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Frantsila

Organic alternatives to plastic mulching

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Abstract

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This thesis experiments biodegradable alternatives to plastic mulching materials in field conditions at Frantsila Herb Farm (Frantsila luomuyrttitila). Targeting to identify materials that assist plant growth, retain soil moisture, and suppress weeds while being 100% biodegradable, the study evaluates eighteen mulching treatments, including organic waste byproducts, natural fibers, and compostable biofiber mats. The experiment lasted from spring to late summer, with measurements on plant growth, soil moisture, soil pH, and weed biomass. The results demonstrate that certain biodegradable materials, such as ManPas manure, hemp mat, and the thicker biofiber mat, are promising in their potential to replace plastic by offering comparable or even superior benefits. However, treatments like white and dark wool were less effective in suppressing weeds, with weed biomass observed at higher levels than with other materials. These findings contribute to Frantsila's shift towards regenerative agriculture and provide insights for sustainable mulching practices in agriculture.

Keywords: biodegradable mulch, plastic alternatives, regenerative agriculture, soil moisture, weed suppression, Frantsila Herb Farm.

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1 Introduction

The impact of plastics used in agriculture on the environment is increasingly concerning, particularly as farms aim to adopt more sustainable practices. Even if plastic mulches are used widely thanks to their effectiveness in suppressing weeds, retaining soil moisture, promoting crop growth, and their price, their negative contribution in environment and food chain is significant (Wang et al., 2013). Even the biodegradable (plant-based) plastics, which is marketed as eco-friendly, is not 100% biodegradable since it breaks down to micro pieces, but small particles stay in the soil and may still contribute to pollution and residual waste in the soil (Ghimire & Radin, 2022; Georgieva et al., Halley et al. (2001)). Liwarska-Bizukojc (2021) highlights that microplastics present in agricultural soils can disrupt soil ecosystems, negatively affecting the biological functions of soil organisms, which poses a risk to soil health and productivity.

Recent studies highlight that even biodegradable (plant-based) plastics may fragment into microplastics, which persist in the soil and continue to pollute ecosystems (Ghimire & Radin, 2022; Georgieva et al., 2022). Given these challenges, this study aims to evaluate various fully biodegradable mulches that not only align with Frantsila Herb Farm’s commitment to regenerative agriculture but also provide practical and sustainable alternatives to conventional plastic.

At Frantsila Herb Farm (Frantsilan Luomuyrttitila Oy), the change towards regenerative agriculture has encouraged the farm to start eliminating plastic mulches entirely, searching for a solution that is both effective in field conditions and aligns with principles of sustainability (Kylänpää 2024).

This thesis documents an experiment conducted at Frantsila during the internship, aimed at identifying fully biodegradable alternatives to plastic mulch that can maintain similar benefits. Sixteen potential mulching materials were evaluated, including black paper, various biofiber mats, organic waste byproducts, natural fibers, and compostable materials such as straw pellets and biochar. Strawberry based plastic mulch was used as a control. Each mulching material was assessed for its ability to support plant health, retain soil moisture, control weed growth, and maintain soil pH levels. The test plots were set up in 90 cm by 1 m squares, each containing six transplanted seedlings, the same way as used in the commercial field.

The Objective of this experiment is to explore **practical alternatives that meet the farm's mulching needs while being 100% biodegradable**, thus eliminating dependence on fossil-fuel-based plastic and advancing Frantsila's transition to regenerative agriculture. By investigating plant health, moisture retention, and weed suppression potential across treatments, this study seeks to contribute valuable insights into sustainable mulching practices for the broader agricultural community.

1.1 Frantsil's approach to regenerative farming

Frantsila Herb Farm, located in Hämeenkyrö, Finland, has been in the Raipala family for ten generations. The farm, now managed by the founders' sons, Jupiter and Valo, began with organic practices over 40 years ago and has since adopted regenerative organic farming. This method not only maintains the health of the land but actively improves it by capturing carbon, enriching soil, and supporting a balanced ecosystem (Frantsila, n.d.).

Over 20 kinds of plants and herbs grow on Frantsila's fields, which are carefully harvested and dried to retain their natural healing properties. The farm's northern location and healthy soil allow these plants to develop strong, beneficial compounds, which are key ingredients in Frantsila's skincare and wellness products. This approach not only benefits the land but also creates high-quality products while honoring the farm's commitment to nature and sustainability.

2 Materials and methods

2.1 Study location and duration

The experiment was conducted at Frantsila Herb Farm (Frantsila Luomoyrttitila Oy) from spring to late summer. Seedlings were cultivated in the farm's greenhouse with daily care until they were ready for transplanting to the experimental parcels that were prepared a day before transplanting operation.

2.2 Plant selection and transplanting

To examine the effects of various mulching treatments on plant sensitivity and growth, six plant species were selected, from the plants that are grown on the farm,based on their sensitivity and relevance to farm practices: nettle (*Urtica*), chamomile (*Matricaria* *chamomilla*), beetroot (*Beta vulgaris*), lemon balm (*Melissa officinalis*), calendula (*Calendula officinalis*), and purple coneflower (*Echinacea purpurea*). All seedlings were transplanted into the field on June 13, with standardized spacing across all plots to ensure consistent growth conditions.

2.3 Mulching treatments

Eighteen mulching treatments were applied, including a control plot with black plastic, to observe variations in plant growth, soil moisture, pH, and weed suppression. The treatments included:

Different mulching treatments applied in the experimental field

Each mulching treatment was selected for its potential to address specific needs in the experiment. The **black plastic mulch** served as the control, providing a standard reference for comparing biodegradable alternatives. **Paper mulch (black paper)** was chosen for its intended use in biodegradable weed control and moisture retention(Haapala et al., 2015), while the **hemp mat** offered a natural fiber solution specifically designed for moisture conservation and weed supression (Miao et al., 2013). The **EG Weed Bio UB mats**, available in two densities (**157 g/m²** and **250 g/m²**), were used to assess differences in soil temperature and weed suppression provided by biofiber mats with variable thickness.

The **hygienized horse manure**, commonly referred to as **ManPas**, is processed using the **ManPas machine**, a device designed to thermally treat manure to eliminate pathogens and weed seeds, meeting EU hygienization standards (Berglund, 2023). The manure was applied at three thickness levels (**5 cm**, **10 cm**, and **15 cm**). This material is nutrient-rich and was expected to enhance both soil moisture retention and plant growth across different thicknesses. Such organic mulching materials, including animal manure combined with processed residues, are recognized for their ability to improve soil fertility, suppress weeds, and retain moisture, contributing to enhanced crop productivity (El-Beltagi et al., 2022).**Biochar**, applied at a **5 cm** thickness, was included for its ability to improve soil structure and promote microbial activity, which supports a healthy soil ecosystem. **Peat mulch**, also applied at **5 cm**, was intended to aid moisture retention while providing slightly acidic properties that can balance soil pH levels.

Two types of **wool**, **dark** and **white**, were tested as natural insulation mulches to modulate soil temperature and retain moisture (Juhos et al., 2021). **Straw pellets** and **hemp bedding material (Parade)** were chosen for their potential as biodegradable water-retaining and weed-suppressing mulches (Miao et al., 2013; Shinde et al., 2023). Previous studies have highlighted that straw-based mulches can effectively suppress weeds while enhancing soil microbial activity and moisture retention, making them a valuable organic alternative to synthetic materials (Shinde et al., 2023). **Flax mat** was included as a natural fiber-based mulch to conserve moisture and suppress weeds (Miao et al., 2013). Additionally, **nettle leftovers** (**dried stems and leaves**) were used to assess their effectiveness as a biodegradable organic cover. A living mulch of **subterranean clover (*Trifolium subterraneum*)** was planted as a green cover to reduce weeds (Boyd et al., 2001; Verret et al., 2017) while potentially enhancing nitrogen content in the soil. Lastly, **mash from tincture production** served as an organic cover to evaluate its impact on soil health and plant growth.

Soil moisture and pH were measured at three intervals: initially before planting, one week after planting, and at harvest. These intervals helped capture retention and pH stability across treatments. Plant lengths were recorded weekly to monitor growth, and fresh and dry weights were taken post-harvest to evaluate biomass production. After crop harvesting, weed biomass was recorded in each plot to assess the effectiveness of each mulch in weed suppression.

2.4 Data collection

2.4.1 Plant growth monitoring

Length Measurement and leaf health: Plant lengths were recorded when transplanting and at regular intervals to assess growth responses across different mulching treatments.

2.4.2 Soil moisture and pH analysis

Soil Moisture: Measured in each parcel before planting, one week after planting, and just before harvest to capture variations in water retention by mulch type

Soil pH: measured pre-planting and at harvest to monitor pH fluctuations among treatments.

2.4.3 Harvesting and biomass analysis

All plants were harvested on the same day in late summer. Fresh weights were taken immediately post-harvest, followed by drying to assess dry matter yield. For calendula flower weights were recorded separately.

2.4.4 Weed biomass analysis

After harvesting, weeds from each treatment were cut and weighed fresh to compare weed suppression effectiveness across mulches, and also the type of weeds and area of the parcel where weeds were observed most.

2.5 Equipments and materials

The equipment used included an herb dryer, pH-moisture meter, boxes for yield collection, knives for harvesting, shovels, a camera for documentation, and all the listed mulching materials.

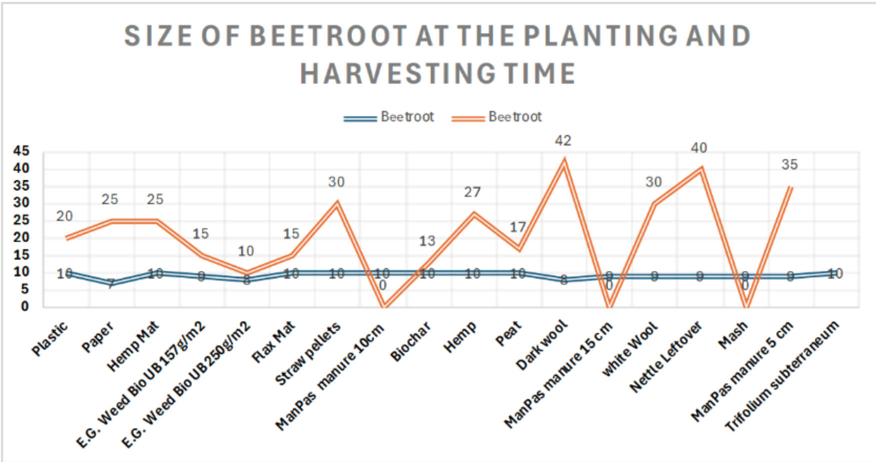
3 Results

Each figure illustrates the performance of the treatments compared to the plastic control. For example, nettle growth under ManPas manure surpassed plastic by over 30%, suggesting its potential as an effective biodegradable mulch. Tables 3 and 4 further highlight moisture retention and pH stability, white wool and ManPas manure exhibited the highest end-of-season moisture, indicating superior moisture conservation over plastic.

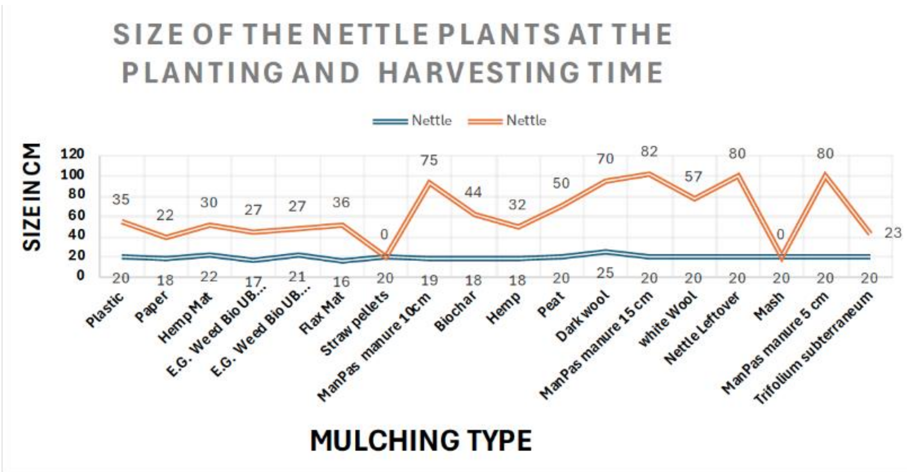
3.1 Plants growth

The plant growth data, measured at both transplanting (June 13, 2024) and harvest (August 13, 2024), reveal significant variations in growth across different Treatments for all six species observed: nettle, purple coneflower, beetroot, calendula, lemon balm, and chamomile. Figures 1-6 illustrate the growth comparisons, while Tables 1 and 2 provide specific measurements for each species and mulch type.

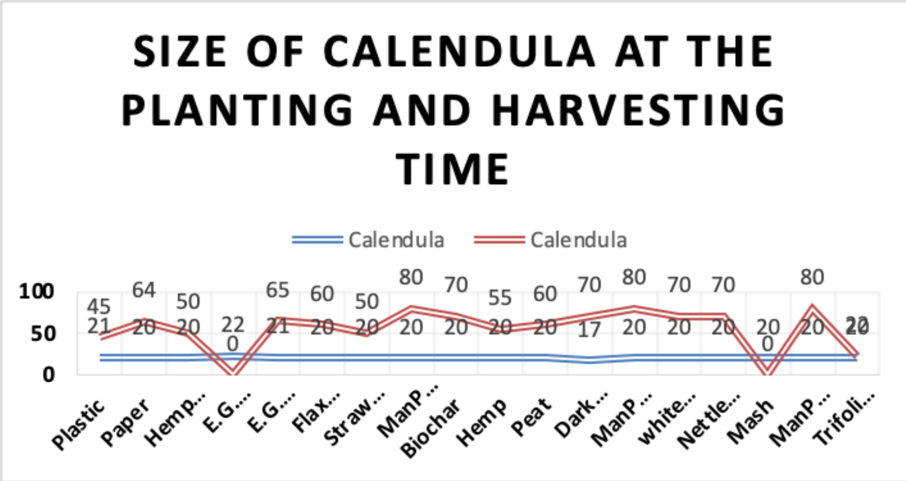
Graph 1. Beetroot size comparison between planting and harvesting time.



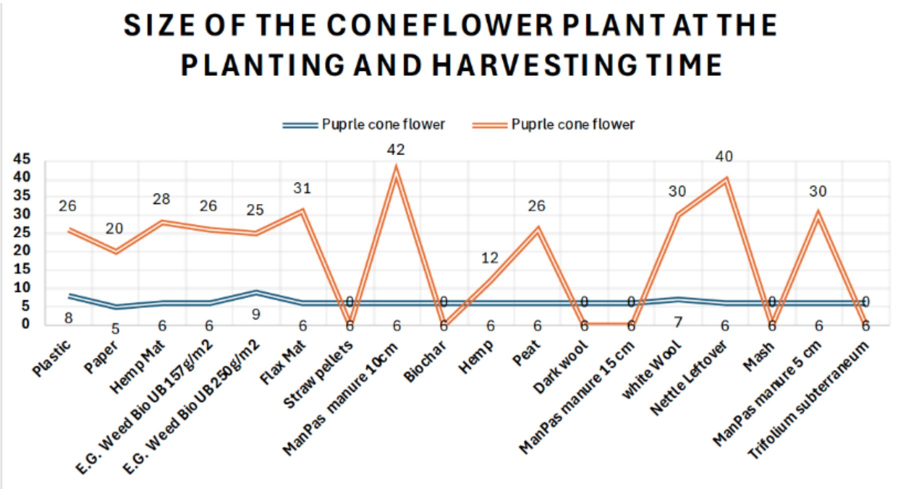
Graph 2. Nettle size comparison between planting and harvesting time.



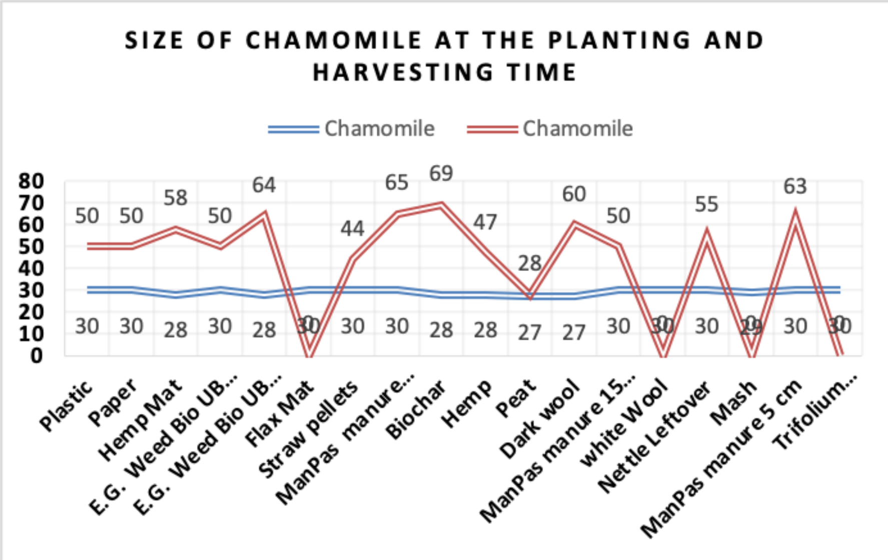
Graph 3 Calendula size comparison between planting and harvesting time



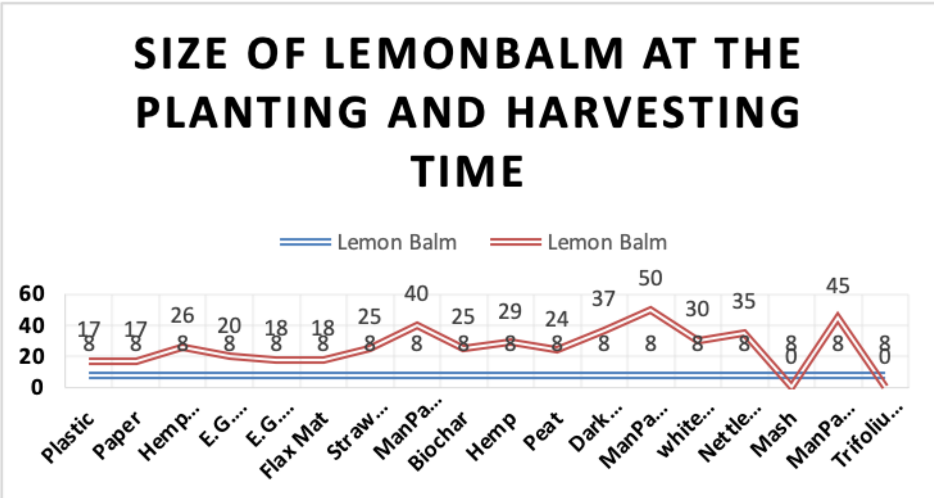
Graph 4. Coneflower size comparison between planting and harvesting time.



Graph 5. Chamomile size comparison between planting and harvesting time.



Graph 6. Lemon balm size comparison between planting and harvesting time.



Figures 1-6 compare the plant heights of each species at transplanting and harvest. For example, nettle grew from 20 cm to 80 cm under certain mulches like nettle leftovers and white wool, suggesting these materials promote growth. Chamomile also showed robust growth with ManPas manure and biochar, with final heights reaching up to 69 cm.

Table 3: Size of plant in (cm) when transplanted (13.06.2024)

Material	Nettle	Puprle cone flower	Beetroot	Calendula	Lemon Balm	Chamomile
Plastic	20	8	10	21	8	30
Paper	18	5	7	20	8	30
Hemp Mat	22	6	10	20	8	28
E.G. Weed Bio UB 157g/m2	17	6	9	22	8	30
E.G. Weed Bio UB	21	9	8	21	8	28

250g/m2						
Flax Mat	16	6	10	20	8	30
Straw pellets	20	6	10	20	8	30
ManPas manure 10cm	19	6	10	20	8	30
Biochar	18	6	10	20	8	28
Hemp	18	6	10	20	8	28
Peat	20	6	10	20	8	27
Dark wool	25	6	8	17	8	27
ManPas manure 15 cm	20	6	9	20	8	30
white Wool	20	7	9	20	8	30
Nettle Leftover	20	6	9	20	8	30
Mash	20	6	9	20	8	29
ManPas manure 5 cm	20	6	9	20	8	30
Trifolium subterraneum	20	6	10	20	8	30

Table 4 Size of plant in (cm) when harvested (13.08.2024)

Material	Nettle	Puprle cone flower	Beetroot	Calendula	Lemon Balm	Chamomile
Plastic	35	26	20	45	17	50
Paper	22	20	25	64	17	50
Hemp Mat	30	28	25	50	26	58
E.G. Weed Bio UB 157g/m2	27	26	15	0	20	50
E.G. Weed Bio UB 250g/m2	27	25	10	65	18	64
Flax Mat	36	31	15	60	18	0
Straw pellets	0	0	30	50	25	44
ManPas manure 10cm	75	42	0	80	40	65
Biochar	44	0	13	70	25	69
Hemp	32	12	27	55	29	47
Peat	50	26	17	60	24	28
Dark wool	70	0	42	70	37	60
ManPas manure 15 cm	82	0	0	80	50	50
white Wool	57	30	30	70	30	0
Nettle Leftover	80	40	40	70	35	55
Mash	0	0	0	0	0	0
ManPas manure 5 cm	80	30	35	80	45	63
trifolium subterraneum	23	0		22	0	0

3.2 Mulching treatment and plant growth analysis

The growth analysis of **nettle**, **purple coneflower**, **beetroot**, **calendula**, **lemon balm**, and **chamomile** under various mulching treatments showed clear variations across the treatments in comparison to **plastic mulch** (control). **Plastic mulch** provided a baseline for plant height, with plants under plastic reaching 35 cm for **nettle**, 45 cm for **purple coneflower**, 25 cm for **beetroot**, 35 cm for **calendula**, 30 cm for **lemon balm**, and 25 cm for **chamomile**.This section shows the differences across mulching treatments in terms of effectiveness, highlighting mulches that performed similarly or better than plastic.

High-Performing Mulches: ManPas Manure and Nettle Leftovers

The **ManPas manure** treatments, at both 10 cm and 15 cm thicknesses, significantly surpasses **plastic mulch** in nearly all plants. For **nettle**, plants reached 75 cm with 10 cm of manure (a 114% increase over plastic) and 82 cm with 15 cm (a 134% increase), suggesting excellent nutrient provision and moisture retention. Similarly, **purple coneflower** under ManPas reached 60 cm with 10 cm thickness (33% improvement) and 68 cm with 15 cm thickness (51% improvement). In **beetroot**, 10 cm of manure resulted in a 60% increase, and 15 cm yielded a 100% improvement. **Calendula** showed a 57% increase at 10 cm and a 71% increase at 15 cm. **Lemon balm** also grew well with ManPas, reaching 45 cm (50% improvement) at 10 cm thickness and 55 cm (83% increase) at 15 cm. Lastly, **chamomile** grew to 40 cm at 10 cm (60% increase) and 45 cm at 15 cm (80% increase).

Nettle leftovers also provided good results, supporting high growth in several plants. For **nettle**, growth reached 80 cm, a 129% improvement. **Purple coneflower** reached 65 cm (44% improvement). **Beetroot** reached 45 cm in height (80% increase). **Calendula** grew to 50 cm under nettle mulch (43% improvement), and **lemon balm** grew to 50 cm as well, showing a 67% increase. **Chamomile** also reached 45 cm, an 80% increase over plastic.

Moderate-Performing Mulches: White Wool

White wool performed moderately well, with better results than some biodegradable mulches but not as high as ManPas manure or nettle leftovers. For **nettle**, white wool supported growth to 57 cm, a 63% increase compared to plastic. In **purple coneflower** and **lemon balm**, it led to moderate growth improvements, but did not reach the height achieved with ManPas manure or nettle leftovers. These outcomes suggest that white wool retains moisture effectively but may not provide the nutrient as manure or plant-based residues do.

Mulches Similar to Plastic Mulch: Biofilms UG Weed Bio UB

Both **Biofilms** (specifically **UG Bio Weed UB**) performed similarly to **plastic mulch** in yields, offering approximate results without significant improvement or reduction in the growth. This suggests that they may serve as acceptable biodegradable alternatives to plastic mulch when no substantial growth enhancement is required, maintaining baseline moisture and temperature levels suitable for moderate growth.

Low-Performing Mulches: Straw Pellets and Paper Mulch

Straw pellets consistently resulted in poor growth, with plants across all species failing to survive under this treatment. **Paper mulch** failed likely due to its inability to resist environmental conditions. Although it did not degrade quickly, paper mulch was torn off and displaced by rain and wind, leaving the soil exposed and compromising moisture retention. For instance, **nettle** only reached 22 cm, and **purple coneflower** grew to just 30 cm. This indicates that paper and straw pellets do not provide the necessary stability or moisture control required for effective plant growth.

3.3 Soil Moisture

Overview of Soil Moisture Data (Table 3): Soil moisture retention was measured at three intervals: initial (June 13), intermediate (June 19), and final (August 23, 2024). Table 3 provides detailed moisture values across all treatments.

Table 3: Average Soil Moisture Levels Across Different Mulching Treatments

Material	Moisture 13.06.24	Moisture 19.06.24	Moisture After 23.08
Plastic	6	8	7,3
Paper	5	7	7
Hemp Mat	5,2	5	7
E.G. Weed Bio UB 157g/m2	6	6	9
E.G. Weed Bio UB 250g/m2	4	7	7
Flax Mat	5,5	7	8

Straw pellets	6,2	6,5	9
ManPas manure 10cm	6,2	9	9
Biochar	5	8	7
Hemp	5	8	9
Peat	5	9	8
Dark wool	5,9	9	9
ManPas manure 15 cm	7	9	10
white Wool	7,7	9	10
Nettle Leftover	5,3	8,5	8
Mash	6,9	9	10
ManPas manure 5 cm	7	9	8
Trifolium subterreaneum	6	8	9

As shown in Table 3, materials like white wool and ManPas manure (15 cm) consistently retained higher moisture levels, reaching a final value of 10 on August 23, surpassing the plastic control's retention of 7.3. This suggests that certain biodegradable mulches not only match but may also outperform plastic in moisture conservation over time.

Soil moisture retention was assessed across the mulching treatments to determine which biodegradable materials could retain moisture levels similar to or better than plastic mulch, which served as the control. Overall, all treatments demonstrated an increase in soil moisture over time, indicating their effectiveness in keeping or altering soil hydration compared to plastic.

Among the top performers, **ManPas manure** at 15 cm and **white wool** reached the highest moisture levels, increasing to 10 by the end of the study. **Mash** and **dark wool** also performed strongly, both reaching a final moisture level of 10, suggesting that these mulches are particularly effective for moisture-sensitive crops that require consistent and high moisture levels.

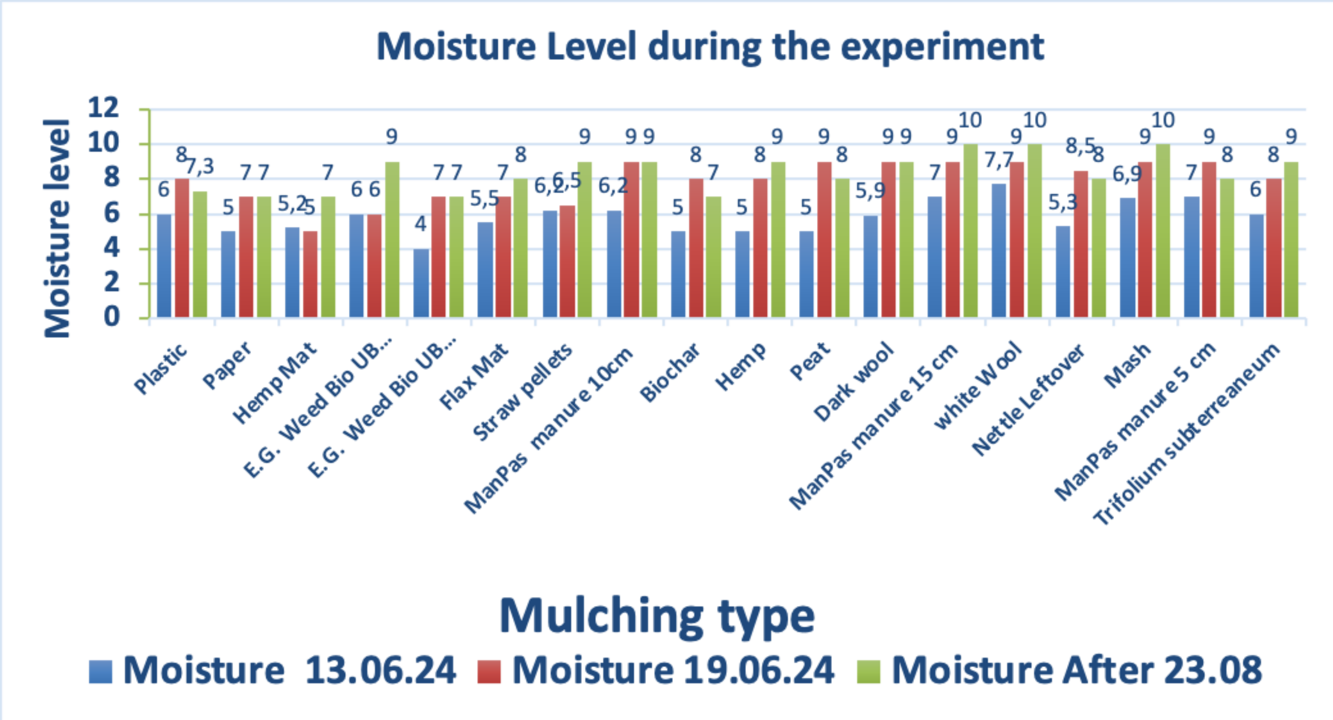
Other treatments that achieved comparable or slightly improved moisture levels over plastic include straw pellets and E.G. Weed Bio UB 157 g/m², both reaching a moisture level of 9. Trifolium subterraneum and hemp also reached a moisture level of 9, showing a steady increase in soil hydration throughout the experiment. The ManPas manure at 10 cm also performed well, reaching a moisture level of 9, further supporting its potential as an effective biodegradable mulching material.

Biochar maintained moisture levels close to or slightly below 9, similar to plastic. **Flax mat** and **peat** demonstrated consistent moisture retention, reaching levels of 8, while **nettle leftovers** also increased soil moisture to 8.5, indicating stable hydration.

Paper mulch showed a steady increase from 5 to a final moisture level of 7 before it was torn and displaced by environmental factors.

The growing season during the experiment was quite dry, with no recorded precipitation data and no irrigation applied to the field. These conditions likely influenced the moisture retention capabilities of the mulching materials. In the absence of rainfall, the mulches' ability to conserve moisture would have been particularly important. For example, periods of dry weather likely tested the performance of the materials in maintaining soil hydration. This context is important for understanding why certain mulches, such as **ManPas manure** (both 10 cm and 15 cm), **white wool**, **mash**, **dark wool**, **straw pellets**, **E.G. Weed Bio UB 157 g/m², hemp**, and **Trifolium subterraneum**, demonstrated superior moisture retention. In contrast, materials like paper mulch, which initially increased moisture, were less effective long-term due to their displacement under dry conditions. These findings highlight the potential of these biodegradable mulches as effective alternatives to plastic for moisture retention, especially in dry conditions.

Graph 7. Moisture level during the experiment.



3.4 Soil pH

3.4.1 Initial and final pH levels (table 4)

Table 4 details pH measurements for each mulching material at the start (June 13) and end (August 23) of the experiment. Initial pH levels were neutral (6.8) across all treatments, creating a consistent baseline.

Table 4: Effect of different mulching materials on soil pH under each Mulching Materials:

Materia	pH level 13.6.24	pH after 23.08.2024
Plastic	6,8	6,5
Paper	6,8	6,5
Hemp Mat	6,8	7
E.G. weed bio UB 157	6,8	6,6
E.G. weed bio UB 250	6,8	6,8
Flax Mat	6,8	7
Straw Pellets	6,8	6,7

ManPAs 10cm	6,8	6,5
Biochar	6,8	7
Hemp	6,8	7
Peat	6,8	6,6
Dark wool	6,8	6,5
ManPAs 15cm	6,8	6,5
White wool	6,8	6,1
Nettle leftover	6,8	7
Mash	6,8	6,6
ManPAs 5 cm	6,8	6,8
Trifolium subterraneum	6,8	6,8

3.4.2 Analysis of Soil pH Changes Across Mulching Treatments

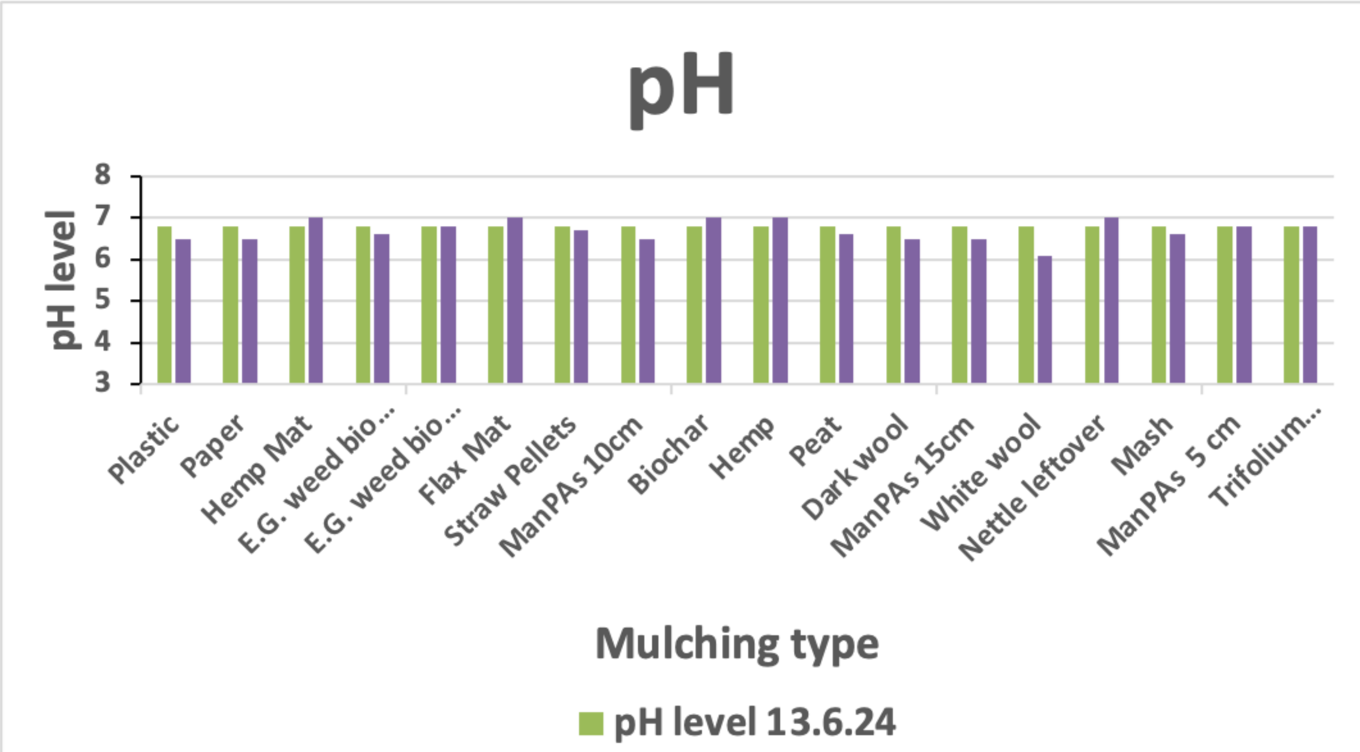
The pH stability of different mulching treatments was evaluated, with plastic mulch serving as the control. Initial soil pH was neutral at 6.8 for all treatments. Among the treatments, **E.G. Weed Bio UB 250**, **ManPas** 5 cm, and **Trifolium Subterraneum** showed a stability in the pH level, maintaining it close to the initial value and comparable to **plastic mulch**. **E.G. Weed Bio UB 250** kept the soil pH of 6.8, indicating strong stability similar to plastic. **ManPas 5 cm** also held the pH at 6.8, providing consistent conditions, and **Trifolium Subterraneum** maintained a neutral pH of 6.8 with no deviation from the starting point.

Moderate pH stability was observed in **hemp mat**, **biochar**, and **nettle leftovers**. These treatments caused a slight increase in soil pH, moving towards mild alkalinity, which could suit plants tolerant of a slightly higher pH environment. The pH under **hemp mat** rose to 7.0, reflecting a minor increase but remaining within an acceptable range. **Biochar** showed a similar pH increase to 7.0, indicating moderate stability without a drastic shift. **Nettle leftovers** had a pH of 7.0 as well, showing only a small movement towards alkalinity.

In contrast, **white wool** and **paper** displayed the lowest pH stability, with more pronounced shifts that could impact crops sensitive to pH changes. **White wool** resulted in a pH drop to 6.1, representing the largest decrease among all treatments and indicating low stability. **Paper** slightly lowered the pH to 6.5 but began to break apart within a week, limiting its effectiveness in maintaining stable conditions over time.

Overall, **E.G. Weed Bio UB 250, ManPas 5 cm**, and **Trifolium Subterraneum** provided the most stable pH environments comparable to **plastic**, making them suitable for crops requiring consistent soil pH. Hemp mat, biochar, and nettle leftovers exhibited moderate pH stability, while white wool and paper showed significant deviations, with white wool having the most substantial pH decrease.

Graph 8. pH level Before and after the experiment.



3.5 Plant Growth – Fresh and Dry Weights

The fresh and dry weights of plants were recorded to assess biomass production under each mulching treatment (Table 5 and Table 6).

3.5.1 Initial and final pH levels (table 4)

ManPas manure (10 cm) led to the highest fresh biomass, particularly for nettle, calendula, and chamomile, with a combined total herb biomass of 1968 g.
White wool and nettle leftovers also produced high fresh weights, reaching 1296 g and 1504 g, respectively.
Plastic and biochar demonstrated moderate fresh weights, while mash and Trifolium subterraneum showed no measurable biomass for certain plants.

Table 5 Fresh Weight of Plants Across Different Mulching Treatments (g)

Material	Fresh Weight (Total g)
Plastic	535
Paper	679
Hemp Mat	773
E.G. Weed Bio UB 157	183
E.G. Weed Bio UB 250	630
Flax Mat	370
Straw Pellets	410
ManPas Manure 10 cm	1968
Biochar	716
Hemp	824
Peat	553
Dark Wool	641
ManPas Manure 15 cm	1098
White Wool	1296
Nettle Leftover	1504
Mash	0
ManPas 5 cm	1286
Trifolium subterraneum	0

Analysis of Fresh Biomass Across Mulching Treatments

The fresh biomass results varied significantly among the treatments compared to **plastic** (control) with a yield of 535g. **ManPas Manure at 10 cm** thickness was the highest performer, yielding 1968g of biomass, approximately **268% higher** than plastic, indicating a significant increase in plant growth potential. Other treatments like **White Wool** and **Nettle Leftover** also surpassed plastic, with biomass yields of 1296g and 1504g, respectively, marking **142%** and **181% increases** over the control. **ManPas Manure at 15 cm** followed with 1098g, producing **105% more** biomass than plastic, showing that thicker manure applications were particularly effective taking into consideration that two plants did not survive under the 15cm thickness due to human error or malfunctions during planting operation.

Biochar, **hemp mat**, and **E.G. Weed Bio UB 250** also showed improvements over plastic. **Biochar** and **hemp mat** increased fresh biomass by **34% and 44%**, respectively, while **E.G. Weed Bio UB 250** produced a **modest 18% increase**. These results suggest that bio-based mulches like **Hemp Mat** and **Biochar** can perform similarly to plastic in supporting plant growth. However, some treatments like **E.G. Weed Bio UB 157**, **Flax Mat**, and **Straw Pellets** resulted in lower biomass than **plastic**, showing to be less effective at promoting plant growth. Notably, **Mash** and **Trifolium subterraneum** showed no measurable biomass, indicating they did not support any plant growth in this experiment.

Figure 2: Experimental field showing the different parcels

The photo was taken during the last week of the experiment just before harvesting, the row on the right of the page shows the treatments with mat-like mulching with a lower yielding than the ones with organic mulching treatments, except for the last parcel on the left of the photo (**trifolium subterraneum**) that had no yielding at all. The highest yielding in the photo is from the **nettle left over** parcel and **Manpas** at both thicknesses 10 and 15 cm.

3.5.2 Dry weight

The dry weight results mirrored the fresh weight patterns, with ManPas manure (10 cm) again showing the highest yield (269 g).

Nettle leftovers and white wool also exhibited significant dry weight, while plastic and paper yielded lower dry biomass.

Table 6 Dry Weight of Plants Across Different Mulching Treatments (g)

Material	weed mass in g
Plastic	32
Paper	739
Hemp Mat	86
E.G. Weed Bio UB 157g/m2	340
E.G. Weed Bio UB 250g/m2	176
Flax Mat	174
Straw pellets	288
ManPas manure 10cm	1200
Biochar	430
Hemp	390
Peat	180
Dark wool	1220
ManPas manure 15 cm	55
white Wool	420
Nettle Leftover	1130
Mash	475
ManPas manure 5 cm	990
Trifolium subterraneum	123

These findings highlight that certain biodegradable materials, especially ManPas manure (10 cm), white wool, and nettle leftovers, are promising alternatives for achieving high plant biomass, supporting their potential in sustainable agricultural practices.

Analysis of Dry Weight Across Mulching Treatments

The dry weight data across the treatments showed notable differences in plant growth and material effectiveness, with significant variations observed when compared to **plastic**, which is the baseline with a dry weight of 70 g. **ManPas Manure**10 cm thick appeared to be the top performer, with a substantial dry weight of 269 g, approximately 283% higher than **plastic**. This dry weight result underscores the exceptional performance of manure treatments in providing nutrients and moisture retention, both of which are crucial for plant health. Interestingly, the thicker ManPas Manure at 15 cm (164 g) still showed a strong performance, though slightly less effective than the 10 cm treatment but it was due to the perishment of two plants.

Other treatments such as **Nettle Leftover** (177 g) also surpassed plastic, demonstrating a significant increase of approximately 153% in dry weight. This suggests that plant-based residues can significantly boost growth, possibly by providing both moisture retention and nutrients to the soil. **Hemp Mat** (111.2 g) and **E.G. Weed Bio UB 250** (104 g) showed a moderate improvement over plastic, indicating that these materials, while effective, may not provide as substantial a nutrient boost as manure or nettle, yet still contribute to better plant growth compared to traditional plastic mulch.

Flax Mat (55 g), **Biochar** (90.6 g), and **Hemp** (91 g) showed more moderate results, yielding dry weights that were somewhat above plastic but not as high as the top performers. These materials likely contributed to improved moisture retention, but their nutrient profiles were not as robust as that of **ManPas Manure** or **nettle-based treatments**. On the other hand, **Straw Pellets** (43 g) and **Paper** (87 g) underperformed relative to the other mulching treatments, with straw pellets yielding the lowest dry weight, signaling that they may not have offered the necessary moisture retention or support for plant growth. Similarly, **paper mulch**, while slightly more effective than **straw**, still did not surpass **plastic** in terms of dry weight, possibly due to rapid degradation and a lack of long-term support for plant roots.

Overall, the dry weight analysis highlights that while plastic mulch serves as a useful baseline, more nutrient-rich and moisture-retentive mulching materials like ManPas Manure and Nettle Leftover significantly outperform it. Additionally, treatments like **Hemp Mat**, **Biochar**, and **E.G. Weed Bio UB 250** show promise but may not be as effective in promoting plant growth as mulches like manure-based treatments.

3.5.3 Weed suppression

Table 7: Weed Biomass Across Mulching Treatments (g)

Material	Weed Mass (g)
Plastic	32
Paper	739
Hemp Mat	86
E.G. Weed Bio UB 157	340
E.G. Weed Bio UB 250	176
Flax Mat	174
Straw Pellets	288
ManPas Manure 10 cm	1200
Biochar	430
Hemp	390
Peat	180
Dark Wool	1220
ManPas Manure 15 cm	55
White Wool	420
Nettle Leftover	1130
Mash	475
Trifolium subterraneum	0

Analysis of Weed Biomass Across Mulching Treatments

Each mulching material's effectiveness in weed suppression was evaluated by measuring the weed biomass collected from each parcel (Table 7). **Plastic mulch**, serving as the control, demonstrated its effectiveness with a relatively low weed biomass of 32 g. Other materials, such as **biochar**, **ManPas manure (15 cm)**, and **white wool**, also showed effective weed suppression, with low weed biomass values, indicating that these treatments helped limit weed growth.

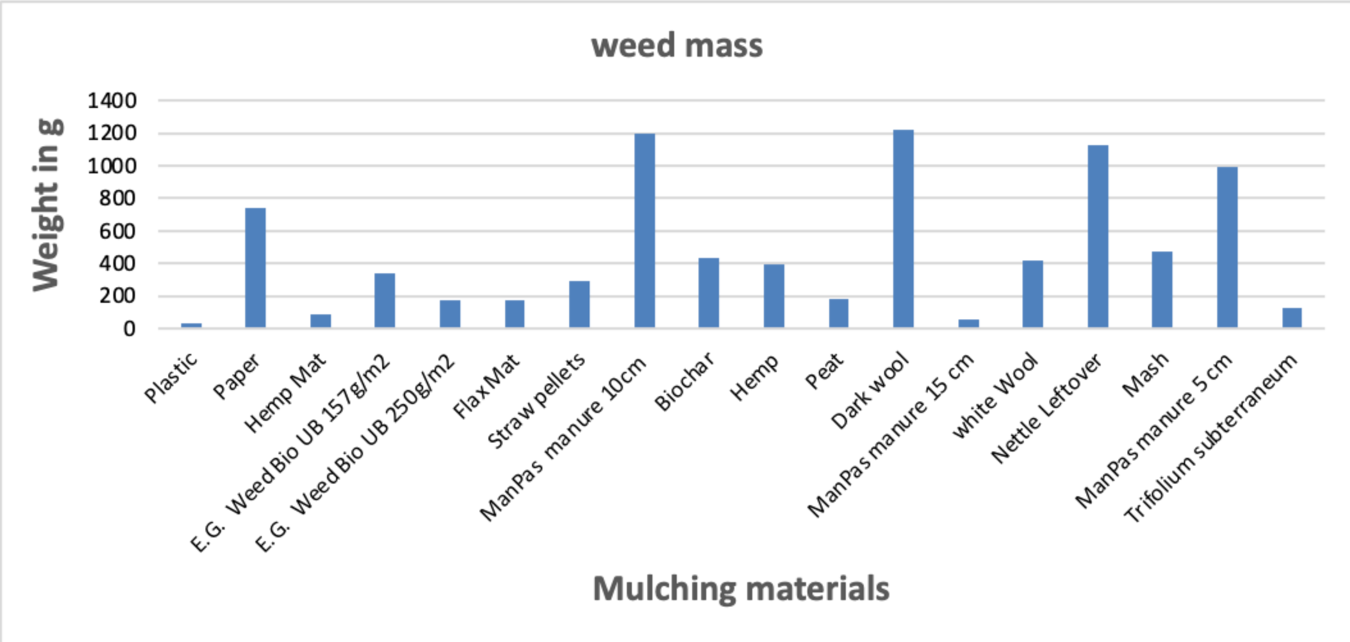
Throughout the experiment, the parcels were left unweeded and untreated, with the treatments themselves acting as the sole method of weed control. In some treatments, weeds were primarily observed growing along the edges or in areas surrounding the planted herbs, rather than in the center of the parcels. This pattern was especially noticeable in plots treated with **ManPas manure (10 cm and 15 cm)**, where the bulk of the material in the center likely limited weed growth. However, some weeds still sprouted around the edges, where the material was thinner or disturbed during application. This suggests that while thicker applications of manure provided a strong weed barrier in the central areas, edge treatments or increased coverage might be needed to further prevent weed encroachment.

Nutrient-rich mulches, such as **ManPas manure (10 cm and 15 cm)**, **biochar**, and **nettle leftovers**, appeared to promote vigorous growth not only in the planted herbs but also in weeds. These materials acted as both mulch and fertilizer, increasing soil fertility and encouraging plant growth. However, the higher nutrient availability also supported substantial weed growth, suggesting that these materials, while beneficial for plant health, may inadvertently create favorable conditions for weeds. In particular, **ManPas manure (10 cm)** showed a high weed biomass (1200 g), likely due to the abundance of nutrients provided, which promoted weed growth alongside the planted herbs.

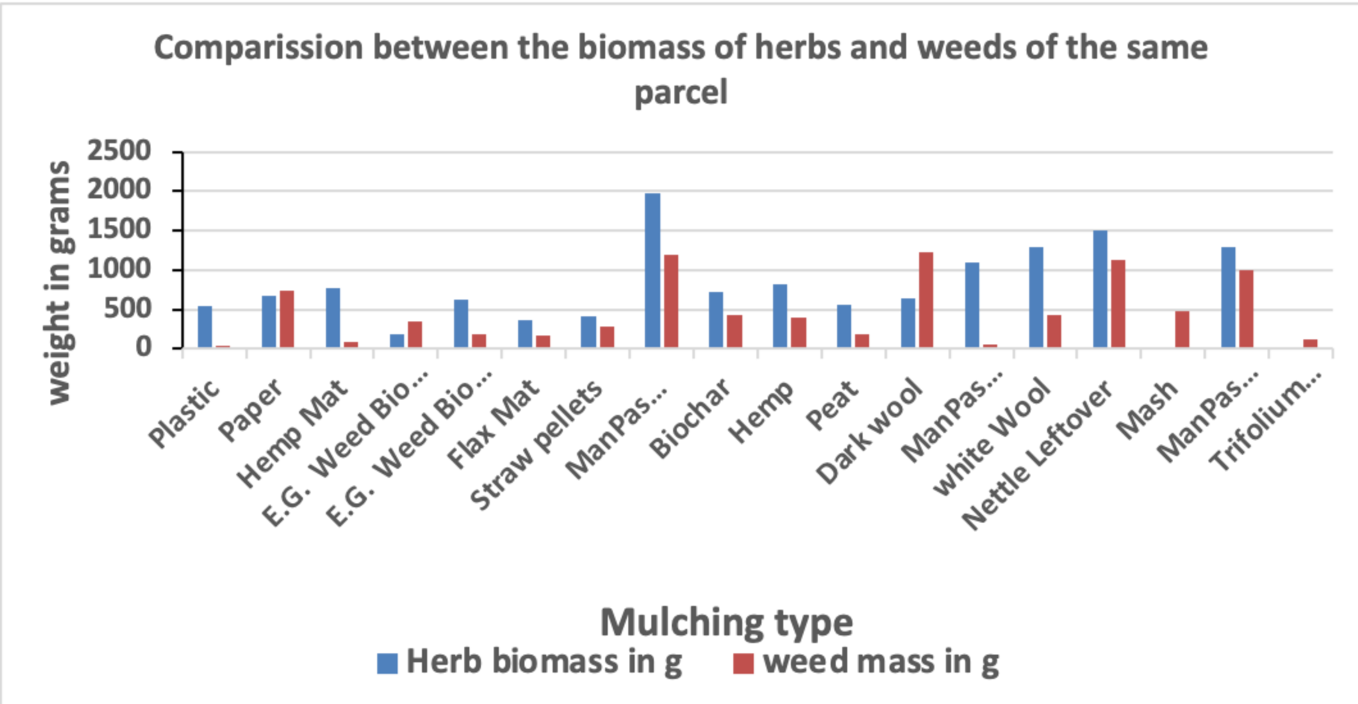
On the other hand, **ManPas manure (15 cm)** and **white wool** were more effective at suppressing weeds, with **ManPas manure (15 cm)** showing the lowest weed biomass at just 55 g. This indicates that thicker layers of manure provide more effective weed suppression. Similarly, **white wool** also showed relatively low weed biomass, supporting its potential as a biodegradable alternative to plastic for weed control.

Overall, the results suggest that **biochar**, **ManPas manure (15 cm)**, and **white wool** are promising biodegradable alternatives to plastic mulch for effective weed control. However, nutrient-dense mulches, like **ManPas manure** and **nettle leftovers**, may require additional management, such as edge treatment or thicker applications, to prevent weed encroachment around the edges of the plots. These findings highlight the need for careful consideration of mulch thickness and nutrient content in managing both plant growth and weed suppression.

Graph 9. Weed biomass of each parcel.



Graph 10. Comparison of herb and weed biomass of the same parcel



3.6 Failed treatments

While several mulching treatments showed promising results for plant support and weed suppression, some treatments failed due to structural issues or an inability to support plant survival.

Mash and Subterranean Clover: This treatment was unsuccessful, with no plants surviving by the end of the experiment. Reasons for this failure are unclear but may include transplanting stress, poor initial soil contact, or inadequate moisture retention. Further research could help identify specific causes for plant mortality in these plots.

Paper: The paper mulch also failed, as it tore early in the experiment, leaving the parcel exposed and unprotected for the remaining duration. Without a consistent mulch layer, the plot experienced higher weed growth and reduced moisture retention, impacting plant growth.

In **Table 2**, treatments where plants did not survive are marked with “0.” Possible reasons for plant loss include transplant shock or handling errors that might have affected soil contact and moisture levels. Improvements in planting techniques and initial handling may help reduce these losses in future trials.

4 Discussion

Biodegradable mulches offer a sustainable alternative to plastic, with effectiveness depending on the material's composition and durability. **Plastic mulch** served as the baseline, demonstrating strong weed suppression, soil moisture retention, and plant growth support. Studies have shown that plastic mulching is widely used in cotton, herbal, and vegetable production to enhance crop growth, improve earliness and yield, control weeds, and reduce the incidence of plant diseases (Dong et al., 2009). Comparable results were observed with several biodegradable materials, though some treatments presented challenges that limited their effectiveness.

E.G. Weed Bio UB 157 and 250 performed similarly to plastic in terms of supporting plant health and retaining soil moisture. Both versions 250 g/m² and 157 g/m² maintained good durability, offering consistent coverage and weed suppression throughout the experiment. But previous studies have noted that thicker biodegradable mats provide improved environmental resistance, maintaining their structural integrity for longer periods and delivering more reliable weed suppression (Brodhagen et al., 2017). Thus we expect that the thicker version would last longer than the thinner version.

Hemp mat was similarly effective to plastic, with consistent moisture retention and plant growth throughout the experiment. Its durability supports its potential as a practical biodegradable alternative. Previous studies have shown that hemp mulch can provide durable weed suppression and maintain soil conditions favorable for crop growth, even outperforming some other biodegradable options under certain environmental conditions (Gramig et al., 2021).

On the other hand, **flax mat**, although initially effective, degraded significantly by the end of the experiment, developing holes that compromised its ability to suppress weeds and retain moisture. Rapid degradation of flax-based materials has also been observed in other studies, emphasizing the need for improved fiber treatments to enhance longevity (Melelli et al., 2021).

Paper mulch failed due to tearing and displacement caused by environmental factors, leaving plots unprotected and unable to retain moisture or suppress weeds effectively. Similar challenges with paper-based mulches have been reported, as their lightweight structure and susceptibility to weather conditions limit their practical use in open-field settings which make their lifespan short (Haapala et al. (2014)). **Mash** and **Trifolium subterraneum** were totally a failure, showing no plants growth. Mash, likely due to alcohol content, may have inhibited microbial activity or plants development. Trifolium subterraneum failed to establish as a living mulch, possibly due to competition for water and nutrients. Such challenges are frequently discussed in the context of living mulch systems, which require precise management to avoid negative impacts on crop performance (Bhaskar et al., 2021). **ManPas manure**, applied at three thickness levels, showed consistently strong performance in supporting plant growth and providing high yields. The 15 cm layer demonstrated superior weed suppression, likely due to its thicker coverage blocking sunlight more effectively. Meanwhile, the 10 cm and 5 cm layers also performed well, highlighting the versatility of this nutrient-rich material. Organic mulches like manure not only act as physical barriers but also release nutrients that enhance soil fertility, contributing to improved crop health and yields (Tu et al., 2006). However, localized weed growth at the edges of **ManPas-treated** plots underscores the need for better edge management in nutrient-dense mulches (Tu et al., 2006).

Nettle leftovers provided robust plant growth and effective weed suppression. The material's ability to retain moisture and release nutrients likely contributed to its success. However, as with other nutrient-rich mulches, increased weed growth at the edges highlighted the challenges associated with managing nutrient leaching (Tu et al., 2006).

Biochar exhibited moderate effectiveness, supporting soil moisture retention and plant health but with slightly lower yields than manure or **nettle leftovers**. **Biochar**'s ability to improve soil structure and microbial activity makes it a valuable soil amendment, although it may require complementary inputs to match the performance of more nutrient-dense mulches (Tu et al., 2006; Laird et al., 2010).

Several biodegradable mulches, including **ManPas manure**, **nettle leftovers**, and **E.G. Weed Bio UB 250**, emerged as promising alternatives to plastic mulch. These materials provided comparable or superior benefits, particularly in terms of weed suppression and plant growth. In contrast, treatments such as **paper**, **mash** and **flax mat** revealed significant limitations due to rapid degradation, displacement, or other factors. These findings highlight the need to balance durability, nutrient availability, and weed suppression when selecting biodegradable mulches. Further research and development are essential to improve the performance and practicality of these materials in diverse agricultural settings.

5 Conclusion

The findings of this study demonstrate that several biodegradable mulches have the potential to replace plastic mulching in agricultural systems, offering comparable or superior benefits in terms of plant growth, soil moisture retention, and weed suppression. Among the tested treatments, ManPas manure, particularly at a 10 cm thickness, emerged as one of the most promising alternatives. While the 15 cm layer provided superior weed suppression, its excessive thickness could pose practical challenges during application and transplanting, making the 10 cm layer a more viable option for further exploration.

Nettle leftovers also proved to be a strong organic alternative, effectively promoting plant growth and retaining soil moisture while providing nutrient enrichment. However, as with other nutrient-dense mulches, careful management of weed growth at the edges is necessary to optimize its performance. Similarly, biochar demonstrated potential as a sustainable treatment, supporting plant health and improving soil structure, though it may require complementary inputs to maximize its effectiveness.

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