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Investigation of Seed Germination Inhibitory Factors by Allelopathy of Purple Nutsedge Essential Oil

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Summary

The effect of allelopathic germination inhibitory effect of essential oil from tubers of purple nutsedge (*Cyperus rotundus* L.) on seeds of weeds and crops was investigated. Test plants were 5 weeds and 5 cultivated crops (Weeds: *Eleusine indica* (L.) Gaertn., *Digitaria ciliaris* (Retz.) Koeler, *Bidens pilosa* L. var. *pilosa*, *Galinsoga quadriradiata* (*ciliata*) (Raf.) Blake, *Trifolium repens* L., Crops: *Zea mays* L., *Daucus carota* L., *Lactuca sativa* var. *crispa*, *Raphanus sativus* var. *sativus*, *Brassica rapa* var. *perviridis*. Addition of 400 ppm concentration of purple nutsedge essential oil significantly reduced the germination percentage of weed seeds. In particular, the germination percentage was remarkably suppressed to 0% in *Galinsoga*. Among crop seeds, the germination rate decreased only in carrot. The germination rate tended to be lower for plants with smaller seed sizes. The seed germination rate of *Galinsoga*, which has the smallest seed size, decreased as the concentration of essential oil increased, even at concentrations of 40 ppm or less. On the other hand, the germination rate of komatsuna seeds did not decrease even at essential oil concentration of 600 ppm.

INTRODUCTION

Allelopathy is a phenomenon in which chemicals released by plants exert some inhibitory or stimulatory effect on other organisms. In agriculture, research is being conducted on its use for weeds suppression and crop growth promotion (Kobayashi and Ito, 1998; Scavo and Mauromicale, 2021). Among green manures, the effectiveness of white mustard and hairy vetch in controlling pests and weeds is thought to be caused by allelopathy. However, the effect is greatly influenced by the target plant species and environment, and for practical application, it is necessary not only to identify the causative agent of allelopathy but also to clarify the factors such as the sensitivity of the recipient plant (Islam and Hasan, 2021).

The purple nutsedge (*Cyperus rotundus* L.) belongs to Cyperaceae. It is a perennial herb that is native to southern Japan and sub-tropical to tropical areas of the world. This herb grows on maritime sands, roadside and shore of paddy field. Tubers of this plants used as a traditional herbal medicine for nervous disease or menstrual problem (Kilani et al., 2008). However, purple nutsedge has an underground tuber, and even if the above-ground part is removed, the remaining tubers continue to sprout. Therefore, in Japan, it is treated as a tough weed that is difficult to eradicate in upland fields. The purple nutsedge has been shown to exhibit growth-inhibiting allelopathic effects (Quayyum et al., 2000; Abo-Altemen et al., 2019). Therefore, in this study, we investigated the effect on the germination percentage of weed and crop seeds using the essential oil of purple nutsedge (Stoller and Sweet, 1987; Keeley, 1987; Komai et al., 1990; Dhillon et al., 1993), which has been reported to have an inhibitory effect on seed germination. Besides, we examined the relationship with the characteristics of the seeds and inhibitory effect of purple nutsedge essential oil.

MATERIALS AND METHODS

Tubers of purple nutsedge collected at the Atsugi Campus of Tokyo University of Agriculture, Kanagawa Prefecture. The essential oil of purple nutsedge was obtained by steam distillation of these tubers. In the germination test, 20 seeds and 2 mL of pure water-diluted purple nutsedge essential oil solution (contained 0.05 % Tween 20) were placed in a glass petri dish (φ60 mm×20 mm) lined with one layer of filter paper (No.2, Advantec Co., Ltd.). Water was used in a control. However, since sweet corn has a larger seed size than others, φ90 mm petri dishes were used and the amount of added water was increased (total amount was 10mL), resulting in an essential oil concentration of 80 ppm. The petri dishes were maintained in an incubator at 24℃ and 18-hour light / 6-hour dark condition. The seed germination rate of each dish was measured.

Test plants were 5 weeds and 5 cultivated crops. Weeds: goosegrass (*Eleusine indica* (L.) Gaertn.), southern crabgrass (*Digitaria ciliaris* (Retz.) Koeler), hairy beggarticks (*Bidens pilosa* L. var. *pilosa*), hairy galinsoga (*Galinsoga quadriradiata* (*ciliata*) (Raf.) Blake), white clover 'Huia' (*Trifolium repens* L.), Crops: 'Golden Bantam' sweet corn (*Zea mays* L.), 'Tokinasi Sansun' carrot (*Daucus carota* L.), red-leaf lettuce (*Lactuca sativa* var. *crispa*), 'Kuroha mino wase' Chinese radish (*Raphanus sativus* var. *sativus*), 'Ajisai' komatsuna (*Brassica rapa* var. *perviridis*). The species and time to germination measurement are shown in Tables 1 and 2, respectively. The survey was repeated three times in each plot. Seed length, thickness and 1000-grain weight were also measured for each test plant.

Table 1. List of test weeds and incubation conditions for seed germination.

Common name	Scientific name	Family name	Incubating temperature (°C)	Light condition	Incubation time (hr)
Goosegrass	*Eleusine indica*	Poaceae	30	18h-L/6h-D	72
Southern crabgrass	*Digitaria ciliaris*	Poaceae	24	18h-L/6h-D	72
Hairy beggar-ticks	*Bidens pilosa* var. *pilosa*	Asteraceae	24	18h-L/6h-D	72
Hairy galinsoga	*Galinsoga quadriradiata*	Asteraceae	22	18h-L/6h-D	72
White clover 'Huia'	*Trifolium repen*s	Fabaceae	24	18h-L/6h-D	72

Table 2. List of test vegetables and incubation conditions for seed germination.

Common name	Scientific name	Family name	Incubating temperature (°C)	Light condition	Incubation time (hr)
Sweet corn 'Golden Bantam'	*Zea mays*	Poaceae	24	18h-L/6h-D	72
Carrot 'Tokinasi sansun'	*Daucus carota*	Apiaceae	24	18h-L/6h-D	120
Red-leaf lettuce	*Lactuca sativa var. crispa*	Asteraceae	24	18h-L/6h-D	72
Chinese radish 'Kuroha mino wase'	*Raphanus sativus* var. *sativus*	Brassicaceae	24	Dark	72
Konatsuna 'Ajisai'	*Brassica rapa var. perviridis*	Brassicaceae	22	Dark	48

RESULTS AND DISCUSSION

Addition of 400 ppm concentration of purple nutsedge essential oil significantly reduced the germination rate of weed seeds. In particular, the germination rate was remarkably suppressed to 0% in hairy galinsoga (**Fig. 1**).

Among crop seeds, the germination rate decreased only in carrot (**Fig. 2**). The germination rate tended to be lower for plants with smaller seed sizes (**Figs. 3 and 4**). In particular, the correlation coefficient between germination rate and 1000-grain weight was as high as 0.73 in plants with 1000-grain weight of 3 g or less.

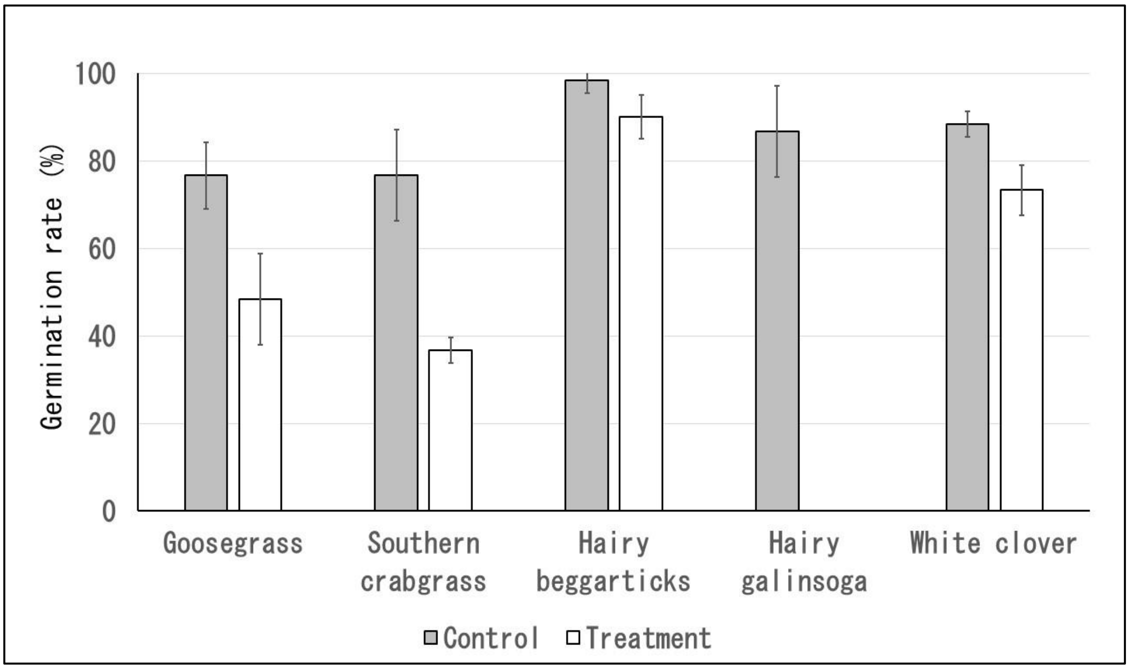

Figure 1. Effect of essential oil obtained from tubers of purple nutsedge at 400 ppm on germination rate of weed seeds (n = 3, error bars are standard deviation).

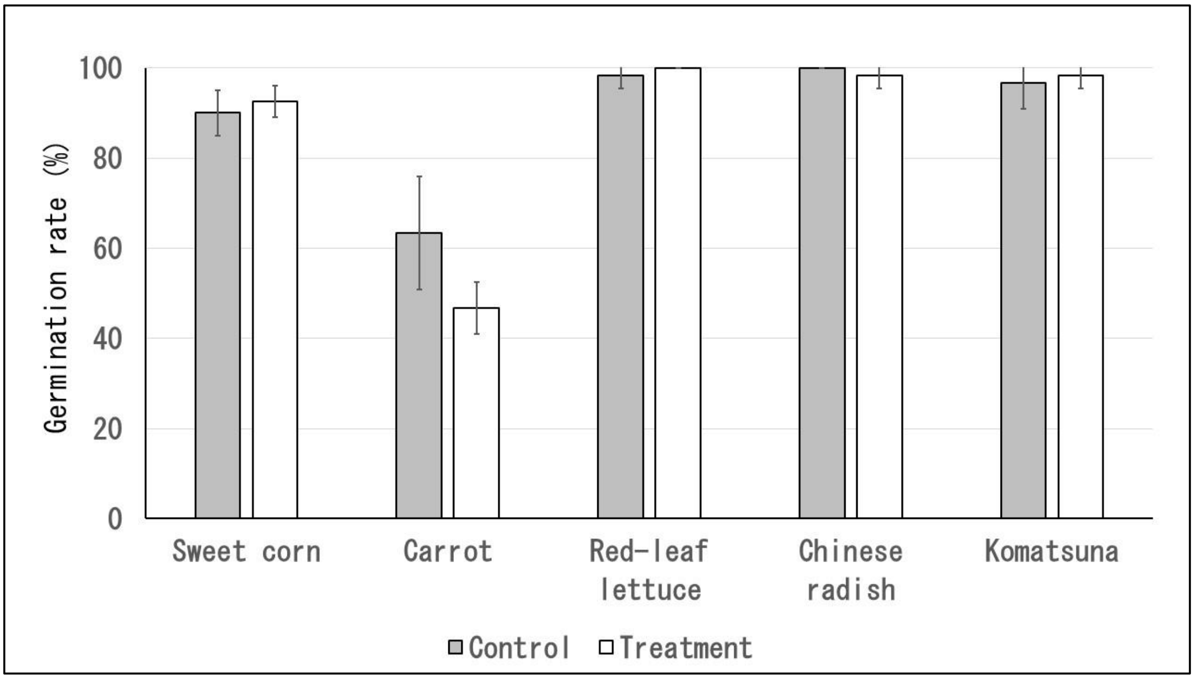

Figure 2. Effect of essential oil obtained from tubers of purple nutsedge at 400 ppm on germination rate of vegetable seeds (n = 3, error bars are standard deviation).

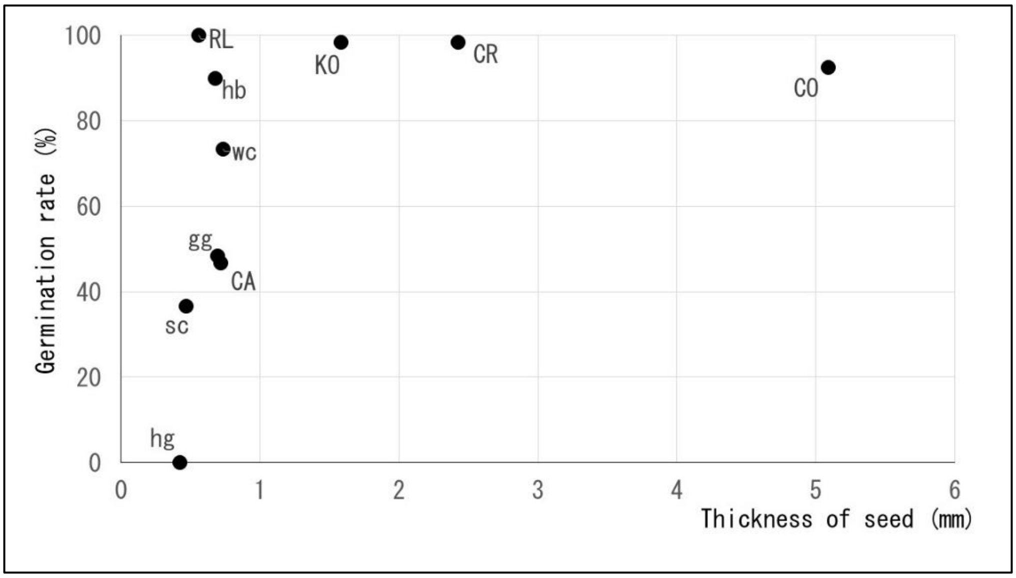

Figure 3. Relationship between thickness of seed and germination rate of seeds treated with essential oil obtained from tubers of purple nutsedge. Abbreviations: gg = goosegrass, sc = southern crabgrass, hb = hairy beggarticks, hg = hairy galinsoga, wc = white clover, CO = sweet corn, CA = carrot, RL = red-leaf lettuce, CR = chinese radish, KO = komatsuna.

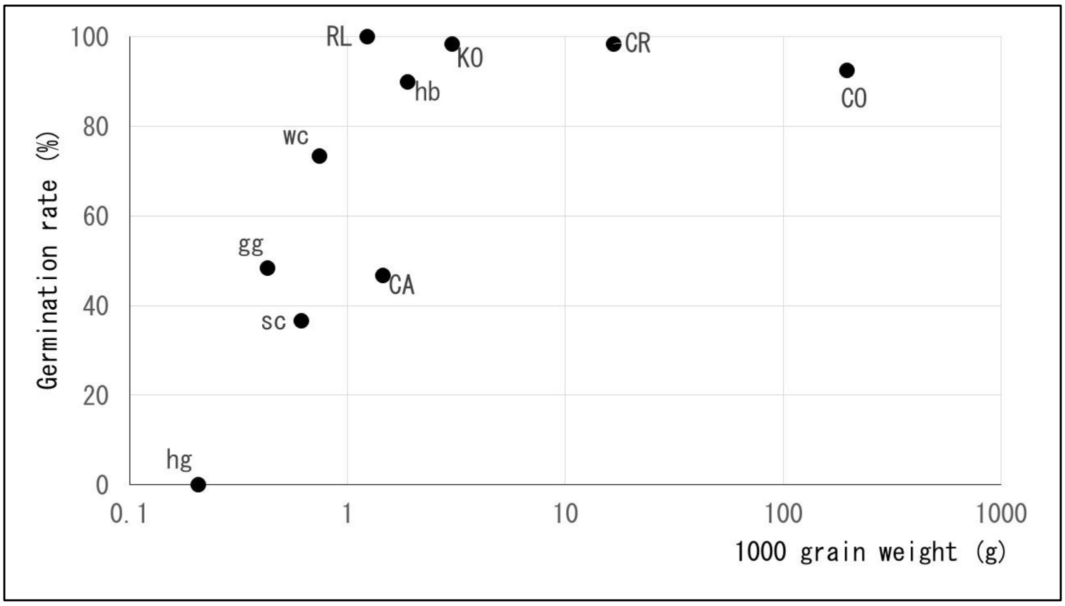

Figure 4. Relationship between weight of seed and germination rate of seeds treated with essential oil obtained from tubers of purple nutsedge. Abbreviations are the same as Figure 3.

The seed germination rate of hairy galinsoga, which has the smallest seed size, decreased as the concentration of essential oil increased, even at concentrations of 40 ppm or less (**Fig. 5**). On the other hand, the germination rate of komatsuna seeds did not decrease even at essential oil concentration of 600 ppm (**Fig. 6**), suggesting that germination of komatsuna seeds would not be affected until concentrations higher than this.

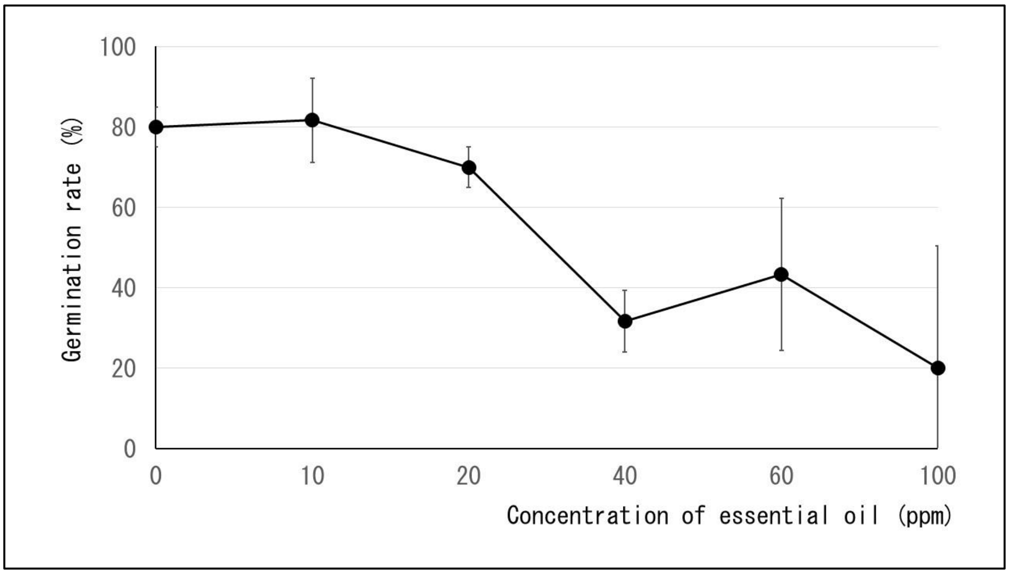

Figure 5. Effect of essential oil concentration of purple nutsedge on germination rate of hairy galinsoga (n = 3, error bars are standard deviation).

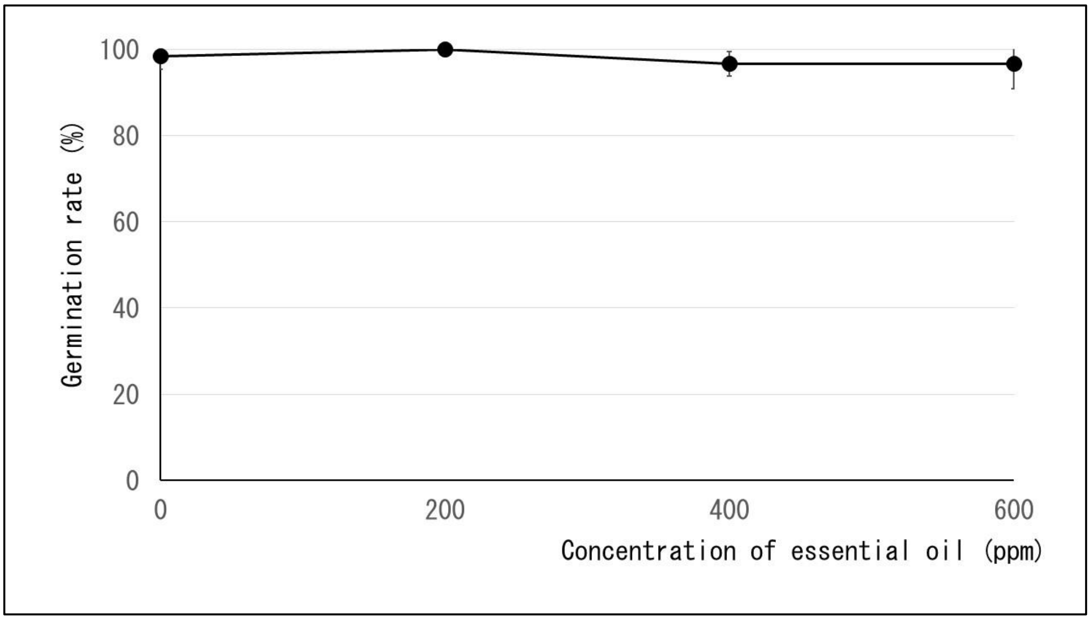

Figure 6. Effect of essential oil concentration of purple nutsedge on germination rate of komatsuna (n = 3, error bars are standard deviation).

From these results, it is considered that the weight of seed to be applied to the seed size greatly affects the suppression of germination by the essential oil of the nutgrass.

However, the difference in germination rate between carrot and lettuce was observed even though the seed size was similar, suggesting that not only the quantitative factor of the inhibitor but also the difference in susceptibility between plant species is involved.

In conclusion, from the above results, it is expected that the essential oil of purple nutsedge can be used as a natural pesticide for controlling weeds small seeds, although it inhibits the germination of weed seeds, but hardly inhibits the germination of crop seeds.

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