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Increasing the Efficiency of Nitrogen Fertilization Through Cobalt Application to Pea Plant

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Abstract: Two experiments, pot experiment and field one, were carried out to study the effect of cobalt (8 ppm) application on increasing the efficiency of inorganic nitrogen fertilizers (ammonium nitrate and urea) and peanut compost using pea plants (*Pisum sativum* L.). Plants grown in new reclaimed sandy soil in Nobaria provience. Plant growth parameters, nodule numbers, weight, N uptake, mineral composition as well as yield and seeds quality were estimated. Mineral fertilizer (NPK) were added as a percentage of recommended dose i.e. 0, 25, 50, 75 and 100 %. The peanut compost was applied at rates of 0, 5, 10, 15 and 20 ton fed^{-1}. Certain concentration of cobalt (8 ppm) was applied as cobalt sulphate, to half of the treatments. The obtained results clearly indicate that the addition of cobalt in the plant media could be magnified the benefit of nutrients uptake by plants even at the low concentrations. Amendment of cobalt can be reduced the mineral and organic fertilizers to the level of about 25 % and 67 % of the recommended dose of both consequently. Cobalt also increased both fresh and dry weight of shoots and roots, nodules number and weight, contents of macronutrients (N, P and K), micronutrients (Fe, Mn and Zn) as well as yield, pods and seeds quality. It could be concluded that cobalt is an essential element for certain microorganisms particularly, those fixing atmospheric nitrogen; its deficiency seems to depress the efficiency of N_2 fixation and decrease nitrate accumulation and gave safety health to human.

Key words: Cobalt-Nitrogen fixation-Pea plants-Nutrients uptake.

INTRODUCTION

Cobalt is an essential element for certain microorganisms particularly those fixing atmospheric N, its deficiency seems to depress the efficiency of N_2 fixation[1]. Many field crops also exhibited different positive response to cobalt in terms of growth, nodulation and nitrogen. Inoculation plants of lentil treated with 1.5 ppm cobalt gave good growth parameters, while un-inoculated plants did not show significant variations in growth in response to cobalt[2]. Similar data were obtained on wheat[3], squash[4], groundnut[5], soyabean[6], fodder ray[7] and cucumber[8].

Cobalt was found to be very necessary element to legumes, in particular, for nodule formation and N_2 fixation processes. Yadov and Khanna[9] and Bolachander *et al*.[10] showed that cobalt requirement and its role in the symbiotic nitrogen fixation mechanism is not well understood, yet its importance for symbiotic nitrogen fixing bacteria is well known. The presence of cobamide coenzymes in the nodules of several legumes and nitrogen fixing non-legumes has further confirmed the role of cobalt in nitrogen fixation. Castro *et al*.[11] found that phaseolus seeds treatment had a significant effect on nodulation, dry weight, physiological quality, vigour, protein and elements content of seeds. Due *et al*[12] and Tenywa[13] reported that cobalt application had a greatest nodulation and number of effective nodules per soyabean plants, as well as total nitrogen accumulation in the shoots. Sharma and Bhandari[14] pointed that cowpea seeds were inoculated with *Bradyrhizobium*, farmyard manure (FYM) and minerals significantly affected the number of nodules per plant, fresh weight of nodules, chlorophyll content at 45 days after sowing, leghaemoglobin content of nodules. Cobalt either singly or in combination with FYM, resulted in the greatest increases in the aforementioned parameters. Bibak[15] reported that while treatment of the winter wheat plants grown on a sandy loam soil supplied with nitrogen increased cobalt uptake by the crop, responses were higher when receiving FYM than in the fields not given FYM. Also, Ismail *et al*[16] showed that cattle manure at rates 1, 2, 4 and 8 % increased the availability and uptake of Co, Cu, Zn and Fe by maize plants. Cobalt had the highest availability index among the tested elements, particularly in the case of cattle manure. Abd El Moez and Nadia Gad[17] reported that the addition of cobalt along with inorganic and organic fertilizers increased the content of macro and micro nutrients in cowpea plants than in the plants were given mineral and organic fertilizers alone. Howel and Skoog[18] found that cobalt also promoted many developmental processes including stem coleoptile elongation, opening of hypocotyle hooks, leaf expansion and bud development.

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However, cobalt is an beneficial element for other plants. Cobalt is also an essential constituent of vitamin B_{12} which is considered to be only cobalt containing compounded. in the ruminants[19]. Troitskaya[20] reported that the vitamin B_{12} content in soyabean root nodules was extremely low compared with other legumes grown on dernopodzolic soils. The low vitamin B_{12} content was not associated either with the soyabean cv. or with the *Rhizobium japonicum* strains used, but was correlated to the unfavourable nutrient conditions of dernopodzolic soils which resulted in inadequate cobalt accumulation in soyabean root nodules for normal vitamin B_{12} synthesis. Yashida[21] pointed that cobalt addition directly proportional to vitamin B_{12} content in *Pahseolus vulgaris*. Soyabean root nodules B_{12} content was increased after adding cobalt, since B_{12} is important in soyabean root nodule production and functioning application of cobalt fertilizers is recommended.

MATERIALS AND METHODS

Soil analysis: Particle size distribution and soil texture along with soil moisture constants of the representative soil samples collected from Research and Production Station, National Research Centre (Nubaria) were determined[22]. Contents of organic matter and $CaCo_3$ as well as EC and pH along with soluble cations and anions were evaluated according to Black *et al*.[23]. Total N and available P, K, Fe, Mn, Zn and Cu were also determined according to Jackson[24]. Total cobalt was determined in Aqua rejia extract, the water soluble cobalt as well as available cobalt (DTPA extractable) being assayed according to Cottanie *et al*[25].

Data of soil analysis were recorded in Table (A). Chemical properties of the composted peanut wastes were shown in Table (B).

Experimental works:

Experiment {1}: A pot experiment was conducted in the greenhouse of the National Research Centre, Dokki, Giza, Egypt. The experiment was carried out to study effect of cobalt on increasing the efficiency of nitrogen fertilization and its effect on nodulation, vegetative growth, yield, pods and seeds quality of pea plants.

Eight treatments with three replicates were carried out with and without addition of cobalt i.e. control, urea, ammonium nitrate, peanut compost, control+8 ppm Co, peanut compost + 8 ppm Co. The basic amount of added mineral fertilizers were 100 kg/fed ammonium nitrate (33.5% N), or urea (46% N), 150 kg /fed superphosphate (15.5 % P_2O_5) and 100 kg/fed potassium sulphate (48 % K_2O) as well as organic peanut compost at rate of 15 ton/fed [normal doses 100%]. Soil sample was air dried and packed in pots (10 kg)of 40 cm diameter. Six seeds per pot of pea plants were sown on February 25th , 2004. Tap water was applied for irrigation to field capacity whenever needed.

Table A: Physical and chemical properties of soil.

Properties	Particle size distribution %			
Physical	Sand	Silt	Clay	Texture
	82.6	14.6	2.8	Sandy loam
	Soil water constant %weight basis			
	Saturation	Field capacity	Wilting point	Available water
	32.0	14.4	3.9	10.5
Chemical	pH	EC	$CaCO_3$	Organic matter
	1:2.5	dSm^{-1}	%	
	8.00	1.00	7.17	0.19
	Soluble cations (meq/l)			
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
	9.0	1.4	3.26	0.268
	Soluble anions (meq/l)			
	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
	0.0	1.18	0.60	12.15
	Total N	Available macronutrients		
		P	K	
		mg/100 g soil		
	15.1	13.0	21.0	
	Available macronutrients			
	Fe	Mn	Zn	Cu
	4.47	2.61	1.44	4.00
	Cobalt (ppm)			
	Soluble	Available	Total	
	0.3	1.77	6.78	

Table B: Chemical properties of composted peanut wastes.

Organic carbon	Total N	C/N ratio	pH 1:2.5	Ec dSm^{-1}	Available nutrients %		Micronutrients DTPA-extractable			
%					P	K	Fe	Mn	Zn	Co
36.2	1.40	25.8	6.5	0.62	1.60	3.9	10.5	9.0	7.6	0.01

The pea seedlings were thinned to four per pots. One plant per pot was harvested after 15, 30 and 45 day from sowing. The plant dry weight and nitrogen uptake were recorded. After 60 days from sowing, morphological growth parameters and number of total nodules, active nodules as well as dry weight and N uptake were recorded. After 75 days from sowing, yield and pods quality were determined.

Experiment (2): A field experiment was carried out at the Research and Production Station (Nubaria) to study the effect of cobalt on nitrogen fixation and its role on increasing the efficiency of N fertilization on pea plants during the winter season of 2004, February 25th . After preparing the soil ditches of 20 cm width were performed.

Fertilizers used:
Nirogen: A- urea (46.5 %N) 100 kg/fed or ammonium nitrate (33.5%N) 100 kg/fed
B- Peanut compost (1.4 N%) 3321 kg/fed,
2. Superphosphate (15.5 % P_2O_5) 150 kg/fed
3. Potassium sulphate (48 % K_2O) 100 kg/fed

Treatments:
A number of 12 treatments was concluded
- Urea 100 % (recommended dose) + Co
- Urea 75 % (recommended dose) + Co
- Urea 50 % (recommended dose) + Co
- Urea 25 % (recommended dose) + Co
- Ammonium nitrate 100 % (recommended dose) + Co
- Ammonium nitrate 75 % (recommended dose) + Co
- Ammonium nitrate 50 % (recommended dose) + Co
- Ammonium nitrate 25 % (recommended dose) + Co
- Pea nut compost 15 ton/fed (recommended dose) + Co
- Pea nut compost 20 ton/fed (recommended dose) + Co
- Pea nut compost 10 ton/fed (recommended dose) + Co
- Pea nut compost 5 ton/fed (recommended dose) + Co

Cobalt added as sulphate salt (8 ppm Cobalt) at seedlings stage by application fertigated once.

Sampling: Samples were taken 60 days after germination to study the vegetative growth parameters expressed as plant height, stem diameter, number of branches and leaves, leaves area, root length, number of both total and active nodules as well as plant biomass.

Data were subjected to proper statistical analysis using the normal (F Test). Means were compared using least significant differences (LSD) according to Gomez and Gomez[26].

RESULTS AND DISCUSSIONS

First experiment: The results in Table (1) reveal that cobalt had a significant beneficial effect on all vegetative growth parameters as, plant height, stem diameter, number of branches and leaves, leaves area and root length. For pea received the normal doses (100 %) of both forms N fertilizer (urea or ammonium nitrate) and organic compost. These results are in harmony with these obtained by El Moez and Nadia Gad[17]. Data also indicated that the addition of cobalt improved nodule formation process as clearly seen in the table with all nitrogen sources specially organic fertilizer. These results agree with the findings of Tenywa[13].

Fig. (1) shows the effect of cobalt on the dry weight and nitrogen uptake at intervals of 15, 30 and 45 days of sowing. The data revealed that cobalt application had a promotive effect on both dry matter content and nitrogen uptake of pea plants treated with the different N forms at the normal doses. Cobalt also, enhanced the number of effective nodules per plant, shoots dry weight and total nitrogen accumulation compared to the cobalt untreated plants. These results are in a good agreement with those found by Vanek and Knop[27].

Table (2) exhibits the effect of cobalt on pods yield and quality under different sources of nitrogen fertilization. Cobalt had a significant favourable effect on early and total pods yields as well as pods length, width and thickness. However, total soluble salts of seeds were

Table 1: Effect of cobalt on vegetative growth parameters and nodulation of pea plants treated with different sources of nitrogen fertilizers.

Vegetative parameters / Fertilizer treatment	Plant height (cm)	Stem diameter	Branch (Number/plant)	leaves	Leaves area (cm^2)	Root length (cm)	Nodules/plant Active	Total
	Without cobalt							
Control	22.7	0.3	4	7	145	7.52	20	57
Urea	26.1	0.5	4	9	176	9.34	30	76
Ammonium nitrate	27.2	0.6	5	10	182	10.0	50	98
Peanut compost	29.8	0.7	6	11	193	11.6	112	135
LSD 5%	1.75	0.10	1	1	10	2.2	4	5
	With cobalt (8ppm)							
Control	31.2	0.9	5	11	194	10.2	40	86
Urea	36.6	1.08	7	12	206	12.3	85	104
Ammonium nitrate	39.5	1.11	7	13	217	132.4	115	135
Peanut compost	44.0	1.05	8	15	224	14.6	160	180
LSD 5%	1.36	0.12	1	1	9	1.9	5	6

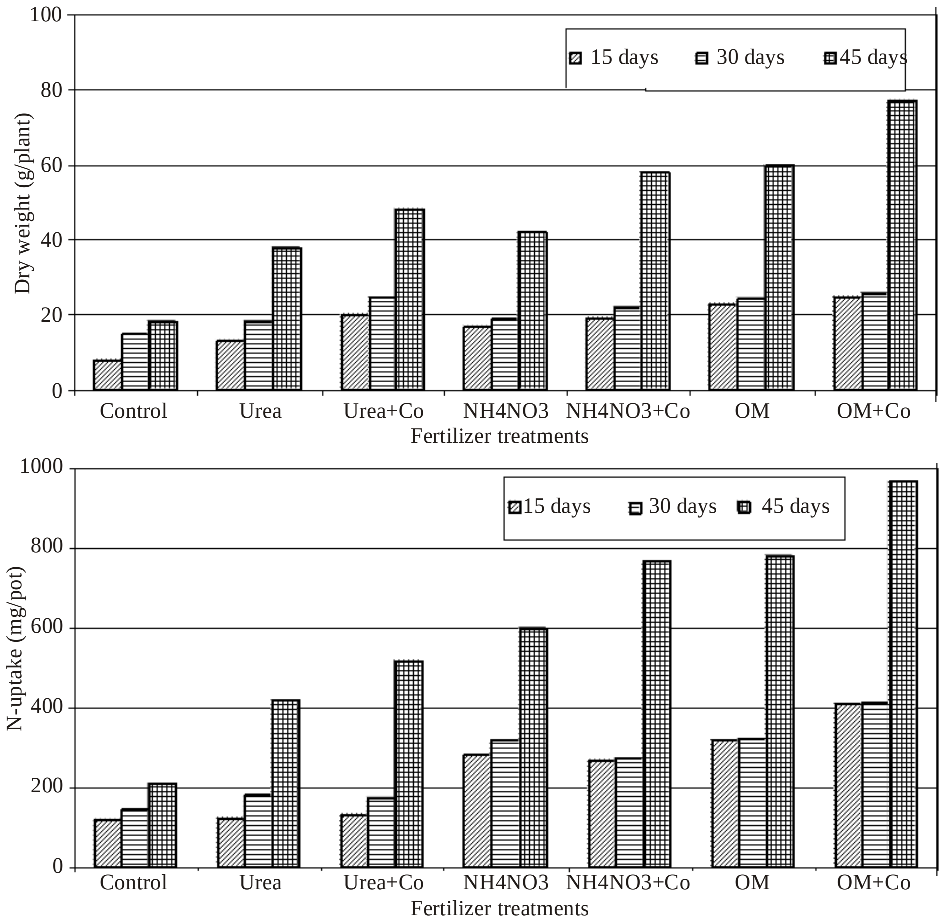

Fig. 1: Effect of cobalt on dry matter content and N-uptake by pea plants.

Table 2: Effect of cobalt on pod yield and quality of pea plants treated with different sources of nitrogen fertilizers.

Yield parameters	Early yield	Total yield	Pods quality			Seed contents		
	Yield (g/plant)		Length (cm)	Width	Thickness	TSS(%)	Cobalt(ppm)	Nitrate(mg/100 fresh tissues)
Fertilizer treatment	Without cobalt							
Control	9.12	44.2	6.51	0.5	0.90	10.0	0.70	56
Urea	10.20	48.5	8.01	0.7	1.02	11.1	0.70	114
Ammonium nitrate	10.70	52.0	7.60	0.8	1.13	11.5	0.80	75
Peanut compost	11.60	56.2	9.21	0.9	1.17	11.7	0.80	64
LSD 5%	0.78	2.4	1.58	0.16	ns	1.0	0.1	11
	With cobalt (8 ppm)							
Control	12.50	60.5	8.70	0.6	1.13	10.3	1.00	35
Urea	14.30	69.2	11.00	0.8	1.15	11.4	1.41	82
Ammonium nitrate	15.40	74.6	12.10	0.9	1.18	11.6	1.80	53
Peanut compost	16.50	80.0	13.60	0.9	1.16	12.2	2.30	42
LSD 5%	1.12	3.6	0.8	0.2	ns	0.7	0.26	4

not significantly affected by cobalt application while nitrate seeds content decreased. Cobalt content of pea seeds ranged between 1.0 – 2.3 ppm. Young[19] reported that the daily cobalt requirement for human nutrition could reach 8 ppm without health hazard.

Data in Table (3) clearly indicated that cobalt increased the N, P and K content of pea seeds with all sources of nitrogen fertilization. These data may go along with Boureto *et al*.[28] who showed that cobalt had better status of N, P and K of *Pahseolus vulgaris* L. Data also, indicated that cobalt had a beneficial significant effect on Mn and Zn content. Table (3) also, showed that Fe content in pea seeds to be decreased with cobalt addition. This may be explained on the basis of results reported by Bisht[29] who showed that certain anatagonistic relationships between the two elements.

Table 3: Effect of cobalt on macro and micro nutrients of pea plants treated with different sources of nitrogen fertilizers (100%).

	Pea seeds content							
	Macronutrients content (%)			Micronutrients content (ppm)			Cobalt content (ppm)	
Seed nutrient contents	N	P	K	Mn	Zn	Fe	Shoots	Seeds
Fertilizer Treatment	Without cobalt							
Control	0.78	0.09	0.69	20.5	9.21	36.5	1.18	0.07
Urea	1.89	0.13	0.95	24.6	12.7	40.2	2.29	1.86
Ammonium nitrate	2.01	0.17	1.31	28.7	15.5	44.6	2.57	1.95
Peanut compost	2.27	0.22	1.52	39.8	21	53	3.4	2.13
	0.01	0.05	0.07	1.4	1.0	1.1	0.18	0.11
	With cobalt (8 ppm)							
Control	0.93	0.12	0.74	27.1	10.6	42.6	1.67	0.12
Urea	2.05	0.31	1.55	32	18.5	40	3.55	1.85
Ammonium nitrate	2.31	0.37	1.8	36	22	36.6	4..93	2.36
Peanut compost	2.66	0.44	1.98	45.9	29.3	34	6.24	3.63
LSD 5%	0.18	0.04	0.08	1.9	1.6	1.3	0.18	0.10

Second experiment:

Mineral fertilization: Data presented in Table (4) revealed that the complete dose of mineral fertilizations (urea or ammonium nitrate) gave a significant promotive effect on all morphological growth parameters specially effective nodules per plant. As percent of the normal dose decreased, all growth parameters decreased. On the other hand, cobalt application with rate of 25% from normal mineral fertilizers increased the common growth rate than did the normal dose (100%) without cobalt.

Fig. (2) reflected similarity trend on shoot and root dry weight. According to Nadia Gad[30], the favourable response associated with cobalt could attributed to the activation maintained by catalse and peroxidase enzyme, these enzymes are known react in contrary to respiration. Cobalt was also, significantly increased indogenous activator hormones as auxins and gibberellins[31]. Cobalt promotes anabolism more than catabolism[4]. The data also proved that cobalt addition could saved 75 % of mineral fertilizers. The results are in harmony with Sawicki[7] who found that cobalt increased fodder ray yield compared with NPK fertilizer alone.

Table 4: Effect of cobalt on morphological growth parameters and nodulation of pea plants treated with mineral fertilizers.

Vegetative parameters		Plant height	Stem diameter	Branches	leaves			Nodules/plant	
Fertilizer treatments	Fertilizer level (%)	cm		Number/plant		Leaves area cm^2	Root length cm	Active	Total
Urea		Without cobalt							
	100	29.5	0.6	6	11	194	11.00	30	76
	75	26.1	0.5	5	9	178	9.50	22	62
	50	20.0	0.3	5	7	144	7.56	18	54
	25	16.7	0.3	4	7	143	6.01	15	47

Table 4: Continued.

Ammonium nitrate	100	32.0	0.7	7	11	205	12.10	50	98
	75	27.3	0.5	5	10	180	10.00	41	87
	50	19.8	0.3	5	9	136	8.02	31	70
	25	17.1	0.3	4	8	134	7.11	23	58
LSD 5%	Fertilizer	1.7	0.01	1	1	6	0.94	2	5
	Level	2.4	0.01	1	1	8	1.12	3	6
	Interaction	3.1	0.03	1	1	10	1.23	4	8
Urea		With cobalt (8 ppm)							
	100	51.1	1.0	8	14	327	15.2	90	104
	75	49.2	0.9	7	12	321	11.5	78	96
	50	43.0	0.7	7	12	286	12.2	70	90
	25	40.3	0.7	6	11	254	12.0	64	86
Ammonium nitrate	100	56.1	1.1	9	15	354	15.5	112	135
	75	51.3	1.0	8	14	329	13.0	98	122
	50	46.5	0.8	7	12	296	13.2	86	113
	25	44.2	0.7	7	12	281	12.3	74	102
LSD 5%	Fertilizer	2.3	0.2	1	1	8	1.11	3	7
	Level	2.9	0.03	2	2	11	1.16	5	9
	Interaction	3.7	0.05	2	2	15	1.26	5	12

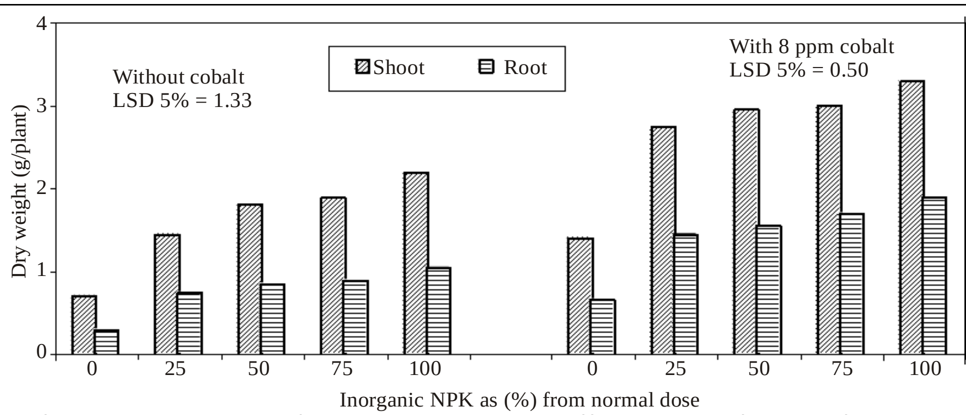

Fig. 2: Effect of cobalt on dry weight of pea plants treated with different levels of mineral fertilizers.

Table (5) clearly indicated that early, total pods yield and average yield per plant as well as pods length, width and thickness were significantly increased with 25 % of normal mineral fertilizers doses in combination with cobalt compared to the normal doses (100%) alone. Although the reduction in the N fertilizer rate to 25 %, cobalt addition increased the pods yield with 11 % and 9% with ammonium nitrate and urea, respectively.

The effect of organic peanut wastes compost with or without cobalt application on the growth of pea plants is given in Table (6). The obtained results showed that the normal dose of the compost (15 ton /fed) had the large value of all morphological growth parameters. Furthermore, supplementing plant media with 8 ppm cobalt significantly enhanced all plant growth characters with the dose of 10 ton /fed more than the 15 ton/fed without cobalt.

Table 5: Effect of cobalt on pea pods yield and quality treated with different level of mineral fertilizers.

Yield parameter / Fertilizer treatments	Fertilizer levels (%)	Yield g/pot	Early yield Ton/fed	Total yield Ton/fed	Pods quality: Length cm	Pods quality: Width	Pods quality: Thickness	Seeds content: TSS %	Seeds content: Cobalt (ppm)
		Without cobalt							
Urea	100	49.6	1.45	7.58	8.01	0.5	1.00	11.1	0.75
	75	43.2	1.41	6.67	7.80	0.6	0.09	10.8	0.69
	50	35.4	1.36	5.38	7.00	0.6	0.09	10.6	0.60
	25	30.1	1.30	4.70	6.30	0.7	0.80	10.1	0.54
Ammonium nitrate	100	54.2	1.58	7.90	7.60	0.6	1.10	11.3	0.83
	75	49.0	1.51	7.16	7.10	0.6	0.90	11.0	0.80
	50	44.1	1.47	6.88	7.00	0.7	0.80	10.7	0.66
	25	38.2	1.42	5.91	6.80	0.7	0.70	10.3	0.60
LSD 5%	Fertilizer	0.56	0.04	0.10	ns	ns	0.07	ns	0.05
	Level	0.80	0.06	0.14	0.22	0.08	0.10	0.61	0.06
	interaction	0.86	0.07	0.17	0.26	0.11	0.13	0.72	0.08
		With cobalt (8 ppm)							
Urea	100	69.0	1.82	10.70	11.00	0.8	1.15	11.5	1.42
	75	64.1	1.79	9.55	10.10	0.8	1.12	11.3	1.30
	50	59.0	1.74	9.20	9.20	0.7	1.12	11.0	1.21
	25	55.1	1.65	8.36	9.00	0.7	1.11	11.0	1.15
Ammonium nitrate	100	75.2	2.02	11.00	12.10	0.9	1.18	11.7	1.81
	75	70.0	1.87	10.40	11.00	0.8	1.16	11.4	1.60
	50	64.1	1.79	9.41	10.20	0.7	1.14	11.1	1.49
	25	59.4	1.72	8.67	9.50	0.7	1.12	11.0	1.38
LSD 5%	Fertilizer	060	0.02	ns	0.48	ns	0.05	ns	0.07
	Level	0.84	0.03	ns	0.68	0.11	0.07	ns	0.11
	interaction	0.96	0.04	ns	0.77	0.16	0.09	ns	0.16

Table 6: Effect of cobalt on vegitative growth parameters and nodulation of pea plant treated with peanut compost.

Vegetative parameters / Compost treatments (ton/fed)	Plant height (cm)	Stem diameter	Branches (Number/plant)	leaves	Leaves area (cm^2)	Root length (cm)	(Nodules/plant) Active	Total
	Without cobalt							
20	36.1	0.8	4	10	195	10.2	102	153
15	38.2	1.1	5	11	212	13	140	194
10	32.3	0.9	5	11	215	9.32	122	176

Table 6: Continued.

5	27.5	0.7	4	9	178	7.04	101	160
LSD 5%	1.52	0.15	ns	ns	11	1.20	10	8
	With cobalt (8 ppm)							
20	41.5	0.91	6	14	276	14	135	180
15	46.6	1.11	8	17	297	18.5	198	227
10	42.0	1.1	7	16	291	16.1	170	206
5	38.2	0.8	5	12	265	11.5	152	193
LSD 5%	3.1	ns	2	2	15	1.2	6	9

Fig. (3) shows that cobalt (8ppm) increased pea shoot and root dry matter content more than the level of 15 ton /fed without cobalt. It is worth to mention that cobalt addition saved 33.3 % from the organic fertilizer.

Data in Table (7) revealed that yield parameters were highly respond to cobalt application combined with 10 ton/fed compost compared to the larger dose of 15 ton/fed without cobalt. The increase in total yield reached to 7.6 % as a result of cobalt treatment.

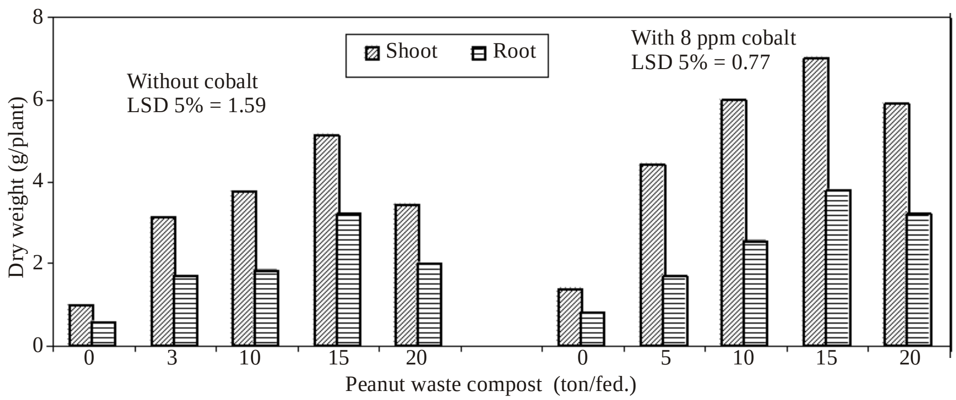

Fig. 3: Effect of cobalt on dry weight of pea plants treated with different levels.

Table 7: Effect of mutual effect of cobalt and different levels of peanut compost on pea yield quantity and quality.

				Pods quality				
		Early yield	Total yield	Length	Broad	Thickness	Seeds content	
Compost treatments (ton/fed)	Yield g/plant	ton/fed		cm			TSS %	Cobalt (ppm)
	Without cobalt							
20	56.8	1.84	8.38	9.5	0.63	0.70	8.28	0.80
15	65.2	2.11	10.20	11.6	0.72	0.85	9.44	0.95
10	59.7	1.92	8.74	11.2	0.70	0.80	10.80	1.46
5	52.0	1.69	7.70	9.8	0.65	0.70	8.00	1.86
LSD 5%	2.2	0.16	0.27	0.71	0.09	0.10	1.02	0.11
	With cobalt (8 ppm)							
20	69.1	1.90	8.65	10.9	0.75	0.90	10.60	1.12
15	81.0	2.62	12.70	13.2	0.90	1.18	13.30	2.30
10	76.2	2.48	12.00	12.0	0.85	1.12	12.10	1.48
5	64.5	2.05	9.93	10.5	0.70	0.90	10.00	1.81
LSD 5%	1.12	0.14	0.40	7.3	0.12	0.11	0.85	0.31

Conclusion: It could be concluded that the addition of cobalt saved about 75 % and 33.3 % of inorganic and organic nitrogen fertilizer, respectively. Moreover, cobalt enhancing the N_2 fixation process in legumes and consequently increased plant N content. Therefore, it could be reduced the nitrogen fertilization dose which is reflected on mitigation of environmental pollution and reduces the agricultural cost for more money to farmers.

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