Iron Supply of Cucumbers in Substrate Culture with Humate

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Keywords: Cucumber, Soilless culture, Greenhouse, Iron supply, Humic acid

Abstract

The aim of the experiments was to investigate the effect of application of a well soluble Fe-humate (HUMIRON®) on rhizosphere and leaves, respectively, on the growth and yield of cucumbers (*Cucumis sativus* cv. Jessica). HUMIRON® type R (extracted from Russian coal) and G (extracted from German coal) were compared. In the first experiment three different concentrations (0.001%, 0.1%, and 0.2%) of HUMIRON® were used in three different growing stages of cucumber plants. In the second experiment HUMIRON-G® and K-humate were applied to the upper or lower surface of the cucumber leaves. Cucumbers were grown in a substrate culture used containers with 8 l perlite. Nutrient solution with and without iron was applied with trickle irrigation. The results clearly show the application of Fe-humate has beneficial effects on the plant growth and the fruit yield if the nutrient solution had a lack of iron. Iron imbalances or deficiency can be counteracted by application of Fe-humate to the root zone. The additional iron supply did not inhibit the growth and decrease the yield even if the iron supply in the nutrient solution is sufficient. The different effects of the humate types (HUMIRON R and G, K-humate) compared here indicate that the influence of humate can be important.

INTRODUCTION

Plant cultivation in hydroponical systems is quite problematic concerning the proper balancing of the nutrient supply. According to previous investigations, humates seem to have a particular favourable effect on the nutrient supply. Therefore the application of humates was tested as an approach to improve both the nutrient balance and plant vitality.

Humates can stimulate the uptake of macro- and microelements. Tattini et al. (1990) and Adani et al. (1998) found that humic acid promotes the uptake of N, P, Fe and Cu of tomato and other plants. The positive effect of humic acid on the uptake of N, P, Fe and Zn was also proved with corn plants (Fortun and Lopez, 1982). Moreover, humates influence the respiration-process, the amount of sugars, amino acids and nitrate accumulated, and make the plants resistant against diseases and viruses. Nevertheless it is very important to stabilize the supply of macroelements; much more essential for plant growth in substrate culture is the sufficient supply with microelements. Often there are disorders of them especially there is iron deficiency. It is assumed that humic acids have special importance for transportation and availability of microelements in the plants (David et al., 1994). Chlorosis could be prevented, by humate application; probably because the availability of iron was enhanced (Fortun and Lopez, 1982; Alvarez et al., 1996; Kreij, de and Hoeven, 1997).

So far, NH_4-, K- or Ca-humates have been used and positive effects on plant growth could be proved (Hoang, 2003). The background of these effects, however, is not completely clarified. But it can be assumed that the effects are not explicable with the content of nutrient applied together with the humates because their concentration is very low. Now, humates with a high content of metal-ions are available. This amount of metal-ions bound on humate could influence the content of micronutrients in the nutrient solutions directly.

The aim of theses experiments was to investigate the effect of application of a well soluble Fe-humate (HUMIRON®) on rhizosphere and leaves, respectively on the growth and yield of cucumbers.

MATERIALS AND METHODS

Plant Material and Growing Conditions

Plants of *Cucumis sativus* L. cultivar Jessica were used for both experiments. For the first experiment cucumber seeds were sown on 7th of October. The plants were transplanted on 28th of October. For the second experiment seeds were sown on 12th of January 2003. Planting was conducted on 28th of January.

Cucumbers were grown in a substrate culture with trickle irrigation. The containers were filled with 8 l perlite. Perlite with an average dry density of 120 kg * m^{-3} was used. The grain size was between 0.06mm and 1.5mm, with 45% of all grains having been 1mm in diameter. Pore volume was 84% v/v, the water holding capacity was 45% v/v, and the air capacity was 39%. The standard nutrient solution (Boehme, 1993) was used with complete macro- and micronutrients (170 ppm N, 50 ppm P, 260 ppm K, 150 ppm Ca, 60 ppm Mg, 3 ppm Fe, 90 ppm HCO_3, 80 ppm S) and compared with the same nutrient solution but without iron addition. The containers were irrigated with a trickle irrigation system. 'Netafim' drippers with a capacity of 2 l h^{-1}were used. The plants were irrigated 2 to 4 times a day and 150ml per irrigation cycle was applied in periods of 10-12 min. The salt concentration (EC) in the nutrient solution was between 2.0 and 2.4 mS cm^{-2}, the pH value ranged from 5.8 till 6.5. For the first experiment artificial light was supplied with lamps of type PL-90 E and a radiation power of 120W m^{-2} was used between 7:00 and 19:00h to guarantee 10 Klux. In the second experiment the PAR ranged from 40 to 70 Wm^{-2}. Night temperature did not drop below 18°C, day temperature was kept around 22°C and relative humidity was, approximately, 70%.

Humate Treatments

In the first experiment two types of HUMIRON® (Humintech GmbH, Germany) were compared; one type contains humic acid extracted from a Russian coal (R) and the other humic acid from a German coal (G). The humates were applied on the root zone. In the second experiment HUMIRON-G®and K-humate were applied to the upper or lower surface of the cucumber leaves. Per plant 20 ml humate were applied. For root zone treatment three different concentrations (0.001%, 0.1%, and 0.2%) of HUMIRON® were used. For leaf application a 0.05% HUMIRON-G® and K-humate solution was used. Plants were treated three times in weekly intervals in following development stages: first treatment: 5-6 leaves stage; second: 7-8 leaves stage; third: 9-10 leaves stage.

Data Collection and Evaluation

For the root zone treatment (first experiment) the plants have been cultivated during the winter time (07-10-2002 till 14-02-2003). Harvesting started in January. The second experiment for leaf application of humates was conducted from January 2003 till April 2003. Harvesting started at 15th of March.

Parameters as leaf area and fruit yield were recorded weekly. Harvests for 10 days were pooled and evaluated together. Fresh weight of leaves and shoots were measured in the end of the vegetation. Values of pH and EC in the nutrient were estimated weekly.

Statistics

The experiment comprised 6 plants per treatment (2 x 3 replicates) randomized distributed. Data were evaluated by ANOVA (SPSS) and the statistic tests Chi square (Pearson) and Tukey-test.

RESULTS AND DISCUSSION

In the beginning of the experiment the pH of the substrate in all variants treated with HUMIRON® was about 7.5. Weekly this value decreased up to a pH of 5.8. Remarkably although the pH dropped no precipitation of the humates could be observed.

Vegetative Growth

The fresh matter of stems and leaves was affected by the application of HUMIRON® (data not shown). The additional iron supply through HUMIRON® enhanced fresh matter of stems and leaves in comparison with the control. The effect, however, was dependent on the type of HUMIRON® used. It seemed that Type R was more effective than type G. If no iron was added to the nutrient solution, the application of HUMIRON® enhanced the fresh matter considerably.

The application of low concentration of humates stimulated the leaf growth in the second experiment (Fig. 3). HUMIRON® R was less effective than K-humate. Due to high variability of the leaf area in each variant the differences could not to be proved to be significant. More information maybe is available if the leaf area index is calculated.

Yield

The yield was clearly dependent on the iron supply and was reduced to a half if to the standard nutrient solution no iron was added (Fig. 1). Moreover, the harvest was delayed in this treatment. If to the nutrient solution iron was added, first cucumbers could be harvested 8 weeks after transplanting. In the variant without iron in nutrient solution the harvest started one week later. The treatment with HUMIRON® could counteract this iron deficiency in respect to the number of fruits harvested and the beginning of harvest (Fig. 1 and 2). Counting the number of harvested fruits after application of HUMIRON® even in the iron deficient nutrient solution in total the same number or even more fruit could be harvested like in the control with standard nutrient solution (Fig. 1). If 0.001% HUMIRON® G was applied the total yield was even higher than in the control with the complete nutrient solution.

Additional iron supply to that in the nutrient solution with the humate seems to be not inhibiting apart from 0.2% HUMIRON® G if the number of fruits is considered (Fig. 1). The mean number of harvested fruits in 10 days (Fig. 2), however, indicates that sometimes at least in tendency after HUMIRON application fewer fruit were harvested compared to the control. In this respect more investigations are necessary also concerning the frequency and amount of Fe-humate application.

The source from which humic acid was extracted (different coals, peat or other organic materials) had remarkable effects on plant growth in former experiments (Levinsky, 1996; Hoang, 2003). In this experiment two types of humic acid extracted from coals with different origin were compared. Only the highest concentration of HUMIRON® G had an inhibiting effect on the plant growth and yield regardless the nutrient solution was iron free or not (Figs. 1 and 2). With lower concentration the influence of HUMIRON® type was not so evident. Nevertheless, also this factor should be taken into account in further experiments.

A common activity to counteract iron deficiencies is foliar spraying of iron chelates like EDDHA. In the second experiment therefore the foliar application of Fe-humate was investigated. Foliar application of other humates affected growth in cucumber as shown in previous experiments (Böhme et al., 2001), the use of Fe-humate, however, was not investigated so far. According to the results from first experiment, a low concentration of HUMIRON® was used. It is obvious that also the application of humates over the leaves affected the yield (Fig. 4). The number of fruit was higher after humate application. In this experiment the standard nutrient was used therefore the iron supply was not limiting factor for plant growth. This could be the reason why Fe-humate had not so high effects as K-humate. Unfortunately, the yield in this experiment was very low also due to the short cultivation period; therefore statistics sometimes could not prove the differences. Nevertheless the effect of humate applied as Fe or K formulation enhanced the yield and much more interesting the quality of cucumbers. The amount of non-marketable fruit decreased considerably after spraying humates (Fig. 5). The effect of Fe-humate to counteract chlorosis due to iron deficiency has to be investigated in further experiments.

CONCLUSIONS

The results show that HUMIRON® can be used to improve plant growth and yield in substrate culture of cucumber. It is possible to apply HUMIRON® in the rhizosphere and on leaves as well. The effect was dependent on the concentration used and 0.2% HUMIRON® was inhibiting for yield. Further experiments have to be done concerning application frequency.

In these experiments plants did not exhibit symptoms of iron deficiency although also nutrient solution without iron addition was used. Therefore we assumed that iron supply was not really limiting in our system and conclude that HUMIRON® can be used as additional factor to improve plant growth and yield. The additional iron supply did not inhibit the growth and decrease the yield even if the iron supply in the nutrient solution was sufficient. The efficiency of Fe-HUMIRON® to counteract chlorosis as strong symptom of iron deficiency has to be investigated in further experiments.

To prove if the effects found are due to the iron applied with the humate or to the humate itself in the experiments other iron chelates should be included. The different effects of the humate types (HUMIRON® R and G, K-humate) compared here indicate that the influence of humate can be important.

ACKNOWLEDGEMENT

The authors thank the Humintech GmbH for supplying the humates used in these experiments.

Literature Cited

Adani, F., Genevini, P., Zaccheo, P. and Zocchi, G. 1998. The effect of commercial humic acid on tomato plant growth and mineral nutrition. J. Plant Nutrition 21(3), 561-575.

Alvarez, F.A., Ganate, A., Juarez, M., Lucena, L.L., Jolley, V.D. and Romheld, V. 1996. Tomato acquisition of iron from iron chelates in a calcareous sandy substrate. J. Plant Nutrition 19, 1279-1293.

Böhme, M. 1993. Parameters for calculating nutrient solution for hydroponics. Eighth international congress on soilless culture, Hunters Rest, Proceedings, Wageningen, 85-96.

Böhme, M., Hoang, T.L. and Vorwerk, R. 2001. Effect of different substrates and mineral as well as organic nutrition on the growth of, cucumber in closed substrate system. Acta Hort. 548, 165-172.

David, P.P., Nelson, P.V. and Sanders, D.C. 1994. A humic acid improves growth of tomato seedling in solution culture. J. Plant Nutrition 17(1), 173-184.

Kreij, C. de and Hoeven, B. 1997. Effect of humic substances, pH and its control on growth of chrysanthemum in aeroponics. Ninth international congress on soilless culture, Jersey, Proceedings, Wageningen, 207- 230.

Fortun C. and Lopez, C. 1982. Influence of humic acid on the mineral nutrition and the development of the maize roots, cultivated in normal nutritive solutions and lacking of Fe and Mn. Anades-de Edafologia-y-agrobiologia (Spain). Jan-Feb/ 1982, V. 41(1-2) p. 335-349.

Hoang, T.L. 2003. Untersuchungen zur Wirkung von Huminsäure auf das Wachstum und die Nährstoffaufnahme von Tomaten (*Lycopersicon esculentum* MILL) und Wasserspinat (*Ipomoea aquatica* NORSSK). PhD thesis, Humboldt-Universität zu Berlin, Landwirtschaftlich-Gärtnerische Fakultät.

Levinsky, B. 1996. Everything about Humates. Eastern Siberia, Irkutsk, Russia. Book translated by R. Faust (www.Humic. com).

Tattini, M., Chiarini, A., Tafani, R. and Castagneto, M. 1990. Effect of humic acids on growth and nitrogen uptake of container-grown olive (*Olea europaea* L. 'Maurino'). Acta Hort. 286, 125-128.

Tables

Table 1. Experimental design.

Biostimulators		**Nutrient solution**	
Compound	**Concentration**	**Standard**	**Without iron**
	0 (control)	X	X
HUMIRON Fe 8% (R)	0.001%	X	X
HUMIRON Fe 8% (R)	0.1%	X	X
HUMIRON Fe 8% (R)	0.2%	X	X
HUMIRON Fe 8% (G)	0.001%	X	X
HUMIRON Fe 8% (G)	0.1%	X	X
HUMIRON Fe 8% (G)	0.2%	X	X

Figures

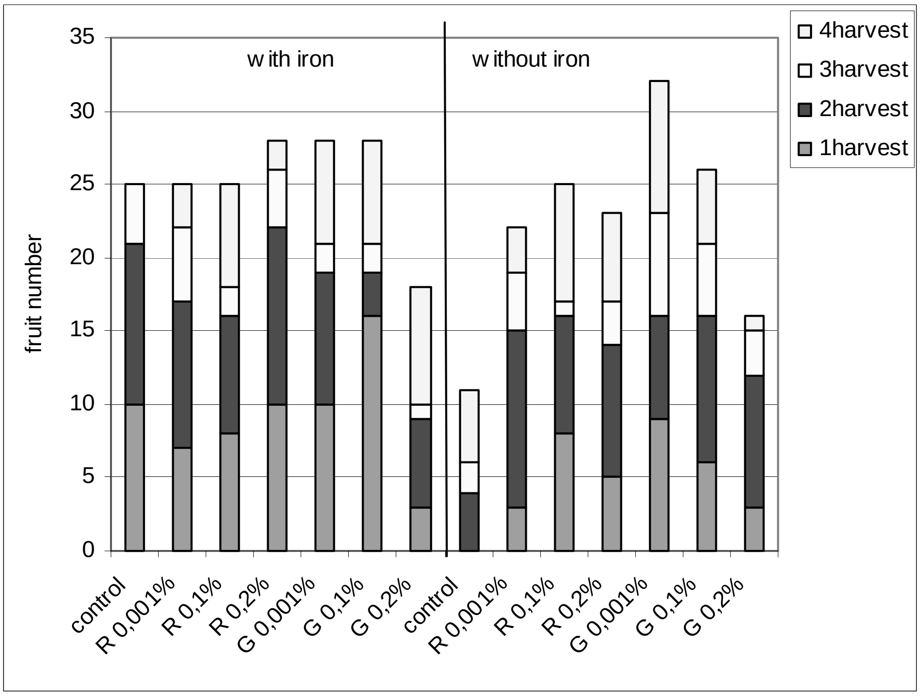

Fig. 1. Effect of HUMIRON R and G application on root zone in combination with standard nutrient solution and nutrient solution without iron addition on total number of fruit harvested in four harvesting periods of 10 days each. No significant differences (Chi-square-test, P=0.05).

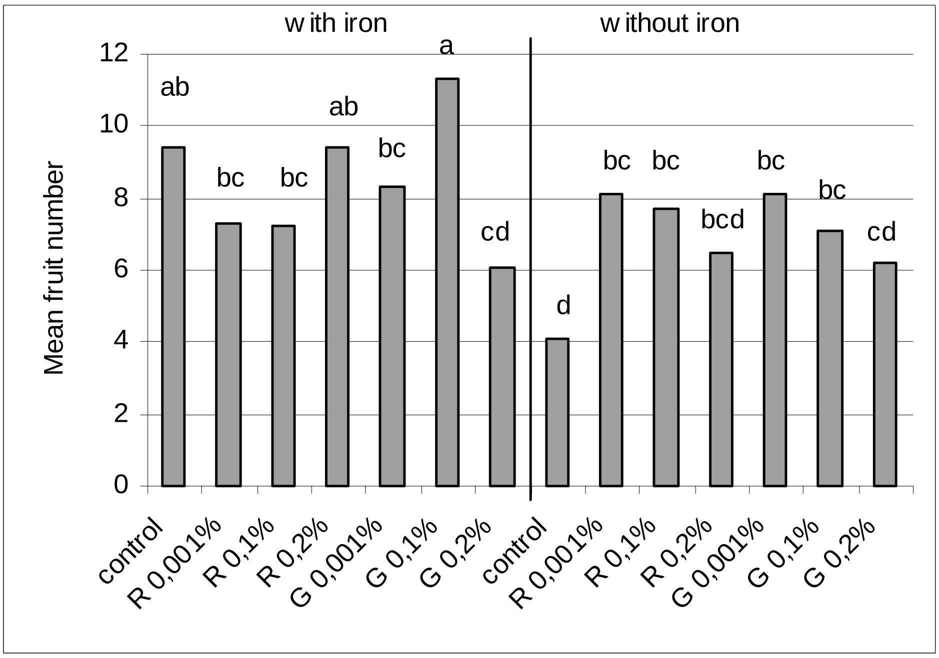

Fig. 2. Effect of HUMIRON R and G application on root zone in combination with standard nutrient solution and nutrient solution without iron addition on mean yield per plant in 10 days. Different letters indicate significant differences (Tukey test, P=0.05).

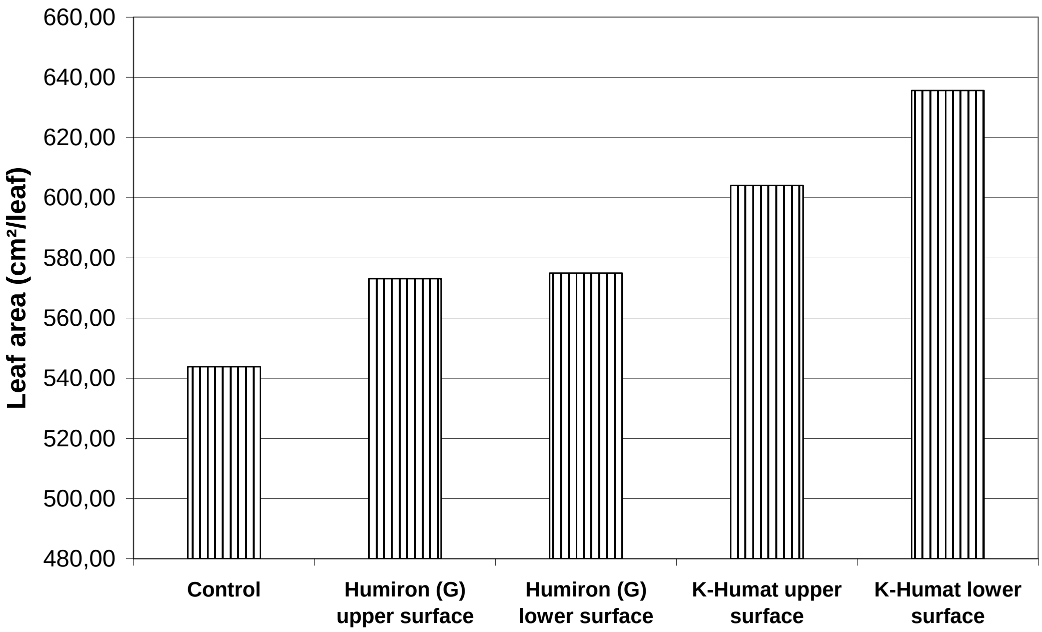

Fig. 3. Effect of HUMIRON G and K-Humat application on upper and lower surface of the leaf on the leaf area. No significant differences (Tukey test, P=0.05).

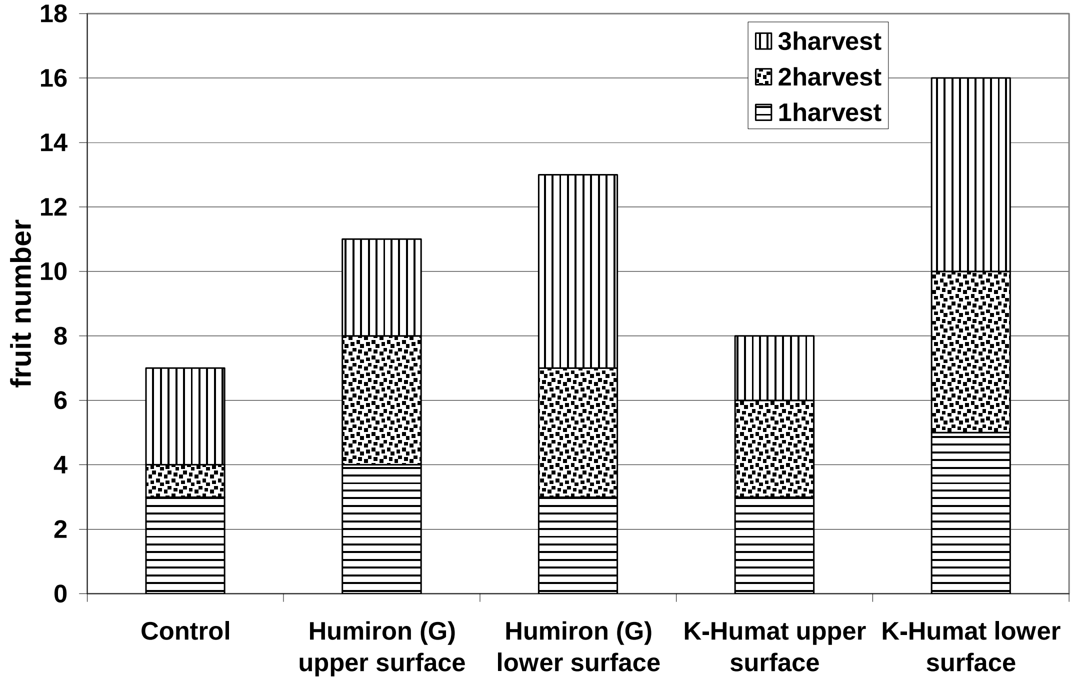

Fig. 4. Effect of HUMIRON G and K-Humat application on upper and lower surface of the leaves on the fruit number. No significant differences (Chi-square-test, P=0.05).

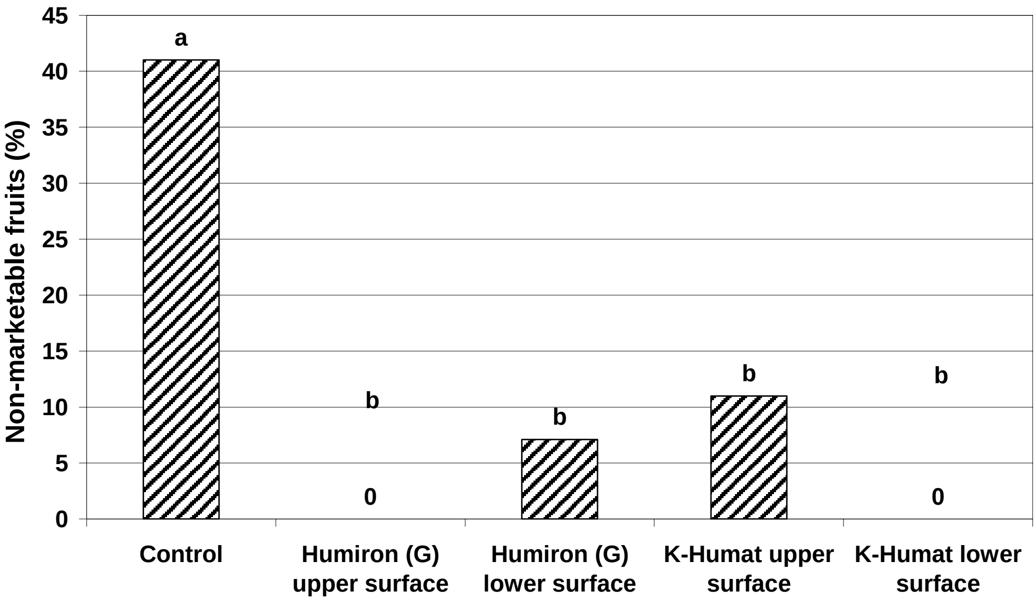

Fig. 5. Effect of HUMIRON G and K-Humat application on upper and lower surface of the leaves on the non-marketable fruits (Tukey test, P=0.05).