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

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Abstract
This article presents a study on growth, yield and soil properties of Pea in acid soil as influenced by the interaction effect of Nitrogen and Molybdenum. The field experiment was conducted 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 three replications comprised of 4 levels of nitrogen (N_1, N_2, N_3, N_4) *viz*., 0, 10, 20, 30 kg/ha and 4 levels of molybdenum (M_1, M_2, M_3, M_4) *viz*., 0, 0.4, 0.8, 1.2 kg/ha at various growth stages. The study showed that the interaction effect of nitrogen and molybdenum produced significant effect on plant height, number of branches per plant, pod length, number of pods per plant, number of seeds per pod, green pod yield (t/ha), nutrient content in plants and in post- harvest soil. However, soil pH, organic carbon, available nitrogen (kg/ha), soil texture (sand, silt, clay %) found non- significant in post- harvest soil. From the results of the present investigation, combined application of N @ 20 kg N/ha and Mo @ 0.8 kg Mo/ha was the most suitable doses for better crop yield.

Keywords: Pea, nitrogen, molybdenum, yield, growth

Introduction
Pisum sativum is an annual plant with a life cycle of one year. It is a cool- season vegetable crop grown in many parts of the world for its fresh, shelled green seeds rich in proteins, vitamins and minerals. India rank second next to China both in terms of area and production (FAO, 2012) [3]. It is grown in an area of 0.42mha with the production of 4.01 million metric tonnes and productivity of 9.5 t/ha in India. It belongs to the family leguminosae and originated in the near East. As it is an leguminous crop, it enriches the soil by fixing atmospheric nitrogen in the soil and restricts soil erosion by providing and effective cover to the land. Peas are well-Known to leave behind residual nitrogen of about 50-60 kg/ha in the soil apart from meeting its own nitrogen requirement. Improving the yield of garden pea can be done by proper nutrient management and genetic makeup of the variety. Fertilizers play an important role on growth and productivity of garden pea.

Molybdenum is an essential component of the major enzyme nitrate reductase in plants. It is also a structural component of nitrogenase, the enzyme actively involved in nitrogen fixation by root-nodule bacteria of leguminous crops. Molybdenum (Mo) is responsible for formation of nodule tissue and increase nitrogen fixation (Sharma *et al*., 1988) [8]. Arnon and Stout (1939) [2] first demonstrated the requirement of molybdenum for plant growth using tomato grown hydroponically. Most crops require molybdenum concentrations less than 1ppm. The plant takes up molybdenum in the form of molybdate anions (MoO_4^{2-} and $HMoO^{4-}$) which are the predominant species in soil solution. It has a significant effect on pollen formation, so fruit and grain formation are affected in molybdenum deficient plants. Deficiency symptoms in legumes are mainly exhibited as nitrogen deficiency symptoms because of the primary role of molybdenum in nitrogen fixation. Legumes and pulses can produce active nodules only when soils are properly supplied with molybdenum (Ahmed, 1982) [1]. Furthermore Mo availability is also reduced in acidic soil.

Nitrogen is one of the most important primary nutrient non-metal elements which requires large quantity for the plant growth and nutrition. It is an essential constituent of proteins and is present in many other compounds of great physiological importance in plant metabolism e.g. nucleotides, phosphatides, alkaloids, enzymes, hormones, vitamins etc. Nitrogen is an integral part of chlorophyll and also imparts vigorous vegetative growth dark green colour to plants.

It also improves the capacity to fix the atmospheric nitrogen symbiotically. Nitrogen application to leguminous crops at lower doses in the initial stage is essential for vigorous start. The capacity for nitrogen fixation was reported to be ranging between 64-121kg/ha (Rennie and Kemp, 1983) [7]. Sun and Liu (2000) [9] reported that pea crop having enough formation of nodules can fix approximately 75 kg N/ha. The amount of fixed nitrogen varies with the type of cultivation method of pea, the soil type, the presence of indigenous available nitrogen in the soil and other environmental conditions. Deficit of nitrogen would result in poor growth and stunting of plants (Makasheva, 1983) [11] and consequently reduction to crop yields (Machler *et al*., 1988; Radin *et al*., 1988) [10, 6].

Materials and Method

The climatic condition of the experimental field is Sub-tropical. The mean maximum and minimum temperature recorded during the cropping season was 23.25 and 8.4 ºC, respectively. The rainfall recorded was 3.3 mm. The average relative humidity in 700h was 88.5% and in 1300h was 43%. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications. The experimental plot was first divided into six blocks. Each block consisted of 8 units of plots. The unit plot size of the field was $9m^2$. The soil of the experimental field was clayey (sand 18%, silt 30% and clay 51.7%) in texture, acidic in soil reaction (pH 5.4), high in organic carbon (1.32%), available sulphur (17.66 mg/kg), medium in available nitrogen (250.88 kg/ha), available phosphorus (18.12 kg/ha), available potassium (238.42 kg/ha) and low in available molybdenum 0.025 (mg/kg).The experiment comprised of 4 levels of nitrogen (N_1, N_2, N_3, N_4) *viz*., 0, 10, 20, 30 kg/ha and 4 levels of molybdenum (M_1, M_2, M_3, M_4) *viz*., 0, 0.4, 0.8, 1.2 kg/ha to form 16 treatments combinations. According to the treatment the full dose of the nitrogen, phosphorus, potassium and molybdenum were applied in each plot during final land preparation in the form of Urea, Single Super Phosphate, Muriate of potash, Ammonium molybdate respectively. Seeds were sown at the spacing of 30 cm row to row and 15 cm plant to plant. The data on plant height, number of branches/plant were taken at 30, 45, 60, 75 DAS 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. With the help of Analysis of variance technique the data obtained from the experiments will be analyzed.

Results and Discussion

Interaction effect of Nitrogen and Molybdenum on growth parameters

The combined application of nitrogen and molybdenum had significant effect on plant height. At 30DAS the maximum plant height (14.10 cm) was observed in the treatment T_{15} (N_4M_3 kg ha^{-1}) which was statistically at par with T_{11} (N_3M_3 kg ha^{-1}) while, the minimum plant height (10.98 cm) was found in T_1 (control) treatment. The maximum plant height 34.24 cm, 45.59 cm, 55.64 cm, 67.24 cm was attained in the treatment combination T_{16} (N_4M_4 kg ha^{-1}) at 45, 60, 75 DAS (Days after sowing) and at maturity however, for 45 DAS and 60 DAS it was statistically at par with T_{11} (N_3M_3 kg ha^{-1}) and the minimum plant height 25.26 cm, 34.53 cm, 46.50 cm, 56.67 cm was found in control treatment (T_1) combination. These results are in agreement to the findings obtained by Rabbi *et al.* (2011) [5]. Number of branches per plant was found non - significant by the interaction of nitrogen and molybdenum at 30DAS. However, at 45, 60, 75DAS and at maturity number of branches per plant was significantly influenced by the interaction of nitrogen and molybdenum. At 30DAS, the maximum number of branches per plant (6.20) was noticed where plants was fertilized with T_{12} (N_3M_4 kg ha^{-1}) which was at par with T_{16} (N_4M_4 kg ha^{-1}) and the lowest number (4.80) was recorded in control treatment. In case of 45 DAS, the highest number of branches per plant was attained in the treatment T_{16} (N_4M_4 kg ha^{-1}) which was statistically at par with the treatment T_{12} (N_3M_4 kg ha^{-1}) and lowest number was recorded in the control treatment. For 60 DAS, 75 DAS and at maturity the highest number of branches per plant 11.06, 14.13, 17.73 were found in the treatment while, the lowest number 7.66, 10.60, 13.33 were obtained in the control treatment. These results are in agreement to the findings obtained by Rabbi *et al.* (2011) [5]. 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. Molybdenum is an essential element; it is a constituent of the nitrogenase enzyme, and every bacteria which fixes nitrogen needs molybdenum during the fixation processes. Molybdenum was required for normal plant growth, reduction supply with molybdenum to the growth medium decreased activities of nitrate reductase and glutamine synthetase involved at initial steps of nitrate assimilation (Hristozkova *et al*. 2006) [4]. So, application of both nitrogen and molybdenum has positive influence on plant height and number of branches per plant.

Interaction effect of Nitrogen and Molybdenum on Yield parameters

The interaction effect of different level of nitrogen and molybdenum on yield parameters were found to be significant. Plant which is fertilized with the treatment combination N_3M_3 kg ha^{-1} (T_{11}) obtained the highest pod length (10.83), highest number of pods per plant (12.60), maximum number of seeds per pod (7.00) and maximum number of green pod yield (8.06 t/ha). While the lowest pod length (5.74), lowest number of pods per plant (6.66), minimum number of seeds per pod (4.66) and minimum green pod yield (3.88 t/ha) were observed on the control treatment T_1 (N_1M_1 kg ha^{-1}). Similar observations was given by Rabbi *et al*. (2011) [5] on garden pea. These may be the result of 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 the yield attributing characters.

Interaction effect of Nitrogen and Molybdenum on nutrient content in plants

The interaction effect of nitrogen and molybdenum on nutrient content in plants was found to be significant. It was observed that the plants which was treated with N_3M_3 kg ha^{-1} (T_{11}) was found the highest N, P, K and S content in pea plants. While, the lowest N, P, K and S content in pea plants was found in the control treatment T_1. Nasreen and Farid (2003) [12] observed highest nitrogen, phosphorus, potassium,

sulphur content in plants with the application of 30 kg N/ha + 1 kg Mo/ha. 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. Increased accumulation of nutrients in vegetative plant parts associated with improved metabolism led to greater translocation of these nutrients to reproductive structures of the crop.

Table 1: Interaction effect of nitrogen and molybdenum on plant height at 30, 45, 60, 75 DAS and at maturity

Nitrogen x Molybdenum (kg/ha)	30 DAS	45 DAS	60 DAS	75DAS	At maturity
N1M1	10.98	25.26	34.53	46.50	56.67
N1M2	12.54	29.34	39.48	50.05	61.28
N1M3	12.88	29.73	40.34	50.44	62.74
N1M4	13.23	31.79	42.28	52.31	65.09
N2M1	12.40	29.10	39.66	50.16	61.81
N2M2	12.95	30.95	42.18	52.40	63.69
N2M3	13.53	33.26	43.48	52.47	64.49
N2M4	13.46	32.83	42.53	52.96	64.91
N3M1	13.57	32.24	43.03	51.88	63.41
N3M2	13.56	32.44	42.70	51.85	63.88
N3M3	13.97	33.06	43.11	53.15	64.65
N3M4	14.08	34.13	44.70	54.10	65.17
N4M1	12.96	31.18	42.38	52.56	63.96
N4M2	13.55	32.41	42.77	52.65	65.64
N4M3	14.10	33.96	43.28	53.62	65.23
N4M4	13.95	34.24	45.59	55.64	67.24
SE d (±) for treatment combination	0.28	0.42	0.54	0.39	0.58
CD (0.05) for Treatment combination	0.57	0.87	1.11	0.79	1.19
CD (0.05) for Interaction (MXN)	0.57	0.87	1.11	0.79	1.19

Table 2: Interaction effect of nitrogen and molybdenum on number of branches per plant at 30, 45, 60, 75 DAS and at maturity

Nitrogen x Molybdenum (kg/ha)	30 DAS	45 DAS	60 DAS	75DAS	At maturity
N1M1	4.80	5.60	7.66	10.60	13.33
N1M2	5.26	6.40	8.13	11.40	14.53
N1M3	5.46	6.66	8.93	11.73	14.86
N1M4	5.80	6.86	9.33	12.26	15.53
N2M1	5.53	6.40	8.26	11.33	14.86
N2M2	5.53	6.73	9.06	11.86	15.33
N2M3	5.80	7.20	9.60	12.66	15.66
N2M4	5.80	7.53	9.93	12.93	15.86
N3M1	5.53	6.80	8.60	11.93	15.40
N3M2	5.80	7.33	9.73	12.86	16.26
N3M3	6.06	7.60	10.26	13.40	16.60
N3M4	6.20	8.33	11.06	14.13	17.73
N4M1	5.66	6.80	9.33	12.40	15.46
N4M2	5.86	7.26	9.86	12.80	16.33
N4M3	6.06	7.53	10.26	13.33	16.86
N4M4	6.13	8.40	10.66	13.73	17.46
SE d (±) for treatment combination	0.17	0.14	0.17	0.15	0.15
CD (0.05) for Treatment combination	0.35	0.28	0.36	0.31	0.31
CD (0.05) for Interaction (MXN)	NS	0.28	0.36	0.31	0.31

Table 3: Interaction effect of nitrogen and molybdenum on pod length, number of pods per plant, number of seeds per pod and green pod yield

Nitrogen x Molybdenum (kg/ha)	Pod length (cm)	Number of pods per plant	Number of seeds per pod	Green pod yield (t/ha)
N_1M_1	5.74	6.66	4.66	3.88
N_1M_2	6.72	7.66	5.13	4.66
N_1M_3	7.44	8.46	5.73	5.37
N_1M_4	7.22	8.40	5.46	5.19
N_2M_1	6.47	7.53	5.26	4.74
N_2M_2	8.25	9.60	5.73	5.46
N_2M_3	9.42	10.13	6.13	5.82
N_2M_4	9.28	9.86	6.33	5.59
N_3M_1	7.43	8.20	5.66	5.30
N_3M_2	10.00	10.33	6.26	6.48
N_3M_3	10.83	12.60	7.00	8.06
N_3M_4	10.52	11.80	6.66	7.42
N_4M_1	7.25	8.26	5.33	5.57
N_4M_2	9.99	10.86	6.00	6.69
N_4M_3	10.54	12.20	6.53	7.70
N_4M_4	10.32	11.73	6.46	7.33
SE d (±) for Treatment combination	0.04	0.13	0.11	0.20
CD (0.05) for Treatment combination	0.09	0.27	0.22	0.41
CD (0.05) for Interaction (MXN)	0.09	0.27	0.22	0.41

Table 4: Interaction effect of nitrogen and molybdenum on N, P, K and S content in plants

Nitrogen x Molybdenum (kg/ha)	N in plants (%)	P in plants (%)	K in plants (%)	S in plants (%)
N1M1	1.62	0.083	0.433	0.313
N1M2	1.64	0.177	0.470	0.367
N1M3	1.78	0.197	0.593	0.397
N1M4	1.72	0.190	0.523	0.393
N2M1	1.69	0.123	0.457	0.333
N2M2	1.83	0.183	0.520	0.497
N2M3	2.01	0.207	0.597	0.517
N2M4	1.96	0.193	0.577	0.510
N3M1	1.76	0.187	0.563	0.457
N3M2	1.82	0.203	0.613	0.500
N3M3	2.34	0.247	0.707	0.587
N3M4	2.28	0.230	0.693	0.513
N4M1	1.82	0.200	0.517	0.487
N4M2	1.84	0.210	0.573	0.477
N4M3	2.24	0.237	0.663	0.567
N4M4	2.22	0.220	0.610	0.520
SE d (±)for Treatment combination	0.04	0.013	0.010	0.011
CD (0.05) for Treatment combination	0.08	0.028	0.021	0.022
CD (0.05) for Interaction (MXN)	0.08	0.028	0.021	0.022

Interaction effect of Nitrogen and Molybdenum on soil-properties in post-harvest soil

The interaction effect of Nitrogen and Molybdenum on soil pH, soil texture (sand, silt and clay %), organic carbon (%), available nitrogen (kg/ha) was found non - significant. However, the interaction effect of nitrogen and molybdenum

on available phosphorus, potassium, sulphur and molybdenum were found significant. The highest available phosphorus, potassium, sulphur content were obtained from the soil where no nitrogen and molybdenum were applied i.e., from control treatment (T_1). While, the lowest available phosphorus, potassium and sulphur content in soil were observed in the treatment T_{16} (N_4M_4 kg ha^{-1}). It might be due to low phosphorus, potassium and sulphur uptake from the soil due to control or lowest dose of nitrogen and molybdenum which decreased the vegetative growth of the crop. Whereas, higher nitrogen and molybdenum dose increased vegetative growth and uptake of phosphorus, potassium and sulphur were more and residual available phosphorus, potassium and sulphur were less in post -harvest soil. These results are in agreement with the findings given by Rabbi *et al.* (2011) [5].

The maximum available molybdenum content in soil was observed from the soil which was treated with the treatment T_{16} (N_4M_4 kg ha^{-1}). It was statistically at par with the treatment T_{12} (N_3M_4 kg ha^{-1}). While, the minimum available molybdenum content in soil was found under control treatment (T_1). Application of nitrogen and molybdenum in the form of urea and ammonium molybdate increases soil pH which leads to increase in residual molybdenum content in soil as availability of molybdenum has a positive relation with soil pH.

Table 5: Interaction effect of nitrogen and molybdenum on soil pH and Sand, Silt and Clay (%) at post - harvest soil

Nitrogen x Molybdenum (kg/ha)	Soil pH	Sand%	Silt%	Clay %	Textural class
N1M1	5.54	18.56	29.90	51.53	CLAY
N1M2	5.68	18.53	30.40	51.06	CLAY
N1M3	5.84	18.50	29.96	51.53	CLAY
N1M4	6.00	18.60	30.33	51.06	CLAY
N2M1	5.77	18.53	30.10	51.36	CLAY
N2M2	5.89	18.33	30.33	51.33	CLAY
N2M3	6.01	18.63	29.93	51.43	CLAY
N2M4	6.07	18.26	30.50	51.23	CLAY
N3M1	5.85	18.53	30.30	51.16	CLAY
N3M2	5.93	18.60	30.33	51.06	CLAY
N3M3	6.04	18.53	30.10	51.36	CLAY
N3M4	6.12	18.60	30.23	51.16	CLAY
N4M1	5.95	18.46	30.26	51.26	CLAY
N4M2	5.96	18.43	30.13	51.43	CLAY
N4M3	6.11	18.43	30.13	51.43	CLAY
N4M4	6.14	18.53	30.30	51.16	CLAY
SE d (±)for Treatment combination	0.10	0.16	0.37	0.32	
CD (0.05) for Treatment combination	0.20	0.32	0.75	0.66	
CD (0.05) for interaction (MXN)	NS	NS	NS	NS	

Table 6: Interaction effect nitrogen and molybdenum on organic carbon, nitrogen, phosphorus, potassium, sulphur and molybdenum content in post- harvest soil

Nitrogen x Molybdenum (kg/ha)	Organic Carbon (%)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)	Available Sulphur (mg/ kg)	Available Molybdenum (mg/ kg)
N_1M_1	1.23	271.83	33.30	300.16	20.85	0.030
N_1M_2	1.35	292.46	31.07	288.12	19.03	0.050
N_1M_3	1.42	334.66	26.62	262.04	18.57	0.063
N_1M_4	1.50	313.71	25.21	212.80	17.20	0.080
N_2M_1	1.34	292.79	30.26	268.36	18.12	0.042
N_2M_2	1.49	313.71	27.42	252.32	17.66	0.070
N_2M_3	1.53	418.19	24.39	232.95	16.72	0.078
N_2M_4	1.56	439.10	23.38	206.08	15.89	0.083
N_3M_1	1.47	334.66	27.03	242.94	17.66	0.063
N_3M_2	1.56	355.58	24.19	221.76	15.38	0.080
N_3M_3	1.63	480.85	21.35	203.84	14.47	0.095
N_3M_4	1.65	459.94	18.53	194.88	13.56	0.098
N_4M_1	1.56	355.58	22.37	217.28	15.38	0.070
N_4M_2	1.64	397.34	18.12	208.31	14.01	0.082
N_4M_3	1.68	501.76	15.29	181.44	12.64	0.097
N_4M_4	1.71	460.18	12.59	163.51	11.72	0.102
SE d (±) for treatment combination	0.02	36.79	0.55	4.52	0.36	0.004
CD (0.05) for treatment combination	0.04	75.13	1.13	9.23	0.75	0.008
CD (0.05) for Interaction (MXN)	NS	NS	1.13	9.23	0.75	0.008

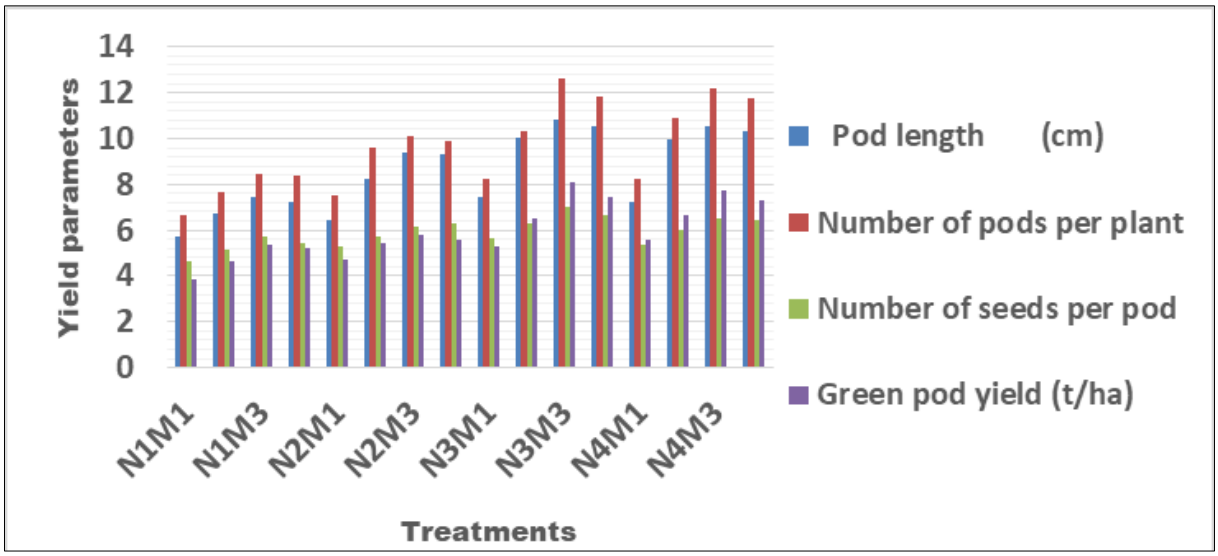

Fig 1: Interaction effect of nitrogen and molybdenum on pod length, number of pods per plant, number of seeds per pod and green pod yield

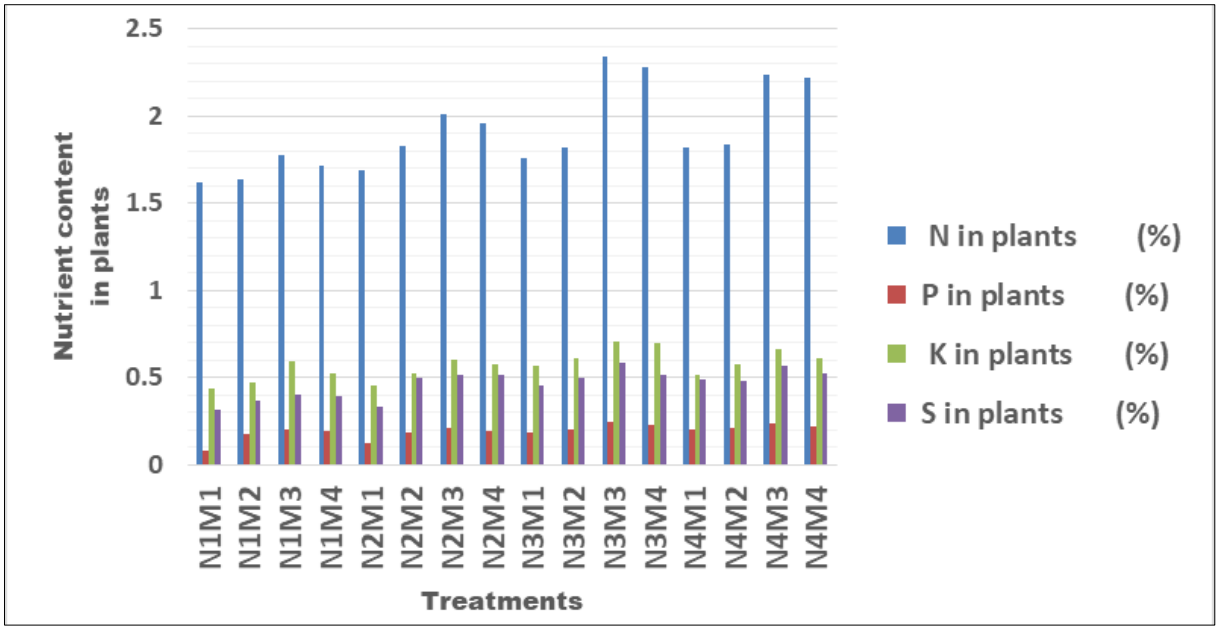

Fig 2: Interaction effect of nitrogen and molybdenum on N, P, K and S content in plants

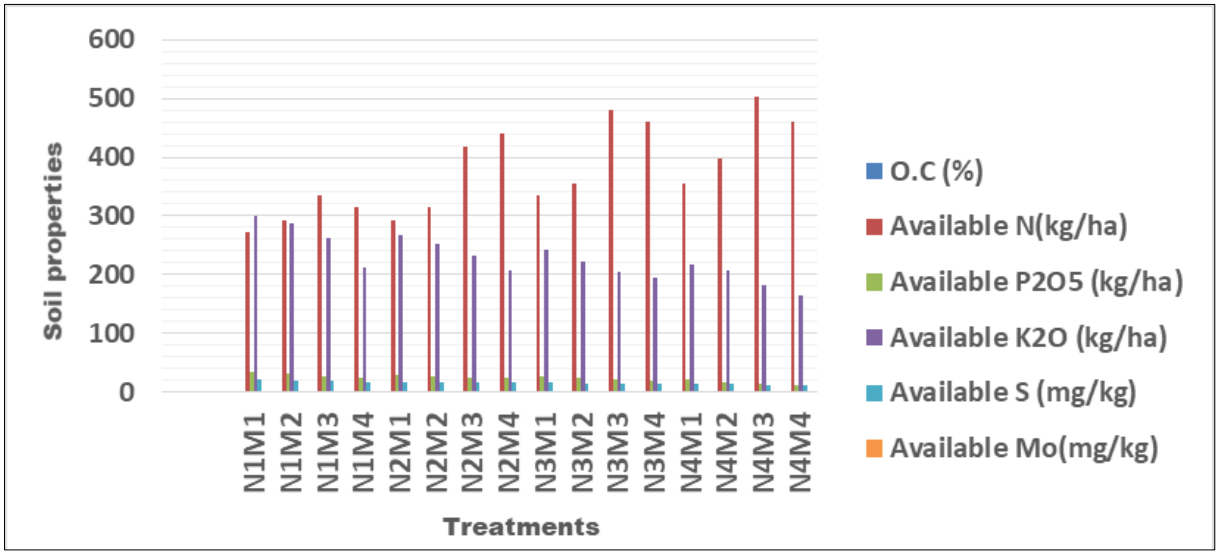

Fig 3: Interaction effect nitrogen and molybdenum on organic carbon, nitrogen, phosphorus, potassium, sulphur and molybdenum content in post- harvest soil

Conclusion

From the study it can be concluded that the interaction effect of nitrogen and molybdenum enhanced crop growth and yield with the treatment of N_3M_3 kg/ha. Further the interaction effect of nitrogen and molybdenum on nutrient content in plants was found significant. Treatment combination N_3M_3 kg/ha obtained the highest nutrient content in plants. And the interaction effect of nitrogen and molybdenum were recorded significant for available phosphorus, potassium, sulphur and molybdenum. Therefore combined application of N @ 20 kg N/ha and Mo @ 0.8 kg Mo/ha was the most suitable doses for better crop yield.

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