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# Allelopathic effects of invasive weed species *Abutilon theophrasti* Medik., *Ambrosia artemisiifolia* L., *Datura stramonium* L. and *Xanthium strumarium* L. on tomato

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**SUMMARY**

*Abutilon theophrasti* Medik, *Ambrosia artemisiifolia L., Datura stramonium L.* and *Xanthium strumarium L.* are four well-known invasive weed species that are widespread in many crops. Laboratory experiments were conducted to evaluate the allelopathic effects of decomposition products of these four invasive weeds on seed germination and early seedling growth of tomato. The results of the study showed that decomposition products obtained from *A. theophrasti, A. artemisiifolia, D. stramonium* and *X. strumarium* had different allelopathic impacts on germination and seedling growth of tomato. The degree of inhibition or stimulation depended on weed species and type of decomposition product. Root decomposition products of all species except *X. strumarium* decreased the early growth of tomato (2-37%). *X. strumarium* had only stimulating effect on early growth of tomato (1-86%). Also, the results showed that leaves of the other three invasive weed species had stimulating effects on early growth of tomato (1-53%). Hence, the allelopathic potential of *X. strumarium*, as well as the leaf decomposition products of the other three invasive weed species could be used to develop an appropriate technology to improve tomato production.

**Keywords**: invasive weeds; allelopathy; tomato; germination; seedlings

## INTRODUCTION

Allelopathy has been broadly defined as the production of chemical compounds by one plant species that influences another plant species (Rice, 1984). Therefore, allelopathy plays a significant role in regulating the growth and development of agricultural and biological systems, and allelopathic chemicals can be produced both by crops and uncultivated plants, many of which are considered as weeds (Singh et al., 2005; Subtain et al., 2014). Allelochemicals can be produced by any part of the plant: roots, rhizomes, stems, leaves, flowers, pollen, fruits or seeds (Norsworthy, 2003; Singh et al., 2005; Matloob et al, 2010; Subtain et al., 2014; Baličević et al., 2015; Zohaib et al., 2016; Sarić-Krsmanović et al., 2019). The action of these compounds is concentration dependent as they inhibit plant growth at high concentrations and promote it at low concentrations (Wakjira et al., 2009; Matloob et al., 2010; Farooq et al., 2011; Katoch et al., 2012).

A large number of allelopathic weeds have been documented in literature as affecting crop plants right from their emergence until maturity, and causing considerable economic losses. Weed allelopathy has been found responsible for disturbing the emergence and stand establishment, growth, yield and physiology of crop plants.

Plant residues, including those of weeds, are known to release large amounts of allelochemicals into soil. Phenolic compounds, lignans, cyanogenins, coumarins, phenolic glycosides, sesquiterpenoids and flavonoids are released into soil from weed plants either by exudation, leaching and/or decomposition of residues (Weston, 1996; Đikić, 2007; Azirak & Karaman, 2008; Beatović et al., 2015; Atak et al., 2016). The accumulation of allelochemicals in soil leads to changes in seed germination and plant growth, primary and secondary roots, chlorosis, nutrient absorption, maturation and reproduction (Narwal et al., 2005; Matloob et al., 2010, Katoch et al., 2012; Baziar et al., 2014; Cheng & Cheng, 2015). Thus, a significant change in seedling growth was observed when *Brassica* species (*Brassica nigra*, *Brassica oleracea*, *Brassica campestris* and *Brassica rapa*) were grown in soil amended with different amounts of residue of the invasive weed *Parthenium hysterophorus* (Wakjira et al., 2009). *P. hysterophorus* material was composted in soil to check possible effects on the emergence and growth of lettuce seedlings. The results indicated inhibitory allelopatic effects on the percent emergence, as well as radical and plumule growth of lettuce seedlings. Also, Onwugbuta-Enyi (2001) reported that *Chromolaena odorata* residues incorporated in soil inhibited growth and reduced the dry weight of tomato plants. According to Baziar et al. (2014), *Lolium pesicum* and *Sinapis arvensis* can strongly affect the germination, growth and performance of barley by producing chemical material with allelopathic properties, leading to unfavorable growth and product yield. Allelopathic potentials of *Ambrosia trifida* essential oil against lettuce, watermelon, tomato and cucumber seed germination and seedling growth were demonstrated at five concentration levels (0.2-1%) (Sarić-Krsmanović et al, 2019).

*Ambrosia artemisiifolia* L., *Datura stramonium* L., *Abutilon theophrasti* Medik and *Xanthium strumarium* L. are four rapidly spreading invasive weed species in many plant crops around the world. These species are generally highly-competitive for nutrients, light and moisture and can drastically reduce yield, harvesting efficiency and crop quality (Bloszyk et al., 1992; Callaway & Aschehoug, 2000; Foy & Inderjit, 2001). In Serbia, *A. theophrasti* , *A. artemisiifolia*, *D. stramonium* and *X. strumarium* are the predominant weed species in all row crops and vegetables, including tomato (Vrbničanin et al., 2015). Foy and Inderjit (2001) listed 123 weed species, including *A. theophrasti, A. artemisiifolia* and *X. strumarium,* as having allelopathic properties. Gressel and Holm (1964) evaluated the allelopatic potential of *A. theophrasti.* For the first time, they demonstrated that *A. theophrasti* seeds produced inhibitors of crop seed germination and seedling elongation. The results of their research were confirmed by Holm and Struckmeyer (1972; cited by Colton & Einhellig, 1980) and Colton and Einhellig (1980).

The expanding practices of integrated pest management have heightened interest in the employment of crop or weed residues in vegetable cropping systems. Plant residues have many potential uses in vegetable cropping systems because they may release compounds that either hinder or stimulate growth of crop or weed seedlings. The focus of this study was to screen the allelopathic potential of residues (decomposition products) of four invasive weeds (*A. theophrasti, A. artemisiifolia, D. stramonium,* and *X. strumarium*) on germination and early seedling growth of tomato as a low competitive crop against weeds.

## MATERIAL AND METHODS

### Plant material

Both aerial (leaf and stem) and underground (root) parts of *A. theophrasti*, *A. artemisifolia*, *D. stramonium* and *X. strumarium*, were collected in Nova Galenika (Belgrade, Serbia) in July 2015. Seeds of tomato (Mondial F1, Enza Zaden) were used in the trial.

### Soil-incorporated residues

The experiment was set up under controlled conditions. The mixture of a commercial substrate (Flora Gard TKS1, Germany) and soil collected from a field without a history of herbicide treatments was used. The soil, sampled from a location in Zemun (Belgrade, Serbia), was a loamy soil (sand 49.8%, silt 33.4%, clay 16.8%), medium calcareous, weakly alkaline and highly humic, rich in total nitrogen and well-supplied with available phosphorus and potassium. Fresh plant material (leaves, stems, roots) of *A. theophrasti*, *A. artemisiifolia*, *D. stramonium* and *X. strumarium* were cleaned several times by tap water, chopped into 1cm long fragments, and mixed with 1 kg of soil (40 g of plant material per 1 kg of soil). The prepared substrates were kept in plastic pots (diameter 14 cm), moistened with 250 ml tap water, covered with filter paper and left for 20 days at room temperature (21-22°C). After that period, 10 tomato seeds were sawn in each pot. The pots were placed in a climate room under the following conditions: 14h/10h photoperiod, 26/21°C (day/night) temperature, 60-70% humidity and 300µE/m2s white light intensity, and they were watered daily. Plants grew for 28 days, upon which period the following parameters were measured: the number of emerged seedlings (%), fresh and dry biomass weight (g), height of plants (cm), root fresh weight (g) and root length (cm). Fresh samples of plants were placed in a drying oven at 60°C for 72 h until constant weight was reached. The experiment design was a randomized complete block with four replications, repeated twice, and data were combined for analysis.

### Data analysis

The data were processed in Statistika 8.0. software, using a two-way factorial analysis of variance (ANOVA), and differences between treatments were tested by Fisher's Least Significant Difference (LSD) test ($P < 0.05$) and Student's t-test ($P < 0.05$).

## RESULTS AND DISCUSSION

The data obtained in this experiment showed that decomposition products (root decomposition product-RDP; stem decomposition product-SDP; leaf decomposition product-LDP) of *A. theophrasti, A. artemisiifolia, D. stramonium,* and *X. strumarium* had different allelopathic effects on the germination and seedling growth of tomato. The degree of inhibition and stimulation depended on the weed species and type of decomposition product.

Germination percentages of tomato seeds are presented in Table 1. Statistical analyses showed that most decomposition products of these four weed species had no significant impact on the germination of tomato seeds. The obtained data showed that a significant degree of inhibition of tomato seed germination was only noted for the LDP of *D. stramonium* and *A. theophrasti* (76% and 79%, respectively) and RDP of *D. stramonium* and *A. theophrasti* (72%). Seed germination is widely used as a parameter in allelopathic bioassays. Many studies have revealed allelopathic effects of weeds (stimulatory or inhibitory) on germination and crop stand establishment. Residues of leaves, stems, roots and whole plants of *Polygonum hydropiper, Acanthus spinosus, Chenopodium album, Cyperus rotundus* and *Imperata cylindrica* and their mixtures have been shown to impose inhibitory effects on the emergence of maize seedlings; they delayed seedling emergence and reduced seedling vigour (Samad et al., 2008). Jefferson and Pennacchio (2003) reported that leaves of four *Chenopodiaceae* species produced allelopathic compounds which inhibited lettuce seed germination.

**Table1.** The influence of leaf, stem and root decomposition products of different weeds on germination percentage of tomato

| Plant material | Germination percentage (%) | | | |
|---|---|---|---|---|
| | ABUTH | AMBEL | DATST | XANST |
| LDP | 79 bc | 85 ab | 76 bc | 91 a |
| SDP | 87 ab | 91 a | 84 ab | 86 ab |
| RDP | 72 c | 91 a | 72 c | 89 a |
| Control | 88 a | | | |

LDP-leaf decomposition products; SDP-stem decomposition products; RDP-root decomposition products; ABUTH-*Abutilon theophrasti*; AMBEL-*Ambrosia artemisiifolia*; DATST-*Datura stramonium*; XANST-*Xanthium strumarium*; a, b, c, ab, ac - LSD test ($p < 0.05$)

The fresh weight of tomato plants grown in soil amended with decomposition products of *A. theophrasti, A. artemisiifolia, D. stramonium* and *X. strumarium* was mostly significantly higher than the weight of control plants. The recorded stimulation, regarding this parametar, ranged from 25% (SDP of *A. artemisiifolia*) to 42% (LDP of *X. strumarium*). However, the RDP of *A. artemisiifolia* and *A. theophrasti* and SDP and RDP of *D. stramonium* significantly reduced the fresh weight of tomato plants, compared to control plants, and the inhibition ranged from 15% (RDP of *A. artemisiifolia*) to 44% (SDP of *D. stramonium*) (Figure 1).

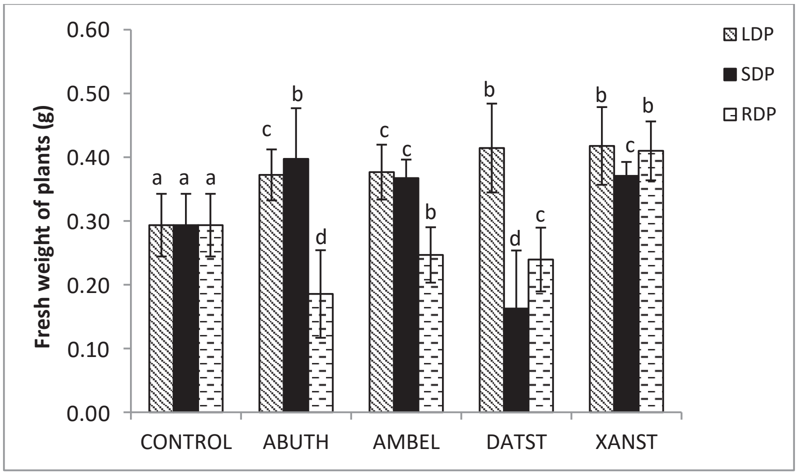


**Figure 1.** The influence of leaf, stem and root decomposition products of different weeds on fresh weight of tomato plants; LDP-leaf decomposition products; SDP-stem decomposition products; RDP-root decomposition products; ABUTH-*Abutilon theophrasti*; AMBEL-*Ambrosia artemisiifolia*; DATST-*Datura stramonium*; XANST-*Xanthium strumarium*; a, b, c, d - LSD test ($p < 0.05$)

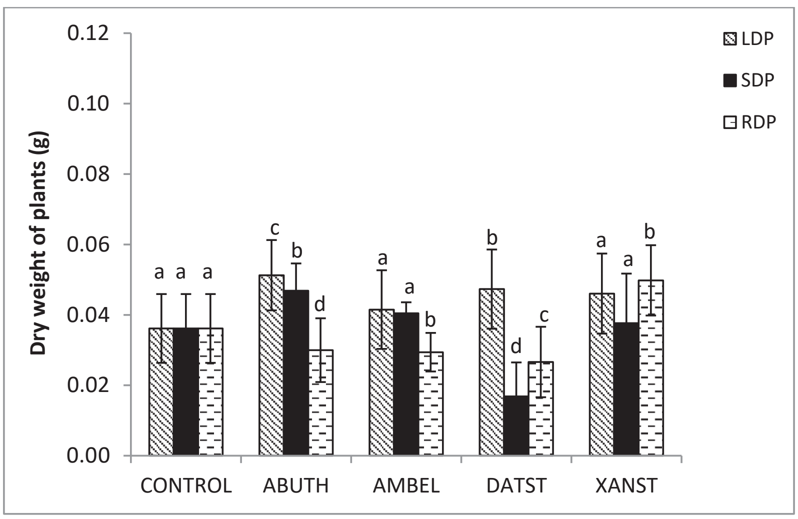


**Figure 2.** The influence of leaf, stem and root decomposition products of different weeds on dry weight of tomato plants; LDP-leaf decomposition products; SDP-stem decomposition products; RDP-root decomposition products; ABUTH-*Abutilon theophrasti*; AMBEL-*Ambrosia artemisiifolia*; DATST-*Datura stramonium*; XANST-*Xanthium strumarium*; a, b, c, d - LSD test ($p < 0.05$)

The dry weight of tomato plants grown in soil amended with the LDP of *D. stramonium*, RDP of *X. strumarium,* and LDP and RDP of *A. theophrasti* was significantly higher than the weight of control plants, and the recorded stimulation ranged from 26% (LDP of *D. stramonium*) to 40% (LDP of *A. theophrasti*). However, the RDP of *A. artemisiifolia*, SDP and RDP of *D. stramonium,* and RDP of *A. theophrasti* significantly reduced the dry weight of tomato plants, and the inhibition ranged from 20% (RDP of *A. artemisiifolia*) to 54% (SDP of *D. stramonium*). There were no significant differences in the other treatments (LDP and SDP of *A. artemisiifolia* and *X. strumarium*) (Figure 2).

The effects of decomposition products of *A. theophrasti, A. artemisiifolia, D. stramonium* and *X. strumarium* on the height of tomato plants were similar to plant fresh weight data. The recorded stimulation of plant height ranged from 7% (RDP of *A. artemisiifolia* and LDP of *D.*

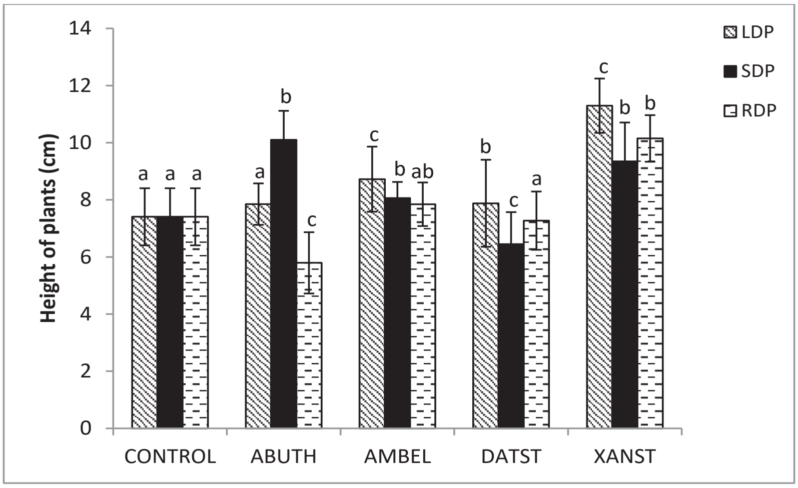


**Figure 3.** The influence of leaf, stem and root decomposition products of different weeds on height of tomato plants; LDP-leaf decomposition products; SDP-stem decomposition products; RDP-root decomposition products; ABUTH-*Abutilon theophrasti*; AMBEL-*Ambrosia artemisiifolia*; DATST-*Datura stramonium*; XANST-*Xanthium strumarium*; a, b, ab, c - LSD test ($p < 0.05$)

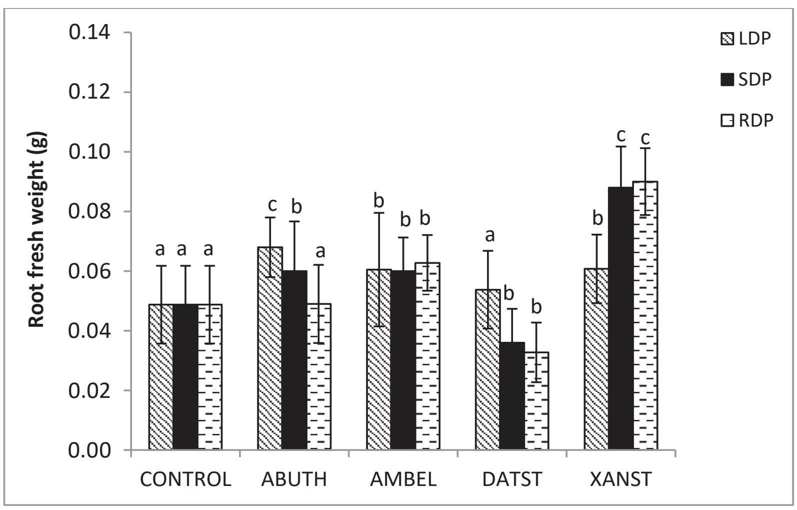


**Figure 4.** The influence of leaf, stem and root decomposition products of different weeds on root fresh weight of tomato; LDP-leaf decomposition products; SDP-stem decomposition products; RDP-root decomposition products; ABUTH-*Abutilon theophrasti*; AMBEL-*Ambrosia artemisiifolia*; DATST-*Datura stramonium*; XANST-*Xanthium strumarium*; a, b, c - LSD test ($p < 0.05$)

*stramonium*) to 53% (LDP of *X. strumarium*). However, the SDP of *D. stramonium* and RDP of *A. theophrasti* significantly reduced the height of tomato plants and the inhibition was 12% and 21%, respectively. There were no significant differences in the other treatments (RDP of *D. stramonium* and LDP of *A. theophrasti*) (Figure 3).

The root fresh weight of tomato plants grown in soil amended with decomposition products of *A. theophrasti, A. artemisiifolia, D. stramonium* and *X. strumarium* was mostly significantly higher than the weight of control plants. The recorded stimulation, regarding this parametar, ranged from 23% (SDP of *A. theophrasti*) to 86% (RDP of *X. strumarium*). However, the SDP and RDP of *D. stramonium* significantly reduced this parametar and the inhibition was 24% and 32%, respectively. There were no significant differences in the other treatments (LDP of *D. stramonium* and RDP of *A. theophrasti*) (Figure 4).

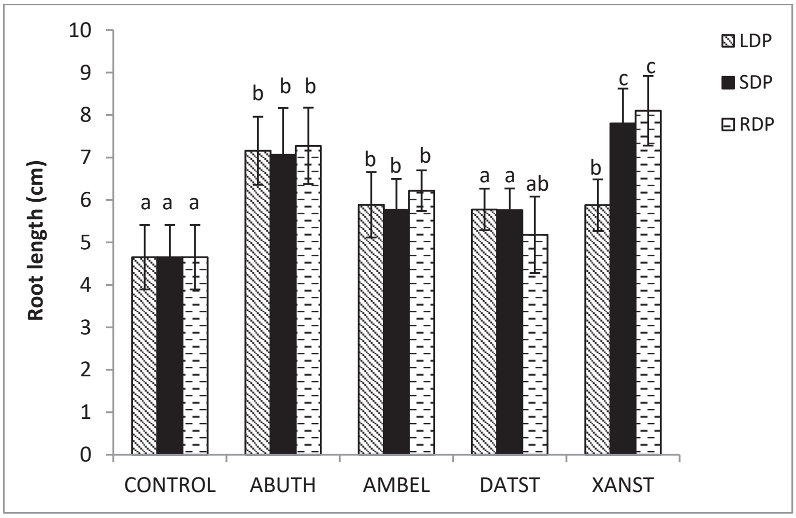


**Figure 5.** The influence of leaf, stem and root decomposition products of different weeds on root length of tomato; LDP-leaf decomposition products; SDP-stem decomposition products; RDP-root decomposition products; ABUTH-*Abutilon theophrasti*; AMBEL-*Ambrosia artemisiifolia*; DATST-*Datura stramonium*; XANST-*Xanthium strumarium*; a, b, ab, c - LSD test ($p < 0.05$)

The root length of tomato plants grown in soil amended with decomposition products of *A. theophrasti, A. artemisiifolia, D. stramonium* and *X. strumarium* was greater than the length of control plant roots in all treatments. The recorded stimulation, regarding this parameter, ranged from 25% (SDP of *A. artemisiifolia*) to 74% (RDP of *X. strumarium*). There were no significant differences in only two treatments: the LDP and SDP of *D. stramonium* (Figure 5).

Weed residues are well-known for their allelopathic effects (inhibition or stimulation) on crops. Most allelochemicals from residues can be released during their decomposition. Allelopathic compounds from weed residues incorporated into soil are generally water-soluble and rapidly solubilized, and they affect both seed germination and crop growth (Colton & Einhellig, 1980; Matloob et al., 2010). The results of our study showed that all four invasive weed species produced allelochemicals that affected seed germination and early growth of tomato (fresh and dry biomass weight, plant height, and root fresh weight and length). The degree of change dependented on the weed species and type of decomposition product. Furthermore, our results showed that the parameters of early growth (fresh and dry biomass weight, plant height, and root fresh weight and length) of tomato were more sensitive in detecting the allelopathic impact of test weed species than seed germination. Some authors (El-Khatib, 2000; El-Khatib et al., 2004) had noticed that susceptibility to allelochemicals increased in the seedling stage, and some morphological abnormalities occurred. They suggested that seedling growth was more affected by allelopathic interaction than seed germination.

The results of our study showed that root decomposition products of all test weeds other than *X. strumarium* suppresed early growth of tomato, and the reduction was 2-37%. Decrease in growth, dry matter and biomass production caused by allelochemicals of *Amaranthus retroflexus* and *Setaria glauca* has been reported in corn and soybean (Bhowmik & Doll, 1983), by *Chenopodium album*, *Amarantus retroflexus* and *Cynodon dactylon* in safflower (Rezaie & Yarnia, 2009) and by *Lolium persicum* and *Sinapis arvensis* in barley (Baziar et al., 2014). Singh et al. (2001) reported that coumarins and phenolic acids, which exist in weed roots, can inhibit plant growth. According to El-Khatib et al. (2004), Singh et al. (2005) and Batish et al. (2009), phenolic acids as the most important group of allelophatic compounds of weeds reduce root growth and decrease the absorption and transmission of mineral elements from roots to other plant parts. The influence of *Lantana camara, Ageratum conyzoides* and *Eupatorium adenophorum* root residues, edded to soil at 5% and 10% concentrations, was found to act inhibitory on the emergence and shoot growth of wheat, rice and maize. The effects were proportional to the concentration of incorporated residues (Katoch et al., 2012). Fresh and dry root material of *P. hysterophorus* was composted in soil to check possible effects on the emergence and growth rate of lettuce seedlings.

The results indicated inhibitory allelopathic effects on the percent emergence, and radical and plumule growth of lettuce seedlings, which were credited to the phenolics released into the soil with water from decomposing residues of *P. hysterophorus* (Wakjira et al., 2009).

Singh et al. (2001) pointed out that allelopathy has a great potential in modern agriculture, i.e. in improving crop productivity and genetic diversity, maintaining ecosystem stability, nutrient cycling and nutrient conservation, and that plant residues, if properly managed, may even lead to enhanced yields. Our results showed that *X. strumarium* was the species with only stimulating effects on the early growth of tomato (1-85%). Also, the presented results show that leaves of the other three invasive weed species had stimulating effects on the early growth of tomato (1-53%). These results are in agreement with some of the results available in literature on allelopathy. Colton & Einhellig (1980) reported that leaves of *A. theophrasti* contain allelochemicals that are released slowly during plant decomposition in soil. Also, Rolim de Almeida et al. (2007) found that air-dried and powdered leaves of the medicinal plant *Byrsonima crassa* exerted stimulatory effects on the root length and weight of tomato (26.8% and 31.7%, respectively). Pure amentoflavone isolated from *B. crassa* leaves stimulated shoot elongation at concentrations ranging from $10^{-4}$ M to $10^{-6}$ M. Some earlier studies revealed that the invasive alien plant *Eupatorium adenophorum* contains a large amount of allelochemicals, especially in leaves, which effect the growth of many plants in nurseries and plantations (Zhao et al. 2009; Katoch et al., 2012). Significant amounts of water-soluble phenolics are reported to be present in *Ageratum conyzoides*-infested soil, leaf debris, and debris-amended soils (Batish et al. 2009). According to Hussain et al. (2007), senna (*Cassia angustifolia)* has a clear positive effect on the seedling growth characteristics of maize, rice and sorghum. Peng (2019) reported that low concentrations of maize aqueous extract (0.5, 1.0 and 2.5 %) significantly stimulated the shoot height, seedling fresh weight and root length of three tested medicinal plants: *Platycodon grandiflorum*, *Salvia miltiorrhiza* and *Scutellaria baicalensis*.

In fact, stimulatory allelopathic effects of any weed on crops can be utilized to develop eco-friendly, cheap and effective 'green growth promoters'. According to our presented data, decomposition products of *X. strumarium,* as well as leaves of *A. theophrasti, A. artemisiifolia* and *D. stramonium* had stimulatory allelopathic effects on early seedling growth of tomato, and could therefore be nominated as good candidates for further field tests.

## CONCLUSIONS

The results showed that decomposition products of *A. theophrasti, A. artemisiifolia*, *D. stramonium* and *X. strumarium* have allelopathic potential, and influence on tomato germination and early seedling growth. The degree of inhibition or stimulation depended on the weed species and type of decomposition product. Early growth (fresh, dry biomass weight, plant height, and root fresh weight and length) were found to be more sensitive parameters than seed germination. Decomposition products of all investigated invasive species, predominantly had no significant influence on the germination of tomato seeds. The highest stimulatory effect was noted for the RDP of *X. strumarium* regarding the root fresh weight parameter (86%). The highest inhibitory effect was found to be exerted by the SDP of *D. stramonium* on the plant dry weight parameter (54%). Root decomposition products of all species except *X. strumarium* suppressed early tomato growth by 2-37%. *X. strumarium* had only stimulatory effect on early tomato growth (1-86%), as well as leaf decomposition products of *A. theophrasti, A. artemisiifolia* and *D. stramonium* (1-53%).

Therefore, some of the future goals should include: (1) identification of the main components of the invasive weed *X. strumarium,* as well as *A. theophrasti, A. artemisiifolia* and *D. stramonium* leaves; (2) field studies focusing on getting more useful information and developing an appropriate technology for using decomposition products to improve tomato production.

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# Alelopatski uticaj invazivnih korovskih vrsta *Abutilon theophrtasti* Medik., *Ambrosia artemisiifolia* Medic., *Datura stramonium* L. i *Xanthium strumarium* L. na paradajz

**REZIME**

*Abutilon theophrasti, Ambrosia artemisiifolia, Datura stramonium* i *Xanthium strumarium* su četiri dobro poznate invazivne korovske vrste koje su rasprostranjene u mnogim usevima. Alelopatski uticaj ova četiri invazivna korova na klijanje i rani porast klijanaca paradajza praćen je u laboratorijskim ogledima. Rezultati istraživanja su pokazali da proizvodi raspadanja koji su dobijeni od *A. theophrasti, A. artemisiifolia, D. stramonium* i *X. strumarium* imaju različit alelopatski uticaj za paradajz i da je stepen ispoljene inhibicije ili stimulacije zavisio od vrste korova i proizvoda raspadanja. Proizvodi raspadanja korena svih vrsta, izuzev *X. strumarium*, su smanjili rani porast paradajza (2-37%). *X. strumarium* je imao samo stimulativni efekat (1-86%), kao i proizvodi raspadanja listova ostale tri korovske (1-53%). Smatramo, da bi se alelopatski potencijal vrste *X. strumarium*, kao i proizvoda raspadanja listova ostale tri vrste mogao iskoristiti za poboljšanje tehnologije proizvodnje paradajza.

**Ključne reči:** invazivni korovi; alelopatija; paradajz; klijanje; klijanci