

## Effect of Different Concentrations of Cobalt on Morphological Parameters and Yield Components of Soybean

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**Abstract:** A pot culture experiment was conducted to estimate the effect of cobalt (0, 50, 100, 150, 200 and 250 mg kg<sup>-1</sup> soil) on morphological parameters, drymatter production, yield and yield components of soybean. Pot culture experiments were conducted during January 2006 to April 2006. Periodical observations were made to record the various morphological parameters, dry matter production and yield responses of soybean. From the results, it is observed that, cobalt at lower concentrations have some beneficial values on soybean.

**Key words:** Soybean, *Glycine max*, Cobalt, Morphological parameters, Drymatter production, Yield components

### INTRODUCTION

While it has been known for many years that cobalt is an essential element for humans, animals and prokaryotes, a physiological function for this element in higher plants has not been identified. The cobalt containing vitamin B<sub>12</sub> does not occur in plants. Whereas normal cobalt concentrations in plants are cited to be as low as 0.1-10 µg g<sup>-1</sup> dry weights, its beneficial role as a trace element has been described [1-3]. Trace elements are necessary for the normal metabolic functions of the plant, but at higher concentrations, these metals are toxic and may severely interfere with physiological and biochemical functions [2-5].

Cobalt is a brittle, hard metal, resembling iron and nickel in appearance, atomic number: 27, atomic symbol: Co, atomic weight: 58.9332, colour: lustrous, metallic, grayish tinge, melting point: 1495°C and boiling point: 2870°C. Cobalt and its salts are used in variety of processes to make superalloys which maintain their strength at high temperature, in paint as a drier, in porcelain enamel finishes as a drying agent, as an ingredient of coloured pigments and in formulating vitamin B<sub>12</sub>. Some radioactive isotopes of cobalt, such as cobalt<sup>60</sup>, are used in treating patients in nuclear medicine and in research.

Soybean belongs to the papilionaceous family or to the leguminous plants and may reach a height of 80 to 100 cm. The flowers are red, white but can also be violet. These beans are sometimes big or small, long, round or oval. The color can also vary. Some are yellow, others are green but can also be brown or violet and some are even black or with spots. The soybean fields are brown when harvesting starts because the leaves of the plant are dry before the beans are mature. The remaining plant has only stems with pods [6].

Soybean plants can be grouped into basically two main types, determinant and indeterminate, both grown mostly in temperate climates. The determinant varieties will flower at a certain time of the year, basically when the days begin to shorten. Indeterminate varieties will continue to flower and put on fruit until the weather dictates that it is time to curtail plant growth. There are many different varieties, which allow soybeans to be produced in different maturity zones. One of the most important agronomic characteristics of soybeans is that it can take nitrogen from the air and "fix" it to be used by the soybean plant.

Objectives of the present study: A pot culture experiment was conducted to estimate the effect of

cobalt (0, 50, 100, 150, 200 and 250 mg kg<sup>-1</sup> soil) on morphological parameters, drymatter production, yield and yield components of soybean.

## MATERIALS AND METHODS

The present investigation has been carried out to find out the effect of cobalt a heavy metal pollutant on growth, biochemicals, enzyme activities and nutrient content of soybean (*Glycine max* (L.) Merr.) cultivar CO-1.

### Materials

**Seed:** The experimental plant, the soybean (*Glycine max* (L.) Merr.) cultivar CO-1 belongs to the family Fabaceae is one of the important pulses of India. Seeds used in the experiments were obtained from the Pulses Division, Tamil Nadu Agricultural University, Coimbatore. Seeds with uniform size, colour and weight were chosen for experimental purpose.

Seeds were surface sterilized with 0.1 per cent mercuric chloride solution and washed thoroughly with tap water and then with distilled water.

**Pot Culture Experiments:** The experiments were conducted during January-April 2007. Soybean (*Glycine max* (L.) Merr.) cultivar CO-1 plants were grown in pots in untreated soil (control) and in soil to which cobalt had been applied (50, 100, 150, 200 and 250 mg kg<sup>-1</sup> soil). The inner surfaces of pots were lined with a polythene sheet. Each pot contained 3 kg of air dried soil. The cobalt as finely powdered (CoCl<sub>2</sub>) was applied to the surface soil and thoroughly mixed with the soil. Ten seeds were sown in each pot. All pots were watered to field capacity daily. Plants were thinned to a maximum of six per pot, after a week of germination. Each treatment including the control was replicated five times.

**Sample Collection:** The plant samples were collected at thirty days interval, upto harvest stage viz., 30, 60 and 90<sup>th</sup> day for the measurement of various morphological and yeild parameters. Six plants from each replicate of a pot was analysed for it's various parameters and the average was calculated. These mean values were used for statistical analysis.

**Morphological Parameters:** The various morphological parameters such as root length, shoot length, total leaf area, dry weight of root and shoot per plant were determined for every samples.

**Leaf Area (cm<sup>2</sup> plant<sup>-1</sup>):** The leaf area was calculated by measuring the length and breadth and multiplied by a correlation factor (0.69), derived from standard method.

**Yield Parameters:** Yield parameters such as number of pods, seed out put per plant and dry weight of seeds and were recorded at 90<sup>th</sup> day samplings.

Pot culture experiments were conducted at Botanical garden in Annamalai University during January 2006 to April 2006. Periodical observations were made to record the various morphological parameters, dry matter production and yield responses, biochemical constituents, antioxidant enzyme activities and nutrient contents of soybean

## RESULTS

### Morphological Parameters

**Root Length (cm plant<sup>-1</sup>):** The root length of soybean plants at different stages of growth under cobalt stress is represented in Table 1. The root length of soybean increased with an increase in age of the plants and decreased (except 50 mg kg<sup>-1</sup>) with an increase in the concentrations of cobalt in the soil. The highest root length of soybean was observed at 50 mg kg<sup>-1</sup> (45.72) on 90<sup>th</sup> day and lowest root length was observed at 250 mg kg<sup>-1</sup> (13.16) on 30<sup>th</sup> day. F-test values were significant at 1% for cobalt levels and sampling days.

**Shoot Length (cm plant<sup>-1</sup>):** Shoot length of soybean at different stages of growth under cobalt stress is represented in Table 1. Maximum shoot length was recorded on 90<sup>th</sup> day at 50 mg kg<sup>-1</sup> (53.40) plants of soybean. 250 mg kg<sup>-1</sup> concentration plants of soybean showed the minimum length of shoot (18.43) on 30<sup>th</sup> day. F-test values for the difference between cobalt levels and sampling days were significant at 1% level.

**Total Leaf Area (cm<sup>2</sup> plant<sup>-1</sup>):** Total leaf area of soybean under cobalt stress recorded at different stages of growth is represented in Table 2. Total leaf area of soybean plants on 30<sup>th</sup> day were found to be 17.81, 138.69, 112.17, 94.36, 74.19 and 56.27 at 0, 50, 100, 150, 200 and 250 mg kg<sup>-1</sup> soil respectively. It increased in the subsequent sampling periods and at 50 mg kg<sup>-1</sup> and decreased at high levels (100-250 mg kg<sup>-1</sup>) of cobalt in the soil. ANOVA values were significant at 1% for cobalt levels and sampling days.

Table 1: Effect of cobalt on root and shoot length (cm plant<sup>-1</sup>) of *Glycine max* (L.) Merr

Cobalt added in the soil (mg kg <sup>-1</sup> )	ROOT			SHOOT		
	Sampling days					
	30	60	90	30	60	90
Control	27.46 <sup>a</sup>	31.93 <sup>a</sup>	36.63 <sup>a</sup>	31.63 <sup>a</sup>	35.03 <sup>a</sup>	41.26 <sup>a</sup>
50	35.23 <sup>b</sup> (+28.29)	14.08 <sup>b</sup> (+28.65)	45.72 <sup>b</sup> (+24.92)	38.47 <sup>b</sup> (+21.62)	44.66 <sup>b</sup> (-27.49)	53.40 <sup>b</sup> (+29.42)
100	22.20 <sup>c</sup> (-19.15)	26.10 <sup>c</sup> (-18.25)	28.26 <sup>c</sup> (-22.85)	28.40 <sup>c</sup> (-10.21)	31.33 <sup>c</sup> (-10.56)	34.73 <sup>c</sup> (-15.82)
150	18.40 <sup>d</sup> (-32.99)	22.23 <sup>d</sup> (-30.37)	25.96 <sup>d</sup> (-29.12)	25.95 <sup>d</sup> (-17.95)	28.03 <sup>d</sup> (-19.98)	31.96 <sup>d</sup> (-22.53)
200	16.20 <sup>d</sup> (-41.00)	18.66 <sup>e</sup> (-41.55)	20.56 <sup>e</sup> (-43.87)	20.17 <sup>e</sup> (-36.23)	26.86 <sup>e</sup> (-23.32)	29.73 <sup>e</sup> (-27.94)
250	13.16 <sup>e</sup> (-52.07)	16.30 <sup>e</sup> (-48.95)	17.96 <sup>f</sup> (-50.96)	18.43 <sup>e</sup> (-41.73)	24.16 <sup>f</sup> (-31.03)	25.80 <sup>f</sup> (-37.46)

(Per cent over control values are given in parentheses)

Values, that are not sharing a common superscript (a,b,c,d,e,f) differ significantly at  $P \leq 0.05$  (DMRT).Table 2: Effect of cobalt on leaf area (cm<sup>2</sup> plant<sup>-1</sup>) of *Glycine max* (L.) Merr

Cobalt added in the soil (mg kg <sup>-1</sup> )	Sampling days		
	30	60	90
Control	117.81	183.61	266.14
50	138.69 (+17.72)	218 (+18.83)	293.18 (+10.16)
100	112.17 (-4.787)	156.64 (-14.68)	209.61 (-21.24)
150	94.36 (-19.90)	122.76 (-33.14)	183.36 (-31.10)
200	74.19 (-37.12)	106.11 (-42.20)	167.41 (-37.09)
250	56.27 (-52.23)	98.37 (-46.42)	128.89 (-51.57)

(Per cent over control values are given in parentheses)

Comparison of significant effects F test

Cobalt levels\*\* Sampling days\*\*

Table 3: Effect of cobalt on root and shoot dry weight (g plant<sup>-1</sup>) of *Glycine max* (L.) Merr

Cobalt added in the soil (mg kg <sup>-1</sup> )	ROOT			SHOOT		
	Sampling days					
	30	60	90	30	60	90
Control	0.423	0.612	0.734	2.615	3.661	6.986
50	0.496 (+17.25)	0.743 (+21.40)	0.812 (+10.62)	2.837 (+8.489)	4.411 (+20.48)	7.213 (+3.249)
100	0.387 (-8.510)	0.541 (-11.60)	0.645 (-12.12)	2.318 (-11.35)	3.156 (-13.79)	6.763 (-3.192)
150	0.318 (-24.82)	0.487 (-20.42)	0.583 (-20.57)	2.161 (-17.36)	2.884 (-21.22)	6.344 (-9.189)
200	0.264 (-37.58)	0.394 (-35.62)	0.531 (-27.65)	1.913 (-26.84)	2.476 (-32.36)	5.863 (-16.07)
250	0.223 (-47.28)	0.363 (-40.68)	0.462 (-37.05)	1.632 (-37.59)	1.606 (-50.66)	5.123 (-36.36)

(Per cent over control values are given in parentheses)

Comparison of significant effects F test

Cobalt levels\*\* Sampling days\*\*

Table 4: Effect of cobalt on yield response (g plant<sup>-1</sup>) of *Glycine max* (L.) Merr

Cobalt added in the soil (mg kg <sup>-1</sup> )	90 DAS	
	Number of pods (Plant <sup>-1</sup> )	Seeds of weights (g)
Control	14.32	07.83
50	18.73 (+30.79)	10.31 (+31.67)
100	12.17 (-15.01)	06.26 (-20.05)
150	10.23 (-28.56)	04.11 (-47.50)
200	7.41 (-48.25)	02.76 (-64.75)
250	04.65 (-67.52)	01.08 (-86.20)

(Per cent over control values are given in parentheses)

Comparison of significant effects F test

Cobalt levels\*\* Sampling days\*\*

### **Dry Matter Production (g plant<sup>-1</sup>)**

**Root:** The root dry weight of soybean plants raised in various levels of cobalt at different stages of growth is furnished in Table 3. When compared to the control, cobalt at 50 mg kg<sup>-1</sup> level in the soil increased the dry weight of root and decreased the same at high levels (100-250 mg kg<sup>-1</sup>) in all the sampling days. Statistical analysis revealed significant (1%) F-test values for cobalt levels in the soil and sampling days.

**Shoot:** Shoot dry weight of soybean plants at various levels of cobalt is furnished in Table 3. Maximum dry weight of soybean was observed on 90<sup>th</sup> day at 50 mg kg<sup>-1</sup> cobalt level (7.213). The minimum shoot dry weight was recorded at 250 mg kg<sup>-1</sup> cobalt level (1.632) on 30<sup>th</sup> day for soybean. F-test values for the difference between the various cobalt levels and sampling days were significant at 1%.

### **Yield Parameters**

**Number of Pods (Plant<sup>-1</sup>):** The maximum number pods were occurred (Table 4) in 50 mg kg<sup>-1</sup> on 90 DAS. The minimum number pods were observed at 250 mg kg<sup>-1</sup>. Number pods of soybean plants decreased (except 50 mg kg<sup>-1</sup>) with increase in cobalt level in the soil.

**Number of Seed out Put (Plant<sup>-1</sup>):** The maximum number of seeds out put was occurred (Table 4) in 50 mg kg<sup>-1</sup> on 90 DAS. The minimum number of seeds out put was observed at 250 mg kg<sup>-1</sup>. Number of seeds out put of soybean plants decreased (except 50 mg kg<sup>-1</sup>) with increase in cobalt level in the soil.

**Seeds Weight (Plant<sup>-1</sup>):** The maximum 100 seeds weight was occurred (Table 4) in 50 mg kg<sup>-1</sup> on 90 DAS. The minimum 100 seeds weight was observed at 250 mg kg<sup>-1</sup>. 100 seeds weight of soybean plants decreased (except 50 mg kg<sup>-1</sup>) with increase in cobalt level in the soil.

## **DISCUSSION**

### **Morphological Parameters**

**Root and Shoot Length:** Root and shoot length of soybean plants decreased with an increase in cobalt level in the soil. Root and shoot length of soybean was found to be higher at 50 mg kg<sup>-1</sup>. Similar decrease in plant height was observed previously [6-8]. A marked decrease in plant height with concomitant decrease of root growth was previously reported [8-10] in plants under metal toxicity.

Cobalt at high levels may inhibit the root growth directly by inhibition of cell division or cell elongation or combination of both, resulting in the limited exploration of the soil volume for uptake and translocation of nutrients and water and induced mineral deficiency [11]. The results of the present study also confirmed these views. Inhibition of root growth is considered to be primarily the result of inhibition of cell elongation, at least in early stages of toxicity, while reduced cell division can obviously affect growth in older stage [9-12].

**Leaf Area:** Leaf area of soybean decreased with increase in the cobalt content of the soil. However it increased at 50 mg kg<sup>-1</sup> soil level. Similar reduction in total leaf area due to metal stress was observed previously [9-11]. The decrease in leaf area at higher concentration of cobalt can be attributed to either a reduction in the number of cells [12]. The metals might be inhibiting mitotic activity or producing cytological abnormalities, mutagenic activities and degradation of DNA [13].

The toxicity generated by cobalt impaired the growth in terms of length, fresh and dry mass of root and shoot and its effects on leaf area. The most prominent effect of heavy metals in plants is the inhibition of growth [9,14] because of the direct exposure of roots to heavy metals. Inhibition of growth is considered to be primarily the result of inhibition of cell elongation, at least in early stages of toxicity, while reduced cell division can obviously affect growth and leaf area in older stage [11-15].

**Dry Matter Production:** Dry matter production in various parts of soybean varied according to cobalt level. Dry matter of root, stem, leaf and shoot was the highest at 50 mg kg<sup>-1</sup> cobalt level. But it showed a gradual decline from 100 mg kg<sup>-1</sup> level onwards. There is large number of reports that the heavy metals increased the dry matter yield of various plants at lower levels [9-14].

The reduction in dry matter yield of plants at higher concentrations of heavy metals was also observed [12-17]. The manifestations of the inhibited dry matter production were also noticed in all parts of the plant at all growth stages at higher cobalt levels. Moreover, cobalt toxicity also interferes with the water relations and membrane permeability [18] and causes the impaired photosynthesis and resulted in a decrease in the growth of plants subjected to cobalt stress.

**Yield Parameters:** The yield and yield components increased due to the cobalt treatment to the soybean plants at lower concentration only. The main

advantageous yield was noted only in 50 mg/kg of cobalt in soil. At higher concentration of cobalt in soil (from 100-250 mg/kg) there was a marked reduction in yield parameters.

Similar yield loss was noted on higher concentrations of heavy metal treatment in many crop plants [7-13]. Previous reports are there to substantiate the findings of this study, such as copper induced yield loss [15]. The reason for the yield reduction of soybean plants under high concentrations of cobalt treatment is the reduction in flower number and production of fruits as reported previously in bean plants under heavy metal treatment [14-17].

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