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Intraspecific Variation in Sonchus Oleraceus, a Biennial Weed Species, Inside and Outside of Tea Gardens

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ABSTRACT

Although the soil and litter of tea trees in tea gardens contain catechins and caffeine, which are known to suppress plant seed germination, various weed species are still able to grow in tea gardens. Sonchus oleraceus is one of the common weed species in tea gardens. In the present study, we compared the germination characteristics of S. oleraceus seeds from a tea garden population and those from seeds of a population outside of the tea garden. The results indicated that the seeds from the tea garden population possess resistance to catechins and caffeine, and they had a higher germination rate than seeds from outside the tea garden in conditions with high concentrations of catechins and caffeine. In addition, the seeds from the tea garden population were able to germinate throughout the season in order to adapt to disturbances owing to tea garden management, although in their natural life history, the seeds of S. oleraceus break dormancy and emerge from summer to autumn.

Keywords: *tea garden, intraspecific variation, Sonchus oleraceus, catechin, caffeine*

Introduction

It is well known that weeds have high plasticity and are therefore able to adapt to the environmental conditions. In addition, weeds are prone to intraspecific mutation, which is one of the reasons they present serious problems in weed control practices (Brainard et al. 2007; Clements et al. 2004; Mayor and Dessaint 1998; Menalled et al. 2001; Sosnoskie et al. 2006). Tea gardens are specific environments for weed species, as they are different from other crop fields and orchards, and it is important to clarify the intraspecific variation in weeds in tea gardens in order to be able to effectively control the weeds in tea gardens.Tea plants (Camellia sinensis (L.) Kuntze) contain alkaloids, polyphenols, and phenolic compounds (Maclas et al. 1996), and they also have allelopathic activity (Waller et al. 1986; Suzuki and Waller 1987).

Extracts from tea plants were found to suppress the germination and growth of some weed species, such as Amaranthus retroflexus and Setaria pumila (Rezaeinodehi et al. 2006). Furthermore, it was reported that the soil extracts from tea fields inhibited root growth in Lepidium sativum (Maclas et al. 1996). In addition, some studies were conducted on the use of extracts from tea leaves for weed control (Khan et al. 2007). Typical allelochemicals contained in tea are catechins and caffeine. Catechins are known to suppress the early growth of weed species, such as Achillea millefolium, Echinochloa crus-galli, Lolium perenne, Trifolium repens, Plantago lanceolata, and Amaranthus retroflexus (Kalinova and Vrchotova 2009). Catechins are known to suppress the germination of some crops, such as onion, lettuce, turnip, carrot, radish, pea, fava beans, wheat, barley, and oats (Ransom 1912) as well as some weed species, such as Amaranthus spinosus, Avena fatua, Echinochloa crus-galli, Vicia sativa, and Vicia hirsuta (Rizvi et al. 1981). In addition, it was indicated that the germination and growth of Borreria hispida, which is a weed present in tea gardens in India, was inhibited by caffeine (Tanti et al. 2016).In Japan, tea branches are repeatedly trimmed to reduce the height of tea trees, and the surface of tea gardens is commonly covered with litter of tea branches and leaves (Seo 2016). According to our previous investigations, the litter of the tea plant, which covers the surface of tea gardens, contained 11 mg of tannins (including catechins) and 1.5 mg of caffeine per 1 g of dry matter (Inagaki and Tsushi 2020). Thus, it is considered that the soil environment of tea fields is unfavorable for weed germination; however, various weed species can be found growing in tea fields (Seo 2016). In our previous study, we found that Stellaria media, which is a common weed species in tea gardens, had high intraspecific variation and was more resistant to catechins and caffeine than S. media individuals that grew outside the investigated tea garden (Inagaki and Tsushi 2020).In the present study, we report that Sonchus oleraceus also has intraspecific mutations which make its seeds resistant to catechins and caffeine. In addition, we also report intraspecific variation in seed germination phenology of S. oleraceus that grew in tea gardens, which helped these plants to adapt to tea garden management.

Materials and Methods

Plant Material

The seeds of S. oleraceus were collected from two populations, one growing in a tea garden at Shizuoka University (Fujieda City, Japan) and another growing on a farm road outside (adjacent to) the tea garden; we regarded them as the tea garden type and the field type, respectively. The seeds were air-dried and stored at room temperature (18–33 °C) until further analyses.

Experiment1. Difference in Resistance of Seed Germination to Catechin and Caffeine between the Two Populations

A total of 30 seeds were set on a filter paper in a petri dish with a diameter of 90 mm. There were a total of ten treatments: 0 g·L-1 (control), 1 g·L-1, 10 g·L-1, and 20 g·L-1 of epicatechin gallate (tea extract, manufactured by NOW Foods; hereinafter referred to as catechin), and 0 g·L-1 (control), 0.01 g·L-1, 0.1 g·L-1, 1 g·L-1, 10 g·L-1, and 20 g·L-1 of caffeine (Wako Pure Chemical Industries, Ltd., Osaka, Japan). According to the results of our preliminary test, the seeds were in a dormant state in both the tea garden type and the field type, and therefore, we added gibberellin (100 mg·L-1; Kyowa Hakko Bio Co., Ltd., Japan) to break seed dormancy. The germination test was performed at 20 °C for 12 h a day under bright light conditions. The test had three replications. The test was conducted in 2016, starting from June 15 for catechin and from June 27 for caffeine, and lasted nine days, after which the final germination rates were calculated.

Experiment2. Difference in Seed Germination Phenology between the Two Populations

The seeds of S. oleraceus were subjected to a germination test on May 10, June 15, August 8, and October 8, 2016. A total of 30 seeds were set on a filter paper in a Petri dish with a diameter of 90 mm without breaking their dormancy. The germination test was performed at 20 ℃ for 12 h a day under bright light conditions. The test had three replications. The test was conducted for nine days, after which the final germination rates were calculated.

Results and Discussion

Fig. 1 shows the final germination rates of the two types at different catechin concentrations. In both types, the germination rate tended to decrease in the 10 g·L-1 and 20 g·L-1 treatments depending on catechin concentrations. This indicated that catechin has a suppression effect on the growth of S. oleraceus seeds. There was a clear difference in the germination rates between the tea garden type and the field type in the 0 g·L-1, 1 g·L-1, and 10 g·L-1 treatments. In addition, there was a difference in the germination rates between the two types in the 20 g·L-1 treatment, namely, no germination was observed in the field type, whereas a significantly higher germination rate ($p<0.05$) was observed in the tea garden type.

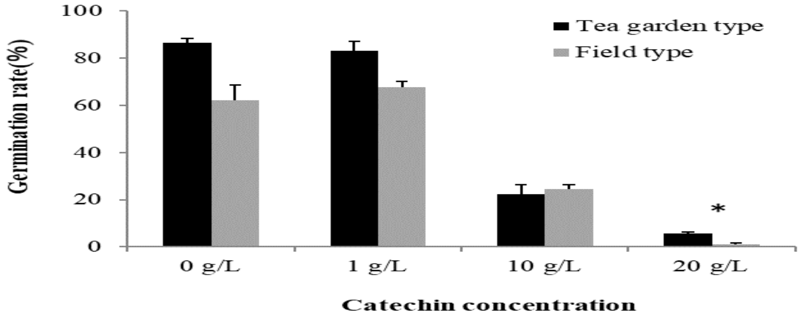

Figure1. *Germination rate of the tea garden type and the field type of Sonchus oleraceus in different concentrations of catechins*

** indicates a significant difference between the tea garden type and out the field type in the same treatment according to the t-test at a confidence level of 5% after arcsin transformation.*

Fig. 2 shows the final germination rates of the two types at different caffeine concentrations. In both types, there was no germination in the 1 g·L-1, 10 g·L-1, and 20 g·L-1. We confirmed that caffeine has a suppression effect on the germination of S. oleraceus seeds. In 0.01 g·L-1 and 0.1 g·L-1 treatments, the germination rate of the tea garden type was statistically higher ($p<0.01$) than that of the field type.

These results strongly suggested that seeds of the tea garden type of S. oleraceus were less sensitive to catechins and caffeine than those of the field type. Similar results were observed in Stellaria media, which is a common tea garden weed (Inagaki and Tsushi 2020). It is known that the resistance of weeds to heavy metals and herbicides is related to a mutation in the sensitivity of weeds to stress (Jain and Bradshaw 1966, McNeilly 1967). Regarding catechins, it was reported that in Europe, grass species that coexist with Centaurea maculosa, which exudes catechins from its roots, are more resistant to catechins than the grasses in North America where C. maculosa does not grow (Bais et al. 2003). The present study revealed that the degree of suppression was lower in the tea garden type than that in the field type. In addition, similar results were observed in our previous study on Stellaria media (Inagaki and Tsushi 2020). Therefore, some weed species that grow in tea gardens, where the litter of the tea plants accumulates on the ground, might develop resistance to catechins and caffeine. Such resistance has also been reported in bacteria from tea gardens (Fan et al. 2011; Huidrom et al. 2011), and catechins and caffeine contained in tea litter and soil may have some impacts on the tea garden ecosystem.

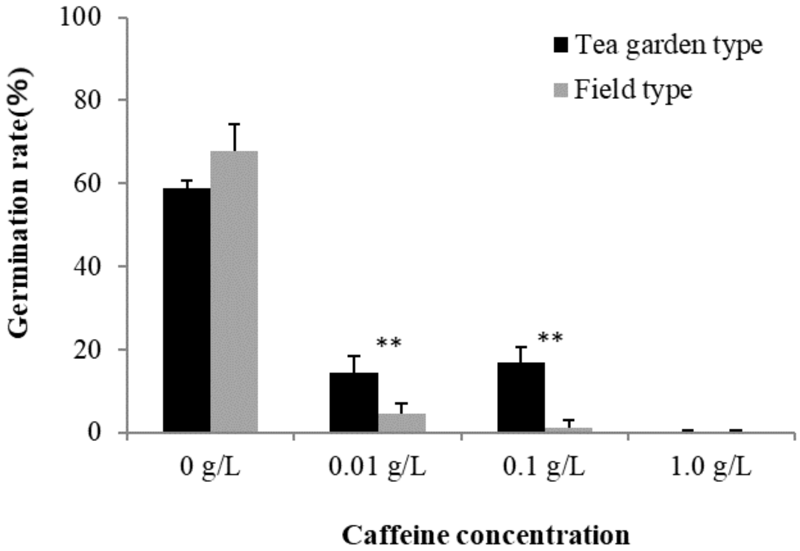

Figure2. *Germination rate of the tea garden type and out the field type of Sonchus oleraceus in different concentrations of caffeine*

*** indicates a significant difference between the tea garden type and the field type in the same treatment according to the t-test at a confidence level of 1% after arcsin transformation.*

We also observed an obvious difference in seed germination phenology between the tea garden type and the field type, i.e., the germination rate of the field type was high only in August, whereas the germination rate of the tea garden type was high throughout the test season, from May to October (Fig. 3). S. oleraceus is a biennial weed species whose seeds emerge from summer to autumn (Asano 1995). The seed germination phenology in the tea field type were found to break dormancy in the summer, which is consistent with the life history of S. oleraceus. In contrast, the seeds of the tea garden type were able to germinate throughout the season. In addition, the germination rate of the tea garden type seeds was higher in May and June than in August and October. The original life history of S. oleraceus plants, which emerge only in autumn, is not always adaptive for tea garden, because there are any disturbances such as harvesting and weeding throughout the year. Therefore, we concluded that the tea garden type has acquired the ability to germinate regardless of seasonality. Furthermore, this asymmetry of emergence in the tea garden type of S. oleraceus may make the control of this weed difficult in tea gardens.

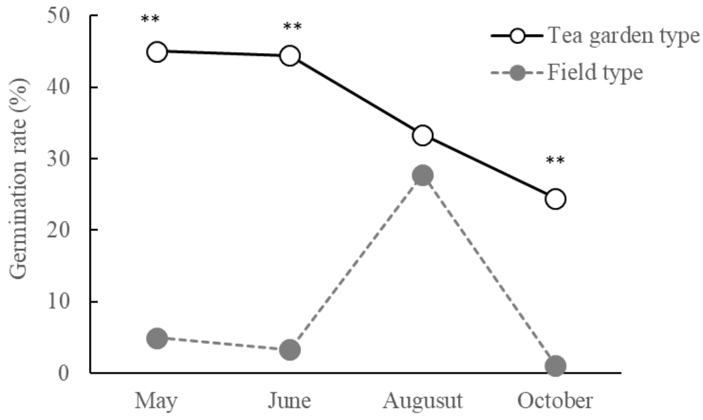

Figure3. *Seasonal change in the germination rate of the tea garden type and the field type of Sonchus oleraceus*

*** indicates a significant difference between the tea garden type and the field type in the same season according to the t-test at a confidence level of 1% after arcsin transformation.*

Conclusion

This study shown that S. oleraceus which is one of the common weed species in tea gardens has intraspecific variation of germination characteristics, and seeds from a tea garden population possess resistance to catechins and caffeine compared with seeds from a population outside of the tea garden. In addition, the seeds from the tea garden population were able to germinate throughout the season in order to adapt to disturbances owing to tea garden management, although in their natural life history, the seeds of S. oleraceus break dormancy and emerge from summer to autumn. It is interesting that weeds develop intraspecific variation in such close areas, outside the tea plantation and inside the tea plantation. Further studies of the intraspecific variation of other weed species are expected to reveal the unique ecosystem formed in tea gardens and provide useful knowledge for weed control in tea garden.

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