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Effect of Food Waste Compost (FWC) and its Non-Aerated Fermented Extract (NFCE) on Seeds Germination and Plant Growth

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Abstract

The aim of this study was to investigate the effect of the food wastes compost (FWC) and its non-aerated fermented extract (NFCE) on seed germination and growth of tomato (*Solanum lycopersicum* L.), watercress (*Nasturtium officinale*), chili pepper (*Capsicum annuum*), peas (*Pisum sativum* L.), chickpea (*Cicer arietinum*) and beans (*Vicia faba*) under greenhouse conditions. The FWC and NFCE were physico-chemically and microbiologically characterized. The NFCE effect was evaluated on tomato, watercress, and chili pepper seeds germination and seedling growth. However, for leguminous, pea, chickpea and bean seedlings, the FWC amended soils and irrigated with NFCE were tested for plants growth. The results of FWC analyses revealed that FWC has neutral pH, low EC and C/N ratio, with fertilizing elements (N, P, K and Mg) and lack of phytotoxic effect. The NFCE was characterized by low EC and relatively high carbon content (COD = 9700 mg/l), and intense microbial activity, notably mesophilic bacteria. Therefore, in fermented compost extract, mesophilic bacteria were increased by 225, yeasts by 25 and molds by 10 times compared to those of the investigated compost. In greenhouse, the diluted NFCE increased significantly ($p < 0.05$) germination and growth of the tested seedlings. Used alone, the FWC amended soil or the NFCE irrigated soil, improved the growth of tested seedlings. The use of soil amended with compost and irrigated by fermented compost extract decreased significantly the growth of the same experimented seedlings. Therefore, the FWC and its fermented extract were a suitable substrate for germination and growth of the studied seeds.

Keywords

Food Wastes, Compost, Fermented Compost Extract, Seed Germination, Seedling, Growth

1. Introduction

Annually, around 1.3 billion tons of food wastes are produced in the world [1] [2]. These wastes may have some negative environmental impacts, such as soil erosion, deforestation, water and air pollution, as well as greenhouse gas emissions that occur in the processes of food production, storage, transportation, and waste management [3] [4]. Along the food supply chain, private households represent the largest food-waste fraction [5]. Considering the huge amounts of food waste produced at the household level, the prevention of such fermentescible waste at the final stages of the supply chain is of utmost importance to help preventing further climate change. However, the research about the field of consumer-generated food wastes in the context of households is still scarce [4] [6] [7]. Despite the studies' number increase, little is known about the determinant factors that encourage, impulse food waste behaviors and practices [8]. Many treatment solutions of food waste were reported, such as animal feeding [9], anaerobic/aerobic digestion [10], composting [2] [11] [12], pyrolysis [13], gasification, incineration and landfill disposal [14]. The choice of the technology to be applied depends on criteria in relation with the waste typology as well as the available means.

Considering composting, the term itself refers to the process of controlled biological maturity under aerobic conditions, where organic matter is decomposed by microorganisms such as fungi and bacteria, to materials with low molecular weight, stable, hygienic, humus-rich, and beneficial both for the agricultural crops and for soil organic matter recycling [15] [16] [17] [18] [19]. The compost is a sustainable, economic, and a feasible way to efficiently utilize nutrients from pre and post-consumers food waste as vegetative wastes from modern agriculture. The fermented compost extract is a nutrient and/or microorganism rich solution, prepared by fermenting compost under non-aerated conditions allowing nutrient dissolution and microbial growth. It has been recognized for its ability to suppress several foliar diseases as well as seed and root rot [17] [20]. Therefore, it can be tailored to its desired use. For example, a compost extract can be used as a soil organic matter builder, a disease suppressant, or a nutrient source [17] [21].

Little works have assessed the compost extract nutritional benefits of plant growth [22]. The fermented compost extracts can be prepared according to several ways; aerated and non-aerated compost teas or extracts have been evaluated for their effect on disease suppression. Welke [23] reported that the application of aerated compost tea increased the strawberry yields. The extract of vermicomposting increased plant production and mineral nutrient content in pak choi [22]. More recently, Morales-Corts *et al.* [24] mentioned that both aerated and non-aerated fermented composts can be applied, at their concentrated forms, to tomato growth medium. In some studies, aerated compost tea has shown impressive results in disease suppression while non-aerated compost extract has not [20] [21] [23] [24]. Moreover, Ingham [21] reported that the compost or the compost extract will supply the organisms and provides the plant needs. Consequently, the plant will feed those efficient organisms which will supply the part needed in micro- and macro-nutrients. The same authors showed that compost tea can also contain nutrients that plants can take-up through their foliage.

Therefore, the aim of this study was to characterize the physico-chemical and microbial properties of the food wastes compost (FWC) and the non-aerated fermented compost extract (NFCE), and to study the effects of these food waste bio-converted materials on germination and growth of several tested seeds.

2. Material and Methods

2.1. Raw Material

The studied compost was obtained from a local composting company of Djerba (South of Tunisia, 33˚48' North 10˚51' East). The compost was prepared using the selected fermentable household wastes, principally including vegetables and fruits. The physico-chemical and microbial characterizations of the food waste compost is represented in **Table 1**.

All the experimented seeds were purchased from a Tunisian local marked (El Baddar Semences Society, Tunis, Tunisia). These are tomato (*Solanum lycopersicum* L.), watercress (*Nasturtium officinale*), chili pepper (*Capsicum annuum*), peas (*Pisum sativum* L.), chickpea (*Cicer arietinum*) and beans (*Vicia faba*); all of the used seed are characterized by a purity rate of 97%. The study was carried out in 2018-2019 at the Laboratory of Microbiology (Department of Biology, Faculty of Sciences of Sfax, Tunisia).

2.2. Analytical Methods

Electrical conductivity and pH were measured in a 1:5 (w/v) water-soluble extraction at 20˚C ± 1˚C [25]. The conductivimeter used was a WTW LF 330 and the pH-meter was a Metler MP 225. The dry matter content was assessed by drying at 105˚C for 24 h [26] and organic matter (OM) by determining the loss-on ignition at 550˚C for 4 h. The total organic carbon (TOC) was determined by dichromate oxidation and measured by the analyzer Shimadzu TOC-500. The total nitrogen (NTK) and inorganic nitrogen NH_4^+ were determined by the Kjeldahl method. Organic nitrogen was calculated as the difference between total nitrogen and inorganic nitrogen [26]. Total P, Ca, Mg, K and Na were brought into solution by acidic digestion: phosphorus was determined colorimetrically as a molybdovanadate phosphoric acid and K, Mg, Ca, Na and Fe by atomic absorption spectrophotometry [26]. Chemical oxygen demand (COD) was measured by the Knechtel method [27].

Table 1. Physico-chemical analysis and microbial characterization of food waste compost.

Parameters		Compost
Basic index	pH	7.40 ± 0.03
	EC (mS/cm)	3.24 ± 0.08
	TS (%)	87.27 ± 0.34
	OM (%)	39.56 ± 0.19
	MM (%)	47.71 ± 0.22
Organic content	TOC (%)	25.60 ± 0.28
	NTK (%)	2.30 ± 0.05
	N organic (%)	1.50 ± 0.03
	C/N	11.13
Inorganic content	NH_4^+ (%)	0.80 ± 0.02
	Pt (%)	9.38 ± 0.13
	K^+ (mg/kg)	68.00 ± 0.09
	Na^+ (mg/kg)	94.28 ± 0.74
	Mg^{2+} (mg/kg)	180.53 ± 0.85
	Fe^{2+} (mg/kg)	46.28 ± 0.32
Granulometric	FM	2.97
Microbial concentration ($\times 10^6$)	Mesophilic bacteria	3.2
	Yeasts	0.28
	Molds	1.3
GI (%)	Tomato	138.80 ± 2.54
	Watercress	195.74 ± 1.36

EC: Electrical conductivity; TS: Total solid; OM: Organic matter; MM: Mineral matter; TOC: Total organic carbon; Pt: Total phosphorous; FM: Fineness modulus; GI: Germination index.

2.3. Determination of Fineness Modulus (FM)

The soil fineness modulus (FM) was determined according to the French Standard NF XP 18 - 540 [28], this is the sum of cumulative percentages retained reduced to a unity, after sieving through 0.16; 0.315; 0,63; 1.25; 2.5 and 5 mm, respectively. The food waste compost fineness modulus was determined based on the following equation [29]:

$$\text{FM} = 1/100\,\Sigma\text{CR\% sieved}\left(0.16, 0.315, 0.63, 1.25, 2.5 \text{ and } 5 \text{ mm}\right)$$

with:

- FM < 1.8: the compost is composed of only fine sand,
- 1.8 < FM < 2.2: the major composition of the compost is fine sand,
- 2.2 < FM < 2.8: the value is optimal; and the compost is made up of suitable sand for satisfactory workability and resistance, and segregation with limited risk,
- 2.8 < FM < 3.2: the sand has generally a low risk of workability and segrega-

tion,
- FM > 3.2: the sand is too coarse.

2.4. Microbial Characterization

The compost sample of 10 g was suspended in 90 ml of a sterile peptone water solution and stirred at 150 rpm for 10 min at 25˚C. The suspension was used for microbial counts by cell enumeration, assessed by the determination of the total number of colony forming units (cfu) according to ISO 7218 [30]. Serial decimal dilutions were carried out and from each dilution (10^{-1} to 10^{-7}) 0.1 ml was plated in triplicate on different agar media: Plate Count Agar (PCA, Pronadisa, Madrid Spain), for the total mesophilic bacteria incubated at 37˚C for 24 h, and Potato Dextrose Agar (PDA, Pronadisa, Madrid, Spain) for yeasts and molds enumeration, incubated at 25˚C for 5 days [31].

2.5. Germination Test

The compost phytotoxicity was evaluated according to the method described by Abid *et al.* [31] on tomato (*Solanum lycopersicum* L.) and watercress (*Nasturtium officinale*) seeds. Germination index (GI) was calculated using the following formula:

$$\text{GI}(\%) = \frac{(\text{Seed germination} \times \text{Treated root lenght})}{(\text{Control seed germination} \times \text{Control root lenght})} \times 100$$

2.6. Fermented Food Waste Compost Extract Preparation

The FWC was first diluted in distilled water (1/8 w/v), then 1 g/l of glucose was added to the suspension which was then incubated at 25˚C for 7 days. The extract was obtained after the centrifugation at 4000 rpm for 15 min, and was stored at 4˚C till use. This extract is one of 11 types of fermented compost extracts which were prepared using an experimental factorial plan (test n˚ 5 in **Table 2**). The extract was then subjected to antimicrobial against pathogenic fungi (data not shown).

2.7. Biometric Parameters of Fermented Compost Extract

The produced fermented compost extract effects on seeds germination of tomato (*Solanum lycopersicum* L.), watercress (*Nasturtium officinale*) and chili pepper (*Capsicum annuum*) were investigated throughout the first 15 days of growth under greenhouse conditions at 25˚C ± 1˚C, 80% humidity and 18/6 h (light/dark) photoperiod. Ten seeds of each plant variety were sown in 72 holes nursery trays, using horticultural nursery media based on coconut beat and peat moss. The seeds of each crop were irrigated daily by 20 ml of fermented compost extract. The latter was used non diluted as well as diluted at 1/2, 1/4 and 1/8 in distilled water. The biometric parameters were studied based on roots and

Table 2. Conditions of fermented compost extract preparation by fractional factorial plan.

Test	Temperature (˚C)	Compost concentration (m/v)	Glucose concentration (g/l)	Fermentation time (days)
1	25	1/8	0	3
2	44	1/8	0	7
3	25	1/5	0	7
4	44	1/5	0	3
5	25	1/8	1	7
6	44	1/8	1	3
7	25	1/5	1	3
8	44	1/5	1	7
9	34.5	0.1625	0.5	5
10	34.5	0.1625	0.5	5
11	34.5	0.1625	0.5	5

hypocotyls lengths, fresh and dry weights of roots and hypocotyls, as well as the seedling vigor and the germination indexes. The seedling vigor index (SVI) was calculated according to the following equations [32]:

$$\text{SVI} = (\text{Seedling lenght} \times \text{Germination percentage})/100$$

2.8. Effect of Food Waste Compost and Its Fermented Extract on the Plants' Growth

The compost was mixed with the greenhouse soil composed of 60% sand, 25% clay and 15% silt, and characterized by neutral pH (7.08 ± 0.12), low electrical conductivity: EC (0.34 ± 0.02 mS/cm), and relatively low organic matter (OM) content (1.52% ± 0.02%). Four different proportions of compost and soil were prepared and irrigated by 20 ml of distilled water or non-aerated fermented compost extract diluted at 1/8 in distilled water then used seed sowing and seedlings growth. Three seed varieties: peas (*Pisum sativum* L.); chickpea (*Cicer arietinum*) and beans (*Vicia faba*) were used to evaluate the efficiency of FWC and NFCE. The substrates compositions and the irrigation conditions are as follows:

A0: 100% soil irrigated with distilled water.

A: 100% soil irrigated with fermented compost extract.

B0: 75% soil and 25% compost irrigated with distilled water.

B: 75% soil and 25% compost irrigated with fermented compost extract.

The compost and its fermented extract effects on the growth of three seedlings of beans, peas and chickpea. The efficiency of different treatments was estimated by measuring the growth parameter including plant height, the stem diameter and the leaves number at day fifteenth of growth in greenhouse.

2.9. Statistical Analysis

The data were analyzed using IBM SPSS statistics version 19 to evaluate the significant variance. The mean values of the treatments were compared using Duncan's multiple range tests at a 5% level of significance ($p < 0.05$).

3. Results and Discussion

3.1. Physico-Chemical and Microbial Characterization of the Studied Compost and Its Extract

The compost derived from food wastes had a neutral pH and relatively high EC. It was also characterized by high organic and mineral matter contents and a low C/N ratio (**Table 1**), reflecting its maturity and conformity to the compost quality standards described by Mustin, [33]. In contrast, Voběrková *et al.* [2] showed an acidic pH of food waste compost around 6 that would be caused by organic acidic metabolism. The same authors found high C/N ratio of 20, explained by the high carbon and nitrogen contents in FWC and in FWC added with biochar, prepared using electrical composter during 35 days. Also, Kucbel *et al.* [12] showed a high EC around 9 mS/cm and a C/N exceeding 23 of household FWC made using automatic composter during 4 weeks. These results were different from those found in our experiments, prepared by conventional methods using natural biodegradation process in open air conditions, during four months. Furthermore, the studied compost has relatively high mineral elements concentrations, especially phosphorus, potassium, sodium and magnesium, which are responsible for the significant plant fertilization. Indeed, it was reported that phosphorus is a constituent of the plants complex nucleic acid structure, which regulates protein synthesis [34]. Therefore, phosphorus is important for plant including cell division of the new tissue, photosynthesis and the complex energy transformations in the plant. Also, potassium is a nutriment required for plant growth since it improves growth, carotene and chlorophyll contents [34]. The microbial characterization of FWC and NFCE showed an important aerobic mesophilic bacteria concentration in mature compost compared to that of molds and yeasts (**Table 1**). Previous researches showed that the mesophilic bacteria were the dominant biomass during compost production, especially at the process beginning, when the temperature is low and the humidity high, and at the end composting stage, when the temperature and the C/N are low [2] [15] [17] [26] [33]. The molds and the yeasts occurrence was in relation with the lignocellulosic activate biomass [26] [33] [35] [36]. Singh and Nain [37] revealed that hundreds of fungi are also capable of degrading lignocellulose materials. They mentioned three major types of fungi known to reside in the dead woods containing the lignocellulose. All of the soft and the brown rot fungi, as well as the white-rot fungi are able to degrade the wood components. The soft rot fungi: *Chaetomium, Ceratocystis*, and *Kretzschmaria deusta* can decompose cellulose but degrade lignin slowly and incompletely. Therefore, the regulation and control of these microorganisms can help to speed up the rate of composting [34]. These findings are in agreement with many others studies which have shown that soil amendment with compost would improve physical soil properties and availability of nutrients that would activate the microbial flora [26] [31] [34] [38] [39] [40]. In 2020, Voběrková *et al.* [2] mentioned high enzymatic activities in FWC, when used alone or supplemented with biochar and sawdust such as deshydrogenases, proteases, β-D-glucosidases, phosphatases and arylsulphatases during 35 days of composts' maturation.

The experimented FWC exhibited an optimal value of FM (2.97), affirming that the compost didn't include fine sand but was formed by slightly coarse particles (**Table 1**). This is an important characteristic of the compost particle size composition. Indeed, the suitable FM value attributes to the compost an appropriate water content retention potent, crucial for plant growth. Moreover, this FM increases the surface aggregate ability, improving the contact with the microbial soil flora.

The experimented NFCE had neutral pH values within the required pH for plant growth (**Table 3**) lower than that of the original compost, reflecting the acidic metabolism of the extract' flora. Furthermore, the extract exhibited the same compost EC value, explained by the compost major minerals solubilisation. In 2011, Pant *et al.* [22] mentioned that the application of vermicompost teas did not affect pH, but significantly increased the EC, N, and K content of pak choi growth media. More recently, the same results were found by Hanc *et al.* [41] who showed a significant increase in the EC value and in the NH_4^+, NO_3, and macro-elements concentrations in the aerated vermicompost extracts. The NFCE showed a high carbon content (COD = 9.70 g/l) explained by the compost high organic load and the glucose added during the fermentation process used. The NFCE exhibited high microbial rate, especially mesophilic bacteria, as was the original compost. The extract fermentation conditions (glucose, temperature of 25˚C and incubation for 7 days) improved the microbial activities in the compost extract. Consequently, the microbial concentrations were increased by 225 times for mesophilic bacteria, 25 times for yeasts, and by 10 times for molds in the NFCE compared to that of the compost. Ingham [21] mentioned that if the fungal biomass is low in the compost, its concentration

Table 3. Physico-chemical and microbial characterization of compost extract.

Parameter	Compost extract
pH	6.93 ± 0.12
EC (mS/cm)	3.12 ± 0.01
COD (mg/l)	9700 ± 50
TOC (g/l)	0.405 ± 0.040
NTK (mg/l)	56.90 ± 1.22
Mesophilic bacteria (ufc/ml)	7.2×10^8
Yeats (ufc/ml)	2×10^5
Molds (ufc/ml)	1×10^5

EC: Electrical conductivity; COD: Chemical oxygen demand; TOC: Total organic carbon; NTK: Total Kjeldahl nitrogen.

remains low in the tea. The same authors reported that bacteria concentration was increased by 100 to 500 times the original number during a tea production, while fungi may only be increased by 5 to 10 times.

3.2. Fermented Compost Extract' Effect on Seeds Germination and Growth

The studied fermented compost extract effects on seed germination of tomato (*Solanum lycopersicum* L.), watercress (*Nasturtium officinale*), and chili pepper (*Capsicum annuum*) were presented in Figure 1 and Table 4. The results showed that the use of non-diluted extract markedly decreased all the biometric analyses values of the germination and the growth for the three experimented seeds compared to the control (distilled water). However, all these values decreased with the NFCE applied doses (dilution 1/2, 1/4, and 1/8). The dilution 1/8 exhibited the best results considering all of the experimented parameters (Figure 1). Particularly, tomato germination was the most affected by the NFCE, followed by watercress then chili pepper, the latter was negatively impacted by

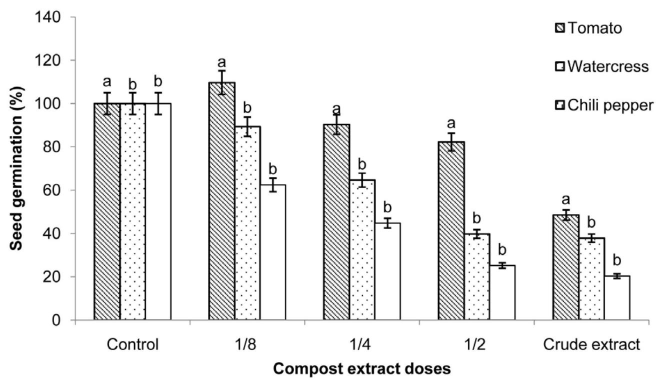


Figure 1. Effect of fermented compost extract on seed germination; (n = 10 and $p < 0.05$).

Table 4. Fermented compost extract effect on aerial parts growth of tomato, watercress and chili pepper after 15 days in greenhouse (n = 10; $p < 0.05$).

Parameters	Tomato					Watercress					Chili pepper				
	Control	Dilution			Non diluted extract	Control	Dilution			Non diluted extract	Control	Dilution			Non diluted extract
		1/8	1/4	1/2			1/8	1/4	1/2			1/8	1/4	1/2	
Fresh weight (mg)	86.21^a	90.06^a	69.24^a	70.85^a	50.96^a	57.11^b	61.68^b	47.56^b	45.79^b	43.37^b	42.65^b	54.13^b	50.89^b	39.54^b	27.76^b
Vigor index	15.2^a	16.2^a	13.7^a	12.7^a	7.98^a	14.3^a	15.6^a	10.7^a	9.7^a	9.0^a	0.5^b	1.7^b	2.7^b	1.2^b	0.3^b
Hypocotyl length (cm)	9.0^a	9.4^a	8.1^a	7.6 ^{a}	7.1^a	5.4^b	6.4^b	6.1^b	5.6^b	5.1^b	0.3^c	1.6^c	1.4^c	0.6^c	0.4^c
Hypocotyl fresh weight (mg)	64.22^a	67.12^a	57.77^a	50.46^a	34.67^a	32.41^b	38.44^b	34.78^b	28.94^b	25.03^b	17.86^c	25.60^c	19.78^c	14.81^c	9.05^c
Hypocotyl dry weight (mg)	25.63^a	28.22^a	25.99^a	25.73^a	20.10^a	11.20^b	14.20^b	15.89^b	11.29^b	10.20^b	9.07^c	11.75^c	8.30^c	6.23^c	5.02^c

Different letters (a - c) indicate significant differences ($p < 0.05$) between different compost extract dilution.

the extract (**Table 4**). This fact could be explained by the eventual presence of inhibiting substrates when used at high concentrations, especially phenolic compounds and lignin, as the main components in composted plant materials [38]. Indeed, the presence of phenolic compounds in vegetable wastes compost was reported, these are specific phytochemical antioxidants naturally present in practically all plant materials [42]. However, in the compost and at high levels, these compounds can produce an adverse environmental impact mainly due to their phytotoxic effect, inhibiting plant germination [26] [35] [43], as well as their effect on soil nitrogen immobilization [44]. Bernal *et al.* [45] mentioned that cellulose, hemicellulose and lignin derived components are partially decomposed during composting and they are transformed at low speed. Jurado *et al.* [46] mentioned that the cellulose is the fraction that is most affected by the composting process, in contrast to lignin and hemicellulose, which concentrations remained almost unchanged in the final product, in comparison to their initial contents in the raw material.

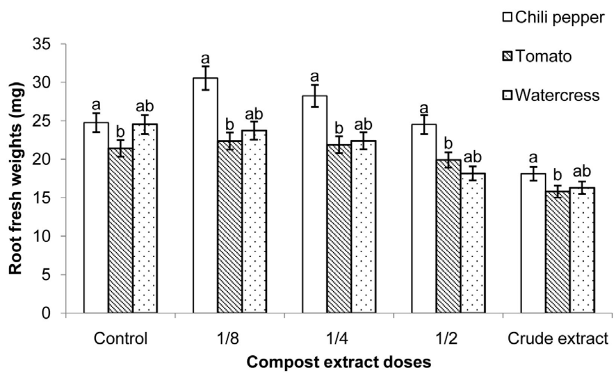
The NFCE germination index showed values exceeding 50%, the limit value indicating the absence of phytotoxicity, as established by Zucconi *et al.* [47]. These values were obtained for tomato seeds on compost extract diluted by 1/2, 1/4, and 1/8, for watercress at the dilutions 1/4 and 1/8, and for chili pepper at the 1/8 dilution (**Figure 1**). The decrease in the compost extract concentration leads to a decrease in its toxic compounds concentration that improves seed germination. The percentage of seed germination of all studied seeds varieties was best fitted linear equation as follows:

- Tomato: Seed germination (%) = −13.03 × [Compost extract doses] + 125.26; $R^2 = 0.780$
- Watercress: Seed germination (%) = −17.38 × [Compost extract doses] + 118.47; $R^2 = 0.950$
- Chili pepper: Seed germination (%) = −19.62 × [Compost extract doses] + 109.51; $R^2 = 0.930$

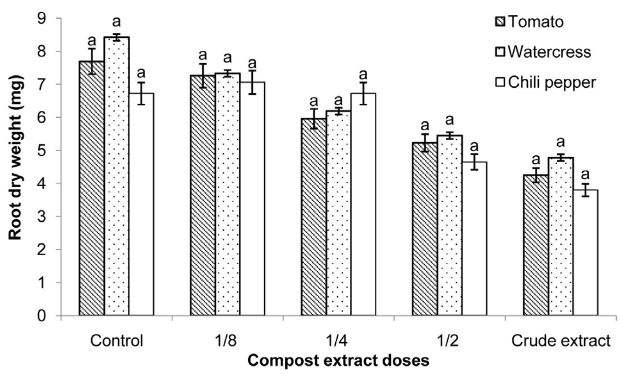
The relatively high values of the squared correlation coefficients (ranged from 0.78 to 0.95) confirmed the models validity.

Nevertheless, the chili pepper showed the highest root fresh weight compared to other plant used, although it had the lowest seed germination percentage, this could be explained by its roots richness in absorbent hairs, with high water content, reflecting their relatively important fresh weight (**Figure 2(a)**).

The fermented compost extract application improved the tomato fresh weight increase and aerial growth (hypocotyls and vigor index) compared to the other seedlings (**Table 4**). There was a significant difference in the NFCE effect on germination and growth of tomato and watercress seedling ($p < 0.05$) for the majority of the studied parameters except for the vigor index (**Table 4**) and the roots dry weight (**Figure 2(b)**). When non-diluted extract was used, the different biological parameter values were 0.54 to 0.79, 0.63 to 0.94 and 0.5 to 0.65 times the control values, respectively for tomato, watercress and chili pepper. However, the NFCE used at different concentrations, significantly affected ($p < 0.05$)



(a)



(b)

Figure 2. Effect of fermented compost extract on root fresh weight (a) and root dry weight (b); (n = 10 and $p < 0.05$).

the germination and the growth of pepper except the fresh weight (**Table 4**) and the fresh and the dry roots weight (**Figure 2**). Furthermore, when irrigated by 1/8 diluted NFCE, aerial fresh parts weights were increased by 26.9%, 18% and 4.5% respectively for the chili pepper, the watercress and the tomato, grown in greenhouse during 15 days. In the same conditions, the chili pepper exhibited the best vigor index improvement, as well as hypocotyl length (+433%) and fresh and dry weights (respectively +43.3% and +29.5%). The results evidenced that tomato plant was the most resistant to the fermented composted effect (**Table 4**).

Kim *et al.* [48] reported the effect of four vermicompost teas concentrations (0.1%, 0.2%, 0.4%, and 0.8%) on shoot growth of the red leaf lettuce, sweet corn and soybean. The same authors mentioned the use of vermicompost tea at 0.8%, significantly increased the root and shoot growth of red leaf lettuce, sweet corn and soybean.

3.3. Food Waste Compost and Its Fermented Extract Effects' on Plants Growth

The FWC and its fermented extract were used as soil amendment for the growth of three seedlings varieties: peas (*Pisum sativum* L.); chickpea (*Cicer arietinum*) and beans (*Vicia faba*) (**Table 5**). The results showed the significant increase ($p < 0.05$) of the plant height, stem diameter and leaves number of all the used

Table 5. Food waste compost and its fermented extract effects on plant's stem growth (cm) after 15 days (n = 10; $p = 0.05$).

Seed variety	Substrate	Height (cm)	Stem diameter (mm)	H/D	Leaves number/plant
Beans (*Vicia faba*)	A0	11.86 ± 0.22^{bc}	0.30 ± 0.03^{b}	39.53	16 ± 0.57^{ab}
	A	18.22 ± 0.45^{a}	0.60 ± 0.01^{a}	30.36	32 ± 1.00^{a}
	B0	16.50 ± 0.50^{ab}	0.40 ± 0.02^{b}	33.00	22 ± 1.50^{ab}
	B	13.24 ± 0.25^{c}	0.30 ± 0.01^{b}	44.13	12 ± 0.57^{b}
Peas (*Pisum sativum* L.)	A0	13.28 ± 0.06^{bc}	0.20 ± 0.01^{b}	67.20	10 ± 1.45^{ab}
	A	16.55 ± 0.32^{a}	0.25 ± 0.05^{a}	66.20	12 ± 0.50^{a}
	B0	13.00 ± 0.10^{ab}	0.20 ± 0.02^{b}	65.00	10 ± 0.57^{ab}
	B	10.44 ± 0.15^{c}	0.15 ± 0.02^{b}	69.60	8 ± 1.00^{b}
Chickpea (*Cicer arietinum*)	A0	9.50 ± 0.50^{bc}	0.20 ± 0.03^{b}	47.50	38 ± 2.07^{ab}
	A	12.75 ± 0.30^{a}	0.30 ± 0.05^{a}	42.50	63 ± 2.00^{a}
	B0	12.21 ± 0.20^{ab}	0.20 ± 0.03^{b}	61.05	58 ± 2.50^{ab}
	B	7.25 ± 0.10^{c}	0.10 ± 0.02^{b}	72.50	30 ± 1.00^{b}

A0: 100% soil was irrigated with distilled water; A: 100% soil was irrigated by the fermented compost extract diluted at 1/8; B0: 75% soil and 25% compost was irrigated with distilled water; B: 75% soil and 25% compost was irrigated by fermented compost extract diluted at 1/8. Values represent the means of three samples (±SE). Different letters (a - c) indicate significant differences ($p < 0.05$) between soil growth conditions.

seedlings when the soil was irrigated with NFCE (A) comparing to that with distilled water (A0) (**Table 5**), confirming the NFCE fertilizing contents, such as organic matter and mineral elements [35]. Furthermore, the addition of the fermented compost extract derivatives improved the young plants rigorous state, defined by the H/D ratio. Actually, the low H/D ratios seedlings are more resistance to harsh climatic conditions (wind and frost) [31].

In parallel, the seedlings height, the stems diameters and the leaves number of all the experimented seeds were more important in the soil amended by 25% of the FWC (B0) compared to the soil used alone (A0), as well as the substrate (soil 75% + 25% FWC) (B). In contrast, the food waste compost prepared by Voběrková *et al.* [2] and and Kucbel *et al.* [12] showed a total phytotoxic on the experimented plants. On the other hand, when soil amended by 25% of compost was irrigated with fermented compost extract (B), the seedlings were shorter and with a reduced leaves number compared to all the other growth conditions. The application of FWC or NFCE, each used alone, improved the seedlings growth ($p < 0.05$). Nguyen *et al.* [39] mentioned that the FWC had positive impact on the growth of the vegetables. Most vegetables grew on compost had a much better weight, height, root length and germination than those growing on soil alone or fertilized by chemicals. Whereas a combined application of FWC and its extract significantly decreased ($p < 0.05$) the height of the seedlings as well as leaves number production and reduced the rigorous state (H/D ratio). It has been well reported that organic waste compost exerts a substantial and direct influence on plant growth by affecting biochemical, physiological, and morphological processes during seed germination, cell development, ions uptake and overall plant growth [15] [35]. But an accumulation of toxic substances such as aromatic compounds and humic acids by combining compost and its fermented derivative induced their phytotoxic effect when exceeding the threshold concentration.

4. Conclusion

In this study, the application of food wastes and its fermented compost extract increased the germination percentage and the seedlings growth of tomato, watercress and chili pepper. Furthermore, the uses of soil amended by compost or by fermented compost extract improved heights, roots diameter and leaves number of peas, chickpea and beans seedlings. Whereas, the combined application of compost and its fermented extract decreased significantly the growth of all the studied seedlings. Consequently, it will be interesting to use compost alone or fermented compost extract alone as agents for crops, promoting plant growth in organic cultivation. Considering the high availability of food waste in the World, the composting of this by-product and its fermented compost extract could offer a sustainable cost effective and eco-friendly process to ensure the organic fertilization of poor soils, deficient in organic matter.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

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