Open Access Library Journal
2023, Volume 10, e10195
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Effect of Five Commercial Rooters and a Formula in Jalapeño Pepper Seedlings

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How to cite this paper: Buelna-Tarín, S., Romero-Félix, C.S., Sánchez-Soto, B.H., Lugo-García, G.A., Reyes-Olivas, Á. and Bojórquez-Ramos, C. (2023) Effect of Five Commercial Rooters and a Formula in Jalapeño Pepper Seedlings. *Open Access Library Journal*, **10**: e10195.
https://doi.org/10.4236/oalib.1110195

Received: April 29, 2023
Accepted: July 28, 2023
Published: July 31, 2023

Abstract

The jalapeño pepper (*Capsicum annuum* L.) is important for the uses it possesses, in addition to being a source of employment. Due to its importance, it is necessary to produce quality seedlings, which own the characteristics that allow them to adapt in the field or greenhouse at the time of transplantation. The objective of this study was to evaluate the effect of five nutrient-rooters and a formula on the growth and accumulation of dry root weight, dry stem weight and dry leaf weight in seedlings of two cultivars of jalapeño pepper. At least one of the treatments will obtain a positive effect on the quality of seedlings, based on the accumulation of dry weight in their organs. Six treatments were evaluated in seedlings of Bravo and Bronco cultivars of jalapeño pepper, in two completely randomized experiments, one per cultivar and with 10 repetitions. The measurements were: root length (LR), root dry weight (PSR), stem dry weight (PST), leaf dry weight (PSH) and the ratio dry weight aerial part/root dry weight (RPAR) at 15 and 30 days after seeding (DAS). The Bronco cultivar exhibited higher dry stem weight (19%), leaf dry weight (21%) and root dry weight (28%) compared to the Bravo cultivar. A differential effect was observed between the treatments evaluated, with outstanding results with the NPK 40-200-370 (ppm) formula on the nutrient-rooters because of its positive effect on the accumulation of dry root weight, dry stem weight and dry leaf weight.

Subject Areas

Agronomy

Keywords

Capsicum annuum L., Dry Weight, Treatments, Seedling Production, Cultivars

1. Introduction

Chili (*Capsicum annuum* L.) ranks second among the eight most cultivated vegetables, with an approximate production of 21.05 $t \cdot ha^{-1}$ nationwide [1]. Chili is important for its uses, such as in food, medicine, industrial and ornamental, as well as being a source of employment [2]. Given its importance, it is necessary to produce pathogen-free seedlings, which have the characteristics that allow them to adapt in the field or greenhouse at the time of transplantation; this can be achieved by producing uniform and well-developed seedlings, product of proper management, thus ensuring quality seedlings with good production [3]. Their quality is ensured by the seedling height, stem diameter, root length, nutrient concentration, number of leaves and leaf area [4] [5]; Lazcano-Bello [6] mentions that the use of high-quality seedlings in nurseries allows producers to reduce seed and plant losses in soil or substrate, the time until reaching the optimum transplant height is reduced and their adaptations are guaranteed. To achieve the above, an adequate application of nutrients is essential, which play an important role in the growth and quality of the seedlings [7] [8]. The role of each nutrient in plant physiology is well known, and it is possible to control seedling growth by manipulating their concentrations and proportions [9]. It has been determined that by applying adequate doses of nutrients, vigorous seedlings with acceptable quality for transplantation are obtained. For example, Souri [9] evaluated the effect of six nutrients on pepper seedlings (*C. annuum*) and highlight that these improved the growth of the seedlings in comparison to the control, concluding that the highest values of leaf area, number of leaves, chlorophyll index, aerial and root biomass and leaf concentration of soluble sugars, N, K, Ca and Zn were due to foliar application of amino acids and humic acids; Nieves-González [10] observed that when using different concentrations of H_2PO_4 (from 1 to 4 $mEq \cdot L^{-1}$) in cucumber and habanero pepper seedlings (*Capsicum chinense* Jacq. "Big Brother" *cv.*) the highest concentration allowed an increase to the phosphorus content in the organs of both species, and the dry weight of the habanero pepper root was higher when a lower concentration of phosphorus was supplied, concluding that cucumber and chili plants subjected to low doses of phosphorus could be at a disadvantage at the time of transplantation, due to not have a reserve of phosphorus in their tissues. Currently, the use of commercial products that promote the rooting of seedlings is being implemented, to stimulate the growth and development of vigorous roots, this being a strategy to facilitate their growth, reduce stress at the time of transplantation and increase the survival of the seedlings themselves [10] [11]. There is plenty of information regarding the yield of the fruit of the chili crop, however, despite the relevant aspects of the production of seedlings for the development of the crop, the works that emphasize the production of seedlings are scarce [12], especially when considering different types of nutrients based on phytohormones, humic and fulvic acids, macronutrients and/or micronutrients that promote the growth and development of vigorous, quality seedlings for transplanting, in order to reduce seedling mortality which is a consequence of poor root development.

The objective of this study was to evaluate the effect of five nutrient-rooters and a formula on the growth and accumulation of root dry weight, stem dry weight and leaf dry weight, in seedlings of two cultivars of jalapeño peppers.

2. Materials and Methods

This investigation was carried out in November 2015, in a tunnel-type greenhouse with a metal structure and polyethylene cover (75% light transmission), located at 25˚45'57" north latitude, 108˚49'23" west longitude and 10 m a.s.l., in the Faculty of Agriculture of Valle del Fuerte, Juan José Ríos, Ahome, Sinaloa, Mexico. In the municipality, the climate is reported as warm humid with an average annual temperature of 25.9˚C, annual minimum, and maximum temperature of 18˚C and 33.9˚C, respectively; the hottest season is from May to October, and the rainiest from July to October, with an average annual rainfall of 383.1 mm [13].

Jalapeño pepper seeds (*Capsicum annuum* L.) of the Bravo and Bronco cultivars of the Vilmorín commercial brand were used. A total of six treatments were tested, of which five are commercial rooting products: T1 (MR), T2 (R), T3 (A), T4 (EP) and T5 (RB) and T6 (40N-200P-370K), which is a formula that is in experimental use. The dose used was in accordance with the manufacturer's recommendations. Table 1 shows the dose and nutritional content of each treatment.

The treatments were evaluated under a completely randomized design with 10 repetitions (two plants per repetition) for each cultivar. Polystyrene trays with 242 cavities were used, with a volume of 24.5 mL and a depth of 6.5 cm in each cavity. As a substrate, a mixture of Canadian sphagnum PRO-MIX® Premier peat (90% - 95%), vermiculite, dolomitic and calcitic limestone and wetting agents were used. One seed was sown per cavity, then the seeds were covered with a light layer of vermiculite to preserve the humidity of the substrate. The application of the treatments was done manually in the irrigation water on the base of

Table 1. Nutrient content of the products used as treatments during this experiment.

Treatments	Nutrient contents
T1 (MR, 5 mL·L^{-1} of water)	530 ppm auxins, cytokinin 45 ppm, vitamins 500 ppm and assimilable phosphorus (P_2O_5) 15,000 ppm.
T2 (R, 10 g·L^{-1} of water)	9% N, 45% P_2O_5, 11% K_2O, 1% MgO, 0.8% S and 400 ppm auxins.
T3 (A, 0.5 g·L^{-1} of water)	11% N total, 55% P_2O_5, 0.28% naphthaleneacetic acid, 0.02% indole-3-butyric acid, 2% fulvic acids and 31.70% conditioners and inerts.
T4 (EP, 10 mL·L^{-1} of water)	5% humic acids, 0.3% naphthaleneacetic acid, 0.3% indole-3-butyric acid and 94% of inert ingredients.
T5 (RB, 1 mL·L^{-1} of water)	1% alpha naphthaleneacetic acid, 8.9% MO, 5.2% CO, 8.5% polysaccharides, 6.6% N, 1.7% N nitric, 2.6% N ammoniacal, 2.3% N urea, 4% P_2O_5, 3% K_2O, 0.1% B, 0.02% Cu chelated + EDTA, 0.4% Fe chelated + EDTA, Mn chelated + EDTA, 0.01% Mo, 0.085% Zn chelated + EDTA and 16% algae.
T6 (40N-200P-370K)	40 ppm N, 200 ppm P and 370 ppm K.

the stem, starting the applications from sowing, then every week until 40 days after sowing (dds), making a total of four applications. Of each of the products used as treatments.

At 45 days after sowing, a destructive harvest of 20 seedlings per treatment was carried out. The variables evaluated were the following: Stem dry weight (PST, mg), leaf dry weight (PSH, mg) and root dry weight (PSR, mg): they were determined by drying the samples in a wood dryer with heat lamps, until the weights were obtained. Constant dry, obtained with an analytical balance (AND A&D Weighing, HR Orion, Medellín, Antioquia, Colombia); root length, it was evaluated by measuring the total length from the nodal region to the apex of the longest root with a graduated ruler. And the dry weight ratio of the aerial part/root dry weight (RPAR), it was obtained as the ratio between the dry weight of the aerial part and the dry weight of the root [14].

An analysis of variance (ANOVA) was carried out using the Statistical Analysis Software [15] program, in combined form ($Y_{ijk} = \mu + T_i + G_j + TG_{ij} + E_{ijk}$) to determine the effects of the treatments (T), cultivars (C) and the C × T interaction. An individual ANOVA for treatments in each cultivar was also carried out. The comparison of means was made with the honest significant difference test or Tukey test (P ≤ 0.05).

3. Results

3.1. Comparison of Bronco and Bravo Cultivars

The comparison between cultivars (*cv*) showed that Bronco *cv.* outperformed Bravo in accumulating stem dry weight (19%), leaf dry weight (21%), and root dry weight (28%). While the Bravo *cv.* had greater root length compared to Bronco *cv.* There were no significant differences (P > 0.05) between cultivars for the dry weight ratio of the aerial part/root dry weight (**Table 2**).

3.2. Rooters Treatments

The ANOVA for treatments detected high values in the variables of growth and accumulation of dry weight in the vegetative organs of the plants; stem dry weight

Table 2. Stem dry weight (PST), leaf dry weight (PSH), root dry weight (PSR), aerial part/root dry weight ratio (RPAR) and root length (LR) of two cultivars of chili.

Cultivar	PST (mg)	PSH (mg)	PSR (mg)	RPAR	LR (cm)
Bravo	21.71^b	35.02^b	30.13^b	2.12^a	7.10^a
Bronco	26.78^a	44.16^a	42.04^a	1.86^a	6.32^b
Tukey ($P \leq 0.05$)	2.42	3.73	4.45	0.45	0.59
F value	17.12**	23.26**	28.23**	1.21ns	6.42*

Means with a different letter in each column indicate significant differences according to the Tukey mean comparison test ($P \leq 0.05$). * = $P \leq 0.05$, ** = $P \leq 0.01$, ns = non-significant differences ($P > 0.05$).

and leaf dry weight were higher in seedlings that received applications of treatment T6 (40N-200P-370K); root dry weight was higher with treatments T6 (40N-200P-370K) and T3 (A); the aerial part dry weight/root dry weight ratio was higher with T2 (R), T1 (MR) and T6 (40N-200P-370K); and the root length was greater with T3 (A) and T6 (40N-200P-370K) (Table 3).

3.3. Cultivars and Rooters Treatments Interaction

The Bronco *cv.* showed the maximum stem dry weight in interaction with the T6 treatment (40N-200P-370K); leaf dry weight with T6 (40N-200P-370K) and T2 (R); root dry weight with treatments T6 (40N-200P-370K), T3 (A) and T1 (MR); and the dry weight ratio of the aerial part/root dry weight with T2 (R), T6 (40N-200P-370K), T1 (MR) and T3 (A) (Table 4). The root length of Bravo *cv.* was statistically the same (P > 0.05) with all treatments (Table 4).

4. Discussion

The production of seedlings of any cultivar requires adequate management of nutrients for this purpose, seeking to have quality seedlings and reduce their stress at the time of transplantation. In this sense, Lazcano-Bello [6] considers that it is important to generate sustainable techniques to obtain seedlings of high quality, vigor and adaptability, especially seedlings with well-developed roots and rapid adaptation to stress conditions caused by transplantation [16], this can be achieved with the application of compounds based on humic and fulvic acids [17], as well as the application of adequate doses of major elements and some microelements [18].

The positive effect of the treatments T6 (40N-200P-370K), T3 (A), T2 (R) and T1 (MR) was due to the nitrogen and phosphorus they contain, which are essential for the growth and productivity of the crops [19]. In addition, treatments T2

Table 3. Stem dry weight (PST), leaf dry weight (PSH), root dry weight (PSR), aerial part dry weight/root dry weight ratio (RPAR) and root length (LR), for all treatments.

Treatments	PST (mg)	PSH (mg)	PSR (mg)	RPAR	LR (cm)
T6 (40N-200P-370K)	50.59^{a}	64.05^{a}	49.23^{a}	2.55^{ab}	7.55^{ab}
T3 (A)	32.80^{b}	46.05^{bc}	49.74^{a}	1.76^{bcd}	8.43^{a}
T2 (R)	19.32^{c}	52.80^{b}	29.33^{b}	3.27^{a}	5.31^{c}
T1 (MR)	23.55^{c}	41.54^{c}	32.915^{b}	2.19^{abc}	6.48^{bc}
T5 (RB)	11.58^{d}	19.60^{d}	30.61^{b}	1.24^{cd}	6.20^{bc}
T4 (EP)	8.36^{d}	14.22^{d}	24.68^{b}	0.92^{d}	6.29^{bc}
Tukey ($P \leq 0.05$)	6.11	9.44	11.29	1.16	1.51
F value	105.78**	68.86**	15.26**	9.38**	8.63**

Means with a different letter in each column indicate significant differences according to the Tukey mean comparison test ($P \leq 0.05$). *$P \leq 0.05$, **$P \leq 0.01$, ns = non-significant differences ($P > 0.05$).

Table 4. Cultivar and treatment interactions for stem dry weight (PST), leaf dry weight (PSH), root dry weight (PSR), aerial part dry weight/root dry weight (RPAR) ratio and root length (LR).

	PST (mg)	PSH (mg)	PSR (mg)	RPAR	LR (cm)
Bravo Cultivar					
T6 (40N-200P-370K)	42.71^{a}	53.55^{a}	42.51^{a}	2.79^{ab}	6.25^{a}
T3 (A)	28.89^{b}	39.04^{bc}	35.37^{ab}	1.87^{abc}	7.60^{a}
T2 (R)	17.23^{cd}	48.22^{ab}	21.80^{b}	3.20^{a}	5.16^{a}
T1 (MR)	22.79^{bc}	37.31^{c}	32.89^{ab}	2.15^{abc}	6.55^{a}
T5 (RB)	11.80^{de}	18.93^{d}	25.94^{b}	1.59^{bc}	6.20^{a}
T4 (EP)	7.90^{e}	14.02^{d}	22.24^{b}	1.09^{c}	6.15^{a}
Tukey ($P \leq 0.05$)	8.38	9.99	14.15	1.53	2.46
F value	37.68**	41.48**	5.89**	4.49**	1.78^{ns}
Bronco Cultivar					
T6 (40N-200P-370K)	58.07^{a}	74.04^{a}	55.95^{a}	2.32^{ab}	8.85^{a}
T3 (A)	36.70^{b}	53.07^{b}	64.11^{a}	1.64^{ab}	9.25^{a}
T2 (R)	21.42^{c}	57.39^{b}	36.85^{b}	3.35^{a}	5.45^{b}
T1 (MR)	24.31^{c}	45.77^{b}	32.94^{b}	2.22^{ab}	6.40^{b}
T5 (RB)	11.36^{d}	20.28^{c}	35.27^{b}	0.89^{b}	6.20^{b}
T4 (EP)	8.83^{d}	14.43^{c}	27.11^{b}	0.76^{b}	6.43^{b}
Tukey ($P \leq 0.05$)	8.87	16.16	18.73	1.76	1.83
F value	71.43**	33.54**	10.55**	5.38**	12.71**

Means with a different letter in each column indicate significant differences accordint to the Tukey mean comparison test ($P \leq 0.05$). *$P \leq 0.05$, **$P \leq 0.01$, ns = non-significant differences ($P > 0.05$).

(R) and T6 (40N-200P-370K) contain potassium, which participates in processes of osmo-regulation, opening and closing of stomata, efficient use of water, translocation of sugars, formation of carbohydrates, state plant energy, regulation of enzyme activities, protein synthesis and many other processes necessary to maintain plant growth and reproduction [20]. Nitrogen is a structural part of the chlorophyll molecule and is the main component of essential proteins for the formation of protoplasm [21]. Melton and Dufault [22] mention that increasing nitrogen levels improves the vegetative development of plants, while phosphorus is the macronutrient in greatest demand for plant growth and the component of several molecules that regulate physiological processes [23]. In this regard, Preciado-Rangel [24], when evaluating the growth of seedlings of chili Jalapeño N *cv.* with different concentrations of nitrogen (NH_4, 0, 1.5 and 3 mmol·L^{-1}) and phosphorus (H_2PO_4, 1, 1.5 and 2 mmol·L^{-1}), their results showed higher root dry weight when applying 1.5 mmol·L^{-1} of NH_4; while when using H_2PO_4 at a dose of

1 mmol·L^{-1} they had higher stem dry weight. Meantime, Acevedo-Alcalá [25], reported higher values in stem dry weight when applying the 20-18-20 formula at doses of 1 and 1.5 g·L^{-1}, greater root length with 0.5 and 1 g·L^{-1}, root dry weight with 0.5 g·L^{-1} and the dry weight ratio of the aerial part/root dry weight with 1 g·L^{-1} in poblano pepper seedlings in greenhouses. Additionally, the T3 (A), T2 (R) and T1 (MR) treatments contain auxins, hormones that promote and accelerate the formation of plant roots [26] [27] [28]. In addition to this, T3 (A) also contains fulvic acids, which modify the primary and secondary metabolism of plants, improve root growth and nutrient uptake by promoting flexibility and elongation of root cells [29] [30]. Vazallo [31], explain that a greater root length in the seedlings allow them to efficiently cope with the transplant and achieve rapid adaptation and absorption of water and nutrients. In other research works, no statistically significant differences were found in stem dry weight, root dry weight, root length and stem length in chili seedlings under the effect of fulvic acids [32].

The T6 treatment (40N-200P-370K), based on nitrogen, phosphorus, and potassium, was outstanding for showing high values in all the variables evaluated in both cultivars (except for the root length of Bravo *cv.*, which was the same with all the treatments). In previous studies, similar results have also been observed when applying nitrogen, phosphorus, and potassium; in this regard, García-Morales [33] registered high values for root dry weight and stem dry weight, in two native varieties of poblano pepper (Chiautzingo criollo and Cháhuac criollo) evaluated in nursery, with three foliar applications of formula 16N-40P-13K, in comparison with the control. Ramírez-Soler [34] observed an increase in the dry weight of leaves, dry weight of roots and total dry matter with respect to the control, when evaluating the effect of the application of high and low doses of N, P, K in tree tomato (*Solanum betaceum* Cav.) during the vegetative stage under greenhouse conditions. Preciado-Rangel [35] and Jiménez-Morales [8] point out that applying high concentration of nitrogen, phosphorus and potassium increased the dry weight of the stem, dry weight of the leaf and dry weight of the root in tomato seedlings.

5. Conclusion

The best treatment in seedlings development, regarding the tested variables of growth was T6 (40N-200P-370K in ppm) applied as foliar, followed by T3 (55 ppm of N, 119 ppm of P, 10 ppm of fulvic acids, 1.4 ppm of naphthaleneacetic acid and 0.1 ppm of indole-3-butyric acid). The Bronco cultivar outperformed Bravo cultivar in most of the variables. The interaction with higher values was Bronco cultivar with T6 (40N-200P-370K), showing vigorous seedlings with acceptable quality for transplantation and overcoming the interaction Bravo cultivar with T6 treatment.

Acknowledgments

The first author thanks the Consejo Nacional de Ciencia y Tecnología (CONACYT) for the scholarship granted for his master's studies in Agricultural Sciences

(CVU: 758516), to the Faculty of Agriculture of Valle del Fuerte for providing the facilities for the research, as well as to the Engineer Erick Gabriel Ríos Jiménez who provided the jalapeño pepper seed.

Conflicts of Interest

The authors declare no conflicts of interest.

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