Original Research Article

Agronomic Response of Bell Pepper to the Aplicatión of Ultrasol Chile® in Fertigatión to the Open Field

ABSTRACT

Aims: Determinethe agronomic response of the bell pepper grown in open field to the application of the Ultrasol chile® fertilizer via fertigation.
To determine

Study design: Was with the completely randomized model with five treatments (T0 or control, 0.6, 0.8, 1.0 and 1.2 g L^{-1} of Ultrasol chile®) and four repetitions each. The comparison of means was by Tukey ≤.05.
It was

Place and Duration of Study: Experimental fields "the Bajío" Buenavista, Plant Breeding Department of the Universidad Autónoma Agraria Antonio Narro. between June 2019 to december 2019.D

Methodology: In bell pepper five treatments were applied(T0 or control, 0.6, 0.8, 1.0 and 1.2 g L^{-1} of Ultrasol chile®). The treatments were carried out via fertigation and applied three times a week, the applications started 15 days after the transplant and until the end of the cycle.

Results: The yield behaved in a similar way with the applied doses of the fertilizer, however, they exceeded the control by more than 90%. Average fruit weight (AFW), fruit length (FL) and equatorial diameter of fruit (EDF) showed a differential statistical response, in which the application of 1 g L^{-1} of Ultrasol chile® via fertigation resulted in a better response and it surpassed the control in 120, 44 and 13.5% respectively. The height of the plant was statistically similar between the control and the 1.2 and 0.8 g L^{-1} treatments. The correlations indicate that the crop yield is a function of the AFW, FL and NFP, in turn the FL and EDF, are what determine the AFW.

Conclusion: the.....The most appropriate dose of Ultrasol chile® for bell pepper grown in the open field was 1 g L^{-1}, since it improves the average weight of fruit, equatorial diameter of fruit and length of fruit, therefore, there is feasibility in the use of this commercial formulation.

Keywords: Capsicum annuum, yield, nutritive solution, irrigation.

1. INTRODUCTION

The cultivation of chilli (*Capsicum annuum* L.) is of great importance worldwide with more than 30 million tons produced annually [1], in Mexico the cultivation of chili peppers is also of great importance with more than 159,0001.59 Lakh hectares cultivated and 3.32 million tons produced annually, of which 30 % is destined for export markets, the main destinations being the United States, Canada and Guatemala [2]. Of the planted area, 7,448 hectares correspond to bell pepper, whose average production is 83.07 tons per hectare and annual global production value of 8,218 million pesos and the states that lead the production are Sinaloa, Sonora, Jalisco, Guanajuato, Baja California Sur and Coahuila, 75 % of the area planted with bell peppers, is cultivated under some type of protected agriculture and ranges from low, medium to high technology, however, 25 % is still cultivated in the open field [3].

On the other hand, research related to the nutrition of bell pepper (*Capsicum annuum* L.) via fertigation, which is nothing more than the mixture of fertilizers dissolved in irrigation water, applied locally for the nutrition of crops, rang from the study of complete nutrient solutions [4,5], nutrient solutions combined with different nitrate/ammonium ratio [6]. Or simply with variations in nitrogen levels [7], potassium [8], calcium [9], which generally develop and focus on protected agriculture, and leave out open field production.

Similarly, studies have been carried out with nutrient solutions from the seedling stage [4,10], electrical conductivity and salinity [8,11,12], or organic fertilization [13,14,15], supplemented with microorganisms such as mycorrhizae [16,17]. Or quantifying the demand or extraction curves of nutrients [18,19,20], that undoubtedly add value and are very useful for the decision-making of the producers of this crop and of national and world agriculture in general.

However, in the market for soluble fertilizers that are applied via fertigation, apart from the best-known conventional fertilizers, there are also prepared formulations that are offered for the different stages of growth and development of crops or for specific crops. same ones that are made availableof producers to facilitate crop nutrition in the production process [21,22]. Although, related studies for the validation of these formulations are limited, scarce, previous reports are only found in tomato, with beneficial effects on the productivity and quality of fruits [23]. Under this context, there is no recent research for specific agro climatic and edaphic zones or regions in México. Therefore, the objective of this research work was to determine the agronomic response of the bell pepper crop in the open field with the application of different doses of Ultrasol chile® via fertigation.

2. MATERIAL AND METHODS

2.1. Location

The experiment was carried out in the experimental field "El bajío" of the Universidad Autónoma Agraria Antonio Narro, in Saltillo, Coahuila, México. Located at 25° 21´ 24´´ NL and 101° 02´ 05´´ WL, at 1762 meters above sea level.

2.2. Seedling Production

For this research we used the hybrid Revolución F_1 of Harris Moran® (Harris Moran, CLAUSE. SA. Rue Louis Saillant ZI La Motte 26800 Portes-Les-Valence France), The seeds were sown in polystyrene trays of 200 cavities, the germination substrate was peat moss and perlite in a proportion of 70:30 respectively. For the nutrition of the seedlings, a com-mercial formulation of N-P-K (20-30-10) added with microelements, 0.5 g L^{-1} five days after the emergency (DAE), 0.75 g L^{-1} to the 15 DAE y g L^{-1} to the 30 DAE before transplantation.

2.3. Field Establishment and Crop Management

The transplanttransplantation was carried out 45 days after the seeds had been sown, and it was carried out in a loamy soil with the characteristics described in table 1. And it was in the autumn-winter cycle of 2019, the cultivation beds were 25 cm high, the distance between beds was 1.80 m, the distance between plants 30 cm, double row per bed, in staggered rows, giving a density of 36,000 plants per hectare approximately. Irrigation was supplied by a strip hose distance between drippers was 30 cm and a flow rate of 0.75 $l.h^{-1}$. The applied treatments were the following; T0 o controlT0 /control 0.6, 0.8, 1.0 y 1.2 g L^{-1} of Ultrasol chile® respectively, all dissolved in the irrigation water with the characteristics described in table 2, each treatment consisted of four repetitions and each repetition of six measurable useful plants. The nutritive solutions with the SQM Ultrasol chile® (Santiago de Chile, Chile) fertilizer treatments whose characteristics are described in table 4,.theyThey were carried out via fertigation and applied three times a week, the applications started 15 days after the transplant and until the end of the cycle. Fort pest control (*Bemisia tabaci, Frankliniella icci-dentalis*, *Bactericera cokerelli*) weekly applications of Spirotetramat at 15.3%, Spiromesifen at 23.1%, Imidacloprid 17 % + betacylfutrin 12 % at the rate of 1 ml L^{-1} y metomilo 90%, at the rate of 1 g L^{-1} were madeprepared.

Table 1. Physicochemical characteristics of the soil fertility analysis, in which the open field cultivation of bell pepper was established.

Physico-chemical characteristics of the soil							
Textural class	Apparent density (g.cm^{-3})	pH (1:2 water)	Total carbonates (%)	Salinity (EC extract, 1:2 water) Ds/m	SP (%)	FC (%)	PWP (%)
Laomy	1.25	8.61	8.25	1.1	40	21.3	12.7
Macroelements in parts per million (ppm)							
N-NO_3	P-Olsen	S	Cl	K^+	Ca^{2+}	Mg^{2+}	Na^+
39.7	65	55.9	ND	658	3995	321	106
Microelements in parts per million (ppm)							
Fe^{3+}	Mn^{2+}	B^{3+}	Zn^{2+}	Cu^+	Mo^{2+}		OM

2.07	3.11	1.31	4.95	0.51	ND	2.06 %

SP = Saturation point, FC = Field capacity, PWP = Permanent wilting point. Methods for the soil analysis: (Ca^{2+} Mg^{2+} Na^{+} K^{+} by ammonium acetate) ($SO4^{2-}$ by turbidimetric) (NO^{3-} NO_3^- by colorimetric) (HCO^{3-} HCO_3^- Cl^- by volumetric) (Fe^{3+} Mn^{2+} B^{3+} Zn^{2+} Cu^{+} by DTPA-sorbitol pH 7) (total carbonates by ac-idacid neutralization) (Organic material by Walkley and Black method), (textural class by Boyoucos) (apparent density by modified test tube method), (SP, FC and PWP by grvimetric).

Table 2. Characteristics of the irrigation water that was used for the dissolution and application of Ultrasol chile® in different doses in the open field cultivation of bell pepper.

Macroelements in Milliequivalents L^{-1}								
NO_3^-	$H_2PO_4^-$	SO_4^{2-}	Cl^-	K^+	Ca^{2+}	Mg^{2+}	Na^+	HCO_3^-
0.41	ND	1.61	2.2	0.1	5.57	2.42	3.22	7.56
Microelements in parts per million (ppm)								
Fe^{3+}	Mn^{2+}	B^{3+}	Zn^{2+}	Cu^+	Mo^{2+}	pH	EC (Ds/m)	SAR
0.0118	0.0047	0.4	0.0891	0.0122	ND	7.5	1.15	1.61

PhpH = Hydrogen potential, EC = Electrical conductivity, SAR = Sodium absorption ratio. Methods for the irrigation water analysis: (Ca^{2+} Mg^{2+} Na^{+} K^{+} by atomic absorption spectrophotometry), ($SO4^{2-}$ SO_4^{2-} by turbidimetry), (NO^{3-} $NO3^-$ by volumetric), (HCO^{3-} Cl^- by volumetric), (Fe^{3+} Mn^{2+} B^{3+} Zn^{2+} Cu^{+} by ICP-AES), (pH by potenciometric), (EC by conductimetric) and (SAR calulcated).

Table 3. Characteristics and nutrient content of the fertilizer SQM Ultrasol chile®.

Nutrient	Content
Total nitrogen	20 %
Total phosphorus (P_2O_5)	10 %
Total potasium (K_2O)	15 %
Total boron	1000 ppm
Total molybdenum	3000 ppm
Total copper	0 ppm
Total iron	5000 ppm
Total zinc	300 ppm
Total manganese	200 ppm
EC (1g L^{-1} a 20°C)	1.5 Ds/m
pH (1g L^{-1} a 20°C)	3.1
Solubility (20°C)	250 g L^{-1}

pH = Hydrogen potential, EC = Electrical conductivity. Froam de technical sheet, Font: (SQM, 2021).

2.4. Fruit Yield Measurements and its Components

The first harvest took place on October 12, while the second harvest on November 2, 2019. The yield (gplanta^{-1}plant^{-1}) resulted from adding the weight of the fruits of each plant of the two harvests carried out, whose fruits were weighed a precision digital scale Sartorius (TS 1352Q37, Gottingen, Germany). To obtain the calculated yield in tons per hectare (t ha^{-1}), the yield of each plant was multiplied by the approximate planting density which was 36,000 plants per hectare. After weighing the fruits, the number of fruits of each plant was counted (NFP), while, the average fruit weight (AFW) was calculated dividing the total weight of fruits by the total number of fruits of each plant. While the equatorial diameter and fruit length EDF and FL respectively were estimated by randomly taking eight fruits per experimental unit in each harvest, and a Truper® digital vernier was used, Truper® (CALDI-6MP, Atlacomulco, México). The height of the plant was determined with a tape measure graduated in centimeter Truper® brand (PRO-5MEC Atlacomulco, México).

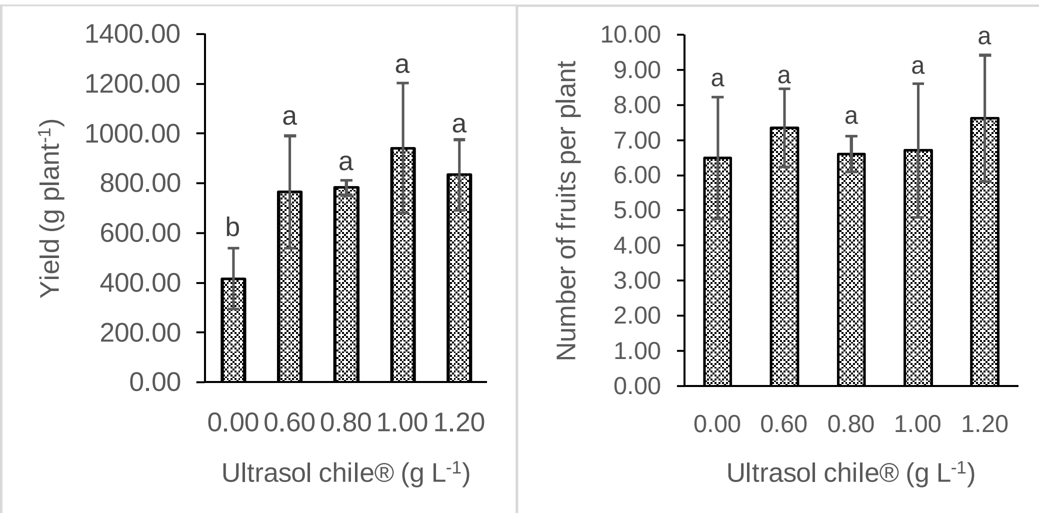
2.5. Statistical Analysis

The experimental arrangementdesign was completely random, while the statistical analysis was carried out with the program SAS 9.1. The completely randomized model was used with five treatments and four repetitions each (ANOVA *P* =.05), Tukey's test was used for the comparison of means (Tukey ≤.05).

3. RESULTS

3.1. Yield and Yield Components

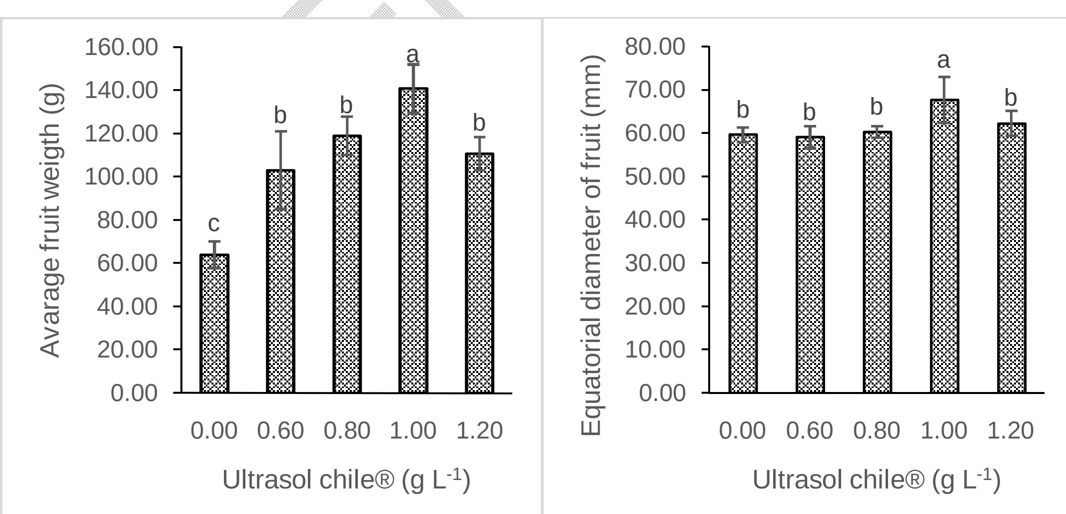
The applications of Ultrasol chile® affected yield and some of its components (ANOVA P =.05). The yield per plant behaved statistically similar with the application of Ultrasol chile® in the different doses tested. However, within doses, the application of 1 g L^{-1} with 942.31 g harvested per plant stands out, while the control treatment was statistically inferior to all the treatments tested (Figure 1A). In the variable of number of fruits per plant, no statistically significant difference was found, therefore, the crop showed a similar behavior between the doses of Ultrasol chile® tested and the control. (Figure 1B).



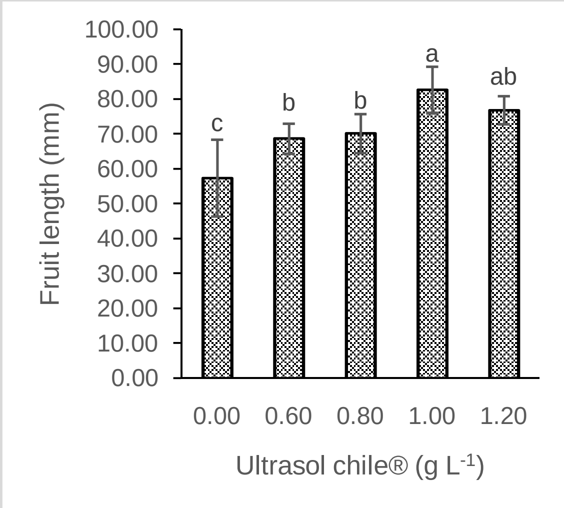
(A)(B)

Figure 1. Effect of Ultrasol chile® applications on yield (g plant^{-1}) (A) and number of fruits per plant (B). ANOVA *P*=.05, Tukey's mean test (Tukey≤.05), vertical bars correspond to standard deviation.

The average fruit weight had a differential statistical response with the treatment of 1 g L^{-1} of Ultrasol chile® with a value of 140.86 g, which exceeded the control by 120 %, which was(to be deleted) followed by the doses of 0.8, 1.2 and 0.6 g L^{-1} which also outperformed the control by more than 60 % (Figure 2A). In the variable of equatorial diameter of fruit, the treatment that was superior was with 1 g L^{-1} of Ultrasol chile® since it exceeded the control in 13.57 %, the rest of the treatments had a similar statistical behavior (Figure 2B). Regarding fruit length, the statistically superior treatments were of 1 and 1.2 g L^{-1} of Ultrasol chile® with 82.78 and 76.88 mm respectively, surpassing the control in 44 and 33 % respectively (Figure 2C).



(A)(B)



(C)

Figure 2. Effect of Ultrasol chile® applications in average fruit weight (A), equatorial diameter of fruit (B) and fruit length (C) and ANOVA *P* =.05, Tukey's mean test (Tukey≤.05), vertical bars correspond to standard deviation.

3.2. Plant Height

The height of the plant did not show a differential statistical response between the control and the doses of 1.2 and 0.8 g L^{-1} of Ultrasol chile®, while with 1 and 0.6 they turned out to be lower than those previously mentioned (Figure 3).

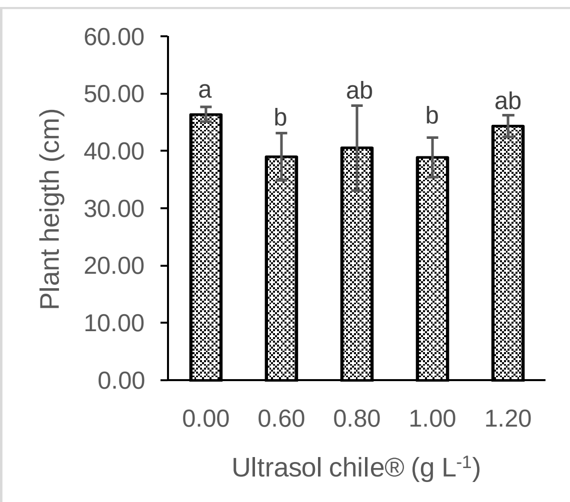


Figure 3. Effect of Ultrasol chile® applications on plant height, ANOVA *P* =.05, Tukey's mean test (Tukey≤.05), vertical bars correspond to standard deviation.

3.3. Yield per Hectare Calculated

The calculated yield per hectare is shown in Figure 4. We extrapolateand also extrapolatedthe yield obtained from each plant to tons per hectare, assuming a population density of 36,000 plants per hectare, it is observed that there is a superior behavior with the applied doses of Ultrasol chile® with respect to the control, and within the doses, the application of 1 g L^{-1} with 33.93 t ha^{-1} stands out, surpassing the control by 125 % (Figure 4), while the rest of the doses applied exceeded the control by more than 80 %.

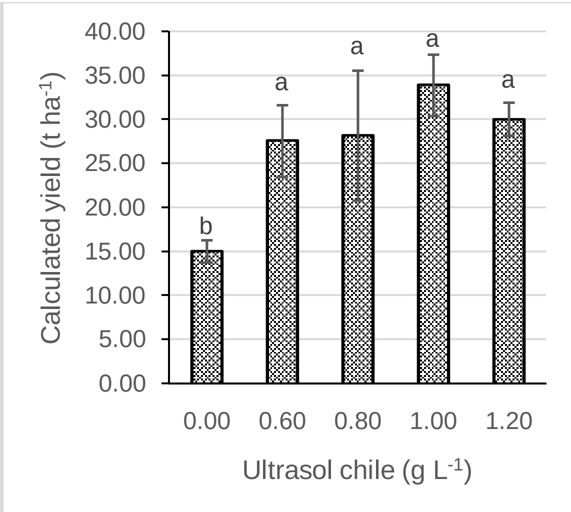


Figure 4. Effect of Ultrasol chile® applications on the calculated yield in tons per hectare. ANOVA *P* =.05, Tukey's mean test (Tukey≤.05), vertical bars correspond to standard deviation.

3.4. Correlation Coefficients Between Evaluated Variables

In table 4 of correlations, it is observed that the average fruit weight, fruit length and number of fruits per plant, are the variables that most positively influenced the yield, with correlations of 0.76, 0.66 and 0.64 respectively. The length of the fruit and the equatorial diameter of fruit are the variables that contributed the most to a greater accumulation of average fruit weight with 0.82 and 0.65 respectively. However, with the height of the plant a negative relationship of -0.60 was found, that is, the higher the average fruit weight, the lower the plant height (Table 1), which could be explained, since the fruits in growth and development have a high demand for photoassimilates and nutrients, therefore they reduce the vegetative growth of the plant. The length of the fruit positively influenced the equatorial diameter of the fruit with 0.60.

Table 4. Pearson's correlation coefficients between variables evaluated in bell pepper grown with different densities, doses of Ultrasol chile® in the open field.

	Yield	Number of fruits per plant	Avarage fruit weigth	Equatorial diameter of fruit	Fruit length
Number of fruits per plant	0.64**				
Avarage fruit weigth	0.76**	-0.21 ns			
Equatorial diameter of fruit	0.34 ns	0.14 ns	0.65**		
Fruit length	0.66*	0.14 ns	0.82**	0.60*	
plant height	-0.35 ns	0.64 ns	-0.60*	-0.14 ns	-0.41 ns

ns= not significant, *= significant *P* ≤.05, **= highly significant *P* ≤.01.

3.5. Discussion

The statistical results observed in the yield are attributed to the fact that the control did not receive exogenous application of nutrients, therefore, a nutritional deficit to optimally perform its physiological and metabolic functions and thus generate photoassimilates necessary to fill the growing fruits and developing [24]. Since the pepper crop has a high demand for primary macronutrients at the beginning of the crop, then a seasonal phase of low demand and later high demand towards the end of the cycle, and potassium is the element with the highest demand in fruiting [25].

Previous studies have indicated that the extraction ratios of N-P-K it is 12:1:12 [20], o well 3.7, 0.5, 3.5, 1.2 y 0.7 kilograms of N-P-K-Ca y Mg, for every ton of fruit produced [26], 3.02, 0.5, 3.9, 0.82 y 0.28 they also indicated [27], amounts thet were deficient in the control, given that the concentration of anions and cations in the nutrient solution determine the crop yield [8], which explains the low production of the control compared to the tested treatments.

The results similar to the control in the variable of number of fruits per plant are attributed to the fact that, probably to the nutrient content of the soil and irrigation water, they were sufficient for fruit set, however, for growth and filling, the demand for nutrients is much higher, so the contribution of the soil and water was not enough, which is evidenced in the variable of average fruit weight. The results found in the number of fruits per plant are very similar to those found when applying earthworm humus [13]. But lower when applying bocashi since with this organic fertilizer up to 14 fruits per plant are obtained [14].

It is important to note that, in general, in the response variables of yield per plant, average fruitweight, equatorial diameter of fruit and fruit length, a similar trend is observed, in which, as the dose of Ultrasol chile® increases the value of these variables, which is attributed to the supply of macronutrients and micronutrients provided by the different doses of the commercial formula Ultrasol chile® so that the plants develop their physiological and metabolic functions properly [24].

On the other hand, with the highest dose of 1.2 g L^{-1} a slight decrease was observed in the aforementioned variables, which could be due to an increase in the electrical conductivity of the applied nutrient solution, since as the dose of the commercial formula increased, consequently the electrical conductivity also increased. Under this context, an increase in the concentration of ions in the nutrient solution causes an increase in the electrical conductivity and the osmotic potential, thus decreasing the absorption of water and some nutrients by the roots of the plants, therefore, their transport to growing and developing fruits [11,24], since the fruiting is when the highest rate of absorption and accumulation of macronutrients occurs mainly [27].

Therefore, an electrical conductivity greater than 2 dS/m decreases pepper yield, but increases bioactive compounds and nutraceutical quality [8], similar effects have been reported with 3 dS/m [28]. This is due to the fact that the plants suffer abiotic stress due to moderate salinity when the electrical conductivity increases, caused by the increase in the concentration of ions in the nutrient solution [29]. For the above, the selection of electrical conductivity in the nutrient solution is a determining factor in yields and fertilization costs per crop cycle [8], since a good management of electrical conductivity is crucial in obtaining good performances and with high quality [30].

On the other hand, the results obtained in plant height are very similar to those found when applying organic fertilizers such as bocashi [14], but they differ from those reported when applying different sources and doses of calcium in the nutrient solution [9].

The yields calculated in tons per hectare obtained in this research are very similar to those reported when applying earthworm humus to open field peppers [30], but lower and different from those found under greenhouse conditions with different calcium formulations, which is due to the particular environmental conditions of greenhouse crops[9]. It has also been reported that, when the quality of individual fruit is affected, consequently, fruits of smaller size and average weight will be found [31], therefore, the quantity and quality of fruits harvested per unit area are the component that most influences the final crop yield [32].

4. CONCLUSION

According to the results, the most appropriate dose of Ultrasol chile® in fertigation for bell pepper grown in the open field was 1 g L^{-1}, since it improves the average weight of fruit, equatorial diameter of fruit and length of fruit, and these are the latter two that con-tribute the most to the yield per plant and consequently to the yield per hectare. The number of fruits per plant was not affected by the tests applied, while the height of the plant was higher with 0.0 and 1.2 g L^{-1}. The variables that determine the yield are the average weight of the fruit, the number of fruits per plant and the length of the fruit. There is feasibility in the use of commercial formulations of soluble fertilizers such as Ultrasol chile®, for the nutrition of the open field bell pepper crop.

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