

**Effect of Humic Acid and Micronutrients on Growth, Yield
and Quality of Cucumber under Polyhouse Condition**
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Thesis
Master of Science in Agriculture
(Horticulture)



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CERTIFICATE-I

Dated: / /2015

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This is to certify that the thesis entitled “**Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber under Polyhouse Condition**” submitted for the degree of **Master of Science in Agriculture** in the subject of **Horticulture**, embodies bonafide research work carried out by **Somendra Meena** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on ..2015.

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This is to certify that the thesis entitled “**Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber under Polyhouse Condition**” submitted by **Mr. Somendra Meena** to the Maharana Pratap University of Agriculture and Technology, Udaipur in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the subject of **Horticulture** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory, we therefore, recommend that the thesis be approved.

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This is to certify that **Mr. Somendra Meena** of the **Department of Horticulture**, Rajasthan College of Agriculture, Udaipur has made all corrections/modifications in the thesis entitled **“Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber under Polyhouse Condition”** which were suggested by the external examiner and the advisory committee in the oral examination held on ----- . The final copies of the thesis duly bound and corrected were submitted on ----- are enclosed herewith for approval.

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**Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of
Cucumber (*Cucumis sativus* L.) under Polyhouse Condition**

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ABSTRACT

The present investigation entitled "Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber (*Cucumis sativus* L.) under Polyhouse Condition." was conducted during August, 2014 to February, 2015 at Hi-Tech Horticulture Unit, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. The experiment was laid out in Completely Randomized Design with three replications and seven treatments. Observations were recorded for different characteristics related to vegetative, yield and yield attributing and moisture content. Treatment T₇ [(RDF + humic acid 10 kg/ha soil application + humic acid 0.1% foliar spray + micronutrient mixture foliar spray (0.5% Zn + 0.2% B + 0.5% Mn)] was best in regards vegetative traits *viz.* vine length (cm), number of branch per plant and leaf area (cm²).

Yield and yield attributing characteristics like number of fruits per vine, fruit weight (g), fruit length (cm), fruit diameter (cm), volume of fruit (cc), yield per plant (kg) and yield per square meter (kg) were significantly influenced by effect of humic acid and micronutrients. The treatment T₇ was significantly superior in respect of yield and yield attributing traits having maximum values of 3.51 kg and 10.96 kg/m² for yield per plant and per square meter, respectively. As far as economics is concerned maximum gross return Rs. 274000 per 1000 square meter, net return Rs. 173770 per 1000 square meter and B:C ratio (1.73) were obtained in T₇. Whereas, on the basis of benefit cost ratio, it could be recommended that cucumber should be supplied by (RDF+ Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) in the polyhouse for attaining the maximum return of cucumber under polyhouse condition.

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1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) belongs to family cucurbitaceae. It is a warm season vegetable, grows throughout the world under tropical and subtropical conditions. It is said to be the native of northern India (Pursglove, 1969). Archeological evidences support that cultivation of cucumber in India was dated back to 3000 years and 2000 years in China. China is considered as one of the secondary centers of genetic diversification (De Candolle, 1882). Family Cucurbitaceae consisting of 118 genera and 825 species (Jeffrey, 1990) among those genus *Cucumis* comprises about 30 species. Cucumber is commonly a monoecious annual (one can encounter with androecious, gynoecious, hermaphrodite and andromonoecious sex types also), trailing or climbing vine (Bailey, 1969).

The fruits of cucumber possesses various medicinal properties *e.g.* cooling effect, prevents constipation, checks jaundice and indigestion (Nandkarni, 1927). Nutritionally 100g of edible portion of cucumber contains 96.3 g moisture, 2.5 g carbohydrates, 0.4 g protein, 0.1 g fat, 0.3 g minerals, 10 mg calcium, 0.4 g fiber and traces of vitamin C and iron. It is eaten raw with salt and pepper or as an component of salad and pickles. The pulp of the fruit is used in making mash cakes. Besides, the seed of cucumbers used in *Ayurvedic* preparation and raw fruits are also being used in cosmetic preparation. In Rajasthan, the approximate area under this crop is around 4550 hectares with total production of about 14323 metric tonnes. Whereas in India, cucumber is cultivated in an area of 18,000 hectares with a production of 1,20,000 metric tonnes (Anjanappa *et al.*, 2012)

The major cucumber growing pockets in Rajasthan are Bharatpur, Alwar, Bhilwara, Jaipur, Tonk, Dholpur and Sawai Madhopur districts. In plains of northern India, it is grown in summer and rainy season.

Parthenocarpic and gynoecious cucumber cultivars increase the potential to yield a high fruit load in controlled environments resulting in a high harvest index. Polyhouse cultivation is still a new and emerging trend for growing vegetables in India. Production of cucumber in India is mainly restricted to its open field cultivation.

India, being a vast country with diverse and extreme agro climatic conditions, the protected vegetable cultivation technology can be utilized for year round production of high value vegetable crops, with more yield. Protected cultivation actually achieves higher water and nutrient use efficiencies. Increasing photosynthetic

efficiency and reduction in transpiratory losses are added advantages of protected cultivation. Both of these factors are of vital importance for healthy and luxuriant growth of crop plants. This technology is highly suitable for farmers in peri-urban areas of the country, especially in northern plains of India. But protected cultivation requires careful planning and attention including selection of suitable cultivar and production technology like spacing, time of planting, water and nutrient management and plant protection to produce economic yield of good quality.

Humic acids are characterized as a heterogeneous natural resource, ranging in colour from yellow to black, having high molecular weight and resistance to decay. Humic acid, as a commercial product contains 44-58 percent C, 42-46 percent O, 6-8 percent H and 0.5-4 per cent N, as well as many other elements (Larcher, 2003). It improves soil fertility and increases the availability of nutrient elements by holding them on mineral surfaces. The humic substances are mostly used to remove or decrease the negative effects of chemical fertilizers from the soil and have a major effect on plant growth. Humic acids promote the conversion of mineral nutrients into forms available to plants. It also stimulates seed germination and viability and its main effect usually being more prominent in the roots. Humic substances can stabilize soil structure (Piccolo and Mbagwu, 1990) and increase cation exchange. Root growth enhancement has been attributed to improved soil structure, stimulation of soil microflora, and plant growth regulator effects (Chen and Aviad, 1990). The availability of nutrients from the humic substances, chelation of nutrients by the humates (Stevenson, 1991) or through more complex physiological interactions (Vaughan *et al.*, 1985).

To improve the yield and quality of the product, it is necessary to pay attention on the optimum balanced use of nutrients through fertilizer application. Plants require mineral elements for normal growth and development. Plants requirements to essential for the normal life processes of plants and are needed in very small amounts are called trace elements or minor elements such as boron, zinc, manganese etc.

Boron (B) plays an essential role in the development and growth of new cell in the plant meristem, improves the fruit quality and fruit set. Boron is needed by the crop plants for cell division, nucleic acid synthesis, uptake of calcium and transport of carbohydrates. Boron also plays an important role in flowering and fruit formation. Boron deficiency affects the growing points of roots and youngest leaves. The leaves become wrinkled and curled with light green colour. Its deficiency affects translocation of sugar, starches, nitrogen and phosphorus, synthesis of amino acids

and proteins. Zinc (Zn) as one of the essential micronutrient in plants is necessary for plant growth and development and involved in many enzymatic activities and IAA formation to increase flower number and fruit set. However, excessive Zn in plants can profoundly affect normal ionic homeostatic systems by interfering with the uptake, transport, osmotic and regulation of essential ions and results in the disruption of metabolic processes such as transpiration, photosynthesis and enzyme activities related to metabolism (Sainju *et al.*, 2003). Manganese (Mn) is necessary in photosynthesis, nitrogen metabolism and to form other compounds required for plant metabolism. In very severe manganese cases, brown necrotic spots appear on leaves, resulting in premature leaf drop. Delayed maturity is another deficiency symptom in some species. White/gray spots on leaves of some cereal crops are a sign of manganese deficiency.

Therefore, keeping above mention facts in view the present study “**Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber (*Cucumis sativus* L.) under Polyhouse Condition**” was carried out at Hi-tech unit, Department of Horticulture, RCA Udaipur, Rajasthan with following objectives:

1. To study the effect of humic acid and micronutrients on growth, yield and quality of cucumber.
2. To work out economics of treatments.

2. REVIEW OF LITERATURE

The literature available on parthenocarpic cucumber pertaining to present investigation is scanty. Hence available literature on all the vegetable crops grown under protected conditions have been reviewed and presented in this chapter under following sub headings:

- 2.1 Effect of humic acid on growth, yield and quality
- 2.2 Effect of micronutrients on growth, yield and quality

2.1 Effect of Humic Acid on Growth, Yield and Quality:

Hartwigsen and Evans (2000) studied the humic acid and substrate treatments promote seedling root development and reported that humic acid did not affect shoot fresh weight and the number of lateral roots. However, humic acid treatment increased the total length of lateral roots. The increase in lateral root growth occurred primarily in lateral roots developing from the lower hypocotyls.

Kanthaswamy *et al.* (2000) studied the growth and yield of cucumber and sprouting broccoli under polyhouse condition and observed that the maximum yield (125.82 t ha⁻¹) was reported at 60×60 cm spacing with pruning of all the primary branches after two nodes. Similarly, the maximum yield (21.06 t ha⁻¹) can be achieved by planting sprouting broccoli seedlings at 30×50 cm spacing with 30 g of urea per plant under polyhouse conditions.

Atiyeh *et al.* (2002) evaluated the influence of humic acids derived from earthworm-processed organic wastes on plant growth and reported that the some effects of humic acids, formed during the breakdown of organic wastes by earthworms (vermicomposting) on plant growth.

Aracon *et al.* (2003) studied the effect of humic acid derived from cattle, food and paper waste vermicompost on growth of green house plants and reported that the substitution of humates ranging from 250–1000 mg kg⁻¹ increases root growth of marigolds and peppers and increased root growth and numbers of fruits of strawberries significantly ($P \leq 0.05$). Leaf area, plant height and above ground dry matter weight increased considerably in plants grown in pots containing humic acid.

Norman *et al.* (2003) studied the effects of humic acids derived from cattle, food and paper-waste vermicomposts on growth of greenhouse plants and they observed that effects of the humic acids on the plant height, leaf area, shoot dry weight, root dry weight of pepper and tomato and found that substitution of humate ranging from 250–1000 mg kg⁻¹ increased root growth of peppers significantly.

Itoo and Manivannan (2004) conducted an experiment to assess the effect of macro and micronutrients in different forms in comparison with humic acid on growth, yield and quality of tomato and reported that the application of Biotab at 20 tablets/pot resulted in the maximum number of primary branches, number of flower clusters per plant and number of flowers per cluster (9.90, 16.40 and 6.24, respectively), maximum number of fruits per plant, fruit yield per plant and single fruit weight (24.85, 1100.86 g and 72.10 g, respectively) and TSS, ascorbic acid content and acidity (7.14 °Brix, 26.10 mg/100 g and 0.72%, respectively).

Dhanasekaran and Bhuvaneshwari (2005) studied the effect of nutrient-enriched humic acid on the growth and yield of tomato and found that the application of humic acid either alone or in combination with NAA and/or nutrient mixture significantly improved the yield of tomato. The combined application of humic acid with NAA and nutrient mixture resulted in the superior yield and quality.

Eyheraguibel *et al.* (2008) studied the effects of humic substances derived from organic waste enhancement on the growth and mineral nutrition of cucumber and conclude that the humic like substance do not increase the percentage and rate of germination but enhance the root elongation of seedlings. Positive effects were also observed on the whole plant growth as well as on root, shoot and leaf biomass.

Dileep and Sasikala (2009) studied on the effect of different organic and inorganic fertilizers on growth, fruit characters, yield and quality of chilli and found that the quality attributes of chilli were significantly influenced by different treatment combinations. The treatments, application of 75 percent RDF (Recommended dose of fertilizer) along with humic acid @ 30 kg/ha was superior in increasing the growth characters like plant height (79.30 cm), number of branches per plant (23.62) and dry matter production per plant (85.81 g) and fruit traits such as fresh fruit weight (2.35 g), dry fruit weight (0.61 g), number of fruits per plant (147.72) and yield of fresh and dry fruit, as highest per plant (347.14 and 90.49 g), per plot (7.71 and 2.01 kg) and per ha. (12.86 and 3.35 t ha⁻¹) respectively.

Mora *et al.* (2010) studied action of humic acid on promotion of cucumber shoot growth involves nitrate-related changes associated with the root-to-shoot

distribution of cytokinins, polyamines and mineral nutrients and reported that beneficial effects of humic substances on shoot development in cucumber could be directly associated with nitrate-related effects on the shoot concentration of several active cytokinins and polyamines.

Olfati *et al.* (2010) studied synthetic humic acid increased nutrient uptake in cucumber soilless culture and observed that humic acid did not affect fruit, root and leaf dry matter of cucumber. Humic acid significantly affected yield attributes and plant yield was higher when plants were treated with complete nutrient solution. Humic acid have significant effect on nutritional elements uptake by cucumber and as a result humic acid decrease element content in nutrient solution due to positive effect.

Khaled and Fawy (2011) studied the effect of different levels of humic acids on the nutrient content, plant growth and soil properties under conditions of salinity and reported that the salinity negatively affected the growth of corn, it also decreased the dry weight and the uptake of nutrient elements except for Na and Mn. Soil application of humic acid increased the N uptake of corn while foliar application of humic acid increased the uptake of P, K, Mg, Na, Cu and Zn. Although the effect of interaction between salt and soil humus application was found statistically significant, the interaction effect between salt and foliar humic acids treatment were not found significant.

Azconal *et al.* (2011) conducted greenhouse experiment to evaluate the effects of humic substances extracted from composted sewage sludge on growth, phenological development and photosynthetic activity of pepper and reported that the mechanisms through which humic acid affected plant growth and development were not associated with an improved nutrient uptake. Although the identity of the growth-promoting factors remains to be found, the results suggest that they may be linked to the chemical structure of the humic substances.

Rady (2011) reported that effects of potassium humate mixed with farmyard manure, as an alternative to mineral-N fertiliser on the growth, leaf mineral composition, fruit yield and quality of tomato on newly-reclaimed soil.

Aminifard *et al.* (2012) studied the effect of humic acid on antioxidant compounds and fruit quality of hot pepper (*Capsicum annuum* var. Red chili) and observed that there was no any difference in total phenolic and carbohydrate between humic acid and control treatments. It was concluded that humic acid applied at 100 mg kg⁻¹ resulted in the highest capsaicin and lycopene contents and the lowest values

were observed in control group. Total soluble solids and titratable acidity increased in response to humic acid treatment and the highest values were obtained from the highest humic acid treatment (250 mg kg⁻¹).

Bing *et al.* (2012) reported that humic-like substances from different compost extracts could significantly promote cucumber growth and they also observed that the application of humic-like substances stimulated auxin-like activity and increased chlorophyll content and nitrogen accumulation in plants. The positive auxin-like activity of humic-like substances could be attributed to the relative distribution of special carbon groups, such as those with a large amount of peptidic and carbohydrate groups or with a low content of phenolic groups. In conclusion, the best growth promotion by application was mainly attributed to the humic-like substances in the aerated fermentation extracts of compost.

Ghehsareh and Kalbasi (2012) concluded that effect of addition of organic and inorganic combinations to soil on growing property of greenhouse cucumber and observed that the yield, number of fruit, biomass weight, plant height, stem diameter of plant and leaf area index in date palm wastes were highest. The amount of fruit stiffness index in date palm wastes and perlite media were highest but the amount of fruit total soluble solids in date palm wastes media was lowest and had significant difference with other substrates.

Mishra *et al.* (2012) concluded that application of different micronutrients individually or in combination significantly increased the yield of tomato. The combined application of all the micronutrients *viz.* B, Zn, Mo, Cu, Fe and Mn produced the highest yield.

Sure *et al.* (2012) studied response of productivity and quality of cucumber to application of the two biofertilizer (humic acid and nitroxin) in fall planting and reported that the all humic acid and nitroxin treatment had significant effect on growth, yield and chemical characteristics including number of leaf/plant, dry matter percent plant, fruit diameter, length and fruit yield ha⁻¹.

Shehata *et al.* (2012) studied the influence of some organic and inorganic fertilizers on vegetative growth, yield and yield components of cucumber plants and observed that the application of humic acid, amino acid and compost especially the high concentration produced heavier plants than magnetic iron, while plants received amino acids spray application scored relatively high plant fresh and dry weights with non significant differences as compared with magnetic iron treatment. Amino acid

and humic acid treatments showed significant differences in the average fruit yield per plant compared with control.

Kazmi (2013) studied the effect of foliar application of humic acid and potassium nitrate on cucumber growth and his results indicated that humic acid and potassium nitrate increased vegetative and reproductive growth by increasing vine length, dry weight and yield. In general, a combination of humic acid + potassium nitrate (40 ppm +100 mg L⁻¹) was the most effective in increasing fruit quality.

Khan *et al.* (2013) studied characterization and effects of plant derived humic acid on the growth of pepper under glasshouse condition and observed that plant growth parameter such as number of branches per plant and fruit weight were significantly improved with humic acid. Maximum branches (11) were found by humic acid application at highest rate (150 mg kg⁻¹), while, lower application rate (30 mg kg⁻¹) maximum fruit weight were obtained. Despite, plant growth improvement, fruit K concentration were also significantly improved with humic acid application. These result suggest that humic acid application at the optimum rate (30 mg/kg) improved plant growth parameter, however soil nutrients concentration only responded to humic acid application at the higher rate side.

Sher *et al.* (2013) studied the response of tomato to nitrogen levels with or without humic acid and concluded that tomato plants should be treated with humic acid and nitrogen at the rate of 5 kg and 125 kg ha⁻¹ respectively, to obtain maximum and quality yield.

10.1 Effect of Micronutrient on Growth, Yield and Quality:

Alphonse and Saad (2000) conducted an experiment on greenhouse grown cucumber in farmyard and chicken manure media in combination with foliar application of zinc, manganese and boron and reported that the all micronutrients increased plant height, but plants sprayed with Mn or Zn had higher total fresh weight observed in plants sprayed with Mn and grown in FYM + sand and the highest values of early yield were observed in plants sprayed with Mn or Zn and grown in FYM + CM and FYM + sand.

Alpaslan and Gunes (2001) studied the interactive effects of boron and salinity stress on the growth, membrane permeability and mineral composition of tomato and cucumber plants and concluded that the boron toxicity symptoms appeared at 5 mg kg⁻¹ B treatments in both plants. Whereas salinity caused an increase in leaf injury due to B toxicity, but it was more severe in cucumber. Dry weights of the plants

decreased with the increasing levels of applied B in non saline conditions, but the decrease in dry weights due to B toxicity was more pronounced in saline conditions especially in cucumber. Salinity \times B interaction on the concentration of B in both plants was found significant. Contrary to this, B concentration of cucumber increased as a result of increasing levels of applied B and salinity.

Gal and Shani (2002) studied the yield, transpiration and growth of tomato under combined excess boron and salinity stress and found that the yield response of tomato to boron nutrition correlates better with boron concentration in the irrigation water and soil solution than with the levels of boron in the plant tissue. Soil boron concentrations of 5 mg kg⁻¹ or higher are expected to impose boron toxicity symptoms.

Sudhan *et al.* (2003) studied the effect of zinc on growth, flowering and yield of cucumber (*Cucumis sativus* L.) and observed that the application of ZnSO₄ @ 25 kg/ha soil application with 0.50 percent foliar spray (T₅) recorded significantly higher vine length and broader leaves than the control and the earlier appearance of female flowers, production of maximum number of female flowers, narrowest sex ratio and highest fruit set percentage when compared to other treatments. Dry matter production was also increased with the application of ZnSO₄ @ 25 kg/ha soil application with 0.50 percent foliar sprays.

Yermiyahu *et al.* (2003) studied response of pepper to boron and salinity under greenhouse condition and observed that the yield weight were not influenced by B concentration of up to 0.37 mM (4 mg L⁻¹) even at the highest salinity level the dry matter weight of the shoot and fruit yield decreased as the sodium chloride concentration increased. The B concentration in the root was correlated positively.

Mohamed and Shaaban (2004) studied the nutrient status and enzyme activity alteration in cucumber seedlings as a response to boron deficiency and they found that the vegetative growth of cucumber plants was negatively affected by B deficiency. Biomass accumulation decreased by as much as 24.3 percent in the shoots and 49.1 percent in the roots. The nutrient concentrations in leaves and roots of B-stressed plants were substantially reduced. Phenolic compounds were accumulated in significant amounts in the roots of boron deficient plants.

Pal *et al.* (2004) conducted an experiment to assess the response of bell pepper (*Capsicum annuum*) cultivars to foliar application of magnesium, boron and zinc and they observed that boron or zinc (1000 ppm) application increased fruit weight. In general, boron application (2000 ppm) enhanced the levels of ascorbic acid, acidity,

carotene and chlorophyll concentration. It was concluded that foliar application of 1000 ppm boron or zinc increased physical attributes, whereas 2000 ppm boron enhanced the quality traits when sprayed thrice at 10 days interval commencing from 50 days after transplanting.

Xiang and Chang (2004) studied on regulation of absorption and utilization of fertilizer in solar greenhouse substrate culture cucumber and evaluated that the fertilizer amount increasing, the N, P and K concentration in the main organs and the N, P and K total absorption amount increased those between high and middling treatments had not significant differences. The substrate culture promoted the growth of cucumber aerial plant. The utilization rate of N and K decreased, that of P increased, with the fertilizer amount increasing. The experiment showed the proper nitrogenous and potassic fertilizer promoted absorption of P.

Smit and Combrink (2005) studied pollination and yield of winter-grown greenhouse tomato as affected by boron nutrition, cluster vibration and relative humidity and observed that at too low B levels in the root zone, the leaves of tomato became brittle and appear pale-green, a considerable fraction of flowers abscises and the fruits lack firmness. The above symptoms appeared at a B concentration level of 0.02 mg L^{-1} in the nutrient solution supplied to a crop grown on quartz-sand, but B concentration of 0.16 mg L^{-1} seemed to be optimal for tomato and levels of up to 64 mg L^{-1} did not cause any toxicity symptoms.

Hakan *et al.* (2006) studied the effect of zinc on growth and shoot concentrations of sodium and potassium in pepper plants under salinity stress and observed that the Zn deficiency in soil significantly reduced shoot growth, particularly under the highest salt treatment. Increases in Zn application from 2 to 10 mg kg^{-1} soil reduced shoot concentration of Na and elevated K concentration. Consequently, K/Na ratios of plants were highest in the highest Zn application condition. The results of the present study indicated the importance of the Zn nutritional status of plants in improving salt stress tolerance. Adequate Zn nutrition is, therefore, important for the maintenance of good growth and yield under saline conditions.

Hua *et al.* (2006) studied the combined effects of excess Mn and antioxidant enzymes in cucumber roots and observed that the growth of cucumber roots and shoots was significantly inhibited. Excess Mn led to an elevation in activities of Mn-sod and Fe-sod, which played an important role in removing excess Mn and its activity significantly decreased under excess Mn and low pH. This indicated their

important roles in scavenging reactive oxygen in tolerance to low pH and excess Mn of cucumber roots.

Kawasaki *et al.* (2007) studied the effect of zinc and copper on physiological disorder in green-house grown cucumber and reported that the main contributing factor for induction of magoyakesyo (a physiological disorder occurring in greenhouse cucumbers cultivated by the pinching technique in Miyazaki prefecture, Japan) is a result of high zinc absorption. Its symptom is known as a suppression of new shoots.

Yildirim *et al.* (2007) conducted an experiment on effect of foliar and soil fertilization of humic acid on productivity and quality of tomato and reported that the foliar and soil humic acid treatments positively affected fruit characteristics including fruit diameter, fruit length, mean fruit weight and fruit number per plant. Similarly, humic acid treatments increased the early yield of tomato compared to control. The yield of tomato was significantly influenced by soil and foliar humic acid applications. The highest yield occurred in foliar spray 20 ml L⁻¹ of humic acid treatment. The study showed that 20 ml L⁻¹ concentration of humic acid sprays could be successfully used to obtain better growth and yield in tomato.

Hong (2008) studied characteristics of mineral elements accumulation of cucumber in plastic house and observed that the minerals content of roots, stems, leaves and fruits changed in different growth stages and decreased significantly during later fruiting stage. The amount of mineral elements absorbed through all stages were in order of K, N, Ca, Mg and P. At the flowering stage, mineral elements absorption and the proportion of P and K increased. Mineral elements absorption reached a peak in flourishing fruiting stage and the proportion of K were highest. The mineral elements were mainly distributed to stems and leaves in initial fruiting stage and considered stem, leaves and fruits in flourishing fruiting stage.

Wang *et al.* (2008) studied effect of boron and low temperature on membrane integrity of cucumber leaves and found that the boron plays an important role in maintaining the integrity of plasma membranes of leaf cells and in alleviating the damage of membrane caused by low temperature.

Akinci *et al.* (2009) studied the effect of humic acid on nutrient composition in broad bean (*Vicia faba* L.) roots and evaluated that the humic acids promote the conversion of mineral nutrients into forms available to plants, it also stimulates seed germination and viability. Treatment with Leonardite, as humic acid

source positively affected germination, harvesting, enhancing root length and biomass in broad bean.

Xin (2009) studied the effects of boron and manganese on quality and antioxidative capacity in tomato and reported that under reduced concentrations of boron, tomato yields and the antioxidative content in tomato were significantly reduced. Under high boron concentrations yield and the antioxidative capacity were increased, however the ascorbic acid content was reduced. Similarly under low manganese both yields and the total antioxidative capacity were reduced however under high manganese levels, yields were not reduced nor were the concentration of ascorbic acid. Total solids were reduced under a high concentration of the micronutrient manganese.

Brahma *et al.* (2010) evaluated performance of capsicum as influenced by bio-regulators and micronutrients inside polyhouse under Assam conditions and observed that fruit number per plant and average fruit weight was maximum with application of NAA 10 ppm and boron 1 ppm at first flowering and increase in yield and yield attributing traits. Therefore, based on the overall performance, it can be revealed that the combine application of NAA 10 ppm and boron 1 ppm at the time of flowering can be practiced for increasing both fruit and seed yield of capsicum inside low cost polyhouse.

Dursun *et al.* (2010) evaluated effects of boron fertilizer on tomato, pepper and cucumber yields and chemical composition and observed that the boron addition of 2.5 kg ha⁻¹ is sufficient to elevate soil boron levels to non-deficient levels.

Yang *et al.* (2011) reported that foliar spray and seed soaking of zinc fertilizers decreased cadmium accumulation in cucumbers grown in Cd-contaminated soils. The cucumber seedlings treated with RM and foliar Zn had a higher capacity for limiting the transfer of Cd to above ground tissues. The results also suggested that increasing seed Zn concentrations sufficiently might act as an efficient, economic and practical method for decreasing Cd uptake in crops grown in mildly Cd-contaminated and Zn-deficient soil.

Hosobuchi and Hikasa (2013) studied the mitigation of excess boron supplied in hot spring waters to tomato and cucumber in heated polyhouse and evaluated that the boron concentrations of the spring waters (15 mg L⁻¹ on average) were significantly higher than those of stream water used for the irrigation of tomato and cucumber at about 2 mg kg⁻¹ and the number of lateral branches was reduced in the

treatment of about 4 mg kg⁻¹ or higher. Consequently, the fruit set on lateral branches and cucumber yield was decreased.

Patil *et al.* (2013) studied the response of foliar application of micro-nutrients on yield and economics of bittergourd (*Momordica charantia* L.) and reported that the highest fruit yield/plant (15.51 kg) and fruit yield (10.6 t ha⁻¹) with maximum B:C ratio of (1:1.79) followed by the treatment mixture of micro-nutrients (B + Zn + Mn + Cu + Fe @ 100 ppm and Mo @ 50 ppm), fruit yield of (9.89 t ha⁻¹) with B:C ratio of (1:1.57), which is significantly higher from the control.

Lal and Kanaujia (2013) studied effect of integrated nutrient management in capsicum under low cost polyhouse condition and reported that application of different levels of fertilizers, organic manures and biofertilizers either alone or in combination significantly increased the growth, yield and quality of capsicum as compared to control. The maximum plant height (54.46 cm), number of leaves per plant (38.89), leaf area (54.60 cm²), number of fruits per plant (10.48), average fruit weight (85.06 g), fruit length (8.56 cm), fruit diameter (5.63 cm), fruit yield (29.70 t ha⁻¹), TSS (9.55 °Brix) and vitamin C (126.31 mg 100g⁻¹) were recorded with the conjoint application of 50 percent NPK + 50 percent FYM + Biofertilizers. There is a significant build up of organic carbon in the soil after harvest of the crop with 50 percent NPK + 50 percent FYM + Biofertilizers. The same treatment also produced the highest net return of Rs. 7, 93, 858.00 ha⁻¹ along with cost:benefit ratio 1:8.16.

Shnai (2014) studied the effect of zinc and boron on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.) cv. Heem Sona, under protected cultivation and observed that the highest fruit weight (72.67 g) was recorded in T₆ and the highest plant height (2.93 m), number of leaves per plant (39.33), number of clusters per plant (12.33), number of fruits per cluster (7.17), number fruit per plant (88.33), yield per plant (6.33 kg), total yield (113.628 t ha⁻¹), shelf life (26.33 days), Total soluble solid (5.67 °Brix), Vitamin C (32.57 mg 100g⁻¹) under Allahabad agro climatic conditions.

Tuti *et al.* (2014) studied the effect of organic and inorganic sources of nutrients on yield, economics on pepper in naturally ventilated polyhouse and observed that the increase in pepper fruit yield with the application of 125 percent recommended NPK was 43.6 percent and 21.6 percent over 75 percent and 100 percent of recommended N, P and K respectively. Similarly, an increase in pepper fruit yield of 18.1 percent was obtained at 100 percent recommended N, P and K over 75 percent of recommended N, P and K application.

3. MATERIAL AND METHODS

The present investigation entitled “Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber (*Cucumis sativus* L.) under Polyhouse Condition” was conducted at the Hi-Tech Horticulture Unit, Department of Horticulture, Rajasthan College of Agriculture, Udaipur (Rajasthan). The details of the materials used, experimental procedure employed and methodology implemented for assessment of treatment effects during the entire course of investigation are described in this chapter.

3.1 Experimental Site and Climatic Conditions:

The experiment was conducted during 2014-15 at the Hi-Tech Horticulture Unit, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. The size of the fully controlled polyhouse was 28 m × 32 m (896 m area) covered with aluminate sheet and ultra violet stabilized low density polyethylene sheet having 200 micron thickness with provision of cooling pads and exhaust fan. Udaipur is situated at 24°34'N latitude and 73°42'E Longitude at an elevation of 582.17 meters above mean sea level. The region falls under agro climatic Zone IV a (Sub Humid Southern Plain and Aravali Hills) of Rajasthan. It has a typical sub-tropical climate, characterized by mild winters and summers. The average annual rainfall of this tract ranges from 760 to 900 mm. More than 90 percent of rainfall is received during mid June to September with scanty shower during winter months.

3.2 Soil of the Experimental Field:

In order to determine the physical and chemical properties and fertility status of soil, the soil samples were collected with the help of screw auger up to the depth of 30 cm. The soil samples were taken from each treatment. The collected soil samples were mixed thoroughly on a clean piece of cloth and the bulk reduced by quartering so that about 500 g of composite sample was obtained.

Collected samples were brought to the laboratory and spread on a thick brown paper. Stones, pieces of roots, leaves and other undecomposed organic residues were removed. Large lumps of moist soil were broken by hand. It was air dried at 20-25°C and 30 to 60 percent relative humidity (Jackson, 1973). After air drying soil samples were crushed gently with the help of pestle and mortar and sieved through 92 mm sieve. Grounded samples were stored in glass containers. The grounded samples were mixed well before a sample was weighed for analysis. Then soil samples were analyzed according to the method given in Table 3.1 and the data of available N, P

and K obtained in the experimental sample prior to the start of experiment are given in Table 3.1.

Table 3.1: Chemical properties of experimental soils

| S. No | Characteristics of soil | Content | Method of analysis | References |
|-------|---|---------|-----------------------------------|----------------------------|
| 1. | Organic carbon (%) | 0.73 | Rapid titration method | Walkley and Black (1947) |
| 2. | Available nitrogen (kg ha ⁻¹) | 258.7 | Alkaline KMnO ₄ method | Subbiah and Asija (1956) |
| 3. | Available phosphorus (kg ha ⁻¹) | 20.70 | Olsen's method | Olsen <i>et al.</i> (1954) |
| 4. | Available potassium (kg ha ⁻¹) | 275.6 | Flame photometer method | Richards (1968) |

3.3 Experimental Details:

Details of treatments with their notations

Notations

Treatments

| | |
|----------------|--|
| T ₁ | RDF (control) |
| T ₂ | RDF + humic acid 10 kg/ha (soil application) |
| T ₃ | RDF + humic acid 0.1 % (foliar spray) |
| T ₄ | RDF + humic acid 10 kg/ha + humic acid 0.1% (foliar spray) |
| T ₅ | RDF + humic acid 10 kg/ha + micronutrients mixture (foliar spray) |
| T ₆ | RDF + humic acid 0.1 % + micronutrients mixture (foliar spray) |
| T ₇ | RDF + humic acid 10 kg/ha + humic acid 0.1 % + micronutrients mixture (foliar spray) |

Note: Micronutrient mixture contains: 0.5% Zn + 0.2% B + 0.5% Mn

RDF - The recommended dose of fertilizer *viz.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha applied through water soluble fertilizer. Soil application of humic acid was applied through drenching after transplanting and foliar spray of humic acid was apply after 30 days, whereas foliar spray of micronutrients mixture were applied 45 days after transplanting. The sources of micronutrients were zinc sulphate (23% Zn and 11% S), Borex (11% B) and Manganese Sulphate (23-28% Mn, 2% Mg and 14-15% S).

3.4 Experimental Design and Layout:

3.4.1 Plan of Work:

The experiment was laid out in a Completely Randomized Design with 3 replications. The details are as under:

| | | | |
|--------|--------------------------|---|----------------------|
| (I) | Condition | : | Controlled polyhouse |
| (II) | Treatments | : | 7 |
| (III) | Replications | : | 3 |
| (IV) | Experimental design | : | CRD |
| (V) | Variety | : | Kian |
| (VI) | Size of individual plot | : | 9*1 m |
| (VII) | Total number of plot | : | 21 |
| (VIII) | Number of plant per plot | : | 36 |

3.5 Crop Raising:

3.5.1 Raising of the Nursery:

For greenhouse cultivation of cucumber, the seedlings were raised on soil-less media in plastic protrays having cells of 2” in size. A mixture of coco-peat, vermiculture and perlite @ 3:1:1 was used as a media for raising seedlings. One seed was sown in each cell. Regular watering and plant protection measures were adopted. Nutrients were applied in the form of N:P:K (1:1:1) @ 140 ppm once a week through the fine sprinkler to maintain the uniformity in application of nutrients. The seedlings were ready for transplanting within 15 days.

3.5.2 Bed Preparation:

The raised beds were prepared having length of 27 meter, width of 1 meter and height of 45 cm above the ground level for the experimental purpose. Basal dose of vermicompost @ 100 quintals per hectare was applied and thoroughly mixed in the soil one week before transplanting.

3.5.3 Transplanting:

Two weeks old seedlings at 2-3 true leaf stage were transplanted at 45 cm x 30 cm spacing. Transplanting was done in the evening and watering was done thereafter.

3.5.4 Intercultural Operations:

First hoeing and weeding was applied after 15 days of transplanting and second was after 20 days of first weeding in all the treatments to keep plots weed free.

3.5.5 Plant Protection Measures:

To protect the crop from the attack of insect and pests like aphids, whitefly and thrips, imidacloprid (0.04%) was sprayed at ten days intervals as a precautionary measure after transplanting. Besides, to protect the crop from fungal disease as *Fusarium* root rot, a fungicide mancozeb @ 2.0 g/litre of water was sprayed at fortnightly intervals during the entire experimental period.

3.5.6 Harvesting:

Fruits were harvested when they were more or less cylindrical and well sized and subsequent harvesting was done three times a week.

3.6 Methodology Used for Recording Observations:

To assess the impact of various treatments on growth, yield and quality of cucumber grown under polyhouse condition, the following observations were recorded. The detail of methodology adopted for recording data are as under:

3.6.1 Vegetative Characteristics:

(I) Vine length (cm):

Vine length of five randomly selected plants was measured with the help of meter scale from the base of the vine to its tip at the time of last picking and average length of vine was calculated and expressed in centimeter.

(II) Number of branches per vine:

Total numbers of primary branches of the individual plants were counted at the time of final harvest from five tagged plants and average was calculated.

(III) Leaf area (cm²):

Leaf area is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area in broadleaf canopies.

3.6.2 Yield and Yield Attributing Characters:

(I) Number of fruits per vine:

Number of marketable fruits were counted at each picking and summed for all the picking for each plot. Average number of fruits per vine was calculated after dividing total number of fruits by total number of plant.

(II) Fruit weight (g):

The weights of ten fresh fruits harvested at horticulture maturity stage from randomly selected five plants were taken and average weight of fruit were calculated and expressed in g.

(III) Fruit Length (cm)

The length of ten fresh fruits harvested at horticulture maturity stage from randomly selected five plants was taken and average length of fruit was calculated and expressed in cm.

(IV) Fruit volume (cc):

The volumes of ten fresh fruits harvested at horticulture maturity stage from randomly selected five plants were taken and average volume of fruit was calculated and expressed in cubic centimeter.

(V) Fruit diameter (cm):

Ten randomly selected fruits used for measuring their diameter. The diameter of the fruit was measured with the help of vernier caliper in centimeter at the centre of each fruit and average was calculated.

(VI) Yield per vine (kg):

Mature fruits were harvested periodically in each treatment separately and the weight was recorded with the help of digital balance. Then cumulative total of all harvesting was calculated and expressed in kg/vine.

(VII) Yield per square meter (kg):

The yield of fruits per sq. meter was calculated by multiplying the average yield of fruits per vine with the number of plants per sq. meter and expressed in kilogram per square meter.

3.6.3 Qualitative characters:

(I) Moisture content (%):

The moisture content of the fruits was determined by taking known weight of fresh fruit dried in oven at 60°C till constant weight was obtained. The moisture content of fruit was calculated by using following formula:

$$\text{Moisture (\%)} = \frac{\text{Fresh weight of fruits (g)} - \text{Dry weight of fruits (g)}}{\text{Fresh weight of fruits (g)}} \times 100$$

Fresh weight of fruits (g)

3.6.4 Leaf and fruit analysis:

Composite leaf and fruit samples using sharp knife were collected, from five randomly selected plants.

- 1 Leaf analysis after 50 days of transplanting (Zn, B and Mn)
2. Leaf analysis after 100 days of transplanting (Zn, B and Mn)
3. Fruit analysis after 50 days of transplanting (Zn, B and Mn)
4. Fruit analysis after 100 days of transplanting (Zn, B and Mn)

3.6.4.1 Method of analysis:

Leaf and fruit nutrients analysis:

To determine the nutrient status of plant before and after the application of treatment following methodology was adopted.

Analysis of plant leaves:

| Nutrient | Method |
|------------------|---|
| Zinc | Estimated from digested aliquot of digestion using Atomic Absorption Spectrophotometer |
| Boron | Colorimetric method |
| Manganese | DTPA-TEA (diethylenetriamine pentaacetic acid - triethanolamine) |

Collection of leaf sample:

1. A composite sample of 30 leaves from all the direction of the plant was collected.
2. Samples were collected when there was minimum loss of leaf moisture *i.e.* early morning or late evening.
3. Samples were collected and kept in paper bag and shifted immediately to the laboratory.
4. Samples were washed thoroughly and quickly (0.2%) dilute by detergent solution to remove waxy coating on the leaf surface. It was diluted by N/10 HCL

solution to remove heavy metals like manganese, boron and zinc etc. followed by distilled water to remove acid and detergent residue and finally in double distilled water.

5. After cleaning, samples were put in a paper bag and placed in hot oven at 70°C for 24 hours.

6. After drying, samples were ground and were stored in clearly labeled polythene bags for further analysis work.

Preparation of plant extract:

Five gram of dried leaf powder was taken in flask, pre- digestion was carried out with 20 ml of HNO₃ on water bath for 30 minutes later on and it was switched over to a hot plate for 15 minutes. The contents of digestion flask were cooled slightly and then 5 ml of ternary acid (a mixture of HNO₃, H₂SO₄ and HClO₄ in the ratio of 10:1:4, respectively) was added to each sample. Digestion was continued on the hot plate to its completion. The residue was poured into 50 ml centrifuge tube. The solutions were then centrifuged for 10 minutes and clear supernatant solutions was immediately decanted into 100 ml volumetric flask and the volume was brought up to the mark with glass distilled water in each case.

3.7 Economics of the treatments:

The economics of different treatments were determined on the basis of cost of treatment and yield per hectare. The net income was calculated by subtracting the treatment cost from gross income. It was expressed net income.

Gross return (Rs. ha⁻¹) = Return from bulk yield

Net return (Rs. ha⁻¹) = Gross return-Total cost of cultivation

$$\text{B:C ratio} = \frac{\text{Net return (Rs ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.8 Statistical Analysis:

The data recorded for various characters were subjected to CRD and interpretations of the data were carried out in accordance to Panse and Sukhatme (1985). ANOVA for this given below;

| Source of variance | d.f. | SS | MSS | Fcal |
|--------------------|--------|-----|-----|---------|
| Treatment | (t-1) | SST | MST | MST/MSE |
| Error | t(n-1) | SSE | MSE | |
| Total | | | | |

*5 % level of significance. ** At 1% level of significance

4. EXPERIMENTAL RESULTS

Results of the experiment entitled “**Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber (*Cucumis sativus* L.) under Polyhouse Condition**” conducted at the Hi-Tech Unit, Department of Horticulture, Rajasthan College of Agriculture, Udaipur during the year 2014-15 are presented in this chapter. The data pertaining to various characters were used for evaluation and statistically analyzed to test their significance and analysis of variance has been given in Table 4.1 to 4.9. The graphical depiction of data for various plant attributes has also been included for better understanding.

4.2.1 Vegetative Characteristics:

The data on vegetative growth characteristics such as vine length, number of branches per vine and leaf area were recorded and presented in Table 4.1 and depicted in Fig. 4.1. The analysis of variance is given in Appendix I.

4.1.1 Vine length (cm)

The data revealed that the vine length was significantly influenced by various treatments having a range of 216.33 cm to 304.33 cm. The maximum vine length (304.33 cm) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by treatment T₆ (RDF + Humic acid 0.1% foliar spray + micronutrients) with a value of (277.67 cm) whereas, minimum vine length (216.33 cm) was observed in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for vine length in treatments T₂ and T₃ were at par with each other.

4.1.2 Number of branches per vine

The data reveals that the maximum number of branches per vine was significantly influenced by various treatments, maximum value (9.0) of this trait was observed for treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) and T₆ (RDF + Humic acid 0.1% foliar spray + micronutrients) followed by (8.6) treatment T₅ (RDF + Humic acid 10 kg/ha + micronutrients) while, minimum value (7.4) for this trait have been observed in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for number of branches per plant for treatments T₃, T₄ and T₅ were at par with each other.

4.1.3 Leaf area (cm²)

It is revealed from data presented in Table 4.1 that application of humic acid and micronutrients significantly increased leaf area in cucumber under polyhouse condition.

On the basis of data, the maximum leaf area (484.91 cm²) was observed in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by (475.53 cm²) treatment T₆ (RDF + Humic acid 0.1% foliar spray + micronutrients) while, minimum (423.36 cm²) in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for leaf area in treatments T₂, T₃, T₄ and T₅ were at par with each other.

4.2 Yield Characteristics:

The effect of humic acid and micronutrients on yield characters of cucumber under polyhouse condition such as number of fruit plant⁻¹, fruit weight (g), fruit diameter (cm), fruit length (cm), volume of fruit (cc), yield kg plant⁻¹ and yield kg per square meter were data are presented in Table 4.2, 4.3 and 4.4 and depicted in Fig. 4.2 to 4.4. The analyses of variance of these characters are given in Appendices II to IV.

4.2.1 Number of fruits per vine

The data pertaining to effect of humic acid and micronutrients showed significant difference on number of fruit per vine of cucumber under polyhouse condition as shown in Table 4.2 and depicted in Fig 4.2.

Results revealed that, maximum number of fruits per vine (28.10) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by treatment T₆ (RDF + Humic acid 10 kg/ha + micronutrients) having a value of (26.90) whereas, minimum value (20.80) for this trait was recorded for treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for number of fruits per vine in the treatments T₄, T₅ and T₆ were at par with each other.

4.2.2 Fruit weight (g)

It is revealed from data presented in Table-4.2 and Fig. 4.2 that application of humic acid and micronutrients significantly increased fruit weight in cucumber under polyhouse condition.

The data showed the maximum weight of fruit (125.00 g) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar

spray + micronutrients) followed by treatment T₆ (RDF + Humic acid 10 kg/ha + micronutrients) having value of 123.00 g whereas, minimum fruit weight (115.86 g) was recorded in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for fruit weight in the treatments T₁, T₂ and T₃ were at par with each other.

4.2.3 Fruit length (cm)

The data pertaining to effect of humic acid and micronutrients showed significant difference on fruit length of cucumber under polyhouse condition as shown in Table 4.3 and depicted in Fig. 4.2.

The maximum fruit length (17.50 cm) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + micronutrients) followed by (17.39 cm) treatment T₆ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) while, minimum fruit length (15.78 cm) was recorded in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for fruit length in treatments T₂, T₃, T₄ and T₅ were at par with each other.

4.2.4 Fruit diameter (cm)

The data pertaining to effect of humic acid and micronutrients showed significant effect on fruit diameter of cucumber under polyhouse condition and presented in Table 4.3 and depicted in Fig. 4.3.

Results showed maximum fruit diameter (3.10 cm) in the treatment T₆ (RDF + Humic acid 0.1% foliar spray + micronutrients) followed by (2.96 cm) treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) whereas, minimum fruit diameter (2.86 cm) was observed in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for diameter in treatments T₁, T₂, T₃ and T₄ were at par with each other.

4.2.5 Fruit volume (cc)

An examination of data presented in Table-4.3 clearly showed that fruit volume was significantly increased by applying humic acid and micronutrients.

However, the data showed that maximum volume of fruit (109.71 cc) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by (108.61 cc) treatment T₅ (RDF +

Humic acid 10 kg/ha soil application + micronutrients) as compared to minimum fruit volume (101.78 cc) in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha). Values obtained for fruit volume in treatments T₅ and T₆ were at par with each other.

4.2.6 Yield per vine (kg)

It is depicted from the data presented in Table 4.4 that the effect of humic and micronutrients had significant influence on yield per vine of cucumber under polyhouse condition.

Results revealed that, highest yield per vine (3.51 kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by treatment T₆ (RDF + Humic acid 10 kg/ha soil application + micronutrients) having value of 3.30 kg as compared to lowest yield (2.82 kg) in treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha). Values obtained for yield per vine in treatments T₁, T₂, T₃, T₄ and T₅ were at par with each other.

4.2.7 Yield per square meter (kg)

The data pertaining to effect of humic acid and micronutrients showed significant effect on yield per square meter of cucumber under polyhouse condition and presented in Table 4.4 and depicted in Fig. 4.4.

On the basis of analysis it was reported that treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) gave maximum yield per square meter (10.96 kg/m²) followed by treatment T₆ (RDF + Humic acid 10 kg/ha soil application + micronutrients) having value of 10.31 kg/m² whereas, the least yielder was treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha) having value of 8.81 kg/m². Values obtained for yield per square meter in treatments T₁, T₂, T₃, T₄ and T₅ were at par with each other.

4.3 Quality Characteristics:

The effects of humic acid and micronutrient on quality characters of cucumber under polyhouse condition such as moisture content were studied. The data are presented in Tables 4.2. The analysis of variance of this character is given in Appendix II.

4.3.1 Moisture content (%)

The data regarding moisture content was not significantly affected by humic acid and micronutrients. Results are presented in Table 4.2 and graphical depiction in Fig. 4.2.

The data reveals that there was not significant difference of treatments on moisture content of cucumber was observed. However it ranges between 90.86 to 93.10 per cent.

4.4 Leaf Analysis at 50 Days after Transplanting:

The data pertaining to leaf nutrient status such as zinc, boron and manganese content at 50 days after transplanting were analyzed and presented in Table 4.5. The analysis of variance has been given in Appendix V.

4.4.1 Zinc Content of leaf (mg/kg)

A perusal of data presented in Table 4.5 revealed that zinc content was significantly influenced by various treatments of humic acid and micronutrients.

The highest value of zinc content of leaf (24.37 mg/kg) was recorded in treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by T₅ (RDF + Humic acid 10 kg/ha soil application + micronutrients) having value of 22.78 mg/kg as compared to lowest value (18.45 mg/kg) in treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for zinc content in treatments T₅ and T₆ were at par with each other.

4.4.2 Boron Content of leaf (mg/kg)

A perusal of data presented in Table 4.5 revealed that boron content was significantly influenced by various treatments of humic acid and micronutrients.

The data indicated that maximum boron content in leaf (18.48 mg/kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) whereas, minimum boron content in cucumber leaf (12.06 mg/kg) was recorded in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for boron content in treatments T₄ and T₅ were at par with each other.

4.4.3 Manganese Content of leaf (mg/kg)

A perusal of data presented in Table 4.5 revealed that manganese content was significantly influenced by various treatments of humic acid and micronutrients.

The maximum manganese content in cucumber leaf (24.07 mg/kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by treatment T₅ (RDF + Humic acid 10 kg/ha soil application + micronutrients) having value of 23.66 mg/kg as compared to lowest (20.29 mg/kg) in treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for manganese content in treatments T₃ and T₄ were at par with each other.

4.5 Leaf Analysis at 100 Days after Transplanting

The data pertaining to leaf nutrient status such as zinc, boron and manganese content at 100 days after transplanting were analyzed and presented in Table 4.6. The analysis of variance has been given in Appendix- VI.

4.5.1 Zinc Content of leaf (mg/kg)

A perusal of data reveals that zinc content was significantly influenced by various treatments of humic acid and micronutrients.

The maximum zinc content in cucumber leaf (25.08 mg/kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrient) followed by treatment T₆ (RDF + Humic acid 0.1% + Humic acid 10 kg/ha soil application + micronutrients) having value of 24.17 mg/kg as compared to minimum zinc content (20.01 mg/kg) in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha). Values obtained for zinc content in treatments T₃, T₄ and T₅ were at par with each other.

4.5.2 Boron Content of leaf

A perusal of data reveals that boron content was significantly influenced by various treatments of humic acid and micronutrients.

The data indicated that maximum boron content in leaf (20.01 mg/kg) was recorded in the treatment T₆ (RDF + Humic acid 0.1% + Humic acid 10 kg/ha soil application + micronutrients) followed by treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) having value of 19.88 mg/kg whereas, minimum boron content in cucumber leaf (14.00 mg/kg) was recorded in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha

and potash@75 kg/ha). Values obtained for boron content in treatments T₃, T₄ and T₅ were at par with each other.

4.5.3 Manganese Content of leaf

A perusal of data revealed that manganese content was significantly influenced by various treatments of humic acid and micronutrients.

The maximum manganese content in cucumber leaf (25.13 mg/kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) and treatment T₆ (RDF + Humic acid 0.1% + Humic acid 10 kg/ha soil application + micronutrients) having value of followed by treatment T₅ (RDF+ Humic acid 10 kg/ha soil application + micronutrients) having value of 24.29 mg/kg as compared to (21.14 mg/kg) treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha). Values obtained for manganese content in treatments T₄ and T₅ were at par with each other.

4.6 Fruit Analysis at 50 Days after Transplanting:

The data pertaining to fruit nutrient status such as zinc, boron and manganese content at 50 days after transplanting were analyzed and presented in Table 4.7. The analysis of variance has been given in Appendix-VII.

4.6.1 Zinc Content of fruit

A perusal of data presented in Table 4.7 revealed that there is no significant difference have been observed in zinc content by various treatments of humic acid and micronutrients.

The data indicated that maximum zinc content in cucumber fruit (42.01 mg/kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) whereas, minimum zinc content in fruit (38.00 mg/kg) was recorded in treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha).

4.6.2 Boron Content of fruit

A perusal of data presented in Table 4.7 revealed that there is no significant difference have been observed in boron content by various treatments of humic acid and micronutrients.

The maximum boron content in cucumber leaf (17.94 mg/kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) whereas, minimum boron content in fruit (15.76 mg/kg) was recorded in treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha).

4.6.3 Manganese Content of fruit

A perusal of data presented in Table 4.7 revealed that there is no significant difference have been observed in manganese content by various treatments of humic acid and micronutrients.

The maximum manganese content in cucumber fruit (25.11 mg/kg) was recorded in the treatment of T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) whereas, minimum manganese content (24.44 mg/kg) was found in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha).

4.7 Fruit Analysis at 100 Days after Transplanting:

The data pertaining to fruit nutrient status such as zinc, boron and manganese content at 100 days after transplanting were analyzed and presented in Table 4.8. The analysis of variance is given in Appendix VIII.

4.6.1 Zinc Content of fruit

A perusal of data presented Table 4.8 revealed that zinc content was significantly influenced by various treatments of humic acid and micronutrients.

The data indicated that maximum zinc content in fruit (44.66 mg/kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) whereas, minimum zinc content in cucumber fruit (39.67 mg/kg) was recorded in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash@75 kg/ha). Values obtained for zinc content in treatments T₁, T₂, T₃ and T₄ were at par with each other.

4.6.2 Boron Content of fruit

A perusal of data presented in Table 4.8 revealed that boron content was significantly influenced by various treatments of humic acid and micronutrients.

The maximum boron content in cucumber leaf (21.11 mg/kg) was recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by treatment T₅ (RDF + Humic acid 10 kg/ha soil application + micronutrients) having value of 19.19 mg/kg as compared to minimum boron content (16.07 mg/kg) in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha). Values obtained for boron content in treatments T₁, T₂ and T₃ were at par with each other.

4.6.3 Manganese Content of fruit

A perusal of data presented in Table 4.8 revealed that manganese content was significantly influenced by various treatments of humic acid and micronutrients.

The maximum manganese content in cucumber fruit (28.86 mg/kg) was found in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) followed by treatment T₆ (RDF + Humic acid 0.1% + micronutrients) having value of 27.34 mg/kg whereas, minimum manganese content in fruit (25.14 mg/kg) was recorded in the treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha). Values obtained for manganese content in treatments T₁, T₂, T₃ and T₄ were at par with each other.

4.8 Economics of the treatments:

The data presented in Table 4.9 and depicted in Fig-4.9 it was observed that maximum net returns (Rs. 173770 per 1000 m²) and benefit: cost ratio (1.73) was observed in the treatment T₇ (RDF + humic acid 10 kg/ha soil application + humic acid 0.1% foliar spray + micronutrient mixture foliar spray) followed by T₆, T₅, T₄ and T₃, where as minimum net returns (Rs. 122150 per 1000 m²) and B:C ratio (1.24) was recorded in treatment T₁ (RDF *i.e.* nitrogen@100 kg/ha, phosphorus@75 kg/ha and potash @75 kg/ha).

5. DISCUSSION

The results of the investigation entitled "Effect of Humic acid and Micronutrients on Growth, Yield and Quality of Cucumber under Polyhouse Condition" showed significant variation in most of the traits studied. Efforts have been made to discuss the significant findings of the experimental results in this chapter. Pertinent literatures of other workers have been cited in order to support the findings of the present investigation.

5.1 Vegetative Characteristics:

It is evident from the data presented in the preceding chapter that various treatments had significant effect on most of the characters of cucumber under polyhouse condition.

Effect of humic acid and micronutrients had significant influence on vine length of cucumber under polyhouse condition. Maximum vine length was reported in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients). This significant increase may be due to shoot promoting effect of humic substances and its effect on root activity and nitrate root-shoot distribution that in turn causes changes in the root-shoot distribution of certain cytokinins, polyamines and abscisic acid thus affecting shoot growth in cucumber (Mora *et al.*, 2010). Similar trend in tomato was also reported by Adani *et al.* (1998) and Lulakis *et al.* (1995).

The data presented in (Table 4.1) revealed that the treatment of humic acid and micronutrients had resulted in significant increase in number of branches per plant of cucumber under polyhouse condition. Highest number of branches per plant was reported in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients). It was probably due to the humic acid rise in chlorophyll and leaf N, P, K content and K concentration increased number of branches in cucumber (Kazemi, M. 2010) and involvement of zinc in the synthesis of tryptophan which is a precursor of indole acetic acid synthesis, consequently it increased the growth of tissue and development. The present results are supported by the finding of Albayrak *et al.* (2005) in turnip.

Leaf area was also significantly influenced by humic acid and micronutrients, this trait is an important variable for most physiological and agronomic studies involving plant growth, light interception, photosynthetic efficiency, evapo

transpiration and response to fertilizers and irrigation. Maximum leaf area was reported in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients mixture). This significant increase may be due to influence of humic acid by increasing the absorption of ions, by facilitating the distribution of heavy metals as chelates within the plant and by affecting metabolic reactions of cucumber and the high water and mineral consumption of plants (Rauthan *et al.*, 1981). Importance of Zn in auxin production is evident where leaf extension is increased when Zn applications are increased from deficient to sufficient (Zhang and Wu, 1989). Similar trends in greenhouse plants were also reported by Atiyeh *et al.* (2002) and Arancon *et al.* (2006).

5.2 Yield and Yield Attributing Characteristics:

Among the various yield and yield attributing characters number of fruits per vine, fruit weight, fruit length, fruit volume, fruit diameter, yield per vine and yield per square meter were recorded in the present investigation. All the yield attributing traits were found to be significantly influenced by effects of treatments.

The data presented in Table 4.5 clearly exhibited that effect of humic acid and micronutrients had significant impact on number of fruits per vine of cucumber. Maximum number of fruits per vine was recorded in the treatment T₇ (RDF+ Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients). This significant increase was probably due to humic acid and micronutrients which influence the respiration-process, the amount of sugars, amino acids and nitrate accumulated and make the plants resistant against diseases and viruses and increase number of fruits per vine of cucumber (Unlu *et al.*, 2011). The greener and healthier leaves produced by the plants adequately supplied with Mn and Zn were better able to support the development of fruit by the plant and significantly increased the total number of fruit (Ruano *et al.*, 1988). These findings are quite analogous with the finding of Karakurt *et al.* (2009) in bell pepper.

Effect of humic acid and micronutrients had a significant influence on fruit weight of cucumber under polyhouse condition. Maximum fruit weight and fruit length was measured in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients). This might be due to humic acid lead to increased fruit weight through positive physiological effect such as impact of metabolism of plant cells, photosynthesis and increasing the concentration of leaf chlorophyll of cucumber (Sure *et al.*, 2012). The results of the present study are in close conformity with Shehata *et al.* (2012) in cucumber.

The data further revealed that effect of humic acid and micronutrients had significant effect on fruit diameter of cucumber under polyhouse condition. Maximum fruit diameter was measured in the treatment T₇ (RDF+ Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) and maximum fruit volume was measured in the treatment T₆ (RDF+ Humic acid 0.1% foliar spray + micronutrients mixture), increased volume of fruit might be due to humic acid is a which contain many elements which improve the soil fertility and increasing the availability of nutrient elements and consequently affects plant growth and yield attributes of cucumber (Shehata *et al.*, 2012). Similar findings have also been reported by Karakurt *et al.* (2009) in bell pepper and Unlu *et al.* (2011) in cucumber.

Effect of humic acid and micronutrients had significant influence on yield per vine and yield per square meter of cucumber under polyhouse condition. Maximum yield per vine was measured in the treatment T₇ (RDF+ Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients) and maximum yield per square meter was also measured in the treatment T₇ (RDF+ Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients). This increment in yield might be due to hormone like activity of the humic acid through their participation in cell respiration, photosynthesis, protein synthesis and various enzymatic reaction and increase yield of cucumber (Heli *et al.*, 2005). Humic acid and micronutrients plays an essential role in the development and growth of new cell in the plant meristem, improves the fruit quality and fruit set. Significant effects of treatment combinations on yield were also reported by Alpaslan *et al.* (2001) in cucumber and Yildirim, E. (2011) in tomato.

5.3 Qualitative Characteristic:

The qualitative trait was found to be non-significantly influenced by effects of humic acid and micronutrients. Maximum moisture content was observed in the treatment T₄ followed by T₃.

5.4 Leaf Nutrient Status:

The results of the present experiment revealed that leaf nutrient status with respect to zinc, boron and manganese content were significantly influenced by humic acid and micronutrients application during the experiments.

Maximum zinc and boron content of leaf was observed in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients). This may be due to zinc and boron enhanced photosynthesis activity,

resulting into the increased production and accumulation of carbohydrates and favorable effect on vegetative growth and retention of flowers and fruits, which might have increased number and weight of fruits and affecting the structural integrity and controlling the permeability of root cell membranes (Sivaiah *et al.* 2013). Increased yield in response to micronutrients (B, Zn and mixture) have been reported by Davis *et al.* (2003) in tomato and Hakan *et al.* (2006) in pepper.

5.5 Fruit Nutrient Status after 100 days of transplanting:

The data further reveal that maximum zinc and boron content in the capsicum fruit were recorded in the treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients mixture foliar spray). This might be due to application of either Mn or Zn significantly improved the growth and development of leaves, confirming the essentiality of these nutrients to plant growth and development. Effect of zinc and boron application as it acts as a catalyst in the oxidation and reduction process together with an indirect action on the metabolism of soil microorganisms and dynamics of uptake of soil nutrients. Mn and Zn both contribute to chlorophyll and auxin production, respectively (Dursun *et al.*, 2002).

6. SUMMARY

The experiment entitled "Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber (*Cucumis sativus* L.) under Polyhouse Condition" was conducted during August, 2014 to February, 2015 at Hi-Tech Horticulture Unit, Department of Horticulture, Rajasthan College of Agriculture, Udaipur. The results obtained and discussed in the preceding chapter have been summarized as below:

- Vegetative characteristics like vine length, number of branches per vine and leaf area were significantly influenced by effect of humic acid and micronutrients. Treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrient mixture) gave maximum vine length (304.33 cm) and leaf area (484.91 cm²). Whereas, number of branches per vine were maximum for treatment T₇ and T₆ having equal value of 9.0.
- Yield and yield attributing characteristics like number of fruits per vine, fruit weight, fruit length, fruit volume, fruit diameter, yield per vine and yield per square meter were significantly influenced by effects of humic acid and micronutrients. Treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrient mixture) recorded significantly higher number of fruits per vine, fruit weight, fruit length, fruit volume having values of 28.10, 125.00 g, 17.50 cm and 109.71 cc, respectively. Effect of humic acid and micronutrients also significantly influenced on fruit diameter. Treatment T₆ (RDF + Humic acid 0.1% foliar spray + micronutrient mixture) was significantly superior for fruit diameter.
- The effects of humic acid and micronutrients on yield per vine and yield per square meter were significant. The treatment T₇ (RDF+ Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrient mixture foliar spray (0.5% Zn + 0.2% Boron + 0.5% Mn) was found to be significantly superior with the highest yield per vine and per square meter with values of (3.51 kg) and (10.96 kg/m²), respectively.
- The moisture content were found to be non-significantly influenced by effect of humic acid and micronutrients. However, the maximum value of moisture content (93.10 %) was observed for treatment T₄ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray).

- The effect of humic acid and micronutrients had significant effect on zinc, boron and manganese content in leaf at 50 day after transplanting and non significantly influence on zinc, boron and manganese content in fruit at 50 day after transplanting in cucumber under polyhouse condition. The maximum zinc content in leaf (24.37 mg/kg), boron content in leaf (18.48 mg/kg), manganese content in leaf (24.07 mg/kg), zinc content in fruit (42.01 mg/kg), boron in fruit (17.94 mg/kg) and manganese in fruit (25.11 mg/kg) was recorded in treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients mixture).
- The zinc, boron and manganese content in leaves and fruit of cucumber at 100 day after transplanting were significantly influenced by humic acid and micronutrients under polyhouse condition. The maximum zinc content in leaf (25.08 mg/kg), manganese content in leaf (25.13 mg/kg), zinc content in fruit (44.66 mg/kg), boron in fruit (21.11 mg/kg) and manganese in fruit (28.86 mg/kg) was recorded in treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + micronutrients mixture).
- As far as economics of the treatments are concern. It has been observed that T₇ was found best as it gave maximum gross return Rs. 274000/- per 1000 square meter, net return Rs. 173770/- per square meter and benefit cost ratio of 1.73.

7. CONCLUSION

On the basis of results obtained in the present investigation entitled “Effect of Humic Acid and Micronutrients on Growth, Yield and Quality of Cucumber (*Cucumis sativus* L.) under Polyhouse Condition” it was concluded that among the treatments used in experiment, treatment T₇ (RDF + Humic acid 10 kg/ha soil application + Humic acid 0.1% foliar spray + Micronutrients mixture foliar spray (0.5% Zn + 0.2% Boron + 0.5% Mn) was found best as it gave maximum yield per vine as well as per square meter. Further it was significantly superior in various yield attributing characteristics like number of fruits per vine, fruit weight, fruit length, fruit volume and fruit diameter. As far as economics is concerned maximum gross return (Rs. 274000 per 1000 square meter), net return (Rs. 173770 per 1000 square meter) and B.C ratio (1.73) were obtained in same treatment.

Table 4.1 Effect of humic acid and micronutrients on vine length, number of branches per plant, and leaf area of cucumber under polyhouse condition

| S.No | Detail of Treatment | Vine length (cm) | No. of branches plant⁻¹ | Leaf area (cm²) |
|-------------|---|-------------------------|---|-----------------------------------|
| 1. | RDF (control) | 216.33 | 7.4 | 423.36 |
| 2. | RDF + Humic acid 10 kg/ha (soil application) | 234.33 | 8.0 | 433.71 |
| 3. | RDF + Humic acid 0.1 % (foliar spray) | 236.67 | 8.2 | 440.81 |
| 4. | RDF + Humic acid 10 kg/ha + Humic acid 0.1 % (foliar spray) | 251.00 | 8.3 | 449.33 |
| 5. | RDF + Humic acid 10 kg/ha + micronutrient mixture (foliar spray) | 263.67 | 8.6 | 460.37 |
| 6. | RDF + Humic acid 0.1% + micronutrient mixture (foliar spray) | 277.67 | 9.0 | 475.53 |
| 7. | RDF + Humic acid 10 kg/ha + Humic acid 0.1% + micronutrient mixture | 304.33 | 9.0 | 484.91 |
| 8. | SEm+ | 4.00 | 0.2 | 11.88 |
| 9. | CD 5% | 12.13 | 0.5 | 36.04 |

Table 4.2 Effect of humic acid and micronutrients on moisture content, number of fruit per vine, fruit weight of cucumber under polyhouse condition.

| S.No | Detail of Treatment | Moisture (%) | Number of Fruits per vine | Fruit weight (g) |
|-------------|---|---------------------|----------------------------------|-------------------------|
| 1. | RDF (control) | 92.41 | 20.80 | 115.86 |
| 2. | RDF + Humic acid 10 kg/ha (soil application) | 92.86 | 21.90 | 116.97 |
| 3. | RDF + Humic acid 0.1 % (foliar spray) | 92.97 | 22.80 | 117.06 |
| 4. | RDF + Humic acid 10 kg/ha + Humic acid 0.1 % (foliar spray) | 93.10 | 24.90 | 119.12 |
| 5. | RDF + Humic acid 10 kg/ha + micronutrient mixture (foliar spray) | 90.86 | 26.20 | 121.86 |
| 6. | RDF + Humic acid 0.1% + micronutrient mixture (foliar spray) | 91.02 | 26.90 | 123.00 |
| 7. | RDF + Humic acid 10 kg/ha + Humic acid 0.1% + micronutrient mixture | 92.86 | 28.10 | 125.00 |
| | | 1.729 | 0.914 | 1.26 |

| | | | | |
|----|--------------|-------|-------|------|
| 8. | SEm+ | | | |
| 9. | CD 5% | 5.246 | 2.774 | 3.82 |

Table 4.3 Effect of humic acid and micronutrients on fruit length, fruit diameter and fruit volume of cucumber under polyhouse condition.

| S.No. | Detail of Treatment | Fruit length (cm) | Fruit diameter (cm) | Fruit volume (cc) |
|-------|--|-------------------|---------------------|-------------------|
| 1. | RDF (control) | 15.78 | 2.86 | 101.78 |
| 2. | RDF + Humic acid 10 kg/ha (soil application) | 16.45 | 2.88 | 102.53 |
| 3. | RDF + Humic acid 0.1 % (foliar spray) | 16.77 | 2.87 | 103.41 |
| 4. | RDF + Humic acid 10 kg/ha + Humic acid 0.1 % (foliar spray) | 17.10 | 2.89 | 104.98 |
| 5. | RDF + Humic acid 10 kg/ha + micronutrient mixture (foliar spray) | 17.06 | 2.95 | 108.61 |
| 6. | RDF + Humic acid 0.1% + micronutrient mixture (foliar spray) | 17.39 | 3.10 | 107.07 |

| | | | | |
|----|---|-------|------|--------|
| 7. | RDF + Humic acid 10 kg/ha + Humic acid 0.1%+micronutrient mixture | 17.50 | 2.96 | 109.71 |
| 8. | SEm+ | 0.25 | 0.05 | 0.27 |
| 9. | CD 5% | 0.77 | 0.15 | 0.83 |

Table 4.4 Effect of humic acid and micronutrients on yield (kg/vine) and yield (kg/sqm) of cucumber under polyhouse condition.

| S.No. | Detail of Treatment | Yield (kg/vine) | Yield (kg/sqm) |
|-------|--|-----------------|----------------|
| 1. | RDF (control) | 2.82 | 8.81 |
| 2. | RDF + Humic acid 10 kg/ha (soil application) | 2.88 | 9.00 |
| 3. | RDF + Humic acid 0.1 % (foliar spray) | 2.92 | 9.12 |
| 4. | RDF + Humic acid 10 kg/ha + Humic acid 0.1 % (foliar spray) | 2.96 | 9.25 |
| 5. | RDF + Humic acid 10 kg/ha + micronutrient mixture (foliar spray) | 3.19 | 9.96 |
| | RDF + Humic acid 0.1% + micronutrient | 3.30 | 10.31 |

| | | | |
|----|---|-------|-------|
| 6. | mixture (foliar spray) | | |
| 7. | RDF + Humic acid 10 kg/ha + Humic acid 0.1% + micronutrient mixture | 3.51 | 10.96 |
| 8. | SEm+ | 0.002 | 0.009 |
| 9. | CD 5% | 0.007 | 0.027 |

Table 4.5 Effect of humic acid and micronutrients on leaf nutrient status of cucumber at 50 days after transplanting under polyhouse condition.

| S.No | Detail of Treatment | Zn (mg/ kg) | B (mg/ kg) | Mn (mg/ kg) |
|------|---|----------------|------------|----------------|
| 1. | RDF (control) | 18.45 | 12.06 | 20.29 |
| 2. | RDF + Humic acid 10 kg/ha (soil application) | 20.46 | 13.64 | 21.25 |
| 3. | RDF + Humic acid 0.1 % (foliar spray) | 21.09 | 14.58 | 21.95 |
| 4. | RDF + Humic acid 10 kg/ha + Humic acid 0.1 % (foliar spray) | 19.94 | 15.47 | 22.00 |

| | | | | |
|----|---|-------|-------|-------|
| 5. | RDF + Humic acid 10 kg/ha + micronutrient mixture (foliar spray) | 22.78 | 15.84 | 23.66 |
| 6. | RDF + Humic acid 0.1% + micronutrient mixture (foliar spray) | 22.58 | 16.83 | 23.50 |
| 7. | RDF + Humic acid 10 kg/ha + Humic acid 0.1% + micronutrient mixture | 24.37 | 18.48 | 24.07 |
| 8. | SEm+ | 0.53 | 0.37 | 0.19 |
| 9. | CD 5% | 1.62 | 1.13 | 0.57 |

Table 4.6 Effect of humic acid and micronutrients on leaf nutrient status of cucumber at 100 days after transplanting under polyhouse condition.

| S.No | Detail of Treatment | Zn (mg/kg) | B (mg/kg) | Mn (mg/kg) |
|------|--|------------|-----------|------------|
| 1. | RDF (control) | 20.01 | 14.00 | 21.14 |
| 2. | RDF + Humic acid 10 kg/ha (soil application) | 21.33 | 15.92 | 21.89 |
| 3. | RDF + Humic acid 0.1 % (foliar spray) | 22.61 | 17.02 | 22.49 |

| | | | | |
|----|---|-------|-------|-------|
| 4. | RDF + Humic acid 10 kg/ha + Humic acid 0.1 % (foliar spray) | 23.05 | 17.17 | 23.04 |
| 5. | RDF + Humic acid 10 kg/ha + micronutrient mixture (foliar spray) | 23.85 | 18.47 | 24.29 |
| 6. | RDF + Humic acid 0.1% + micronutrient mixture (foliar spray) | 24.17 | 20.01 | 25.13 |
| 7. | RDF + Humic acid 10 kg/ha + Humic acid 0.1% + micronutrient mixture | 25.08 | 19.88 | 25.13 |
| 8. | SEm+ | 0.37 | 0.20 | 0.11 |
| 9. | CD 5% | 1.15 | 0.62 | 0.33 |

Table 4.7 Effect of humic acid and micronutrients on fruit nutrient status of cucumber at 50 days after transplanting under polyhouse condition.

| S.No | Detail of Treatment | Zn (mg/kg) | B (mg/kg) | Mn (mg/kg) |
|------|--|------------|-----------|------------|
| 1. | RDF (control) | 38.00 | 15.76 | 24.44 |
| 2. | RDF + Humic acid 10 kg/ha (soil application) | 38.65 | 16.33 | 24.58 |

| | | | | |
|----|--|-------|-------|-------|
| 3. | RDF + Humic acid 0.1 % (foliar spray) | 38.80 | 16.83 | 24.71 |
| 4. | RDF + Humic acid 10 kg/ha + Humic acid 0.1 % (foliar spray) | 39.03 | 17.62 | 24.67 |
| 5. | RDF + Humic acid 10 kg/ha + micronutrient mixture (foliar spray) | 41.87 | 17.78 | 25.07 |
| 6. | RDF + Humic acid 0.1% + micronutrient mixture (foliar spray) | 41.89 | 17.88 | 25.09 |
| 7. | RDF+ Humic acid 10 kg/ha + Humic acid 0.1% + micronutrient mixture | 42.01 | 17.94 | 25.11 |
| 8. | SEm+ | 1.34 | 0.56 | 0.187 |
| 9. | CD 5% | 4.05 | 1.70 | 0.566 |

Table 4.8 Effect of humic acid and micronutrients on fruit nutrient status of cucumber at 100 days after transplanting under polyhouse condition.

| S.No | Detail of Treatment | Zn (mg/ kg) | B (mg/kg) | Mn (mg/kg) |
|------|---------------------|----------------|--------------|---------------|
| 1. | RDF (control) | 39.67 | 16.07 | 25.14 |

| | | | | |
|----|---|-------|-------|-------|
| 2. | RDF + Humic acid 10 kg/ha (soil application) | 40.04 | 16.72 | 25.17 |
| 3. | RDF + Humic acid 0.1 % (foliar spray) | 40.20 | 17.91 | 26.11 |
| 4. | RDF + Humic acid 10 kg/ha + Humic acid 0.1 % (foliar spray) | 40.66 | 18.52 | 26.77 |
| 5. | RDF + Humic acid 10 kg/ha + micronutrient mixture (foliar spray) | 44.51 | 19.19 | 27.04 |
| 6. | RDF + Humic acid 0.1% + micronutrient mixture (foliar spray) | 44.38 | 19.09 | 27.34 |
| 7. | RDF + Humic acid 10 kg/ha + Humic acid 0.1% + micronutrient mixture | 44.66 | 21.11 | 28.86 |
| 8. | SEm+ | 0.43 | 0.24 | 0.08 |
| 9. | CD 5% | 1.33 | 0.75 | 0.24 |

Table 4.9 Effect of humic acid and micronutrients on economics of treatments (1000m²)

| S.No. | Detail of Treatment | Yield (ton/1000m ²) | Total cost of cultivation | Gross return (₹) | Net return(₹) | B.C. Ratio |
|-------|---------------------|------------------------------------|------------------------------|---------------------|------------------|---------------|
| 1. | T ₁ | 8.81 | 98100.00 | 220250 | 122150 | 1.24 |
| 2. | T ₂ | 9.00 | 98960.00 | 225000 | 126040 | 1.27 |
| 3. | T ₃ | 9.12 | 99060.00 | 228000 | 128940 | 1.30 |
| 4. | T ₄ | 9.25 | 99560.00 | 231250 | 131690 | 1.32 |
| 5. | T ₅ | 9.96 | 99630.00 | 249000 | 149370 | 1.49 |
| 6. | T ₆ | 10.31 | 99370.00 | 257750 | 158380 | 1.59 |
| 7. | T ₇ | 10.96 | 100230.00 | 274000 | 173770 | 1.73 |

*cucumber rate- ₹ 25/ kg⁻¹

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