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Studies on the Allelopathic Potential of *Acacia dealbata* Link.: Allelopathic Potential Produced During Laboratory Decomposition of Plant Residues Incorporated Into Soil

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ABSTRACT

Allelopathic effects produced during the decomposition of different plant materials coming from *Acacia dealbata* incorporated into soil were studied by means of two bioassays on *Lactuca sativa* var. Great Lakes, *Trifolium repens* and *Lolium perenne*. Results confirm their extraordinary potential allelopathic capacity. In particular, decomposing leaves showed high phytotoxic capacity followed by flowers. The third assayed material, roots, happened to be the least inhibiting one, even though at different moments it inhibited significantly the germination and the radicle growth of the assayed species.

Toxicity keeps high during long periods, even up to the end of experiences (16 weeks), with some differences related to the assayed receiving species.

Keywords: Acacia dealbata, Lactuca sativa, Trifolium repens, Lolium perenne, phytotoxicity, allelopathy, plant residues decomposition

Introduction

Allelopathy is a very widespread phenomenon in the nature (Rice, 1974, 1979, 1984; Reigosa *et al*., 1999) but it should not be considered to have an universal character because we should expect that plants, that have co-evolutioned, will be adapted to their corresponding metabolites emission (Harper, 1977; Muller 1969; Rabotnov, 1974; Reigosa *et al*., 1999; Teasdale *et al*., 2012).

Allelopathic natural effects produced by tree species on understorey plants have been often found (AlMousawi & AlNaib, 1975, 1976; AlNaib & AlMousawi, 1976; AlNaib & Rice, 1971; Davis, 1928; Del Moral & Cates, 1971; Del Moral & Muller, 1969; Gliessman, 1978; Jose & Gillespie, 2006; Lee & Monsi, 1963; Lodhi, 1976, 1978; McPherson & Thompson, 1972; Mensah, 1972; Molina *et al*., 1991; Reigosa & González, 2006; Souza-Alonso *et al*., 2014; Tubbs, 1973).

Several species of *Acacia* genus, mainly *A. dealbata* (Casal *et al*., 1985; Carballeira & Reigosa, 1999; Lorenzo *et al*., 2008, 2010, 2011; Reigosa & Carballeira, 2016; Reigosa *et al*., 1984) and *A. melanoxylon* (González *et al*., 1995; Hussain *et al*., 2011a, 2011b) have phytotoxic properties and have shown some potential allelopathic phenomena, perhaps contributing to their high invasive capacity (Al Harum *et al*., 2015a; Grove *et al*., 2012; Lorenzo *et al*., 2010, 2012, 2013; Zhang *et al*., 2009).

Allelochemicals can be released to the environment by different ways: exudation of compounds through the root, leaching of aerial parts, decomposition of plant residues, release of volatile compounds and release of organic compound through seeds and fruits (Al Harum *et al*., 2015a, 2015b; Ballester, 1971; Guo *et al*., 2016; Reigosa *et al*., 1999; Rice, 1974, 1984; Stowe & Kil, 1981; Teasdale *et al*., 2012; Whittaker & Feeny, 1971; Xiao *et al*., 2007; Zhang & Yu, 2001). The plant litter is an important component of the soil and during the decomposition process phytotoxic substances can be released or synthetized. Litter decomposition has been considered as the greatest source, in general, of effective allelopathic substances (Ballester, 1972; Bonanomi *et al*., 2016; Chaves *et al*., 2015; Del Moral & Cates, 1971; Guo *et al*., 2016).

Toxicity of these substances existing in the soil depends on their nature and concentration, and on the conditions (aerobiosis or anaerobiosis, humidity, temperature) where the decomposition process is carried out, so resulting, in general, a greatest toxicity under anaerobiosis conditions; soil humidity and

temperature also affect (Al Harum *et al*., 2015b; Jankju, M.; Patrick, 1971; Patrick & Koch, 1958; Rashid *et al*., 2005; Ruan *et al*., 2016; Uddin *et al*., 2014).

On a previous study (Reigosa *et al*., 1984) phenols with phytotoxic potential were found on the soils collected under *A. dealbata*; allelopathic potential capacity of soil extracts was also assessed (Reigosa & Carballeira, 2016). Likewise it shall be pointed out, from the mentioned study, the fast variations on such allelopathic capacity. By means of the present study it is intended to know if the different plant residues coming from the *Acacia dealbata* can lead to allelopathic phenomena when they are incorporated in the soil.

Material and methods

The area where the samples were taken has been widely described in a previous work (Carballeira & Reigosa, 1999).

The assay of plant residues decomposition in the laboratory was divided into two stages. For the first, named "Decomposition of Plant Residues I", roots and leaves of *Acacia dealbata* incorporated with an inorganic commercial balanced soil in two concentrations are used: 10% in weight or high ratio and 3% or low ratio; additionally mixed mixtures made up of roots and leaves having the same proportion both of them, and reaching the whole 10% and 3% in weight. Original commercial soil having no added plant material was used as control.

In order to prepare each mixture both the soil and the plant material was dried in sufficient amounts to cover all the assay. The plant material was ground into a ball grinder and, once it was turned into powder, it was mixed with soil taking into account the mentioned proportions. Initially the whole of treatments were macerated, all time at field capacity, into a chamber at 28º C and the material was withdrawn after 1 day, 1 week, 2 weeks, 4 weeks, 8 weeks and 16 weeks, these being used in the bioassays referred to as I.1, I.2, I.3, I.4, I.5 and I.6 from now on (Arias, 1982; Menges, 1988).

Three replications were done per treatment and they were used for the bioassay (including control) by sewing 100 seeds per Petri dish. *Lactuca sativa* var. Great Lakes was used for all the treatments and *Trifolium repens* and *Lolium perenne* only for treatments having a low ratio of plant material (roots, leaves or a mixing of both of them).

The assay we will name "Decomposition of Plant Residues II" followed a similar methodology, but with flowers and leaves and by bioassaying those portions having a high proportion of plant material with *L. perenne* and *T. repens*. This bioassay was brought under maceration as previously explained and was withdrawn to be bioassayed after 1 day, 1, 2, 4, 8 and 16 weeks so the assays were named II.1, II.2, II.3, II.4, II.5 and II.6 respectively.

Statistical treatments. Results were tested for normality and homocedasticity. One-way ANOVAs were performed to test the existence of statistically significant differences, and then LSD tests were performed.

Results

Decomposition of Plant residues I

The results corresponding to the bioassays carried out on *Lactuca sativa* have been summarized in the fig. 1 (Germination bioassays) and in the fig. 2 (Radicle growth bioassay). Concerning the germination, there are clear high inhibiting capacities starting since the assay I.3 (corresponding to two weeks after the beginning of the experiment). On some treatments, specially, on the high concentration leaves, the inhibiting capacity is kept up to the end of the experiment. It stands out the inhibiting capacity of treatments containing leaves in front of those containing only roots. The inhibiting effect shown on radicle growth is still more pronounced than on germination. The assays showing a greater inhibiting capacity are those from I.4 to I.6 (4 to 16 maceration weeks), the same as in the germination results; it stands out in both of them the inhibiting capacities of treatments having a high concentration over those having low concentration and those including leaves.

The two other seeds (*Lolium perenne* and *Trifolium repens*) were only assayed with treatments corresponding to low concentrations, but except for little discrepancies, the results confirm the behavior of *Lactuca sativa*. Such results are summarized in the fig. 3 and 5 (Germination) and 4 and 6 (Radicle length). The greatest toxicity of leaves in front of roots is confirmed, as well as the maxima of inhibition between 4 and 16 maceration weeks. It can also be remarked that *T. repens* appears to be more inhibited than *L. perenne*.

It was also carried out a reliable test with treatments having a high concentration during the assay I.6 on both of these species and it was found as for the case of *L. sativa* a germination level of 0%.

Decomposition of Plant Residues II

The germination results of *L. sativa* are shown in the figure 7. Again the parts having a high proportion of leaves (either alone or mixed with flowers) turn out to be the most inhibiting ones, but mixtures of flowers having high or low concentration turn out to be quite inhibiting ones, especially on the assays II.3

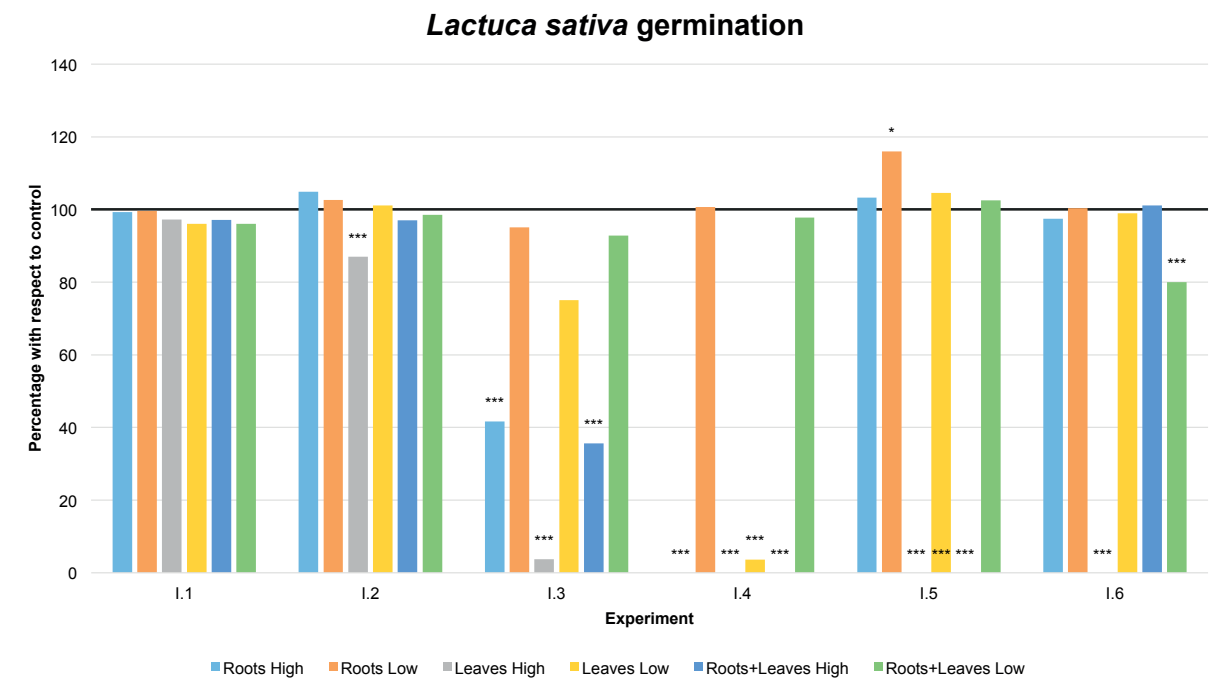

Figure 1.

Decomposition of Plant Residues I. Germination bioassays. Species Used: *Lactuca sativa*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

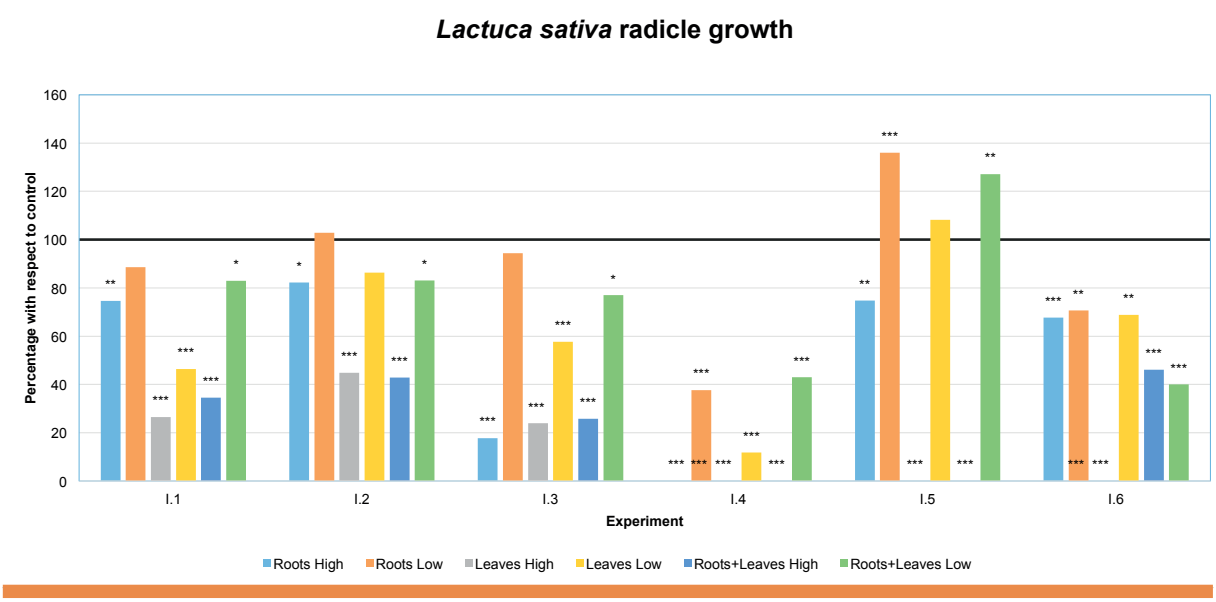

Figure 2.

Decomposition of Plant Residues I. Radicle growth bioassays. Species Used: *Lactuca sativa*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

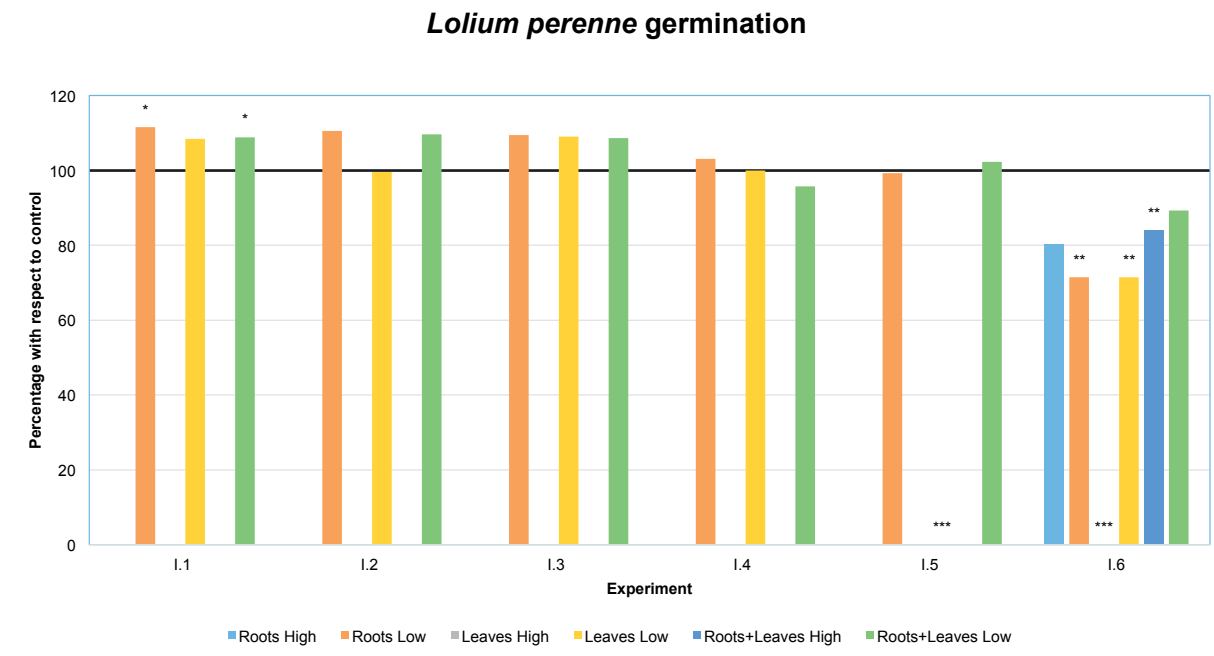

Figure 3.

Decomposition of Plant Residues I. Germination bioassays. Species used: *Lolium perenne*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

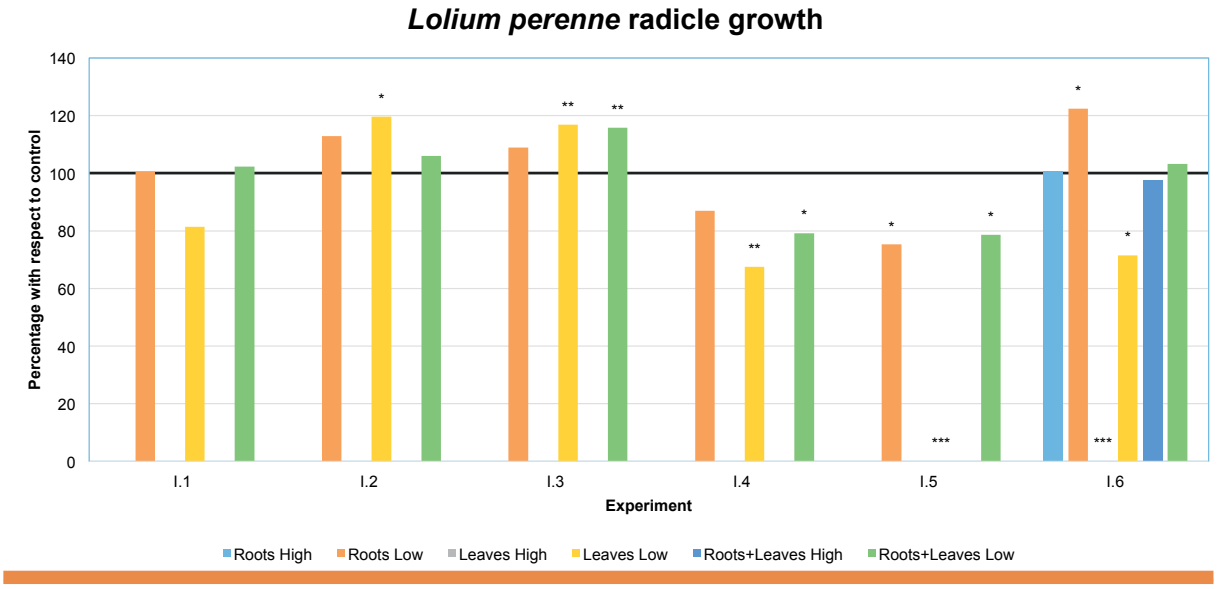

Figure 4.

Decomposition of Plant Residues I. Radicle growth bioassays. Species used: *Lolium perenne*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

and II.4 (corresponding to 2 and 4 maceration weeks), as well as the part having low concentration of leaves. At the end of the series of experiences (II.5 and II.6) strong inhibitions are kept in treatments with high proportion of leaves.

The effects on the radicles growth of *L. sativa* are shown in the fig. 8. The inhibition pattern is appreciably similar to the one shown on germination, even though it is more pronounced.

The effects on the germination of *L. perenne* and *T. pratense* are summarized in the figures 9 and 11. The effects are quite less drastic than on *L. sativa*, so statistically significant inhibition is only found on some assays of leaves in high concentration. The results corresponding to the radicles growth are shown in the figures 10 and 12. The results demonstrate slightly higher inhibiting capacity, especially on *T. repens*. The strongest inhibiting effects appear on the assays II.4 and II.5, especially on leaves in high concentration. The flowers also show some statistically significant inhibiting effect.

Discussion

The decomposition of plant residues in the laboratory demonstrates the great allelopathic potential of plant residues coming from *A. dealbata*, especially the leaves and also to some extent the flowers and, at a smaller lever the roots, during all the period that these experiences were carried out. Therefore, phytotoxicity was very high even though we will compare them to other producing species (Chiapusio *et al*., 1997; Juste *et al*., 1985).

The assayed proportions turn out to be very close to the field values, such as it is revealed by another work (González *et al*., 1995) where it has been studied by the litter bags technique, the real allelopathic capacity produced *in situ* as well as the excessive foliage contribution to the soil all the year round. Therefore, we can come to the conclusion that this saprocynodynamic process of toxins release can play a very important allelopathic role, so its effect is reinforced by other eccrisadynamic processes as the leaching of aerial parts (Reigosa *et al*., 1999).

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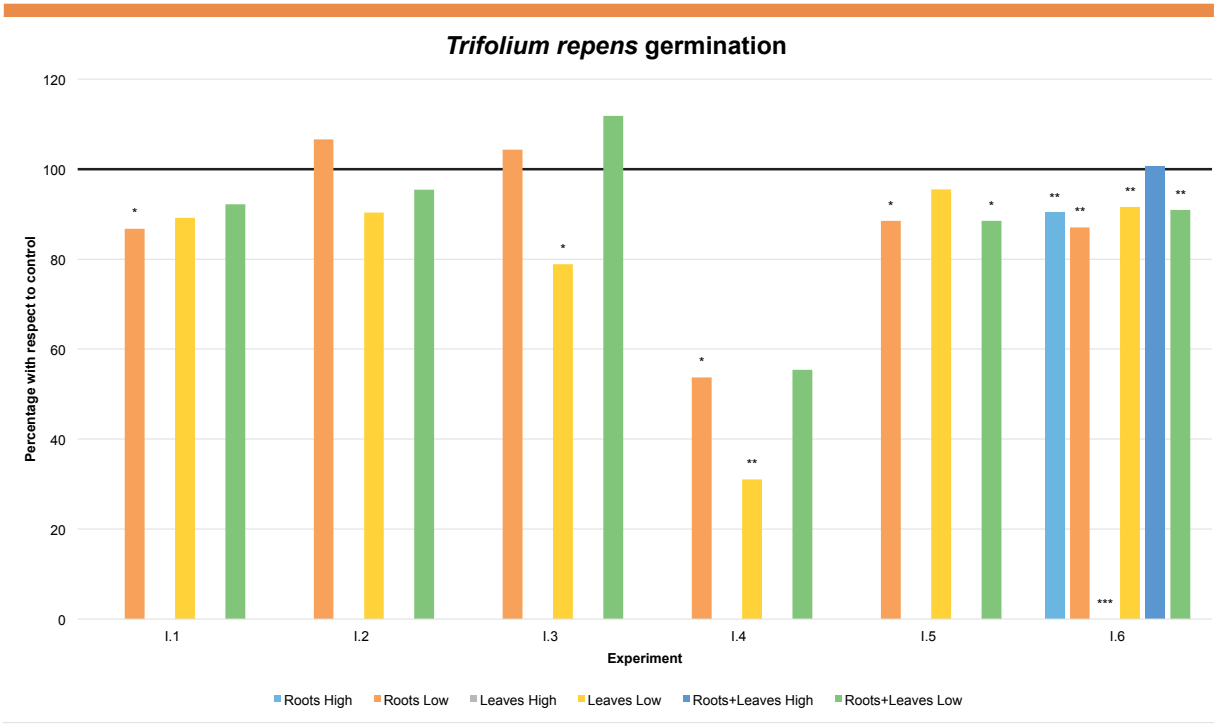

Figure 5.

Decomposition of Plant Residues I. Germination bioassays. Species used: *Trifolium repens*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

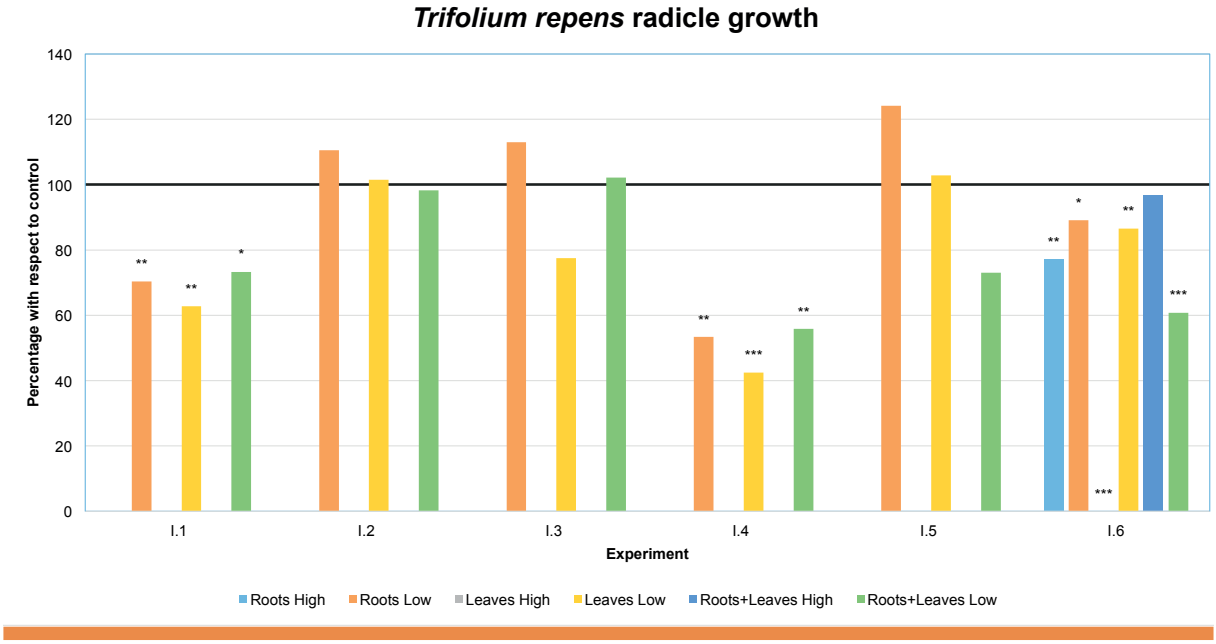

Figure 6.

Decomposition of Plant Residues I. Radicle growth bioassays. Species used: *Trifolium repens*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

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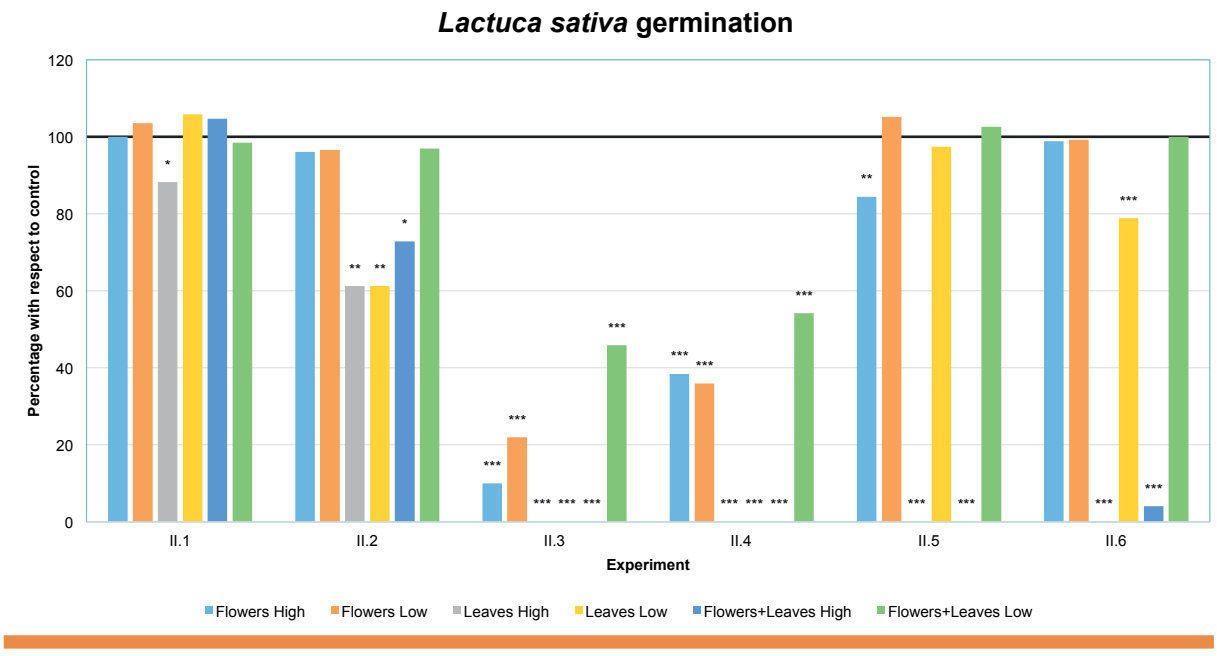

Figure 7.

Decomposition of Plant Residues II. Germination bioassays. Species used: *Lactuca sativa*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

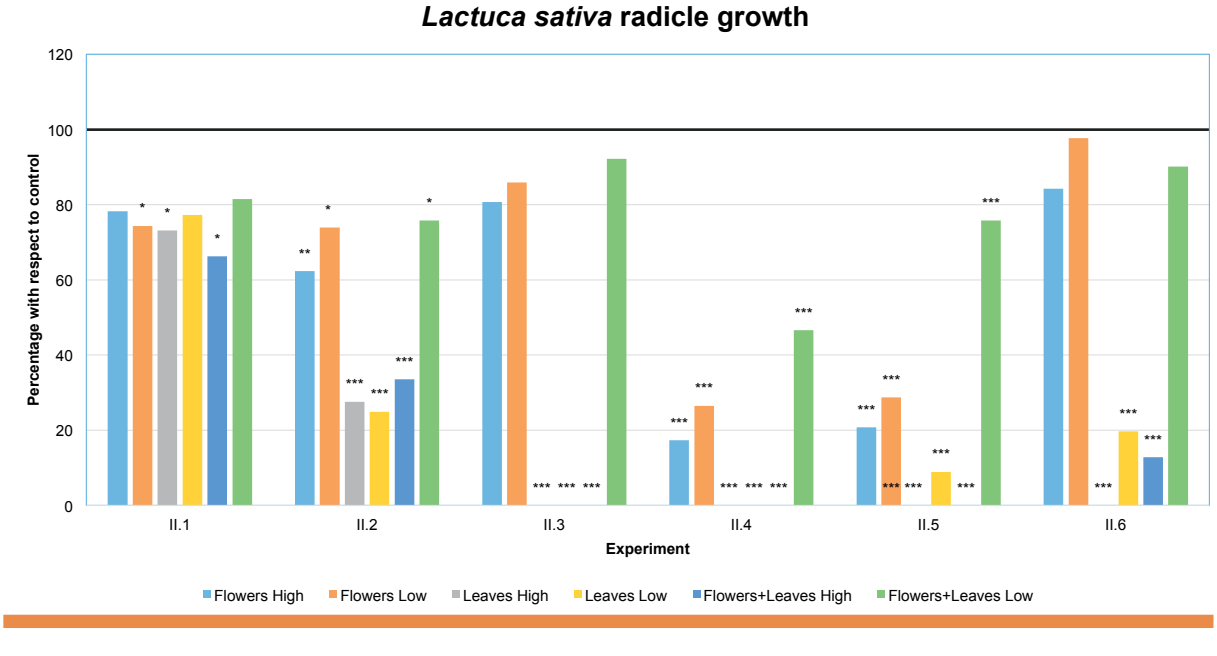

Figure 8.

Decomposition of Plant Residues II. Radicle growth bioassays. Species used: *Lactuca sativa*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

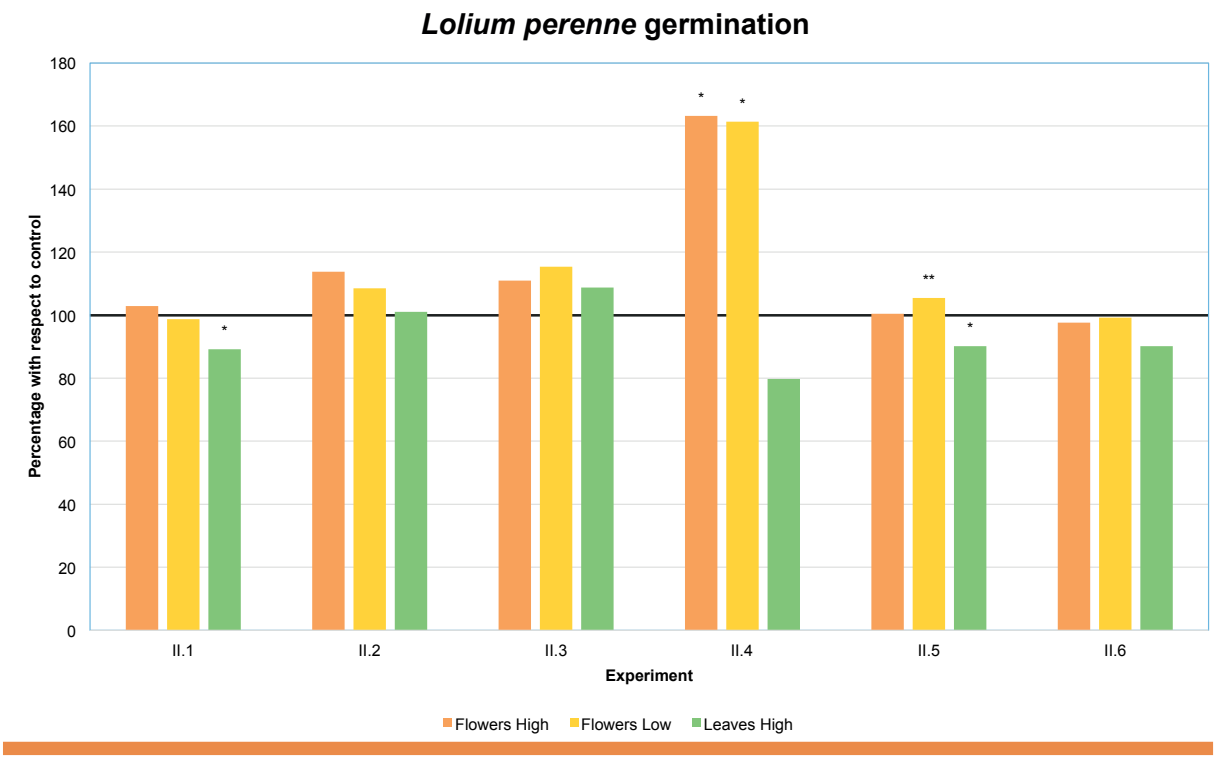

Figure 9.

Decomposition of Plant Residues II. Germination bioassays. Species used: *Lolium perenne*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

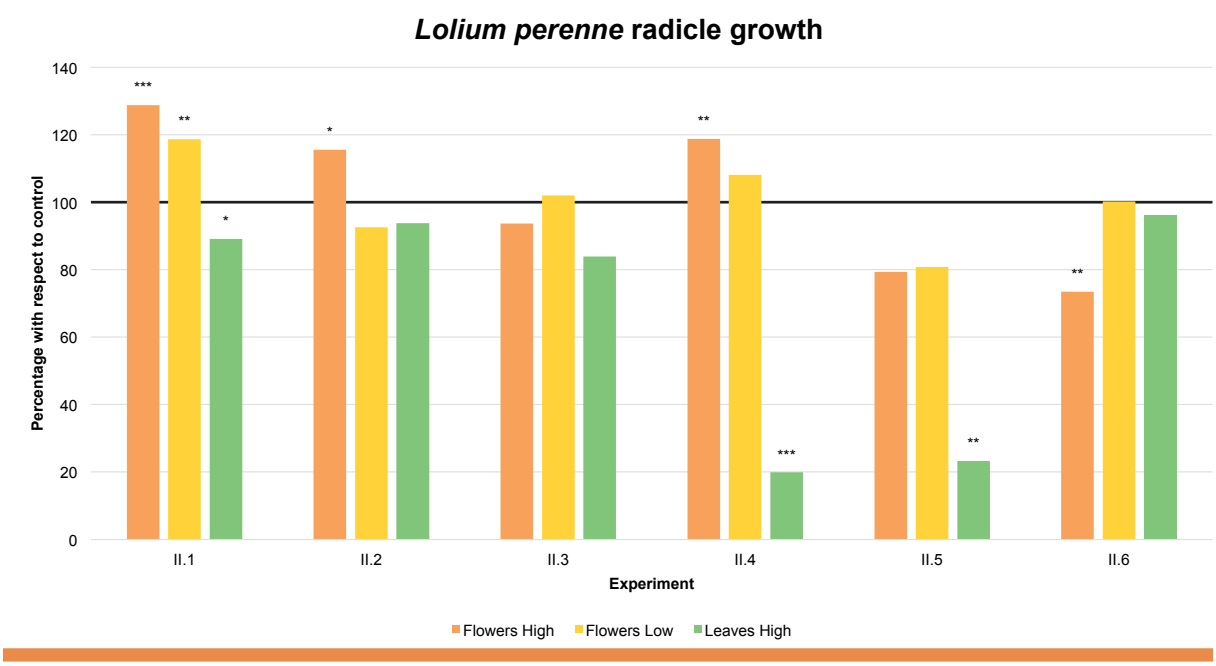

Figure 10.

Decomposition of Plant Residues II. Radicle growth bioassay. Species used: *Lolium perenne.* All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

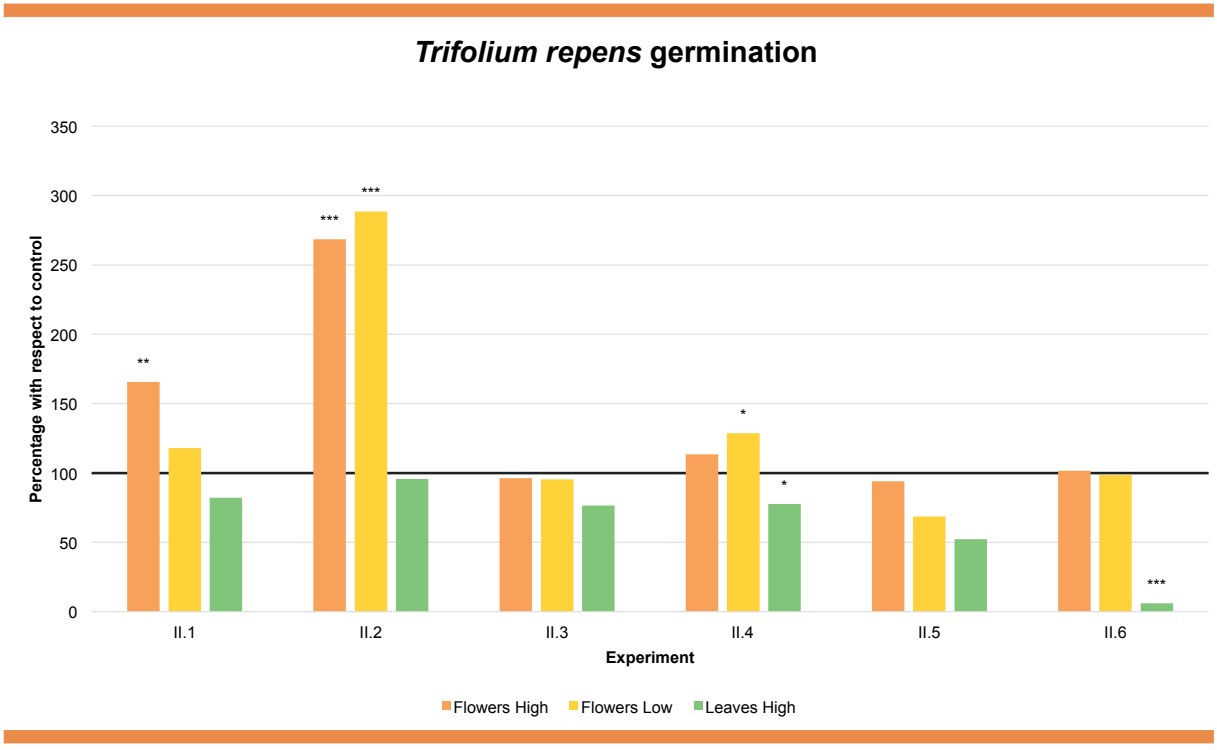

Figure 11.

Decomposition of Plant Residues II. Germination bioassays. Species used: *Trifolium repens*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001

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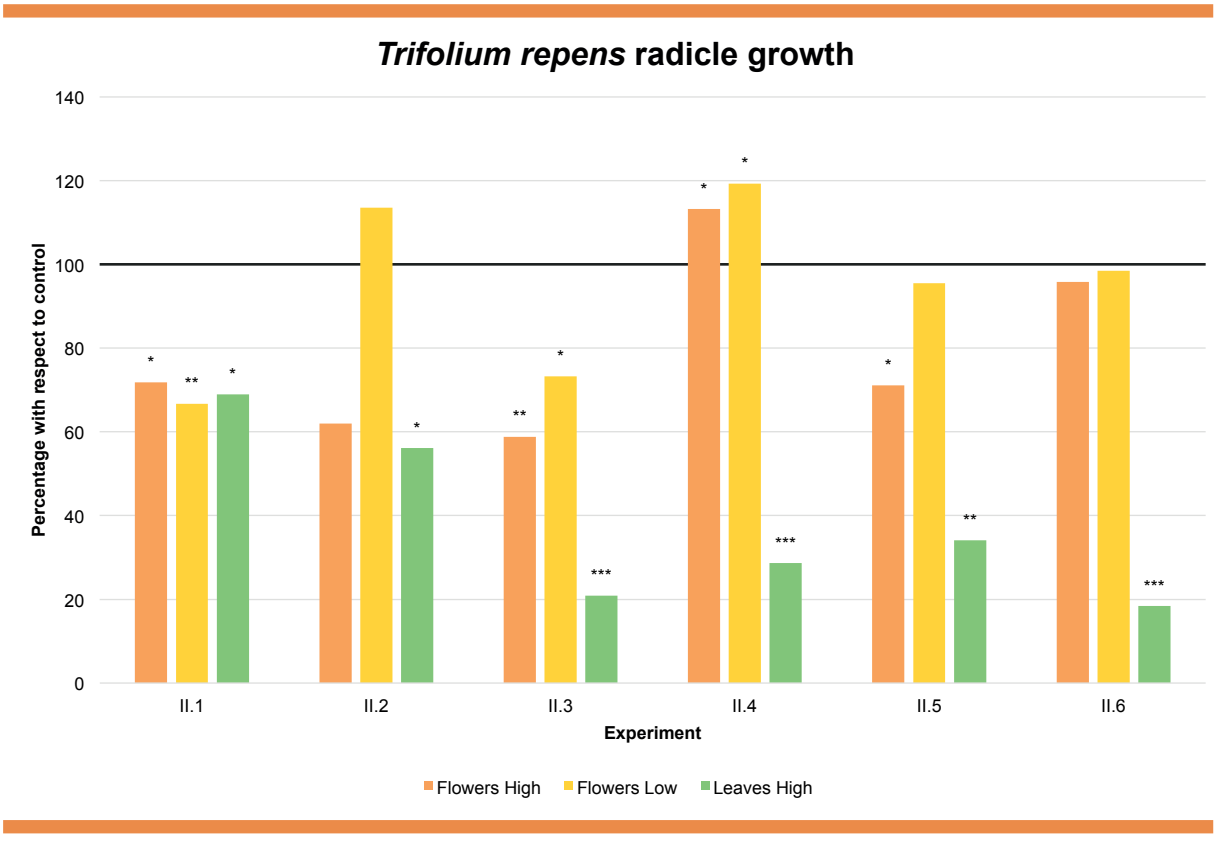

Figure 12.

Decomposition of Plant Residues II. Radicle growth bioassay. Species used: *Trifolium repens*. All data are compared to the control. Statistical significant differences (ANOVA plus LSD) are shown: * = p<0.05; ** = p<0.01: *** = p<0.001