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Effect of iron and molybdenum on growth and yield of summer groundnut (*Arachis hypogaea* L.)

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Abstract
A field experiment was conducted during *zaid* season of 2020 at SHUATS Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (UP) on sandy loam soil so as to evaluate the effect of iron and molybdenum on growth and yield of groundnut. The treatment consisted of 3 levels of Iron *viz.*, $FeSO_4$ 15 kg/ha soil application, 1% $FeSO_4$ foliar spray and 7.5 kg/ha soil application + 1% $FeSO_4$ foliar spray and 3 levels of Molybdenum *viz.*, $(NH_4)_6Mo_7O_{24}$ at 0.5 kg/ha, 1.0 kg/ha and 1.5 kg/ha. The experiment was laid out in Randomized Block Design with ten treatments replicated thrice. Study revealed that with application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ recorded significantly higher plant height (60.20 cm), number of nodules/plant (50.66) and maximum plant dry weight (57.80 g) at harvest stage as compared to other treatment combinations. The treatment with application 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ also recorded significantly higher number of pods/plant (16), number of kernels/pod (2.13), grain yield (2940.97 kg/ha) and haulm *yield* (4400.93 kg/ha) as compared to all the treatment combinations.

Keywords: Groundnut, Iron, Molybdenum, Growth, Yield

Introduction
Groundnut (*Arachis hypogaea* L.) also known as peanut is an important oil seed crop and a grain legume Groundnut belonging to family Leguminaceae and is the fourth most important source of edible oil and is also known as "The King of Oilseeds" and it is third most important source of vegetable protein, being a valuable source of all the nutrients, low-priced commodity groundnut is also called as wonder nut and poor men's cashew nut. Groundnut is presently grown in about 90 countries in different agro-climatic regions between latitudes 40 ºS and 40 ºN. India has a cultivation history of growing groundnut around 250 years and is the largely produced oil seed in India; it is also an important cash crop. India is the second largest producer of groundnut after China. China ranks first in groundnut production with 17.39 million tonnes followed by India 6.10 million tonnes. Gujarat is the leading state in terms of total oilseed production. India's groundnut cropping area for the year 2020-2021 was estimated to be around 41.23 lakh hectares (Anonymous, 2020-21) [2] and exports about 638.59 MT worth of 5,381 crores were exported during the time period. It contributed to sustainable agriculture being a legume and is cultivated in both *kharif* and *zaid* by farmers. According to Satish *et al*., 2011 [13], groundnut is primarily used for extraction of oil, with an analysis of about 46.70%. It is also consumed directly because of its high food value, which is again due to its higher content of protein (22.0%), carbohydrate (10.0%) and minerals (3.0%).

Molybdenum (Mo) is a structural component of nitrogenase, the enzyme activity involved in nitrogen fixation by root nodule bacteria of leguminous crops by free living nitrogen fixing organism. Reduction of N_2 to NH_3, is mediated through the enzyme 'nitrogenase'. Nitrogenase is made up of two components - one with iron and molybdenum and second with iron only. N-fixation is essentially an anaerobic process. The oxygen supply to bacteroid is excluded due to presence of leghemoglobin around it. This pigment limits the oxygen supply and protects oxygen sensitive nitrogenase from damage. At the same time enough oxygen is made available at the site for generation of ATP. The quantum of N fixed is closely related to the amount leghemoglobin and the extent of bacteroid tissues in nodules. The first stable intermediate in N-fixation is ammonia. This nitrogen is then converted into amino acids and proteins thereby the plants are benefited.

Among micronutrients, generally, plants require a wide variety of elements to improve the yield and seed quality of the produce. Usually in black soils the availability of some of mineral elements such as iron can more serious problem in the cultivation of this oilseed crops. It is well known that foliar application of iron provides rapid and efficient utilization of applied nutrients. This method also helps in overcoming nutrient deficiency and also helps in

providing nutrients at critical stages of crop growth. Foliar feeding is economical in these days of high fertilizer and labour cost and this practice needs to be largely adopted. Iron is essential micronutrient for crop growth. It is associated with water uptake and water relation in the plant, it plays an important role in the synthesis of chlorophyll and also helps in absorption of other nutrients.

Materials and Methods

The experiment was carried out during *zaid* season of 2020 at CRF (Crop Research Farm), Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (UP). The farm is geographically situated at 25° 24' N latitude and 81° 51' E longitude. The experiment was laid out in Randomized Block Design (RBD) with ten treatments replicated thrice. The experiment comprising ten treatment possible combination of factor, *viz.*, T_1-15 kg/ha $FeSO_4$ soil application + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$, T_2-15 kg/ha $FeSO_4$ soil application + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$. T_3-15 kg/ha $FeSO_4$ soil application + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$, T_4-1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$, T_5-1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$, T_6-1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$, T_7-7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$, T_8-7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$, T_9-7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$, T_{10}-Control plot. The mean (maximum and minimum) temperature was 37.98 °C and 24.21 °C respectively, mean (maximum and minimum) relative humidity was 82.16 percent and 45.26 percent during the crop growing season. The experimental soil was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.318%), low in available N (70 Kg/ha), medium available P (12.50 Kg/ha) and medium available K (216.10 Kg/ha). Fertilizers were applied in the form of urea, single super phosphate and murate of potash, respectively. Entire dose of P and ½ of N and K was applied as basal through placement during sowing. The remaining ½ dose of N and K was applied as top dressing after 40 days after sowing. Iron as $FeSO_4$ and Molybdenum as $(NH_4)_6Mo_7O_{24}$ were applied as per the treatment combinations at the time sowing. Foliar application of $FeSO_4$ @ 1% at 30 and 45 days after sowing were applied as per the treatment combinations. Iron @ 5 kg/ha was dissolved in 500 liters of water and sprayed through power sprayer.

Groundnut seeds were treated with *Rhizobium* bacteria and *Trichoderma* @ 2.5 kg/ha and 4g/kg of seeds respectively. Gypsum as a soil application was applied at the rate of 500 kg/ha at 35 days after sowing. The furrows were opened and seed were dibbled with a spacing of 30 cm x 10 cm and covered by soil. Shelling was done manually, seeds were winnowed, cleaned and seed weight per net plot was recorded on hectare basis and expressed in kg/ha. The observation regarding yield were recorded after harvesting of crop.

Statistical analysis

The experimental data analysed statistically by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance of overall difference among treatments by the F test and conclusion were drawn at 5% probability level. Economics of treatments was also worked out (Gomez and Gomez, 1984) [6].

Chemical analysis of soil

Composite soil samples are collected randomly before the layout of experiment was laid so as to determine the soil properties initially. The soil samples are collected from 0-15 cm depth and were dried under shade, then powdered with the help of a wooden pestle and mortar then sieved through a 2 mm sieve and was then subjected to further analysis. The physical properties of soil were evaluated by using the Bouyoucos hydrometer method outlined by Bouyoucos (1927) and for organic carbon by rapid titration method by Nelson (1975). Available nitrogen was estimated by alkaline permanganate method by Subbiah and Asia (1956), available phosphorus by Olsen's method as outlined by Jackson (1967),

Results and Discussions

Data pertaining to growth parameters which are plant height (cm), number of nodules/plant, dry weight (g/plant) were recorded at harvest and tabulated in Table 1.

Table 1: Growth attributes of Groundnut as influenced by iron and molybdenum levels.

Treatment combinations	Plant Height (cm)	No. of nodules/ plant	Dry Weight (g)
15 kg/ha $FeSO_4$ soil application + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	55.08	40.99	46.81
15 kg/ha $FeSO_4$ soil application + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$	55.33	43.44	49.24
15 kg/ha $FeSO_4$ soil application + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	57.92	48.22	51.27
1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	56.88	45.44	50.00
1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$	57.84	45.88	51.23
1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	58.33	48.88	53.82
7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	58.70	49.10	54.60
7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0kg/ha of $(NH_4)_6Mo_7O_{24}$	59.53	49.88	55.71
7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	60.20	50.66	57.80
Control	54.05	39.66	43.30
F-test	S	S	S
SEm(±)	0.34	0.58	0.69
CD (P=0.05)	1.00	1.73	2.10

The maximum plant height was recorded with application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ (60.20 cm) which was significantly superior over all the treatments and treatment of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$ (59.53 cm) is statistically at par. Increase might be due to as iron is directly or in directly involved in the production of chlorophyll and foliar application is known to be very responsive as the availability of Fe by its foliar application is not affected by soil pH in tandem which ensures higher yield, while in case of number of nodules per plant treatment with 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ was recorded maximum number of nodules

(50.66) which is significantly superior all over the treatments and treatment with 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$ (49.88) and 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ (49.10) are statically at par. Data related to plant dry weight revealed that the treatment with 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ was recorded maximum dry weight (57.80 g) which is significantly superior all over the treatments and treatment with 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$ (55.71 g) is statically at par. The increase might be due to molybdenum as every N_2 fixing bacterium needs Mo during the process of fixation and also responsible nodule tissue formation. The present findings are in close agreement with the results obtained by Bhagiya *et al*. (2005) [3] and Hirpara *et al*. (2019) [7].

Yield Attributes

Economic yield is expressed as a function of factors that contribute to yield, which are known as yield attributes. The variations in yield due to treatments could be attributed to the variations in the yield attributing parameters. The main yield attributing parameters in groundnut are viz., No. of pods/plant, No. of kernels/pod, Seed index were recorded at harvest and tabulated in Table 2. Data on yield attributes revealed that with the application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha $(NH_4)_6Mo_7O_{24}$ recorded maximum No. of pods per plant (16) which was significantly superior over all the treatments**.** However, treatments with application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$ (15.67)**,** 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ (15.33)**,** 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ (15.33), 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$ (15.00)**,** 15 kg/ha $FeSO_4$ soil application + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ (14.67) were statistically on par. Treatment with application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha $(NH_4)_6Mo_7O_{24}$ was recorded maximum No. of kernels per (2.13) over all the treatments and there was no significant difference among treatments. Treatment with of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha $(NH_4)_6Mo_7O_{24}$ was recorded maximum Seed index (38.57g) which was followed by treatment with 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ (37.82) and no significant difference was observed among treatments. Improvement in soil fertility and productivity due to application of micronutrients might have supported enhancing the yield attributes. The rise in pods/plant and kernels/pod are attributed by the Fe and Mo which are known to be important components of nitrogenase enzyme thereby increasing nitrogen's activity which results in boosting up the pods/plant which ultimately results in increase the yield in groundnut.

Table 2: Yield attributes and Yield of groundnut as influenced by iron and molybdenum levels.

Treatment combinations	No. of pods/plant	No. of kernels/pod	Seed index	Seed yield (kg/ha)	Haulm yield (kg/ha)	Harvest index (%)
15 kg/ha $FeSO_4$ soil application + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	12.67	1.87	37.40	2393.47	3528.33	40.42
15 kg/ha $FeSO_4$ soil application + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$	13.33	1.87	35.89	2473.30	3540.33	41.14
15 kg/ha $FeSO_4$ soil application + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	14.67	2.0	36.09	2694.30	3868.40	41.06
1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	13.67	2.0	36.71	2596.57	3634.50	41.70
1% $FeSO_4$foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$	15.00	2.0	35.77	2620.50	3743.80	41.21
1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	15.33	2.0	36.62	2767.40	4112.60	40.23
7.5 kg/ha $FeSO_4$soil application and 1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	15.33	2.0	37.82	2805.10	4273.60	39.63
7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$	15.67	2.0	35.95	2895.00	4242.93	40.56
7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$	16.00	2.13	38.57	2940.97	4400.93	40.12
Control	12.00	1.80	34.73	2317.83	3477.17	40.01
F - test	S	NS	NS	S	S	NS
SEm (±)	0.77	0.07	0.81	30.87	79.16	0.50
CD (0.05%)	2.30	-	-	91.73	235.21	-

Yield

Enhancement in yield of economic part is usually dependent upon the total dry matter produced and its distribution among different parts of the plant due to better total nitrogen as well as Fe uptake and their translocation to the reproductive parts and improvement in yield. Treatment with application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha $(NH_4)_6Mo_7O_{24}$ was recorded maximum Seed yield (2940.97 kg/ha) which was significantly superior over all the treatments. However, treatment with application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$ (2895.00 kg/ha) was statistically on par with treatment with 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha $(NH_4)_6Mo_7O_{24}$. Treatment with application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha $(NH_4)_6Mo_7O_{24}$ was recorded maximum Haulm yield (4400.93 kg/ha) which was significantly superior over all the treatments. However, treatment with application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.0 kg/ha of $(NH_4)_6Mo_7O_{24}$ (4242.93 kg/ha), 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ (4273.60 kg/ha) and treatment with 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ (4112.60 kg/ha) were statistically on par. Application of 1% $FeSO_4$ foliar spray + 0.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ recorded maximum Harvest Index (41.70%), the lowest was recorded in control (40.01%) and no significant difference was observed among treatments.

Fig 1: Growing stage

Fig 2: Maturity stage

Fig 3: Harvesting stage

Conclusion

In the light of the above research trail, well demonstrated the positive effects of micronutrients particularly Fe + Mo treatment on various growth and yield parameters of groundnut plant. There was an increase in the seed yield of groundnut by 26.88% over the control. The application of 7.5 kg/ha $FeSO_4$ soil application and 1% $FeSO_4$ foliar spray + 1.5 kg/ha of $(NH_4)_6Mo_7O_{24}$ obtaining higher yield attributes and yield of Groundnut crop useful for eastern Uttar Pradesh condition. Since the findings that were recorded are based on the research done in one season it may be repeated for further confirmation.

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