International Journal of Chemical Studies 2019; 7(5): 980-987

International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 980-987
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Received: 19-07-2019
Accepted: 21-08-2019

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Effect of application of ammonium molybdate on nutrient status and yield of pigeon pea grown in Vertisol

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Abstract
A field experiment was conducted during 2018-19 to study the "Effect of application of ammonium molybdate on nutrient status and yield of pigeon pea grown on Vertisol" 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 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 found that Available macro and micronutrients at various growth stages of pigeon pea found to be decreased continuously from flowering to harvesting due to plant uptake of nutrients for their vegetative and reproductive growth. The yield parameters like seed yield and stover yield was increased due to application of RDF + ammonium molybdate through foliar application @ 0.5% followed by the treatment receiving RDF + Ammonium molybdate @ 2 kg ha^{-1}.

Keywords: Ammonium molybdate, nutrient status, yield, pigeon pea, vertisol, macro and micronutrients, seed yield, stover yield

Introduction
Pigeon pea (*Cajanus Cajan* L.) is a perennial legume from family Leguminacae (Fabaceae). The common names of pigeon pea are Tropical green pea, Arhar and Red gram in India. It is a perennial crop 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. Anonymous (2014a) [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}. Anonymous (2014b) [5] reported 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). It is successfully grown on black cotton soil, well drained with a pH ranging from 7.0 to 8.5. The interest in foliar fertilizers are due to multiple advantages of foliar application methods such as rapid and efficient response to the plant needs, less product needed and independence from soil conditions. It is also recognized that the supplementary foliar fertilization during crop growth can improve the mineral status of plant and increase the crop yield (Elayaraja and Angayarkanni. 2005) [10]. Among the micronutrients Zn, Fe, B, Mn and Mo improved the yield appreciably and foliar spray of micronutrients proved to be economical in pulses (Savithri *et al*. (2001) [24].
Molybdenum (Mo) was identified as an essential element for higher plants in 1939. Most crops require less than 1 ppm of this element. The lowest concentration of any essential nutrient soils contain about 0.36 to 5.0 ppm total molybdenum. It is found in trace amounts in the mineral olivine, in some iron and aluminium oxides and hydroxides and clay silicates. Molybdate is a trace element found in soil and is required for the growth of most biological organism including plants and animals. The available soil Molybdenum (Mo) can be extracted by using

Griggs and Tamm's reagent at pH 3.3. This method is known as ammonium oxalate method, and from plant by using atomic absorption spectrophotometer (A.A.S.) method Mo is extracted.

Material and Methods

A field experiment was conducted during year 2018-19 to study the "Effect of application of ammonium molybdate on nutrient status and yield of pigeon pea grown on Vertisol" at Research Farm of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Soil analysis:

Soil samples were collected before sowing, at flowering, at pod formation and at harvest stage of crop from surface layer (0-15 cm) from each treated plots of the layout. Soils were air dried, ground with wooden mortar and pestle and passed through 2 mm sieve. The sieved samples were stored in polythene bags with proper labelling for further analysis. These soil samples were subjected to various chemical estimations as per the standard methods given below. Soil Reaction pH was determined in (1:2.5) soil water suspension using digital pH meter (Jackson, 1976) [12], Electrical conductivity was determined in (1:2.5) soil water suspension by using conductivity bridge meter (Jackson, 1976) [12], Organic carbon Walkley and Black's wet digestion method was used for the determination of organic carbon from soil (Jackson, 1976) [12], Calcium carbonate was determined by rapid titration method as suggested by Piper (1966) [21], available Nitrogen was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956) [27], available Phosphorous from soil was extracted by 0.5 M sodium bicarbonate (pH 8.5) as an extractant and measured calorimetrically at 420 nm wave length as described by Olsen *et al*. (1954) [19], available Potassium was determined by using neutral normal ammonium acetate as an extractant using flame photometer (Jackson, 1976) [12], available Molybdenum was determined by using ammonium oxalate method by using spectrophotometer described by (Griggs J.L, 1953) [11], available micronutrient Zn, Fe, Mn and Cu were determined by using DTPA extractant as described by Lindsay and Novell (1978) using AAS (Parkin Elmer Analyst 200 model).

Seed yield

The plants from each net plot were harvested and seeds were separated by threshing, after sun drying the pods, seed yields obtained in each net plot were weighted (kg) and further it was calculated on the hectare basis (kg ha^{-1}).

Soil nutrient status of experimental site

The soil of the experimental site is alkaline having pH (8.14) and Ec (0.29 dSm^{-1}) with organic carbon (OC) content (3.80 g kg^{-1}), calcium carbonate ($CaCO_3$) content (23 g kg^{-1}) and low in available N (150.64 kg ha^{-1}), phosphorous (P_2O_5) content (11.20 kg ha^{-1}) and high in available potassium (K_2O) content (590.32 kg ha^{-1}) and available copper content (2.5 mg kg^{-1}), available manganese content (5.08 mg kg-1) and available zinc content (0.40 mg kg^{-1}), available ferrous content (4.10 mg kg-1) and low in available Mo content (0.15).

Table 1: Initial (Before sowing) properties of the experimental soil

Sr. No.	Particulars	Unit	Value
1.	pH (1: 2.5)		8.14
2.	EC	dSm^{-1}	0.29
3.	Organic carbon	g kg^{-1}	3.80
4.	Calcium carbonate	g kg^{-1}	23
5.	Available nitrogen	kg ha^{-1}	150.64
6.	Available phosphorus	kg ha^{-1}	11.20
7.	Available potassium	kg ha^{-1}	590.32
8.	Available Cu	mg kg^{-1}	2.5
9.	Available Mn	mg kg^{-1}	5.08
10.	Available Zn	mg kg^{-1}	0.40
11.	Available Fe	mg kg^{-1}	4.10
12.	Available Mo	mg kg^{-1}	0.15

Results and Discussion

Physico-chemical properties of soil at critical growth stages of pigeon pea

pH and EC

The data narrated in Table 2 showed that the influence of molybdenum application on residual soil pH and EC was non-significant. Range of pH and EC at flowering 8.13 to 7.95 with mean 8.0 and 0.30 to 0.27 dSm^{-1} with mean 0.28 dSm^{-1} at pod filling 8.05 to 7.85 with mean 7.94 and 0.29 to 0.26 dSm^{-1} with mean 0.27 dSm^{-1} and at harvest 7.95 to 7.81 with mean 7.86 and 0.28 to 0.26 dSm^{-1} with mean 0.27 dSm^{-1}. However, the pH and EC values lowered with application of molybdenum.

The results were matches with Quaggio *et al*. (2004) [22] studied response of peanut to lime and molybdenum application in low pH soils they found that the soil pH increased from 4.2 in control plots to 5.7 in the plot under the highest liming rate and molybdenum application. Chatterji and Bandyopadhyay (2017) [8] studied that with application of molybdenum through seed treatment resulted in decrease in pH from 5.73 to 5.71 in cowpea growing soil.

Table 2: Effect of different treatments of ammonium molybdate on pH and Electrical conductivity of soil at critical growth stages of pigeon pea

Sr. No.	Treatments	Soil pH (1:2.5)			EC (dSm^{-1})		
		FS	PFS	AH	FS	PFS	AH
T_1	Absolute control	8.13	8.05	7.95	0.30	0.29	0.28
T_2	RDF (25:50 $N:P_2O_5$ kg ha^{-1})	7.98	7.98	7.90	0.29	0.28	0.27
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	7.98	7.93	7.85	0.29	0.28	0.27
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	7.98	7.90	7.82	0.28	0.27	0.27
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	7.95	7.85	7.81	0.27	0.26	0.26
	Mean	8.00	7.94	7.86	0.28	0.27	0.27
	SE(m)±	0.05	0.03	0.03	0.01	0.01	0.01
	C.D. at 5%	NS	NS	NS	NS	NS	NS
	C.V%	1.23	0.75	0.78	5.85	3.75	3.08

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

Calcium carbonate ($CaCO_3$) and Organic carbon (OC)

The data indicated in Table.3 revealed that there is non-significant result found in case of soil $CaCO_3$. The range of $CaCO_3$ and organic carbon was varied from 22.55 to 21.75 g kg^{-1} with mean value 22.26 g kg^{-1} and 4.0 to 4.5 g kg g^{-1} with mean value 4.26 g kg^{-1} at flowering, 22.05 to 21.05 g kg g^{-1} with mean 21.29 g kg^{-1} and 4.1 to 4.6 g kg^{-1} with mean 4.36 g kg^{-1} at pod filling and 21.05 to 20.35 g kg^{-1} with mean 20.72 and 4.2 to 4.6 g kg^{-1} with mean 4.46 g kg^{-1} respectively. The soil organic carbon content was found significantly highest in the treatment RDF + soil application of ammonium molybdate @ 2 kg ha^{-1} (T_4) at flowering (4.4 g kg^{-1}), pod filling (4.5 g kg^{-1}) and at harvest (4.6 g kg^{-1}), respectively. The treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) was at par with RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4). However, the lowest value of soil organic carbon noted in absolute control (T_1).

The research findings matching with work done by Reddy *et al*. (2007) [23] recorded that the results were non-significant as a result of application of sodium molybdate in pigeon pea crop.

Table 3: Effect of different treatments of ammonium molybdate on calcium carbonate and organic carbon content of soil at critical growth stages of pigeon pea

Sr. No.	Treatments	Soil $CaCO_3$ (g kg^{-1})			Organic carbon (g kg^{-1})		
		FS	PFS	AH	FS	PFS	AH
T_1	Absolute control	22.55	22.05	21.05	4.0	4.1	4.2
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	22.28	21.73	21.10	4.2	4.2	4.4
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	22.53	21.48	20.78	4.2	4.4	4.5
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	22.20	21.05	20.53	4.5	4.6	4.6
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	21.75	20.18	20.15	4.4	4.5	4.6
	Mean	22.26	21.29	20.72	4.26	4.36	4.46
	SE(m)±	0.227	0.155	0.166	0.01	0.01	0.01
	C.D. at 5%	NS	NS	NS	0.02	0.02	0.02
	C.V%	2.04	1.46	1.6	3.47	2.7	2.8

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

Available macronutrient at critical growth stages of pigeon pea

Available nitrogen

The data narrated in Table 4 and showed that there was influence on soil available nitrogen as a result of application of different treatments. The range of soil available nitrogen at three critical growth stages of pigeon pea varied from 162.39 to 234.77 kg ha^{-1} with mean value 203.71 kg ha^{-1}, 158.49 to 227.35 kg ha^{-1} with mean value 196.13 kg ha^{-1} and 150.88 to 215.92 kg ha^{-1} with mean value 190.80 kg ha^{-1} respectively. The soil application of ammonium molybdate @ 2 kg ha^{-1} with RDF (T_4) shows significantly superior values for soil available nitrogen at flowering 234.77 kg ha^{-1}, pod filling 227.35 kg ha^{-1} and at harvest 215.92 kg ha^{-1} followed by treatment RDF +Ammonium molybdate foliar application @ 0.5% (T_5). However, significantly lower soil available nitrogen noted in control plot (T_1). The availability of nitrogen in soil declined with crop growth due to plant uptake.

Table 4: Effect of different treatments of ammonium molybdate on available Nitrogen at critical growth stages of pigeon pea

Sr. No.	Treatments	Available N (kg ha^{-1})		
		Flowering	Pod filling	At harvest
T_1	Absolute control	162.39	158.49	150.88
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	190.51	179.67	178.08
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	210.58	200.07	201.46
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	234.77	227.35	215.92
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	220.30	215.08	207.67
	Mean	203.71	196.13	190.80
	SE(m)±	3.85	3.01	4.67
	C.D. at 5%	11.85	9.26	14.40
	C.V%	3.78	3.06	4.9

The findings of researchers discussed for clarify the results of Alam *et al.* 2015 [1] studied that the effect of different Molybdenum levels on No_3-N content of soil and found increase in No_3 content of soil with increase in Mo levels 0 to 1 mg kg^{-1} in vetch growing soil. Singh *et al.* (2014) [25] found that NH_4-N, NO_3-N, Organic N, available N and total N were also recorded higher with combined micronutrients application. Basavarajappa *et al*. (2013) [7] revealed that the higher soil available nitrogen may be due to higher microbial activity, higher root activity in the rhizosphere, improved soil physical properties and chemical properties. The organism during mineralization convert organically bound nutrients to inorganic form resulting in higher availability of nutrients. Karpagam and Rajesh (2014) [15] recorded that with the increased levels of molybdenum 0 to 1000 g ha^{-1} availability of nitrogen increased significantly from 100.3 to 105.4 kg ha^{-1} in green gram growing soil. Reddy *et al.* (2007) [23] studied the effect of application of sodium molybdate along with RDF at 1.5 and 3 kg ha^{-1} on availability of nitrogen and found nitrogen availability increased positively up to 252 kg ha^{-1} .Chatterji and Bandyopadhyay (2017) [8] studied that with application molybdenum the availability of nitrogen increased 182.26 kg ha^{-1} as compared to control 171.11 kg ha^{-1} in cow pea growing soil.

Available phosphorus

The data narrated in Table 5 showed that there was a significant results found in case of soil available phosphorus at three critical growth stages of pigeon pea with different treatments of ammonium molybdate. The range of soil available phosphorus varied from 11.21 to 14.03 kg ha^{-1} with mean value 12.84 kg ha^{-1}, 10.09 to 13.37 kg ha^{-1} with mean value 11.97 kg ha^{-1} and 9.02 to 12.53 kg ha^{-1} with mean value 10.68 kg ha^{-1}, respectively. The treatment RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4) found superior at all critical growth stages i.e. flowering 14.03 kg ha^{-1}, pod filling 13.37 kg ha^{-1} and at harvest 12.53 kg ha^{-1} followed by treatment which receiving foliar application of ammonium molybdate @ 0.5% along with RDF (T_5). However, the lowest soil available phosphorus noted in control plot (T_1). The soil phosphorus is mobilized by soil application of molybdenum because it helps in improvement in microbial population and activities.

Table 5: Effect of different treatments of ammonium molybdate on available phosphorus at critical growth stages of pigeon pea

Sr. No.	Treatments	Available P_2O_5 (kg ha^{-1})		
		Flowering	Pod filling	At harvest
T_1	Absolute control	11.21	10.09	9.02
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	12.47	12.09	10.30
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	13.18	12.13	10.37
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	14.03	13.37	12.53
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	13.33	12.21	11.19
	Mean	12.84	11.97	10.68
	SE(m)±	0.13	0.14	0.17
	C.D. at 5%	0.41	0.43	0.52
	C.V%	2.07	2.32	3.17

The findings closely related with findings of Karpagam and Rajesh (2014) [15] observed that the availability of phosphorus increased from 44 to 46.4 kg ha^{-1} with increasing levels of molybdenum from 0 to 1000 g ha^{-1} in green gram growing soil. Reddy *et al.* (2007) [23] found that phosphorus positively increased from 18 kg ha^{-1} to 20 kg ha^{-1} due to application of sodium molybdenum at 3 kg ha^{-1} compared to control. Chatterji and Bandyopadhyay (2017) [8] observed that availability of phosphorus increased from 18.11 kg ha^{-1} to 21.25 kg ha^{-1} due to application of molybdenum by seed treatment in cowpea growing soil.

Available potassium

The data presented in Table 6 indicated that there was a significant results found in case of soil available potassium with different treatments of ammonium molybdate at three critical growth stages of pigeon pea. The range of soil available potassium varied from 614.05 to 748.07 kg ha^{-1} with mean value 684.32 kg ha^{-1}, 600.15 to 733.5 kg ha^{-1} with mean value 672.81 kg ha^{-1} and 593.92 to 720.91 kg ha^{-1} with mean value 665.80 kg ha^{-1}, respectively. The treatment RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4) found superior with values 748.07, 733.07 and 720.91 kg ha^{-1} at flowering, pod filling and at harvest, respectively over rest of the treatments and treatment RDF + Ammonium molybdate foliar application @ 0.5% (T_5) found at par with RDF + Ammonium molybdate soil application @ 2 kg ha^{-1} (T_4). However, significantly lower soil available potassium observed in control plot (T_1).

Table 6: Effect of different treatments of ammonium molybdate on available potassium at critical growth stages of pigeon pea

Sr. No.	Treatments	Available K_2O (kg ha^{-1})		
		Flowering	Pod filling	At harvest
T_1	Absolute control	614.05	600.15	593.92
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	649.92	636.80	632.88
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	688.61	683.05	677.82
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	748.07	733.07	720.91
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	720.95	710.99	703.46
	Mean	684.32	672.81	665.79
	SE(m)±	14.55	10.02	8.21
	C.D. at 5%	44.84	30.88	25.31
	C.V%	4.25	2.98	2.47

The results were matches with Quaggio *et al*. (2004) [22] studied response of peanut to lime and molybdenum application in low pH soils and found that the exchangeable K increased with the level of lime (2 t ha^{-1}) and molybdenum (300 g ha^{-1}) from 1.4 to 1.9 m mol dmS^{-3}. Reddy *et al.* (2007) [23] recorded the available potassium increased positively with application of sodium molybdate. Chatterji and Bandyopadhyay (2017) [8] observed that availability of potassium increased from 116.21 to 118.31 kg ha^{-1} with application of molybdenum seed treatment in cow pea growing soil.

Available micronutrient at critical growth stages of pigeon pea

Available zinc and ferrous

The data narrated in Table 7 indicated that there was a significant result found in case of DTPA extractable zinc and ferrous with different treatments of ammonium molybdate at three critical growth stages of pigeon pea. The range of soil available zinc and ferrous varied from 0.41 to 0.57 mg kg^{-1} with mean value 0.49 mg kg^{-1} and 4.18 to 4.93 mg kg^{-1} with mean value 4.51 mg kg^{-1} at pod filling, 0.39 to 0.54 mg kg^{-1} with mean value 0.47 mg kg^{-1} and 4.06 to 4.85 mg kg^{-1} with mean value 4.38 mg kg^{-1} at pod filling and 0.38 to 0.53 mg kg^{-1} with mean value 0.46 mg kg^{-1} and 3.99 to 4.76 mg kg^{-1} with mean value 4.34 mg kg^{-1} at harvest, respectively. The treatment application of ammonium molybdate through soil @ 2 kg ha^{-1} along with RDF (T_4) found superior at three critical growth stages i.e. flowering 0.57 and 4.93 mg kg^{-1}, pod filling 0.54 and 4.85 mg kg^{-1} and at harvest 0.53 and 4.76 mg kg^{-1} followed by the treatment receiving foliar application of ammonium molybdate @ 0.5% (T_5). However, lowest DTPA extractable zinc and ferrous observed in control plot (T_1).

Table 7: Effect of different treatments of ammonium molybdate on available zinc and ferrous at critical growth stages of pigeon pea

Sr. No.	Treatments	DTPA Zn (mg kg^{-1})			DTPA Fe (mg kg^{-1})		
		FS	PFS	AH	FS	PFS	AH
T_1	Absolute control	0.41	0.39	0.38	4.18	4.06	3.99
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	0.48	0.46	0.44	4.34	4.29	4.18
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	0.48	0.47	0.46	4.45	4.34	4.35
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	0.57	0.54	0.53	4.93	4.85	4.76
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	0.55	0.53	0.51	4.68	4.40	4.44
	Mean	0.49	0.47	0.46	4.51	4.38	4.34
	SE(m)±	0.02	0.01	0.01	0.06	0.04	0.04
	C.D. at 5%	0.04	0.03	0.04	0.17	0.13	0.14
	C.V%	5.47	5.33	4.86	2.48	1.89	2.01

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

The findings closely related with findings of Kannan *et al.* (2014) [14] reported that zinc is found to be deficient in black soils because presence of calcium carbonate decreased the availability of zinc due to higher soil pH. Arunachalam *et al*. (2013) [6] revealed that this might be due to the fact that under alkaline condition of zinc cation charged largely to their oxides or hydroxides and there by lower the availability of Zn. Chaturvedi *et al.* (2010) [9] stated that the low Fe content in soil might be attributed to the formation of insoluble higher oxides of Fe at higher pH and adsorption of Fe on the surface of CaCO3 particles.

Available copper and manganese

The data recorded in Table 8 revealed that there was a significant results found in case of DTPA extractable copper and manganese with different treatments of ammonium molybdate at three critical growth stages of pigeon pea The range of soil available copper and manganese varied from 2.77 to 3.23 mg kg^{-1} with mean value 2.82 mg kg^{-1} and 5.14 to 6.05 mg kg^{-1} with mean value 5.45 mg kg^{-1} at flowering, 2.50 to 3.02 mg kg^{-1} with mean value 2.80 mg kg^{-1} and 5.12 to 5.91 mg kg^{-1} with mean value 5.43 mg kg^{-1} at pod filling and 2.46 to 2.83 mg kg^{-1} with mean value 2.65 mg kg^{-1} and 4.82 to 5.87 mg kg^{-1} with mean value 5.36 mg kg^{-1} at harvest, respectively. The application of ammonium molybdate through soil @ 2 kg ha^{-1} along with RDF (T_4) showed maximum availability of copper and manganese at three critical growth stages i.e. flowering 3.23 and 6.05 mg kg^{-1}, pod filling 3.02 and 5.91 mg kg^{-1} and at harvest 2.59 and 5.46 mg kg^{-1} followed by the treatment receiving foliar application of ammonium molybdate @ 0.5% (T_5). The availability of copper in soil found non-significant at harvest. The significantly lower DTPA extractable copper and manganese was observed in absolute control (T_1).

Table 8: Effect of different treatments of ammonium molybdate on available copper and manganese at critical growth stages of pigeon pea

Sr. No.	Treatments	DTPA Cu (mg kg^{-1})			DTPA Mn (mg kg^{-1})		
		FS	PFS	AH	FS	PFS	AH
T_1	Absolute control	2.77	2.50	2.46	5.14	5.12	4.82
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	2.82	2.77	2.73	5.38	5.35	5.41
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	2.78	2.83	2.66	5.41	5.37	5.27
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	3.23	3.02	2.83	6.05	5.91	5.87
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	2.81	2.91	2.59	5.47	5.43	5.46
	Mean	2.82	2.80	2.65	5.49	5.43	5.36
	SE(m)±	0.09	0.04	0.10	0.05	0.04	0.08
	C.D. at 5%	0.26	0.11	NS	0.16	0.11	0.23
	C.V%	6.09	1.32	7.56	1.84	1.32	2.79

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

Available molybdenum

The data presented in Table 9 and depicted in fig.1 showed that available molybdenum content of soil was influenced by different treatments of ammonium molybdate at three critical growth stages of pigeon pea. The range of soil available molybdenum varied from 0.18 to 0.30 mg kg^{-1} with average value 0.21 mg kg^{-1}, 0.16 to 0.28 mg kg^{-1} with average value 0.20 mg kg^{-1} and 0.14 to 0.26 mg kg^{-1} with average value 0.18 mg kg^{-1}. The significantly highest residual available molybdenum content was recorded in the treatment RDF along with soil application of ammonium molybdate @ 2 kg ha^{-1} (T_4) and the values are 0.30, 0.28 and 0.26 mg kg^{-1} at flowering, pod filling and at harvest, respectively. It was followed by the treatment receiving foliar application of ammonium molybdate @ 0.5% (T_5). However, the lowest soil available molybdenum observed in absolute control (T_1) followed by RDF (T_2).

Table 9: Effect of different treatments of ammonium molybdate on available molybdenum at critical growth stages of pigeon pea

Sr. No.	Treatments	Available Mo (mg kg^{-1})		
		Flowering	Pod filling	At harvest
T_1	Absolute control	0.18	0.16	0.14
T_2	RDF (25:50 N:P_2O_5 kg ha^{-1})	0.18	0.17	0.15
T_3	T_2+Ammonium molybdate seed treatment @1g kg^{-1} of seed	0.17	0.18	0.15
T_4	T_2 +Ammonium molybdate soil application@ 2kg ha^{-1}	0.30	0.28	0.26
T_5	T_2+Ammonium molybdate foliar application @ 0.5%	0.23	0.22	0.21
	Mean	0.21	0.20	0.18
	SE(m)±	0.013	0.01	0.01
	C.D. at 5%	0.041	0.03	0.04
	C.V%	12.710	9.12	13.35

Few researchers noticed similar observations, Alan *et al.* 2015 [1] studied that total molybdenum content of soil increased from 0.19 to 0.54 mg kg^{-1} with different levels of molybdenum application 0 to1 mg kg^{-1}. Karpagam and Rajesh (2014) [15] studied the different levels of molybdenum application 0 to 1000 g ha^{-1} on molybdenum availability in green gram growing soil and found that increased availability of molybdenum from 0.04 to 0.14 mg kg^{-1}. Reddy *et al.* (2007) [23] recorded that availability of molybdenum affected by application of molybdenum and values varied from 0.4 to 0.5 ppm when compared to control.

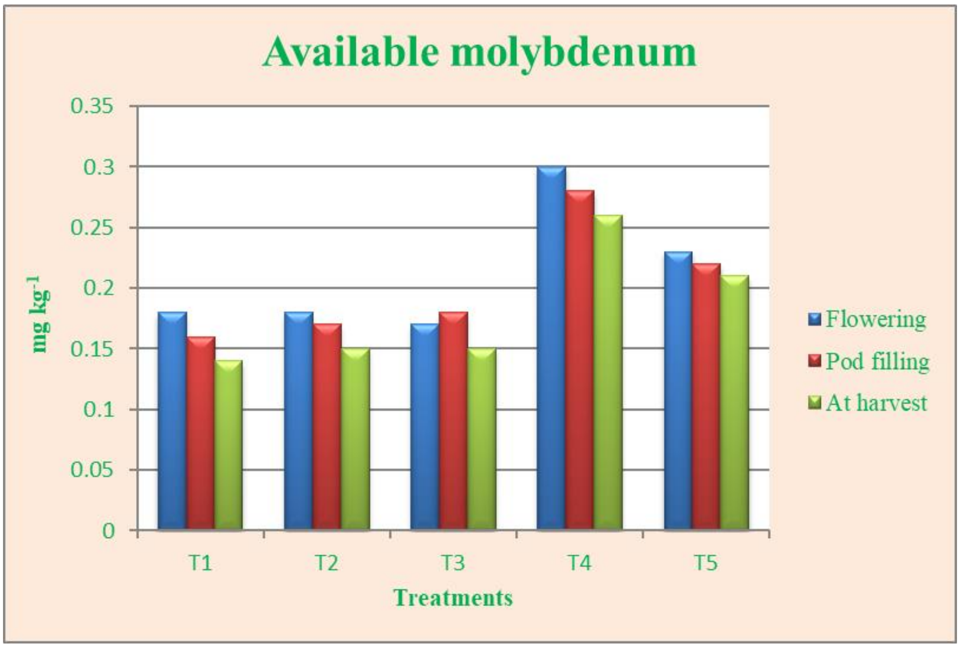

Fig 1: Effect of different treatments of Ammonium molybdate on available molybdenum at critical growth stages of pigeon pea

Seed yield and dry matter production of pigeon pea

The data observed in Table 10 and depicted in fig.2 and 3showed that effect of application of ammonium molybdate on seed yield, stover yield and total biomass production of pigeon pea varied from 795 kg ha^{-1} to 945 kg ha^{-1} seed yield with mean value 878 kg ha^{-1}, 1060.98 to 1417.56 kg ha^{-1} stover yield with mean value 1220.80 kg ha^{-1} and 1855.98 to 2362.56 kg ha^{-1} total biomass production with mean value 2098.80 kg ha^{-1} , respectively. 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) 910, 1274.50 and 2184.5 kg ha^{-1}, RDF + Ammonium molybdate seed treatment @1g kg^{-1} of seed (T_3) 880, 1232.40 and 2184.5 kg ha^{-1} . However, the lowest seed, stover and total biomass yield were recorded in absolute control (T_1).

The results were matches with Kailash *et al.* (2017) [13] studied that application of multi micronutrients along with molybdenum both by foliar and soil application increases the yield 984.7 and 951.5 kg ha^{-1} than the RDF alone 941.8 kg ha^{-1}. Similarly, Yadav *et al.* (2017) [28] reported that molybdenum application at 1.0 kg ha^{-1} significantly increased seed, stover and biological yield. Manga *et al.* (1999) [17] reported that the molybdenum application increased the number of pods per plant, number of seeds per pod and seed yield. The seed yield increases were 15.7 and 25.9% when 0.5 and 1.0 kg ammonium molybdate ha^{-1} applied respectively. Sonavane *et al.* (2015) [26] found that BSMR-736 variety of pigeon pea produced maximum and significantly higher grain and stalk yields. Similar results revealed by Manohar (2014), Kumar and Sharma (2005).

Table 10: 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

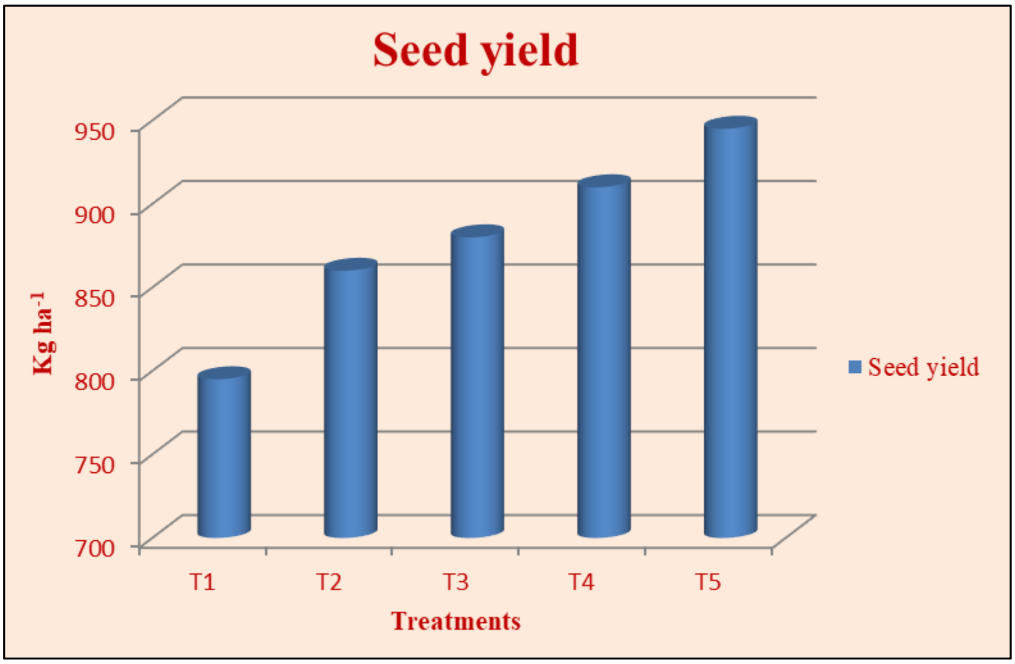

Fig 2: Effect of different treatments of Ammonium molybdate on seed yield of pigeon pea

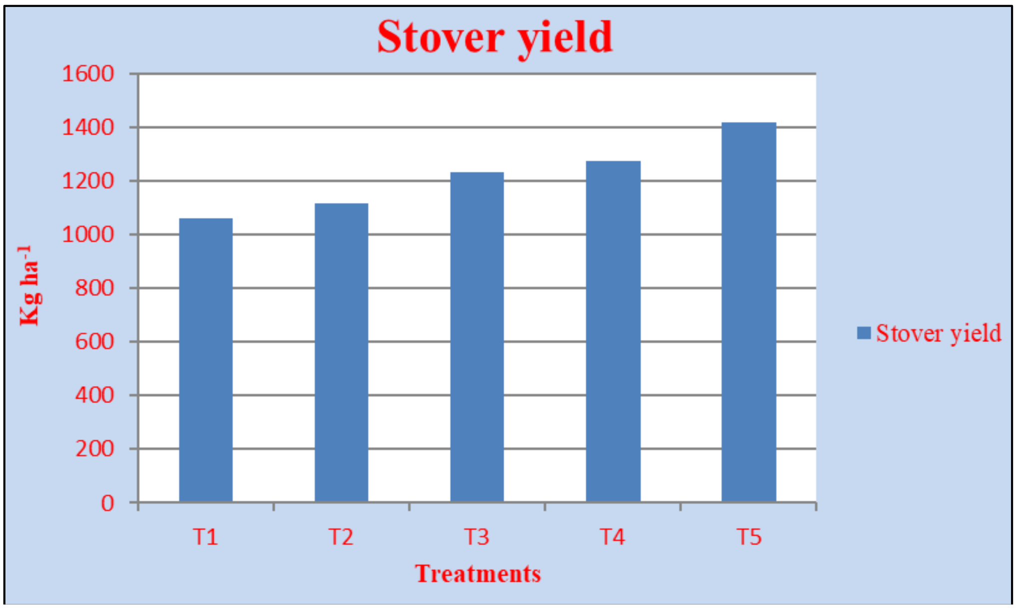

Fig 3: Effect of different treatments of Ammonium molybdate on stover yield of pigeon pea

Conclusion

Soil fertility status of available N, P, K, Fe, Zn, Mn, Cu and Mo improved due to application of RDF + ammonium molybdate through soil application @ 2 kg ha^{-1} at critical growth stages of pigeon pea followed by the application of ammonium molybdate through foliar application @ 0.5% along with recommended dose of fertilizer. Application of RDF + ammonium molybdate through foliar application @ 0.5% significantly, enhanced seed and stover yield of pigeon pea.

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