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Application of compost tea, co-inoculation and inorganic fertilization on Swiss chard plants
Aplicación de té de composta, co-inoculación y fertilización inorgánica en plantas de acelga

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SUMMARY

Swiss chard is a horticultural crop with a highly nutritious value. These crops' production required nutrients, which can be provided through mineral nutrient solutions or biofertilizers. Biofertilizers are products that contain beneficial microorganisms that improve soil quality and that promote plant growth. Additionally, these microorganisms carry out nitrogen fixation and phosphate solubilization. The present work assessed the application of compost tea, co-inoculation (*Azospirillum* and *Glomus*), and inorganic fertilizer over the growth (roots, stem, and leaves) and nutrient content in Swiss chard (*Beta vulgaris* var. Forhook Giant) plants. The present work was carried out in a greenhouse using a randomized complete block design. Swiss chard plants treated with compost tea + inorganic fertilization (CTIF) accumulated more root and stem dry weight (4.06 and 8.10 g respectively), and, on the other hand, the leaf *dry weight increased under* three treatments: inorganic fertilization (IF), compost tea + co-inoculation (CTCi) and CTIF (12.5, 9.22 and 10.5 g respectively). Leaf area was greater in the IF and CTIF treatments. In Control (C) P and Mg content were higher; CTCi treatment increased the N, K, and Mn content; the co-inoculation (Ci) treatment increased Cu content as well as CTIF treatment increased the Ca, Fe, Zn, and B contents and in a lesser extent also the P, Mg, Cu, and Mn contents. The biomass partitioning coefficient indicates that in six samples (from a total of seven samples), most of the photosynthates (PS) were used by the plants to form new leaves or to increase the size of the leaves. If an alternative method of fertilization is desired, it is recommended that a combination of biofertilizer and inorganic fertilization should be used, such as, the combination of compost tea and mineral solution that increased the production and the concentration of nutrients in the Swiss chard crop.

Index words: *azospirillum*, *biofertilizers*, *glomus*, *steiner solution.*

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RESUMEN

La acelga es un cultivo hortícola de alto valor nutritivo y en México se producen más de 12 mil toneladas al año. Para su producción, estos cultivos requieren nutrientes, los cuales pueden ser aportados a través de soluciones de nutrientes minerales o biofertilizantes. Los biofertilizantes son productos que contienen microorganismos benéficos que mejoran la calidad del suelo y que favorecen el crecimiento de las plantas. Además, estos microorganismos realizan la fijación de nitrógeno y la solubilización de fosfato. El presente trabajo evaluó la aplicación de té de compost, co-inoculación (*Azospirillum* y *Glomus*) y fertilizante inorgánico sobre el crecimiento (raíz, tallo y hojas) y contenido de nutrientes en plantas de acelgas (*Beta vulgaris* var. Forhook Giant). El presente trabajo se llevó a cabo en un invernadero utilizando un diseño de bloques completos al azar. Las plantas de acelga tratadas con té de compost + fertilización inorgánica (CTIF) acumularon más peso seco en raíces y tallos (4.06 y 8.10 g respectivamente), por otro lado, el peso seco de la hoja aumentó bajo tres tratamientos: fertilización inorgánica (IF), té de compost + co-inoculación (CTCi) y CTIF (12.5, 9.22 y 10.5 g respectivamente). El área foliar fue mayor en los tratamientos IF y CTIF. El contenido de P y Mg también fue mayor en los controles (C). El tratamiento con CTCi aumentó el contenido de N, K y Mn; el tratamiento de coinoculación (Ci) incrementó el contenido de Cu, así como el tratamiento de CTIF incrementó los contenidos de Ca, Fe, Zn y B y en menor medida también los contenidos de P, Mg, Cu y Mn. El coeficiente de partición de biomasa indica que en seis muestreos (de un total de siete muestreos), la mayoría de los fotosintatos (PS) fueron utilizados por las plantas para formar o aumentar el tamaño de las hojas. Si se desea un método alternativo de fertilización, se recomienda utilizar una combinación de biofertilizante y fertilización inorgánica como la combinación de té de composta y solución mineral que aumentó la producción y la concentración de nutrientes en el cultivo de acelgas.

Palabras clave: *azospirillum*, *biofertilizantes, glomus*, *solución steiner*.

INTRODUCTION

Biofertilizers are classified as nitrogen fixers, phosphorus solubilizers, growth-promoting rhizobacteria and mycorrhizal fungi (specific traits that bacteria of the genus *Azospirillum* and fungi of the genus *Glomus* possess), soil improvers (compost and its derivatives) and those containing microorganisms capable of controlling pathogens such as compost tea (Dukare *et al.,* 2011; Fasusi, Cruz and Babalola, 2021; Mahanty *et al*., 2017; Olivares-Campos, Hernández, Vences, Jáquez and Ojeda, 2012; Puente, García, Rubio and Perticari, 2010). The use of biofertilizers allows for higher crop yields at a lower cost, and is environmentally friendly, it helps in preserving the soil in terms of fertility and biodiversity (Mahanty *et al*., 2017).

Among biofertilizers, compost tea is a solution rich in nutrients and beneficial microorganisms resulting from the reaction of an aerobic compost in water, and it can be brewed for a few days or more than two weeks, with and without active ventilation or the addition of nutrients (molasses, casein, biocarbon, etc.), and also can be applied to prevent diseases (Edenborn, Johnson, Edenborn, Albarran and Demetrion, 2018; García-Olivares, Mendoza and Mayek, 2012; Ingham, 2005; Ochoa-Martinez *et al*., 2009; St. Martin and Brathwaite, 2012; Zaccardelli, Pane, Scotti, Palese and Celano, 2012).

It has been shown that compost tea increases the growth and development, as well as the chlorophyll content (Zaccardelli, Pane, Villecco, Palese and Celano, 2018), but not the number of leaves as mentioned by Segarra, Reis, Casanova and Trillas (2009), in a tomato crop. Radin and Warman (2011), studied the effect of the application of compost and compost tea from municipal solid waste in a tomato crop and observed that in a combination of compost and compost tea, K content in leaves increased compared to those in which conventional NPK fertilizer was applied. Siddiqui, Islam, Naidu and Meon (2011) determined that the greatest growth, yield, and terpenoid content in *Centella asiatica* (L) was obtained when the application was made with compost tea, combined with conventional NPK fertilizer in a 50/50 ratio. Hargreaves, Adl and Warman (2009) concluded that compost tea application foliar provided the required nutrients for growth in a strawberry crop, obtaining the same yields as those in which compost was applied solely to the soil.

Zaccardelli *et al*. (2018) assessed the effect of foliar application of compost tea on the poblano pepper crop (*Capsicum annuum* L.), for two years, observing an increase in the production (number of fruits per plant) of 21.9% and 16.3% for the first and second year respectively. Similar results were reported by Pane, Palese, Celano and Zaccardelli (2014) in which compost tea was foliar-applied to soil (drenching) on lettuce and rutabaga (swede) crops, obtaining a yield increase of 24 and 32%, respectively, and additionally, the chlorophyll content increased, and the physiological and nutritional status improved.

Microorganisms play an essential role in agriculture, such as *Azospirillum brasilense*, a bacteria that has been isolated from the rhizosphere of a wide range of cultivated and wild plants in the world, responsible for carrying out biological nitrogen fixation, siderophores production, phosphorus solubilization, an increase of root hair occurrence (increasing the specific surface of the root allowing it to absorb more water and minerals) and also promote plant growth through physiological mechanisms such as the production of phytohormones and polyamines, such as cadaverine (Camelo, Vera and Bonilla, 2011; Cassan *et al*., 2009; Levanony and Bashan, 1991; Loredo-Osti, López, Espinosa, 2004; Okon and Labandera, 1994; Perrig *et al*., 2007).

Arbuscular mycorrhiza is an endosymbiotic mutual association where the fungus grows into the root of the plant improving phosphorus uptake, growth hormones production, proteins, lipids, and sugars, tolerance to salinity and heavy metals, and preventing diseases caused by pathogenic microorganisms present in the root. *Glomus arbuscular* is an arbuscular mycorrhiza fungus that inhabits the rhizosphere of higher plants and is reported to increase the water uptake by the plant and solubilize the phosphate present in the soil to increase assimilation by plants (Barrera-Berdugo, 2009; Geo, Nair and Vijayan, 2018; Koide and Kabir, 2000; Lira-Saldivar *et al.,* 2014; Vierheilig, 2004).

Numerous studies have focused on the assessment of co-inoculation of bacteria of the genus *Azospirillum* and *mycorrhiza* (Glomus); Ardakani, Mazaheri, Mafakheri and Moghaddam (2011), evaluated the effect of applying *Azospirillum*, *Streptomyces*, *mycorrhiza* and *cow manure* combined and independently in a wheat crop, determining that the mixture with the four elements was adversely due to the antagonizing influence of *Streptomyces,* on the mycorrhizal fungus, while with the combination of *Azospirillum*, *mycorrhiza*, and manure improved the absorption efficiency of N, P and K. Walker *et al*. (2012) tested the effect of interactions of *Pseudomonas-Azospirillum-Glomus* combined and independently compared to mineral fertilization in a corn crop and reported that inoculation or co-inoculation had no impact on plant biomass, but it increased the total root surface, the total root volume and triggered significant beneficial changes in root functioning.

The objective of the present work was to assess the effect on plant growth (stem, roots, and leaves) when applying compost tea, co-inoculation, inorganic fertilization, and combinations of them in Swiss chard plants *Forhook Giant* var.

MATERIALS AND METHODS

Study Area, Plant Material and Crop Management

The experiments were carried out in the months from March to July in a greenhouse belonging to the Universidad Autonoma Agraria Antonio Narro, located in Saltillo, Coahuila, Mexico, with geographical coordinates of latitude 25° 27′ N 101° 02′ W and an altitude of 1610 meters.

The Swiss chard seedlings *Beta vulgaris* var. Forhook Giant (seeds purchased from ITSCO Agro, SAPI de CV) was carried out on polystyrene trays with 200 cavities, in which one seed per cavity was sown with peat moss substrate. Treatments are described in Table 1; a total of 800 seeds of Swiss chard were used (*Beta vulgaris* var. Forhook Giant). After 29 days the seedlings were transplanted to 3 kg pots with

Table 1. Description of each treatment used in the present study.

Treatment code	Description
CT	Compost Tea
CTIF	Compost Tea + Inorganic Fertilization
IF	Inorganic Fertilization
CTCi	Compost Tea + Co-inoculation
Ci	Co-inoculation
CiIF	Co-inoculation + Inorganic Fertilization
C	Control

a substrate containing soil, peat moss, and perlite (1: 1: 1) added at this time the Steiner solution and compost tea were applied once a week (CT, CTIF, IF, CTCi and CiIF) depending on each case as described in Table 1 and were irrigated with tap water twice a week. In the cases of the C and Ci treatments, only irrigation twice a week was done during the entire experiment.

Treatments

A total of seven treatments and twenty-one repetitions with seven samplings were established for the present work as described in Table 1. Every sampling consisted in withdrawing 3 (of the 21) replicates of each treatment. The samplings were carried out every ten days after transplanting.

Co-Inoculation

The disinfection and inoculation of seeds were carried out as described by Pérez-García (2017[1]), all seeds were previously disinfected (using Tween 20, ethanol, sodium hypochlorite, sodium thiosulfate), and half of the seeds (400) were co-inoculated with *Azospirillum brasilence* and *Glomus intraradices* (using gum arabic as adherent). The sown co-inoculated seeds were used to form the seedling for the CTIF, CTCi, and Ci (Table 1) treatments. Co-inoculation was only carried out during this stage.

Compost Tea

Compost tea was prepared using mature compost (5 months of composting) constituted by vegetal and animal waste, as well as cow manure (80:20). The compost tea was prepared by adding 1 kg of compost per 20 liters of water. The compost tea was brewed for 7 days with aeration.

Inorganic Fertilization

Inorganic fertilization was made with Steiner nutrient solution (Steiner, 1984[2]), carried out in both cases, in co-inoculated and non-inoculated seeds. The 25% nutrient solution was applied once a week during the first 45 days after transplantation and at 50% for the remaining trial.

[1] Pérez-García, M. (2017). *Evaluación del Efecto de Dos Microorganismos en la Colonización de la Raíz y Promoción del Crecimiento y Desarrollo de Plántulas de Maíz* (*Zea mays* L.). Tesis para obtener el titudo de Ingeniero en Agrobiologia, Universidad Autónoma Agraria Antonio Narro. http://repositorio.uaaan.mx:8080/xmlui/handle/123456789/8482

[2] Steiner, A. A. (1984). The universal nutrient solution. In *Proceedings 6th International Congress on Soilless Culture* (pp. 633-650). Wageningen, The Netherlands: ISOSC.

Pest and Disease Management

Two commercial products were used for pest and disease control. The first commercial product is Bralic® (*Allium* spp. 12.5%), and the second commercial product was DiPel DF (*Bacillus thuringiensis* var. Kurstaki).

Bralic attacks the nervous system of insects with sulfur substances called allomones and is usually applied to eliminate *Trips spp*., *Liriomyza sp*., and *Bemisia tabaci*. The product DiPel DF is made of different toxins that target insect larvae, and it is mainly used to eliminate caterpillars of lepidopterous.

Analytical Methods

All samples (for all treatments) were separated into roots, stems, and leaves. Previous to measuring, the roots were cleansed to remove the substrate. The roots and stems were measured with a Vernier caliper and the leaf area was determined with a leaf area meter (LI-COR Model LI3100C). After measuring, the roots, stems and leaves were sampled and dried (65 °C for 72 h) in the drying oven (TERLAB model TE-H70DM) and subsequently weighed in an analytical balance (US SOLID model USS-DBS15-3) to determine the root dry weight, stem dry weight and leaf dry weight. The biomass partitioning coefficient for root (BPC_R), stem (BPC_S), and leaf (BPC_L) were calculated according to the following equations:

$$BPC_S=\frac{\text{stem dry weight}}{\text{total dry weight}} \tag{1}$$

$$BPC_R=\frac{\text{root dry weight}}{\text{total dry weight}} \tag{2}$$

$$BPC_L=\frac{\text{leaf dry weight}}{\text{total dry weight}} \tag{3}$$

In the case of the last samplings, the whole plant was dried in a dry oven at 65 °C for 72 h, and subsequently, the plants were subjected to a grinding process in a mortar for further determinations of macro and micronutrients. Macro and micronutrients K, Ca, Mg, Fe, Cu, Zn, Mn, and B were determined with an atomic emission spectrometer ICP Optical Varian 725-ES), and the total was determined with the semi-micro Kjeldahl method as described by Bremner (1965). For each treatment, only one analysis was carried out.

Experimental Design and Statistical Analysis

A complete randomized block experimental design with 21 replicates for each of the seven treatments was applied. Every sampling consisted in withdrawing 3 (of the 21) replicates of each treatment. An analysis of variance (ANOVA) was conducted along with a Tukey test ($P \geq 0.05$) using the InfoStat software 2020 (Di Rienzo *et al*., 2020).

RESULTS AND DISCUSSION

Emergence

The emergence of the Swiss chard was observed on the fourth day after seedling, achieving an 88% after 14 days for seeds with and without co-inoculation, it is noteworthy that seedlings from seeds that were co-inoculated had an emergence rate 25% higher, than those without co-inoculation. The results obtained in the present work showed that co-inoculation had a beneficial effect on the emergence of Swiss chard plants. Different authors have reported similar results in the use of biofertilizers, such as Delshadi, Ebrahimi and Shirmohammadi (2017), who reported that the use of inoculation or co-inoculation with *Azotobacter vinelandii*, *Pantoea agglomerans,* and *Pseudomonas putida* in *Onobrychis sativa* L seeds, showed increased germination compared to the seeds that were not inoculated or co-inoculated. Another report on the use of co-inoculation by Zeffa *et al*. (2019), reported an increase in the concentration of indole acetic acid (IAI) in seeds of different maize genotypes that were inoculated with *Azospirillum brasilense*, also mentioning that this contributed to improved also the germination percentage and growth in the plants.

Dry Weight

Swiss chard plant root dry weight results showed that there was no significant difference in samples 1, 3, 4, and 5 in all treatments assessed, meanwhile, in samples 2, 6, and 7 in the case of CTIF and CT treatments, the root dry weight was greater than the other treatments (Table 2). In 6 out of 7 samples of plants treated with CTIF, the root dry weight results were the highest, followed by 5 out of 7 samples for the plants treated with CT. The use of compost tea in tomato plants has been previously reported, mentioning that plants under this treatment have produced three times more root dry weight, and, additionally, a suppressive effect over Fusarium oxysporum has also been observed (Morales-Corts, Pérez and Gómez, 2018), González-Solano, Rodríguez, Trejo, García and Sánchez (2013), reported that the use of vermicompost tea in lettuce, basil, and coriander led to an increase in dry biomass weight in similar amounts as when using the Steiner solution. The use of compost tea (grape marc) with no aeration in pepper seedlings produced an increase in root dry weight (Marín *et al*., 2014). Ingham (2005) mentioned that the increase in the root size is attributed to the nutrients and growth-promoting substances that are present in the vermicompost or compost teas. In the present work, the highest values for root length were obtained in plants with Ci treatment (Table 2). In five of the seven samplings, the Ci treatment showed the greatest results in root length (statistically significant difference). This can be attributed to the fact that mycorrhiza (Glomus intraradices) is known to increase the root exploration volume due to the mycelium being an extension of the roots (Ardakani *et al*., 2011). Additionally, the rhizobacteria Azospirillum, a vegetable plant growth promoter (present in the commercial product AzoFert®) increases the root

Table 2. Root length of Swiss chard plant using different treatments.

	Sampling						
Tt	M1	M2	M3	M4	M5	M6	M7
	- mm -						
Ci	106.44 ± 4.83 a	129.74 ± 17.28 ab	112.99 ± 13.29 a	122.0 ± 8.49 c	403.5 ± 45.46 b	792.0 ± 15.56 a	874.25 ± 41.20 a
CiIF	98.51 ± 6.58 a	79.03 ± 3.41 b	100.49 ± 8.69 a	147.0 ± 4.24 abc	358.5 ± 30.41 abc	479.4 ± 1.41 bcd	597.23 ± 35.32 c
IF	68.88 ± 8.97 b	82.13 ± 2.76 b	135.78 ± 50.17 a	120.0 ± 14.14 c	278.45 ± 4.24 bcd	327.50 ± 9.19 d	478.95 ± 38.89 d
CT	62.63 ± 2.28 b	73.06 ± 3.44 b	128.16 ± 6.06 a	171.73 ± 7.20 ab	381.0 ± 15.56 ab	417.70 ± 24.04 cd	504.85 ± 32.21 d
CTCi	104.45 ± 3.90 a	127.07 ± 4.88 ab	125.44 ± 17.87 a	172.51 ± 3.54 a	265.2 ± 49.50 cd	578.50 ± 51.62 b	698.55 ± 14.85 b
CTIF	60.12 ± 10.0 b	103.06 ± 7.38 b	143.01 ± 10.13 a	122.05 ± 9.19 bc	237.01 ± 5.66 d	600.0 ± 25.50 b	723.14 ± 46.15 b
C	60.08 ± 8.55 b	129.16 ± 20.53 ab	166.70 ± 82.00 a	160.10 ± 25.46 abc	414.0 ± 2.83 a	540.60 ± 82.02 bc	610.24 ± 27.77 c

Tt = treatments. Those means that are not significantly different were assigned a common letter ($P < 0.05$). Ci = co-inoculation; CiIF = co-inoculation + inorganic fertilization; IF = inorganic fertilization; C = control; CT = compost tea; CTCi = compost tea + co-inoculation; CTIF = compost tea + inorganic fertilization.

length in tomato seedlings (Terry, Núñez, Pino and Medina, 2001). The greater dry matter weight in the stems was obtained in the plants with CTFI treatment (in 5 out of 7 samples), meanwhile, the lowest values were obtained in the case Ci treatment (Table 4).

It is worth mentioning that the IF and CTIF treatments increased the stem length of fresh plants (Table 3). In five of the seven samplings, the IF and CTIF treatments obtained higher values for root length (Table 4). González-Solano *et al*. (2013), reported that using vermicompost tea rendered similar values of stem length (dry weight) in basil when using the Steiner solution, and higher values were obtained in comparison to the Steiner solution when using vermicompost tea in lettuce and coriander plants. Marín *et al*. (2014), reported that in pepper seedlings that were treated with compost tea (from grape marc without aeration), the dry stem weight was increased. In the case of leaf dry weight for 3 out of 7 samples (samples 3, 6, and 7, Table 3) there was no significant difference in all treatments. The highest values for dry leaf weight were obtained in the cases of plants treated with IF, CT, and CTIF (in 5 out of 7 samples). The highest number of leaves per plant was obtained in the cases of plants treated with IF, followed by those treated with CTIF (data not shown).

Table 3. Dry weight of Swiss chard plants using different treatments.

		Sampling						
Organ	Tt	1	2	3	4	5	6	7
		- -	g	- -				
Root	Ci	0.01 ± 0.005 a	0.02 ± 0.003 b	0.09 ± 0.03 a	0.30 ± 0.01 a	0.72 ± 0.03 a	1.42 ± 0.74 ab	2.57 ± 1.00 ab
	CiIF	0.01 ± 0.005 a	0.03 ± 0.001 ab	0.10 ± 0.05 a	0.42 ± 0.11 a	0.88 ± 0.05 a	1.18 ± 0.56 ab	1.83 ± 0.31 b
	IF	0.01 ± 0.004 a	0.03 ± 0.004 ab	0.17 ± 0.12 a	0.38 ± 0.12 a	1.14 ± 0.03 a	1.91 ± 0.78 ab	3.25 ± 0.37 ab
	CT	0.01 ± 0.004 a	0.03 ± 0.005 ab	0.20 ± 0.09 a	0.31 ± 0.05 a	0.79 ± 0.24 a	2.08 ± 0.06 a	2.33 ± 1.17 ab
	CTCi	0.01 ± 0.005 a	0.02 ± 0.001 ab	0.11 ± 0.01 a	0.44 ± 0.17 a	0.92 ± 0.41 a	0.68 ± 0.01 b	1.90 ± 0.35 b
	CTIF	0.01 ± 0.004 a	0.04 ± 0.006 a	0.12 ± 0.04 a	0.30 ± 0.02 a	0.81 ± 0.24 a	1.39 ± 0.33 ab	4.06 ± 0.51 a
	C	0.01 ± 0.004 a	0.02 ± 0.004 ab	0.08 ± 0.02 a	0.46 ± 0.16 a	0.68 ± 0.21 a	1.17 ± 0.43 ab	1.44 ± 0.36 b
Stem	Ci	0.002 ± 0.001 a	0.02 ± 0.001 b	0.32 ± 0.08 a	0.92 ± 0.01 b	2.88 ± 0.13 a	2.43 ± 0.12 c	7.96 ± 0.33 a
	CiIF	0.002 ± 0.001 a	0.05 ± 0.001 ab	0.35 ± 0.07 a	1.38 ± 0.48 ab	3.07 ± 0.15 a	3.25 ± 0.60 bc	4.94 ± 0.10 ab
	IF	0.003 ± 0.001 a	0.04 ± 0.001 b	0.61 ± 0.39 a	1.49 ± 0.28 ab	3.86 ± 0.72 a	4.77 ± 0.64 a	7.04 ± 0.22 ab
	CT	0.003 ± 0.001 a	0.05 ± 0.009 ab	0.72 ± 0.08 a	1.51 ± 0.06 ab	3.12 ± 0.04 a	3.02 ± 0.02 bc	4.35 ± 0.37 b
	CTCi	0.002 ± 0.001 a	0.03 ± 0.001 b	0.42 ± 0.04 a	1.65 ± 0.28 a	4.07 ± 2.50 a	3.18 ± 0.23 bc	6.11 ± 0.14 ab
	CTIF	0.003 ± 0.001 a	0.07 ± 0.006 a	0.31 ± 0.05 a	1.49 ± 0.06 ab	3.76 ± 1.12 a	3.77 ± 0.88 ab	8.10 ± 0.51 a
	C	0.003 ± 0.001 a	0.03 ± 0.006 b	0.31 ± 0.10 a	1.05 ± 0.13 ab	2.93 ± 0.41 a	3.26 ± 0.42 bc	6.63 ± 1.39 ab
Leaf	Ci	0.01 ± 0.002 a	0.12 ± 0.018 c	0.87 ± 0.23 a	1.65 ± 0.08 c	5.78 ± 0.05 ab	5.69 ± 0.45 a	9.02 ± 0.58 a
	CiIF	0.01 ± 0.002 a	0.24 ± 0.006 ab	1.24 ± 0.55 a	2.82 ± 0.09 ab	4.64 ± 0.38 b	6.31 ± 0.69 a	7.88 ± 0.68 a
	IF	0.01 ± 0.000 a	0.20 ± 0.003 abc	2.03 ± 1.17 a	2.49 ± 0.10 abc	8.61 ± 0.42 a	7.29 ± 0.28 a	12.5 ± 0.11 a
	CT	0.01 ± 0.000 a	0.23 ± 0.049 abc	1.92 ± 0.50 a	2.69 ± 0.17 ab	6.33 ± 0.55 ab	6.27 ± 0.37 a	7.30 ± 1.10 a
	CTCi	0.01 ± 0.002 a	0.13 ± 0.004 bc	1.13 ± 0.02 a	3.16 ± 0.40 a	6.55 ± 0.22 ab	6.76 ± 0.48 a	9.22 ± 0.53 a
	CTIF	0.01 ± 0.000 a	0.27 ± 0.005 a	1.17 ± 0.09 a	2.68 ± 0.15 ab	6.17 ± 0.38 ab	7.26 ± 0.51 a	10.5 ± 0.91 a
	C	0.01 ± 0.000 a	0.15 ± 0.005 bc	0.85 ± 0.03 a	1.88 ± 0.01 bc	5.78 ± 0.86 ab	6.45 ± 0.78 a	7.98 ± 0.14 a

Tt = treatments.Those means that are not significantly different were assigned a common letter ($P < 0.05$). Ci = co-inoculation; CiIF = co-inoculation + inorganic fertilization; IF = inorganic fertilization; C = control; CT = compost tea; CTCi = compost tea + co-inoculation; CTIF = compost tea + inorganic fertilization.

Table 4. Stem length of Swiss chard plants using different treatments.

Tt	Sampling						
	M1	M2	M3	M4	M5	M6	M7
	mm						
Ci	12.8 ± 2.13 a	47.46 ± 2.65 ab	124.36 ± 26.97 a	173.0 ± 4.24 ab	207.5 ± 19.09 bc	216.5 ± 4.95 c	231.62 ± 10.09 c
CiIF	16.66 ± 0.98 a	76.32 ± 2.33 b	117.8 ± 9.97 a	185.5 ± 2.12 a	215.5 ± 10.85 bc	237.5 ± 3.54 c	272.31 ± 10.72 b
IF	15.11 ± 5.65 a	93.10 ± 4.66 a	122.36 ± 34.37 a	190.5 ± 2.12 a	233.5 ± 0.81 b	275.5 ± 0.97 a	292.33 ± 10.04 b
CT	14.67 ± 2.86 a	68.10 ± 4.75 bc	131.65 ± 7.69 a	183.5 ± 9.19 a	214.5 ± 0.71 bc	221 ± 8.49 c	257.11 ±1 7.39 bc
CTCi	13.67 ± 0.05 a	60.66 ± 0.83 c	131.74 ± 1.37 a	192.5 ± 6.36 a	249.0 ± 2.83 a	253.5 ± 4.95 b	286.44 ± 15.22 b
CTIF	18.50 ± 3.44 a	98.62 ± 1.89 a	124.03 ± 13.65 a	178.0 ± 8.49 a	208.0 ± 1.41 bc	257.5 ± 7.61 b	325.24 ± 11.95 a
C	12.96 ± 2.26 a	95.68 ± 1.05 a	127.64 ± 15.92 a	153.5 ± 4.95 b	184.5 ± 7.78 c	214.15 ± 16.97 c	245.21 ± 25.94 bc

Tt = treatments. Those means that are not significantly different were assigned a common letter ($P < 0.05$). Ci = co-inoculation; CiIF = co-inoculation + inorganic fertilization; IF = inorganic fertilization; C = control; CT = compost tea; CTCi = compost tea + co-inoculation; CTIF = compost tea + inorganic fertilization.

González-Solano *et al*. (2013), also mentioned that the use of vermicompost tea led to an increase in the leave dry weight of basil, coriander, and lettuce, being the last two crops with even higher values compared to plants treated with the Steiner solution. Haggag, Merwad, Shahin, Hoballah and Mahdy (2014), reported that the use of compost tea alone or combined with chemical fertilizer increases the values of leaves dry weight and leaves per plant. Marín *et al*. (2014), mentioned that the leaf dry weight values increased (pepper seedlings) when using vermicompost tea.

The use of compost or vermicompost tea with and without the addition of nutrients has been reported to increase the values for dry weight in plants. Siddiqui *et al*. (2011), mentioned that the use of compost tea and NPK fertilizers in a ratio of 1:1 increased the dry matter obtained in Centella asiatica. Moncayo-Luján, Álvarez, González, Salas and Chávez (2015), mentioned that the use of vermicompost and compost tea increased the dry matter obtained in basil plants. Salas-Pérez, Borroel, Ramírez and Moncayo (2018), reported that the use of compost tea and compost tea with ascorbic acid increased 18% the dry matter obtained in a hydroponic green fodder crop. Additionally, it can be mentioned that fresh weight is also increased with the use of compost tea (this value was not determined in the present work), as described by Kim *et al*. (2015), in lettuce plants that were treated with compost and vermicompost teas.

Leaf Area

From an agroindustrial perspective, the most important is to promote organ growth, in the case of Swiss chard plants, when big, green, and healthy leaves are desired (directly proportional to leaf area). The Swiss chard plants that were treated with IF and CTIF obtained the greatest leaf area as shown in Table 5. Similar results as those obtained in the present work are described by Marín *et al.* (2014), where the pepper seedlings that were treated with compost tea from grape marc showed an increase in the leaf area. A leaf area increase in coriander plants was also reported by González-Solano *et al.* (2013) when using vermicompost tea compared to Steiner solution.

Biomass Partitioning Coefficient

The biomass partitioning coefficient provides an insight into how biomass is distributed among its different organs, and these calculations are of great importance when new organs appear in plants, such as tubers, bulbs, fruits, and so

Table 5. Leaf area of swiss chard plants using different treatments.

	Sampling						
Tt	1	2	3	4	5	6	7
	mm^2						
Ci	3.4 ± 0.04 a	59.60 ± 9.50 b	237.32 ± 34.4 a	556.67 ± 49.40 c	1545.69 ± 127.7 ab	1607.35 ± 171.8 a	2227.43 ± 68.3 ab
CiIF	3.4 ± 0.04 a	101.4 ± 10.7 ab	348.32 ± 110 a	746.72 ± 153.4 abc	1322.81 ± 30.10 b	1773.95 ± 38.50 a	1801.37 ± 66.3 b
IF	4.1 ± 0.30 a	80.11 ± 5.80 ab	591.06 ± 371 a	833.84 ± 12.60 abc	2474.94 ± 84.10 a	2039.60 ± 63.90 a	2990.25 ± 75.0 b
CT	4.1 ± 0.30 a	106.2 ± 14.6 ab	519.77 ± 100 a	853.90 ± 26.50 ab	1687.93 ± 34.50 ab	1704.60 ± 54.00 a	1942.56 ± 317 ab
CTCi	3.4 ± 0.04 a	65.19 ± 2.10 b	253.66 ± 14.6 a	842.14 ± 175.2 ab	2349.49 ± 173.7 ab	1927.30 ± 9.60 a	2471.40 ± 125 ab
CTIF	4.1 ± 0.30 a	124.7 ± 3.40 a	506.12 ± 30.9 a	957.94 ± 60.90 a	1552.06 ± 35.80 ab	1996.33 ± 242.0 a	2782.87 ± 95.8 ab
C	4.1 ± 0.30 a	74.91 ± 5.00 b	297.73 ± 6.30 a	646.00 ± 43.20 bc	1755.95 ± 17.90 ab	1825.24 ± 175.2 a	2164.13 ± 23.9 ab

Tt = treatments. Those means that are not significantly different were assigned a common letter ($P < 0.05$). Ci = co-inoculation; CiIF = co-inoculation + inorganic fertilization; IF = inorganic fertilization; C = control; CT = compost tea; CTCi = compost tea + co-inoculation; CTIF = compost tea + inorganic fertilization.

forth (Di Benedetto and Tognetti, 2016). The results obtained in the present work showed that in the first sampling, the photosynthates were mainly used for the formation of biomass in roots and leaves, and to a lesser extent, stems (Table 6). In the following samplings, it can be observed that the photosynthates were used to form leaves, followed by the formation of the stem, and to a lesser extent, roots. This is advantageous in the case of Swiss chard plants, in order to have leaves continue their size increase, while the stem must grow thicker.

Nutrient Analysis in Leaves?

Ten micro-and macronutrients were determined, N (Nitrogen), P (Phosphorus), K (Potassium), Ca (Calcium), Mg (Magnesium), Fe (Iron), Cu (Copper), Zn (Zinc), Mn (Manganese), and B (Boron), (Table 7). Results obtained showed that plants that were subject to the CT treatment presented a higher concentration of Ca, Fe, Zn, and B (9630, 213.5, 25.6 and 54 mg kg^{-1} respectively). The Ci treatment led to an increase in N, Ca, Zn, Mn, and B (28 600, 8700, 19.3, 39.7 and 55 mg kg^{-1} respectively); the IF treatment increased the Ca, Fe, Cu, Zn, and B (10 400, 217, 8, 25.1, and 52.3 mg kg^{-1} respectively) content in plants. Results also showed that when these treatments were combined in some cases, the nutrient content increased; however, in other cases, the nutrient content declined. The CTIF treatment led to an increase in N, Ca, Fe, Cu, Zn, Mn, and B (26 800, 10 700, 246, 8.3, 31.5, 39.7, and 60.5 mg kg^{-1} respectively) content; the CTCi treatment increased the N, K, Ca, Zn, Mn, and B (30 000, 2600, 9000, 15.5, 41.9, and 54.1 mg kg^{-1} respectively) content; meanwhile the CiIF treatment increased the Ca, Zn and B (8600, 19.4, and 52.3 mg kg^{-1} respectively). The CTIF was the treatment that led to an increase in seven of the ten nutrients that were determined in the present work. The plants that presented a higher N content were Ci, CTCi, and CTIF, Terry *et al*. (2001) and Ardakani *et al*. (2011), reported similar results. Meanwhile, the plants with the CiIF and IF treatments presented lower N values. Velasco-Velasco, Ferrera and Almaraz (2001), reported that N content increased by 30% in plants when Azospirillum, Glomus, and vermicompost treatments were applied, and a 100% increase in N was observed when a combination of vermicompost+Glomus and vermicompost+Glomus+Azospirillum were applied; additionally, these combinations also led to an increase of a 100% in P content. However, in the present work, the Ci treatment did not increase the P content as expected, attributing this to Glomus being a phosphorus solubilizing microorganism (Ardakani *et al*. 2011).

Table 6. Swiss chard biomass partition coefficient.

Organ	Tt	Sampling						
		1	2	3	4	5	6	7
	Ci	0.454	0.125	0.070	0.080	0.073	0.180	0.138
Root	CiIF	0.454	0.100	0.059	0.084	0.099	0.125	0.166
	IF	0.425	0.107	0.060	0.093	0.071	0.154	0.149
	CT	0.425	0.058	0.070	0.061	0.072	0.190	0.177
	CTCi	0.454	0.117	0.065	0.083	0.080	0.071	0.093
	CTIF	0.425	0.100	0.075	0.062	0.086	0.109	0.183
	C	0.425	0.086	0.064	0.157	0.072	0.110	0.097
	Ci	0.090	0.187	0.250	0.317	0.292	0.272	0.390
Stem	CiIF	0.090	0.166	0.207	0.291	0.323	0.296	0.329
	IF	0.148	0.178	0.219	0.330	0.283	0.326	0.334
	CT	0.148	0.147	0.253	0.336	0.324	0.275	0.321
	CTCi	0.090	0.235	0.257	0.308	0.382	0.314	0.348
	CTIF	0.148	0.150	0.194	0.321	0.376	0.311	0.400
	C	0.148	0.173	0.256	0.294	0.325	0.288	0.458
	Ci	0.454	0.687	0.679	0.602	0.634	0.546	0.471
Leaf	CiIF	0.454	0.733	0.733	0.623	0.577	0.578	0.504
	IF	0.425	0.714	0.719	0.576	0.644	0.519	0.516
	CT	0.425	0.794	0.676	0.602	0.603	0.533	0.500
	CTCi	0.454	0.647	0.676	0.607	0.536	0.613	0.558
	CTIF	0.454	0.687	0.679	0.602	0.634	0.546	0.471
	C	0.425	0.739	0.680	0.547	0.602	0.601	0.444

Tt = treatments. Ci = co-inoculation; CiIF = co-inoculation + inorganic fertilization; IF = inorganic fertilization; C = control; CT = compost tea; CTCi = compost tea + co-inoculation; CTIF = compost tea + inorganic fertilization.

Table 7. Micro-and macronutrients content in Swiss chard plants using different treatments.

Element	Units	Treatment						
		Ci	CiIF	IF	CT	CTCi	CTIF	C
N	g kg^{-1}	28.58	26.25	25.78	26.60	29.98	26.83	26.60
P	g kg^{-1}	3.13	3.03	3.22	3.17	2.59	3.23	3.37
K	g kg^{-1}	53.40	80.89	65.88	82.13	84.72	81.36	83.73
Ca	g kg^{-1}	8.71	8.59	10.44	9.63	8.99	10.70	8.50
Mg	g kg^{-1}	7.22	7.02	7.42	7.32	7.36	8.57	8.66
Fe	mg kg^{-1}	157.6	168.9	217.0	213.5	151.7	245.6	173.8
Cu	mg kg^{-1}	8.29	7.63	7.96	5.26	6.38	8.28	7.87
Zn	mg kg^{-1}	19.32	19.41	25.15	25.57	15.48	31.47	12.94
Mn	mg kg^{-1}	39.67	24.28	30.61	28.49	41.92	39.70	31.87
B	mg kg^{-1}	54.97	52.26	52.29	54.03	54.10	60.47	49.21

Tt= treatments. Ci = co-inoculation; CiIF = co-inoculation + inorganic fertilization; IF = inorganic fertilization; C = control; CT = compost tea; CTCi= compost tea + co-inoculation; CTIF = compost tea + inorganic fertilization.

CONCLUSIONS

The results obtained in the present work showed that the dry matter, the leaf area, calcium, iron, magnesium, copper, zinc, manganese, and boron content in plants was favored or increased when a combination of compost tea and inorganic fertilization was applied. The combination of compost tea and co-inoculation led to an increase in the nitrogen, potassium, and manganese content. Finally, the plants that were under treatments of a combination of co-inoculation and inorganic fertilization presented a low content of macro-and micronutrients, being magnesium and manganese the elements in lower concentrations.

ETHICS STATEMENT

No applicable.

CONSENT FOR PUBLICATION

No applicable.

AVAILABILITY OF SUPPORTING DATA

The data that support the findings of this study are available on request from the corresponding author (S.Y.M.A.).

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

Experimental design, data analysis, writing and translation: J.A.R.G. and S.Y.M.A. The experimental execution: C.N.G.G. Assistance in different task, such as, execution, data collection, solution making and crop care: L.I.T.T., D.A.C., L.M.G.M. and A.M.L.

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