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Impact of organic and mineral mulch on species richness and weed biomass in newly established wildflower meadows

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Abstract

Creating wildflower meadows through sowing often results in weed emergence during the first year, with irrigation further encouraging annual weed germination. Mulching helps to reduce weeds, alter nutrient levels, and retain soil moisture. This study aimed to investigate the effects of organic (compost) and inorganic (sand) mulch on the number of germinated wildflower species and weed biomass over a two-year period without irrigation. A late autumn (European continental climate) sowing was performed using three wildflower mixtures. Sand and compost, each applied 75 mm thick, were used as mulching materials, with one plot left unmulched as a control. Weed biomass was measured, and species richness and abundance were assessed in the second year. Statistical analysis showed that mulch significantly influenced both species richness and weed biomass. Sand mulch proved particularly effective for establishing wildflower meadows, reducing weed growth. Initially, compost showed good results, but its effects diminished over time, leading to more weeds and reduced species richness. These findings are useful for establishing flowering meadows on soils with a high weed seedbank.

Key words: wildflower meadows, perennials, mulch, species richness, weed biomass, autumn sowing

Introduction

Lawn areas constitute a dominant component of urban green infrastructure on a global scale (Ignatieva & Hedblom, 2018). They are the largest consumers of water compared to other alternatives (Smetana & Crittenden, 2014). Water is becoming an increasingly scarce resource due to the rising frequency of droughts (Hoekstra & Mekonnen, (2012); Hoekstra et al., 2012). The use of wild seeds to create flowering meadows not only reduces the need for irrigation but also has the least environmental impact (Smetana & Crittenden, 2014).

The establishment of flowering meadows, combined with mulching, can offer several advantages. Mulch is used to suppress weed growth. The use of legumes as living mulch further reduces the presence of weeds (Surault et al., 2024). When using organic or mineral mulch to control weed growth, it is crucial to ensure that the mulch is free of weed seeds. According to Hitchmough (2017), the effectiveness of mulching depends on the thickness of the mulch layer, and when applying sand as mulch, irrigation is also necessary to achieve optimal results. According to Sparke et al., (2011), mixing subsoil with 33% compost yields good results for the seed mix of meadow species used. Good results are also achieved with a composition of 15-30% compost added to a mixture of sand and river silt.

Mulching with mineral substrates can reduce the nutrient content of the soil, with nutrient-poor soil hindering the growth of grasses and giving an advantage to the desired flowering plants. The presence of rock fragments in the soil, particularly those ranging in size from 2 to 20 mm, is crucial for the content of carbon and nitrogen. Both the size and quantity of rock particles affect the vegetation cover (Ruggeri et al., 2016).

Mulching also reduces the kinetic energy of raindrops and protects against erosion, making it suitable for the establishment of flowering meadows on sloped terrain (Krautzer et al., 2011). Additionally, mulching increases soil moisture content (Wang et al., 2024). Even a small amount of hay has a positive effect on retaining moisture in the soil, with an even greater impact observed when hay is mixed with soil (Prihar et al., 1996).
Bare soil can evaporate between 40% and 70% of average annual rainfall (Wendt et al., 1970). Mulching with compost reduces soil bulk density and increases porosity, thereby contributing to soil aeration. The increase in porosity also enhances the soil's infiltration properties, creating favorable conditions for the development of soil microorganisms, hyphae, and plant roots, which further reduce bulk density (Frey et al., 1999; Sparke et al., 2011).

Increased moisture levels also benefit earthworms, which contribute to soil aeration. Their population increases in nutrient-rich environments. For instance, mulching with crop residues can create favorable conditions, provided that the plants do not contain alkaloids or excessive amounts of fiber (Buck et al., 1999).

The aim of this study is to examine the effects of mineral and organic mulching on weed abundance and the development of meadow species in autumn sowing without supplemental irrigation.

Methods and materials

Experimental design and field work

Two types of mulching substrates were selected for the experiment: mineral (river sand) and organic (compost). Both materials were sourced locally. The sand, with a particle size fraction of 0-4 mm, was natural and extracted from the "Krivina" quarry near Sofia. It was stored in bags which prevented the introduction of weed seeds. The compost was processed at the "Han Bogrov" site of the Sofia Waste Treatment Plant.

An analysis of the compost from the corresponding year showed that no weed seeds were present. The levels of heavy metals were within permissible limits, and there were no traces of Escherichia coli, Listeria monocytogenes, or Salmonella sp. (Institute for Sustainable Plant Production, 2022). The compost was moderately saline (Brouwer et al., 1985). The parameters of the compost affecting seed germination are shown in table 1.

Three types of seed mixtures for flowering meadows were used: universal (06), for rich soil (02), and for poor and dry soil (06a). The seeds originated from wild species, propagated in the Syringa Kräutergärtnerei GbR nursery in Hilzingen, Germany. The experimental plots were set up at the Training and Experimental Farm "Vrazhdebna" located in the Vrazhdebna district of Sofia (42.70844824996861, 23.43658163140544). The species composition in the mixtures, as well as soil and climatic conditions, were detailed in a previous publication (Hristova, 2024).

The soil was tilled, cleared of roots, and leveled. Nine plots of 1.5 x 1.5 meters were designated. Three were mulched with sand, three with compost, and the remaining were left without mulch. The mulch was applied to a thickness of 7.5 cm. The plots were fully exposed to sunlight, with only the eastern side shaded by coniferous trees until noon.

In early autumn 2021, agro-meteorological conditions were unfavorable, characterized by drought followed by excessive rainfall (National institute of meteorology and hydrology of Bulgaria, 2022). As a result, late sowing took place in early December 2021. At the time of sowing, the soil was excessively moist due to rainfall in this period (National institute of meteorology and hydrology of Bulgaria, 2021).

The experimental plots were mowed once a year, on August 8, 2022, and July 27, 2023. At the end of the first year, the number of germinated species from sowing mixes was recorded, and the species' cover was measured during the second growing season. Periodic assessments of species richness were made from May to June 2023.

Weed biomass (both aboveground and belowground systems) was collected over two growing seasons. The biomass was dried at 85° C for 48 hours and weighed using an electronic scale with an accuracy of 0.01g.

<u>Data Analysis</u>

The Linear Mixed Models (LMM) method (IBM SPSS Statistics 28) was used for data analysis. Species richness and weed biomass were chosen as dependent variables, with date introduced as a random factor. The independent variables were mulch type, seed mixture type, and their interaction.

Two separate analyses were conducted to assess the influence of mulch type on species richness and weed biomass, as these factors were measured at different times. The first analysis examined the effects of mulch type and seed mixture on species richness, while the second focused on the impact of mulch type on weed biomass. Species richness was determined by the total number of recorded species during May-June 2023.

Results

<u>*Field Work*</u>

Species richness

The number of individuals from the seed mixtures at the end of the first year (table 2) showed the highest count in the combination of the poor soil mixture and sand. The second-highest count was observed in the universal mixture combined with sand.

Due to the differences in the number of species in the mixtures, the next table (table 3) presents the percentage ratio of germinated species relative to the total number of species in each mixture. The highest percentages were recorded in mixtures grown on the sand substrate, with the combination of sand and the poor soil mixture showing the largest percentage of germinated species.

Visual comparison of vegetation across different mulch types

As shown in figure 1, the plots mulched with sand exhibited the highest species diversity and the fewest weeds. The vegetation in these plots also appeared healthier compared to the compost-mulched and control plots.

<u>*Weed Presence*</u>

In the early part of the first growing season, weeds in the control plots consisted mainly of small, annual, dicotyledonous species, with a large number but smaller size. In the sand plots, the weeds were fewer but larger in size, whereas the compost plots were dominated by monocotyledonous species. Common weeds observed

Table 1. Parameters of the compost affecting seed germination

Parameter	Result	Unit
Organic matter	40.0	%
Total organic carbon (TOC)	23.3	%
Total nitrogen	1.7	%
C/N ratio	13.7	
Water content	42.5	%
pH	7.06	
Salt content	3.2	g/l
Electrical conductivity	933.50	µS/cm
Moisture	657.9	g/l
Germination coefficient	100	%

Source: Institute for Sustainable Plant Production (2022)

Table 2. Individual count at the end of the first year (2022)

Mixture	Sand	Soil	Compost
06	38	9	7
02	28	8	7
06a	41	4	3

Legend: 06 - Universal mixture, 02 - Mixture for rich soil, 06a - Mixture for poor and dry soil

Table 3. Species richness of plant communities from different mixture types on various mulch types

Mixture	Mulch	Recorded Species	Species in Mixture	Germinated-Species Ratio (%)
02	Sand	11	26	42.31
02	Soil	9	26	34.62
02	Compost	6	26	23.08
6a	Sand	18	36	50.00
6a	Soil	8	36	22.22
6a	Compost	8	36	22.22
6	Sand	19	39	48.72
6	Soil	12	39	30.77
6	Compost	16	39	41.03

Legend: 06 - Universal mixture, 06a - Mixture for poor and dry soil, 02 - Mixture for rich soil

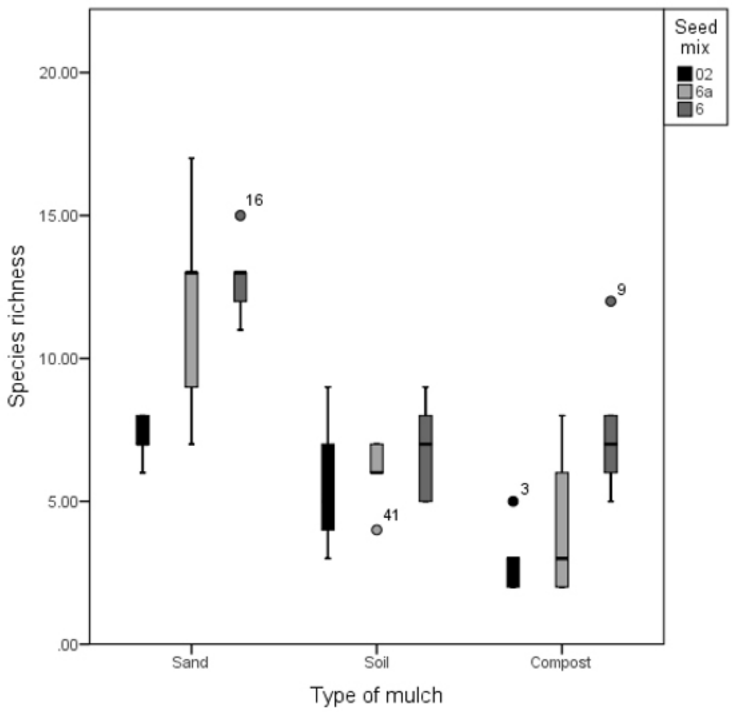
A: Sand B: Soil C: Compost

Fig. 1. Vegetation in different mulch types

Table 4. Descriptive statistics for species richness by mulch type and mixture type

Mixture	Mulch	N	Mean	SD	Coefficient of Variation (%)
02	Sand	5	7.20	0.83666	11.6%
02	Soil	5	5.60	2.40832	43.0%
02	Compost	5	3.00	1.22474	40.8%
02 Total	-	15	5.27	2.34419	44.5%
6a	Sand	5	11.80	3.89872	33.0%
6a	Soil	5	6.00	1.22474	20.4%
6a	Compost	5	4.20	2.68328	63.9%
6a Total	-	15	7.33	4.25385	58.0%
6	Sand	5	10.60	1.48324	11.6%
6	Soil	5	6.13	1.78885	26.3%
6	Compost	5	4.93	2.70185	35.6%
6 Total	-	15	7.22	3.34806	36.9%
Total	Sand	15	10.60	3.39748	32.1%
Total	Soil	15	6.13	1.80739	29.5%
Total	Compost	15	4.93	2.93906	59.6%
Total	-	45	7.22	3.67973	51.0%

Legend: 06 - Universal mixture, 6a - Mixture for poor and dry soil, 02 - Mixture for rich soil



Legend: 02 – Mixture for rich soil, 06 – Universal mixture, 06a – Mixture for poor and dry soil

Fig. 2. Impact of Mulch Type and Seed Mixture on Species Richness

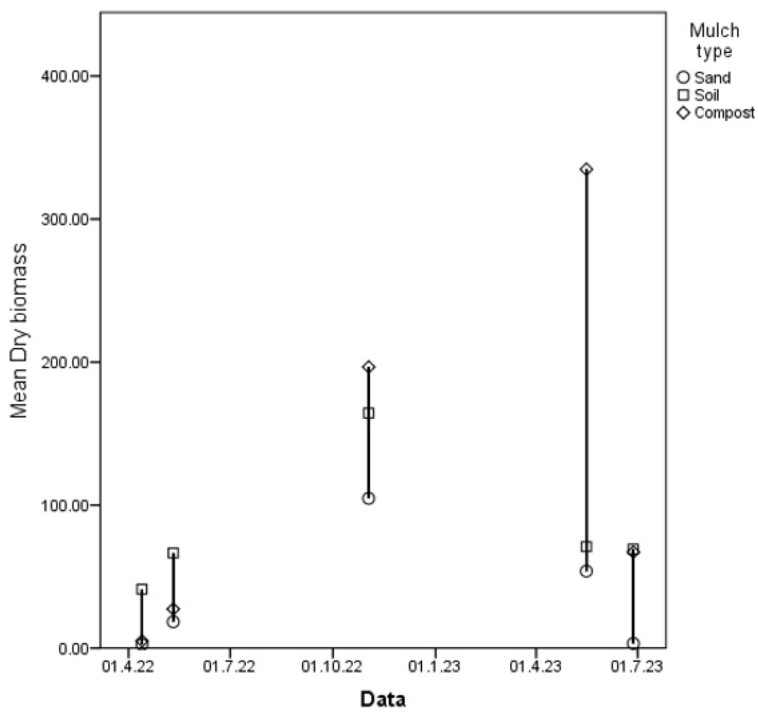


Fig. 3. Effect of mulch type on weed biomass (dry weight)

included knotgrass (*Polygonum aviculare* L.), redroot pigweed (*Amaranthus retroflexus* L.), and shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.). Later, annual weeds such as horseweed (*Erigeron canadense* L.), and field larkspur (*Consolida regalis* S. F. Gray.) appeared, while green foxtail (*Setaria viridis* (L.) P.Beauv.) emerged along the periphery.

<u>Statistical Analysis of Results</u>

Effect of Mulch on Species Richness

The statistical analysis shows a significant effect of mulch type on species richness (F(2, 36) = 26.991, p = 0.000), as well as the effect of seed mixture type (F(2, 36) = 10.955, p = 0.000). The interaction between mulch type and mixture type was not significant (F(4, 36) = 2.083, p = 0.103), indicating that the two main factors—mulch type and seed mixture—are significant independently of each other.

Species richness was highest in sand mulch, especially when using the universal mixture. Standard deviations and the coefficient of variation indicate the greatest variability in compost mulch, while sand mulch had the lowest variability (table 4).

As shown in figure 2, the highest mean species richness is found in the sand mulch. Compost mulch produced the lowest average values, and the combination of sand and the mixture for poor and dry soils exhibited the highest number of species but also the largest dispersion.

<u>Weed Biomass</u>

The initial measurements show that weed biomass (dry weight) was lowest in the sand and compost-mulched plots. Over time, weed biomass grew the most in composted plots and the least in sand-mulched plots. By the end of the observation period, weeds had decreased in all plots, but they remained lowest in the sand-mulched plots (fig. 3).

Discussion

Mulching with compost appears to favor weed species, which suppress meadow species. This result aligns with the findings of Sparke et al. (2011). A compost content of more than 45% creates a highly fertile environment, which is conducive to weed growth.

Sand mulch produced the best results for both species richness and the reduction of annual weed species. The mixture for poor soil and the universal mixture performed most effectively in combination with sand. The autumn sowing method eliminated the need for irrigation. Long-term studies on the effect of sand mulch on species richness in seed mixtures should be conducted to better understand its benefits.

The findings are applicable for establishing flowering meadows in both urban settings and on agricultural land, particularly in phosphorus-rich soils with a high weed seed bank.

Conclusion

Compost mulch had a negative impact on species richness in flowering meadows created from seed. Late autumn sowing, combined with sand mulch, yielded good results for establishing flowering meadows without irrigation. Mulch with good infiltration properties allowed for sowing when the soil was waterlogged due to heavy rainfall. The seed mixture for poor soil developed most successfully in combination with sand mulch, and the universal mixture also showed promising results.

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