INFLUENCE OF ZINC AND HUMIC ACID ON YIELD, NUTRITIONAL QUALITY, UPTAKES AND ECONOMIC RETURNS OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.) (PAULISTA) UNDER FIELD CONDITIONS

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ABSTRACT: *Zinc deficiency is wide spread, mostly on alkaline calcareous soils in dry areas of the world. A field study was conduct to explore soil application of Zn (5, 7.5 and 10 kg ha^{-1}) along with humic acid 4.5 kg acre^{-1} on the growth, yield and nutrient uptake in french bean (Phaseolus Vulgaris L.) cv. Paulista. Zinc fertilization along with humic acid (H.A) increased grain yield and yield attributes. Maximum grain and straw yield as well as highest net return were achieved by the cumulative use of 10 kg Zn ha^{-1} and H.A. The yield and yield components were relatively higher due to combined use of Zn + H.A than individual effect of Zn and humic acid. Unfilled pods plant^{-1} were significantly decrease with the application of Zn and H.A. Zn concentrations and Zn uptakes in grain and straw were enhanced with increasing level of Zn. Results of present study showed thathighest net return of fresh matter (1729 $, 1274 €& 170233Rs) and for dry matter (2718 $ / 2003 € / 267593 Rs) respectively) was recorded with the combine application of Zn 7.5 kg ha^{-1} with H.A. We concluded that under Zn-deficient soil conditions, seed yield of french bean can be maximized by soil application of the zinc and humic acid fertilization.*

Keywords: *Phaseolus Vulgaris*, Zinc fertilization, Yield, Uptakes, Humic acid, Economics

INTRODUCTION

French bean (*Phaseolus Vulgaris* L.) is belongs to family Leguminosae which occupy a leading place between grain legumes in the world. Globally more than 16.7 million tons of dry beans are produced per annum, with a net production value of US $5717 millions. Out of this production, 81% produces in tropical countries, while 225.6 million hectares is cultivated in Pakistan producing about 130 million tons annually [1]. It is an important legume vegetable grown for tender pods and dry seeds, which form a rich source of crude protein (21.25%), fat (1.7%) and carbohydrates (70%). French bean is relatively healthy and possible source of carbohydrates; minerals; crude fiber and ether extract are concentrated in seed while crude protein and vigor accumulates in the cotyledons [2].

Soils of arid and semi arid region are generally alkaline and calcareous in nature having low organic matter, nutrient mining with intensive cultivation and imbalance fertilization causes nutrient deficiencies. High pH and low level of organic matter reduces solubility and mobility of macro and micro nutrients which causes decline in crop production and quality [3,4]. Micronutrient deficiency is increasing in most of the annual crops because of intensive cropping systems, use of modern high-yielding cultivars, loss of topsoil organic-matter content by erosion, burning crop residues, liming acid soils, and use of inadequate rates in most cropping systems [5]. About 50% of soils used for cereal production in the world contain low levels of plant-available Zn, which reduces not only grain yield but also nutritional quality of grains [6]. This deficiency can significantly be decreased by application of micronutrients [7].

Zinc, a micronutrient is required for plant growth relatively to a smaller amount. The growth and yield of fresh green pods of french bean has been decreased because of various micronutrient deficiency especially zinc. Important functional roles for Zn are auxin metabolism, influence on activities of dehydrogenase and carbonic anhydrous enzymes, synthesis of cytochrome C, and stabilization of ribosomal fractions [8]. Significant role of Zn is the regulation of the stomatal aperture, which is accounted for possible role of Zn in maintaining a high K content in guard cells. Zinc is closely involved in the nitrogen metabolism of plants [9]. It plays both a catalytic and structural role in enzymatic reactions [10]. RNA polymerase, carbonic anhidrase, phospholipase are believed to be the most important enzymes containing Zn. It interacts with membrane lipids; also plays a key role in regulation of transcription, chromatin structure, protein-protein interactions [11].

Humic acid (H.A) is one of the main macrobiotic organic fertilizers, which is a fundamental constituent of humic material. It increases fertility of soil and improves various soil properties like soil permeability, stomatal aeration, aggregation, water holding ability, exchange of ions and accessibility through buffering of pH [12]. Humic acid is reported to accelerate uptake and translocation of mineral nutrients like nitrogen, phosphorus, potassium, calcium and magnesium and enhance seed germination [13,14].Application of humic acid augmented various biochemical attributes like chlorophyll pigment, starch, proteins content, free Amino acids, soluble phenols in pod and shoot of bean plants [15,16].As Pakistani soils are lacking in organic matter and micronutrients, therefore realizing the yield potential and role of micronutrient particularly boron and humic acid in french bean (*Phaseolus Vulgaris* L.). The role of Zn and H.A in diverse biochemical process of crop plants is well reported, however, its particular role in french bean under local conditions has yet to be explored. Consequently a research work was performed to appraise the soil application of alone and combined effect of Zn with H.A, on growth, yield and Zn uptake in french bean (*Phaseolus Vulgaris* L.).

MATERIAL AND METHODS

Experimental Site and Treatment Description

This study was conducted at an upland field (clay loam) that has been cultivated at Agricultural Research Station Baffa, Mansehra city, province of Khyber Pakhtunkhwa, Pakistan (34^0 26' 0" North, 73^0 13' 0" East). During the experimental period, the average temperature was 29.4 ^{0}Cand the precipitation was 258.6 mm. Three soil samples (0-15 cm) were collected from the experimental area to visualize the physio-chemical properties of soil. The soil was classified as Ihyeon series (clay loam) with pH 7.3 containing (0.83%) organic matter, (0.042%) total Nitrogen, (9.00 mg kg^{-1}) available phosphorus and (11.0 mg kg^{-1}) soil extractable potassium (Table 1&2).

The field experiment was organized as randomized complete block design (RCBD) having eight treatments and three replicates of french bean cv. Paulista. Within the field, net plots size was 5.4 m^2 (3 x 3 x 0.6). The treatment comprised three levels of zinc (5, 7.5, and 10 kg ha^{-1}), humic acid (4.5 kg $acre^{-1}$) alone and combination with all the three levels of Zn. Fertilization except Zn were applied to supply the essential nutrients to plants. Recommended dose of nitrogen, phosphorous, potassium were applied at 60, 80 and 60 kg ha^{-1}) in the form of urea (46% N), single super phosphate (20% P) and murate of potash (60% K). Full dose of phosphorous & potassium were applied as basal fertilizers, while the nitrogen was applied in two equal splits (half at sowing time and remaining at vegetative stage).

Zinc was applied as zinc sulphate (35% Zn) and humic acid (Enrich), 4.5 kg $acre^{-1}$ was applied in soil before seeding according to treatment plan. Uniform seeds of french bean (30 kg ha^{-1}) were sown on 17^{th} April 2013 keeping plant to plant distance (20cm) and row to row distance (60cm). Experiment was irrigated with canal water. All the agronomic practices were performed throughout the growing season.

Harvesting and statistical analysis

Plants were harvested at maturity (75-80 days after sowing). The observations were recorded from each randomly selected plot; plant growth data (Plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$ and plant dry weight) and yield parameters (number of pods $plant^{-1}$, length of pod, weight of pod, grains pod^{-1}, unfilled pods $plant^{-1}$, grain yield straw yield and harvest index).

All data was subjected to analysis of variance (ANOVA) by using Statistics 8.1, and the differences between the treatments means were evaluate using Duncan Multiple Range Test (DMRT) at $P < 0.05$.

Zinc analysis

After the harvesting of crop, representative plant samples of grain and straw were collected and washed with distilled water and dried in an oven to a constant dry weight. Dried plant samples were ground to powder by using in a mortar and pestle. Dried grain and straw samples (0.50 g) were acid digested with HNO_3 or $HClO_4$. Then filtrate the digest and Zn was determined by spectrophotometer [4]. Zinc concentrations in grain and straw were multiplied with grain and straw yield respectively to calculate the Zn uptake in grain and straw of french bean.

Financial Examination

Net Returns (increased value of yield produced due to application of zinc combined with humic acid) and BCR (benefit-cost ratio), between the additional crop yield value and total cost, were calculated by the measures described by [17,18].

B:C = gross return (Rs ha^{-1}) /cost of cultivation (Rs ha^{-1})

RESULTS

Growth Parameters

Our data illustrated that plant height, number of leaves per plant, no of branches per plant and plant dry weight were significantly improved with the increasing levels of zinc; however magnitude of increase was higher in combine application of Zn levels with H.A (Table.2). Plant height ranged from 55.1 to 69.4 cm. Maximum plant heights was obtained with the application of 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with control plants. Number of leaves was significantly increased with soil applied 7.5 & 10 kg Zn ha^{-1} in combination with humic acid. Maximum number of leaves $plant^{-1}$ were obtained with the appliance of 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with

Table:1.Chemical analysis of soil samples before sowing of french bean in the experimental fields illustrating the texture of soil, organic matter, soil pH, saturation level, electrical conductivity and N, P, K, Zn, B (mg kg^{-1}) concentrations.

S. No	Sample Id	Soil Texture	Saturation %	pH	N %	P ($mgkg^{-1}$)	K ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)	B ($mgkg^{-1}$)	EC (dSm^{-1})
Chemical properties of the soil before sowing										
1	(0-15cm)	Clay Loam	42	7.3	0.043	8.90	120	0.60	0.20	0.68
2	(0-15cm)	Clay Loam	40	7.1	0.042	9.00	140	0.55	0.35	0.65
Chemical properties of the soil after harvest of crop										
S. No	Sample Id	Soil Texture	Saturation %	pH	N %	P (mgkg-1)	K (mgkg-1)	Zn (mgkg-1)	B (mgkg-1)	EC (dSm-1)
1	(0-15cm)	Clay Loam	54	7.2	0.051	10.20	140	1.20	0.55	0.57
2	(0-15cm)	Clay Loam	55	7.4	0.055	10.31	160	1.25	1.00	0.59

Table.2 Effects of soil application of Zinc levels and humic acid on plant height, number of leaves plant^{-1}, number of branches plant^{-1} of French bean (*Phaseolus Vulgaris* L.)Paulista.

Treatment	Plant height (cm)	Leaves plant^{-1}	Branches plant^{-1}	Dry plant weight (g)	Pods plant^{-1}	Pod length (cm)
Control	55.1±0.1f	13.1±0.2c	10.2±0.02g	21.6±0.03g	31.2±0.5d	14.3±0.2c
Zn_5	60.1±0.2e	15.6±0.2bc	11.0±0.03f	23.2±0.03f	35.9±0.3c	14.9±0.2bc
$Zn_{7.5}$	63.0±0.2c	16.2±0.2ab	11.5±0.03d	24.2±0.03bcd	37.9±0.3b	15.3±0.2ab
Zn_{10}	63.4±0.2c	16.3±0.3ab	11.5±0.02d	24.4±0.04bc	37.9±0.2b	15.3±0.2ab
$H.A_{4.5}$	61.5±0.2d	15.9±0.4bc	11.2±0.02e	23.9±0.02e	35.1±0.0c	14.9±0.1bc
Zn_5+$H.A_{4.5}$	64.9±0.2b	16.5±0.1ab	11.6±0.03c	24.8±0.03b	37.5±0.3b	15.3±0.1ab
$Zn_{7.5}$+$H.A_{4.5}$	68.6±0.2a	17.3±0.1a	12.1±0.02b	25.9±0.02a	40.3±0.1a	15.8±0.1a
Zn_{10}+$H.A_{4.5}$	69.4±0.1a	17.5±0.3a	12.2±0.02a	25.7±0.02a	41.0±0.1a	15.9±0.1a
L.S.D values	0.82	1.33	0.09	0.13	1.41	0.83

Table.3 Effects of soil application of Zinc levels and humic acid on number of pods plant^{1}, Length of pod, grains pod^{-1} and unfilled pods plant^{-1} of French bean (*Phaseolus Vulgaris* L.)Paulista.

Treatment	Grains pod^{-1}	Pod weight (g)	Unfilled pod plant^{-1}	Straw yield (t / ha)	Grain yield (t / ha)	Harvest index (%)
Control	5.4±0.1d	5.11±0.01d	2.18±0.02a	3.26±0.05d	2.35±0.01d	41.9±0.4b
Zn_5	5.8±0.1c	5.83±0.06bc	1.64±0.02e	3.45±0.04c	2.79±0.01c	44.7±0.3a
$Zn_{7.5}$	6.1±0.1bc	6.1±0.06ab	2.06±0.02c	3.67±0.03b	3.06±0.02b	45.5±0.3a
Zn_{10}	6.1±0.1bc	6.1±0.12ab	2.07±0.01b	3.69±0.06b	3.08±0.01b	45.5±0.3a
$H.A_{4.5}$	5.8±0.1c	5.6±0.11c	2.07±0.01b	3.39±0.05cd	2.74±0.01c	44.7±0.3a
Zn_5+$H.A_{4.5}$	6.1±0.1abc	6.1±0.01ab	1.85±0.02d	3.73±0.02b	3.07±0.01b	45.1±0.1a
$Zn_{7.5}$+$H.A_{4.5}$	6.4±0.1ab	6.3±0.1a	1.57±0.03f	3.97±0.01a	3.38±0.02a	45.9±0.1a
Zn_{10}+$H.A_{4.5}$	6.5±0.0a	6.4±0.02a	1.57±0.03f	4.01±0.02a	3.40±0.01a	45.8±0.1a
L.S.D values	0.39	0.34	0.06	0.17	0.05	1.30

Table.4 Effects of soil application of zinc levels and humic acid on concentration of Zn in straw and concentration of Zn in grain of French bean (*Phaseolus Vulgaris* L.)Paulista.

Treatment	Zn conc. St. (mg / kg)	Zn conc. Gr. (mg / kg)	Zn uptake st. (kg ha^{-1})	Zn uptake gr. (kg ha^{-1})	T. Zn uptake (kg ha^{-1})
Control	24.9±0.08f	18.0±0.05g	81.6±1.6g	42.4±0.1g	124.0±1.6g
Zn_5	28.2±0.08d	20.8±0.09e	97.4±0.9e	58.0±0.2e	155.4±0.7e
$Zn_{7.5}$	29.5±0.2c	21.9±0.06d	108.2±1.1d	67.2±0.5d	175.4±1.5d
Zn_{10}	30.7±0.1b	22.8±0.07c	113.2±1.3c	70.2±0.1c	183.3±1.2c
$H.A_{4.5}$	26.2±0.08e	19.0±0.03f	88.9±1.1f	52.1±0.2f	141.0±1.2f
Zn_5+$H.A_{4.5}$	29.2±0.07c	21.9±0.07d	108.9±0.8cd	67.2±0.4d	176.0±1.1d
$Zn_{7.5}$+$H.A_{4.5}$	30.7±0.08b	23.2±0.05b	121.9±0.2b	78.3±0.2b	200.3±0.2b
Zn_{10}+$H.A_{4.5}$	31.7±0.11a	24.1±0.06a	127.3±1.1a	81.9±0.4a	209.2±1.5a
L.S.D values	0.47	0.31	4.59	1.55	5.33

Table.5. Effects of soil application of zinc levels and humic acid on economics(net returns) of fresh and dry matter of french bean (*Phaseolus Vulgaris* L.)Paulista

Treatment	TotalCost			Fresh Pod yield				Dry Seedyield			
	Pak rupees	US Dollar	Euro	Net returns (Rs)	US Dollar	Euro	B:C ratio	Net returns (Rs)	US Dollar	Euro	B:C ratio
Control	82409	837	617	105911	1076	793	1.3	173911	1767	1302	2.1
Zn_5	89984	914	674	133216	1353	997	1.5	213736	2171	1600	2.4
$Zn_{7.5}$	93772	953	702	151668	1541	1135	1.6	240188	2440	1798	2.6
Zn_{10}	97560	991	730	148600	1510	1112	1.5	237360	2411	1777	2.4
$H.A_{4.5}$	88484	899	662	130956	1330	980	1.5	210076	2134	1573	2.4
Zn_5+$H.A_{4.5}$	96059	976	719	149381	1517	1118	1.6	237781	2415	1780	2.5
$Zn_{7.5}$+$H.A_{4.5}$	99847	1014	747	170233	1729	1274	1.7	267593	2718	2003	2.7
Zn_{10}+$H.A_{4.5}$	103635	1053	776	168445	1711	1261	1.6	266565	2708	1996	2.6

*(1 US$ = 98.44 Rs, 1 € = 133.58 Rs)

control plants. Number of branches plant^{-1} was significantly increased with all the soil applied levels of Zn and humic acid. Maximum number of branches plant^{-1} were obtained with the application of 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with control plants. Dry plant weight was significantly increased with 7.5 & 10 kg Zn ha^{-1} along with humic acid (Table.2). Maximum dry weight of plant was obtained with the use of 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with control plants.

Yield & Yielding attributes

Yield and yield attributes were illustrated in table 2&3. Pod plant^{-1} was significantly increased with all the alone soil applied levels of Zn, humic acid and Zn applied along with humic acid (Table.2). Maximum pod plant^{-1} was obtained with the application of 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with control plants. Pod length was significantly increased with $Zn_{7.5}$, Zn_{10} levels combined with humic acid. Maximum pod length was obtained with the appliance of 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with control plants. Number of grains pod^{-1} was significantly increased with alone soil application of Zn_5 level, humic acid and Zn_{10} along with humic acid (Table.3). Highest number of grains pod^{-1} were recorded with use of 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with control plants. Soil applied levels of 7.5 & 10 kg Zn ha^{-1} along with humic acid and alone application of humic acid significantly increased weight of pod. Maximum pod weight was recorded with 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with control plants. Unfilled pods plant^{-1} was significantly reduced with soil applied Zn levels, humic acid and Zn levels combination with humic acid (Table.3). Least number of unfilled pods plant^{-1} were recorded with 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the maximum was obtained with control plants. All the soil applied Zn levels combined with humic acid significantly increased grain and straw yield (Table.3). Maximum grain and straw yield was recorded with 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the lowest was obtained with control plants. All the alone soil applied Zn levels, humic acid and Zn levels combined with humic acid were significantly increased harvest index (Table.3). Maximum value of harvest index was recorded with 7.5 & 10 kg Zn ha^{-1} in combination with H.A; while the **lowest** was obtained with control plants.

Zinc uptake and concentration

Nutrient-uptake and concentration of Zn in straw and grains of french bean plant has been summarized in table 4. Concentration of Zn in straw and grains was significantly increased with increasing levels of Zn alone, combined with humic acid; however the magnitude of increase was different in different treatments (Table.4). Zn concentration in straw and grain was lower in plants receiving no zinc (control) than the plants fertilized with Zn combination with H.A (Table.4). Zinc concentrations varied from 24.9 to 31.7 mg kg^{-1} in straw and 18 to 24.1 mg kg^{-1} in grain. The highest value of Zn concentration in straw and grain was occurred in 10 kg Zn ha^{-1} in combination with H.A and the lowest range occurred in control plants. Zn uptake in straw was also significantly increased with increasing levels of Zn and combination with humic acid. Zn uptake in straw of plants receiving no Zn (control) was lower than the plants fertilized with Zn and combination with H.A (Table.4). Zn uptake in straw varied from 81.6 to 127.3 kg ha^{-1}. The highest range of Zn uptake in straw was occurred in 10 kg Zn ha^{-1} in combination with H.A and the lowest range occurred in control plants. Zn uptake in grain was significantly increased with increasing levels of Zn and combination with humic acid; however the amount of increase was different in different treatments. Zn uptake in grain of plants receiving no Zn (control) was lower than the Zn up take in plants fertilized with Zn combination with H.A (Table.4). Zn uptake in grain varied from 42.4 to 81.9 kg ha^{-1}. The highest range of Zn uptake in grain was occurred in 10 kg Zn ha^{-1} along with H.A and the lowest range occurred in control plants. Zn uptake was comparatively higher in straw than grains.

Quality

Our results represented that the crude protein contents were significantly increased with the individual application of Zn levels and combined with humic acid (Fig 1). Soil application of humic acid alone was significantly lower than combined application of all the Zn levels combined with humic acid. Maximum crude protein contents were achieved with the combined application of 10 kg Zn ha^{-1} in combination with H.A; however increase due to 7.5 & 10 kg Zn ha^{-1} was statistically at par with each other. Likewise, stimulation in crude protein contents due to the individual effect of 7.5 & 10 kg Zn ha^{-1} were also statistically similar but higher than control. The lowest crude protein contents were recorded with control plants (Fig 1).

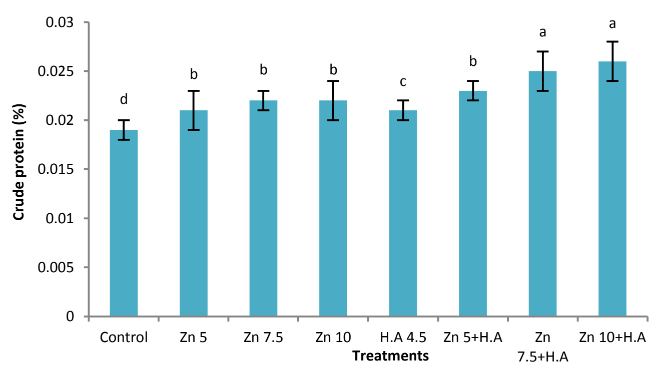

Fig. 1.Effect of soil application of zinc levels and humic acid on crude protein content (%) in seeds of French bean (*Phaseolus vulgaris* L.). var. Paulista.

Similarly, carbohydrate contents in seeds of french bean were markedly enhanced with the increasing level of individually applied Zn levels, humic acid as well as combined application of H.A with all the Zn levels (Fig 2). The combined application of H.A with Zn levels exerted a synergistic effect on carbohydrate contents which was highest with 10 kg Zn ha^{-1} combined with H.A. The increase in carbohydrate content with the application of 7.5 & 10 kg Zn ha^{-1} as individually and in combination with H.A was statistically comparable (Fig 2).

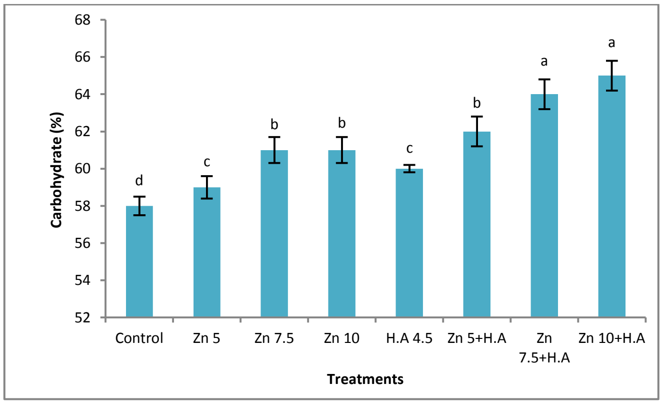

Fig.2. Effect of soil application of zinc levels and humic acid on carbohydrates content (%) in seeds of French bean (*Phaseolus vulgaris* L.). var. Paulista.

Economics

The standard of the financial attribute net return) fresh and dry matter improved extensively with increasing the application rate of zinc. The maximum value of gross return for fresh matter was recorded on account of 10 kg Zn ha^{-1} alongwith H.A, (US$ 2764, € 2037, Rs 272080 ha^{-1}). Maximum value of net return for fresh matter (US$ 1729, € 1274, Rs 170233 ha^{-1}), costing (US$ 1014, € 747, Rs 99847 ha^{-1}) was calculated with 7.5 kg Zn ha^{-1} alongwith H.A as compared to control. The fertility level 7.5 kg Zn ha^{-1} along with H.A showed considerably highest benefit cost ratio of (1.7) for fresh matter (Table.5).

Highest gross return for dry matter (US$ 3761, € 2771, Rs 370200 ha^{-1}) was recorded with 10 kg Zn ha^{-1} along with the supreme humic acid treatment. While maximum net return of (US$ 2718, € 2003, Rs 267593 ha^{-1}) for dry matter was calculated with 7.5 kg Zn ha^{-1} alongwith H.A as compared to control (fig 4). The fertility level 7.5 kg Zn ha^{-1} along with H.A showed highest benefit cost ratio of (2.7) for dry matter respectively as compared to control.

DISCUSSION

Our results showed that application of various levels of Zn along with humic acid exerted beneficial effects of proper fertilization on growth and development. Vegetative parameters such as height of plant, leaves number and branches $plant^{-1}$, plant dry weight were significantly increased with the Zn levels along with humic acid. 26% more plant height, 19% more number of leaves $plant^{-1}$, 20% more branches $plant^{-1}$, 20% dry plant weight were increased by the application of Zn along with humic acid (Table.2). Our results are in line with Aminet al., (2001); who obtained greater plant growth after applying higher levels of Zn [7]. Combined application of zinc with humic acid significantly produced higher plant growth and dry matter production, which was due to better uptake of water and nutrient absorption with the soil application of H.A. Our findings are also matched by the conclusion of Ahmed et al., (2010); who suggested that by soil submission of humic acid; enhance compounds (organic) such as chlorophyll pigment, starch (sugar), protein substance, AA (amino acid), entirely soluble phenols in shoots and pods of snap bean plants. The beneficial effect of humic acid on the growth and yield was reported by several authors [15]. Zinc application significantly increased yield and yield parameters (Table.2&3). Highest grain yield 44%, 23% straw yield was obtained with soil application of Zn levels with H.A. Our results are in line with Gurmani et al., (2012); who reported the soil application of zinc, resulted in affirmative outcome of plant's growth, biochemical attributes and enzymatic activities in tomato [19].

The concentration of Zn increased in straw and grain with increasing levels of Zn application (Table.4). Results are in line with Kaya et al., (2001); who reported increased concentration of Zn in straw and grains with Zn application in many crop species grown on Zn-deficient soil in Pakistan and world-wide [14].

CONCLUSION

It was induced from the results that various levels of soil applied zinc alone and in combination with humic acid proved beneficial for the enhancement of growth, Zn uptake, yield and quality of french bean under Zn deficient soil. Overall, soil applied zinc at 7.5 & 10 kg Zn ha^{-1} along with the humic acid at 4.5 kg $acre^{-1}$ was found efficient for realizing economic and profitable yield of french bean under field conditions.

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