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Exploitation of the Herbicide Effect of Compost for Vineyard Soil Management

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Abstract: Soil management in vineyards is a crucial component of sustainable viticulture. Weed control under the row has traditionally been addressed using mechanical, physical, and chemical techniques, but herbicides pose environmental and health risks. The circular economy offers an alternative approach by converting organic waste into a resource, such as compost. This study explores the effectiveness of compost derived from the organic fraction of municipal solid waste (MSW) not only as a mulching technique but also as a potential biological agent for weed control through allelopathic mechanisms in vineyards. Experiments were conducted both in the field and under controlled conditions. In the field, compost was applied under the vine row as mulch and incorporated into the soil. Under controlled conditions, germination tests were performed to assess weed inhibition at different compost concentrations. Field results demonstrated that compost applications, both as mulch and incorporated into the soil, significantly inhibited weed growth during the first period after application compared to the tilled control without compost. Thus, this inhibition is not limited to physical mulching; it also applies to the release of allelopathic compounds from compost. Controlled condition experiments showed strong inhibition of germination in *Cichorium intybus* and *Foeniculum vulgare* seeds, confirming the anti-germinative effects of compost, particularly on small-seeded weed species. Compost is a promising tool for sustainable vineyard management, offering fertilization and weed-suppression benefits while reducing herbicide use.

Keywords: viticulture; municipal solid waste (MSW); circular economy; anti-germinative effect; weed control; allelopathic mechanisms

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1. Introduction

Soil management in vineyards is an essential component of ensuring sustainable and high-quality viticulture [1]. A crucial aspect of this management is the control of weeds, which can reduce grape yields by competing with vines for vital resources such as water,

nutrients, and light [2,3]. Traditionally, weed control has been approached through a single technique or a combination of mechanical, physical, and chemical techniques [4]. Mechanical techniques, such as tillage and the use of specialized weeding machinery, are widely employed to remove weeds between the vine rows [5]. Mechanical under-row weed control in the vineyard is a sustainable choice compared to chemical control, with tillage-based approaches being especially efficient [6]. Physical techniques, such as mulching, are a popular alternative as they prevent weed germination by creating a protective barrier on the soil surface. New engineering technologies such as flame weeding are less time-consuming than conventional practices but more expensive than mechanical weeding and less efficient than hand weeding [7]. The use of natural or synthetic materials for mulching has been demonstrated to be effective in reducing weed pressure while improving soil moisture retention and promoting vine growth [8]. However, the adoption of new technologies, such as biodegradable mulches, is becoming increasingly common in the pursuit of sustainability [9,10]. Simultaneously, the use of chemical herbicides remains widespread, despite growing concerns about their potential negative impacts on the environment and human health. Herbicides can contaminate groundwater and harm soil biodiversity, creating dependency that compromises the long-term sustainability of viticulture [11,12]. The search for more eco-friendly alternatives is thus a priority for both producers and researchers, in line with the increasing demand for sustainable agricultural practices.

In this context, the circular economy emerges as an innovative and sustainable approach to organic waste management, transforming waste into valuable resources. Municipal solid waste (MSW) compost is a concrete example of circular economy practices, where agricultural residues, food waste, and other organic materials are recycled to produce organic soil amendments [13]. In addition to improving soil structure and enriching it with organic matter, compost can be used as mulch to control weed growth. Studies have shown that compost can play a key role not only as a physical barrier [14,15] but also as a biological and chemical control agent, actively inhibiting weed growth due to its complex chemical composition [16,17]. The application of MSW compost offers beneficial side effects. It promotes microbiological activity, which enhances the turnover of organic matter in the soil. Additionally, it helps to maintain lower soil temperatures during the summer, mitigating heat stress on plant roots and thereby improving plant health and overall functionality [14].

The chemical inhibition of weeds by compost is a phenomenon that can gain attention in scientific research. Several studies have highlighted that compost, through allelopathic processes, can release chemicals that inhibit weed germination and growth [18,19]. This allelopathic property is attributed to a variety of organic compounds released during the decomposition of organic matter, particularly short-chain carboxylic acids and phenolic acids, as well as phenolic moieties of humic acids present in the compost and other secondary metabolites [20,21]. These compounds can negatively affect weed development, offering a natural and sustainable alternative to chemical herbicides.

The objective of this study was to explore the effectiveness of compost derived from the organic fraction of MSW not only as a mulching technique but also as a potential chemical agent for weed control in vineyards. To confirm this hypothesis, tests were set up both in-field and in controlled conditions. This approach could afford new options for more sustainable and circular soil management, reducing the environmental impact of viticulture and promoting a transition towards low-input agriculture. In a context where sustainability is a global priority, the adoption of innovative techniques, such as the use of MSW compost, represents a significant step towards reducing the environmental footprint and improving soil quality in vineyards.

2. Materials and Methods

2.1. Experimental Plan in Field

The field experiment was carried out in 2022–2023, in a commercial Primitivo (*Vitis vinifera* L.) vineyard belonging to Tenute Eméra di Claudio Quarta (Lizzano, Apulia, Italy; Latitude 40°21′10″ N, Longitude 17°25′32″ E, Altitude 13 m a.s.l.). In this field, 13-year-old vines grafted onto 1103 Paulsen rootstocks are planted in rows oriented North–South. The distance between vines is 0.90 m in the row and 2.20 m between rows. The training system is a vertical shoot position (VSP), pruned as a spur cordon The climate of the Salento Peninsula, classified as Csa according to the Köppen–Geiger system [22], is Mediterranean, typically hot and dry in summer and mild and wet in winter [23]. For the climate analysis, a weather station located at 40°23′08″ N, 17°26′56″ E and operated by the Apulian Civil Protection Agency was used.

Table 1 reports the seasonal evolution of key weather parameters for the period 1991–2020. Winter months (i.e., December, January, and February) are characterized by mild temperatures and regular rainfall, with a moderate number of wet days. As spring progresses (i.e., March, April, and May), temperatures increase noticeably while precipitation becomes more variable and slightly less frequent. The summer period (i.e., June, July, and August) exhibits the typical features of a Mediterranean climate, with high temperatures and a marked drop in both rainfall and wet days, reflecting prolonged dry spells occasionally interrupted by short, intense events. In autumn (i.e., September, October, and November), temperatures begin to decline while rainfall increases again, both in intensity and frequency.

Table 1. Overview of the main weather parameters for the period 1991–2020.

Month	Air Temperature (°C)			Precipitation (mm)	Wet Days (>1 mm)
	T_{avg}	T_{max}	T_{min}		
January	10.3	14.1	6.5	53.3	7
February	10.7	14.7	6.6	45.8	6
March	12.7	16.9	8.5	57.3	6
April	15.6	20.1	11.2	44.5	6
May	20.2	25.1	15.3	26.8	4
June	24.9	30.1	16.7	19.9	3
July	27.8	33.3	22.2	17.6	2
August	27.9	33.3	22.5	27.0	2
September	23.6	28.3	18.8	54.3	5
October	19.4	23.7	15.1	70.7	6
November	15.2	19.1	11.3	76.0	7
December	11.4	15.1	7.8	70.1	8

The analyzed period from November 2022 to May 2023 was characterized by slightly warmer-than-average conditions, particularly in December and May, accompanied by notable variability in precipitation. While December and April experienced significantly above-average rainfall, February was marked by an unusually dry spell.

On the 28 October 2022, different soil managements were obtained under the row (about 50 cm width) following a randomized experimental design (Figure 1), with 9 replications (6 vines/replication) for each of the following treatments:

- Tilled soil without compost addition (TS);
- Compost (16 kg/vine) burial by shallow tillage (CT);

– Compost mulching (16 kg/vine) after tillage (CM).

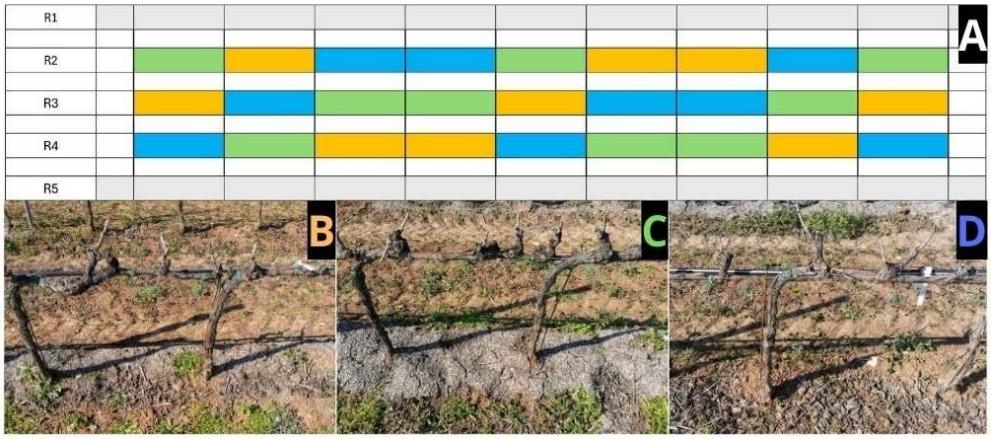

Figure 1. Map and pictures of the soil management. (**A**) Map of the soil management. Each line (Rn) represents a row. Each rectangle represents a 6-plant plot included between two poles. Different colors indicate different soil management: orange = compost burial by shallow tillage (CT); green = compost mulching after tillage (CM); blue = tilled soil without compost addition (TS); and grey = border area. Photos show the treatments 15 weeks after compost distribution: (**B**) compost burial by shallow tillage (CT); (**C**) compost mulching after tillage (CM); and (**D**) tilled soil without compost addition (TS).

A soil physical-chemical characterization was performed on samples collected at 0–20 cm depth immediately before the beginning of field trials. The soil in the study area is classified as *Terra Rossa*, a typical Mediterranean red clay soil developed on limestone. According to the World Reference Base for Soil Resources (WRB) [24], it corresponds to a *Chromic Luvisol*, characterized by a clay-rich B horizon, reddish coloration due to iron oxide accumulation, and formed through prolonged weathering and decalcification processes of calcareous parent material [25]. A composite soil sample was collected from each of the three rows indicated in Figure 1A (namely, R2, R3, and R4). Each sample was taken along the vine row, at a point equidistant from two adjacent vines, using a hand trowel. Samples were analyzed separately; then, results were averaged. Soil texture, pH (both in H_2O and in a $CaCl_2$ solution), electrical conductivity (EC), organic carbon content (OC), total nitrogen content (TN), available P, exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+, and K^+), and cation exchange capacity (CEC) were determined following the standard procedures for soil analyses [26]. pH and EC were determined using soil–liquid ratios of 1:2.5 (m/v) and 1:2 (m/v), respectively; OC was determined by the Walkley–Black method, TN by the Kjeldahl method, available P through the Olsen method, and exchange complex analyses using the BaCl2-triethanolamine (pH 8.2) method.

Compost pH and EC were measured on 1:10 (m/v) compost: H2O suspension, after filtration [27]. The determination of OC and TN was carried out by the Springer–Klee and Kjeldahl methods, respectively. After oven-drying at 40 °C, compost was finely milled and analyzed for heavy metal content using a portable X-ray fluorescence spectrometer (XRF Analyzer NITON XL3t GOLDD, Thermo Fisher Scientific, Waltham, MA, USA), as described in Gattullo et al., 2017 [28]. Analyses were performed on three different aliquots sampled from the compost pile, and results were averaged.

Between November 2022 and May 2023, weed growth was quantified in different soil management conditions. The percentage of soil covered by grass was measured using the smartphone application "Canopy Cover Free v2.0" [14,29]. This application calculates the green area percentage in a photo of the soil. In each block, 3 photos were collected

(between the vines 2nd–3rd; 3rd–4th; and 4th–5th). Thus, on each date, 27 measurements were collected for each treatment.

Data was analyzed using R v3.6.3 and R_Studio v.4.3.3 software [30]. For weed control, ANOVA was used to compare means between treatments for each measurement date. Additionally, to evaluate the effects of treatments across the whole monitored period, a repeated-measures ANOVA was used. All ANOVAs were followed by a post hoc test (Duncan's) at $p \leq 0.05$.

2.2. Experimental Plan in Controlled Conditions

The germination trial in controlled conditions started on 12 March 2024. In total, 150 seeds per species from four different herbaceous plants were selected for the experiment: two wild species, *Foeniculum vulgare* (fennel) and *Cichorium intybus* (chicory), collected in the first week of December 2023 from the botanical garden of the University of Salento; and two commercial species, *Vicia faba* var. minor (faba bean) and *Secale cereale* (rye). All seeds were stored in a controlled environment inside paper bags. The seeds of each species were subjected to five different treatments with aqueous compost extract, including control. The compost extract was obtained by conducting a modified version of the method outlined in the Chinese Standard for Organic Fertilizers [31]. In each treatment, a certain amount of wet MSW compost was mixed with 100 mL of deionized water, the mixture was shaken for 1 h and then filtered, and the filtrate was collected [32]. The doses of compost for the treatments were as follows:

- Only deionized water, without compost (treatment = 0).
- 10 g of compost in 100 mL of deionized water, corresponding to a 1:10 (w/v) ratio (treatment = 1).
- =30 g of compost in 100 mL of deionized water, corresponding to a 3:10 (w/v) ratio (treatment = 2).
- =50 g of compost in 100 mL of deionized water, corresponding to a 1:2 (w/v) ratio (treatment = 3).
- =100 g of compost in 100 mL of deionized water, corresponding to a 1:1 (w/v) ratio (treatment = 4).

For each treatment and species, Petri dishes (90 mm in diameter) were prepared, with 10 seeds placed on bibulous paper in each dish. In total, 600 seeds were distributed across 60 Petri dishes (4 species $\times$ 5 treatments $\times$ 3 replicates each $\times$ 10 seeds each).

Following selection, the seeds were selected and pre-treated by being submerged in hypochlorite aqueous solution (2%, volumetrically) for 30 s; thereafter, they were rinsed with distilled water. This procedure was employed to sterilize the seeds and reduce the risk of contamination during the experiment. The treated seeds were placed in the prepared Petri dishes and moistened with 5 mL of their respective compost extract treatments. The dishes were then placed in growth chambers set to a constant temperature of 20 °C. Light conditions were maintained at 18 h of light and 6 h of darkness throughout the duration of the experiment. Germination was monitored daily from 12 March 2024 until 25 March 2024. Seeds were considered germinated when the radicle had reached a length of at least 2 mm. During the monitoring period, the number of germinated seeds in each Petri dish for each treatment was recorded, and germination percentages were calculated for each treatment.

Finally, the Germination Index (GI) was calculated as follows:

$$\text{GI}\ (\%) = (\text{GR} \times \text{RL}) \div 100$$

where GR is the ratio of the number of germinated seeds in compost extract to the number of germinated seeds in the control in terms of percentage, and RL is the ratio of radicle

length of all seeds in the compost extract and radicle length of all seeds in the control in terms of percentage.

Data was analyzed using R v3.6.3 and R_Studio v.4.3.3 software [30]. For germination dynamics a repeated-measures ANOVA was used to evaluate the effects of treatments across the whole monitored period. For the Germination Index, one-way ANOVA was used to compare means between treatments for each species and between each level of treatment. All ANOVAs were followed by a post hoc test (Duncan's) at $p \leq 0.05$.

2.3. Municipal Solid Waste Compost

The compost used in this work was MSW compost provided by Heracle SRL, and the analysis of the production batch is available in the Supplementary Materials (Supplementary Table S1). This compost was produced through the aerobic stabilization of the organic fraction of municipal solid waste, which was obtained after a mechanical separation process that removed non-organic materials. The input to the composting plant consisted of approximately 88% source-separated organic waste (mainly food waste) from the Brindisi province, 10% green waste (such as grass clippings, pruning residues, and brushwood), and 2% organic waste from food processing.

The organic material underwent composting in static aerated biocells, followed by a maturation phase in biocells. The resulting compost was stabilized and screened, and it complies with the quality standards set by Italian legislation for agricultural use [33].

3. Results

The results of soil characterization are reported in Table 2. The soil was clayey and slightly alkaline, with a low EC and a low level of organic matter content but an adequate level of TN. The soil C/N ratio was slightly lower than the ideal range (9–11), revealing the prevalence of organic matter oxidation processes over humification processes. Soil characterization also revealed the high level of available P and a high CEC, as expected due to the high level of clay (46% on average). Based on the values of exchangeable bases and CEC, it can be concluded that the soil possessed a high level of exchangeable Ca^{2+}, a medium level of Mg^{2+}, and a medium-high level of K^+. Additionally, the ratio between Mg^{2+} and K^+ was balanced.

Table 2. Soil physical chemical properties (mean ± SD, *n* = 3).

Texture	pH (H_2O)	pH ($CaCl_2$)	EC (dS m^{-1})	OC (g kg^{-1})	TN (g kg^{-1})	C/N
Clay	8.21 ± 0.11	7.22 ± 0.13	0.19 ± 0.02	10.09 ± 0.44	1.27 ± 0.12	8.00 ± 0.40
Organic matter (g kg^{-1})	**$P_{available}$ (mg kg^{-1})**	**Ca^{2+} ($cmol_{(+)}$ kg^{-1})**	**Mg^{2+} ($cmol_{(+)}$ kg^{-1})**	**K^+ ($cmol_{(+)}$ kg^{-1})**	**Na^+ ($cmol_{(+)}$ kg^{-1})**	**CEC ($cmol_{(+)}$ kg^{-1})**
17.39 ± 0.77	26.45 ± 5.56	30.43 ± 2.16	3.28 ± 0.18	1.76 ± 0.25	0.52 ± 0.06	41.44 ± 1.93

The results of compost chemical analyses (Table 3) used in this work revealed that compost complied with the reference values imposed by the Italian legislation (Italian Directive n. 75/2010) [33] for the OC content, C/N ratio, and heavy metal content. Specifically, the OC content was approximately 36.9%, well above the minimum legal threshold of 20%, while the C/N ratio was around 18.7, remaining below the maximum allowed limit of 25. Chromium, Ni, Pb, and As were not detected by XRF analysis, while Cu and Zn were found at levels below the limits imposed by the Italian Directive n. 75/2010 [33].

Table 3. Main chemical properties of the compost used for the experiments (mean ± SD, $n = 3$).

pH	EC (dS m^{-1})	Salinity (meq 100 g^{-1})	OC (% d.w.)	TN (% d.w.)	C/N	Zn (mg kg^{-1} d.w.)	Cu (mg kg^{-1} d.w.)
7.3 ± 0.1	5.7 ± 0.1	77.5 ± 0.7	36.9 ± 0.9	2.0 ± 0.1	18.7 ± 0.7	173.5 ± 5.2	65.4 ± 1.7

As for the results of field trials, the repeated measures ANOVA tests (Figure 2) indicated that the compost application significantly affected the weed growth trend during the time with respect to the tilled control without compost, but no significant differences in the trend were observed between the two types of compost application (mulching or burial with tillage). In general, the compost inhibited weed growth in the first period after application (about two and a half months) and stimulated it starting from about the end of February. The weed growth inhibition in the first period was significant with respect to the tilled control for both the compost managements. However, it is worth noting that it was better maintained with mulching at the end of the first period. At the beginning of springtime, the presence of compost, independently of the management type, increased weed growth. This effect was slightly stronger and more stable in the case of compost burial, as shown by the higher weed cover percentages and lower variability among replicates, particularly from February to May (Figure 2).

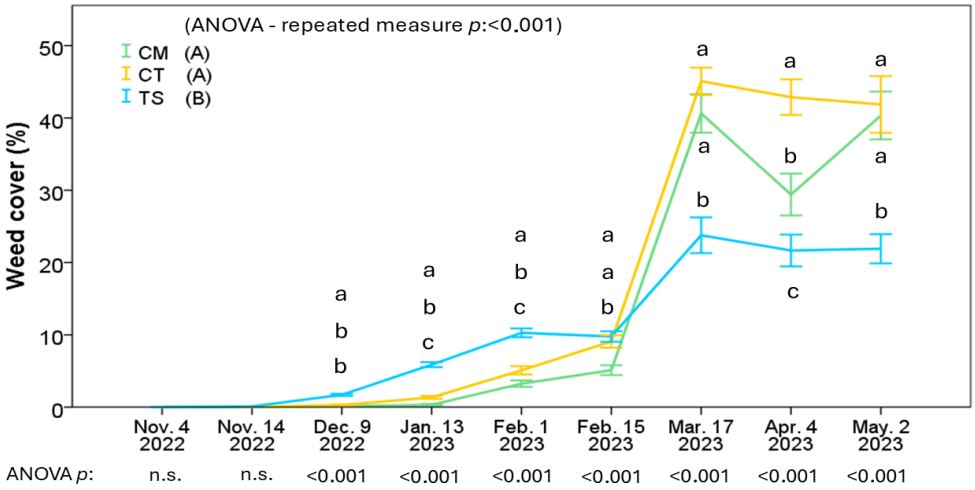

Figure 2. Effect of soil management on the percentage of weed cover. CT = compost burial by shallow tillage; CM = compost mulching after tillage; TS = tilled soil without compost addition; and n.s = not significant. The whisker indicates the standard error. Different lowercase letters indicate significantly different means between the treatments for each date (Duncan post hoc test, $p < 0.05$). Different capital letters indicate significantly different means between the treatments with repeated measures for the entire duration of the surveys (Duncan post hoc test, $p < 0.05$).

For what concerns the results in controlled conditions, the germination dynamics of the tested species over time are illustrated in Figure 3. In Figure 3A, repeated measures ANOVA revealed that the application of a high ratio of compost extract significantly influenced the sprouting of *Cichorium intybus* seeds. A similar effect was observed in Figure 3B for the seeds of *Foeniculum vulgare*. Regarding *Secale cereale*, significant differences were identified between Treatments 1, 2, and the control, while Treatments 3 and 4 did not differ significantly from Treatment 2. Moreover, Treatment 3 showed no significant difference from Treatment 1. For *Vicia faba*, no significant differences were detected between treatments with higher compost extract inputs, though a slight difference was observed between Treatment 1 and the control.

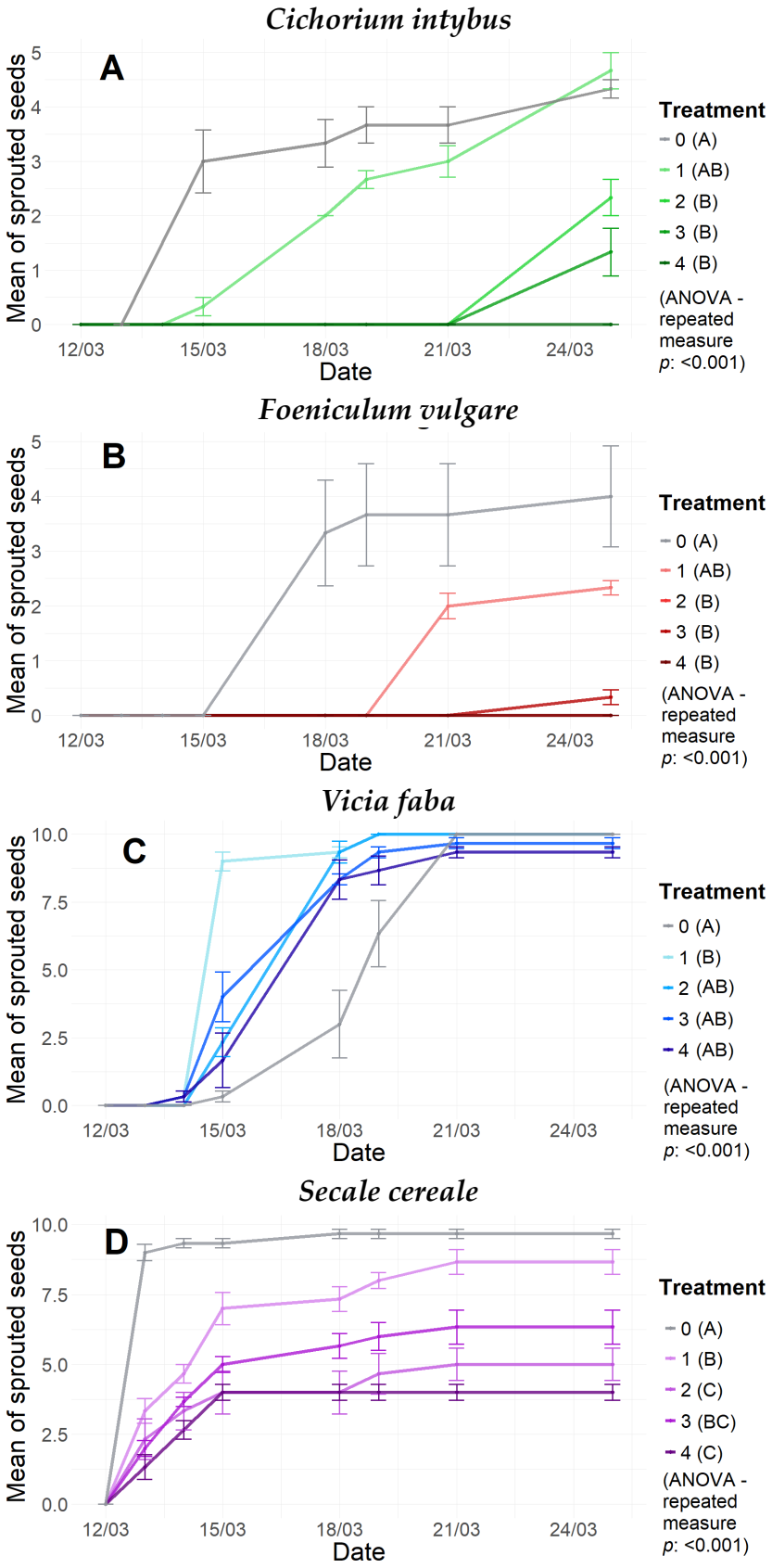

Figure 3. Evolution of the means of sprouted seeds by treatment for the four species under investigation: (**A**) *Cichorium intybus*, (**B**) *Foeniculum vulgare*, (**C**) *Vicia faba*, and (**D**) *Secale cereale*. Different capital letters next to legend indicate significantly different means between each treatment with repeated measures for the entire duration of the surveys (Duncan's, $p < 0.05$).

Table 4 depicts the GI, expressed as a percentage, for the four species subjected to different treatments, excluding the control. According to Italian legislation [33], the value of a GI above the threshold of 60% is the discriminant to indicate whether a compost has phytotoxic action or not. For all species, Treatment 1 consistently exceeded the threshold, while the other treatments exhibited strong inhibition of germination in *Cichorium intybus*, *Foeniculum vulgare*, and *Secale cereale*. In contrast, the germination index of *Vicia faba* appeared unaffected by the higher compost extract input across the treatments.

Table 4. Germination index for the four species under investigation by treatment (means ± SE, $n = 3$). All ratios are expressed as weight/volume (w/v), where "w" refers to the weight of compost and "v" to the volume of water used for the extract. Different lowercase letters, next to the values, indicate significantly different means between single treatments, and different capital letters indicate significantly different means between single species (means ± SE, $n = 3$).

Species	1:10 (w/v)	3:10 (w/v)	1:2 (w/v)	1:1 (w/v)
Cichorium intybus	96.37 ± 13.37 (a–A)	29.74 ± 8.85 (a–B)	20.95 ± 16.62 (a–B)	0 (a–B)
Foeniculum vulgare	65.18 ± 14.20 (a–A)	0 (a–B)	4.16 ± 4.16 (a–B)	0 (a–B)
Vicia faba minor	100 ± 21.42 (a–A)	86.63 ± 15.47 (b–AB)	76.59 ± 17.50 (b–B)	64.06 ± 6.12 (b–B)
Secale cereale	91.52 ± 20.41 (a–A)	29.73 ± 7.63 (a–B)	54.36 ± 23.53 (ab–AB)	17.75 ± 10.69 (a–B)

4. Discussion

Compost is well known for its fertilizing properties, such as nutrient enrichment and organic matter contribution to the soil [34]. These properties can enhance soil structure and support plant growth, as observed in the experiment under field conditions (Figure 1). The soil chemical characterization revealed a good level of soil fertility except for the content and the stability of soil organic matter, which might be enhanced through soil organic amendment with high-quality organic matrices, including compost. Indeed, the application of compost, rich in organic carbon (36.9%) and with an appropriate C/N ratio (18.7), can compensate for this deficiency by improving soil organic matter quality and promoting a microbiologically active environment. The stimulation of plant growth appears several months after the compost application. This delay is due to the slow mineralization of organic matter within the compost and the gradual leaching of nutrients into deeper soil layers, allowing them to reach plant root systems [1,35].

In contrast, during the first period following compost application, a marked inhibition of the weed growth was observed. In the field trials, weed cover remained below 10% for approximately 75 days after treatment application, particularly in the plots with compost, as shown in Figure 2. This inhibition could be explained, in part, by the physical mulching effect of the compost layer itself. The shading effect created by the compost on the soil surface likely prevents sunlight from reaching weed seeds, thus impeding their germination [14]. Nevertheless, weed growth suppression was also recorded in the case of compost burial through shallow tillage. This suggests that, beyond its physical shading effect, compost may exert a chemical influence that inhibits weed germination. During the composting process, various chemical compounds, such as phenolic acids, ammonia, and short-chain fatty acids, are formed. These compounds have been shown to possess anti-germinative properties, particularly against small weed seeds [36]. Such findings indicate that compost not only acts as a physical barrier to weeds but also introduces allelopathic substances that can directly impact seed germination.

The germination tests conducted under control conditions further corroborated the anti-germinative effects of compost, especially on small-seeded weed species. For example, *Foeniculum vulgare* and *Cichorium intybus* showed poor germination rates with compost extract at 3:10, and below. These results align with previous research, which suggests that small seeds are vulnerable to allelochemical effects [37]. Small seeds are more exposed to allelochemical compounds due to their higher surface-to-volume ratio and possess fewer reserve substances [38]. Many common wild weeds have small seeds, making them especially susceptible to both the physical and chemical weed-suppression mechanisms provided by compost. This sets compost as a dual-function tool in sustainable agriculture, contributing both to soil fertility and weed control.

On the other hand, *Vicia faba* beans, often used as artificial grassing in vineyards [39], were not affected by the compost application. *Vicia faba*, being larger-seeded legumes, may be less sensitive to the inhibitory compounds present in compost. This suggests an interesting combination of the beneficial effects of grassing with legumes [39], which is commonly carried out to enhance soil fertility and structure, and the herbicide effect of compost on competitive weeds. The combination of legume-based grassing, which contributes to nitrogen fixation, with the weed-suppressing effects of compost presents a promising strategy for vineyard soil management. Such a system could allow for the simultaneous benefits of nutrient enrichment, weed control, and reduced competition between crops and weeds.

In vineyard systems, soil should be managed to avoid excessive competition among crops and the weeds [2], especially in rows, where weeds are typically removed to favor vine development. [40]. The use of compost, with its dual role as both a soil fertilizer and a weed suppressant, could be a valuable addition to vineyard management practices. By leveraging both the fertilizing and herbicidal properties of compost, growers could reduce their reliance on synthetic herbicides while promoting soil health and maintaining vine productivity. Further research should explore the long-term impacts of MSW compost on soil health; the persistence of its weed-inhibiting compounds; and its integration with other sustainable vineyard practices, such as cover cropping with legumes, to enhance both productivity and environmental sustainability.

5. Conclusions

The results of this study demonstrated that municipal solid waste (MSW) compost can play a dual role in vineyard soil management, acting both as a soil amendment and as a weed suppressant. The compost used contained 36.9% organic carbon and had a C/N ratio of 18.7, values that comply with Italian legislation and contribute to improving soil organic matter quality and microbial activity.

Field trials revealed that compost application, either as mulch or through burial, significantly reduced weed cover for the first 3 months after application, with weed cover percentages remaining below 10% during this period. This inhibitory effect is attributable not only to physical mulching but also to the release of allelopathic compounds, as confirmed by germination trials under controlled conditions. Specifically, compost extracts inhibited seed germination in *Cichorium intybus* and *Foeniculum vulgare*, with germination indices dropping to 0% at high compost concentrations.

Additionally, compost contributed to the circular economy by valorizing organic waste, reducing the need for chemical herbicides, and enhancing soil fertility with minimal environmental impact. Its integration into vineyard management offers an innovative strategy for lowering the environmental footprint and promoting soil health in a sustainable and resource-efficient way.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/environments12060190/s1, Table S1: Supplementary Table S1. "Report of compost sample test".

Author Contributions: P.R. contributed to the conceptualization, methodology, and data curation of the experiment under controlled conditions, as well as the writing, review, and editing. L.S.M., M.S., and R.A.A. contributed to the methodology and data collection of the experiment conducted under controlled conditions. F.M., C.D., and D.G.D. were involved in the conceptualization, methodology, and data curation of the field experiment. C.E.G. was responsible for the chemical and physical analyses of soil and compost and contributed to writing and review. G.P. provided the climate and meteorological section in material and method. G.Z. contributed to the conceptualization of the manuscript and its review. L.R. coordinated the overall work and contributed to writing and review. All authors have read and agreed to the published version of the manuscript.

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