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# STUDY ON THE USE OF PAPER WASTE AS AN ALTERNATIVE SUBSTRATE FOR *FICUS BENJAMINA* SPECIES

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***Abstract***

*The main objective of the paper was to establish the effectiveness of paper waste added to a growth medium, avoiding waste management processes, which require time and energy, but providing an efficient solution for using paper waste as a nutrient substrate for plants cultivated in containers. It was specifically aimed to evaluate the percentage of peat that could be replaced by waste paper for the ornamental plant Ficus benjamina cv. 'Golden King' in an experiment with 4 variants in 3 repetitions (V1 - 100% peat, V2 - 80% peat+20 % paper waste, V3 - 70% peat+30% paper waste, V4 -50% peat+50% paper waste) in 2023. In conclusion, based on the research carried out, it can be stated that paper waste mixed with peat in a proportion of 30% can be used as an alternative substrate.*

***Key words****: paper, waste, alternative substrate, peat.*

## INTRODUCTION

The practice of using waste paper for horticultural plant production is considered an alternative of peat after composting (Molitor & Bruckner, 1997) and has gained popularity in recent years due to its environmental benefits.
One challenge in finding a suitable peat substitute is ensuring that the growing medium can support optimal plant growth without the need for additional fertilizers or pesticides (Pasquier et al., 1982).
Research is ongoing to develop new, sustainable substrates for horticulture that can replace peat while maintaining plant health and productivity. This includes investigating novel materials as well as studying the interactions between plants and different growing media.
By using waste paper as an alternative substrate, we can reduce the demand for peat extraction, which is a non-renewable resource that is often harvested unsustainably from natural peatlands (Hirschler et al., 2022).
Composted waste paper can provide a valuable source of organic matter and nutrients for plants, helping to improve soil structure and fertility. Additionally, using waste paper for horticultural purposes can help to divert this material from landfill, reducing the amount of waste contributing to pollution and waste valuable resources, minimizing costs for both industry and the environment (Vannucchi et al., 2020).
In 2020, a quantity of paper and cardboard of 32.7 million tons was generated in the EC member countries, which represents 41.2% of packaging waste. The highest recycling percentage of paper and cardboard waste was recorded in Belgium at 79.2%, followed by Norway (78.8%) and Luxembourg (71.9%), while in Romania the recycling percentage was of 44.6%) (***, Eurostat, 2021).
35 % of the felled trees cut worldwide are used for paper production, paper consumption has increased with 400 % over the last 40 years globally (Cheung & Pachisia, 2015) and due to the fact that single-use plastic products have been replaced by paper and cardboard ones. It is considered that paper is contributing to 31% of the global packaging market (Jones & Comfort, 2017).
Overall, using waste paper for horticultural plant production is a sustainable and environmentally-friendly practice that can help to conserve natural resources and reduce waste. It offers a viable alternative to peat and can contribute to the circular economy by closing the loop on paper production and consumption.
Both recycling and the recovery of paper and cardboard with energy recovery bring benefits

in terms of reducing greenhouse gas emissions and of course significant benefits to landfills (***, H.G. 870/2013).

The results of the study done by Jones et al., 2020, suggest that composted waste paper has the potential to be a valuable resource in agriculture, helping to improve soil quality and support plant growth.

The research done by Chrysargyris et al., 2018, found that using 30% paper waste as a substitute for peat in potting culture for marigold and petunia did not have any negative effects on plant growth or development. However, when they tried to use the same substitution rate for *Matthiola*, they found that the physicochemical properties of the substrate needed further improvement in order to support optimal plant growth.

This study suggests that while paper waste can be a viable substitute for peat in certain potting cultures, it may not be suitable for all plant species without additional adjustments to the substrate (Chrysargyris et al., 2019).

The addition of paper waste can increase the organic matter content and lowered the pH of the substrate. These changes can have both positive and negative effects on plant growth, depending on the specific needs of the plant species being grown. Additionally, the altered physicochemical characteristics of the substrate may impact the overall health and stability of the plant ecosystem in which the substrate is used (Chrysargyris et al., 2020).

## MATERIALS AND METHODS

This study was undertaken to evaluate the suitability of paper waste as growing media for *Ficus benjamina* cv. 'Golden King' plants cultivated in containers and it was specifically aimed to evaluate the percentage of peat that could be replaced by waste paper. The study involved the establishment of experimental containers with varying percentages of paper waste mixed with peat, as a growth medium and the characterization of the components that were used for the nutrient mixture through physical and chemical analyses.

The morphological characters such as plant height, length of shoots, length of leaves, width of leaves, length of internodes, and number of shoots were measured over a period of time of 4 months.

At the end of the experimental period, determinations were made on the root and aerial parts: number of roots, root length (cm), root diameter (cm), root weight, aerial part weight, and total plant weight (g).

This research study was done at the greenhouses of the Botanical Garden A.I. Buia, Craiova. The temperature in the greenhouse was 20-22°C and humidity between 60-80%.

Paper waste, used as an alternative substrate, came from A4 paper, which was cut into paper strips with a length of 3 cm and a width of 0.5 mm, the biological material used was constituted by the *Ficus benjamina* species, cv. 'Golden King', species of decorative plant through leaves in the *Moraceae* family, native to Asia and Australia.

The experimental scheme (Table 1) had 4 variants, and each variant of the experimental scheme had 3 repetitions. Peat and paper waste were mixed in different percentages according to Table 1 in plastic containers with a diameter of 9 cm and a volume of 0.45 l, which has a capacity of 105 g of substrate.

Table 1. Experimental scheme

| Variants | Growth media |
|---|---|
| V1(control) | 100% peat |
| V2 | 80% peat+20% paper waste |
| V3 | 70% peat+30% paper waste |
| V4 | 50% peat+50% paper waste |

The peat used as substrate in the containers is a fine Baltic white peat, free from weeds, pests and diseases, with an average diameter size between 0-20 mm and has the following chemical composition shown in Table 2. Peat fertilizer (N.P.K. + trace elements) provides a sufficient level of nutrients for 3 to 6 weeks.

Table 2. Chemical composition of peat substrate

| Parameter | Value |
|---|---|
| pH | 5.8 |
| EC (mS/cm) | 0.112 |
| Organic matter (%) | 79 |
| N (%) | 4.6 |
| P (%) | 0.9 |
| K (%) | 2.5 |
| Ca (%) | 4.2 |
| Mg (%) | 1.4 |
| Fe (mg/kg) | 3000 |
| Zn (mg/kg) | 90 |
| Cu (mg/kg) | 20 |
| Mn (mg/kg) | 80 |
| Mo (mg/kg) | 5 |
| Density (kg/m$^3$) | 171.1 |

The physico-chemical analyzes of the substrates from the 4 variants were carried out according to the following methods:

- pH in distilled water, potentiometric determination 1:4;
- humus (H%), Walkley-Black method modified by Gogoasa;
- total nitrogen (N%) - Kjeldahl method;
- mobile phosphorus ($P_{AL}$), Egner - Riehm - Domingo method, spectrophotometry, $\lambda = 660$ nm;
- mobile potassium ($K_{AL}$) extraction with ammonium acetate lactate similar to $P_{AL}$ by flamephotometry;
- electrical conductivity (EC), conductometric determination 1:5 dilution method;
- organic matter determined by calcination;
- Mg, Cu, Fe spectrophotometric determination.

The interpretation phase consisted in the interpretation of analytical data, their correlation with field determinations and observations. The experimental data for plant growth parameters, were analysed using one-way analyses of variance (ANOVA) and Tukey's post-hoc test at a significance level of 0.05 performed by using the MINITAB statistical package (Minitab, State College, PA, USA). The experimental values are presented as the mean of three replicates.

## RESULTS AND DISCUSSIONS

The physico-chemical composition of the substrate (peat-paper waste) is presented in Table 3.

Table 3. Physico-chemical composition of the substrate (peat-paper waste)

| Parameter | Variant | | | |
|---|---|---|---|---|
| | V1 | V2 | V3 | V4 |
| pH | 5.8 | 5.95 | 6.12 | 6.24 |
| EC (mS/cm) | 0.112 | 0.197 | 0.230 | 0.323 |
| Organic matter (%) | 79 | 78 | 78 | 76 |
| N (%) | 4.83 | 3.93 | 3.492 | 2.6 |
| P (%) | 0.94 | 0.758 | 0.696 | 0.489 |
| K (%) | 2.62 | 2.144 | 1.906 | 1.431 |
| Mg (%) | 1.47 | 1.176 | 1.038 | 0.751 |
| Ca (%) | 4.41 | 3.564 | 3.141 | 2.295 |
| Fe (mg/kg) | 3150 | 2537.18 | 2230.77 | 1617.95 |
| Zn (mg/kg) | 94.5 | 78.18 | 70.02 | 53.7 |
| Cu (mg/kg) | 21 | 23.72 | 25.08 | 27.8 |
| Mn (mg/kg) | 84 | 68.38 | 60.84 | 45.4 |
| Mo (mg/kg) | 5.25 | 4.2 | 3.67 | 2.625 |

According to Chrysargyris et al., 2019, the chemical composition of paper waste is as follows: electrical conductivity of 1.175 mS/cm, pH of 6.31, organic matter 75.52%, nitrogen 0.37%, potassium 2428.5 mg/kg, phosphorus 389.2 mg/kg, Ca 1804.8 mg/kg, Mg 332.7 mg/kg, Fe 85.9 mg/kg, Cu 34.6 mg/kg.

The addition of paper waste in the growth substrate in percentages of 20%, 30% and 50% leads to an increase of pH value from 5.8 for variant V1 (moderately acidic reaction) to 6.24 for V4 (weakly acidic reaction), an aspect also observed by Chrysargyris et al., 2019.

Increasing the pH value in the weak acid range leads to greater solubility and mobility of nitrogen, phosphorus, potassium, copper and zinc. The absorption of nutrients, with the exception of molybdenum, is greatly favored by the slightly acidic reaction (Rusu et al., 2005).

The electrical conductivity increases in all variants, registering the value of 0.112 mS/cm in V1 and reaching 0.323 mS/cm in V4, EC being in all 4 variants below the value of 0.5 mS/cm which is the optimal value for substrates (Fascella, 2015; Zulfiqar et al., 2019).

According to Craig & Cole, 2000, electrical conductivity values between 0.1-1.8 mS/cm and pH values between 5.0 and 6.5 indicate a normal availability of nutrients for plants, all values recorded for all variants being between these limits. Peat is widely used in growing plants in containers because most of the nutrients are easily available to the plants (Vannucchi et al., 2020).

The content of macroelements and microelements decreases from V1 to V4, with the exception of copper, which registers an increase from the value of 21 mg/kg (V1) and reaches the value of 27.8 mg/kg (V4). This increase in copper can be explained by the high content of copper in the paper used for the substrate.

Figure 1. Summary images during experimental research

The mobility of copper is dependent on pH (Dodocioiu et al., 2009), as can be observed from Table 3, the copper content increasing as the pH increases.

In a strongly acidic environment, copper cations accumulate the most in the root system of plants and less in other organs, and the movement of the soil reaction towards the pH = 6.8-7 range increases their translocation and accumulation in the aerial organs (Rusu et al., 2005).

Table 4. Effect of different culture substrates on vegetative growth parameters at the end of experiment

| Variants | Height of plants (cm) | Length of shoot (cm) | Length of leaf (cm) | Width of leaf area (cm) | Length of internode (cm) | Number of shoots |
|---|---|---|---|---|---|---|
| V1 (Co) | 16.27a | 1.76b | 7.00a | 2.33a | 2.13a | 13.67a |
| V2 | 13.23a | 2.50a | 5.73ab | 2.36a | 2.26a | 11.67a |
| V3 | 9.20b | 1.60b | 5.60ab | 2.30ab | 1.80a | 6.00b |
| V4 | 7.50b | 1.50b | 4.43b | 1.93b | 2.00a | 4.67b |
| **F test** | **22.46*** | **8.10*** | **5.66*** | **5.43*** | **1.11** | **32.38*** |

Means comparison were done using Tukey's test ($p<0.05$). Different letters indicate statistically significant differences between treatments.

In *Ficus benjamina*, the addition of paper waste reduced vegetative growth (plant height, shoot length, leaf length, leaf width, internode length, number of shoots), while the addition of 20% paper waste caused an increase in the average length of the shoots and the average length of the internodes compared to the other analyzed variants.

The addition of paper waste in the *Ficus benjamina* culture substrate caused a significant decrease in the average height of the plants in the variants where 30% paper waste (V3) and respectively, 50% paper waste (V4) were used, compared to the control variant (V1 - 100% culture substrate) and with variant V2 - 20% paper waste.

There were no significant differences between the control variant (V1 - 100% culture substrate) and V2 - 20% paper waste, nor between the variants V3 - 30% paper waste and V4 - 50% paper waste.

Given that rapid plant growth is not advantageous for the majority of ornamental plants (Manda et al., 2008), the addition of paper compost to the growing substrate could prove beneficial, with the potential effect of maintaining or even reducing plant size.

The average length of shoots, after 4 months from the start of the experiment, recorded the highest value at V2 - 20% paper waste, and the lowest value at V4 - 50% paper waste.

From a statistical point of view, there are significant negative differences between V2 and the other experimental variants.

The average length of the leaves recorded the highest value at V1 - 100% substrate, and the lowest value at V4 - 50% paper waste. From a statistical point of view, there is a significantly negative difference between V1-100% substrate and V4 - 50% paper waste, the differences between the other variants are not statistically ensured.

In the case of the average width of the leaves, only V4 (1.93 cm) recorded a significant decrease compared to V1 (2.33 cm) and V2 (2.36 cm) (Table 4).

For plants grown in pots, the characteristics of the leaves are an important parameter, because they give a compact appearance and commercial value to these plants (Nicu & Manda, 2023).

The addition of paper waste in the culture substrate did not have a significant influence on the average length of the internode, the values being between 1.80 cm (V3) and 2.26 cm (V2).

The average number of shoots per plant recorded a significant decrease in the average height of the plants in the variants where 30% paper waste (V3) and 50% paper waste (V4) were used compared to the control variant V1 - 100% culture substrate and with V2 - 20% paper waste. There were no significant differences between V1 - 100% peat substrate and V2 - 20% paper waste, nor between the V3 and V4 variants.

In Table 5 is presented the effect of different substrates on the variability of the morphological characters of the roots.

Table 5. Effect of different culture substrates on root morphology, aerial and root biomass in *Ficus benjamina*

| Variant | Number of roots | | Root length (cm) | | Root diameter (cm) | | Root weight (g) | | Aerial weight (g) | | Total weight plant (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean±SD | CV | Mean±SD | CV | Mean±SD | CV | Mean±SD | CV | Mean±SD | CV | Mean±SD | CV |
| V1(co) | 5.33±0.57b | 10.83 | 12.00±1.00a | 8.33 | 7.66±0.47b | 6.16 | 1.09±0.09b | 8.75 | 5.93±0.30a | 5.14 | 7.02±0.40a | 5.70 |
| V2 | 4.66±0.57b | 12.37 | 16.63±0.35a | 2.11 | 5.16±0.30c | 5.91 | 0.89±0.06b | 6.81 | 3.05±0.07b | 2.54 | 3.68±0.52b | 14.23 |
| V3 | 8.33±0.57a | 6.93 | 13.07±0.19a | 1.52 | 9.30±0.20a | 2.15 | 1.43±0.09a | 6.74 | 2.14±0.07c | 3.53 | 3.57±0.16b | 4.48 |
| V4 | 4.66±0.57b | 12.37 | 10.03±0.15c | 1.52 | 1.90±0.40d | 21.05 | 0.94±0.04b | 4.26 | 1.28±0.21d | 16.63 | 2.22±0.25c | 11.37 |

Analyzing the obtained data, it is observed that for root diameter, aerial weight and total weight of the plant, a large variability is recorded depending on the culture substrate.

The highest number of roots was recorded at V3 (8.33 roots), while the lowest number of roots was observed at V2 and V4 (4.66 roots), with the difference being statistically significant.

Significant differences were recorded regarding the diameter of the roots, the average values being in the range of 1.9 cm (V4) and 9.3 cm (V3), compared to the control V1, only V3 recorded higher values than this.

The average root weight reached its maximum value at V3 (1.43 g), which also corresponds to the highest number of roots, and the difference compared to the other analyzed variants is statistically significant.

Regarding the aerial part of the plant, the limits of variation are between 1.28 cm (V4) and 3.05 cm (V2), compared to the control variant which recorded a value of 5.93 cm. For this parameter, significant differences were observed between all variants, with a decrease in values as the proportion of paper waste increased.

The same trend is observed for the total weight of the plants, with the highest values recorded in the control variant (V1 - 7.02 g), and the lowest values corresponding to the variant with the highest addition of paper waste (V4 - 2.22 g).

## CONCLUSIONS

The present study suggests that for the container culture of *Ficus benjamina*, the culture substrate can be replaced with up to 20% paper waste with an insignificant reduction of the main parameters that indicate vegetative growth, respectively the aesthetic value of the plants.

Given that rapid plant growth is not an advantage for most ornamental plants, the addition of waste paper to the growing medium could prove beneficial, with a potential effect of maintaining or even reducing plant height.

Using waste paper as a substrate for potted plants can be an ecological and economical alternative to conventional substrates. Recycled paper can be used to provide support and nutrients to plants, while helping to reduce the amount of waste that ends up in the environment.

Recycled paper can also have economic advantages as substrate welfare costs can be reduced compared to conventional substrates. By recycling paper waste to use as plant substrate, energy needed to produce new substrates can also be saved.

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