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Can ligneous residues be recycled for weed control?

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The use of pesticides in agriculture causes problems for human health and the environment, so that alternative solutions for weed control are urgently requested. In this study we test the possibility to recycle composted wood and white fir bark as biopesticide at three different experimentation scales: (i) in Petri dish, hot water extracts of the ligneous residues were used for a germination test with rapeseed and winter wheat seeds; (ii) in greenhouse pots, two successive cycles of rapeseed sowings were carried out with an equivalent of 300 m³ ha⁻¹ and 600 m³ ha⁻¹ of ligneous residues so to assess the effect on crop seedling biomass; (iii) in a field experiment, 300 m³ ha⁻¹ of ligneous residues were spread as mulch or incorporated into the soil just before the sowing of rapeseed in 2022 without any herbicide application. We observed that fresh bark extract prevented winter wheat and rapeseed germination, while extracts of decomposed bark and composted wood did not affect crop seed germination. In the greenhouse experiment, the biomass of rapeseed seedlings was lower with ligneous residues compared to the control, particularly with bark. In the field, only the bark had a negative effect on the number of emerging weeds during the autumn 2022, while no difference in weed biomass was observed between treatments in the following spring 2023. Overall, the 3-cm thick mulch alone was not sufficient to control the weed biomass in the field but seems promising as part of an integrated weed management strategy.

KEYWORDS

biopesticide, composted wood, germination, mulch, seedling growth, weed biomass, white fir bark

1 Introduction

The use of pesticides can be a danger for human health and can cause numerous environmental problems (Vijgen et al., 2018; Kaur et al., 2024; Zhou et al., 2025). Chemical pesticides can cause short-term health problems (e.g., headaches, nausea, skin irritation) and/or chronic health problems (e.g., cancer, diabetes) (Kim et al., 2017), particularly with farmers who are directly exposed (Hou and Wu, 2010; Kumar et al., 2023). Pesticide residues in food are a concern for consumers' health (Bonner and Alavanja, 2017). In addition, the use of pesticides can induce antibiotic resistance with indirect threat to human health (Qiu et al., 2022), whereas the use of herbicides can favor the development of resistant weeds (Gaines et al., 2020). Furthermore, the use of pesticides threat the quality of water resources (Aydinalp and Porca, 2004) as well as soil biota, a key factor of soil fertility (Pelosi et al., 2021).

However, pesticide use may be considered necessary by the majority of farmers as long as alternative solutions are not applied (Popp et al., 2013).

Developing alternatives to the use of synthetic pesticides, or at least decreasing the pesticide pressure, is crucial. The use of natural allelopathic molecules (= biopesticides) could be a sustainable and environmentally friendly solution that poses fewer risks to human health and the environment (Ayilara et al., 2023). Studies are underway to identify chemical compounds derived from bio-residues that could be used as nano-pesticides for weed control (Batool et al., 2024). Some formulations based on plant extracts are currently available on the market, but their use in agriculture remains sporadic and technically demanding (Khamare et al., 2022). The half-life of allelopathic compounds of biopesticides is generally short and their manufacture is costly (Motmainna et al., 2021). Application of organic wastes containing biopesticides is a potential solution to eliminate the need for costly extraction and formulation processes.

Wood chip mulch can be an excellent alternative to synthetic herbicides and is often used in orchards (Borges et al., 2024) or urban settings (Granatstein and Mullinix, 2008; Mia et al., 2020; Webber et al., 2022). Water extractions from wood chips of various tree species have demonstrated allelopathic effects (Duryea et al., 1999; Rathinasabapathi et al., 2005; Saha et al., 2018). Applied as mulch, wood chips can combine the effect of the allelopathic compounds with the physical effect of preventing light from reaching the soil and, therefore, prevent the germination of weeds (Khamare et al., 2022). The minimum thickness required to observe the physical effect is not clearly defined and probably varies depending on the context. In some cases, a thickness of 3 cm may be sufficient to observe an effect (Putnam and DeFrank, 1983). In large-scale farming such as field crops, the use of wood chips as mulch to control weeds is not common. In such a context, wood chips should decrease weed pressure without impacting the crop germination and growth. In addition, the quantities required to cover large areas may be too high in relation to the availability of wood chips and/or their cost, which can become a limiting factor.

In this study we test the possibility of recycling ligneous residues as bioherbicides to control weeds in annual field crops. To reach this goal, we combine germination tests, a greenhouse trial as well as a field trial using two types of ligneous residues to assess if: i) they contain water-soluble and anti-germination compounds that can affect the germination of cash crop seeds; ii) they have allelopathic effects on the growth of rapeseed seedlings in two successive greenhouse trials; and iii) they can mitigate weed development in the field after application of 300 m³ ha⁻¹ of ligneous residues as mulch (i.e. 3 cm thick) or incorporated into the soil.

2 Materials and methods

2.1 Origin of wood residues

In this study two types of ligneous residues were tested, i.e. white fir bark and composted wood. At “La Rippe” sawmill, the

white fir (*Abies alba*) logs are stored before being sawn and the white fir bark flakes off during storage, hereafter simply referred as “barks”. The barks are then stored as a pile which includes fresh and partly decomposed barks (Supplementary Figure 1). The volumes of stored bark generated represent a constraint for the sawmill.

The second ligneous residue is represented by composted (mainly deciduous) wood that is produced at the “Gros-de-Vaud” composting facility. Here, after three months of composting, the produced compost is sieved to be sold. However, some of the ligneous residues have not reached a sufficient stage of decomposition to be transformed into compost and remain on the sieve to form “composted wood” that then represents for the composting facility a restrictive by-product.

2.2 Germination test on two cash crops

Hot water extracts of composted wood, fresh barks and decomposed barks were prepared. In 1 l beaker, 500 ml of each of the three ligneous residues were placed and a similar volume of demineralized water was added, i.e. about 500 ml. The beakers were then placed in an oven at 40°C for 48 hours to perform the hot water extractions. Next, the solution contained in each beaker was filtered using a kitchen strainer.

The germination test was carried out by scattering 20 winter wheat and 20 rapeseed seeds on two sheets of blotting paper placed on top of each other (to optimize humidity) in a Petri dish with a diameter of 13.5 cm. There were four treatments, i.e., fresh bark, partly decomposed bark, composted wood, as well as demineralized water as control with four replicates per treatment for each of the two selected crops so as a total of 32 Petri dishes. The seeds were then periodically moistened by spraying the correspondent ligneous extract or demineralized water for the control. The Petri dishes were incubated at constant humidity in an environmental test chamber (MLR-352, PHC corporation, Japan). They were maintained with 18 hours per day at 21°C with light (800 W) and 6 hours per day at 10°C in darkness to favor seeds germination. The number of germinated and viable seeds (i.e. with sprouting cotyledon and/or sprouting roots) was then counted after 7 days of incubation.

2.3 Greenhouse experiment on rapeseed growth

Surface (0–15 cm) soil was collected from a Calcaric Cambisol (sand = 338 g kg⁻¹, silt = 425 g kg⁻¹ and clay = 237 g kg⁻¹ SOC = 14.6 g kg⁻¹), air-dried and sieved at 2mm mesh size. Soil was not sterilized in autoclave. Pots (15 cm diameter and 11 cm high) were filled with soil only (= control) or a mixture of soil and fresh white fir bark (from La Rippe sawmill), or soil and decomposed white fir bark, or soil and composted wood (from Gros-de-Vaud compost company) at doses equivalent to 300 m³ ha⁻¹ and 600 m³ ha⁻¹. The doses were calculated based on the surface area of the pot, i.e. 7.5² × π × 3 ≈ 530 cm³ and 7.5² × π × 6 ≈ 1060 cm³ per pot as an input equivalent to 300 m³ ha⁻¹ and 600 m³ ha⁻¹. One batch of soil/ligneous residues was prepared for the 4 pots replicates of each treatment. In a box, 4 pot volumes of soil were homogenized with 4 volumes of ligneous residues and then, 4 pots were fulfilled with the

mixture. The temperature and air humidity in the greenhouse were maintained at 18–22°C and 80%, respectively. Then, 6 rapeseed seeds were sown in each pot on June 15, 2022. Watering was carried out to keep the soil wet. On June 28, 2022, the six emerging seedlings from each pot were collected, counted, and freshly weighed to calculate the average biomass of seedling in each pot. The same pots were then kept, and the experiment was repeated with second sowing of rapeseed that was carried out on July 6. Similarly, rapeseed seedlings were then collected, counted, and weighed on July 18, 2022.

2.4 Field trial

The field trial was carried out at Agroscope-Nyon on an agricultural field conducted, as conventional farming since decades with the same crop rotation (wheat/rapeseed/wheat/maize) and characterized by a Calcaric Cambisol (sand = 214 g kg⁻¹, silt = 339 g kg⁻¹ and clay = 447 g kg⁻¹, SOC = 277 g kg⁻¹). Winter wheat was harvested in July 2022 and no subsequent soil tillage was carried out. Then, 300 m³ ha⁻¹ of white fir bark residues (from La Rippe sawmill) and composted wood (from Gros-de-Vaud compost company) was spread on the 24th August 2022 on 8 m × 8 m plots to form each a 3 cm thick mulch layer. A rototiller was then used to incorporate the white fir bark or composted wood on four plots, while the mulch was left intact on four other plots distributed randomly in the field. A total of 20 plots were set up for the 4 replicates × 5 treatments according to field design of [Supplementary Figure 2](#), i.e. control without residues vs incorporated white fir bark vs white fir bark mulch vs incorporated composted wood vs composted wood mulch. Rapeseed (*Brassica napus*) was sown at a density of 320'000 seeds ha⁻¹ with a row spacing of 50 cm using an precision seed drill (Kuhn) combined with a strip-tiller, preventing the bark or the composted wood from coming into contact with the seeds and concentrating these ligneous residues in the row spacing in order to maximize the inhibition of weed growth. For the goal of this study, neither herbicides nor mechanical weeding were applied. Daily precipitation and mean of temperature from August 2022 to July 2023 are shown in [Supplementary Figure 3](#).

On October 8, 2022, and March 10, 2023, botanical surveys of adventitious flora were carried out on four 50 cm squares (4 × 0.25 m²) randomly placed on each of plots in order to determine the density of each adventitious species. On March 10, 2023, the adventitious plants were collected and dried (at 45 °C during 48h). Monocotyledon and dicotyledon were weighed separately. Rapeseed (*Brassica napus*) was harvested with a Haldrup combiner on a 16 m² surface area on June 26, 2023.

2.5 Statistical analyses

Statistical analyses were performed in the R environment, versions 4.0.2 (R Core Team 2020). For each experiment, treatment effect was tested using ANOVA-one way with permutational test using `anova.lway` written by Borcard and Legendre (<http://numericalecology.com/rcode/>). For significant effect ($p < 0.05$), treatments were compared using the Least Significant difference method with the `pairw.anova` function from

the `asbio` package. For the field trial, all the 50 cm square were considered ($n = 80$). Therefore, nested ANOVA (instead of one-way ANOVA) were carried out with permutational test with treatment as main factor and plot as nested factor. Nested ANOVA was tested using the `nest.anova.perm` function written by Borcard and Legendre (<http://numericalecology.com/rcode/>). Finally, correlations were performed between grain yield and weed density and weed biomass.

3 Results

3.1 Germination test

ANOVA one-way with permutational test shown a significant effect ($p < 0.001$) of treatments on germination of winter wheat and rapeseed seeds. Fresh bark extract prevented the germination of both winter wheat and rapeseed seeds ([Table 1](#)). In contrast, water extract from decomposed bark and composted wood did not hamper the percentage of germinability of the grains compared to the control. According to visual observations, fresh bark water extract likely decreased radicle length of rapeseed seedlings ([Supplementary Figure 4](#)).

3.2 Greenhouse experiment

Overall, the biomass of rapeseed seedling tended to decrease (i.e. although not significantly) from the 1st sowing to the 2nd sowing only for the control, whereas the seedling biomass tended to increase in all the other treatments ([Table 2](#)).

ANOVA one-way with permutational test showed a significant effect ($p < 0.01$) of treatments on rapeseed biomass. Compared to the control, after the 1st sowing the mean biomass of each rapeseed seedling was significantly lower in all the treatments. Overall, both the fresh and the decomposed bark were associated to lower rapeseed biomass compared to the composted wood, indicating a stronger negative effect of bark on seedling with increasing the relative dose ([Table 2](#)). Not-significant differences were observed between fresh and decomposed bark residues.

ANOVA one-way with permutational test did not show a significant effect ($p < 0.05$) of treatments on rapeseed biomass at the end of the 2nd sowing. The differences between the control and the treatments decreased ([Table 2](#)). The results of the 2nd sowing indicate that the detrimental effects of ligneous residues on rapeseed biomass was much lower compared to the 1st sowing.

We also observed that the height of the seedling decreased when roots grew near ligneous chips ([Supplementary Figure 5](#)).

Germination rate was lower for the “decomposed bark (300 m³ ha⁻¹)” treatment compared to other treatments for the 1st and 2nd sowing.

3.3 Field trial

Nested ANOVA with permutational test showed significant effects ($p < 0.05$) for total weed density and winter wheat regrowth

TABLE 1 Proportion of viable germinated seedlings (with sprouting roots and sprouting cotyledon) receiving water extracts from the three ligneous residues, i.e., fresh white fir bark, decomposed white fir bark, and composted wood residues, as well as pure water as control.

Treatment	Wheat (%)	Rapeseed (%)
Control	93 ^a	96 ^a
Fresh white fir bark	0 ^b	0 ^b
Decomposed white fir bark	94 ^a	95 ^a
Composted wood	88 ^a	98 ^a

Each value is the mean of 4 replicates. Different letters indicate significant differences at $p < 0.05$ for the same crop species between the four treatments for which the effects previously tested using ANOVA one-way were significant ($p < 0.05$).

in autumn 2022, after two months since the start of the field trial. Incorporated bark and mulch of bark decreased significantly the density of emerged total weed seedlings compared to the control (Table 3). Such a decrease was mainly due to a reduction of wheat plant regrowth from the previous year. Both the incorporated bark and the mulch treatments decreased not-significantly the number of total monocot and dicot weed seedlings compared to the other treatments.

In April 2023, similar trends as October 2022 were observed but the treatment effect was not significant ($p < 0.05$) using nested ANOVA with permutational test. Density of winter wheat regrowth, biomass of monocot and total weed were lower for bark and higher for composted wood, although not significantly.

In October 2022 and April 2023, 16 and 15 species of weeds were observed, of which 4 and 5, respectively, were observed on only one plot (Supplementary Tables 1–4). Only wheat regrowth, *Geranium dissectum* and *Myosotis arvensis* were observed on all plots, highlighting the heterogeneity of weed biodiversity in the field trial.

Rapeseed yields largely differed across plots and ranged between 1.4 t ha^{-1} and 3.9 t ha^{-1} (dry weight) due to field heterogeneity. However, no significant differences were found between treatments where we observed a mean grain yield corresponding of 2.1 t ha^{-1} for the control, 2.2 t ha^{-1} for the mulch of composted wood, 2.0 t ha^{-1} for the incorporated composted wood, 2.6 t ha^{-1} for the mulch of bark and 2.1 t ha^{-1} for the incorporated bark. In fact, the treatments were related to wheat regrowth ($\text{adj } R^2 = 0.12$, $p < 0.05$) which was not linearly related to grain yield. Nevertheless, grain yield was

negatively correlated with total, monocot and dicot weed densities (Supplementary Table 5). When considering data of October 2022 and April 2023, *Geranium dissectum* was the weed species most negatively related to grain yield.

4 Discussion

The Petri dish test showed an anti-germinative effect of the hot water extract from the fresh white fir bark on winter wheat and rapeseed seeds (Table 1). Several studies have demonstrated the anti-germinative effect of water extracts from mulch derived from different tree species (Taylor and Shaw, 1983; Saha et al., 2018; Kazemi and Jozay, 2020), whose allelopathic compounds can vary in efficiency depending on the clone or organ of the tree species (Bielinis et al., 2019). Anti-germinative effect may be linked to numerous molecules such as certain phenolic acids, fatty acids, hormones, or terpenes, which are capable of inhibiting water absorption or interfering with biochemical mechanisms related to dormancy (Romano et al., 2025). A ligneous residue: water mass ratio of 10% can be sufficient to demonstrate allelopathic effects (Rathinasabapathi et al., 2005). With a higher wood residue/water volumetric ratio ($\approx 100\%$) in our experiment, we assume that the concentration of compounds extracted with hot water was high. However, the decomposed bark extract had no effect on germination (Table 1). This suggests that most of the water-extractable anti-germinative compounds initially contained in the fresh bark were lost as leachates or degraded to other inactive compounds during bark decomposition at the sawmill facility. Nevertheless, the growth of rapeseed rootlets after germination still appears to have been negatively affected by the decomposed bark extract, while the roots of winter wheat were not affected (Supplementary Figure 4). This highlights the specific sensitivity of different species to similar active ingredients (Reigosa and Souto, 1999). Also, the absence of negative effects on seed sprouting from the water extract of composted wood indicates that almost all the soluble anti-germinative compounds were lost and/or degraded during the composting process (Romano et al., 2025).

The results of the greenhouse experiment clearly showed that all the treatments with ligneous residues had a negative effect on

TABLE 2 Mean biomass of one rapeseed seedling and mean germination rate after the 1st and the 2nd sowing.

Treatments	1 st sowing	2 nd sowing	1 st sowing	2 nd sowing
	Seedling biomass (mg)		Germination (%)	
Control	919 ^a	749	67	79
Fresh bark ($300 \text{ m}^3 \text{ ha}^{-1}$)	188 ^{bcd}	434	83	83
Fresh bark ($600 \text{ m}^3 \text{ ha}^{-1}$)	132 ^{cd}	245	75	79
Decomposed bark ($300 \text{ m}^3 \text{ ha}^{-1}$)	250 ^{bcd}	438	54	42
Decomposed bark ($600 \text{ m}^3 \text{ ha}^{-1}$)	91 ^d	176	71	75
Composted wood ($300 \text{ m}^3 \text{ ha}^{-1}$)	357 ^{bc}	472	79	75
Composted wood ($600 \text{ m}^3 \text{ ha}^{-1}$)	435 ^b	694	71	75

Each value is the mean of 4 pot replicates where 6 grains per pot were initially sown. Different letters indicate significant differences at $p < 0.05$ for the same sowing between the six treatments for which the effects previously tested using ANOVA one-way were significant ($p < 0.05$).

TABLE 3 Number of emerged weed seedlings per square meter measured in October 2022 in the rapeseed field trial.

Treatment	Total	Dicot	Monocot	Wheat regrowth
	-----seedlings number m ⁻² -----			
Control	64.5 ^a	38.25	26.25	25 ^a
Incorporated composted wood	64.75 ^{ab}	39.75	25	24.25 ^{ab}
Mulch of composted wood	52 ^{abc}	28.5	23.5	23.25 ^{ab}
Incorporated bark	38.75 ^{bc}	28.25	10.5	10.25 ^{bc}
Mulch of bark	38.25 ^c	26.75	11.5	6.25 ^c

Each value is the mean of 4 replicates. The total number of weeds has been separated into two categories: re-growth of previous winter wheat and other weed species. Different letters indicate significant differences at $p < 0.05$ for the same variable between the five treatments for which the effects previously tested using nested ANOVA one-way were significant ($p < 0.05$).

biomass production of rapeseed seedlings only during the first sowing cycle (Table 2). However, the negative effect on rapeseed biomass production of composted wood was lower than that of bark, which is consistent with the results of the germination test. Nevertheless, we assume that anti-germinative compounds in fresh bark extracted with hot water were partly different from those that reduced seedling biomass production since germination (germination test, Table 1) and seedling growth (greenhouse trial, Table 2) were negatively affected by different treatments. We should consider that hot water can extract compounds very efficiently, to such an extent that Xu et al. (2008) showed the same capacity as methanol to extract of various antioxidants from citrus peel. Therefore, the high concentration of compounds extracted from ligneous residues by hot water does not necessarily reflect natural field leaching condition and limits the ecological relevance. As allelopathic compounds can be released in different ways [e.g., by solubilization or following the decomposition of organic matter (Duryea et al., 1999)], their nature can be widely different. Allelopathic compounds can be classified into 14 categories according to their chemical similarities, and their water solubility can vary (e.g., water-soluble organic acids vs long chains of fatty acids) (Khamare et al., 2022). Some allelopathic compounds may be less soluble and more efficient (Rathinasabapathi et al., 2005). In our study, we did not investigate the compounds from ligneous residues and therefore we do not know the molecular form of active compounds. In our greenhouse experiment, a negative effect on seedling growth have only been observed on seedlings within a few millimeters of the ligneous residue (Supplementary Figure 5; personal observation), suggesting that active compounds have diffused very little into the soil. This observation explains why the

application of 600 m³ ha⁻¹, which increased the contact area between seedlings and wood chips by a factor of 2 compared to an application of 300 m³ ha⁻¹, was more efficient (Table 2). The lack of significant effect for the second rapeseed sowing suggests that the half-life of active compounds of bark was rather limited. In general, solubilized allelopathic compounds remain highly active for about ten days and can persist for up to 50 days (Xuan et al., 2005), which is consistent with our results.

In the field trial, the negative effect of bark treatment on emerging weed seedlings in autumn allowed to partly control weeds two months after the rapeseed sowing (Table 3). However, bark treatment did not efficiently control the weed growth in spring (Table 4), confirming the short-time effect observed in the greenhouse trial. The application of mulch of bark alone was not sufficient to control weed. However, it could be used to control the weed development at early stages (i.e. when a mechanical intervention is critical since it can negatively affect crop seedlings) and this strategy may be combined with one or two inter-row hoeing in spring and/or other options, for example the use of herbicides (e.g. band spraying) and/or a higher rapeseed density to enhance competition with weeds (Vykydalová et al., 2024). Treatments did not modify weed flora except winter wheat regrowth which was decreased by bark. However, the other graminoid specie observed [*Lolium multiflorum*, (Supplementary Tables 1, 3)] was not influenced by treatments, showing that bark has a more negative effect on certain graminoid species. The spectrum of species preferentially targeted by compounds contained in bark [such as phenolic acids, flavonoids, lignans (Benković et al., 2014)] should be clarified in future studies. In addition, bark could possibly be mixed with other chemical herbicides, as already suggested by other authors

TABLE 4 Mean weed biomass measured in April 2023 in the rapeseed field trial.

Treatment	Total	Dicot	Monocot	Total	Dicot	Monocot	Wheat regrowth
	-----g m ⁻² -----			-----seedlings number m ⁻² -----			
Control	109.3	29.7	79.6	39.75	27.75	12	11
Incorporated composted wood	144.0	30.1	113.9	45.75	29.5	16.25	7
Mulch of composted wood	133.9	33.2	100.7	35.75	21	14.75	8
Incorporated bark	83.4	44.6	38.8	37.5	24.25	13.25	7
Mulch of bark	79.2	60.6	18.6	35.75	26.5	9.25	4.25

Each value is the mean of 4 replicates. No treatment effect tested using nested ANOVA one-way was significant ($p < 0.05$).

(Farooq et al., 2011), in order to reduce the load of plant protection products per hectare. In addition, this specific effect of bark could also reinforce the mulch effect since graminoid weeds are less affected by the physical constraints of mulch compared to other weed species (Abouzienna et al., 2008).

Under our experimental field conditions, the expected anti-germinative effect of the mulch (due to the soil cover preventing light from reaching the soil) was not observed considering the weed density emergence and insufficient to totally control weed development but could be used combined to other methods as previously discussed. This highlights that a mulch thickness of 3 cm was not sufficient to achieve the expected physical effect (i.e. prevent weed seedlings sprouting) under our experimental conditions. In the literature, contrasting results were reported from greenhouse experiments. For example, a 5 cm thick gravel mulch (i.e., used as a control to quantify the allelopathic effect of wood chip mulch) had no effect on weed growth compared to no mulch (Rathinasabapathi et al., 2005), while a 3 cm layer of mulch was reported to be sufficient to significantly reduce weed growth (Putnam and DeFrank, 1983), without the chemical and physical effects being quantified separately. Nevertheless, a 3 cm thick layer of mulch can specifically affect the emergence of smaller seeds, which have a lower hypocotyl elongation potential than larger seeds (Ligneau and Watt, 1995). In orchards, recycling green waste or pruning residues can be used to produce a thicker layer of wood chips mulch (up to 25 cm) (Greenly and Rakow, 1995), which is almost guaranteed to be effective. On the other hand, spreading mulch 5–10 cm thick on large farms seems complicated given the quantities of woody material this would represent per hectare (i.e., 500–1000 m³) and the availability of the resource. The amount of residual ligneous would be huge and not so easy to find. In fact, 300 m³ ha⁻¹ is already an enormous amount compared to ramial wood chips inputs, which can typically vary from around 50 m³ to 200 m³ per hectare (Barthès et al., 2010; Gilli, 2012; Fontana et al., 2023). To be realistic, ligneous residues should be available not so far from the field and ideally free of charge. Recycling by-products from forestry industry as bio-pesticide could be a win-win scenario. Mutually beneficial exchanges should be established between the forestry industry and the agricultural sector.

Although the effect of ligneous residues capable of decreasing crop performance was highlighted for more than 50 years (McCalla and Norstard, 1974), it can be avoided by distributing the ligneous residues so to avoid any contact with the seed rows (Elliott et al., 1978). Accordingly, neither the emergence of rapeseed nor the final grain yield was negatively affected by ligneous residues compared to control, probably because the strip-tiller avoided contact between rapeseed roots and ligneous residues. However, although that the weed biomass ($\approx 80\text{--}145\text{ g m}^{-2}$, Table 4) can be considered as a low to medium weed pressure (Adeux et al., 2019; Masson et al., 2024), it possibly competed with rapeseed plants causing a lower yield compared to contiguous field with the same rotation and treated with herbicide (4.4 t ha⁻¹, data not shown). The correlation between grain yield and total weed density was negative but weak, suggesting that other limiting factors were inherent to the field. Anyway, *Geranium* (i.e. the weed species the most negatively related to the yield Supplementary Table 5) is very common un rapeseed crops and known to compete with rapeseed grain yield (Hanzlik et al., 2012).

5 Conclusions

This study investigated the possibility of recycling ligneous residues as biopesticides on crop seed germination, on crop seedling development and on weed density and weed biomass at early crop stages and before crop flowering, under field conditions. White fir bark showed a strong anti-germinative effect on rapeseed and winter wheat seeds. Bark and, to a lesser extent, composted wood still had an allelopathic effect on the growth of rapeseed seedlings. In the field, the effect of ligneous residues on weed growth was limited. Although bark significantly reduced the number of emerging weed seedlings two months after sowing and greatly limited the density of winter wheat regrowth, no difference in total weed biomass was observed eight months after sowing, either when the ligneous residues were incorporated into the soil or applied as mulch. A 3-cm thick layer of mulch was not sufficient to control the weeds without any other weed management techniques but seems promising as part of an integrated weed management strategy. A higher amount of mulch would be limiting for field crops given the volumes of woody material that this would be required. However, the negative effect of bark on winter wheat regrowth could potentially be used in combination with a reduced herbicide application or other agronomic weed management, even if special care should be taken so to avoid that away ligneous residues are in contact with the crop seedlings, for example using a strip-tiller for crop sowing. Although we reported a limited effect of solely ligneous residues as biopesticides for weed control under field conditions, the input of organic matter to agricultural soils is an added value that should be considered for improving soil quality.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

MF: Writing – original draft, Data curation, Software, Methodology, Formal analysis, Visualization, Investigation, Conceptualization, Writing – review & editing. LB: Investigation, Conceptualization, Methodology, Writing – review & editing, Funding acquisition, Project administration. SE: Methodology, Writing – review & editing, Investigation. SM: Methodology, Conceptualization, Writing – review & editing, Investigation. AG: Conceptualization, Writing – review & editing. PB: Writing – review & editing. OS: Writing – review & editing, Conceptualization, Funding acquisition, Project administration.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fagro.2026.1789426/full#supplementary-material>

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