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Impact of Cobalt Application Methods on Chickpea Yield, Nutrient Uptake and Status of Soil

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ABSTRACT

A field experiment was conducted during *rabi* season of 2015-2016 at Navsari Agricultural University, Navsari to study the impact of cobalt application methods on chickpea yield, nutrient content and soil status. Four cobalt application methods with three levels of each were evaluated with one absolute control and one with seed priming of water were evaluated with randomized block design with three replications. Least level of seed treatment, soil application and foliar application of cobalt gave highest chickpea seed yield and decreased there after. As cobalt levels increased, NPK content and uptake are decreased linearly in all the methods except seed priming method, however cobalt content and uptake increased linearly by seed treatment and foliar application, on the contrary it decreased linearly by seed priming and soil application of cobalt. Soil application of cobalt at 50 g ha^{-1} recorded highest chickpea seed yield, residual NPK and Co and which can be useful for succeeding crop and this can be recommended from the cobalt nutrition point of view in plants and animals followed by seed priming at 1 ppm.

Key words: Chickpea, Cobalt application methods, Cobalt levels, Elemental soil nutrients, Nutrient uptake.

INTRODUCTION

Human beings need at least 22 mineral elements through balanced diet (Thacher *et al*., 2006). Currently, two billion people throughout the world are coming across micronutrients deficiency (Velu *et al*. 2014). At least 17 elements are considered as essential in plants. Soil supply macronutrients *viz*. N, P, K, Ca, Mg and S in large amount and micronutrients namely Fe, Mn, B, Mo, Co, Zn, Cl and Ni in a small amount. More elements can be added in the list of essential/beneficial nutrients in the future are Na, Co, Va and Se. Vegetative or reproductive growth of the plant is impossible with deficiency of micronutrients/beneficial nutrients. Micronutrients are essential nutrients and to be supplied in very small quantity to crops. For the requirement of these micronutrients, plants have to depend on soil or micronutrients supplied to the soil in the form of impurities through fertilizer. Recently, multi micronutrients deficiencies are diagnosed more frequently. To achieve good crop yield, it is necessary to recognize and correct the deficiencies of micronutrients.

Cobalt is one of the beneficial element required in legume and non-legume plants for various physiological actions. Cobalt is involved in DNA synthesis through cynocobalamine dependent ribonucleoside triphosphate reductase; it works as a cofactor for the activity of nitrogenase enzyme. Cobalt is beneficial in plants due to its essentiality in soybean, alfalfa and clover, turned out to be an agronomic interest (Halsworth *et al*., 1965). *Rhizobium* is the specific bacteria responsible for legume nodulation and atmospheric nitrogen fixation into amino acids and proteins. Cobalt is responsible for *Rhizobium* growth. Cobalt is the precursor for cynocobalamine, which is a constituent of pigment leghaemoglobin synthesized in *Rhizobium* bacteria. Quantity of leghaemoglobin in nodules is directly proportional to nitrogen fixation. In *Bradyrhizobium* and *Rhizobium* species, three enzymes *viz*. ribonucleotide reductase, methionine synthase and methyl malonyl-CoA mutase are known to be cobalt-induced and cobalamine-dependent, changes in their activities are responsible for nodulation and nitrogen fixation in legumes (Dilworth and Bisseling, 1984). Out of these enzymes, synthesis of leghaemoglobin is done by methylmalonyl CoA mutase. Hence cobalt deficiency directly responsible for reduction in vitamin B_{12} production, nodule development and nitrogen fixation. Looking to the importance of cobalt in legumes this experiment was planned with four methods of cobalt application to identify right method and right dose of cobalt for achieving highest seed yield, nutrient uptake and soil nutrient status.

MATERIALS AND METHODS

The experiment was carried out during *rabi* season of 2015-16 at Navsari Agricultural University, Gujarat. The region enjoys a predominantly maritime climate. The pre-planting composite soil samples were collected from the experimental soil at 0-30 cm depth. The soil was low in elemental nitrogen (N) (188.16 kg ha^{-1}), medium in

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phosphorus (P) (38.33 kg ha^{-1}), high in potassium (K) (327.74 kg ha^{-1}) and Co content was 0.32 mg kg^{-1}. (Jackson 1973) The climate of the experimental site was typically tropical, characterized by humid, diurnal and warm monsoon with heavy rainfall, quite cold winter and fairly hot summer. The experimental treatments were consisted of four methods of cobalt application (CoCl$_2$) *i.e.* seed priming at 0.5, 1 and 1.5 ppm, seed treatment at 1, 2 and 3 g kg^{-1} seed, soil application at 50, 100 and 150 g ha^{-1} and foliar application at 0.01, 0.025 and 0.05% twice at 30 DAS and just before flowering. Two control treatments (seed priming with and without water) were there. On-farm seed priming was done by dissolving CoCl$_2$ in water for two hours and air-dried in shadow thereafter, seed treatment was given by mixing CoCl$_2$ in viscous jaggery solution, applied to chickpea seeds and dried the seeds in shade, soil application of CoCl$_2$ was done through fertigation at 15 DAS at three-leaf stage and foliar application of CoCl$_2$ twice at 30 DAS and just before flowering was done by dissolving CoCl$_2$ with water. Chickpea (GG-2) was seeded with spacing of 30 cm x 10 cm with RDF of 20:40:00 N, P$_2$O$_5$ and K$_2$O kg ha^{-1}, respectively. The uptake of major nutrients was worked out by the method given by Parkinson and Allen, 1975. The uptake was calculated by multiplying dry matter accumulation to N, P and K concentration of stover and seed (Jackson 1973). For Co, the soil samples after harvest of chickpea were also collected to analyze DTPA-Co content (Lindsay and Norvell, 1978). Digested plant samples acid extract was used to analyze Co content by using AAS. The treatment effect was worked out based on the least significant difference (LSD) at 5% probability level (Gomez and Gomez, 1983).

RESULTS AND DISCUSSION

Seed and stover yield: Application of cobalt through seed treatment (26.98 and 42.08 q ha^{-1}), soil application (27.80 and 42.59 q ha^{-1}) and foliar application (27.58 and 42.31 q ha^{-1}) methods has recorded highest seed and stover yield of chickpea at their first level itself (Table 1). Foliar spray of cobalt has significantly increased fababean seed yield when cobalt spray level was increased from 0.24 and 0.48 g L^{-1}, however seed yield was decreased when seed priming was doubled from 0.07 and 0.14 g kg^{-1} (Attia *et al.*, 2016). Among all cobalt application methods, application of cobalt at 50 g ha^{-1} has exhibited significantly higher chickpea seed (27.80 q ha^{-1}) and stover yield (42.59 q ha^{-1}) and which were found at par with all three levels of seed priming and first two levels of seed treatment, soil application and foliar spray of cobalt. Nitrate reductase and nitrite reductase may be inhibited due to oxidative stress of cobalt. Photosynthesis is affected due higher dose of cobalt by seed treatment, soil application and foliar spray at second and third level and at third level of seed priming, leads to reduction of chickpea yield linearly with increase in cobalt dose. Leguminous crops can synthesize sufficient vitamin B$_{12}$, that can ultimately leads to synthesize adequate Lb. (Dilworth and Bisseling 1979). Looking to the heavy metal nature of cobalt, comparatively soil application of 50 g Co ha^{-1} and seed priming of cobalt at 1 ppm has registered highest chickpea seed yield by spending least amount of cobalt chloride.

NPK content and uptake: Among all cobalt application methods and their levels, significantly higher N (3.50% and 97.22 kg ha^{-1}), P (0.61% and 16.99 kg ha^{-1}) and K (1.45% and 40.28 kg ha^{-1}) content and uptake respectively was observed by soil application of 50 g cobalt ha^{-1} and which was found at par with all seed priming levels, first two levels of seed treatment, foliar and soil application of cobalt. Among seed treatment, soil application and foliar application of cobalt, as the concentration of cobalt in these treatments were increased there was linear decrement of N, P and K content

Table 1: Nutrient content and uptake of chickpea seed influenced through cobalt.

Treatment	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Content N (%)	Content P (%)	Content K (%)	Content Co (mg kg^{-1})	Uptake N (kg ha^{-1})	Uptake P (kg ha^{-1})	Uptake K (kg ha^{-1})	Uptake Co (g ha^{-1})
Control (absolute)	22.09	34.51	2.65	0.37	1.05	0.63	58.45	8.14	23.13	1.38
Control (water priming)	22.99	37.09	2.92	0.42	1.08	0.75	67.20	9.89	24.83	1.72
Seed priming 0.5 ppm	24.33	38.03	3.08	0.44	1.14	1.50	74.87	10.61	27.75	3.65
Seed priming 1.0 ppm	26.67	41.23	3.36	0.47	1.27	1.43	89.54	12.56	33.85	4.33
Seed priming 1.5 ppm	24.77	39.57	3.12	0.46	1.15	1.13	77.33	11.33	28.47	2.79
Seed treatment 1 g kg^{-1} seed	26.98	42.08	3.39	0.48	1.29	0.63	91.33	13.00	34.76	1.69
Seed treatment 2 g kg^{-1} seed	24.54	39.34	3.12	0.45	1.15	1.00	76.55	10.97	28.12	2.45
Seed treatment 3 g kg^{-1} seed	22.50	36.23	2.88	0.40	1.07	1.25	64.83	8.99	24.19	2.81
Soil application 50 g ha^{-1}	27.80	42.59	3.50	0.61	1.45	1.50	97.22	16.99	40.28	4.17
Soil application 100 g ha^{-1}	25.82	40.42	3.26	0.47	1.15	1.25	84.15	12.04	29.78	3.23
Soil application 150 g ha^{-1}	22.23	35.00	2.81	0.37	1.06	1.00	62.56	8.22	23.64	2.22
Foliar application 0.01% (twice)	27.58	42.31	3.44	0.55	1.33	1.02	94.91	15.26	36.77	2.84
Foliar application 0.025% (twice)	24.17	37.40	3.06	0.43	1.14	1.28	74.04	10.39	27.55	3.10
Foliar application 0.05% (twice)	20.67	34.51	2.63	0.17	1.02	1.76	54.35	3.58	21.11	3.63
S.Em. ±	1.32	1.98	0.14	0.02	0.06	0.07	4.62	0.55	1.69	0.13
C.D. at 5%	3.83	5.75	0.42	0.06	0.19	0.23	13.45	1.61	4.93	0.40

and uptake was seen. Method wise special trend regarding N, P and K content and uptake was that the lowest concentration of cobalt application methods *viz.* seed treatment (1 g $CoCl_2$ kg^{-1} seed), soil application (50 g $CoCl_2$ ha^{-1}) and foliar application (0.01%) has registered highest N (3.39, 3.50 and 3.44%), P (0.48, 0.61 and 0.55%) and K (1.29, 1.45 and 1.33%) content and N (91.33, 97.22 and 94.91 kg ha^{-1}), P (13.00, 16.99 and 15.26 kg ha^{-1}), K (34.76, 40.28 and 36.77 kg ha^{-1}) uptake, respectively. Cobalt fertigation was given at 0, 5, 10 and 20 ppm to faba bean and it was revealed that 20 ppm fertigation level had given highest NPK content in chickpea seed during both the seasons (Kandil, 2007). Total N content in the shoot (136.12 mg plant^{-1}) and root (22.46 mg plant^{-1}) was increased up to 100 µg cobalt sulfate and decreased thereafter up to 200 µg by soil application of cobalt to *Lablab purpureus* (Younis, 2011). Same observations were recorded in this experiment where soil application of 50 g ha^{-1} cobalt which is the least dose and has registered highest NPK content and uptake over 100 and 150 g ha^{-1} cobalt. As the small dose of cobalt became conducive for chlorophyll content, nodule count and Lb synthesis, chickpea crop has luxuriantly absorbed required NPK and other nutrients from the soil and which is reflected in chickpea seed yield and its nutrient composition. Hence minimum dose of cobalt through all methods helped for nutrients absorption from the soil. Treatment wise percentage increase of NPK content and uptake of most superior levels of cobalt over lowest chickpea seed NPK content and uptake with descending order was soil application of cobalt at 50 g $CoCl_2$ ha^{-1} (33.07, 258.82, 38.09% and 78.87, 374.58, 90.81 %), foliar application at 0.01% (30.79, 223.52, 30.39% and 74.62, 326.25, 70.62 %), seed treatment at 1 g kg^{-1} seed (28.89, 182.35, 26.47% and 68.04, 263.13, 64.66 %) and seed priming at 1 ppm (27.75, 176.47, 24.50% and 64.74, 250.83, 60.35 %), respectively. As far as NPK enrichment in seed is concerned soil application of 50 g $CoCl_2$ ha^{-1} turned out to be the best treatment and the same treatment has registered highest seed yield of chickpea. Soil application of 50 g cobalt ha^{-1} has correspondingly increased NPK content and uptake by 32.08, 64.86 and 38.09% and by 66.33, 108.7 and 74.14%, respectively of chickpea over absolute control. Lowest NPK content (2.63, 0.17 and 1.02%, respectively) and uptake (54.35, 3.58 and 21.11 kg ha^{-1}) were observed through foliar application of cobalt at 0.05% and which was followed by absolute control.

Cobalt content and uptake: Cobalt content and uptake in chickpea seed was decreased linearly by soil application of cobalt from 50 to 150 g cobalt ha^{-1}. However, seed priming of cobalt has increased cobalt content (1.43 mg kg^{-1}) and uptake (4.33 g ha^{-1}) up to the second level and shown a declining trend thereafter. Among all cobalt application methods and levels, foliar application of cobalt at 0.05% (1.76 mg kg^{-1}) exhibited highest cobalt content, but the highest cobalt uptake (4.33 g ha^{-1}) was observed in seed priming of chickpea at 1 ppm and which was at par with soil application of cobalt at 50 g ha^{-1}. The same results correlate with the findings of Gad and Kandil (2012) who observed that absorption of cobalt in peppermint and coriander was increased when cobalt was supplied to plant media over control. Method-wise significantly highest cobalt content in chickpea was observed through foliar application of cobalt at 0.05% (1.76 mg kg^{-1}) > soil application at 50 g ha^{-1} (1.50 mg kg^{-1}) > seed priming at 1 ppm (1.50 mg kg^{-1}) > seed treatment at 3 g kg^{-1} seed (49.37 mg kg^{-1}) (Table 1). As the absorption (1.76 mg kg^{-1}) of cobalt through the foliar application is higher at 0.05% the corresponding yield of chickpea seed yield through this treatment is lowest (20.67 q ha^{-1}). It means a foliar spray of cobalt at high concentration on chickpea crop gets absorbed in plants metabolism and creating the detrimental effect of crop physiology and reducing all growth, yield contributing characters and ultimately showing its effect through reducing chickpea seed yield. Method-wise significantly lowest cobalt content in chickpea was observed through seed treatment of cobalt at 1g kg^{-1} seed (0.63 mg kg^{-1}) < seed treatment at 2 g kg^{-1} seed (1.00 mg kg^{-1}) < soil application at 150 g ha^{-1} (1.00 mg kg^{-1}) < foliar application at 0.01% (1.02 mg kg^{-1}) (Table 1). Most suitable methods of cobalt application with their concentration were soil application at 50 g ha^{-1}, foliar application at 0.01%, seed treatment at 1 g $CoCl_2$ kg^{-1} seed and seed priming at 1 ppm became favourable for higher synthesis of leghaemoglobin, which is barring the exposure of O_2 to nitrogenase activity in the root nodules of *Rhizobium* bacteria. Looking to the purpose of experiment of identification of most suitable cobalt application method and level, seed priming of cobalt at 1 ppm (26.67 q ha^{-1}) and seed treatment of cobalt at 1 g $CoCl_2$ kg seed (26.98 q ha^{-1}) has registered at par yield of chickpea with soil application of 50 g $CoCl_2$ ha^{-1} (27.80 q ha^{-1}) and all these methods has enriched the chickpea seeds with cobalt by 127 and 138%, respectively over absolute control. This positive influence of cobalt chloride on growth of crop may be due to plants physiological activities which were helped plants to develop different organs and ultimately influenced for development of plant parts and its growth efficiency (Jayakumar and Jaleel, 2009). Hence, seed treatment of 1 g $CoCl_2$ kg^{-1} seed and seed priming of cobalt at 1 ppm has registered at par yield with that of highest chickpea yield but at the same time they have absorbed lowest and slightly higher cobalt content over soil application of 50 g $CoCl_2$ ha^{-1}, respectively.

Elemental N, P and K in soil affected by cobalt application methods: Residual N, P and K in the soil have shown a very special kind of results due to various methods and levels of cobalt. Among all methods and levels of cobalt tried, significantly superior residual elemental N (320.66 kg ha^{-1}), P (48.76 kg ha^{-1}) and K (322.84 kg ha^{-1}) were observed with soil application of 50 g $CoCl_2$ ha^{-1} (Table 2) and the same treatment also registered given highest chickpea yield

(27.80 q ha^{-1}). An inverse relationship was found between residual available N, P and K with all the methods of cobalt application except seed priming, as the cobalt levels were increased residual available N, P and K were decreased. Method wise, highest residual elemental N, P and K were recorded with seed priming of 1.0 ppm $CoCl_2$ (201.49, 36.19 and 280.26 kg ha^{-1}, respectively), seed treatment of cobalt with 1 g $CoCl_2$ kg^{-1} seed (211.68, 39.21 and 291.23 kg ha^{-1}, respectively), soil application of 50 g $CoCl_2$ ha^{-1} (320.66, 48.76 and 332.84 kg ha^{-1}, respectively) and 0.01% foliar spray of $CoCl_2$ (235.20, 41.22 and 329.86 kg ha^{-1}, respectively). The specialty of these four treatments is that all these four treatments have correspondingly recorded highest residual elemental N, P and K and they all have recorded highest chickpea seed yield which was at par with each other. Cobalt was supplied to chickpea in a pot culture experiment at 0, 1, 2 and 4 ppm levels, it is found that application of cobalt at 1 ppm has given highest residual N, P and K in soil and the same level has executed highest dry matter yield of chickpea, however as the levels of cobalt were increased the residual N, P and K were also decreased consecutively (Swarnakar 2004). It means wherever the chickpea seed yield is higher and residual elemental N, P and K in that particular treatment is also higher. This may be because of these four treatments of cobalt with the least dose were very much conducive for nitrogen fixation. This nitrogen fixation not only helped to satisfy the nitrogen need of chickpea to receive highest seed yield but also helped to keep excess nitrogen as residual nitrogen in the soil for succeeding crop. It is also seen that, the third level of cobalt in seed treatment, soil application and foliar application method has executed lowest residual elemental N (174.05, 169.34 and 138.77 kg ha^{-1}), P (25.64, 23.12 and 11.06 kg ha^{-1}) and K (228.89, 218.25, 208.29 kg ha^{-1}) and the availability is even lowest than control treatment of water priming (kg 179.54, 25.64 and 244.88 NPK ha^{-1}). The extreme case is found with the third level of foliar application method where the residual elemental N (155.23 kg ha^{-1}), P (16.59 kg ha^{-1}) and K (212.09 kg ha^{-1}) are even lesser than the absolute control treatment. It shows that these treatments were so phytotoxic to chickpea that the plants, neither got a chance to fix atmospheric nitrogen nor supplied desired nitrogen to chickpea crop to have good seed yield.

Elemental cobalt in soil: In this experiment seed priming and seed treatment was done just before sowing, however soil application of cobalt was done through fertigation at three leaf stage and cobalt was applied through foliar spray at 30 DAS and just before flowering. A relative comparison also made between presowing concentration of cobalt in soil (0.82 mg kg^{-1}) with all cobalt application methods after harvest of chickpea. Broadly residual elemental soil cobalt availability in chickpea root zone was increased in all four cobalt application methods and their levels as compared to initial elemental available soil cobalt. Available elemental cobalt in soil increased from 1.06 to 1.40 mg kg^{-1} in absolute control and 150 g $CoCl_2$ ha^{-1}, respectively (Table 2). Cobalt priming has not shown any specific trend of elemental availability of soil cobalt. Application of cobalt through seed treatment (1.31 to 1.13 mg kg^{-1}) and foliar application (1.31 to 1.06 mg kg^{-1}) has linearly decreased the available elemental cobalt with increase in cobalt level, on the contrary available elemental cobalt in soil linearly increased with increase in soil application of cobalt (1.29 to 1.30 mg kg^{-1}). Soil application of $CoCl_2$ shown higher cobalt content in chickpea seed yield over $CoSO_4$ (Rod *et al*., 2019). Least concentration of cobalt through seed treatment of 1 g $CoCl_2$ kg^{-1} seed and foliar application of 0.01% $CoCl_2$ has executed highest chickpea seed yield because of optimum absorption dose of cobalt and which became favorable for growth, nitrogen fixation and yield of chickpea, hence the residual

Table 2: Available nutrients as influenced by cobalt application methods.

Treatment	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Co (mg kg^{-1})
Control (absolute)	155.23	16.59	212.09	1.06
Control (water priming)	179.54	25.64	244.88	1.13
Seed priming 0.5 ppm	191.30	28.65	269.75	1.19
Seed priming 1.0 ppm	201.49	36.19	280.26	1.25
Seed priming 1.5 ppm	198.35	33.18	271.18	1.19
Seed treatment 1 g kg^{-1} seed	211.68	39.21	291.23	1.31
Seed treatment 2 g kg^{-1} seed	192.86	31.67	269.75	1.19
Seed treatment 3 g kg^{-1} seed	174.05	25.64	228.89	1.13
Soil application 50 g ha^{-1}	320.66	48.76	332.84	1.29
Soil application 100 g ha^{-1}	199.92	34.18	272.80	1.38
Soil application 150 g ha^{-1}	169.34	23.12	218.25	1.40
Foliar application 0.01% (twice)	235.20	41.22	329.86	1.31
Foliar application 0.025% (twice)	190.51	26.64	265.01	1.13
Foliar application 0.05% (twice)	138.77	11.06	208.29	1.06
S.Em. ±	10.80	1.85	13.88	0.06
C.D. at 5%	31.39	5.38	40.36	0.18
Initial	188.16	38.33	327.74	0.82

Table 3.1: Correlation between important parameters as influenced by seed priming.

	GY	N	P	K	Co
Grain Yield (GY)	1				
N content in seed (N)	0.990^{**}	1			
P content in seed (P)	0.937^{NS}	0.970^{*}	1		
K content in seed (K)	0.988^{*}	0.960^{*}	0.872^{NS}	1	
Co content in seed (Co)	0.806^{NS}	0.866^{NS}	0.838^{NS}	0.764^{NS}	1

Table 3.2: Correlation between important parameters as influenced by seed treatment.

	GY	N	P	K	Co
Grain Yield (GY)	1				
N content in seed (N)	0.971^{*}	1			
P content in seed (P)	0.965^{*}	0.993^{**}	1		
K content in seed (K)	0.996^{**}	0.959^{*}	0.943^{NS}	1	
Co content in seed (Co)	-0.371^{NS}	-0.138^{NS}	-0.139^{NS}	-0.400^{NS}	1

Table 3.3: Correlation between important parameters as influenced by soil application.

	GY	N	P	K	Co
Grain Yield (GY)	1				
N content in seed (N)	0.989^{*}	1			
P content in seed (P)	0.972^{*}	0.950^{NS}	1		
K content in seed (K)	0.913^{NS}	0.888^{NS}	0.982^{*}	1	
Co content in seed (Co)	0.921^{NS}	0.967^{*}	0.891^{NS}	0.847^{NS}	1

Table 3.4: Correlation between important parameters as influenced by foliar spray.

	GY	N	P	K	Co
Grain Yield (GY)	1				
N content in seed (N)	0.982^{*}	1			
P content in seed (P)	0.934^{NS}	0.867^{NS}	1		
K content in seed (K)	0.990^{*}	0.982^{*}	0.878^{NS}	1	
Co content in seed (Co)	-0.339^{NS}	-0.161^{NS}	-0.613^{NS}	-0.255^{NS}	1

*Significant at 0.05 **Significant at 0.01

cobalt in these treatment was more. However seed treatment of 3 g CoCl$_2$ kg^{-1} seed and foliar application of 0.05% CoCl$_2$ were had highest concentration of chickpea seed cobalt and has absorbed higher cobalt in chickpea plants body and become phytotoxic, hence the residual cobalt in these levels was lower. As the cobalt application dose was increased the soil availability of cobalt was also increased and reached upto its maximum concentration of 0.38 ppm (Basu, *et al*., 2006). In a pot experiment on chickpea four levels of cobalt were used 0, 1, 2 and 4 ppm, the one ppm level given highest chickpea pod yield, however the residual cobalt content in soil was increased as the levels of cobalt were increased and it was 0.17, 0.52, 0.72 and 1.03 ppm, respectively (Swarnkar 2004). On an average one kilogram soil contains about eight milligram cobalt, around the earth this number varies between 0.1-70 mg kg^{-1}. The concentration of cobalt for a productive and healthy soil should be between 1-2 mg kg^{-1}(Anonymous 2019). In this experiment also the residual elemental available cobalt in soil varies between 1.06-1.40 mg kg^{-1}. Hence this shows it's a safe limit of cobalt in soil and this experiment have not at all polluted the soil, also the residual cobalt seems to be safer and useful for the succeeding crop.

Correlation study of cobalt application methods: Tables 3.1, 3.2, 3.3 and 3.4 showing a correlation between the grain yield and nutrient content where, all cobalt application methods showing a correlation between chickpea seed yield and N content in seed, it means all cobalt application methods participated in leghaemoglobin synthesis which further helped fix atmospheric nitrogen in root nodules and further transformation of nitrogen in chickpea seed yield. Among all cobalt application methods chickpea seed yield was not at all correlated with cobalt content in seed, this shows that legumes requires cobalt for legheamoglobin synthesis and ultimately for efficient nitrogen fixation and favours for its absorption in plant and seed because of its toxic nature with higher dose. Among all cobalt application methods, N content in seed is not correlated with all methods except soil application of cobalt, it is evident from soil application of cobalt at 50 g ha^{-1} where this treatment has recorded highest N and second highest cobalt content in seed, it means cobalt can be fortified in chickpea seed yield with highest chickpea seed yield. Hence looking to the correlation studies, the preference of cobalt application method to chickpea can be in the following order soil application > seed treatment > seed priming > foliar application.

CONCLUSION

Among all cobalt application methods, soil application of cobalt at 50 g $CoCl_2$ ha^{-1} has executed highest chickpea seed and stover yield, nutrient content, uptake and available soil nutrients. Highest cobalt content in foliar application method at 0.05% was corresponding to lowest seed yield. Hence soil application of 50 g cobalt chloride ha^{-1} seed can be recommended among four methods of cobalt application tried, followed by first level of foliar and seed treatment methods. As these treatments has given highest chickpea seed yield, highest nutrient contnet and at the same time the residual nutrient performance is also best without nutrients mining. Hence this treatment can fix more N, P and K in soil as a residual nutrients and which can be beneficial for succeeding crop.

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