Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 2139-2144
Received: 10-11-2020
Accepted: 12-12-2020

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Influence of ammonium molybdate supplementation on quality, yield and nutrient content of pigeon pea (*Cajanus cajan*)

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Abstract
A field experiment was conducted during 2018-19 to study the "Influence of Ammonium molybdate supplementation on quality, yield and nutrient content 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 highest test weight and seed protein content was recorded by application of - RDF + Ammonium molybdate through foliar application @ 0.5%. The results revealed that various yield parameters like seed yield and stover yield and total biomass was increased due to application of RDF+ ammonium molybdate through foliar application.

Keywords: ammonium molybdate, quality, nutrient content yield, 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. It is a rich source of proteins i.e. about 22 per cent lysine, riboflavin, thiamine, niacin and iron. It plays a great role in providing protein rich diet and also in improving native soil fertility reported by Anonymous (2014 a) [3, 4]. 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 (2014 b) [3, 4] 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 varieties 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) [25].

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) [22] 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) [12].

Material and Methods

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

Quality parameters

Protein content (nitrogen content) from the grain samples was estimated by Micro-kjeldhal's method (AOAC, 1975) and N content was multiplied by 6.25 to get per cent crude protein. The weight of 100 seeds of pigeon pea from each net plot was recorded and designated as test weight of pigeon pea.

Plant analysis

Macronutrients and micronutrients were estimated by following standard methods mentioned in A.O.A.C (1975), Jackson (1973) [13] and Lindsay and Norvell (1978) [19].

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.

Effect of different treatments of ammonium molybdate on quality parameters of pigeon pea

The data narrated in Table.1 revealed that the quality parameters influenced by application of RDF +Ammonium molybdate by foliar spray @ 0.5% (T_5) which gave maximum value of 11.87 g and 21.61%, respectively over other treatments followed by RDF + soil application of ammonium molybdate @ 2kg ha^{-1} (T_4). However, the less test weight and protein content were noticed in absolute control (T_1). The protein content is found more in treatment (T_5) due to higher concentration of nitrogen in seed.

Table 1: Effect of different treatments of ammonium molybdate on quality parameters of pigeon pea

Sr. No.	Treatments	Test weight (g)	Protein content (%)
T_1	Absolute control	9.86	18.38
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	10.70	19.16
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	11.05	19.78
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	11.53	20.74
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	11.87	21.61
	Mean	11.2	19.93
	SE(m)±	0.10	0.28
	C.D. at 5%	0.31	0.87
	C.V%	1.83	2.82

The results supported by the finding of Suryawanshi *et al.* (2016) [28] found that the application of molybdenum with *Rhizobium* + PSB have the protein content and oil content in seed was significantly higher in seed over control. Hugar and Kurdikeri (2000) [11] studied the effect of application methods and levels of zinc and molybdenum on seed yield and quality in soybean and noted that, the application of Zn and Mo at 2 g kg^{-1} seed treatment + 0.5 per cent foliar application recorded more protein content and test weight. Similar findings confirmed with Deo and Kothari (2002) [7] and Alben *et al.* (2012) [2].

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).

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

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) [30] reported that molybdenum application at 1.0 kg ha^{-1} significantly increased seed, stover and biological yield. Manga *et al.* (1999) [20] 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.

Macronutrient content at critical growth stages of pigeon pea

Nitrogen content

The data narrated in Table 3 showed that the nitrogen content in pigeon pea stover at three critical growth stages *viz*. was flowering, pod filling, at harvest and seed nitrogen content. Treatment receiving foliar spray of ammonium molybdate @ 0.5% along with RDF (T_5) found significantly superior 2.30, 1.92 and 1.18%, respectively over rest of treatments. The seed nitrogen content 3.46% also significantly influenced by similar treatment and treatment RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4) found at par with (T_5) concern to both stover and seed nitrogen content. The nitrogen concentration in pigeon pea plant was highest at flowering stage and decline at harvesting stage of the crop but the concentration was higher in seed. This trend may be due to high mobility of the nitrogen from vegetative tissues to reproductive organs after flowering stage.

The results are in conformity to the findings of Suryawanshi Arpit *et al*. (2016) [28] revealed that the soil application at 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB showed maximum nitrogen content in seed and stover found superior over control. Similarly, Gad and Kandil (2013) [8, 9] also studied the effect of molybdenum under different levels of nitrogen on growth, nodules efficiency, yield and quality of cowpea obtained that the molybdenum significantly increased the content of N, P, K, Mn, Fe, Cu, Zn and Mo. Similar results were supported by the findings of Manohar (2014) [21], Gupta *et al*. (2012) [10], Kumar and Sharma (2005) [17, 18]. Alan *et al*. 2015 recorded the content of nitrogen in hairy vetch plants increased due to molybdenum application at 0.5 mg kg^{-1} over control.

Phosphorus content

The data assessed in Table 3 showed that the phosphorus content of pigeon pea stover at three critical growth stages and seed phosphorus content. The treatment receiving RDF with foliar spray of ammonium molybdate @ 0.5% (T_5) resulted in maximum phosphorus content in stover at flowering, pod filling and at harvest with values 0.41, 0.39 and 0.27% and similar treatment shows maximum phosphorus concentration in seed 0.46% also. For both seed and stover phosphorus concentration treatment RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4) found at par with RDF + Ammonium molybdate foliar application @ 0.5% (T_5). However, least values are found in absolute control (T_1). The phosphorus concentration in pigeon pea plant was highest at flowering stage and decline at harvesting stage.

Table 3: Effect of different treatments of ammonium molybdate on macronutrient content at critical growth stages of pigeon pea

Sr. No.	Treatments	N content (%)				P content (%)				K content (%)			
		Stover			Seed	Stover			Seed	Stover			Seed
		FS	PFS	AH		FS	PFS	AH		FS	PFS	AH	
T_1	Absolute control	1.85	1.46	0.69	2.94	0.37	0.31	0.20	0.38	1.22	1.04	0.74	1.46
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	1.95	1.55	0.90	3.07	0.38	0.34	0.21	0.41	1.38	1.15	0.80	1.52
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	2.06	1.72	0.97	3.16	0.38	0.35	0.23	0.42	1.53	1.28	0.81	1.55
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	2.21	1.83	1.05	3.32	0.39	0.37	0.26	0.43	1.75	1.46	0.96	1.58
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	2.30	1.92	1.18	3.46	0.41	0.39	0.27	0.46	1.99	1.49	1.04	1.63
	Mean	2.07	1.69	0.95	3.19	0.38	0.35	0.23	0.42	1.57	1.28	0.87	1.54
	SE(m)±	0.05	0.06	0.06	0.05	0.01	0.01	0.01	0.01	0.04	0.03	0.02	0.02
	C.D. at 5%	0.14	0.17	0.17	0.14	0.02	0.03	0.03	0.02	0.11	0.09	0.06	0.06
	C.V%	4.45	6.55	11.6	2.82	2.44	6.15	7.39	2.56	4.52	4.65	4.2	2.7

(FS-Flowering stage, PFS-Pod filling stage and AH-At harvest)

The research findings confirmed with work done by Suryawanshi *et al.* (2016) [28] revealed that the soil application at 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB showed maximum P content by seed, stover and total with 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB. The similar results supported by findings of Sale and Nazirkar (2013) [24], Gupta *et al*. (2012) [10], Yadav *et al.* (2017) [30], Laltlanmawia *et al.* (2004) and Dadhich (1997) [6].

Potassium content

The data pertained in Table 3 showed that the potassium content of pigeon pea stover at three critical growth stages and seed potassium content. Among all treatments the treatment receiving foliar spray of ammonium molybdate @ 0.5% along with RDF (T_5), significantly superior over other treatments at flowering 1.99% pod filling 1.49% and at harvest 1.04% and similar treatment found superior in case of potassium concentration in seed 1.63%. The lowest seed and stover content of potassium found in absolute control (T_1). The potassium concentration in pigeon pea plant was highest at flowering stage and decline at harvesting stage of the crop but the concentration was higher in seed.

The results are in conformity to the findings of Suryawanshi *et al.* (2016) [28] revealed that the soil application at 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB showed maximum K content by seed, stover and total with 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB. The results supported by the findings of Alben *et al*. (2012) [2] and Gad (2012) [8, 9].

Micronutrient content at critical growth stages of pigeon pea

Zinc content

The data presented in Table 4(a) showed that the concentration of Zinc in pigeon pea stover at three critical growth stages *viz.* was flowering, pod filling, at harvest and seed zinc concentration. Among all treatments treatment receiving foliar spray of ammonium molybdate 0.5% along with RDF (T_5) found significantly superior at all critical growth stages 55.78, 48.08 and 32.06% respectively over rest of treatments and similar treatment found superior in case of zinc concentration of seed 44.70%. However, the lowest values for both stover and seed Zn concentration found in absolute control (T_1). The zinc concentration in pigeon pea plant was highest at flowering stage and decline at harvesting stage of the crop but the concentration was higher in seed.

The findings confirmed with findings of Sale and Nazirkar (2013) [24] reported that nutrient content differed significantly due to application of zinc and iron through foliar spray with Mo. The highest content of nitrogen, phosphorus, potassium was recorded in treatment receiving zinc and iron foliar spray and was found superior over rest of the treatments. Similarly, Khan *et al*. (2013) [12, 16] reported that build-up of available N, Zn and Mo in soil, nitrogen content significantly increased with the application of 5.0 kg Zn ha^{-1}, 0.5 kg Mo ha^{-1} and Rhizobium inoculation. Zinc and molybdenum content were also significantly increased by the supply of 2.5 kg zinc and 0.5 kg Mo ha^{-1}.

Ferrous content

The data narrated in Table 4(a) showed that the concentration of ferrous in pigeon pea stover at three critical growth stages *viz*. was flowering, pod filling, at harvest and seed ferrous concentration. From among all treatments treatment receiving foliar spray of ammonium molybdate @ 0.5% along with RDF (T_5) found significantly superior 713.78, 408.09 and 257.52% respectively over rest of the treatments and similar treatment found superior in case of ferrous concentration of seed 176.62%. However, the lowest values for both stover and seed ferrous concentration found in absolute control (T_1). The ferrous concentration in pigeon pea plant was highest at flowering stage and decline at harvesting stage of the crop but the concentration was higher in seed.

Copper content

The data assessed in Table 4(a) showed that the concentration of copper in pigeon pea stover at three critical growth stages *viz*. was flowering, pod filling, at harvest and seed copper concentration. Among different molybdate treatments treatment receiving foliar spray of ammonium molybdate @ 0.5% along with RDF (T_5) found significantly superior 43.33, 32.95 and 25.77% respectively over rest of treatments and similar treatment found superior in case of copper concentration of seed 23.64%. However, the lowest values for both stover and seed Cu concentration found in absolute control (T_1) the copper concentration in pigeon pea plant was highest at flowering stage and decline at harvesting stage of the crop but the concentration was higher in grain.

The results supported by the findings of Gad and Kandil (2013) [8, 9] 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.

Table 4(a): Effect of different treatments of ammonium molybdate on micronutrient content at critical growth stages of pigeon pea

Sr. No.	Treatments	Zn content (%)				Fe content (%)				Cu content (%)			
		Stover			Seed	Stover			Seed	Stover			Seed
		FS	PFS	AH		FS	PFS	AH		FS	PFS	AH	
T_1	Absolute control	43.19	38.52	22.7	28.3	621.42	327.90	197.44	112.66	24.73	19.54	11.48	10.29
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	45.26	40.76	26.0	35.2	642.87	347.32	207.59	124.32	29.66	21.79	15.63	12.27
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	48.36	43.28	28.0	38.8	661.71	365.11	237.15	142.32	34.75	25.96	18.21	15.18
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	47.91	43.52	28.7	41.1	674.39	394.57	242.65	149.51	37.60	28.16	21.01	18.51
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	55.78	48.08	32.06	44.70	713.78	408.09	257.52	179.62	43.33	32.95	25.77	23.64
	Mean	48.1	42.83	27.6	37.62	662.83	368.59	228.47	141.68	34.01	25.68	18.42	15.97
	SE(m)±	1.45	1.49	0.89	1.45	9.88	9.54	11.75	6.47	1.54	1.01	0.95	1.11
	C.D. at 5%	4.46	4.60	2.76	4.48	30.45	29.41	36.20	19.93	4.75	3.11	2.92	3.41
	C.V%	6.02	6.97	6.48	7.72	2.98	5.18	10.28	9.13	9.07	7.87	10.29	13.85

(FS-Flowering stage, PFS-Pod filling stage and AH-At harvest)

Table 4(b): Effect of different treatments of ammonium molybdate on micronutrient content at critical growth stages of pigeon pea

Sr. No.	Treatments	Mn content (%)				Mo content (%)			
		Stover			Seed	Stover			Seed
		FS	PFS	AH		FS	PFS	AH	
T_1	Absolute control	61.12	25.54	19.20	10.94	0.26	0.18	0.12	0.42
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	64.80	37.18	22.46	12.93	0.29	0.23	0.15	0.48
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	66.46	42.83	28.75	14.36	0.31	0.26	0.17	0.51
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	68.48	48.77	31.14	18.06	0.37	0.27	0.20	0.52
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	73.88	58.43	35.60	21.24	0.40	0.31	0.23	0.55
	Mean	66.94	42.55	27.39	15.50	0.32	0.25	0.17	0.49
	SE(m)±	1.25	1.46	1.20	0.77	0.01	0.01	0.01	0.01
	C.D. at 5%	3.85	4.50	3.69	2.38	0.04	0.03	0.03	0.03
	C.V%	3.74	6.86	8.74	9.98	7.78	7.99	9.57	4.38

(FS-Flowering stage, PFS-Pod filling stage and AH-At harvest)

Manganese content

The data pertained in Table 4(b) showed that the concentration of manganese in pigeon pea stover at three critical growth stages *viz*. was flowering, pod filling, at harvest and seed manganese concentration. The treatment receiving foliar spray of ammonium molybdate @ 0.5% along with RDF (T_5) found significantly superior 73.88, 58.43 and 35.60% respectively over rest of the treatments and similar treatment found superior in case of manganese concentration of seed 21.24 %. However, the lowest values for both stover and seed Manganese concentration found in absolute control (T_1). The Manganese concentration in pigeon pea plant was highest at flowering stage and decline at harvest of the crop but the concentration was higher in seed.

The research findings confirmed with work done by Gad and Kandil (2013) [8, 9] 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) [8, 9] studied the effect of cobalt and molybdenum combination under different levels of nitrogen on growth, nodules efficiency, yield and quality of cowpea plants. They found that cobalt and molybdenum in combination significantly increased the Mn content. Similar results supported by the findings of Singh *et al.* (2014) [2, 18, 26] and Kannan *et al.* (2014) [15].

Molybdenum content

The data presented in Table 4(b) showed that the concentration of molybdenum in pigeon pea stover at three critical growth stages *viz.* was flowering, pod filling, at harvest and seed molybdenum concentration. The treatment receiving foliar spray of ammonium molybdate @ 0.5% along with RDF (T_5) found significantly superior 0.40, 0.31 and 0.23% respectively over rest of the treatments. The molybdenum concentration of seed 0.55 % was also found in similar treatment. The treatment RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4) found at par with RDF + Ammonium molybdate foliar application @ 0.5% (T_5) in case of stover and seed molybdenum content. However, the lowest values for both stover and seed molybdenum concentration found in absolute control (T_1). The molybdenum concentration in pigeon pea plant was highest at flowering stage and decline at harvesting stage of the crop but the concentration was higher in seed at harvest.

The results are in conformity to the findings of Sale and Nazirkar (2013) [24] found highest content of molybdenum in treatment receiving foliar application of zinc and iron with seed fortification of molybdenum. Manohar (2014) [21] 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. Similar findings confirmed with Kumar and Sharma (2005) [17, 18] Vyas *et al.* (2003) [29] and Yadav *et al.* (2017) [30]. Alan *et al.* 2015 revealed the content 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 quality and yield of pigeon pea. Nutrient content status of plant and seed N, P, K, Fe, Zn, Mn, Cu and Mo improved due to application of RDF + ammonium molybdate through foliar application @ 0.5 % ha^{-1} at critical growth stages of pigeon pea followed by the treatment Ammonium molybdate soil application@ 2kg ha^{-1} along with RDF at critical growth stages of pigeon pea.

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