Research Article

Cobalt Application Improves the Growth and Development of Mung Bean

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Abstract | Cobalt plays an important role in nitrogen (N) fixation occurring within the nodules of legume plants. However, the variable reports for Cobalt (Co) effects on plant growth and crop yields urged to research and verify if the Co is an essential component particularly for leguminous crops. A greenhouse study was conducted to evaluate the effect of Co on inoculation slurry treated seeds of mung bean (*Vigna radiata* L.) to observe the yield and development of the plant. A factorial completely randomized design (CRD) was adopted for this experiment, where Cobalt nitrate ($Co(NO_3)_2$) was applied at the rates of 10ppm, 20ppm, and 30ppm in combination of inoculation on mung bean three verities Chkwal-06, NM-16 and NM-11. Analyzed data was recorded related to mungbean growth and development parameters Mungbean have maximum response with inoculated 30ppm cobalt nitrate + slurry treatment in respect to growth, yield attributes, nodule number, nodule weight and higher grain yield over control. The increase in nodule formation (nodule size 0.0988cm and the nodule weight 136.87mg) was found in NM-11@ Cobalt Nitrate 30ppm and 20pmm respectively. Better nodule grading 3.25 were found at treatment 30ppm cobalt nitrate in NM-16. Similar yield response achieves in a three different mung bean varieties.

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Introduction

Mung bean (*Vigna radiata* (L.) Wilczek) is an important legume crop (Lambridges and Godwin, 2006) which is a commonly grown crop in tropical and sub-tropical regions of the world (Hoorman, Islam and Sundermeier, 2009). Like any other leguminous crops, mung bean is a very good resource of nitrogen by nitrogen fixation in the soil through the nodules. This is an important Kharif crop in Pakistan (Imran et al., 2015), and 88 % of its production is in Punjab district (mainly Layyah, Bhakkar, Mianwali and Rawalpindi). Although Mung bean is considered a short duration crop as it matures in 60-120 days (Smith and Roberts, 1987), however, in Pakistan some of the popular cultivars of Mung bean have longer growth period of 90-110 days (Jahan and Golam, 2012). This crop fits well in crop rotations to improve soil fertility by atmospheric nitrogen fixation through Rhizobial symbiosis.

Recent studies identify Co as a biologically essential component of several enzymes and coenzymes, and plays an important role in a broad range of

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physiological and biochemical functions (Okamoto and Eltis, 2011; Jaykumar et al., 2008). Although Co may not be essential for all crops but may be vital for particular plant (Minz et al., 2018). Oves *et al.*, 2016 reported the requirement of Co for symbiotic association between plant and microbes, as Co is needed for N_2 fixation in legumes and root nodules of non-legumes. Study determined that the process of nitrogen fixation interestingly requires Co much greater than for ammonium nutrition. Interestingly, the Co deficiency resulted in the nitrogen deficiency symptoms. Various studies showed an increase in formation of leghaemoglobin upon application of Co, that is an integral component of N_2 fixation. Ultimately, enhancement of nodule formation is acquired which directed the crop yield (Das et al., 2000; Bakkaus et al., 2005; Almeida et al., 2007). Research determined that total uptake of N, P and K was significantly affected by the combined inoculations of *Rhizobium* and Co (Almeida et al., 2007). Cobalt also promotes many developmental processes including stem and coleoptiles elongation, opening of hypocotyls hooks, leaf disc expansion and development. However, the excessive dose of Co may result in adverse effect on plant growth (Minz et al., 2018).

Recently, more emphasize is given on increased use of biological treated seeds (Philippot et al., 2013). Legumes are best known seeds for the treatment of seed inoculation to maximize yield potential. Callaghan, 2016 reported that inoculation in legumes with the correct rhizobial partner is very important for the crop establishment, especially in the absence of required strain. Association of legumes with microorganisms is considered very important in agriculture (Ali et al., 2010). Therefore, it was hypnotized that inoculated seeds of mungbean verities will perform better under application of cobalt. The objective was cobalt increase growth and development in mungbean. Keeping these facts, a green house experiment was conducted to investigate the combined effect of Co and inoculum slurry on production potential and quality of mung bean.

Material and Methods

Three mung bean varieties were used from NARC viz CHAKWAL-06, NM-16, NM-11. A seed treated with inoculum slurry using Biozote Max of each mung bean variety has been sown in pots under controlled conditions by incorporating different rates of Co. Inoculum slurry has been used for the treatment of seeds. A pot experiment was conducted under factorial completely randomized designs (CRD) with four replications. Soil for the experiment was collected from University of Arid Agriculture Rawalpindi. Soil samples have been drawn before sowing for the measurement of pH which was 7.1dsm^{-1} and electrical conductivity 2.41 dsm^{-1} with the mung bean crop parameters. Source of Cobalt was Cobalt nitrate Co (NO_3). $6H_2O$. Control treatment was with zero cobalt addition and no seed treatment.

Preparation of inoculum slurry for seed treatment and lab experiment

A lab experiment has been performed to inoculate seeds of each mung bean variety using Biozote Max as inoculum. 15g of inoculum, 5g sugar and 30ml of water were mixed in a 50ml beaker. 50 seeds of each variety were soaked for half an hour in slurry solution and shade dried. The treated seeds were sown in the pots filled with sand to check the effect of inoculant on germination of the selected mung bean varieties. 15 grams of inoculum was used for 2 kg of sand per 50 seeds of mung bean varieties in each pot. From this lab trail, two varieties were chosen with the best and the least performance.

Plant growth experiment in greenhouse

The two selected mung bean varieties from the lab experiment were treated with three levels of Co (10 ppm, 20 ppm and 30ppm) on inoculum slurry treated seeds. The treated seeds were sown in pots filled with soil. Plant growth data and nodule formation was recorded at different growth stages of the plant. Leaf area index was recorded, and crop growth rate (gm^{-2} day^{-1}) was calculated by using formula given by Beadle (1987). Net assimilation rate (NAR) (gm^{-2} day^{-1}) was calculated by the formula given by Beadle (1987). Collected data was statistically analyzed statistically using analysis of variance (ANOVA) technique. Statistics 8.1 software was deployed to transcribe data statistically. The treatments and varieties were compared by using Least Significant Difference (LSD) technique at 5% probability level. Nodule formation was determined by counting in numbers.

Results and Discussion

Effect of Cobalt on growth attributes of mung bean

Plant Height: Maximum plant height was 31.383cm at treatment 40ml inoculum slurry whereas minimum plant height was observed at treatment 10ml inoculum slurry (23.467cm) which was followed by treatment 30ml inoculum slurry (28.367cm) whereas among varieties maximum plant height 32.437cm was observed in V2 (NM-16) which was followed by 27.125cm in V3 (NM-11) and least plant height 23.250cm was observed in V1 (Chakwal-06) Table 1. With the application of inoculum slurry to the seeds of the mung bean crop increased plant height, leaf area, number of leaves and number of branches. All the varieties produced different plant height. Effect of treatment and variety on mung bean crop was highly significant. So concluded that V2 (NM-16) is best performer and V3 (NM-11) is least performer variety. These results are similar with the findings of Awomi et al. (2012).

Table 1: *Plant height (cm) as influenced by the different levels of inoculum slurry.*

Treatments	V1 (Chakwal-06)	V2 (NM-16)	V3 (NM-11)	Mean
T1 10ml slurry	29.50 abc	29.500 abc	20.800 d	23.467 B
T2 20ml slurry	30.90 abc	30.900 abc	27.650 bcd	27.200 AB
T3 30ml slurry	33.20 ab	33.200 ab	28.050 bcd	28.367 A
T4 40ml slurry	36.150 a	36.150 a	32.000 ab	31.383 A
Mean	23.250 B	32.437 A	27.125 A	

LSD Values = 0.05

Number of branches: Interactive effect of varieties and treatment on mung bean plant, but means of varieties and treatment exhibited highly significant effect. Maximum number of branches were observed in treatment 40ml inoculum slurry (4.6333) whereas minimum number of branches were observed at treatment 10ml inoculum slurry (2.600). Maximum number of branches 4.2250 were produced by V2 (NM-16) and 3.7750 number of branches were produced by V3 (NM-11) Table 2 Minimum number of branches 2.9750 were produced by the V1 (Chalwal-06). With increasing the rate of inoculum, maximum no of branches per plant was produced. Source of cobalt had significant effect on the mung bean plant while all varieties produce different number of branches. Requirement of nutrients is not immediate for the branches of the mung bean plant but productive soils would maintain the strength of branches which otherwise may show slow growth (Awomi et al., 2012).

Table 2: *Number of branches^{-1} as influenced by the different levels of inoculum slurry.*

Treatments	V1 (Chakwal-06)	V2 (NM-16)	V3 (NM-11)	Mean
T1 10ml slurry	2.000 f	3.1000 de	2.7000 ef	2.6000 C
T2 20ml slurry	3.100 de	4.3000 abc	3.3000 cde	3.5667 B
T3 30ml slurry	2.800 ef	4.4000 ab	4.3000 abc	3.8333 B
T4 40ml slurry	4.000 bcd	5.1000 a	4.8000 ab	4.6333 A
Mean	2.9750 B	4.2250 A	3.7750 A	

LSD Value = 0.05

Number of leaves: Number of leaves per plant increased by treating the seed with cobalt. Varieties produced plants with different number of leaves. Among varieties maximum number of leaves (21.125) were produced by V3 (NM-11) and least (13.00) was produced by V1 (Chakwal-06) Table 3. Maximum numbers of leaves were measured in treatment 40ml inoculum slurry (20.833) and minimum numbers of leaves were measured in treatment 10ml inoculum slurry (16.500) which was followed by treatment 20ml inoculum slurry (17.000) and treatment 30ml inoculum slurry (19.000). Requirement of nutrients is not immediate for the leaves of the mung bean plant but productive soils would maintain the health of leaves which otherwise may show slow growth and development process.

Table 3: *Number of leaves per plant as influenced by different levels of inoculum slurry.*

Treatments	V1 (Chakwal-06)	V2 (NM-16)	V3 (NM-11)	Mean
T1 10ml Slurry	10.000 d	18.500 abc	21.000 ab	16.500 A
T2 20ml Slurry	12.000 cd	18.500 abc	20.500 ab	17.000 A
T3 30ml Slurry	14.500 bcd	22.000 ab	20.500 ab	19.000 A
T4 40ml Slurry	15.500 bcd	24.500 a	22.500 ab	20.833 A
Mean	13.00 B	20.875 A	21.125 A	

LSD Value = 0.05

Leave area per plant: Data shows us that interactive effect of varieties and treatments are highly significant. Treatment caused significant effect on the varieties of mung bean plant. Varieties also produced significant result. Maximum leaf area was produced in treatment 40ml inoculum slurry (7.6465cm^{-2}) and least was produced by treatment 10ml inoculum slurry (5.1388 cm^{-2}). Interactive effect between variety and treatment (V×T) shows that the maximum leaf area (16.753cm^{-2}) was observed in treatment 40ml inoculum slurry with V2 (NM-16) Table 4. Least leaf area (1.500 cm^{-2}) was observed in V1 (Chakwal-06) at treatment 10ml inoculum slurry. Increasing the rate of inoculum slurry increased leaf area per plant. Inoculum slurry produced highly significant effect on mung bean varieties while varieties effect was also significant. Mung bean is a leguminous crop and fixes atmospheric nitrogen in root nodules of the crop for effective nodulation with the help of rhizobia. Many plants however have greater need of nutrients but productive soils would assist the potential of leaf, which may be disintegrated when the leaves become flaccid due to loss of water.

Table 4: *Leaf area per plant (cm^{-2}) as influenced by different levels of inoculum slurry.*

Treatments	V1 (Chakwal-06)	V2 (NM-16)	V3 (NM-11)	Mean
T1 10ml Slurry	1.5000 g	11.525 d	2.392 fg	5.1388 C
T2 20ml Slurry	1.895 g	13.714 c	3.351 ef	6.3198 B
T3 30ml Slurry	2.047 g	15.063 b	3.453 ef	6.8538 B
T4 40ml Slurry	2.520 fg	16.753 a	3.667 e	7.6465 A
Mean	1.990 C	14.264 A	3.216 A	

LSD Value = 0.05

Germination count: Data shows that treatment of seed with inoculum showed maximum germination. Maximum germination 34.925 was observed in V2 (NM-16) which was followed by 33.488 in V1 (Chakwal-06) while minimum germination 31.837 was observed inV3 (NM-11) Table 5. Increasing the rate of inoculum increased germination percentage of mung bean crop. All three varieties gave different germination percentage while treatment had non-significant effect. Requirement of nutrients for germinating seeds is not immediate but productive soils would assist the potential of seedling emergence, which may not perform well under environmental conditions.

Leaf area per plant; Data revealed that the application of cobalt gave maximum leaf area 29.260cm^{-2} at 30 ppm Cobalt nitrate and least was recorded in Control which was 23.503 cm^{-2} in V1 (NM-16). In V2 (NM-11) the highest leaf area was produced at 30 ppm Cobalt nitrate 29.430 cm^{-2} and least was produced in control 21.039 cm^{-2}. Among treatments highest value 29.345cm^{-2} of leaf area per plant was measured at treatment 30ppm cobalt nitrate and minimum value 22.271 cm^{-2} was measured at control Table 6. Increasing the rate of cobalt increased the leaf area of the mung bean crop. Cobalt significantly affected the lead area. Many plants however have greater need of nutrients but productive soils would assist the potential of leaf, which may be disintegrated when the leaves become flaccid due to loss of water.

Table 5: *Germination Count as influenced by the different levels of inoculum slurry.*

Treatments	V1 (Chakwal-06)	V2 (NM-16)	V3 (NM-11)	Mean
T1 10mlSlurry	32.800 ab	33.650 ab	31.150 b	32.533 B
T2 20ml Slurry	32.300 b	34.100 ab	30.500 b	32.300 B
T3 30ml Slurry	34.150 ab	34.800 ab	31.950 b	33.633 AB
T4 40ml Slurry	34.700 ab	37.150 a	33.750 ab	35.200 A
Mean	33.488 AB	34.925 A	31.837 B	

LSD Values = 0.05

Table 6: *Leaf area $plant^{-1}$ as influenced by the different cobalt level.*

Treatments	V1 NM-16	V2 NM-11	Mean
T1 Control	23.503 b	21.039 b	22.271 C
T2 10ppm	26.825 a	26.595 a	26.710 B
T3 20ppm	28.235 a	28.272 a	28.254 AB
T4 30ppm	29.260 a	29.430 a	29.345 A
Mean	26.956 A	26.334 A	

LSD Values = 0.05

Table 7: *Leaf area index (LAI) as influenced by the different cobalt level.*

Treatments	V1 NM-16	V2 NM-11	Mean
T1 Control	2.8912 bc	2.5466 c	2.7189 B
T2 10ppm	3.4448 a	3.1991 ab	3.3220 A
T3 20ppm	3.3397 a	3.3966 a	3.3682 A
T4 30ppm	3.5612 a	3.5626 a	3.5619 A
Mean	3.3092 A	3.1762 A	

LSD Values = 0.05

Leaf area index: From the results revealed that application of cobalt increased leaf area index (LAI), maximum LAI was produce at 30ppm Cobalt nitrate (3.5612 cm) and minimum LAI was produce at control (2.8192cm) while in V2 (NM-11) maximum LAI was produce at 30ppm Cobalt nitrate (3.5626 cm) minimum LAI was produce at control (2.5466 cm) Table 7. Among treatments 30ppm Cobalt nitrate gave highest value of leaf area index 3.5619 while lowest value was 2.7189 at control.

By increasing the amount of Cobalt enhanced leaf area index of the mung bean crop. Treatment significantly affected the leaf area index. Mung bean is an important legume crop which fixes nitrogen in root nodules of the plant. Many plants however have greater need of nutrients but productive soils would assist the potential of leaf, which may be disintegrated when the leaves become flaccid due to loss of water. Leaf area index was overall increased by the effect of cobalt.

Fresh weight: Treatment and varieties showed significant effect on the fresh weight of the mung bean plant. Data revealed that with the application of cobalt maximum fresh weight was produced. In V1 (NM-16) highest fresh weight was produced at 30ppm Cobalt nitrate (18.510g) and least fresh weight was produced at control (7.392g). In V1 (NM-11) highest fresh weight was produced at 30ppm Cobalt nitrate (12.698g) and least fresh weight was produced at Control (6.769g). Maximum fresh weight 13.379g was measured in V1 (NM-16) while minimum fresh weight 9.847g was measured in V2 (NM-11) Table 8. By increasing the rate of Cobalt application fresh weight of mung bean plant was increased. Treatment and varieties produce significant effect on the crop. These results are similar with the findings of Awomi et al. (2012). Mung bean is a leguminous crop and requires Cobalt for effective nodulation. With the application of Cobalt, the uptake of NPK was relatively increased thereby increasing the fresh weight of the mung bean crop.

Table 8: *Fresh weight plant^{-1} as influenced by the different cobalt level.*

Treatments		V1 NM-16	V2 NM-11	Mean
T1	Control	7.392 de	6.769 e	7.080 C
T2	10ppm	12.098 bc	9.234 cde	10.66 B
T3	20ppm	15.515 ab	10.687 cd	13.101 B
T4	30ppm	18.510 a	12.698 bc	15.604 A
Mean		13.379 A	9.847 B	

LSD Values = 0.05

Crop growth rate: The effect of cobalt on mung bean produced maximum crop growth rate 9.4036 gm^{-2}day^{-1} which was statistically at par with 30ppm cobalt nitrate and least was 3.6563 gm^{-2}day^{-1} at Control in V1 (NM-16) while in V2 (NM-11) the highest crop growth rate was 7.9189 gm^{-2}day^{-1} at 30ppm Table 9. Cobalt nitrate, least at Control which was 4.1694 gm^{-2}day^{-1}. By increasing the rate of Cobalt gave maximum crop growth rate. The source of Cobalt had significant effect. Maximum value of crop growth rate was measured at treatment 30ppm cobalt nitrate (8.66125 gm^{-2} day^{-1}) while minimum was measured at control (3.91285 gm^{-2}day^{-1}). Pattern of crop growth rate was similar in both the varieties. Maximum crop growth rate was produced due to the increased nodulation and the maximum nitrogen fixation in the root nodules of the mung bean crop. Application of Cobalt had significant effect on growth and development attributes like dry weight, Number of branches per plant and number of nodules per plant. These results are similar with the findings of Samant (2014) who reported that the application of cobalt increased CGR in mung bean crop.

Table 9: *Crop growth rate (CGR) as influenced by the different cobalt levels.*

Treatments		V1 NM-16	V2 NM-11	Mean
T1	Control	3.6563 e	4.1694 de	3.91285 D
T2	10ppm	6.1020 bc	5.6085 cd	5.85525 C
T3	20ppm	7.9170 ab	6.5704 bc	7.2437 B
T4	30ppm	9.4036 a	7.9189 ab	8.66125 A
Mean		6.7697 A	6.0668 A	

LSD Values = 0.05

Net assimilation rate: Data indicated that the highest net assimilation rate in V1 (NM-16) was produced at 30ppm Cobalt nitrate 4.3865 gm^{-2}day^{-1} and least was at Control 2.2158 gm^{-2}day^{-1}. In V2 (NM-11) the maximum NAR value was produced at 30 ppm Cobalt nitrate 3.7282 gm^{-2} day^{-1} and least NAR was produced at Control which was 2.7625 gm^{-2} day^{-1} Table 10. Among treatments highest value of net assimilation rate was 4.0574 gm^{-2} day^{-1} at treatment 30ppm cobalt nitrate and least value comes to be 2.4892 gm^{-2} day^{-1} at control which was followed by 3.6110 gm^{-2}day^{-1} at treatment 20ppm cobalt nitrate. By increasing the rate of Cobalt produced highest net assimilation rate. Cobalt had significant effect on net assimilation rate of the mung bean crop. With the application of Cobalt, uptake of Nitrogen, Phosphorous and Potassium was increased relatively. Similarly, application of cobalt significantly gave better growth as compared to that of the Control. This may be due to the maximum nodulation and bacterial activity in rhizosphere following to Cobalt utilization. These results are similar with the findings of Awomi et al. (2012) who reported that application of Cobalt increased net assimilation of mung bean crop. Tolerance level of cobalt in different verities also differ in relation with the ability of plant to sustain the activity of superoxide dismutase and guaicol peroxidase and to maintain glutathione (Ali et al., 2018).

Table 10: *Net assimilation rate (NAR) as influenced by the different cobalt level.*

Treatments		V1 NM-16	V2 NM-11	Mean
T1	Control	2.2158 c	2.7625 bc	2.4892 C
T2	10ppm	3.0410 bc	3.0272 bc	3.0341 BC
T3	20ppm	3.9099 ab	3.3122 abc	3.6110 AB
T4	30ppm	4.3865 a	3.7282 ab	4.0574 A
Mean		3.3883 A	3.2075 A	

LSD Values = 0.05

Dry weight per plant: Data revealed that the application of cobalt nitrate produced highest dry matter at 30ppm Cobalt nitrate which was 4.9360g and least was 1.9712g at Control in V1 (NM-16). In V2 (NM-11) maximum dry weight was produced at 30 ppm cobalt nitrate 4.2328g and lowest dry weight was recorded at Control 2.2564g Table 11. Highest dry weight per plant was measured at treatment 30ppm cobalt nitrate (4.5844 $gm^{-2}day^{-1}$) while lowest value (2.1138 $gm^{-2}day^{-1}$) was measured at control. Cobalt is a micronutrient which is required by the leguminous crop to promote nodulation. With the application of Cobalt, uptake of Nitrogen, Phosphorous and Potassium was increased relatively Awomi et al. (2012).

Table 11: *Dry weight plant^{-1} as influenced by the different cobalt level.*

Treatments		V1 NM-16	V2 NM-11	Mean
T1	Control	1.9712 f	2.2564 ef	2.1138 D
T2	10ppm	3.2261 cde	3.0781 de	3.1521 C
T3	20ppm	4.1374 abc	3.5625 bcd	3.8499 B
T4	30ppm	4.9360 a	4.2328 ab	4.5844 A
Mean		3.5677 A	3.2824 A	

LSD Values = 0.05

Effect of Cobalt treatment on nodulation parameters

Size of nodules: The effect of different cobalt treatments on nodule size of two mung bean varieties is given in Figure 1. Maximum nodule size 0.0988cm was measured in V_2 (Nm-11) at treatment 30ppm cobalt however minimum nodule size 0.0625cm was measured in V_1 (NM-16) Figure 1. Mung bean is a leguminous crop and nodules formation is the important feature of this crop. Nodule size describes the size of nodules we came across during our research. Increasing the rate of cobalt increased the size of the nodules. Source of cobalt had significance impact on mung bean crop. Mung bean is a crop which forms nodules on the roots of the crop plant. Cobalt is a micronutrient whose application increases the formation of nodules in the crop plant. These results are similar with the findings of Elahi, Mustafa and Mirza (2004).

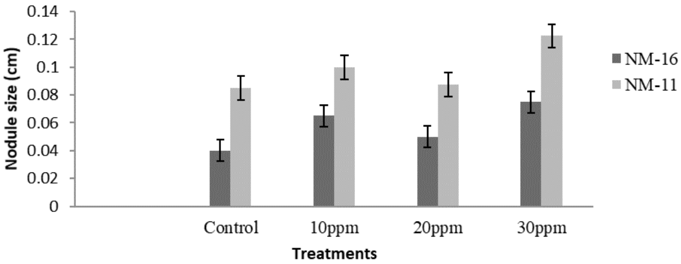

Figure 1: *Size of nodule (cm) of mung bean as influenced by the different cobalt levels.*

Numbers of nodules: Maximum numbers of nodules 31.162 were recorded in V_1 (NM-16) when cobalt nitrate was used at 30ppm as compared to its respective control treatment 21.826 in V_2 (NM-11) Figure 2. It was also clear from the results that the minimum number (24.941) of nodules were recorded in V_2 (NM-11). By increasing the application of cobalt increased the number of nodules on the roots of the mung bean crop. These results are similar with the findings of Elahi, Mustafa and Mirza (2004).

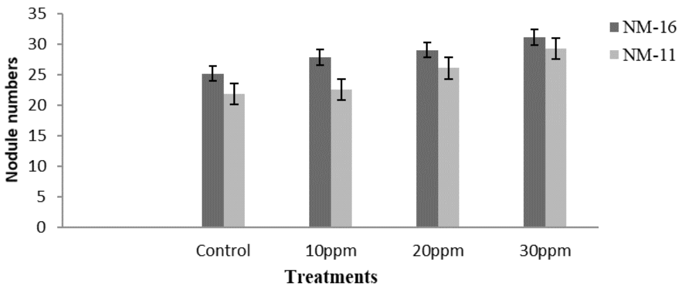

Figure 2: *Nodule numbers of mung bean as influenced by the different cobalt levels.*

Nodule weight: The highest nodule weight 136.87mg was recorded in V_2 (NM-11) with the treatment where cobalt nitrate was at 20ppm for seed treatment whereas lowest nodule weight 100.23mg was weighed with control treatment in V_1 (NM-16) Figure 3. These results are similar with the findings of Bashir et al. (2016).

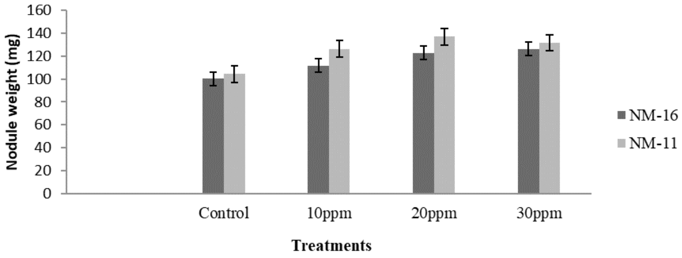

Figure 3: *Nodule weight (mg) of mung bean as influenced by the different cobalt levels.*

Nodule grading: Maximum number of nodules 3.25 were found at treatment 30ppm cobalt nitrate in V_1 (NM-16) and classified as class with better nodulation and graded as 3 grade whereas minimum numbers of nodules 1.5 were found at control in V_1 (NM-16) Figure 4. However, Table 12 shown Criteria for Nodule grading:

Numbers	Class	Grade
<5	Poor nodulation	0
5-10	Fair nodulation	1
10-20	Good nodulation	2
20-40	Better nodulation	3
>40	Excellent nodulation	4

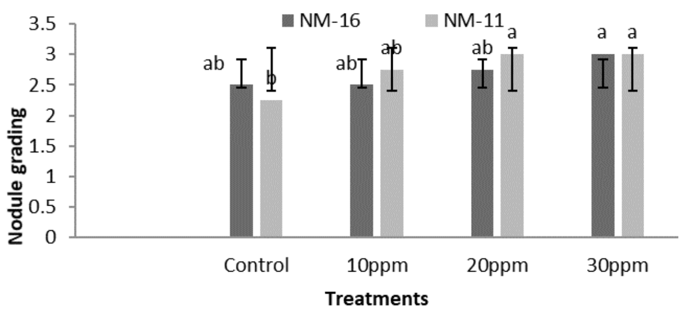

Figure 4: *Nodule grading on the basis of number of nodules as influenced by different levels of Cobalt.*

Conclusions and Recommendations

Application of cobalt and slurry for seed inoculation proved to be the best @40ml of slurry and 30ppm of cobalt concentration for improving growth and nodulation parameters of mung bean.

Authors Contribution

Mohammad Aquil Siddiqui: This author conceived the idea, and conducted the work. Carried-out detailed analysis of the traits for varietal performance against the check varieties. Moreover, this author drafted the manuscript.

Muhammad Tahir Khan: Assisted in conducting study and writing the manuscript. Finalized the references formatting. Conducted the analysis for correlation of the studied traits.

Ghulam Shah Nizamani: Analyzed the statistical data. Helped in collecting agronomic traits data of the crop. Improved the manuscript through proof reading.

Shafquat Yasmeen: Helped in collecting agronomic traits data of the crop.

Imtiaz Ahmed Khan: Supervised the manuscript writing. Critically reviewed the article and provided technical inputs.

Abdullah Khatri: Provided the technical input, supervised the work through his feedback.

Nighat Seema Soomro: Conducted the analysis for correlation studied of the traits.

Muhammad Rashid Nizamani: Assisted in recording agronomic traits of the crop.

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