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ORIGINAL PAPER

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ALLELOPATHIC EFFECT OF ORGANIC MULCHES ON VEGETABLE GERMINATION AND EARLY DEVELOPMENT

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ABSTRACT

Plants, as well as their residues (mulches), release physiologically active substances (allelochemicals), which may affect plant germination, development, and productivity. In this study we investigated the allelopathic effects of aqueous extracts of organic mulches (winter wheat straw, peat, sawdust, and gramineous grass) at different concentrations on germination and early growth of radish (*Raphanus sativus* L.), carrot (*Daucus sativus* Röhl.), and lettuce (*Lactuca sativa* L.). It was found, that the strongest negative effect on the germination and shoot and root development of investigated vegetables was with the highest concentration (1 : 10) of the grass aqueous extract. Peat mulch aqueous extracts had the least negative impact on all vegetable seed germination. Straw and peat mulches stimulated the early growth of *R. sativus* shoots, but there was a negative affect on *D. sativus* shoot development. The aqueous extracts of various organic mulches had negative effects on *R. sativus*, while mostly positive effects found on *L. sativa* root development.

Key words: organic mulches, allelopathy, seed germination, shoot and root length

INTRODUCTION

Use of organic mulches may affect a number of factors that can influence the productivity of cultivated plants [Larson 1997, Forcella et al. 2003, Döring et al. 2005]. Plant mulching is particularly important in organic farming for integrated weed control and as sourse of nutrients which are released during mulch decomposition. The major advantage of using organic mulches is the consequent increase of organic matter in soil [Paustian et al. 1997, Saroa and Lal 2003, Ni et al. 2016]. Natural mulch decomposes over time and it becomes a part of soil itself. Moreover, a slow release of nutrients from decaying mulches is beneficial for plant nutrition. Kar and Kumar [2007] estimated that straw mulching significantly increased the amount of mobile potassium and phosphorus. Pine needles (*Pinus roxburghii*), poplar leaf (*Populus deltoides*) and silver oak (*Grevillea robusta*) used for mulching significantly increased organic carbon, available nitrogen, phosphorus, potassium, and soil biological activity [Kumar et al. 2014]. Mulching with wood chips did not affected soil bulk density, pH, total nitrogen content, but consistently improved soil organic matter content [Ni et al. 2016].

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Mulching is one of the most appropriate physical methods for weed control [Matković 2017]. Plant residues, such as straw, grass, or cover crops, and peat, used for mulching can suppress weeds and decrease weed infestation [Arentoft et al. 2013, Kosterna 2014a, b, Kumar et al. 2014, Błażewicz-Woźniak et al. 2015, Thankamani et al. 2016], prevent weed seed germination and growth due to release of phytotoxic substances during plant residue decomposition [Putnam et al. 1983, Schilling et al. 1985, Blum et al, 1997]. The release of biochemicals into the environment by a plant or another organism and the impact of those chemical compounds on the other organisms describe allelopathy [Rice 1995]. Allelopathic characteristics are typical for decomposing straw, since it produces aliphatic acids; also microorganisms release amino acid derivatives [Putnam 1983]. Investigations shows, that mulch from buckwheat and rye straw is efficient for limiting weed infestation [Katerna 2004a]. The changes in the allelopathic compounds are determined by their chemical modification, influence of microorganisms, interaction with the soil humus, and effects of physical factors [Slapakauskas 2006]. Some authors have pointed out that allelopathic wood residues may also decrease weed infestation [Rathinasabapathi et al. 2005, Jodaugienė et al. 2006, Gruber et al. 2008].

Organic mulches have different impacts on crop yields. Some researchers state that mulching with organic mulches may increase crop yield [Sharma and Sharma 2003, Singh et al. 2007, Kar and Kumar 2007, Katerna 2004a, Ni et al. 2016, Thankamani et al. 2016]. According to the data from other reports, peat, sawdust, and straw mulches can actually decrease crop productivity due to inapropriate C : N ratio [Johnson et al. 2004, Sønsteby et al. 2004]. Grass mulch has been found to have a positive effect on plants grown in poor soil, i.e. it increases below and above-ground plant biomass, root dry matter mass, as well as amounts of organic carbon, potassium, phosphorus, calcium, and magnesium in soil, and finally, it helps to preserve soil moisture [Cadavid et al. 1998, Sharma and Achrya 2000, Jodaugienė et al. 2008, Ni et al. 2016].

The aim of this research was to estimate allelopathic impacts of range of organic mulch extracts on germination of different vegetables seeds.

MATERIAL AND METHODS

Experimental design. The object of the investigation was the germination of seeds of radish (*Raphanus sativus* L.), carrot (*Daucus sativus* Röhl.), and lettuce (*Lactuca sativa* L.) using aqueous extracts of different organic mulches at a range of concentrations. The laboratory experiments were carried out with the following treatments: 1) distilled water; 2) chopped winter wheat straw extract; 3) fen peat extract; 4) fresh sawdust extract; 5) chopped graminous grass extract. Mulch of graminous grasses included *Festuca rubra* L., *Lolium perenne* L. and *Poa pratensis* L. Fresh sawdust was of conifers and deciduous trees mixture.

Bioassay. The investigation was performed to find out the effect of organic (natural-origin) mulch extract on seed germination of radish (*R. sativus*), carrot (*D. sativus*), and lettuce (*L. sativa*), and the length of shoots and roots. Different concentrations of aqueous extracts were prepared using standard methodology. Seperated absolutely dry organic mulches (10 g) was separately soaked in distilled water (100 ml) (at a concentration of 1 : 10) and it was kept for 24 hours at room temperature (18°C). Later other aqueous extracts at concentrations of 1 : 50, 1 : 250, 1 : 1250, and 1 : 6250, were prepared through further dilution adding required quantity of distillated water [Lazauskas 1990]. All concentrations including 1 : 10 were tested as factors. The seeds were germinated on filter paper in Petri dishes moistened with the prepared aqueous extracts in a climate chamber at a temperature of 20°C. Fifty carrot and lettuce seeds, and 30 radish seeds per Petri dish were used. Seedligs of carrot and lettuce were measured after five days and seedlings of radish after three days from sowing using milimetric paper. The experiment was carried out with four replications. The results were compared to the controls of the experiment with distilled water.

Statistical analysis. All investigation data were evaluated using one way analysis of variance (ANOVA) with the least significant difference (LSD) test from software package SYSTAT 10 [SSPS, 2000]. The influence of different mulches on vegetables at all concentrations compared with distilated water seperatedly. In cases of significant differences

between a treatment and control, the levels of probability are marked as follows: * significant difference at the 95% probability level, ** significant difference at the 99% probability level, *** significant difference at the 99.9% probability level. The vegetables seed germination data, as well as calculations of the length of shoots and roots, were transformed according to the following formula: L10(x + 1). L10 is common logarithm (base 10).

RESULTS AND DISCUSSION

The results of the experiment with *R. sativus* seed germination showed that the straw and peat organic mulch aqueous extracts at different concentrationshad no significant effect (fig. 1).

Sawdust mulch extracts at all concentrations improved radish germination. Howerver, only at 1 : 1250 and 1 : 6250 concentrations the differences were significant. It stimulated germination of radish by 9 and 7 percentage points (pps) compared to the control. Grass mulch extract at a concentration of 1 : 10 had a significant ihibitory effect on the germination of radish seeds, it decreased by 54 pps. Diluted grass mulch extracts at concentrations from 1 : 50 to 1 : 6250, had no significant effect compared to the distilled water control. Others have observed similar tendencies while investigating allelopathic effect of grass extracts on radish germination. Kryzeviciene and Paplauskiene [2002] reported that radish germination, shoot and root growth was suppressed under the influence of investigated perennial grasses (*Poa pratensis* L., *Lolium perenne* L., *Phleum pratense* L. and *Festuca pratensis* Huds.) water extracts at the highest concentrations, whereas the lowest concentrations stimulated germination in most cases. Allelopathic activity also depended on development stage of perennial grasses.

Measurements of radish shoot length showed that the shoot length in distilled water reached 8.6 mm (fig. 2), and the different concentrations of organic mulch extracts in most cases had a stimulating effect. Straw mulch extracts at all concentrations significantly increased the growth of radish shoots by 45–66%, compared to the distilled water control. Peat mulch extracts at concentrations of 1 : 10, 1 : 50, and 1 : 250 increased radish shoot length significantly by 16–36%. Other concentrations stimulated the growth of radish shoots, but not significantly. Sawdust mulch extracts at 1 : 10 concentration had a significant in hibitory effect on the growth of radish shoots by 19%. Sawdust mulch extracts at concentrations of 1 : 50 and 1 : 250 significantly increaed radish shoot growth from 20% to 26% compared to the control.

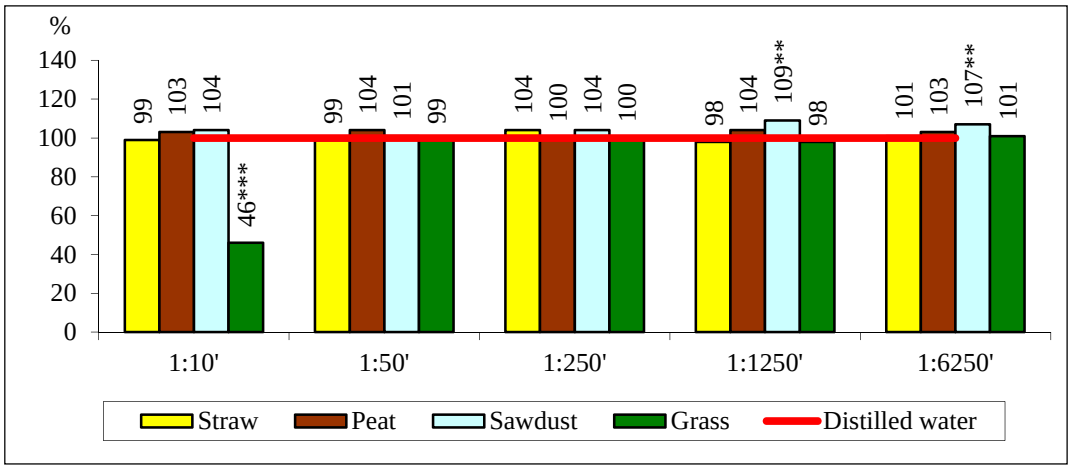

Fig. 1. Influence of organic mulch extracts at different concentrations on the germination of radish *(R. sativus)*; ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

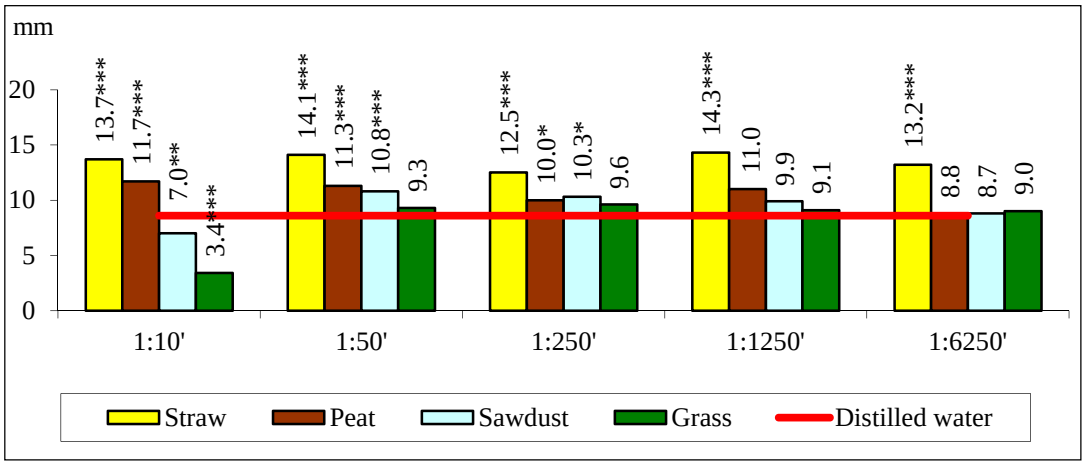

Fig. 2. Influence of organic mulches extracts at different concentrations on the length of radish *(R. sativus*) shoots; * significant difference at 95% probability level, ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

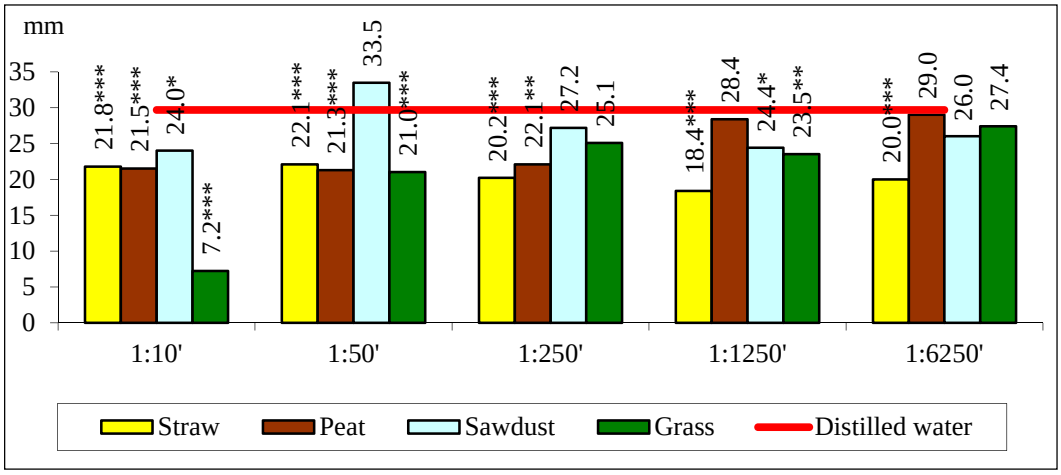

Fig. 3. Influence of organic mulch extracts at different concentrations on radish (*R. sativus*) root lengths; * significant difference at 95% probability level, ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

Other concentrations also had a positive influence on the growth of radish shoots, but not significantly. With the grass mulch extract at the 1 : 10 concentration a significant inhibitory effect of 60% on length of radish shoot was detected. Grass mulch extracts at lower concentrations from 1 : 50 to 1 : 6250 showed not significant stimulating effect of 5–12%, in comparison with that of the control.

Measurements of the length of radish roots showed that the roots reached a length of 29.7 mm in distilled water (fig. 3). The extracts of organic mulches at different concentrations in most cases had an inhibitory effect on the development of the radish roots. Diverse concentrations (1 : 10, 1 : 50, 1 : 250, 1 : 1250, and 1 : 6250) of straw mulch extracts had a significant inhibitory effect of 26–38% compared to that of the

control. Peat mulch extracts at concentrations of 1 : 10, 1 : 50, 1 : 250 inhibited the growth of roots significantly by 25–28%, compared to the control. Extracts at lower concentrations, such as 1 : 1250 and 1 : 6250, inhibited the growth of radish roots in comparison to the control. However, these differences were not significant. Sawdust mulch extracts affected the growth of radish roots very differently. Extracts at concentrations of 1 : 10 and 1 : 1250 reduced radish root growth significantly by 18–19% and at concentration of 1 : 50 increased the length of roots by 13% in comparison with the control, but not significantly. Grass mulch extracts at concentrations of 1 : 10, 1 : 50, 1 : 1250 significantly inhibited the development of radish roots, but extracts at concentrations of 1 : 250 and 1 : 6250 demonstrated no significant suppressive effect.

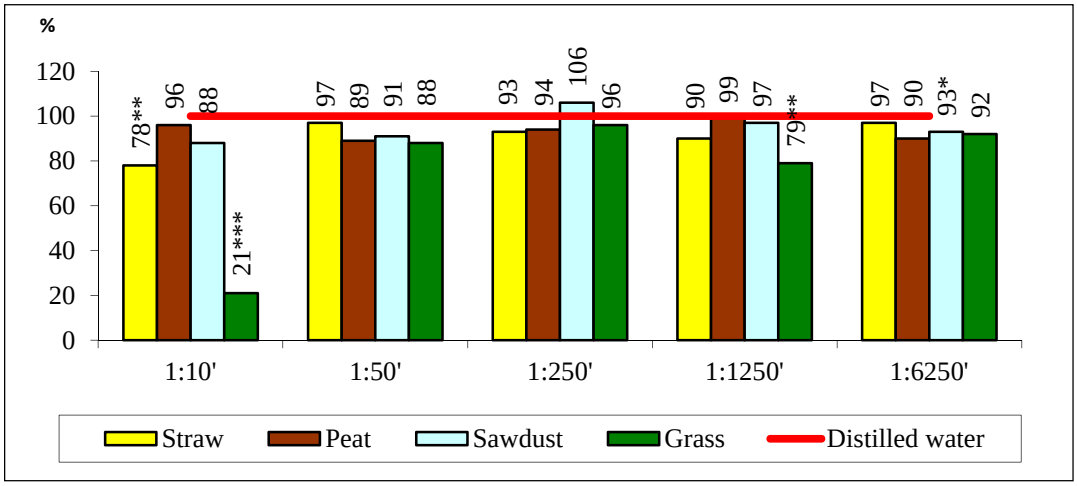

Fig. 4. Influence of organic mulch extracts at different concentrations on the germination of carrot (*D. sativus*); * significant difference at 95% probability level, ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

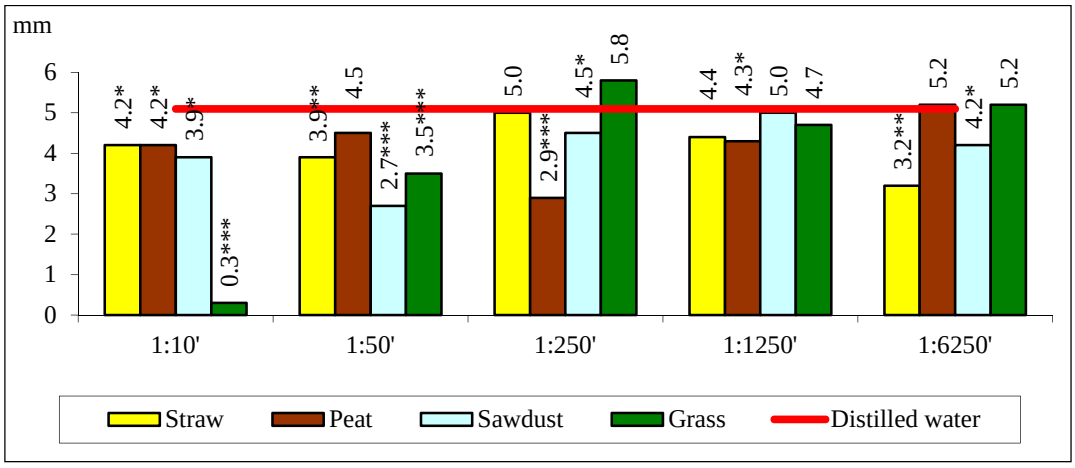

Fig. 5. Influence of organic mulches extracts at different concentrations on the length of carrot (*D. sativus*) shoots; * significant difference at 95% probability level, ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

When the lengths of the carrot shoots grown in the distilled water were measured these were 5.1 mm long (fig. 5). Straw mulch extracts only at concentrations of 1 : 10, 1 : 50, and 1 : 6250, inhibited carrot shoot development significantly, from 20% to 37%, in comparison to the control. Peat mulch extracts at concentrations of 1 : 10, 1 : 250, and 1 : 1250 suppressed the growth of carrot shoots significantly. This investigation found that the shoots were shorter by 16 to 43% than the controls. Sawdust mulch extracts at most concentrations inhibited the growth of carrot shoots by 12–47%, except at the concentration of 1 : 1250 which had no significant impact on the length of carrot shoots compared to the contol. Grass mulch extracts at concentrations 1 : 10 and 1 : 50 significantly reduced growth of carrot shoots by 94 and 31% respectively. Grass mulch extracts at lower concentrations, from 1 : 250 to 1 : 6250 had no significant effect on carrot shoot growth compared to the control.

After measuring the length of roots of carrots it was established that organic mulch extracts at the range of concentrations affected the development of carrot roots irregularly. The length of the roots of the carrots germinated in distilled water was 11.2 mm (fig. 6). Straw mulch extracts, in most concentrations, stimulated the growth of the carrot roots. With the straw mulch extracts at the 1 : 10 concentration, carrot root length was 10% shorter compared to the distilled water control, whereas at the concentrations of 1 : 250 and 1 : 6250 root lenght was significantly longer by 14–27%. The other concentrations had no significant influence on carrot root development.

Peat mulch extracts at all concentrations had no significant effect on carrot rooth length. It was found, that sawdust mulch extracts at all concentrations had no significant effect on carrot root growth. Sawdust mulch extracts at all concentrations inhibited the growth of carrot roots by up to 11% compared to the control, exceptone concentration (1 : 250) which had a slightstimulating effect. Grass mulch extracts at the concentrations of 1 : 10, 1 : 50, and 1 : 1250 significantly reduced root lengths by 17–76% compared to the distilled water control. Other extracts had no significant effect for the development of carrot roots.

Organic mulch extracts at the range of concentrations had different affects on lettuce (*L. sativa*) seed germination (fig. 7). In most cases organic mulch extracts inhibited the germination of lettuce. Laboratory and field experiments carried out by Tesio et al. [2011] showed that extracts from Jerusalem artichoke (*Helianthus tuberosus* L.) residues were consistently inhibitory to germination and seedling growth of lettuce. In our experiments, straw mulch extracts at the highest concentrations, such as 1 : 10 and 1 : 50, reduced germination of lettuce significantly by 40 and 19 pps respectively. However, when diluted up to the concentrations of 1 : 250, 1 : 1250, and 1 : 6250 this extract had a not significant stimulating effect by up to 16 pps, compared to the control. Peat mulch extracts at the lowest concentration of 1 : 6250 inhibited the germination of lettuce significantly, while at all other concentrations from 1 : 10 to 1 : 1250 there were no significant effect compared to the control. Sawdust mulch extracts of various concentrations had uneven impact on lettuce seed germination. Sawdust mulch extracts at the following concentrations 1 : 10, 1 : 50, and 1 : 1250 inhibited the germination of lettuce significantly by 8–36 pps, compared to the control. This extract at concentrations of 1 : 1250 and 1 : 6250 not significantly stimulated germination of lettuce seeds. Grass mulch extracts at the different concentrations had similar influence on lettuce germination. Grass mulch extracts at the higher concentrations, from 1 : 10 to 1 : 1250 reduced germination significantly by 11–83 pps. However, after diluting the grass mulch extract to a concentration of 1 : 6250, a not significant stimulating effect to lettuce germination was found.

Measurements of the lettuce shoots showed that their length in distilled water reached 13.2 mm (fig. 8). The impacts of organic mulch extracts at different concentrations on the growth of lettuce shoots varied greatly.

Straw mulch extract only at the concentration of 1 : 250 signicantly stimulated the growth of the lettuce shoots by 17% compared to the control, but the other concentrations had no significant effect. Peat and sawdust mulch extracts at all of the concentrations also had no significant influence on lettuce shoot development. Grass mulch extracts at the con-

centration of 1 : 10 decreased the growth of lettuce shoots significantly by 96%. Grass mulch at the concentration of 1 : 250 significantly stimulated lettuce shoot development by 21%, but at the other concentrations there were no significant effects.

The measurements of lettuce seedlings grown in disstiled water showed that lettuce roots were 24.4 mm long (fig. 9). Organic mulch extracts at the range of concentrations had differential impacts on the development of lettuce roots.

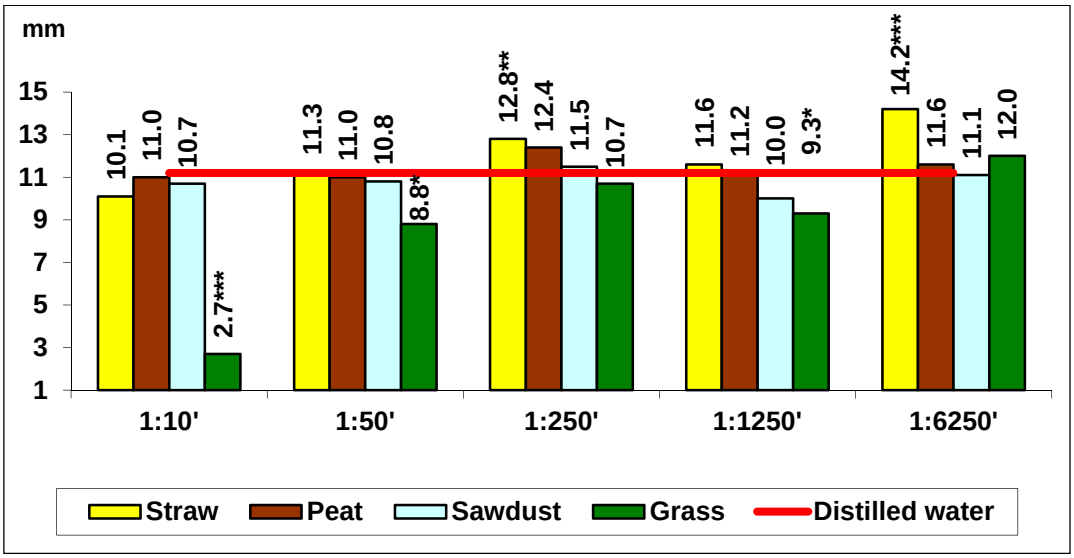

Fig. 6. Influence of organic mulch extracts at different concentrations on carrot (*D. sativus*) root lengths; * significant difference at 95% probability level, ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

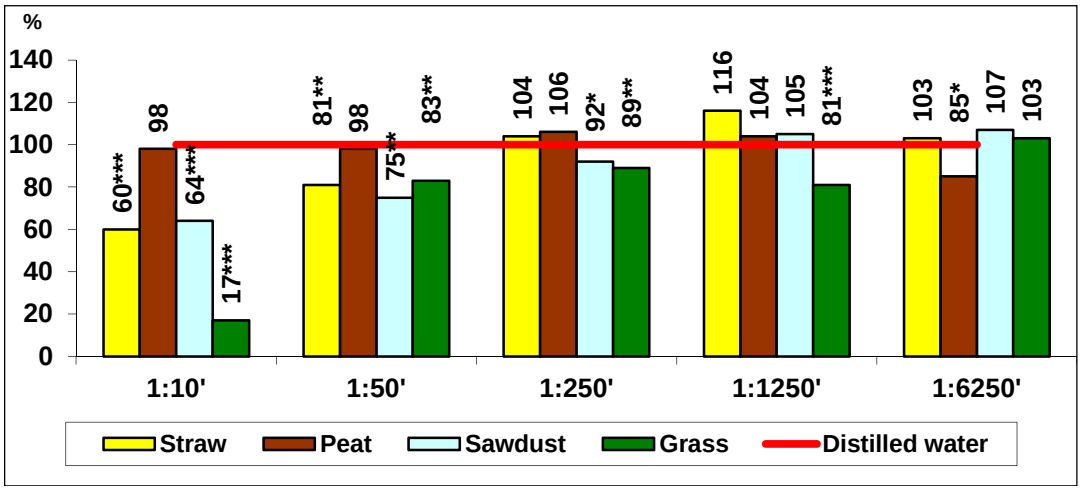

Fig. 7. Influence of organic mulch extracts at the range of concentrations on the germination of lettuce (*L. sativa*); * significant difference at 95% probability level, ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

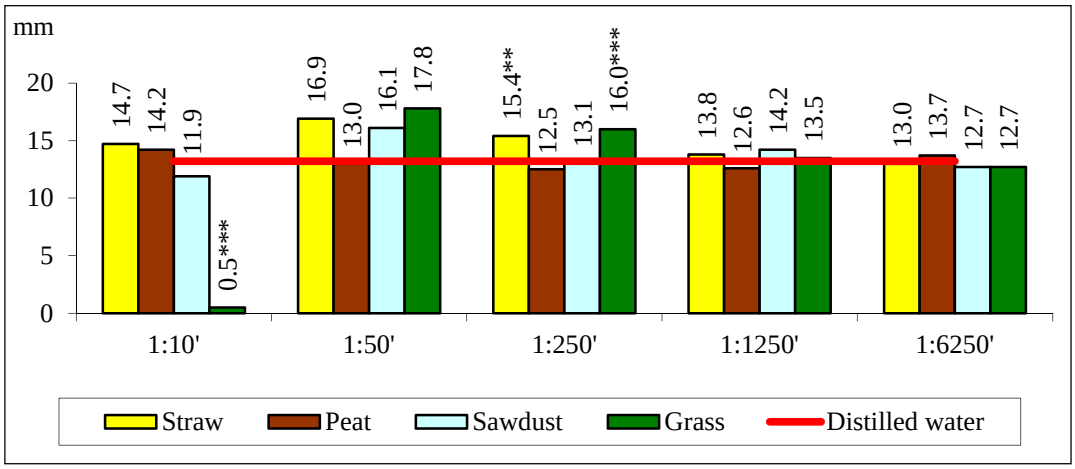

Fig. 8. Influence of organic mulch extracts at the range of concentrations on the length of lettuce (*L. sativa*) shoots; ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

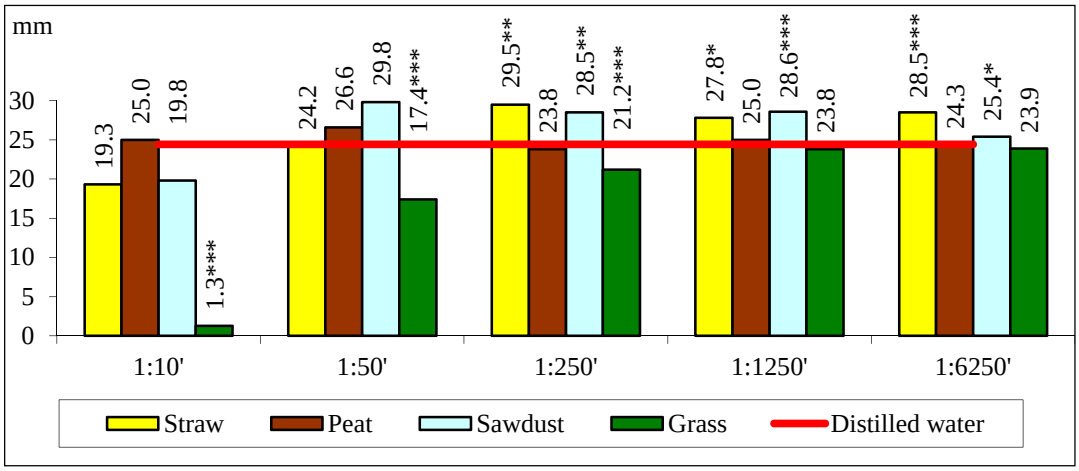

Fig. 9. Influence of organic mulch extracts at the range of concentrations on lettuce (*L. sativa*) root lengths; * significant difference at 95% probability level, ** significant difference at 99% probability level, *** significant difference at 99.9% probability level

Straw mulch extracts only at the lower concentrations significantly stimulated the growth of lettuce roots by 14 to 21% compared to the control. Beneficial effects of hay mulch on root growth and yield of strawberry have, also, been reported by Kumar and Dey [2011]. The different concentrations of peat and sawdust mulch extracts at the highest concentrations of 1 : 10 and 1 : 50 had no significant influence on the development of the lettuce roots compared to the distilated water. Diluting the sawdust extract to concentrations of 1 : 250, 1 : 1250, and 1 : 6250 increased the growth of the lettuce roots significantly by 4–17%. Grass mulch extracts at the higher concentrations of 1 : 10, 1 : 50, and 1 : 250 had an inhibitory effect of 13–95%. However, grass mulch extracts at the lower concentrations 1 : 1250 and 1 : 6250 had no significant influence compared to the control.

CONCLUSIONS

The strongest negative effect on the germination of vegetable (*Raphanus sativus* L., *Daucus sativus* Röhl. and *Lactuca sativa* L.) seeds and development of shoots and roots was at the highest concentration (1 : 10) of grass mulch aqueous extract. Dilution of this concentration resulted in a reduction in negative effect. Straw and sawdust mulch aqueous extracts at the higher concentrations (1 : 10 and 1 : 50) had the strongest negative effect on the germination of *L. sativa*, while peat mulch aqueous extracts showed the least negative impact on all tested vegetable seed germination. Straw and peat mulch aqueous extracts stimulated early growth of *R. sativus* shoots. No significant effect was found for *L. sativa* except at 1 : 250 concentration of straw mulch extract and a negative effect on *D. sativus* shoot development at 1 : 10 concentration of all mulches extracts.

The aqueous extracts of all tested organic mulches at 1 : 10 concentration and of starw mulch at all concentrations had negative effects on *R. sativus* while positive effects found on *L. sativa* root development in straw and sawdust mulches extracts at lower concentrations from 1 : 250 to 1 : 6250. *D. sativus* root length did not differ significantly, except negative effect under the influence of the higher concentrations of the grass mulch aqueous extracts and positive effect of the straw mulch extracts at lower concentrations.

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