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Effect of nitrogen and molybdenum on crop growth, yield and soil properties of pea in acid soil (*Pisum sativum* L.)

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Abstract
A field experiment entitled "Effect of Nitrogen and Molybdenum on Crop growth, yield and soil properties of Pea (*Pisum sativum* L.) in acid soil" was carried out at the research field of Central Agricultural University, Iroishemba, Imphal, Manipur during the Rabi season of 2019 - 2020. The experiment was laid out in Factorial Randomized Block Design (FRBD) with 3 replications. There were 16 treatments combinations in the experiment consisting of 4 levels of nitrogen (N1, N2, N3, N4) *viz*., 0, 10, 20, 30 kg/ha and 4 levels of molybdenum (M1, M2, M3, M4) *viz*., 0, 0.4, 0.8, 1.2 kg/ha. The results revealed that application of nitrogen level N3 (20 kg N/ha) and molybdenum level M3 (0.8 kg Mo/ha) significantly increased crop growth, yield parameters, nutrient content in plants and in post- harvest soil.

Keywords: Nitrogen, molybdenum, pea, growth, yield

Introduction
Garden pea (*Pisum sativum* L.) is one of the most widely spread legume crops. It belongs to the family of Leguminosae and subfamily of Papilionoideae. It is a cold climate crop which can self-pollinate itself and can also be grown in tropical countries in the winter season. Garden pea is the second most important leguminous crop in the world (Pawar *et al.*, 2017) [11]. In India it is cultivated usually as a cold season crop in Northern India plains and as a summer crop in hilly regions. It is believed to have originated from Ethiopia, part of Europe and Asia as reported by Choudhary (1967) [4]. Garden pea occupies an approximated area of 540 thousand hectares having a production of 5427 thousand tonnes of grain throughout India (Anonymous, 2017) [1]. It is largely cultivated in Jaipur, Baran, Bundi, Kota and Bharatpur districts of Rajasthan. Garden pea has been a restorer of soil fertility due to their unique ability of symbiotic nitrogen fixation (Rana *et al*., 1998) [14]. As a nitrogen-fixing crop with a high assimilating capacity in the roots, it uses the chemical compounds having low solubility and low accessibility to cereals from the cultivated soil layer or from deeper layers. As a preceding crop, it can facilitate an increase in the efficiency of organic matter utilisation by subsequent crops like grain and cash crops. Cultivation of this crop is a highly profitable business and also very attractive to the farmers due to its short durability. Nitrogen is one of the major elements for growth and development of a crop plants (Tanaka *et al.*, 1984) [16]. It is an essential element during synthesis of chlorophyll, enzymes and proteins in plants. It is also a component of amino acid-the building blocks of proteins. Nitrogen plays a key role in various physiological processes. It imparts dark green colour in plants, initiates rapid early growth and improves the capacity to fix the atmospheric nitrogen symbiotically. It promotes the growth and development of leaves, stem and other vegetative parts. It also increases the protein content in harvested peas. Nitrogen utilisation efficiency depends on the soil-N content and method of its application. Nitrogen application to leguminous crops at lower doses in the initial stage is essential for vigorous start. Molybdenum (Mo) is an essential micronutrient with an important role in nitrogen (N) metabolism and protein synthesis in plants. Mo acts as a co-factor for nitrogenase enzymes to catalyse the redox reaction to convert the elemental nitrogen (N) into ammonium (NH4+) ions during symbiotic nitrogen fixation (Mendel and Hänsch 2002) [9].

and nitrate reductase enzymes which are required for the assimilation of soil nitrates. As a result plant N metabolism is closely related to the Mo concentration in soil, especially for leguminous crops (Mendel and Hänsch 2002) [9]. Due to this relationship, Mo-deficient legumes results in an unusual proliferation of nodules, leading to nitrogen (N) deficiency (Marschner 2011) [8].

Materials and Methods

The experiment was carried out at the research field of Central Agricultural University, Iroishemba, Imphal, Manipur during the Rabi season of 2019 - 2020. The climatic condition of Imphal is sub- tropical. The experiment comprised of 16 treatments combinations in the experiment consisting of 4 levels of nitrogen (N1, N2, N3, N4) *viz*., 0, 10, 20, 30 kg/ha and 4 levels of molybdenum (M1, M2, M3, M4) *viz*., 0, 0.4, 0.8, 1.2 kg/ha and were laid out in Factorial Randomized Block Design (FRBD) with three replications. According to the treatment the full quantity of the nitrogen, molybdenum, phosphorus and potassium were applied during final land preparation in the form of Urea, Ammonium molybdate, Single Super Phosphate, Muriate of potash, respectively. The seeds (cv. Arkel) were sown in rows of 30 cm and plant to plant distance maintain at 15 cm.Observations on plant height, number of branches/plant were taken at 30, 45, 60, 75DAS and at maturity whereas pod length, number of pods/plant, number of seeds/pod, green pod yield (t/ha) were taken at harvest. N, P, K and S content in plants were analysed and the post- harvest soil was analysed for physical and chemical properties. The data obtained from the experiments will be analyzed with the help of Analysis of variance technique.

Table 1: Physio-chemical parameters of the initial soil of the experiment

Parameters	Value	Status
A. Physical properties		
1. Soil texture i) Sand (%) ii) Silt (%) iii) Clay (%)	18.3 30 51.7	Clay
B. Chemical properties		
1. pH	5.4	Acidic
2. Organic carbon (%)	1.32	High
3. Available N (kg/ha)	250.88	Medium
4. Available P2O5 (kg/ha)	18.12	Medium
5. Available K2O (kg/ha)	238.42	Medium
6. Available Sulphur (mg/kg)	17.66	High
7. Available Molybdenum (mg/kg)	0.025	Low

Results and Discussion

Growth parameters

Effect of nitrogen

At 30DAS and 45DAS the maximum plant height 13.80 cm and 32.96 cm were recorded in the treatment N3 (20 kg N/ha) which were statistically at par with N4 (30 kg N/ha). In case of 60DAS, 75DAS and at maturity the maximum plant height 43.51 cm, 53.62 cm and 65.52 cm were recorded in the treatment N4 (30 kg N/ha) and for 60DAS it was statistically at par with N3 (20 kg N/ha). While the minimum plant height were recorded in N1 (control) treatment. Singh *et al.* (2015) [15] obtained the maximum plant height of pea by the application of 30 kg N/ha which supports the present findings. The maximum number of branches per plant (5.93, 10.03 and 16.53) were obtained from the treatment N4 (30 kg N/ha) which were statistically at par with N3 (20 kg N/ha) at 30DAS, 60DAS and at maturity. For 45DAS and 75DAS, the maximum number of branches per plant (7.51 and13.08) were recorded in the treatment N3 (20 kg N/ha) which were statistically at par with N4 (30 kg N/ha). Whereas, the minimum number of branches per plant was observed in the control treatment N1.This result are in agreement to the findings obtained by Singh *et al.* (2015) [15].The increase in growth parameters by the application of nitrogen may be due to increase in amount of growth substances and naturally occurring phytohormone. Probably, the increase in auxin supply with increasing supply of nitrogen brought about increase in the growth parameters. One of the main functions of nitrogen is the initiation of meristematic activity of plant. The cell division and enlargement are also accelerated by ample supply of nitrogen. Thus, the growth of plant by and large depends on nitrogen.

Effect of Molybdenum

The maximum plant height 13.68 cm, 33.25 cm, 43.78 cm, 53.75 cm, 65.60 cm were recorded in the treatment M4 (1.2 kg Mo/ha) and the minimum plant height were found in M1 (control) treatment at 30, 45, 60, 75 DAS (Days after sowing) and at maturity. The result of this finding are in agreement with studies done by Hirpara *et al.* (2019) [6]. And the highest number of branches per plant 5.98, 7.78, 10.25, 13.26, 16.65 were recorded from the treatment M4 (1.2 kg Mo/ha) and the lowest number of branches per plant were found from the treatment M1 (control) at 30, 45, 60, 75 DAS and at maturity. Hirpara *et al*. (2019) [6] recorded the highest number of number of branches per plant with the application of 1kg Mo/ha. Molybdenum is a constituent of enzyme nitrogenase, which is required for the process of nitrogen fixation, it is also a constituent of enzyme nitrate reductase which is responsible for the reduction of nitrates to ammonia in plant resulting into increased amino acid and protein synthesis in cell of plant, causing better growth of plant.

Yield parameters

Effect of nitrogen

Application of nitrogen level N3 (20 kg N/ha) observed the maximum pod length (9.69 cm) and number of seeds per pod (6.40) while, the highest number of pods per plant (10.76) and green pod yield (6.82 t/ha) were obtained from the nitrogen level N4 (30 kg N/ha) and it was statistically at par with the nitrogen level N3 (20 kg N/ha). However, the lowest pod length, number of pods per plant, number of seeds per pod, green pod yield were found in the nitrogen level N1 (control). Similar results were also reported by Bunker *et al*. (2018) [3] on garden pea. The increase in yield parameters was probably due to source and sink relationship. Due to the improvement in photosynthesis and carbohydrate metabolism results in greater formation of photosynthates and metabolites in source and later on translocated in the newly formed sinks i.e, reproductive structures (flowering and seed setting) which ultimately increased yield attributing characters.

Effect of molybdenum

The maximum pod length (9.56 cm), maximum number of pods per plant (10.85), highest number of seeds per pod (6.35) and maximum green pod yield (6.74 t/ha) were recorded from the plants which was treated with molybdenum level M3 (0.8 kg Mo/ha) and the lowest pod length, minimum number of pods per plant, lowest number of seeds per pod and minimum green pod yield were found from the plants which was treated with molybdenum level M1 (control). This result are in agreement to the findings obtained by Rabbi *et al.* (2011) [13]. The increase in yield attributing characters with application of molybdenum might be due to its unique role in enhanced nitrogen fixation, thereby increasing availability to the plants for better growth and development.

Nutrient content in plants
Effect of nitrogen
Application of nitrogen level N3 (20 kg N/ha) produced the highest N, P, K and S content in plants and for N, P, S content in plants was statistically at par with the treatment N4. The lowest N, P, K and S content in plants were obtained from the nitrogen level N1 (control). Similar results was observed by Bunker (2018) [3] with the application of 20 kg N/ha on garden pea. These results are in harmony with the findings of Nasreen and Farid (2003) [10]. This might be due to the increase availability of nutrient in the root zone as well as in the plant system. Increase availability of nutrient in the root zone coupled increase metabolic activity at cellular level probably might have increased the nutrient uptake which reflect nutrient content in plants.

Effect of molybdenum
Molybdenum level M3 (0.8 kg Mo/ha) gave the highest N, P, K and S content in plants and for P content in plants it was at par with M4. While, the lowest N, P, K and S content in plants were obtained from the molybdenum level M1 (control). These results are in close conformity with the findings of Nasreen and Farid (2003) [10]. This might be due to the application of higher level of molybdenum which enhances biological nitrogen fixation and vegetative growth of the plant so, the uptake of nutrient was more which reflect nutrient content in plants.

Post- harvest soil status of available nutrients
Effect of nitrogen
Application of nitrogen level N4 (30 kg N/ha) gave the highest soil pH (6.04), maximum available nitrogen (428.71 kg/ha), maximum available molybdenum (0.088 mg/kg) and highest organic carbon (1.64%). However, the highest available phosphorus (29.05 kg/ha), highest available potassium (265.78 kg/ha), highest available sulphur (18.91 mg/kg) were obtained in the nitrogen level N1 (control). For available nitrogen and available molybdenum it was at par with N3. The lowest soil pH, organic carbon (%), available nitrogen (kg/ha), available molybdenum were found in the nitrogen level N1 (control) and the lowest available phosphorus (kg/ha), available potassium (kg/ha), available sulphur (mg/kg) were obtained from the nitrogen level N4 (30 kg N/ha). However, the effect of different level of nitrogen on soil texture (sand, silt and clay %) was found non- significant. Increase in soil pH might be due to formation of bicarbonate when urea is added to the soil which then reacts with H^+ ions in soil solution and increases soil pH. Bull *et al*. (1964) [2] postulated that urea at high concentrations drastically reduces the activity of hydrogen ions, leaving the activities of other ions more or less unchanged. Hossain (2007) [7] observed highest soil pH with the application of 40 kg N/ha. Urea application increases the biomass of most group of saprotrophic microorganisms, thereby accelerating litter decomposition which leads to increase in organic carbon. Similar observation was done by Hossain (2007) [7]. Application of lowest dose of nitrogen or control (where no nitrogen was applied) decreased vegetative growth and as a result low phosphorus, potassium, sulphur uptake from soil. Whereas, higher nitrogen dose increased vegetative growth and uptake of phosphorus, potassium, sulphur was more and residual available nutrients was less in post- harvest soil. These observations are in close conformity with the findings of *Rabbi et al*. (2011) [13]. Application of higher level of nitrogen in soil solution which also promotes the nitrogen fixation by pea crop thereby, increasing residual nitrogen content in soil. Availability of Mo increases with the application of nitrogen, this might be due to increase of pH with the application of higher level of nitrogen in the form of urea. As availability of molybdenum has a positive relation with soil pH.

Effect of molybdenum
Molybdenum level M4 (1.2 kg Mo/ha) produced the highest soil pH (6.08), available molybdenum (0.091 mg/kg), highest organic carbon (1.60%) and the highest available nitrogen (433.86 kg/ha) were noted in the molybdenum level M3 (0.8 kg Mo/ha). While, the highest available phosphorus (28.24 kg/ha), highest available potassium (257.18 kg/ha), highest available sulphur (18 mg/kg) were obtained in the molybdenum level M1 (control).For soil pH it was at par with M3 and for available nitrogen it was at par with M4.The lowest soil pH, available molybdenum (mg/kg), organic carbon (%), available nitrogen (kg/ha) were noted in the molybdenum level M1 (control) while, the lowest available phosphorus (kg/ha), available potassium (kg/ha), available sulphur (mg/kg) were obtained in the molybdenum level M4 (1.2 kg Mo/ha). Different levels of molybdenum on soil texture (sand, silt and clay %) was found non- significant. Similar observation was obtained by Hossain (2007) [7] for soil pH. Application of molybdenum increases residual organic carbon, this might be due to positive relation between molybdenum and organic carbon. A definite fraction of molybdenum is associated with soil organic matter (Grigg, 1953) [5]. Hossain (2007) [7] observed highest organic carbon (%) with the application of 0.5 kg Mo/ha. Application of molybdenum to the soil increases the symbiotic nitrogen fixation of the plant which leads to increase in availability of residual nitrogen in soil. These results are in agreement with the findings of Hirpara *et al.* (2019) [6]. Control or lowest dose of molybdenum decreased vegetative growth and as a result low phosphorus, potassium, sulphur uptake from soil. Whereas, higher molybdenum dose increased vegetative growth and uptake of phosphorus, potassium, sulphur was more and residual available nutrients was less in post -harvest soil. And it may be due to the antagonistic effect of molybdenum and sulphur which reduces residual sulphur content in soil at higher dose of molybdenum. Similar observation was given by Rabbi *et al*. (2011) [13]. Increased concentration of added molybdenum in the soil solution increases the residual molybdenum in soil.Hirpara *et al.* (2019) [6] observed the highest residual molybdenum content in soil with the application of 1 kg Mo/ha.

Table 2a: Effect of nitrogen on plant height at 30, 45, 60, 75 DAS and at maturity

Nitrogen levels (kg/ha)	30 DAS	45 DAS	60 DAS	75DAS	At maturity
N1	12.41	29.03	39.16	49.82	61.44
N2	13.08	31.53	41.96	52.00	63.72
N3	13.80	32.96	43.39	52.74	64.28
N4	13.64	32.94	43.51	53.62	65.52
SE d (±)	0.14	0.21	0.27	0.19	0.29
CD (0.05)	0.28	0.43	0.55	0.39	0.59

Table 2b: Effect of molybdenum on plant height at 30, 45, 60, 75 DAS and at maturity

Molybdenum Levels (kg/ha)	30 DAS	45 DAS	60 DAS	75DAS	At maturity
M1	12.48	29.44	39.90	50.27	61.46
M2	13.15	31.28	41.78	51.74	63.62
M3	13.62	32.50	42.55	52.42	64.28
M4	13.68	33.25	43.78	53.75	65.60
SE d (±)	0.14	0.21	0.27	0.19	0.29
CD (0.05)	0.28	0.43	0.55	0.39	0.59

Table 3a: Effect of nitrogen on number of branches per plant at 30, 45, 60, 75 DAS and at maturity

Nitrogen levels (kg/ha)	30 DAS	45 DAS	60 DAS	75DAS	At maturity
N1	5.33	6.38	8.51	11.50	14.56
N2	5.66	6.96	9.21	12.20	15.43
N3	5.90	7.51	9.91	13.08	16.50
N4	5.93	7.50	10.03	13.06	16.53
SE d (±)	0.09	0.07	0.09	0.08	0.08
CD (0.05)	0.18	0.14	0.18	0.15	0.15

Table 3b: Effect of molybdenum on number of branches per plant at 30, 45, 60, 75 DAS and at maturity

Molybdenum levels (kg/ha)	30 DAS	45 DAS	60 DAS	75DAS	At maturity
M1	5.38	6.40	8.46	11.56	14.76
M2	5.61	6.93	9.20	12.23	15.61
M3	5.85	7.25	9.76	12.78	16.00
M4	5.98	7.78	10.25	13.26	16.65
SE d (±)	0.09	0.07	0.09	0.08	0.08
CD (0.05)	0.18	0.14	0.18	0.15	0.15

Table 4a: Effect of nitrogen on pod length, number of pods per plant, number of seeds per pod and green pod yield

Nitrogen levels (kg/ha)	Pod length (cm)	Number of pods per plant	Number of seeds per pod	Green pod yield (t/ha)
N1	6.78	7.80	5.25	4.77
N2	8.35	9.28	5.86	5.40
N3	9.69	10.73	6.40	6.81
N4	9.52	10.76	6.08	6.82
SE d (±)	0.02	0.07	0.05	0.10
CD (0.05)	0.05	0.13	0.11	0.21

Table 4b: Effect of molybdenum on pod length, number of pods per plant, number of seeds per pod and green pod yield

Molybdenum levels (kg/ha)	Pod length (cm)	Number of pods per plant	Number of seeds per pod	Green pod yield (t/ha)
M1	6.72	7.66	5.23	4.87
M2	8.74	9.61	5.78	5.82
M3	9.56	10.85	6.35	6.74
M4	9.33	10.45	6.23	6.38
SE d (±)	0.02	0.07	0.05	0.10
CD (0.05)	0.05	0.13	0.11	0.21

Table 5a: Effect of nitrogen on N, P, K and S content in plants

Nitrogen levels (kg/ha)	N in plants (%)	P in plants (%)	K in plants (%)	S in plants (%)
N1	1.69	0.162	0.505	0.368
N2	1.87	0.177	0.538	0.464
N3	2.05	0.217	0.644	0.514
N4	2.03	0.217	0.591	0.513
SE d (±)	0.02	0.007	0.005	0.005
CD (0.05)	0.04	0.014	0.010	0.011

Table 5b: Effect of molybdenum on N, P, K and S content in plants

Molybdenum levels (kg/ha)	N in plants (%)	P in plants (%)	K in plants (%)	S in plants (%)
M1	1.72	0.148	0.493	0.398
M2	1.78	0.193	0.544	0.460
M3	2.09	0.222	0.640	0.517
M4	2.04	0.208	0.601	0.484
SE d (±)	0.02	0.007	0.005	0.005
CD (0.05)	0.04	0.014	0.010	0.011

Table 6a: Effect of nitrogen on soil pH and Sand, Silt and Clay (%) at post - harvest soil

Nitrogen levels (kg/ha)	Soil pH	Sand%	Silt%	Clay%	Textural class
N1	5.76	18.55	30.15	51.30	CLAY
N2	5.94	18.44	30.21	51.34	CLAY
N3	5.98	18.56	30.24	51.19	CLAY
N4	6.04	18.46	30.20	51.32	CLAY
SE d (±)	0.05	0.08	0.18	0.16	
CD (0.05)	0.10	NS	NS	NS	

Table 6b: Effect of molybdenum on soil pH and Sand, Silt and Clay (%) at post - harvest soil

Molybdenum levels (kg/ha)	Soil pH	Sand%	Silt%	Clay%	Textural class
M1	5.77	18.52	30.14	51.33	CLAY
M2	5.86	18.47	30.30	51.22	CLAY
M3	6.00	18.52	30.03	51.44	CLAY
M4	6.08	18.50	30.34	51.15	CLAY
SE d (±)	0.05	0.08	0.18	0.16	
CD (0.05)	0.10	NS	NS	NS	

Table 6c: Effect of nitrogen on organic carbon, nitrogen, phosphorus, potassium, sulphur and molybdenum content in post- harvest soil

Nitrogen level (kg/ha)	Organic Carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)	Available Sulphur (mg/ kg)	Available Molybdenum (mg/ kg)
N1	1.37	303.16	29.05	265.78	18.91	0.056
N2	1.48	365.94	26.36	239.93	17.09	0.068
N3	1.57	407.76	22.77	215.85	15.26	0.084
N4	1.64	428.71	17.09	192.63	13.43	0.088
SE d (±)	0.01	18.40	0.28	2.26	0.18	0.002
CD (0.05)	0.02	37.57	0.56	4.61	0.37	0.004

Table 6d: Effect of molybdenum on organic carbon, nitrogen, phosphorus, potassium, sulphur and molybdenum content in post- harvest soil

Molybdenum level(kg/ha)	Organic Carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)	Available Sulphur mg/ kg	Available Molybdenum (mg/ kg)
M1	1.40	313.72	28.24	257.18	18.00	0.051
M2	1.51	339.77	25.20	242.63	16.52	0.070
M3	1.56	433.86	21.91	220.06	15.60	0.083
M4	1.60	418.23	19.92	194.32	14.59	0.091
SE d (±)	0.01	18.40	0.28	2.26	0.18	0.002
CD (0.05)	0.02	37.57	0.56	4.61	0.37	0.004

Conclusion

From the results of the present investigation, it can be concluded that individual effect of nitrogen and molybdenum on crop growth, yield, nutrient content in plants and chemical properties of post -harvest soil was found positive and significant. The highest yield was found in application of N @ 20 kg N/ha and Mo @ 0.8 kg Mo/ha.

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