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RESEARCH ARTICLE

Growth and Productivity of Two Varieties of Phaseolus Vulgaris in the Presence of Heavy Metals and Fertilizers

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ABSTRACT

In the presence of work growth and productivity of different varieties of *Phaseolus vulgaris* (red bean) were examined in the presence of Urea, foliar fertilizer, Cobalt, Copper and blend in the field. The increase in concentrations of Cobalt and Copper affects plant height. The length of the Cobalt and Copper-treated plants was 24.8 cm and 26.8 cm respectively compared to the control (28 cm). The blend solution (Co-120+Cu-120) treated plants showed a decrease in length i.e. 27.3 cm. Maximum plant growth was observed in the foliar fertilizer-treated plants, where the plants attained a length of 34.7 cm followed by Urea treated plants (34.3 cm). This revealed that the application of foliar fertilizer and urea enhances plant growth. The high concentration Cobalt treated plants show a decrease in length and productivity as compared to control. Our analysis revealed that Copper intake has a comparatively better effect on plant growth than Cobalt.

Key words: Copper, Cobalt, Urea, Foliar fertilizer, Red bean

INTRODUCTION

Red kidney beans are a staple in many people's diets around the world, especially in developing and undeveloped tropical and subtropical regions (Siddiq et al., 2010). The legumes and grains families are by far the most important food sources on the planet; grains provide starch, while legumes such as beans, peas, and alfalfa provide protein and lipids (John, 2005). The bean plants belong to the Vignasavi genus, the Leguminosae-papilionoidae family, and the Phaseoleae tribe, which comprises roughly 80–100 species. The term "common bean" mainly refers to edible legumes of the genus Phaseolus, family Leguminosae, subfamily Papilionoideae, tribe Phaseoleae, and subtribe Phaseolinae, which grow in the tropics and Asia There are about 50 wild-growing species in the genus Phaseolus distributed only in the Americas (Asian Phaseolus have been reclassified as Vigna). Beans, in general, are rich in macronutrients, micronutrients, and antioxidant substances, and have a wide range of applications in human and animal nutrition. They do, however, contain a few anti-nutritional components that limit their ingestion and decrease nutrient digestion and bioavailability (Worku & Sahu, 2017). Colored beans also contain polyphenols, which may reduce the bioavailability of micronutrients like iron (Fe). Bean seed coatings have a high concentration of polyphenols. Flavonoids are found in higher concentrations in colored beans than in white beans (Tako & Glahn, 2010).

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For millennia, these essential crops have been an important component of the human diet, but the output of legumes is not increasing at the same rate as corn, wheat, rice, and soybeans, and consumption has been steadily declining in both developed and developing countries (FAO, 2016). Protochlorophyll is found in bean leaves, when the leaves are exposed to light, they quickly convert to chlorophyll (Smith & Benitez, 1954). Legumes are second only to the Gramineae in importance to humans, due to their distinctive floral shape, podded fruit, and the ability of 88% of the species investigated to date to form nodules with rhizobia. Legumes are divided into 670 to 750 genera and 18,000 to 19,000 species (De Faria et al., 1989). Lentils were first used in pastures and for soil development by the Romans, according to Varro (Haroon et al., 2022). Legumes should be grown in light soils, not so much for their crops as for the benefit they provide to other crops (Bolatova et al., 2024). Supplementing people's diets with plant proteins is one way to improve their nutritional condition. As a result, the nutritional evaluation of proteins from plant species must be prioritized. Legumes (poor man's meat) are essential for human nutrition because they're high in protein, calories, and certain minerals and vitamins (Deshpande, 1992). They are also known as grain legumes since they are primarily produced for their edible seeds. They take up a lot of cropped land all around the planet. Grain legumes are grown in both tropical and temperate climates and are used as a pulse (dhal) with cereals. They increase the protein level of cereal-based meals and may help to improve their nutritional quality. Certain important amino acids, particularly lysine, are lacking in cereal proteins (Haroon et al., 2023). Oilseed legumes, such as soybeans and peanuts, are grown for both their protein and oil content, whereas grain legumes, such as common beans, lentils, lima beans, cowpeas, fava beans, chickpeas (garbanzos), and common peas, are grown primarily for their protein contents. Pulses refers to beans, peas, and lentils, and is derived from the Latin word "puls" which refers to an ancient bean porridge. Dry beans are distinguished from peas and lentils by the physical shape of the seed where dry beans are kidney-shaped or oval, peas are circular, and lentils are flat discs. Green leaves and immature pods are edible as vegetables in temperate climates. Dry beans make up a major amount of the protein ingested by low and middle-income families. Young leaves are eaten as a salad in many regions of Asia (Ganesan & Xu, 2017). Beans are consumed as mature grain and immature seed, as well as both leaves and pods as vegetables.

The genetic makeup of beans is complex, having a mix of main and minor gene pools, races, and intermediate types, with some interbreeding between wild and domesticated varieties. Beans are thus a crop that may fit into a variety of niches, both agronomically and in terms of market choice (Jimayu & Gebre, 2022). Beans have a protein composition that ranges from 20 % to 30 % of their total calories. The demand for methionine in rats is 50 percent more than in humans. As a result of the low Sulphur amino acids (SAAs) content of bean proteins, the protein-efficiency ratios of beans are quite low (Messina, 1999)

Stress on Plants

Environmental stress causes significant crop quality and productivity losses. Excess generation of active oxygen species (AOS), including superoxide (o_{27}), hydrogen peroxide (H_2o_2), and hydroxyl radicals (OH), is one of the major processes by which plants are destroyed under poor environmental conditions. Plants exposed to high and low temperatures have been proven to experience oxidative stress, especially when combined with high light intensities, drought, air pollutants (e.g. ozone or Sulphur dioxide), UV light, and herbicides (Inzé & Montagu, 1995). Cobalt, a transition metal, is required to produce numerous enzymes and co-enzymes. It has been proven to have varying degrees of effect on plant development and metabolism, depending on the quantity and status of cobalt in the rhizosphere and soil (Khan et al., 2023). Cobalt forms complexes when it interacts with other elements (Palit et al., 1994). The toxicity of cobalt ions and their binary mixtures are studied at varying test levels using duckweed as the test organism. The accumulations of metal ions are determined by atomic absorption spectroscopy. The type of toxic interactions in binary mixtures is assessed as \`synergistic', \`antagonistic', and \`additive' by a statistical approach (Shakeel et al., 2023).

Cobalt has several advantages, including the ability to delay leaf senescence, boost drought resistance in seeds, regulate alkaloid buildup in medicinal plants, and prevent ethylene biosynthesis (Palit et al., 1994). Heavy metals like Lead (Pb) are one of the major heavy metals of antiquity and have gained considerable importance as a potent environmental pollutant. Apart from the natural weathering processes, Pb contamination of the environment has resulted from mining and smelting activities, Pb-containing paints, gasoline and explosives as well as from the disposal of municipal sewage sludges enriched in Pb (Chaney & Ryan, 1994). Plants quickly absorb it from the soil and store it in various organs. Pb is a protoplasmic poison that builds up over time, is slow to function, and is difficult to detect. Pb-contaminated soils reduce agricultural output dramatically, creating a severe challenge for agriculture (Johnson and Eaton, 1980).

Fertilizer Effect on Plant Growth

Natural sources of nitrogen (N) such as precipitation and fixation by Rhizobacteria are not enough to maximize crop productivity, thus, chemical fertilizers have been used for a long period to increase Nitrogen-availability and plant uptake (Bhatti et al., 2024). The rate of N fertilizer application has increased tremendously, a trend that is expected to continue (Adesemoye et al., 2009). The fertilizer industry is the source of natural radionuclides and heavy metals as a potential source. It contains a large majority of heavy metals like Hg, Cd, As, Pb, Cu, Ni, and Cu as well as natural radionuclides like 238U, 232Th, and 210Po (Savci, 2012; Hussain et al., 2023).

Inorganic fertilizers have been regularly employed to support and maximize the growth of these plants for many years (Rahman et al., 2022; Liu et al., 2024). However, to conserve agriculture, the use of organic fertilizer has gained more relevance globally in recent decades. Organic fertilizers have been found to aid in the preservation of natural resources and the reduction of ecosystem damage (Mäder et al., 2002; Bhatti et al., 2024). Most farmers use inorganic fertilizers for better production due to their easy and rapid availability to plants (Thy and Buntha, 2005). Organic fertilizers not only provide organic matter and nutrients, but they also improve the soil's microbial population, as well as its physical, biological, and chemical qualities (Albiach et al., 2000). Organic fertilizers, on the other hand, benefit the soil and boost nutrient availability, which helps to preserve crop quality and yield, and they are less expensive than inorganic fertilizers (Thy & Buntha, 2005).

Foliar Spray

The application of fertilizers through foliar spray is recognized globally as an effective, preventive, and curative measure to compensate for their deficiency. This has special importance in arid and semi-arid regions where osmotic pressure promotes the absorption and activity of these elements influenced by the behavior of plants and the timing of foliar application (Marschner, 1995).

The combined effects of Zn seed treatment and humic acid foliar spray on agronomic performance and protein content of a commonly grown Turkish common bean (Kaya et al., 2005; Shakeel et al., 2023). If potassium is applied to the plants as a foliar spray. The use of foliar spray to deliver important trace elements is widely documented in the literature (Bangar et al., 1991). It would be quite interesting to include potassium in foliar spray media for plants cultivated in a saline environment. The presence of wide leaves with hairs (trichomes) is thought to improve the retention of water spray coating and make minerals available for stomatal absorption.

MATERIALS AND METHODS

This experiment was conducted to explore the effects of fertilizers and heavy metals on the development, and seedling growth of different common bean types. The seed were sown on 01 Dec 2020 and different concentrations were applied on 29 Dec 2020. The plant started flowering on Feb 8, 2021.

Seed varieties were collected from a shop in Mardan. The seeds were surfaced sterilized and sown in pots that were half-filled with soil and half-filled with sand. The pots were meticulously labeled. Plants were grown under controlled environmental conditions in a growth chamber and the chamber was covered on both sides with plastic to keep a consistent temperature for optimum growth. For two to three weeks, the circumstances were maintained. The pots (12) were labeled properly with the names of two varieties of beans (Red Bean and Roman Bean) and placed in the growth chamber with a suitable environment with the addition of a little water to keep moisture in control. Solution of heavy metals (Pb/Co) and fertilizers (Urea/Foliar spray) were added three times to plants through a syringe and recorded how plants can grow.

Heavy Metals

Cobalt Solution:

1-Co-120 (30 milligrams of cobalt in 100 mL distilled water)/ **2-Co-240** (60 milligrams of cobalt in 100 mL distilled water)/**3-Co-360** (90 milligrams of cobalt in 100 mL distilled water).

Copper Solution

1-Cu-120 (30 milligrams of copper in 100 mL distilled water)/**2-Cu-240** (60 milligrams of copper in 100 mL distilled water)/**3-Cu-360** (90 milligrams of copper in 100 mL distilled water).

Blend Solution

The blend solution was prepared by taking 30mg each of Cobalt and Copper in 100ml distilled water.

RESULTS

The height of plants was monitored and measured once a week, for 13 weeks in total. The control plant attains a length of 28 cm at the end of the 13^{th} week (Red Bean-Roman). The plant attains a final height of 28 cm at the end of the 13^{th} week. Urea-treated plants attained a final height of 34.3 cm. We can see the increase in plant growth from weeks (2-12) that how much faster its growth is increased. Foliar fertilizer-treated plants of Roman variety exhibited more plant height in week 7,9. The blend-treated plant stopped their growth from week 9 because of excess of heavy metals treatment as plants were damaged. Cobalt-120 concentration treated plant of Roman variety every week revealed growth mostly in week 4 which is 2.7cm. Cobalt-240 concentration treated Roman plant reached a final height of 25.5 cm. The Copper-120 and 240 were also estimated highly in promoting and prohibiting plant height, their final plant heights were 31.2 and 28.3 respectively. Cobalt-360 and copper treatment varieties also showed fluctuation in their plant height respectively. Fertilizer-treated varieties including Urea and foliar fertilizer showed positive regulation on plant height compared to the control. In contrast, the blend concentration treated variety showed a reduction in plant height.

Table 1: The applications of different concentrations of Urea, Cobalt and Copper on red bean and Roman bean growth. Foliar spray shows maximum growth (34.7), Urea (34.4 cm)/ Cobalt-120, 240, 360/ Copper-120, 240, 360/ Blend.

Plant Height in cm		
	Amount	Height
Control		28
Urea		34.3
Foliar fertilizer		34.7
Cobalt	120	27.5
	240	25.5
	360	24.8
Roman Blend		14
Control		27.4
Urea		33.1
Foliar fertilizer		35.1
Copper	120	31.2
	240	28.3
	360	26.8
Red Blend		27.3

Plant Height

The plant height showed cleared variation in the treated plant compared to the control. Plants treated with urea have an increased height compared to control as well as foliar-treated plants. Blend-treated plants have smaller heights than control. The Cobalt-treated plants show a decrease in height while Copper-treated plants are slightly taller than the control. Copper is an important micronutrient for plant development and growth. It improves the function of lignin in the cell wall and functions as a catalyst in photosynthesis and respiration. Copper can be extremely harmful to plants in high amounts, causing symptoms e.g. Chlorosis and necrosis.

Leaf Width

The leaf width of treated plants was greatly affected compared to that of control. Urea and foliar-treated plants have increased leaf width compared to the control. The blend-treated plant leaf area was smaller than that of the control, but the heavy metals-treated plant leaf width is much greater than that of the control. The excess of Cobalt concentration affected plants' height due to damage to plant leaves. Cobalt helps in nitrogen fixation, but excess of Cobalt and Copper can damage the plant. Excess of Cobalt results in toxicity, which leads to loss of leaves, pale coloured leaves and discoloured veins.

Number of Buds

The number of pods in urea, foliar and heavy metals treated plants were more compared to control.

Production

The total production of a control plant was lesser than that of a treated plant with urea, and foliar. The heavy metals-treated plants had about the same production as that of Control.

Bean Leaves

Bean leaves of all sorts are edible and are used in a variety of cooked meals throughout the world. Long bean leaves are commonly used in curries in the Far East. The large leaves in the whole plant have a length of 7 cm and a width of 5.5 cm. The total number of leaves in a plant was 12-15 and generally the leaves were either small or large. The length of the leaf was 3.5 cm and width 3cm.

Table 2: The table shows the plant leaf area of all treated plants along with the control. The leaf area of foliar fertilizer-treated plant.

Plants leaf area			
	Length	Width	Area
Control	5.3cm	4.9cm	25.95
Urea	6.2cm	6cm	37.2
Foliar fertilizer	6.5cm	6.1cm	39.65
Cobalt			
120	5.4cm	5cm	27
240	5.6cm	4.8cm	26.88
360	4.4cm	4cm	17.6
Blend	3.4cm	3cm	10.2
Control	4.6cm	4.3cm	19.78
Urea	6.8cm	6.2cm	42.16
Foliar fertilizer	7cm	6.5cm	45.5
Copper			
120	5.2cm	5cm	26
240	5.1cm	5cm	25.5
360	4.2cm	4cm	16.8
Blend	5cm	4.7cm	23.5

Table 3: The table shows several pods, seeds and weights of Urea, Foliar and Heavy metals treated plants along with control.

Treatments	Concentration	Number of pods	Number of seeds	Weight
Control		10	34	10g
Urea		26	98	51g
Foliar		23	84	32g
	120	21	81	30g
Cobalt	240	18	71	24g
	360	5	38	12g
Control		12	68	40g
Urea		25	150	76g
Foliar		27	164	82g
Copper	120	22	130	68g
	240	18	105	59g
	360	8	44	28g
Blend		20	114	63g

DISCUSSION

Use of fertilizers Urea, foliar, cobalt and copper at different rates significantly increased the plant height as compared to control. Greater plant height was observed in beans where urea and foliar are used. Our results showed that plants treated with urea are large in height and healthy appearance. The results indicated that morphological characteristics like plant height and stem diameter are significantly increased by combined treatments of *R. japonicum* and urea as compared to control and other treatments (Gul et al., 2019). Our results show that a low concentration of cobalt-treated plants can increase their height as compared to control and highly concentrated plants have a decrease in height as compared to control. The increase in plant height was maximum (23%) at 1.5 mg kg-1 Cu application in comparison to a control plant. The number of tillers was maximum in control plants which decreased to a minimum in the plants at 1.5 mg kg-1 Cu level. However, all the tillers of control plants were not of effective type. Thus, the plants at low copper had decreased height (Kumar et al., 2009).

Our results show a low dose of Cu plant height reached 27.5 cm and the high concentrated plant height reached 24.8 cm. Some heavy metals, e.g. Cu, at a low dose are essential microelements for plants, but in higher doses, they may cause metabolic disorders and growth inhibition for most plant species. The effects of Cu concentration in soil on the growth rate of *Brassica juncea* L. The height of plants reaches the highest value of 19.5 cm (Cu, 2008).

Copper is one of the essential micronutrients, or trace minerals, that plants need for growth. High concentrations of copper can cause growth reduction which is not good for plants. Our results show the low concentration of Co-treated plants increased their height as compared to those who had been treated with a high concentration of Copper and also appeared small damage on the leaves of plants. Owing to excess Co and at any level of P, the concentration of Co increased in different plant parts from that of control plants, maximum was in roots and minimum in fruits. The accumulation of Co was more in young than old leaves, the effects were more pronounced with adequate Plant withdrawal of Co from excess Co-treated plants significantly reducing the accumulation of Co in different parts, whereas no effect, instead of decreasing, the concentration of total plant increased (Chatterjee & Chatterjee, 2003). In our project cobalt shows more toxicity as compared to copper also there is a difference in their treated plant height. Their high doses can affect the plant's height. Cobalt appeared to exert a much more toxic effect than copper. This is interesting given the previous finding that copper had a greater influence on the retardation of germination (Baker et al., 1983). Our results show a low level of Co can increase the plant height and show an increase in productivity. The low level of Co (20 mg/kg soil) caused a significant increase in plant height, No. of branches and fruits per plant, as well as fresh and dry weights of roselle calyces as compared with the high level (40 mg /kg soil). These observations are consistent with previous reports according to (Aly et al., 1991). Our results show that copper-treated plants show an increase in height as compared to control. The copper supplied to the substrate favored the plant growth soon after treatment. In the present study, the height of the main stem was always higher in the treated plants than in the control (Pietrini et al., 2019)

Conclusion

In the current study different treatments i.e. Urea, Foliar, Cobalt and Copper were applied to different varieties of *Phaseolus vulgaris* sub ssp. vulgaris. Among all of them, Foliar shows the maximum growth. The growth in blend-treated plants is reduced. In Cobalt and Copper treated plants, copper shows more growth and production than cobalt.

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