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Subesh Kumar
M.Sc. Horticulture, Department of Horticulture & Post Harvest Technology, Palli Shiksha Bhawan, Vishva Bharti University, Shantiniketan, West Bengal, India

Govind Kumar
SMS-Agronomy, KVK Jalalgarh, Purnea, Bihar, India

Snehsish Chakravorty
Professor, Department in Horticulture & Post Harvest Technology, Palli Shiksha Bhawan, Vishva Bharti University, Shantiniketan, West Bengal, India

Dr. Sangita Mehta
SMS-Horticulture, KVK Jalalgarh, Purnea, Bihar, India

Corresponding Author:
Dr. Sangita Mehta
SMS-Horticulture, KVK Jalalgarh, Purnea, Bihar, India

Effect of humic acid and zinc sulphate on growth and yield of French bean (*Phaseolus vulgaris* L.)

Subesh Kumar, Govind Kumar, Snehsish Chakravorty and Dr. Sangita Mehta

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Abstract
The present investigation entitled 'Effect of humic acid and zinc sulphate on growth and yield of French bean' was carried out at Horticulture Farm of Palli-Siksha Bhavana (*Institute of Agriculture*), Visva-Bharati, Sriniketan, West Bengal during Rabi season of 2021-22. The experiment was laid out in a factorial randomized block design consisting of nine treatments with three replications. Treatments comprised of soil application of humic acid (0, 10 and 15 kg per hectare) and foliar application of zinc sulphate (0, 0.75% and 1%). The characters studied in this experiment are plant height, number of branch per plant, number of days to first flowering, fifty percent flowering, 100% flowering, average pod yield per plant, pod yield per plot, pod yield per ha-1. The statistical analysis indicated that humic acid and zinc sulphate failed to show any remarkable influence on growth and yield of French bean. The growth and flowering parameters like plant height, number of branch per plant, number of days to first flowering, 50 percent flowering, and 100% flowering were not positively affected by combined application of humic acid and zinc sulphate. However, number of days to 50 % flowering significantly influenced with zinc sulphate. On the other hand, yield attributes like pod length, pod diameter, number of pod per plant, average pod weight, pod weight per plant, pod weight per plot, total pod yield per hectare showed non- significant effect towards application of humic acid and zinc sulphate, though, mere numerical variation was observed. However, pod weight per plant influenced significantly with various level of zinc sulphate.

Keywords: Humic acid, zinc sulphate, growth, yield, treatments, French bean

Introduction
French bean (*Phaseolus vulgaris* L.), commonly called kidney bean, haricot bean or snap bean is a member of the family Leguminosae. It is a self -pollinated annual plant (Cobley *et al.*, 1976). It is a short duration crop having an average lifespan of 65- 110 days from emergence to physiological maturity (Buruchara, 2007) [6]. French bean (*Phaseolus vulgaris* L.) was introduced in India during the 17th century from Europe (Simmonds, 1976) [9]. The primary center of origin is accepted to be Mexico and Central America while the Peruvian Ecuadorian area is considered to be a secondary center (Evans, 1976) [9].

French bean is largely grown in hilly areas of Himachal Pradesh, Jammu-Kashmir and north-eastern states during summer, and in parts of Uttar Pradesh, Maharashtra, Karnataka and Andhra Pradesh it is grown in winter and autumn. In northern plains, it is cultivated on a limited scale as autumn or spring crop.

Immature tender pods generally consumed as green vegetables and dry seeds as pulse. It is a rich source of vegetable proteins as compared to other vegetables. It also contains dietary fiber, and complex carbohydrates and also provides folic acid. Per 100 gm of edible part contains 4.5% carbohydrates, 1.7% proteins, 0.1% fat, 221 IU vitamin A and 0.5% minerals. It is also known to have anti-diabetic properties and good for dropsy, dysentery, eczema, emollient, hiccups, itch, bladder burns, cardiac and kidney related issues. It is carminative, depurative, and diuretic (Duke, 1981) [8]. Fresh market cultivars are often flat or oval-shaped while for processing, round podded varieties are recommended.

The extraction of humic acid is done from different sources such as coal, peat, humus, soil, and oxidized lignite. Humic acid have positive influence on the growth of shoots and roots and the absorption of nitrogen, potassium, calcium, magnesium, and phosphorus by plants. Moreover, its important role for the improvement of growth, production, and quality of agricultural products is due to the presence of hormonal compounds (Abdel-Mawgoud *et al*. 2007) [1].

Being a vital component of soil organic matter, it improves physico-chemical characteristics of soil like particle aggregation, water permeability, soil aeration, water holding capacity, ion exchange, and also enhances soil fertility through increased availability of nutrients through pH buffering (Tan, 2003) [16]. Humic acid had been reported to improve soil health through reduction of soil-borne diseases (Mauromicale *et al*. 2011) [13].

The micronutrients are essential for normal plant growth. The adverse effect of their deficiency in plants on the growth, metabolism, and reproductive phase. Zinc plays an important role in protein and chlorophyll synthesis as well as nucleic acid. Being a constituent of tryptophan, a precursor of auxin, it also helps in auxin synthesis (Hafeez *et al*. 2013) [10]. It activates the functions of many enzymes such as aldolases, and transphosphorylases and enhances various physiological processes like cell division, protein synthesis, and maintenance of membrane structure (Andreini *et al*. 2006, Broadley *et al*. 2007, and Marschner, 2012) [3, 5, 12]. It promotes biosynthesis of growth hormone, and formation of starch apart from its positive role on seed production and its maturation (Brady and Weil, 2002) [4].

The nutrient requirement generally depends upon the crop, cultivar, soil, and various environmental factors. Therefore, it was felt necessary to undertake a location-specific trial for french bean to determine its requirement of humic acid and zinc considering its growth and yield prospect in the lateritic belt of the Birbhum district of West Bengal having suitable agro-climate during the winter season.

Materials and Methods

The field experiment was conducted at the Horticultural Farm, Department of Horticulture and Post-Harvest Technology, Palli-Sikshsa Bhavana (Institute of Agriculture), Visva-Bharati, West Bengal from November 2021 to March 2022. The experimental site was present in the red and lateritic zone of West Bengal at $23^0$42" N latitude and $87^0$30" E longitude.

During the crop growth period (25 Nov.2021 to 10 March 2022) the minimum and maximum tempt. Ranged from 10.23 to 31.33 respectively. The average RH range was 60.14 - 87.14. The average bright sunshine hours per day ranged from 2.04 hours to 9.41 hours. The total rainfall received during the cropping period was 19.14 mm

The experimental design was laid out in factorial randomized block design with three replications and nine treatments.

The size of the individual plot was 2.5 m in length and 2 m in width (2.5 × 2 m) and the whole area was intercepted by an irrigation cum drainage channel of 50 cm. The bund beside the channel was 15 cm and the intra-replication bund was 30 cm. The details of experiment, treatments and layout have been in table1 and table 2 respectively.

Table 1: Experimental details

Crop	French bean
Variety	Falguni
Design	Factorial RBD
Total no. of treatment	9
Number of replications	3
Total no. of plot	27
Size of each plot	2.5m × 2 m = 5m2
Spacing	30 × 15 cm
Plant population per plot	112
Season of cultivation	Rabi
Levels of Zinc	Three levels (0, 0.75%, 1.0%)
Levels of humic acid	Three levels (0, 10 and 15 kg/ha)

Table 2: Details of treatments

Treatments details		
T1	HA_0Zn_0	Control
T2	HA_0Zn_1	No humic acid + Zinc sulphate @ 0.75%
T3	HA_0Zn_2	No humic acid + Zinc sulphate @ 1%
T4	HA_1Zn_0	Humic acid @ 10 kg/ha + No zinc sulphate
T5	HA_1Zn_1	Humic acid @ 10 kg/ha + Zinc sulphate @ 0.75%
T6	HA_1Zn_2	Humic acid @ 10 kg/ha + Zinc sulphate @ 1%
T7	HA_2Zn_0	Humic acid @ 15 kg/ha + No zinc sulphate
T8	HA_2Zn_1	Humic acid @ 15 kg/ha + Zinc sulphate @ 0.75%
T9	HA_2Zn_2	Humic acid @ 15 kg/ha + Zinc sulphate @ 1%

Note: HA_0 = No humic acid, HA_1= 10 kg/ha, HA_2 = 15 kg/ha, Zn_0 = No zinc, Zn_1 = 0.75%, Zn_2 = 1%

The land was prepared by repeated ploughing and harrowing to obtain fine tilth. Then the land was divided into 27 small plots having a dimension of 2.5 × 2 m. Well-decomposed farm yard manure (FYM) was applied @ 25 tones/ha during the preparation of the plots. According to the treatment, the required amount of nitrogen was applied @ 60 kg/ha in 2 split doses (1/2 part as basal dose and remaining half as top dressing after 40 days of sowing) and the total amount of phosphorus @ 50 kg/ha and potassium @ 70 kg/ha was applied as basal. All the three nutrients i.e., nitrogen, phosphorus and potash were applied in the form of urea, single super phosphate and muriate of potash, respectively.

Seeds were treated with rhizobium culture (Sabour Rhizo) @ 4-6 ml/kg of seed. The culture was collected from Bihar Agricultural University, Sabour, Bhagalpur.

Results and Discussions

T+he results obtained under the experiment entitled "Effect of humic acid and zinc sulphate on growth and yield of French bean (*Phaseolus vulgaris* L.)" in lateritic soil of Birbhum, West Bengal were analyzed and presented thoroughly with the help of different tables.

Growth and flowering parameters

Growth of the French bean was studied with respect to plant height, number of branch er plant, and number of days taken to first flowering, fifty percent flowering, and 100% percent flowering.

Plant height (cm)

Data presented in table 3 showed variable effects of humic acid on plant height observed at 40 days, 55 days and 70 days. The maximum height (52.4 cm) was achieved in HA_1 (10kg/ha) after 70 days, though, it was reduced at higher level (HA_2). Minimum plant height (51.5 cm) was observed in HA_0 (control). But overall the effects shown was not significant and minor increase in height is observed.

The perusal of data indicated that plant height measured at final stage (i.e.70 DAS) was not influenced markedly by the application of different levels of zinc, though, numerical increase in plant height was observed. Maximum plant height (53.3 cm) was recorded at 70 days with foliar application of zinc sulphate at 1% (Zn_2), while minimum value in this regard (51.4 cm) was observed with with Zn_1 (0.75%).

The interaction between humic acid and zinc did not show remarkable effect on the plant height. The maximum plant height (53.9 cm) was recorded under combined application of humic acid (10 kg/ha) and zinc (1%) in HA_1Zn_2. The minimum plant height (49.4 cm) was recorded in the HA_0Zn_1. The enhanced effects due to interaction of zinc and humic acid were in conformity with findings of Yilmaz *et al*. (2013) [17].

Table 3: Effect of Humic acid and Zinc sulphate and their combination on plant height

Treatment	Plant height(cm)		
	40 DAS	55 DAS	70 DAS
Humic acid (HA)			
HA_0	41.4	48.5	51.5
HA_1(10kg/ha)	40.0	47.2	52.4
HA_2(15kg/ha)	43.0	48.4	52.3
S.Em (±)	0.95	0.98	1.26
CD	NS	NS	NS
Zinc sulphate (Zn)			
Zn_0	42.0	48.2	51.6
Zn_1 (0.75%)	40.0	47.2	51.4
Zn_2 (1%)	42.4	48.7	53.3
S.Em (±)	0.95	0.98	1.26
CD	NS	NS	NS
(HA ×Zn)			
HA_0Zn_0	40.6	46.1	51.5
HA_0Zn_1	40.00	50.0	49.4
HA_0Zn_2	43.5	49.3	53.7
HA_1Zn_0	40.8	49.4	50.7
HA_1Zn_1	37.6	44.8	52.8
HA_1Zn_2	41.6	47.3	53.9
HA_2Zn_0	44.6	49.1	52.6
HA_2Zn_1	42.5	46.8	52.0
HA_2Zn_2	41.9	49.4	52.3
S.Em (±)	1.66	1.71	2.18
CD	NS	NS	NS

Note: *= 5 % significance **= 1 % significance

Number of branch per plant

The number of branch per plant recorded in different growth stages as influenced by the different levels of humic acid and zinc and their interaction are presented in Table 4. It was evident from the results, that the application of humic acid failed to influence the number of branch per plant markedly, though, numerical increment in the value in dose dependent manner was evident. The highest number of branch (9.5) was observed when HA_2 (15 kg/ha) was applied, and lowest value in this regard was recorded in HA_0 (control).

The response of the plant to zinc application exhibited the similar trend. However, application at its highest level in Zn_2 (1%) resulted the highest number of branch per plant (9.6). The lowest number of branch (9.2) was observed in Zn_1 (0.75%).

The combined application of humic acid and zinc did not show any remarkable effect on number of branch of French bean. However, application of HA_0Zn_2 resulted highest number of branch per plant (9.9). On the other hand, the lowest number of branch per plant (8.8) was observed at HA_0Zn_1.

Similar trend in number of branch per plant was also reported by Doddamani *et al*., (2020) [7].

Table 4: Effect of humic acid and zinc sulphate and their combination on number of branch per plant

Treatment	Number of branch/ plant		
	40 DAS	55 DAS	70 DAS
Humic acid (HA)			
HA_0	3.6	5.6	9.4
HA_1	3.2	5.5	9.4
HA_2	3.6	5.7	9.5
S.Em (±)	0.08	0.05	0.29
CD	0.24*	NS	NS
Zinc sulphate (Zn)			
Zn_0	3.7	5.7	9.5
Zn_1	3.2	5.5	9.2
Zn_2	3.4	5.6	9.6
S.Em (±)	0.080	0.05	0.29
CD	0.24**	NS	NS
HA ×Zn			
HA_0Zn_0	3.7	5.7	9.5
HA_0Zn_1	3.5	5.5	8.8
HA_0Zn_2	3.6	5.7	9.9
HA_1Zn_0	3.7	5.5	9.3
HA_1Zn_1	2.9	5.5	9.6
HA_1Zn_2	3.1	5.5	9.4
HA_2Zn_0	3.8	5.8	9.7
HA_2Zn_1	3.4	5.6	9.3
HA_2Zn_2	3.5	5.7	9.5
S.Em (±)	0.14	0.08	0.50
CD	NS	NS	NS

Number of days to first flowering

The results for number of days to first flowering as influenced by different levels of humic acid and zinc sulphate and their combination were presented in Table 5.

Analysis of results indicated that application of various levels of humic acid failed to exert any significant influence on number of days to first flowering. However, reduction in number of days to first flowering was observed at moderate level of humic acid (HA_1 @ 10 kg/ha), though, it was mere numerical.

Application of zinc could not influence the number of days to first flowering, though, maximum delay in first flowering (47.1) was observed with moderate level of applied zinc (Zn_1) and the minimum value for the same (46.0) was recorded in control (Zn_0).

The interaction between humic acid and zinc sulphate did not show any remarkable effect on number of days to first flowering. The minimum number of days to first flowering (45.7) was recorded under combined application in HA_1Zn_0. However, maximum number of days to first flowering (47.3) was recorded in HA_1Zn_1.

Number of days to 50 % flowering

The results on number of days to 50% flowering as influenced by different levels of humic acid and zinc sulphate and their combination were presented in Table 5.

The recorded data indicated that application of various levels of

humic acid had failed to show any remarkable effects on number of days to 50% flowering. The maximum number of days to 50% flowering (50.1) was observed with moderate level of applied humic acid (10 kg/ha) and the minimum value in this regard (49.4) was recorded in control (HA_0).

Perusal of data indicated that application of zinc significantly influenced the number of days to 50% flowering. Remarkable earliness with respect to number of days to 50% flowering (48.9) was observed with non-application of zinc in control plots. On the other hand, maximum delay with respect to number of days to 50% flowering (50.4) was observed with medium level of applied of zinc in Zn_1 (10 kg/ha).

The interaction between humic acid and zinc sulphate could not influence the number of days to 50 % flowering markedly. The lowest number of days to 50% flowering (48.3) was recorded in control plots (HA_0Zn_0) followed by HA_2Zn_0, HA_1Zn_0, HA_1Zn_2. However, maximum number of days to 50% flowering (51.3) was recorded in HA_1Zn_1.

Number of days to 100 % flowering

The results number of days to 100% flowering as influenced by different levels of humic acid and zinc sulphate and their combination were presented in Table 5.

The analysis data indicated that application of various levels of humic acid failed to show any remarkable effects on number of days to 100% flowering. However, numerical decrease in number of days to 100% flowering (52.9) was recorded in control plots and the maximum value in this regard (54.0) was noted where humic acid was applied at the rate of 10 kg/h delay (HA_1).

Moreover, failure to influence the number of days to 100% flowering with any statistical significance was observed with application of zinc. However, numerical increase in number of days to 100% flowering (53.8) was observed with moderate level of applied zinc (10 kg/h) in Zn_1 and the minimum value for the same (52.2) was recorded in control (Zn_0).

It was also noted that combined application of humic acid and zinc sulphate could not show any remarkable influence on number of days to 100% flowering. The lowest number of days to 100% flowering was recorded under combined application in HA_2Zn_0 followed by HA_0Zn_0, and HA_0Zn_1. However, maximum number of days to 100% flowering (55.3) was recorded in HA_1Zn_1.

Table 5: Effect of humic acid and zinc sulphate and their combination on number of days to flowering

Treatment	Number of days to		
	1st flowering	50% flowering	100% flowering
Humic acid (HA)			
HA_0	46.4	49.4	52.9
HA_1	46.3	50.1	54.00
HA_2	46.7	49.8	52.9
S.Em (±)	0.35	0.41	0.57
CD	NS	NS	NS
Zinc sulphate (Zn)			
Zn_0	46.0	48.9	52.2
Zn_1	47.1	50.4	53.8
Zn_2	46.3	50.0	53.8
S.Em (±)	0.35	0.41	0.57
CD	NS	1.24*	NS
Interaction (HA ×Zn)			
HA_0Zn_0	46.3	48.3	51.7
HA_0Zn_1	47.0	50.0	52.7
HA_0Zn_2	46.0	50.0	54.3
HA_1Zn_0	45.7	49.3	53.3
HA_1Zn_1	47.3	51.3	55.3
HA_1Zn_2	46.0	49.7	53.3
HA_2Zn_0	46.0	49.0	51.7
HA_2Zn_1	47.0	50.0	53.3
HA_2Zn_2	47.0	50.3	53.7
S.Em (±)	0.61	0.71	1.00
CD	NS	NS	NS

Yield parameters

Yield attributes and yield of French bean was studied with respect to number of pod per plant, pod yield per plant, pod yield per plot, and pod yield per hectare.

Average pod weight

Data regarding average pod weight was analyzed and presented in the Table 6.

The response of the plant towards humic acid had failed to influence the average pod weight significantly. However, the maximum pod weight (5.4 g) was observed in HA_0 (control), and minimum value (5.1 g) was recorded in HA_2.

A critical examination of data indicated that various level of zinc sulphate could not influenced the average pod weight markedly. The highest pod weight (5.4 g) was noted in Zn_0, and lowest value in this regard (5.1 g) was observed in Zn_1.

On other hand, combined application of humic acid and zinc sulphate did not influence the average pod weight significantly. However, the lowest average pod weight (4.9 g) was recorded under combined application in HA_0Zn_1 and HA_2Zn_2, while highest average pod weight (5.7g) was recorded in HA_0Zn_0 (control).

This was found to be contradictory to findings of Karakurt *et al*., 2012 [11].

Average pod yield per plant (g)

Observation recorded on average pod weight per plant were statically analyzed and presented in the table7.

The data revealed that average pod weight per plant did not differ significantly with different levels of humic acid. However, maximum average pod weight per plant (106.7 g) was observed in HA_0 (control) and minimum value (94.0 g) in HA_1.

The response of the plant to zinc application exhibited the similar trend on the pod weight per plant. However, maximum average pod weight per plant (111.0 g) was observed in Zn_0 (control) and minimum value in this regard (92.0 g) was observed in Zn_1.

The data in the table also revealed that combined application of humic acid and zinc sulphate failed to show marked effect on average pod weight per plant. The lowest average pod weight per plant (89.4 g) was recorded under combined application HA_2Zn_1, while highest average pod weight per plant (122.2 g) was recorded in HA_0Zn_0 (control).

In previous discussion it was already revealed that variation of average pod weight per plant with the application of humic acid and zinc sulphate was not statistically significant. Moreover, failure of positive contribution of number and weight of pod per plant along with their dimension might be the reason for negative response of average pod weight per plant with applied treatments. However, this was found to be contradictory to findings of Rasheed *et al*., (2017) [14].

Pod yield per plot (kg)

Pod weight per plot had been analyzed and presented in the Table 6.

Statistical analysis of data indicated that the different levels of humic acid failed to impart any significant influence on pod weight per plot. The recorded data showed that the highest pod weight per plot (4.9 kg) was observed in HA_0 (control) and lowest pod weight per plot (4.4 kg) was obtained under HA_1.

Moreover, non-significant influence of various levels of zinc sulphate on pod weight per plot was also noted with mere numerical variation in the data. However, maximum pod weight per plot (5.3 kg) was observed in Zn_0 (control), and minimum pod weight per plot (4.0 kg) was noted in Zn_1.

Further analysis of data indicated that variation of pod weight per plot with combined application of humic acid and zinc sulphate had no statistical significance. However, the maximum pod weight per plot (5.7 kg) was obtained in HA_2Zn_0, and the minimum value in this regard (3.8 kg) was recorded in HA_2Zn_1.

Pod yield per hectare (ton)

Data pertaining to total pod yield per hectare was statically analyzed and represented in Table 11and Fig 9.

The recorded data indicated failure of remarkable variation in total pod yield per hectare with application of various levels of humic acid. Mere numerical variation, however, was recorded with the highest pod yield per hectare (9.9 ton) in HA_0 (control), and lowest value (8.7 ton) was observed in HA_1.

The analyzed data presented in table clearly depicted that the various level of zinc application had failed to influence the pod yield per hectare markedly. However, the maximum pod yield per hectare (10.7 ton) was observed in Zn_0 (control), and minimum pod yield per hectare (7.9 ton) was recorded in Zn_1.

It was found that the combined application of various level of humic acid and zinc sulphate could not impart any significant variation in pod yield per hectare. However, the highest pod yield per hectare (11.4 ton) was recorded under combined application of HA_2Zn_0 while the lowest pod yield per hectare (7.5 ton) was recorded in HA_2Zn_1.

Failure to respond positively towards application of different humic acid and zinc as revealed in various yield contributing characters might have negative impact on the total yield per hectare. The result of this experiment with respect to yield per hectare was in contradictory with the finding of Rasheed *et al*., (2017) [14].

Table 6: Effect of Humic acid and Zinc sulphate and their combination on average pod weight (g), average pod yield plant-1 (g), pod yield plot^{-1} (kg) and pod yield ha-1 (ton)

Treatment	Average pod weight (g)	Avg. pod yield plant^{-1} (g)	Pod yield plot^{-1} (kg)	Pod yield/ ha(ton)
	Humic acid (HA)			
HA_0	5.4	106.7	4.9	9.9
HA_1	5.2	94.0	4.4	8.7
HA_2	5.1	99.1	4.6	9.2
S.Em (±)	0.11	4.81	0.42	0.85
CD	NS	NS	NS	NS
	Zinc sulphate (Zn)			
Zn_0	5.4	111.0	5.3	10.7
Zn_1	5.1	92.0	4.0	7.9
Zn_2	5.3	96.8	4.6	9.2
S.Em (±)	0.11	4.81	0.42	0.85
CD	NS	14.43*	NS	NS
	HA ×Zn			
HA_0Zn_0	5.7	122.2	5.5	10.9
HA_0Zn_1	4.9	93.8	4.0	8.0
HA_0Zn_2	5.6	104.0	5.4	10.7
HA_1Zn_0	5.2	97.3	4.8	9.7
HA_1Zn_1	5.1	92.9	4.1	8.3
HA_1Zn_2	5.2	91.8	4.1	8.2
HA_2Zn_0	5.2	113.4	5.7	11.4
HA_2Zn_1	5.3	89.4	3.8	7.5
HA_2Zn_2	4.9	94.4	4.3	8.7
S.Em (±)	0.19	8.33	0.73	1.47
CD	NS	NS	NS	NS

Summary and Conclusion

The present investigation was carried out to study the "Effect of humic acid and zinc sulphate on growth and yield of French bean (*Phaseolus vulgaris* L.)" during 2021-22, at Horticulture Farm, Palli Siksha Bhavana, (Institute of Agriculture) Visva-Bharati, Sriniketan, Dist. Birbhum under prevailing agro-climatic condition of red & lateritic zones of West Bengal. The investigation involved a field experiment with three levels of humic acid (0, 10 kg and 15 kg ha^{-1}) and three levels of zinc sulphate (0, 0.75% and 1%) laid out in factorial randomized block design.

The observations were recorded on growth and flowering parameters i.e. plant height, number of branch per plant, number of days to first flower, number of days to 50 percent flowering, number of days to 100% flowering; yield attributes and yield parameters i.e. average pod length, average pod diameter, average pod weight, average pod yield per plant, average number of pod per plant, pod yield per plot, yield per hectare.

The application of humic acid and zinc could not show remarkable effect on the vegetative characters like plant height and number of branch per plant, though, numerical variation was observed in data. The application of humic acid and zinc sulphate failed to exert any remarkable influence on number of days to first flowering, 50% flowering and 100% flowering except inconsistent numerical variation.

All the yield attributing characters failed to respond markedly with application of different treatments.

Yield is the most important component of any crop performance under a set growing condition. Application of different levels of humic acid and zinc sulphate could not show any positive impact on yield parameter.

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