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International Journal of Current Research
Vol. 7, Issue, 04, pp.14268-14274, April, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

REVIEW ARTICLE

INFLUENCE OF Fe AND Zn ON VEGETATIVE MORPHOLOGY AND GROWTH PARAMETERS OF BARLEY (*Hordeum vulgare* L.)

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ARTICLE INFO

Article History:
Received 20th January, 2015
Received in revised form
27th February, 2015
Accepted 10th March, 2015
Published online 28th April, 2015

Key words:
Iron (Fe),
Zinc (Zn),
Hordeum vulgare.

ABSTRACT

The present study was spread over investigation concerned with the effect of Fe and Zn singly or in combination on morphological characteristics of barley (*Hordeum vulgare* L.)" var. K-125 (Azad) was performed during Nov. 2009 to April 2011 at Christ Church College, Kanpur. The most effective treatment of Fe + Zn in form of inorganic salts FeSO4 and ZnSO4 was compared with its chelated form (Fe – EDTA + Zn + EDTA). Seeds of *Hordeum vulgare* L. were soaked in 20, 40 and 60 ppm of Fe, Zn, their combinations i.e. Fe20 + Zn20, Fe20 + Zn40, Fe40 + Zn20, Fe40 + Zn40 and Fe + Zn (chelated) and three sprays at intervals of 14 days, the first spray being 20 DAS (days after sowing). The observation revealed that vegetative morphology and growth parameters were highly promoted by all treatments of Fe and Zn. Among the three concentrations of Fe applied alone Fe20 ppm was the best dose for inducing maximum growth parameters. When Zn was applied alone it was Zn40 which promoted the better growth except height. A comparison of Fe and Zn showed that effect of Zn was always better in increasing all the vegetative morphology and growth parameters except biomass duration. Treatments of Fe60 and Zn60 were less effective in increasing all growth parameters. Among the combined treatments of Fe and Zn it was Fe20 + Zn40 which shows maximum favourable effects on vegetative morphology and growth parameters this combined form (Fe20 + Zn40) was then compared with the chelated form of Fe and Zn i.e. Fe-EDTA and Zn-EDTA. The promotory effect with the latter application was significantly more than the former application. On the basis of the results one can conclude that soluble inorganic salts in low doses are generally as effective as synthetic chelate in foliar sprays.

INTRODUCTION

Barley was the first cereal crop to be cultivated. The Egyptians and Greeks considered it to have been a gift of the Gods. It is nutritive, toxifying and detoxifying. There is no known toxicity. Next to wheat, maize and rice, barley (*Hordeum vulgare* L.) which is grown worldwide on an area of about 57 million hectares (Karvy Comrade Ltd, 2010) is number four of world's cereal crop being very important for livestock feeding and human alimentation. The growing worldwide demand for barley is placing pressure on new innovations to improve the cultivars with greater yield (World Barley Outlook, 2010). Production was 14 million tons in 2009-10 and is fourth in terms of total world Production (Barley World, 2006). It is consumed in the form of chapatti, sattu etc but it's by-product at industrial level is very important for preparing barley water, malt and barley wines. Barley contains nitrogenous compounds (12.981%), gum (6.744%), sugar (3.2%), starch 59.95% and fat (2.17%). It also contains astounding amounts of proteins, vitamins and minerals, beta carotene, B1, B2, B6, C, folic acid, panthothenic acid, essential and non essential amino acids making it the most nourishing food stuff known to man. It contains high levels of chlorophyll, a substance said to inhibit cancer and several antioxidants that prevent degenerative disease. Studies suggest the medicinal effects are caused by beta glucon, a type of fibre which barley contains, which is also claimed to be protective against bowel cancer. Balanced and co-ordinate development of plant body is controlled by minerals, organic substances and hormonal factors involving wide range of growth nutrients. Among the many macro and micronutrients essential for plant growth iron and zinc are essential metals for cell metabolism. Zinc is essential for sugar regulation and enzymes that control plant growth (Halvin *et al.*, 1999). Formation of some growth hormones, auxinmetabolism, activity of dehydrogenases enzymes, synthesis of cytochrome etc. are influenced by zinc. Observation of zinc deficient plants suggested that they are deficient in growth regulators (Follett *et al.*, 1981). Bottrill *et al.* (1970) found that zinc deficiency depressed the rate of photosynthesis. Micronutrients like Fe and Zn are essential for plants and humans (Kaya *et al.* 1999; Hao *et al.* 2007). Their deficiency is widespread in humans (FAO, 2002; Hao *et al.*, 2007). The most recent estimates indicate that approximately 50% of the global population suffers from Zn and Fe

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deficiencies, predominantly third world countries (Welch and Graham, 1999). Therefore, improving staple food with high micronutrient density (specially Zn and Fe) is long term sustainable agricultural solution to 'hidden hunger' in developing countries (Vallee and Falchuk, 1993; Graham and Welch, 1996). The objective of this study was to evaluate the effect of various levels of Fe and Zn alone and in combination on growth parameters of barley. Plant morphological characteristics and yield forming components must be better understood if maximum yields are to be realized and exploited. Plant growth analysis is generally expressed in the indices of growth such as height; number of leaves/plant; leaf area/plant; leaf area index; leaf area duration; relative leaf growth rate; absolute growth rate. Nutrient deficiencies have also been corrected by using metal chelators (Szladils, 1956; Datta *et al.*,1962; Pandey and Pandey 2002).

Metal chelators are soluble in water and dissociate slightly. It is because of this fact that they are ideally suited for application to the crops deficient in particular micronutrient. They are more effective than normal salts of these nutrients (Singh, 2004). The rate of absorption of chelating agents associated with metallic cations is relatively higher than that of chelating agents without the associate of cations. The absorption of Fe was greater with Fe-EDTA than when Fe was given alone (Erdal *et al.*, 2004). Application of metal chelators on different plants increased their growth (Agui *et al.* 1983; Singh *et al.* 1987; Gatti *et al.*, 1991; Duhan and Dudeja, 1998; Suman Lata, 1998). Chelates may be applied to the soil or as spray to the foliage. Joshi *et al.* (1983) reported that foliar application was more effective than soil application which increased yield of soybean significantly.

Keeping in mind the above importance, the present study has been undertaken to investigate the effect of Fe and Zn on the vegetative growth, reproductive morphology and yield of *Hordeum vulgare* L. with the following objectives:

- To elucidate the influence of Fe and Zn on morphological characters.
- To estimate the combined effect of Fe and Zn on morphological characters.

Various morphological characters play an important role in yield determination and are of immense importance in understanding the plant growth and development. Since crop yields are based on land area, the crop growth analysis should also be expressed on land area rather than individual basis. Watson (1947) introduced more crop oriented concept of leafiness in relation to land area which he named as Leaf Area Index. Leaf Area Index (LAI) indicates the total surface area of the leaves above a certain area of ground surface. Measurement of this trait shows the capacity of agricultural plants to absorb solar radiation energy (Liatukas *et al.*, 2009). Leaf angle is angle between the stem and leaf and it determines how efficiently light is absorbed. LAI depends on the leaf angle. The greater the angle the less erect the leaves will be and more efficient to absorb light. Watson (1947) intergrated the area under LAI versus time. He defined leaf area duration (LAD) as a measure of the ability of plant to produce and maintain leaf area and its whole opportunity for assimilation during growing season. Among a variety of growth parameters biomass duration has been used for plant growth analysis (Hunt 1982). Biomass duration can be a unique measure to show a summed functioning of biomass during a period of time. Kvet and Ondok (1971) formulated biomass duration and emphasized its biological meaning. Watson (1952) showed that leaf area duration which was the first concrete form of biomass duration was more important than net assimilation rate in determining yield of crops. The relationship between leaf area duration (LAD) at different stages of growth and productivity has been studied and a definite relation has been found (Devendra *et al.*, 1983 and Saleem *et al.*, 2009). Relative Leaf Growth Rate (RLGR) is the change in area / unit area/ day, involves consideration of physiological activity like photosynthesis, respiration, mineral uptake and metabolic balance. RLGR is further affected by meristematic activity and the mechanism involves in leaf expansion and origin of new organs. The RLGR and leaf area are most affected by minerals and fertilizers (Hunt *et al.*, 1985). *Hordeum vulgare* L. is an important cereal crop and hardly any work has been done on the effect of Fe and Zn on growth parameters. With this background the present investigation was aimed to find out the suitable dose of Fe and Zn for increasing the yield potential and to correlate the effect of these micronutrients with the growth parameters. The present investigation will be of applied significance to growers of commercial crop of *Hordeum vulgare* L.

MATERIALS AND METHODS

The experiments were conducted on seeds of *Hordeum vulgare* L. var. K-125 (Azad) were obtained from Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Mineral iron (Fe), zinc (Zn) and Fe – EDTA (Fe chelated) and Zn-EDTA (Zn chelated) were obtained from the market.Different concentration of Fe and Zn (20, 40 and 60 ppm) were prepared from 1000 ppm stock solution of each chemical. Distilled water served as control. After preparation of solution of Fe and Zn seeds of *Hordeum vulgare* L. were soaked in desired solution for 48 hrs at 25ºC. Simultaneously a control, in which seeds were soaked in distilled water, was also conducted. The experiment was laid out in randomized block design with twelve treatments and three replications. A few drops of teepol were added as a wetting agent in each solution, followed by vigorous shaking. The first treatment was done by seed soaking in the respective solutions. This was followed by the first spray 20DAS (days after sowing). Two more sprays of the respective solutions were made at intervals of 14 days. Control plants were sprayed with distilled water having few drops of teepol.

Twelve treatments were applied as follows:

- Control
- Fe 20 ppm (Fe20)
- Fe 40 ppm (Fe40)
- Fe 60 ppm (Fe60)
- Zn 20 ppm (Zn20)
- Zn 40 ppm (Zn40)
- Zn 60 ppm (Zn60)
- Fe20 + Zn20
- Fe20 + Zn40

- Fe40 + Zn20
- Fe40 + Zn40
- 20 ppm of Fe – EDTA + 40 ppm of Zn – EDTA

i.e. Fe + Zn (Chelated)

RESULTS AND DISCUSSION

In the present study which was aimed at the response of Fe and Zn on growth and yield of *Hordeum vulgare* L. Chart A shows the doses of Fe and Zn, when applied alone and in combination, which induced maximum effect. The values of maximum effects are also shown. Among the three concentrations of Fe applied alone Fe20 ppm was the best dose for inducing maximum height (65.60 cm), diameter of shoot base (0.41 cm), leaf area (35.52 cm2), leaf number / plant (9.45), leaf area / plant (337.44 cm2), leaf area index (0.57), leaf area duration (10.73), RLGR (0.028 cm2. cm-2. day-1). When Zn was applied alone it was Zn20 which promoted height to a maximum of 71.33 cm (46.29% increase over control) (Fig. 1). However, Zn40 was best dose in promoting the diameter of shoot (0.48 cm), leaf area (47.69 cm2), leaf number / plant (11.66), leaf area / plant (577.82 cm2), LAI (0.95), leaf angle (19.10º), LAD (15.93), RLGR (0.030 cm2.cm2.day-1) and Stomatal Index (28.80%). A comparison of Fe and Zn showed that effect of Zn was always better than their application alone in increasing all the vegetative morphology and growth parameters except biomass duration, Also, combination treatments of Fe and Zn were always better in promoting the above mentioned parameters. Treatment of Fe20+Zn20 promoted height to 75.46 cm (54.76% increase over control) (Fig. 1), diameter of shoot base to 0.46 cm (i.e. 39.39% increase over control), However, Fe20+Zn40 induced maximum diameter of shoot base (0.46 cm) leaf area (50.96 cm2), leaf number / plant (13.58), leaf area / plant (692.68 cm2), LAI (1.18),leaf angle (19.96º), LAD (21.13), RLGR (0.040 cm2 cm-2 day-1). Fig. 2 reveals that percentage increase over control of LAI was 171.43 with Fe20. With Zn40 it was 347.62 (maximum) increase over control.

With combined treatments of Fe + Zn the best effect was with Fe20 + Zn40 (461.90). Fe + Zn (chelated) caused 547.62 percentage increase over control of LAI. A variety of parameters such as LAI, LAD, Relative Growth Ratehave been used for plant growth analysis (Hunt, 1982). The increase in LAI due to increased leaf area with increasing nutrients levels as observed in the present study could be because of increased amount of cellular constituents, mainly protoplasm (Sheshagiri, 1998) and also due to influence of phytochroms in promotion of cell division, cell enlargement, cell differentiation and cell multiplication resulting in consistant and statistically significant increase in total leaf area/plant and leaf area index (Rao and Padmaja, 1994; Van Volkenburg, 1999). Higher LAI may be due to increased auxin activity, production of carbohydrates and other organic compounds (Kiruthikadevi, 2002) leading to accelerated meristematic activity at shoot apex (Ramanujan, 1982). Takeda Oka and Agata, (1983) observed that high yielding rice varieties had higher LAI and consequently produced more dry matter. Huang and Miao, (1982) observed that higher leaf area associated with higher grain yield in rice. Tsai (1984) suggested that increased LAI either before or after heading could increase rice grain yield. Swain *et al.* (1986) reported that flowering and LAI were associated positively with dry matter content and yield. Increased LAI can be related to increased yield as observed by Malone *et al.* (2002); Liatukos *et al.* (2009); Xu *et al.* (2010). Fe and Zn fertilization resulted in an increased persistance of LAI and was measured by leaf area duration (LAD). Increase in leaf area as a result of increased number of leaves/plant is usually associated with increase in LAD. The ability to maintain green (LAD-stay green) throughout grain filling (Jenneer and Rathjen, 1975) may have implications on yield potential. Buttery, (1969) has correlated LAI with RLGR presuming that LAI was increased by fertilizer application presumably because of higher RLGR.

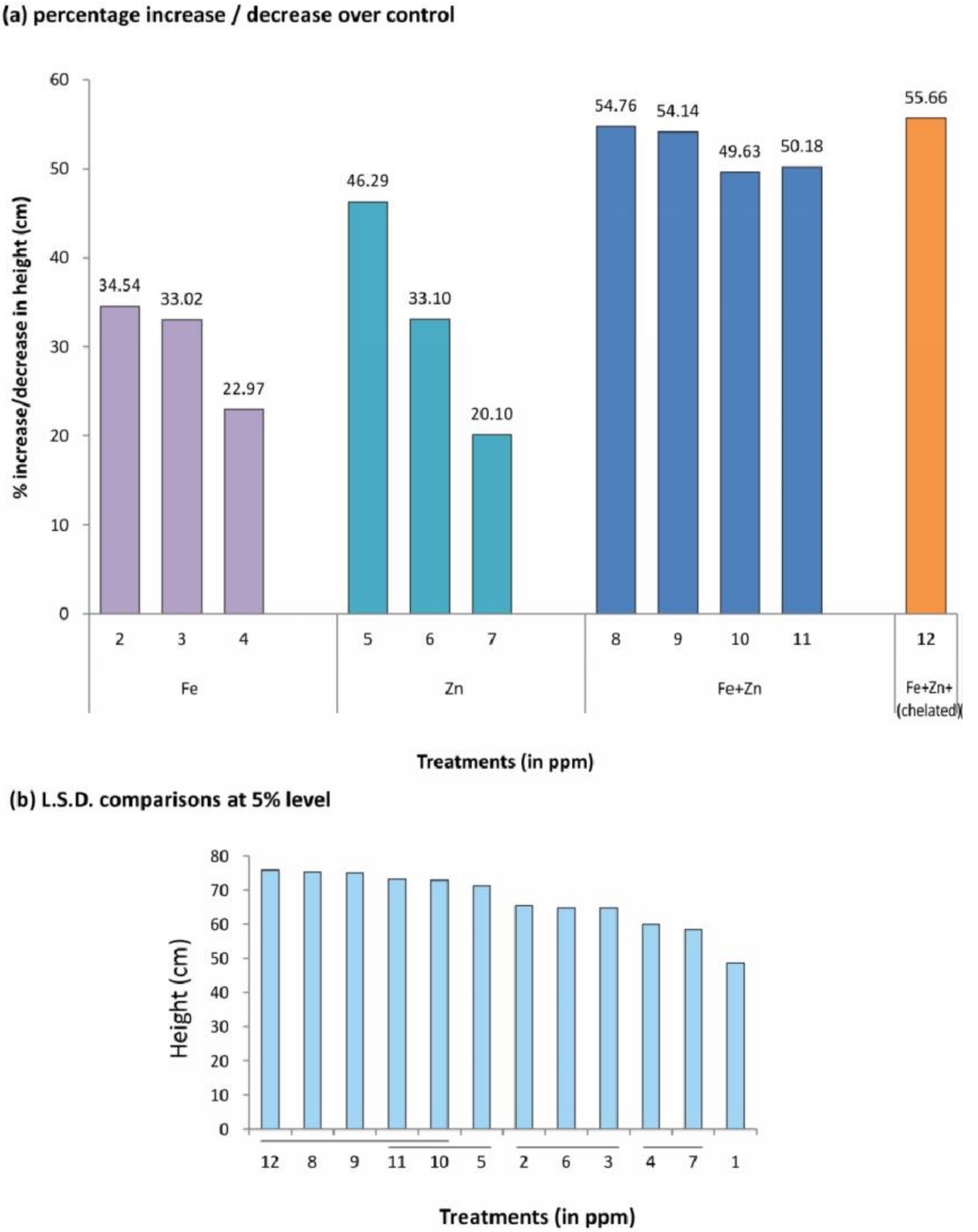
Chart A: Doses which showed maximum promoting effect on growth parameters as compared to control

Treatments	Control	Fe alone		Zn alone		Fe + Zn		Fe+Zn (Chelated)
		Fe_{20}	Fe_{40}	Zn_{20}	Zn_{40}	$Fe_{20}+Zn_{20}$	$Fe_{20}+Zn_{40}$	
Height (cm)	48.76	65.60		71.33		75.46		75.90
		(34.54)		(46.29)		(54.76)		(55.66)
Diameter of shoot (cm)	0.33	0.41			0.48	0.46	0.46	0.49
		(24.24)			(45.45)	(39.39)	(39.39)	(48.48)
Leaf Area (cm^2)	26.64	35.52			47.69		50.96	54.16
		(33.33)			(79.02)		(91.29)	(103.30)
Leaf no. of plant	4.74	9.45			11.66		13.58	14.82
		(99.37)			(145.99)		(186.50)	(212.66)
Leaf area/plant (cm^2)	126.74	337.44			577.82		692.68	796.84
		(166.25)			(355.90)		(446.54)	(528.72)
LAI	0.21	0.57			0.95		1.18	1.36
		(171.43)			(347.62)		(461.90)	(547.62)
Leaf angle (º)	15.63		18.73		19.10		19.96	21.26
			(19.83)		(22.20)		(27.70)	(36.02)
LAD	4.47	10.73			15.93		21.13	23.83
		(140.04)			(256.38)		(372.71)	(433.11)
RLGR (cm^2.cm^{-2}/day)	0.020	0.028			0.030		0.040	0.041
		(40.0)			(50.0)		(100.0)	(105.00)
Stomatal Index (%)	23.33	27.20			28.80		29.40	29.97
		(16.59)			(23.45)		(26.02)	(28.46)

Figures in parenthesis depicts percentage increase over control

Figure - 1

Response of Fe and Zn treatments to height of Hordeum vulgare L.



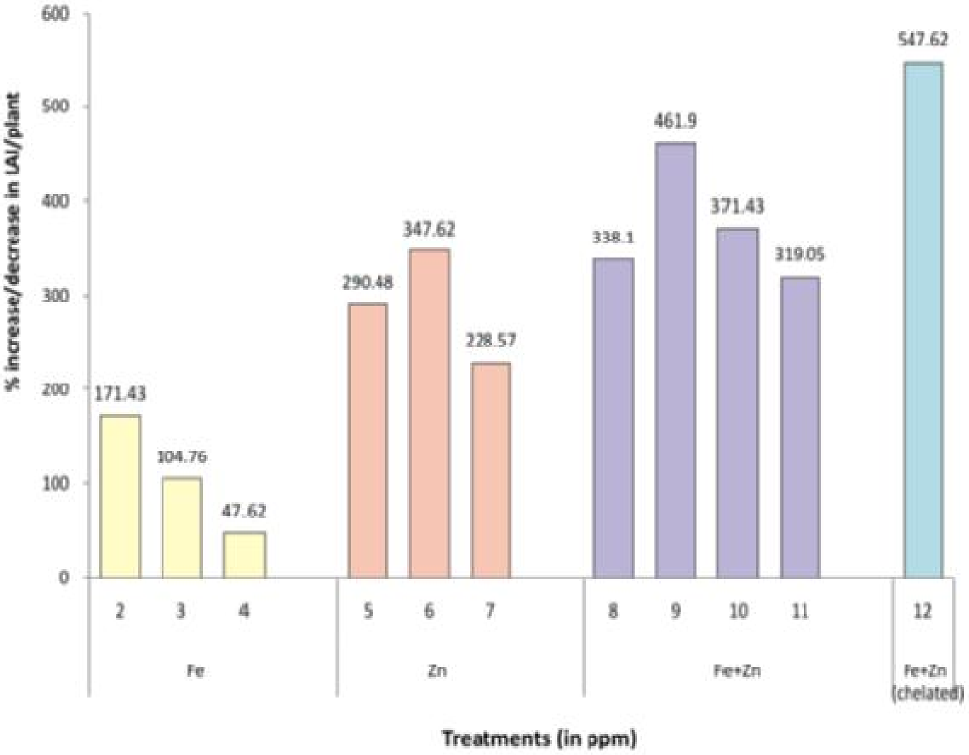
L.S.D. = Least Significant Difference
1 = Control
2= Fe20
3= Fe40
4=Fe60
5= Zn20
6=Zn40
7=Zn60
8= Fe20+Zn20
9=Fe20+Zn40
10= Fe40 + Zn20
11= Fe40+ Zn40
12= Fe + Zn (chelated)

L.S.D. is from mean data as seen in respective table.

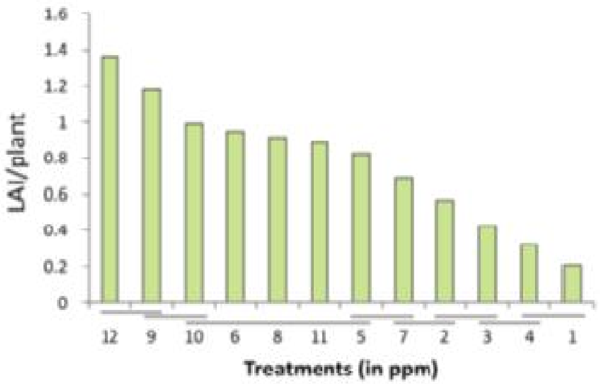
Figure- 2

Response of Fe and Zn treatments to Leaf Area Index of Hordeum vulgare L.

(a) percentage increase / decrease over control



(b) L.S.D. comparisons at 5% level



L.S.D. = Least Significant Difference
1 = Control
2= Fe20
3= Fe40
4=Fe60
5= Zn20
6=Zn40
7=Zn60
8= Fe20+Zn20
9=Fe20+Zn40
10= Fe40 + Zn20
11= Fe40+ Zn40
12= Fe20 + Zn40 (chelated)

L.S.D. is from mean data as seen in respective table.

More rapidly growing species have a faster RLGR associated with more rapid development of leaf area (Poorter and Vander Werf, 1998). Leaves will expand a large surface area when the necessary nutrients are available (Chapin, 1991).A study of literature reveals that mineral and chelating agents when supplied alone or in combination increased growth. The literature has also helped understand that enhanced growth with chelators like EDTA could be due to its ability to act as auxins and also to combine with metals and transport them into the plant system thus decreasing mineral deficiencies and increasing productivity of crops. Therefore, in the present experiments chelated form of Fe and Zn i.e. Fe – EDTA and Zn – EDTA were used. Summarizing the effect of Fe and Zn it was observed that Fe20 + Zn40 was generally the best dose to promote maximum favourable effects on vegetative morphology and growth parameters. As seen in Chart A, Fe + Zn (chelated) promoted all parameters more than Fe20 + Zn20. Conclusively, on the basis of observations it can be said that foliar sprays of soluble inorganic salts in low doses are generally effective. Therefore, for foliar sprays of Fe and Zn inorganic salts of Fe and Zn (i.e. FeSO4 and ZnSO4) may be chosen because of their lower cost.

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