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Usability of Jerusalem artichoke tuber waste in lettuce (*Lactuca sativa* var. longifolia) seedling production

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Abstract

The growing medium, which is crucial for seedling production, directly affects germination and the subsequent root system. This medium not only provides support to the plant, but also acts as a source for water and nutrients. It also allows diffusion in the roots and provides gas exchange between the root and the atmosphere outside the root. In this study, the usability of Jerusalem artichoke tuber residues in lettuce seedling cultivation was investigated under greenhouse conditions.For this purpose, was added main media (peat, perlite, peat 50%+perlite 50%) and different proportions Jerusalem artichoke residues of 32, 48, and 96 grams. At the end of the experiment, the number of leaves, plant weight, plant height, leaf length, leaf width, leaf surface area, root length and root weight values were measured. A statistically significant effect of media types was determined in all measured parameters. A statistically significant effect of medium types was determined in all measured parameters. In general, it has been observed that the 32 g L^{-1} Jerusalem artichoke residue additives made to the peat cause an increase in many values. The most prominent issue in increases is that the effect on the values from the weight unit is higher than the ones in the length unit. This result shows that Jerusalem artichoke residues lead to stronger tissues in lettuce seedlings.

Keywords: Growing Media, Organic, Reuse, Roots

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INTRODUCTION

Despite the rapid increase in the world population, the gradual decrease of the limited agricultural areas has increased the need for food and directed the producers to the cultivation of more productive, high quality and disease and pest resistant products from the unit area (Demirsoy &Uzun, 2019).

One of the most important issues affecting the success in vegetable growing is the use of the right seedlings as starting material (Polat et al., 2017). Obtaining quality seedlings is related to both the use of quality seeds and the preparation of the right seedling growing environment. There is a strong relationship between the amount / availability of nutrients and the amount of organic matter in plant growing medium (Demiral, 2000).

A suitable growing environment is essential for quality seedling production and directly affects growth and the subsequent root system. The growth medium is not only the place where the growth takes place, but also serves as a nutrient source for plant growth (Aytekin *et al*., 2021). Good selection of organic and inorganic growing media plays a key role in successful seedling production. It is reported that the growing media mixtures (silt, leaf compost, farm manure, cocopeat and perlite) used in different ratios have significant effects on the physiological and morphological characteristics of the plants (Hussain *et al*., 2016). The quality of the seedlings used is directly related to the yield and quality of the final product. Before that, the environments used in seedling production directly affect seedling development and production cost (Yılmaz & Kınay, 2016).

Peat has traditionally been used as the main seedling growing media component in Europe (Landis *et al*, 2009). Today, annual peat production in Europe is over 40 million m3. high cation exchange capacity, low nutrient levels, low pH, suitable water holding capacity and air capacity are the most important reasons why Peat is in such demand

(Prasad et al, 2018). Despite all these positive features, the high cost of energy used to extract peat and transport it over long distances (which has to be transported from northern Europe to other regions) and its contribution to the carbon footprint raises environmental concerns (Landis et al., 2009, Gruda, 2019).

Studies investigating commercial soilless mixture materials that can be used in seedling growing environments have mostly focused on the availability of regional organic wastes rather than inorganic materials (Polat *et al*., 2017). In addition, some industrial and agricultural waste materials, which cause environmental pollution and financial losses, contribute to the increase of organic matter content of the soil by being evaluated both in seed sowing and seedling planting, and by adding a certain amount of plant nutrients if necessary. A practical solution to minimizing the generation and disposal of waste materials would be to compost the biodegradable waste in situ and then use the compost as a component of the growing medium for seedling production (Veijalainen *et al*., 2008).

Coconut fibers were mixed with peat in different ratios and tried as an organic seedling growing medium in curly lettuce (Colla *et al*., 2007).It has been reported that the highest results in terms of fresh weight, dry weight, and leaf area characteristics of the seedlings were measured in media consisting of 40% and 60% coconut fiber. Aklıbaşında *et al*. (2011) investigated the effects of paddy husk, tuff and peat materials on yellow pine seedling production. At the end of the experiment, the best seedling growth porosity was obtained from peat medium with a porosity of 60.1% and a usable water volume of 15.9% and 10% paddy husk. It was observed that the seedlings did not develop in the environment consisting only of rice husk. Peat with 30% with rice husk medium gave almost the same results as the medium consisting only of peat.

The American origin Helianthus genus has around 50 species grown in the world. Jerusalem artichoke is categorized in this genus (Heiser, 1978). Jerusalem artichoke is highly tolerant of most environmental stress conditions and has the potential to grow aggressively. The most important advantage of rapid growth is the low pesticide requirement and the increased amount of biomass per area. In addition to containing different kinds of vitamins, minerals, it contains complex carbohydrate inulin, which can improve health in humans. Because of these properties, Jerusalem artichoke is considered not only as a human or animal feed, but also as a promising plant for ethanol production (Kays *et al.*, 2007). Although Turkey is not the homeland of Jerusalem artichoke, it has been cultivated for a long time. Considering Turkey's very different ecological conditions and selection by breeders over time, it is assumed that significant genetic variation can be observed in local Jerusalem artichoke accessions. In 2018, the gene pool of Jerusalem Artichokes started to be created at Erciyes University. Within the scope of this project, a collection was created with tuber samples from different provinces and towns of Turkey and this collection was enlarged with crossbreeding studies (Hanci & Tuncer, 2019; Hanci, 2021).

In this study, the usability of dry tuber residues, which occur during the production of Jerusalem artichoke flour, as a medium additive in the production of lettuce seedlings was investigated comparatively.

MATERIALS AND METHODS

The research was carried out in the greenhouses of Sivas-Şarkışla Research Station of Middle Black Sea Transitional Zone Agricultural Research Institute on April 2022. Jerusalem artichoke tuber waste (JA) was obtained from the gene pool of Erciyes University Faculty of Agriculture. In the study, “TS1 Klasmann Deilmann” peat was used as the main component (N:80 mg/dm, P_2O_5: 200 mg/dm, K_2O:360 mg/dm, Mg:100 mg/dm). As the other main component, sterile agricultural perlite was used (pH 6.5-7, 4-6 mm in diameter, with a density of 1 kg/20 lt (±5%)

For the preparation of the media containing Jerusalem artichoke tuber waste, one liter volume of main media (peat, perlite, peat 50%+perlite 50%) were placed in clean containers. Jerusalem artichoke residues are the hard material with a diameter of 0.5-0.7 mm remaining after grinding the tubers dried at 55 degrees Celsius for 36 hours for flour production. (Hanci *et al.* 2020) Lots of 32, 48, and 96 grams of this material were added to one liter of main media and mixed homogeneously.

The prepared mixtures were filled into plastic viols with 4x4x8 cm volumes. Lettuce (*Lactuca sativa* var. longifolia cv. Grise Maraichere) seeds were used as plant material. The seeds were sown at a depth of 1 cm in April 2022. In the experiment, which was carried out in 3 replications according to the randomized plots trial design, 108 seeds were used in each plot.

The experiment was followed for 45 days, the number of leaves, plant weight, plant height, leaf length, leaf width, leaf surface area, root length, root weight were measured in the seedlings obtained and the ratios of the relevant parameters to each other were calculated. The data were analyzed by using JMP Pro 17.0 statistical package program, analysis of variance was performed and statistically significant parameter values according to the results of analysis of variance were compared with LSD test.

RESULTS AND DISCUSSION

As a result of the analysis of variance, it was determined that the difference between the seedling growing media was significant at the 5% level in terms of all lettuce seedling characteristics. The effects of different seedling growing media on seedling characteristics are given in Table 1 and 2. The germination rate of seeds was 100% in the whole experiment.

Table 1. Interaction Effect of Growing Media and Jerusalem Artichoke Supplements.

Main media	Jerusalem Artichoke supplement ($g\ L^{-1}$)	Number of leaves (pcs)	Whole Plant Weight (g)	Root Weight (g)	Total Leaf Weight (g)	Root/Leaf Ratio (Weight)
Peat	0	16.89±0.4 a	22.67±0.8 bc	4.44±0.1 b	18.22±0.2 bc	0.25±0.02 cd
	32	14.33±0.3 ab	42.11±1.1 a	15.06±0.2 a	27.06±0.5a	0.45±0.08 b
	48	13.44±0.3 bc	33.44±1.0 ab	7.00±0.1 b	26.44±0.6 ab	0.30±0.04 bcd
	96	9.78±0.3 def	20.56±0.9 c	3.72±0.1 b	16.83±0.2 cd	0.21±0.05 cd
Perlite	0	6.67±0.2 f	10.89±0.6 c	1.89±0.1 b	9.00±0.3 d	0.20±0.04 d
	32	8.11±0.3 def	16.33±0.7 c	3.22±0.1 b	13.11±0.4 cd	0.24±0.04 cd
	48	9.56±0.4 def	22.89±0.9 bc	4.72±0.2 b	18.17±0.5 c	0.27±0.05 cd
	96	7.22±0.4 ef	13.78±0.3 c	2.04±0.1 b	11.73±0.4 cd	0.17±0.02 d
Peat+ Perlite	0	10.33±0.4 cde	21.78±0.5 bc	3.7±40.1 b	18.03±0.3 c	0.25±0.04 cd
	32	8.67±0.3 def	23.44±0.5 bc	5.42±0.2 b	18.02±0.4 c	0.30±0.04 bcd
	48	11.22±0.5 bcd	18.67±0.6 c	6.89±0.3 b	11.78±0.2 cd	0.63±0.07 a
	96	9.11±0.4 def	18.89±0.5 c	4.61±0.3 b	14.28±0.4 cd	0.36±0.05 bc
Mean		*10.44±1.6*	*22.12±2.1*	*5.23±1.1*	*16.89±2.2*	*0.30±0.4*
F value		*6.993*	*3.515*	*5.805*	*3.560*	*5.639*

**Means within a column that have a different small letter are significantly different from each other ($p \leq .05$).*

When the number of leaves of the seedlings is examined, it is seen that the highest result is observed in seedlings grown in peat media without JA added (16.89 per plant). The lowest value was obtained from seedlings grown in perlite without any organic material such as peat or JA (6.67 per plant). In whole plant weight values, the addition of 32 and 48 $g\ L^{-1}$ JA to peat caused higher results than other treatments (42.11 and 33.44 g respectively). As with the number of leaves, perlite media caused these values to decrease, but 48 $g\ L^{-1}$ JA application increased the values relatively. A difference was observed in the increase in all plant biomass (root+stem+leaf) on peat-based media. This situation has also been experienced in peat+perlite-based media. Although the lowest plant biomass was measured in perlite medium, one of the highest results could be obtained with the addition of 48 $g\ L^{-1}$ JA (Table 2).

When the whole plant weight and whole plant height values are examined together, it is clearly seen that 32 and 48 $g\ L^{-1}$ JA additions to peat cause weight gain without affecting the length. This proves that the addition of JA promotes firmer structure of plant tissues. Except for these two treatments, there is a correlation between the two parameters in all results (Figure 1). As a result of the measurement made after the root zone of the plants was removed, the highest value was obtained with the addition of 32 $g\ L^{-1}$ JA to the peat. The same application gave the highest result in terms of total leaf surface area. While each JA dose increase in peat led to a decrease in the amount of leaves, the weight increase experienced with the addition of 32 and 48 $g\ L^{-1}$ JA was found to be significant, just as in the root length/weight balance (Figure 2). All seedlings medias examined in the study had the same effect on root weight, except peat+32 $g\ L^{-1}$ JA (15.06 g). Similar results were also observed in root length results. As with other parameters, the negative effect of perlite was not observed in root weight, but it was repeated in root length. Supplementation of 48 $g\ L^{-1}$ JA was able to partially eliminate this effect of perlite (Figure 3). The addition of Jerusalem artichoke residues at the highest dose resulted in decreases in all parameters, except total leaf surface area and total leaf weight, compared to the 48 g/l treatment, and in some cases even compared to the control, although this decrease varied depending on the base media.

Table 2. Interaction Effect of Growing Media and Jerusalem Artichoke Supplements.

Main media	Jerusalem Artichoke supplement (g L^{-1})	Whole Plant Length (cm)	Root Length (cm)	Leaf Length (cm)	Leaf Width (cm)	Total Leaf Area (cm^2)	Root/Leaf Ratio (Length)
Peat	0	24.00±0.9 a	3.56±0.4 ab	15.02±0.9 a	3.8±0.4 bc	148.16±3.4 bc	0.24±0.01 bcd
	32	24.11±0.8 a	4.44±0.5 a	11.55 bcd	3.96±0.5 bc	219.98±2.5 a	0.39±0.02 a
	48	24.00±0.9 a	3.33±0.4 b	10.51±0.9 d	3.89±0.6 bc	215.02±3.6 ab	0.32±0.02 ab
	96	23.17±0.7 a	2.33±0.2 cde	12.49 bc	3.79±0.4 bcd	136.87±1.9 cd	0.21±0.03 cd
Perlite	0	16.70±0.6 c	1.74±0.3 de	7.37±0.4 e	3.04±0.4 e	73.18±1.4 d	0.24±0.02 bcd
	32	17.44±0.8 c	1.97±0.2 de	7.38±0.5 e	3.15±0.3 de	106.61±2.0 cd	0.27±0.06 bc
	48	22.50±0.9 a	3.00±0.4 bc	11.69±0.7 bcd	4.19±0.5 abc	147.71±2.3 c	0.27±0.05 bc
	96	17.67±0.5 bc	1.56±0.2 e	10.76±0.5 cd	4.43±0.6 ab	95.40±1.2 cd	0.15±0.02 d
Peat + Perlite	0	23.2±0.9 a	2.59±0.4 bcd	10.45±0.6 d	3.67±0.4 cde	146.63±3.0 c	0.27±0.05 bc
	32	23.00±0.8 a	3.08±0.2 bc	11.99±0.9 bcd	4.13±0.5 abc	146.54±3.1 c	0.27±0.04 bc
	48	22.67±0.9 a	3.56±0.4 ab	12.73±0.9 b	4.64±0.4 a	95.76±2.2 cd	0.28±0.07 bc
	96	21.33±0.8 b	2.72±0.4 bcd	11.48±0.8 bcd	4.08±0.6 abc	116.09±2.1 cd	0.24±0.05 bcd
Mean		*21.66±1.9*	*2.82±0.9*	*11.12±1.1*	*3.90±0.8*	*137.33±2.8*	*0.26±0.09*
F value		*4.168*	*3.012*	*9.778*	*3.979*	*3.560*	*3.032*

**Means within a column that have a different small letter are significantly different from each other (p ≤ .05).*

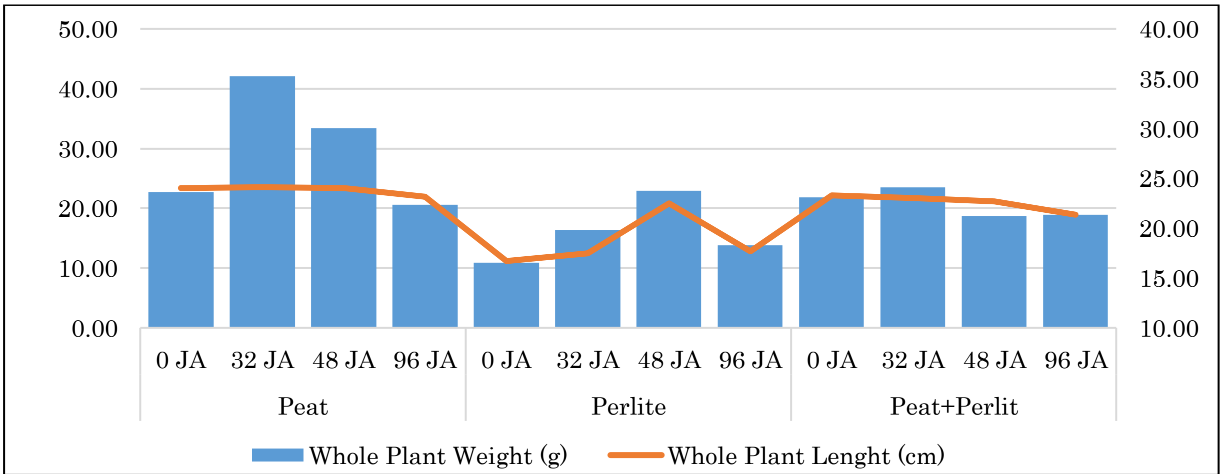

Figure 1. Relationship Between Whole Plant Weight and Whole Plant Length.

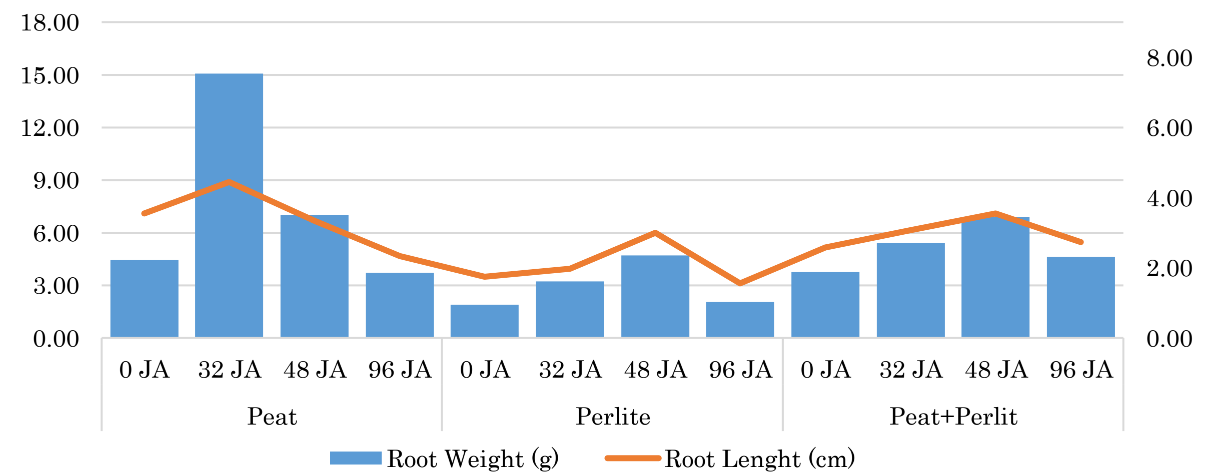

Figure 2. Relationship between root weight and root length.

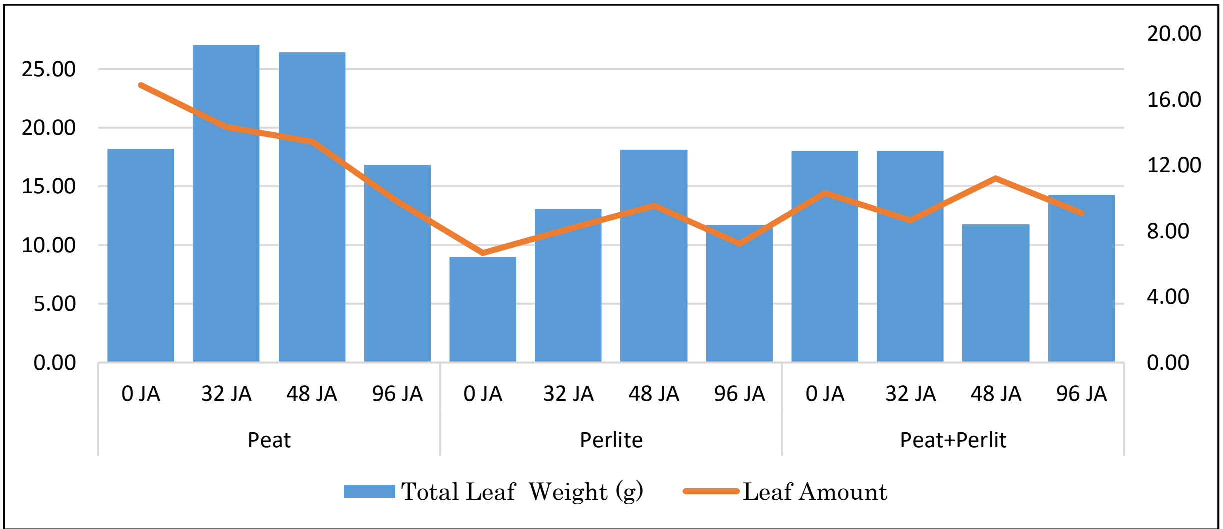

Figure 3. Relationship Between Total Leaf Weight and Number of leaves.

Depending on where they come from, agricultural 174 wastes are not only biodegradable by nature but also full of nutrients (carbohydrates, proteins, fibers, minerals, vitamins, etc.). Waste evaluation not only resolves the issue of disposal but also the issue of environmental degradation. Interest in converting agricultural and industrial wastes into commercially valuable products is growing rapidly. Effective management of agro-industrial waste based on sustainable criteria is an inexpensive, accessible, and widely available alternative that provides a model for adding economic value to the agro-industrial chains of crops (Gruda, 2019).

In the study of Zhu *et al* (2021), residues of Jerusalem artichoke were added in three soils differing in salinity, and the physical and chemical properties of soil and soil microbial community were defined over time. After residue incorporation, the soil organic matter content increased at first and then decreased whereas the soil salinity decreased significantly. pH level fluctuated between 6.8 and 8.0. The population of moderate halophiles and cellulose-decomposing bacteria in soil increased. Overall, the addition of Jerusalem artichoke residues can improve the soil's physical and chemical properties and the microbial community structure. The authors suggest that this situation may ensure a hypothetical foundation for the development of saline-alkali soils, reasonable usage of crop residues, and promoting sustainable development of modern agriculture. Shiven *et al* (2013) investigated the effect of Jerusalem artichoke residues on soil enzyme activities and microbial communities in tomato continuous cropping soil. They used the 2% (w/w) Jerusalem artichoke residue as the treatment material in the soil. At the end of the study, they reported that Jerusalem artichoke residue increased the activity of soil sucrose and urease. In addition, the soil sucrose activity showed a robust negative correlation with Fusarium and Bacillus. In general, the results disclosed that Jerusalem artichoke residues altered the soil bacterial and fungal community compound and the soil enzyme activities. Although the effects of Jerusalem artichoke residues on soil chemistry and biological content were investigated in these studies, the results indirectly support the results of our study. In our study, even at certain doses, Jerusalem artichoke residues positively affected some vegetative parameters of lettuce seedlings. Especially the addition of 32 g L^{-1} Jerusalem artichoke residue to peat led to significant increases in leaf and root weights

The findings of our study show that the highest dose (96 g L^{-1}) of Jerusalem artichoke residues had a negative effect on plant growth.Some reports indicate that high carbohydrate accumulation in soil can indirectly negatively affect plant growth. In particular, carbohydrates lead to rapid multiplication of microorganisms, causing them to consume more resources essential for plant growth, such as oxygen and nitrogen. This reduces the amount of oxygen reaching plant roots and can lead to depletion of plant nutrients. When microorganisms multiply in soils high in carbohydrates, they start to use more nitrogen for growth and energy production. This can reduce the level of nitrogen needed for plants, which slows down their growth.Carbohydrates, especially when they cause intense microorganism activity, can reduce the oxygen level in the root zone, limiting oxygen uptake by the roots. This can negatively affect plant health, leading to root rot and even plant death (Wang *et al*., 2024; Vincze *et al*., 2024).

Atiyeh *et al.* (2000) compared a standard commercial hydroponic growing medium with alternative media prepared with various organic products. At the end of the study, the germination rates of tomato, pepper, lettuce, and marigold seeds in the coconut/perlite mixture were similar to the results in the standard medium. However, the germination rate of tomato, pepper, and lettuce seedlings was low in peat/perlite medium. Replacing of 10% or 20% of either vermicomposting with coconut/perlite and peat/perlite blends significantly increased seedling growth and overall plant growth was as good as, and sometimes better than the Metro-Mix 360. In the study of Pinter *et al* (2019), the efficiency of the different types of composts (grape marc and a mixture of grape marc, goat manure, and leaves of alfalfa), on the germination and biomass of lettuce seedlings was surveyed. Results showed that composts increased lettuce biomass, with the highest values obtained in mixture compost treatments. Also, the compost mixture indicated the highest seedling biomass. Bassaco *et al.*, (2019) evaluated the effect of rice husk and rabbit manure vermicompost and the bovine rumen on the quality of lettuce seedlings. It was reported that the use of the rice husk and the vermiculite in the substrate improves physical conditions, as a soil conditioner, favoring the lettuce seedling development. The results obtained from these studies are generally in line with the results obtained from our study. In our study, it has been proven again that perlite alone cannot be an ideal growing medium, and the addition of Jerusalem artichokes has relatively eliminated this negativity. The main effective applications are additions to peat. Especially, 32 g L^{-1} of Jerusalem artichoke residue per liter of peat led to an increase in many parameters.

Carbohydrates are used in plant cells for growth and as a source of energy. However, these carbohydrates are mostly stored for cell wall synthesis and as structural components. Cell growth usually occurs through cell expansion and volume increase, which leads to an increase in the biomass of the plant. However, this effect is not directly reflected in length, as length growth is more sensitive to hormonal signals and water balance. Weight gain is a direct consequence of the accumulation of carbohydrates and other components in the tissues (Wang *et al*., 2024; Vincze *et al*., 2024).

In plants, growth in height is mainly controlled by hormones (e.g. gibberellins) and is related to the tendency of cells to elongate. Carbohydrates are concentrated in tissues such as roots, stems or leaves, increasing the weight of the cells. This leads to an increase in biomass in the internal tissues of the plant, with a limited effect on growth in height. In other words, carbohydrates are more associated with the condensation and weighting of tissues, leading to mass growth rather than height growth (Hayat *et al.,* 2010).

CONCLUSION

Reusing organic wastes from plant cultivation or processing in agricultural production and incorporation into growth media can efficiently increase soil organic matter and mineral nutrient content, develop soil structure and fertility, and increase yields. In this study, the combinations formed by the addition of tuber residues from Jerusalem artichoke flour production to various seedling growing media without any pretreatment were compared in the production of lettuce seedlings at the first time. All seedlings medias examined in the study had the same effect on root weight, except peat+32 g L^{-1} JA (15.06 g). Similar results were also observed in root length results. As with other parameters, the negative effect of perlite was not observed in root weight, but it was repeated in root length. Supplementation of 48 g L^{-1} JA was able to partially eliminate this effect of perlite. The results of the study showed that the Jerusalem artichoke residues added to the peat at a rate of 32 g L^{-1} led to an increase in many measured morphological data. The most prominent issue in these increases is that the effect on the values from the weight unit is higher than the ones in the length unit. This result shows that Jerusalem artichoke residues lead to stronger tissues in lettuce seedlings.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Declaration of Interests

The author has no conflict of interest to declare.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

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