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Impact of ammonium molybdate supplementation on growth, yield and nutrient uptake of pigeon pea (*Cajanus cajan*)

YP Swami, SL Waikar and SC Sallawar

Abstract
A field experiment was conducted during 2018-19 to study the "Impact of Ammonium molybdate supplementation on growth, yield and nutrient uptake of Pigeon pea (*Cajanus cajan*)" at experimental farm, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experiment was laid out on Vertisol with five treatments replicated four times in randomized block design. The treatment consists of T_1- Absolute control, T_2- Only RDF (25:50 kg N and P_2O_5 ha^{-1}), T_3- RDF + Ammonium molybdate through seed treatment @1 g kg^{-1} seed, T_4-RDF + Ammonium molybdate through soil application @ 2 kg ha^{-1}, T_5-RDF + Ammonium molybdate through foliar application @ 0.5%. The results revealed that various growth and yield parameters like plant height, number of branches, number of pods, seed yield and stover yield was increased due to application of RDF+ ammonium molybdate through foliar application.

Keywords: ammonium molybdate, growth, yield, nutrient uptake, pigeon pea, vertisol

Introduction
Pigeon pea (*Cajanus Cajan* L.) is a perennial legume from family Leguminacae (*Fabaceae*). Common names of pigeon pea are "Tropical green pea", Arhar and Red gram in India. It is a perennial which can grow into a small tree. The 91 per cent of the world's pigeon pea is produced in India. India ranks first in area and production in the world with 76.65% and 67.28% of world acreage and production, respectively. The Productivity of India was 587 kg ha^{-1} reported by Anonymous (2014b) [3] that more than 80% of pigeon pea production comes under six states namely Maharashtra, Madhya Pradesh, Karnataka, Uttar Pradesh, Gujarat and Jharkhand. The state wise trend shows that Maharashtra ranks 1st both in area and production 29.68% and 27.86%. The varities of pigeon pea in Maharashtra are BDN-711, BSMR-736, BDN-708, Asha and Vaishali (BSMR 853). Among the micronutrients Zn, Fe, B, Mn and Mo improved the yield appreciably and foliar spray of micronutrients proved to be economical in pulses reported by Savithri *et al*. (2001) [27].

Molybdenum is a key element required by the microorganisms for nitrogen fixation. It is a structural component of nitrogenase enzyme which is actively involved in nitrogen fixation by *Rhizobium* bacteria in the root nodules of leguminous crops and simultaneously essential for absorption and translocation of iron in plants as well as seed. Even though, the micronutrients required in relatively smaller quantities for plant growth, they are as important as macronutrient and its deficiency suppress the growth or even complete growth inhibition may occurred reported by (Mengel *et al*. 2001). Micronutrients often act as co-factors in enzyme system and participate in plants most importantly, they are also involved in the key physiological processes of photosynthesis and respiration revealed by (Marschner, 1995; Mengal *et al*. 2001) [24, 25] and their deficiency can impede these vital physiological processes thus limiting seed yield. Micronutrient deficiency can greatly disturb plant yield and quality. By supplying plant with micronutrients, either through soil application, foliar spray or seed treatment, increases yield or quality further micronutrient use efficiency can be achieved. The application of nutrients not only increase the yield of crop, but also increase the density of nutrient in the grain which now prerequisite for the human health reported by (Imtiaz *et al*. 2010) [11].

Material and Methods
A field experiment was conducted during year 2018-19 to study the "Impact of Ammonium molybdate supplementation on growth, yield and nutrient uptake of Pigeon pea (*Cajanus cajan*)" at Research Farm of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Plant analysis
Macronutrients and micronutrients were estimated by following standard methods mentioned in A.O.A.C (1975), Jackson (1973) [12] and Lindsay and Norvell (1978) [20].

Total molybdenum
It was determined by using colorimetric method as described by Johnson and Arkley (1954) [14].

Results
The findings of the present study as well as relevant discussions have been presented under following heads.

Growth promoting characters of pigeon pea at critical growth stages of pigeon pea
Plant height
The data presented in Table 1 indicates that height of pigeon pea at three critical growth stages was influenced by different treatments and result revealed that the plant height at flowering, pod filling and at harvest influenced by ammonium molybdate, treatment receiving RDF + Ammonium molybdate through foliar application @ 0.5% (T_5) found significantly superior at flowering, pod filling and at harvest respectively. The treatment RDF + Ammonium molybdate through soil application @ 2 kg ha^{-1} (T_4) and RDF + Ammonium molybdate through Seed treatment @1 g kg^{-1} seed (T_3) found at par with (T_5). However, lower value of plant height was noticed in absolute control (T_1) at all the growth stages of crop.

Findings confirmed with Singh *et al.* (2015) [2, 19, 30-32] reported that integrated use of micronutrients (B, Co and Mo) produced maximum plant height. Handiganoor *et al.* (2017) [10] revealed that two foliar sprays of potassium molybdate (0.1%) + zinc sulphate (0.5%) in EDTA from + borax (0.2) during flowering stage recorded significantly maximum plant height.

Number of branches per plant
The data narrated in Table 1 shows that number of branches per plant in pigeon pea at three critical growth stages. Among different treatment of ammonium molybdate treatment receiving RDF + Ammonium molybdate through foliar application @ 0.5% (T_5) found superior over rest of the treatment with highest number of branches at flowering 14.80, at pod filling and at harvest 19.75 and treatment RDF + Ammonium molybdate through soil application @ 2 kg ha^{-1} (T_4) found at par with treatment (T_5). However, less no of branches per plant was noticed in absolute control (T_1) at all the growth stages of crop.
The results supported by the findings of Singh (2001) [2, 19, 30-32] found that soil application of Molybdenum at 0.5 kg ha^{-1} and foliar spray of ammonium molybdate at 0.5% significantly increased the number of branches per plant at pod filling and at harvest and found at par with each other. Similarly, Jat (1992) [13] reported that application of ammonium molybdate at 1.0 kg ha^{-1} significantly increased branches per plant in green gram. Similar findings confirmed by Shivkumar and Kumutha (2003) [29] and Gupta *et al*. (2012) [9].

Table 1: Effect of different treatments of ammonium molybdate on growth promoting characters of pigeon pea at critical growth stages

Sr. No.	Treatments	Plant height in (cm)			No. of branches plant^{-1}		No. of pods plant^{-1}	
		Flowering	Pod filling	At harvest	Flowering	Pod filling and at harvest	At pod filling	At harvest
T_1	Absolute control	80.89	138.70	142.45	9.00	14.15	111.25	110.40
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	86.48	142.30	152.65	11.70	16.15	120.45	120.45
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	88.70	146.75	157.50	12.90	17.75	128.80	128.78
T_4	T_2+Ammonium molybdate soil application@ 2kg ha^{-1}	90.90	148.30	161.10	13.45	18.35	136.15	136.90
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	95.30	154.90	166.95	14.80	19.75	147.25	146.38
	Mean	88.45	146.19	156.13	12.37	17.35	128.78	128.58
	SE(m)±	2.30	3.34	4.06	0.61	0.57	3.88	3.19
	C.D. at 5%	7.08	10.29	12.52	1.86	1.76	11.94	9.81
	C.V%	5.2	4.57	5.2	9.78	6.64	6.02	4.95

Number of pods per plant
The data assessed in Table 1 shows that number of pods per plant in pigeon pea at pod filling and at harvest stage. Among different treatments of ammonium molybdate treatment RDF + Ammonium molybdate through foliar application @ 0.5% (T_5) found superior at both pod filling 147.25 and at harvest 146.38 and followed by treatment RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4). However, less no of pods per plant was noticed in absolute control (T_1) at both pod filling and at harvest of crop respectively.
The results are in conformity to the findings of Shinde *et al.* (2017) [28] chickpea seeds with the combination of $ZnSO_4$ + Boron + Ammonium molybdate + $FeSO_4$ (each at 1g kg^{-1}) of seed along with two foliar sprays (0.5, 0.2, 0.1 and 0.5 per cent, respectively) recorded significantly highest number of pods per plant. Similarly findings confirmed with Gupta *et al*. (2012) [9] found that application of Ammonium Molybdate in combination with *Rhizobium* + PSB + RDF significantly increased number of pods per plant.

Seed yield and dry matter production of pigeon pea
The data presented in Table 2 showed that effect of application of ammonium molybdate on seed yield, stover yield and total biomass production of pigeon pea. The results revealed that the seed, stover and total biomass yield was found maximum in treatment RDF + Ammonium molybdate through foliar application @ 0.5% (T_5) *viz*. 945, 1417.56 and 2362.56 kg ha^{-1} respectively, over rest of the treatments and found at par with RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4) and RDF + Ammonium molybdate seed treatment @1g kg^{-1} of seed (T_3). However, the lowest seed, stover and total biomass yield were recorded in absolute control (T_1).
The findings confirmed with Kailash *et al.* (2017) studied that application of multi micronutrients along with molybdenum both by foliar and soil application increases the yield than the RDF alone. Similarly the results supported by findings of Yadav *et al.* (2017) [36] reported that molybdenum application at 1.0 kg ha^{-1} significantly increased seed, stover and biological yield. Manga *et al.* (1999) [21] reported that the

molybdenum application increased the number of pods per plant, number of seeds per pod and seed yield. Sonavane *et al.* (2015) found that BSMR-736 variety of pigeon pea produced maximum and significantly higher grain and stalk yields.

Table 2: Effect of different treatments of ammonium molybdate on seed yield and dry matter production of pigeon pea

Sr. No.	Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Total biomass (kg ha^{-1})
T_1	Absolute control	795	1060.98	1855.98
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	860	1118.60	1978.6
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	880	1232.40	2112.4
T_4	T_2+Ammonium molybdate soil application@ 2kg ha^{-1}	910	1274.50	2184.5
T_5	T_2+Ammoniummolybdate foliar application @ 0.5%	945	1417.56	2362.56
	Mean	878	1220.80	2098.80
	SE(m)±	32.60	42.78	60.47
	C.D. at 5%	90.10	125.80	178.15
	C.V%	6.32	10.80	12.40

Macronutrient uptake at harvest of pigeon pea

Nitrogen uptake

The data pertained in Table 3 showed that the nitrogen uptake by stover, seed and total. Nitrogen uptake i.e. by stover, seed and total the treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) found superior over rest of the treatments 16.73, 32.70 and 49.42 kg ha^{-1} which was followed by RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4). However, the lowest values were observed in absolute control (T_1). The uptake of nitrogen was more in treatment (T_5) due to higher concentration of nitrogen in seed and stover and their yield was also higher in treatment in the similar treatment.

The results are in the conformity to the findings of Suryawanshi Arpit *et al*. (2016) [34] revealed that the soil application at 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB showed maximum nitrogen uptake by seed, stover and total found superior over control. Similarly, Khan *et al*. (2013) [11, 17] reported that build-up of available N, Zn and Mo in soil, nitrogen uptake significantly increased with the application of 5.0 kg Zn ha^{-1}, 0.5 kg Mo ha^{-1} and *Rhizobium* inoculation. Zinc and molybdenum uptake were also significantly increased by the supply of 2.5 kg zinc and 0.5 kg Mo ha^{-1}. Similar results confirmed by Manohar (2014) [22, 23], Gupta *et al*. (2012) [9], Kumar and Sharma (2005) [18, 19]. Alan *et al*. 2015 recorded the content and uptake of nitrogen in hairy vetch plants increased by 41.2% due to molybdenum application at 0.5 mg kg^{-1} over control.

Phosphorus uptake

The data narrated in Table 3 showed that the phosphorus uptake values for stover, seed and total. Phosphorus uptake i.e. by stover, seed and total the treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) found superior over rest of the treatments with values 3.83, 4.35 and 8.17 kg ha^{-1} which was found at par with RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4). However, the lowest values were observed in absolute control (T_1). The uptake of phosphorus is more in treatment (T_5) due to higher concentration of phosphorus in seed and stover and their yield is also higher in similar treatment.

The research findings confirmed with work done by Suryawanshi *et al.* (2016) [34] revealed that the soil application at 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB showed maximum P uptake by seed, stover and total was found with 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB. Similarly results supported by the findings of Sale and Nazirkar (2013) [26], Gupta *et al*. (2012) [9], Yadav *et al.* (2017) [36], Laltlanmawia *et al.* (2004) and Dadhich (1997) [5, 6].

Potassium uptake

The data assessed in Table 3 showed that In case of potassium uptake i.e. by stover, seed and total. Among all the treatments treatment RDF+ Ammonium molybdate foliar application @ 0.5% (T_5) shows maximum value 14.74, 15.4 and 30.15 kg ha^{-1}, respectively followed by treatment RDF + Ammonium molybdate @ 2 kg ha^{-1} (T_4), while absolute control (T_1) showed minimum values.

The results are in conformity to the findings with Suryawanshi *et al.* (2016) [34] result revealed that the soil application % 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB observed maximum K uptake by seed, Stover and total found superior over control. Similarly, Sale and Nazirkar (2013) [26] reported that nutrient uptake differed significantly due to application of zinc and iron through foliar spray and with Mo application. The highest uptake of potassium was recorded 122.8 kg ha^{-1}. Similar findings confirmed with Alben *et al*. (2012) [2] and Gad (2012) [7, 8].

Table 3: Effect of different treatments of ammonium molybdate on macronutrient uptake at harvest of pigeon pea

Sr. No.	Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
		Stover	Seed	Total	Stover	Seed	Total	Stover	Seed	Total
T_1	Absolute control	7.32	23.37	30.69	2.12	3.02	5.14	7.85	11.6	19.46
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	10.07	26.40	36.47	2.35	3.53	5.88	8.95	13.0	22.02
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	11.95	27.81	39.76	2.83	3.70	6.53	9.98	13.6	23.62
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	13.38	30.21	43.59	3.31	3.91	7.23	12.24	14.3	26.61
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	16.73	32.70	49.42	3.83	4.35	8.17	14.74	15.4	30.15
	Mean	11.89	28.09	39.98	2.88	3.70	6.59	10.75	13.58	24.37
	SE(m)±	1.22	1.40	2.32	0.24	0.18	0.38	0.80	0.52	0.98
	C.D. at 5%	3.41	3.92	6.49	0.67	0.50	1.06	2.24	1.45	2.77
	C.V.%	11.48	8.34	9.45	9.40	8.60	7.70	9.10	7.63	8.28

Micronutrient uptake at harvest of pigeon pea

Zinc uptake

The data pertained in Table 4 (a) showed that zinc uptake values of stover, seed and total. Zinc uptake i.e. by stover, seed and total the treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) found superior over rest of the treatments with values 46.21, 42.2 and 88.45 g ha^{-1}. However, the lowest value was observed in absolute control (T_1). The uptake of zinc is more in treatment (T_5) due to higher concentration of zinc in seed and stover and their yield is also higher in similar treatment.

The findings confirmed with Sale and Nazirkar (2013) [26] reported that nutrient uptake differed significantly due to application of zinc and iron through foliar spray and with Mo. The highest uptake of nitrogen, phosphorus, potassium was recorded highest in treatment receiving zinc and iron foliar spray and was found superior over rest of the treatments. At harvest, the highest uptake of molybdenum recorded highest in treatment receiving foliar application of zinc and iron with seed fortification of molybdenum and was superior over rest of the treatments. Similarly, Khan *et al*. (2013) [11, 17] reported that build-up of available N, Zn and Mo in soil, nitrogen uptake significantly increased with the application of 5.0 kg Zn ha^{-1}, 0.5 kg Mo ha^{-1} and *Rhizobium* inoculation. Zinc and molybdenum uptake were also significantly increased by the supply of 2.5 kg zinc and 0.5 kg Mo ha^{-1}.

Ferrous uptake

The data presented in Table 4 (a) showed that ferrous uptake i.e. by stover, seed and total. The treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) found superior over rest of the treatments with values 365.05, 169.74 and 534.79 g ha^{-1}. However, the lowest value was observed in absolute control (T_1). The uptake of ferrous is more in treatment (T_5) due to higher concentration of ferrous in seed and stover and their yield is also higher in similar treatment.

Table 4(a): Effect of different treatments of ammonium molybdate on micronutrient uptake at harvest of pigeon pea

Sr. No.	Treatments	Zn uptake (g ha^{-1})			Fe uptake (g ha^{-1})			Cu uptake (g ha^{-1})		
		Stover	Seed	Total	Stover	Seed	Total	Stover	Seed	Total
T_1	Absolute control	24.08	22.5	46.58	209.48	89.56	299.04	12.18	8.18	20.36
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	29.08	30.2	59.36	232.21	106.92	339.13	17.48	10.55	28.04
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	34.51	34.1	68.65	292.26	125.24	417.51	22.44	13.36	35.80
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	36.58	37.4	73.98	309.26	136.05	445.31	26.78	16.84	43.62
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	46.21	42.2	88.45	365.05	169.74	534.79	36.53	22.34	58.87
	Mean	34.09	33.38	67.40	281.65	125.50	407.15	23.08	14.25	37.33
	SE(m)±	1.90	1.20	3.42	11.24	7.20	9.20	1.2	0.90	1.80
	C.D. at 5%	5.32	3.36	9.57	31.47	20.16	25.76	3.36	2.52	5.04
	C.V%	10.6	8.60	7.48	6.24	5.60	7.40	5.20	6.8	9.20

Copper uptake

The data narrated in Table 4 (a) showed that copper uptake values of stover, seed and total. Copper uptake i.e. by stover, seed and total the treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) found superior over rest of the treatments with values 36.53, 22.34 and 58.87 g ha^{-1}. However, the lowest value was observed in absolute control (T_1). The uptake of ferrous is more in treatment (T_5) due to higher concentration of ferrous in seed and stover and their yield is also higher in similar treatment.

The results supported by the findings of Gad and Kandil (2013) [7, 8] studied the effect of molybdenum under different levels of nitrogen on growth, nodules efficiency, yield quantity and quality of cowpea and obtained that the molybdenum significantly increased the content of Cu.

Manganese uptake

The data assessed in Table 4 (b) showed that manganese uptake i.e. by stover, seed and total. The treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) found superior over rest of the treatments with values 50.47, 20.07 and 70.74 g ha^{-1}. However, the lowest value was observed in absolute control (T_1). The uptake of manganese was found more in treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) due to higher concentration of manganese in seed and stover.

The results are in the conformity to the findings of Gad and Kandil (2013) [7, 8] revealed that the effect of molybdenum under different levels of nitrogen on growth, nodules efficiency, yield and quality of cowpea and obtained that the molybdenum significantly increased the content of Mn. Similarly, Gad (2012) [7, 8] studied the effect of cobalt and molybdenum combination under different levels of nitrogen on growth, nodules efficiency, yield and quality of cowpea plants. Similar results supported by the findings of Singh *et al.* (2014) [2, 19, 30-32] and Kannan *et al*. (2014) [16].

Table 4(b): Effect of different treatments of ammonium molybdate on micronutrient uptake at harvest of pigeon pea

Sr. No.	Treatments	Mn uptake (g ha^{-1})			Mo uptake (g ha^{-1})		
		Stover	Seed	Total	Stover	Seed	Total
T_1	Absolute control	20.18	8.70	28.88	0.13	0.33	0.46
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	25.12	11.12	36.24	0.17	0.41	0.58
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	35.43	12.64	48.07	0.21	0.45	0.66
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	39.69	16.43	56.12	0.25	0.47	0.73
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	50.47	20.07	70.54	0.33	0.52	0.85
	Mean	34.17	13.79	47.97	0.21	0.43	0.65
	SE(m)±	1.32	0.80	1.52	0.02	0.01	0.02
	C.D. at 5%	3.69	2.24	4.24	0.056	0.028	0.056
	C.V.%	5.60	4.50	8.16	9.4	4.22	5.60

Molybdenum uptake

The data pertained in Table 4 (b) showed that molybdate uptake values of stover seed and total. The treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) found superior over rest of the treatments with values 0.33, 0.52 and 0.85 g ha^{-1} followed by the treatment RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4) in case of stover, seed and total molybdenum uptake. However, the lowest value was observed in absolute control (T_1). The uptake of molybdenum is more in treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) due to higher concentration of molybdenum in seed and stover. The seed yield was also higher similar treatment.

The findings confirmed with Sale and Nazirkar (2013) [26] found highest uptake of molybdenum in treatment receiving foliar application of zinc and iron with seed fortification of molybdenum. Manohar (2014) [22, 23] at Jobner reported that the increasing levels of molybdenum up to 1.0 kg ha^{-1} significantly increased N, S and Mo concentration in seed and N concentration in straw. The results supported by the similar findings of Kumar and Sharma (2005) [18, 19] Vyas *et al.* (2003) [35] and Yadav *et al.* (2017) [36]. Alan *et al*. 2015 revealed the uptake of molybdenum by hairy vetch increases in treatment receiving 1 mg kg^{-1} molybdenum application.

Conclusions

Application of RDF + ammonium molybdate through foliar application @ 0.5 significantly enhanced growth and yield of pigeon pea. Nutrient uptake status of stover, seed and total N, P, K, Fe, Zn, Mn, Cu and Mo improved due to application of RDF + ammonium molybdate through foliar application @ 0.5% ha^{-1} followed by the treatment Ammonium molybdate soil application@ 2kg ha^{-1} along with RDF at harvest stage of pigeon pea.

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