.00	115.00	108.78
	0.25	108.67	115.33	114.67	112.89
	0.5	111.00	114.67	113.00	112.89
Zeena park-I	0	89.67	86.00	88.67	88.11
	0.25	91.33	92.67	91.00	91.67
	0.5	85.33	91.67	89.33	88.78
	0	96.50	97.00	101.83	98.44
	0.25	100.00	104.00	102.83	102.28
	0.5	98.17	103.17	101.17	100.83
Meta war-I		107.67	112.67	114.22	111.52
Zeena park-I		88.78	90.11	89.67	89.52
Mean		98.22	101.39	101.94	

LSD value of $P< 0.05$ for variety = 0.594

***Grain yield*:** The results indicate that there are notable variations in grain yield amongst the pea types (Table 10). The treatment plot containing Fe 2 and Mo 0.25 kg ha^{-1} recorded the maximum grain production of 9799 kg ha^{-1} and 3866.7 kg ha^{-1}, respectively, whereas the Metawar-I and Zeena park-I types of pea crop recorded the minimum grain yield of 6667 kg and 2400 kg, respectively. According to these findings, the greatest grain yield was obtained above and below the normal level of Fe and Mo, and below this level, the grain production in both pea types was severely reduced.

Interestingly, the pea variety Metawar-I produced six times as much as Zeena park-I. This trait of the variety Metawar-I is not solely ascribed to genetic development; it might also be the result of unfavorable environmental factors. For example, the Zeena park-I variety did poorly in the experiment owing to unsuitable climatic circumstances. Additionally, in addition to the Zeena park-I variety's poor growth performance, this may also be seen from the decreased nodule development and negligible nitrogen uptake, which eventually impacted the pea crop's overall grain production.

Table 10. Impact of applying iron and molybdenum on pea grain yield (*Pisum sativum* L.) crop.

Varieties	Mo (kg ha^{-1})	Fe (kg ha^{-1}) 0	2	5	Mean
Meta war-I	0	6666.6	6858.8	6784.6	6770.0
	0.25	6673.7	6533.3	6866.6	6691.2
	0.5	6422.2	6733.3	6777.7	6644.4
Zeena park-I	0	2400.0	2666.6	3600.0	2888.9
	0.25	2777.7	3577.8	3622.2	3325.9
	0.5	3622.2	2866.6	3577.7	3355.5
	0	4533.3	4762.7	5192.3	4829.4
	0.25	4725.7	5055.5	5244.4	5008.6
	0.5	5022.2	4800.0	5177.7	5000.0
Meta war-I		6587.5	6708.5	6809.7	6701.9
Zeena park-I		2933.3	3037.0	3600.0	3190.1
Mean		4760.4c	4872.7b	5204.8a	

LSD value of P< 0.05 for Fe = 516.4; LSD value of P< 0.05 for variety = 2404.7

***Nutrient contents in plant leaves and Nitrogen concentration*:** To determine the amount of nitrogen fixed by the plant, which may be used for sowing in the following season, the nitrogen content of plant leaves was examined during the blooming stage. The concentration of N in plant leaves rose as the quantities of Fe and Mo fertilizers were raised, according to the results (Table 11). The results showed that the minimum N concentrations in Metawar-I and Zeena Park-I varieties were 0.30% and 1.17%, respectively, whereas the maximum concentrations in the treatment plot, where Fe 2 and Mo 0.25 kg ha^{-1} were administered, were 4.95% and 3.62%, respectively. The findings also demonstrated that, for both pea types, no treatment plot was discovered to be N-deficient about the threshold values published by Westermann (2005) and Kaiser et al. (2005). This is solid proof that there is still enough N_2 in the pea plant leaves, as appropriate nutritional levels are necessary for seed germination. Furthermore, plants grown on nutrient-rich media generate greater biomass, which improves their ability to absorb nutrients from the soil. The most well-known effect of iron and molybdenum is on legumes' ability to fix N_2 (Kaiser et al., 2005).

The results also indicated that there were not many variations in the N-contents of the two types and that the N-concentration increased in both in a manner akin to the growth in Fe concentration in plant leaves, indicating that Fe was likely a major factor in the N-fixation process by the pea crop. These findings are consistent with the earlier research conducted by Kaiser et al. (2005). Additionally, plant nitrogen and iron were regressed against one another in the current study (Figure 1), and it was shown that when plant iron rose, plant N concentration increased linearly in both pea crop kinds. However, because of the little variance in the Fe-content of pea leaves, the association between the Zeena Park-I variety and the Metawar-I variety was not statistically significant.

Table 11. Impact of applying iron and molybdenum on pea N content (*Pisum sativum* L.) crop.

Varieties	Mo (kg ha^{-1})	Fe (kg ha^{-1}) 0	2	5	Mean
Meta war-I	0	0.30	1.94	2.40	1.55
	0.25	0.93	3.30	3.60	2.61
	0.5	2.31	3.70	3.45	3.15
Zeena park-I	0	1.17	2.22	2.67	2.02
	0.25	2.64	3.62	3.33	3.20
	0.5	3.10	3.43	3.18	3.24
	0	0.74	2.08	2.54	1.78b
	0.25	1.79	3.46	3.47	2.90a
	0.5	2.71	3.57	3.32	3.20a
Meta war-I		1.18	2.98	3.15	2.44
Zeena park-I		2.30	3.09	3.06	2.82
Mean		1.74b	3.03b	3.11a	

LSD value of P< 0.05 for Fe = 0.48; LSD value of P< 0.05 for Mo = 2.77; LSD value of P< 0.05 for Fe x Varieties = 0.83

***Fe concentration*:** The findings demonstrated that the quantities of Fe and Mo fertilizers had a substantial impact on the Fe content in plant leaves (Table 12). The treatment plot, where Fe 2 and Mo 0.25 kg ha^{-1} were applied concurrently, has the highest Fe content of 268. For the control group, there was the lowest concentration, which was 118 µg g^{-1} in both the stem and the leaves of the plant whereas the second group's concentration was 8 µg g^{-1} in the stem and 15 µg g^{-1} in the leaves of the plant and the third group had a concentration of 152 µg g^{-1} in the leaves of the plant. At 8 µg g^{-1} and 87. 9 µg g^{-1}. These were the mean values of the data: The level of ferritin in the leaves of both types of peas has increased significantly with the increase of the applied Fe and Mo. However, the observed increase in the Fe concentration in plant leaves with an increase in Fe and Mo levels may be attributed to the synergistic effect of Fe and Mo within the plants.

This conclusion is backed by earlier studies done by Zaroug & Munns (1997). Pea leaf iron concentration increased, which was another finding. Results also showed that neither pea variety was found to be Fe-deficient in either treatment plot. According to the data, the increase in Fe-concentration in plant leaves is correlated with a corresponding increase in N-concentration, suggesting that Fe was an essential component in N-fixation by pea crop (Zaroug & Munns, 1997) found. In general, the pea variety Metawar-I had a higher concentration of Fe than Zeena park-I, suggesting that Metawar-I was more effective than Zeena park-I in absorbing the Fe nutrients.

Table 12. Effect of iron and molybdenum application on Fe µg g^{-1} by pea (*Pisum sativum* L.) crop.

Varieties	Mo (kg ha^{-1})	Fe (kg ha^{-1}) 0	2	5	Mean
Meta war-I	0	118.87	137.73	137.73	131.44
	0.25	138.43	179.23	179.47	165.71
	0.5	157.10	189.47	177.47	174.68
Zeena park-I	0	87.97	94.00	102.00	94.66
	0.25	94.53	152.67	154.33	133.84
	0.5	94.27	140.33	149.33	127.98
	0	103.42	115.87	119.87	113.05b
	0.25	116.48	165.95	166.90	149.78a
	0.5	125.68	164.90	163.40	151.33a
Meta war-I		138.13	168.81	164.89	157.28
Zeena park-I		92.26	129.00	135.22	118.83
Mean		115.19b	148.91a	150.06a	

LSD value of P< 0.05 for Fe = 7.82; LSD value of P< 0.05 for Mo = 167.9; LSD value of P< 0.05 for Varieties = 19.43; LSD value of P< 0.05 for Fe x Mo = 13.54

***Conclusion*:** The injection of iron and molybdenum to both pea types had a substantial effect on days to bloom, but no significant effect on days to seedling emergence. In contrast to other treatment plots or the control, seed emergence and flowering took the fewest number of days in those treatment plots when Fe 2 and Mo 0.25 kg ha^{-1} were treated. The application of Fe 2 and Mo 0.25 kg ha^{-1} significantly enhanced the grain production in both types, Metewar-I and Zena park-I, although the difference did not reach statistical significance. Additionally, it was observed that the pea variety Zeena park-1 produced almost six times less than that of Metewar-I. The treatment plots with Fe 2 and Mo 0.25 kg ha^{-1} applied to both kinds had the highest number of nodules, whereas the control group had the fewest nodules with no application of Fe or Mo. In general, the Metawar-I variety outperformed the Zeena park-I variety in terms of nodulation and N-uptake. According to these findings, the Zeena Park-I cultivar used less N than the Meta war-I type. During the flowering stage, the nitrogen concentration in the leaves of both the Melewar-I and Zena Park-I cultivars increased in response to elevated soil levels of iron and molybdenum. Both kinds' increases in N concentration followed a similar pattern, and the changes in N content were not particularly substantial. This suggests that Fe was probably a major element in the N-fixation process by the pea crop. Equally striking was the correlation between the application of Fe and Mo to both pea varieties and a corresponding spike in leaf Fe concentration. Overall, the iron content was higher in Metawar-I peas compared to Zeena park-I peas, indicating that Meta war-I was more efficient at absorbing the iron elements. After applying Fe 2 kg ha^{-1} and Mo 0.25 kg ha^{-1} under the experimental circumstances, the overall findings indicated that variety Metewar-I outperformed variety Zeena Park-I in terms of grain production, nodule count, and nitrogen absorption.

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***SDGs addressed*:** Zero hunger, good health and well-being.

***Policy referred*:** National Micronutrient Fertilization Policy; Sustainable Soil Fertility and Integrated Nutrient Management (INM) Policies; Climate-Smart Agriculture and Sustainable Crop Production Policies; Integrated Disease Management (IDM) Policy Guidelines.

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