Does Allelopathy Play a Role in Suppression of Mugwort 
(*Artemisia vulgaris*) by Alfalfa?

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Abstract: Alfalfa suppresses mugwort growth in the field. In the present study, the allelopathic effect of alfalfa on mugwort was examined using the above-ground (AGAB) and under-ground alfalfa biomasses (UGAB), and their water extracts. The sprouting of mugwort rhizomes or seed germination, growth of seedlings and leaf color changes in mugwort seedlings were evaluated in pot experiments. AGAB mixed into soil highly inhibited sprouting of mugwort rhizome fragments and growth of seedlings. The inhibitory effect was increased, and gradual leaf discoloration (yellowing) was observed in response to a higher dose of AGAB. However, UGAB affected neither sprouting of mugwort rhizome fragments nor growth of seedlings. The growth of mugwort seedlings was not significantly affected by water extracts of either AGAB or UGAB applied after emergence. The seed germination and seedling growth were significantly reduced by water extracts of AGAB and UGAB in the petri dishes experiments. These results indicated that the allelopathic effect of alfalfa along with the competitive ability and harvesting regime may play an important role in suppressing mugwort growth.

Key words: Allelopathy, Germination, Leaf Color, Mugwort, Rhizome Sprouting, Seedling Growth.

Mugwort (*Artemisia vulgaris* L.) is said to be one of the most hazardous perennial weeds in the world (Holm et al., 1977). Mugwort is found in almost all farming systems on all continents (Holm et al., 1996) such as hazelnuts, nurseries, orchards and tea plantations in Black Sea Region of Turkey (Guncan, 1982; Onen, 1999). The reproduction of mugwort is mainly through rhizome fragments (Guncan, 1982), but occasionally reproduced with seeds in the Turkey (Onen, 2006). The extensive rhizome system provides new shoots, and competes for water and nutrients with crops. Mugwort contains numerous phytotoxic components, and is highly phytotoxic to seed germination and seedling growth of a number of crops and weeds (Hoffmann and Herrmann, 1982; Misra and Singh, 1986; Inderjit and Fo, 1999; Onen and Oz, 1999, 2002; Onen et al., 2002), and even phytotoxic on itself (Onen, 2007). Since, the control of mugwort is quite difficult (Bradley and Hagood, 2002); the crop production and maintenance expenses are increased, crop yield and quality are reduced, and biodiversity is severely reduced (Bing, 1983; Holm et al., 1996; Inderjit and Bhowmik, 2002).

Alfalfa (*Medicago sativa* L.), called the “Queen of the Forages” owing to the nutritional quality, is an herbaceous cool season perennial legume, lives for five to twelve years, and is harvested three to seven times a year. The crop forms a dense stand, and produces high biomass, and the roots grow deeper than 140 cm (Pietola and Smucker, 1995; Xuan and Tsuzuki, 2002). The strong growth makes alfalfa one of the most competitive crops in suppressing weeds (Anderson, 1999). Alfalfa was also reported having water-soluble allelopathic chemicals that reduces establishment and growth of other plants (Abdul-Rahman and Habib, 1989; Hedge and Miller, 1990; Ells and McSay, 1995a).

Alfalfa suppresses mugwort growth under the field conditions (Onen, 1999). However, mugwort is reported quite competitive and resistant to frequent cutting and other broadleaf weed management practices (Guncan, 1982; Bing, 1983). Frequent mowing of weeds for two vegetation periods, as applied in alfalfa cropping, decreased the mugwort stem number by about 39%. When the weed stems were cut at two- and three-month intervals, the decrease in stem numbers were 27% and 2%, respectively (Ozer and Onen, 2002). Thus, suppression of mugwort by alfalfa cannot solely be explained by competition or harvesting regime, and allelopathy is probably involved in the interaction. Assessment of allelopathic effect on mugwort might offer an attractive environmentally friendly alternative to herbicides in agricultural pest management (Farooq et al., 2011). The
objective of this study was to investigate the extent of allelopathy in alfalfa-mugwort interaction by evaluating the effect of alfalfa residues incorporated into soil and water extracts on the growth and leaf color of mugwort in a greenhouse, and the effect of alfalfa extracts on mugwort seedlings in laboratory experiments.

Material and Methods

Greenhouse and laboratory experiments were conducted to determine the allelopathic effect of above-ground alfalfa biomass (AGAB) and under-ground alfalfa biomass (UGAB) mixed into soil on sprouting of mugwort rhizomes and growth of seedlings. The inhibitory effects of water extracts of AGAB and UGAB on seed germination and impact of the extract applied by foliar spray on mugwort seedlings were also evaluated. The seeds and rhizome fragments of mugwort and alfalfa (Kayseri variety) plant tissues were collected from the Fruit Seedling Production Station in Tokat-Turkey and nearby fields. The greenhouse temperature ranged from 19 to 30°C through the experiments.

1. Alfalfa residues mixed into soil

AGAB and UGAB were air-dried, ground and thoroughly mixed into the silty clay loam soil on which alfalfa had not been sown, at rates of 0 (control), 1, 2, 3, and 4%. AGAB in each harvest (5 times a year in the region) was almost equal to 1% of incorporated rate, while total AGAB within a year was almost equal to 4% of the rate of soil incorporation. The soil was air-dried at room temperature, ground and passed through a 2-mm sieve. One and a half kg of soil mixture was homogenously placed in 10 cm × 16 cm × 21 cm plastic trays. Five rhizome fragments of mugwort, 1 cm in length, were planted in separate trays, and watered to field capacity. The trays were left to drain for one day. The weights were recorded and water was supplied as needed to maintain the initial moisture. The experiments were continued for 4 wk, and seedlings were harvested. Sprouting percentage of rhizome fragments, lengths of shoots, leaf color, and fresh weights of shoots and roots of seedlings were determined. Treatments in the experiment were arranged in a completely randomized design with four replicates, and repeated twice.

Three leaves selected at random from each plastic tray were sampled, and the color of each leaf was determined twice. Leaf color was described in a three-dimensional color space with designations of lightness (L*), red to green scale (a*), and blue to yellow scale (b*), respectively. Colorimetric parameters of mugwort seedlings were taken as L*, a*, and b* values using a Chromameter (Minolta CR-300 Chroma Meter, Osaka, Japan). Hue angles were calculated to represent actual leaf color changes of mugwort seedlings after the soil incorporation of alfalfa plant materials (Little, 1975):  

\[ \text{Hue angles} = \tan^{-1} \left( \frac{b}{a} \right) \]

2. Foliar applied alfalfa extracts

Ten-cm diameter plastic pots were filled with 600 g of soil, and three 1 cm length mugwort rhizome fragments were planted into each pot. The pots were watered as needed. The seedlings were thinned to 1 per pot after emergence. Mugwort plants at the three-leaf stage were sprayed with full-strength water extracts of AGAB and UGAB (contained 5% acetone, v/v) at a rate of 209 L ha⁻¹. Distilled water (contained 5% acetone, v/v) was applied as control. The details of extract preparations were given in the laboratory experiments. Pots were covered with cellophane to prevent soil contamination (Norrswhy, 2003). The experiment was set up in a completely randomized design with five replicates, and experiment was conducted three times. The experiments were continued for 2 wk, and shoots of mugworts were harvested from the soil surface; and, lengths and weights were determined.

3. Effects of alfalfa extracts on seed germination

Air-dried AGAB and UGAB were ground. Ten grams of plant biomass were weighed, and soaked in 100 mL of distilled water for 24 hr, separately. The extracts were stirred for 5 min, filtered through filter paper (Whatman No 1, Whatman Int. Ltd., Maidston, England), centrifuged at 5000 rpm for 15 min, and supernatants were collected. The extracts were diluted in distilled water to make 5, 10, 25, and 50% (v/v) concentrations, with distilled water used as the control (0%). Twenty-five mugwort seeds were evenly distributed in each 9 cm diameter petri dish lined with two layers of filter paper. Five ml of extract solution or distilled water (control) was pipetted into a petri dish, and sealed with parafilm. Experiment was conducted with four replicates in a completely randomized design. Petri dishes were incubated at 12 hr dark/light at an average temperature of 24°C (Onen, 2006). Germinated seeds were counted every day, until no germination was observed for three successive days. A seed that produced at least a 1 mm radicle was considered as germinated (Katembe et al., 1998). At the end of the incubation period (10 d), radicle and hypocotyl lengths of mugwort seedlings were measured, and percentage germination (PG), mean germination time (MGT) and percentage inhibition or stimulation (PIS) were calculated as follows (Saxena et al., 1996):

\[ \text{PG} = \left( \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \right) \times 100 \]

\[ \text{MGT (days)} = \frac{\sum (t_i \times n_i)}{\sum n_i} \]

\[ \text{PIS} = 100 - \left( \frac{\text{PG in extracts (%)}}{\text{PG in control (%)}} \right) \times 100 \]

Where \( t_i \) is the number of days starting from the beginning date of the experiment, and \( n_i \) is the number of seed germinated daily. The PG data were arcsine transformed before analysis to normalize the data.
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Table 1. Regeneration of mugwort rhizome fragments, and growth of seedlings regenerated from rhizome fragments affected by soil incorporated above-ground alfalfa biomass (AGAB) and under-ground alfalfa biomass (UGAB).

| Soil incorporated alfalfa material | Soil incorporated amount (%) | Regenerated rhizome number | PIS | Shoot length (cm) | Root length (cm) | Fresh shoot weight (g) | Fresh root weight (g) |
|------------------------------------|------------------------------|---------------------------|-----|-------------------|------------------|------------------------|------------------------|
| Control                            | 0                            | 4.5 a                     | 0.0 | 6.2 a             | 5.6 ab           | 1.16 a                 | 0.75 a                 |
| AGAB                               | 1                            | 3.6 ab                    | -20.0 | 4.7 b           | 4.6 ab           | 0.62 b                 | 0.50 b                 |
|                                   | 2                            | 2.6 b                     | -42.2 | 2.2 c           | 1.8 c           | 0.19 c                 | 0.22 c                 |
|                                   | 3                            | 1.5 c                     | -66.7 | 1.7 c           | 0.3 d           | 0.08 c                 | 0.04 cd                |
|                                   | 4                            | 0.8 c                     | -82.2 | 1.2 c           | 0.1 d           | 0.03 c                 | 0.01 d                 |
| UGAB                               | 1                            | 4.5 a                     | 0.0  | 5.1 ab           | 4.8 ab           | 1.15 a                 | 0.69 ab                |
|                                   | 2                            | 4.5 a                     | 0.0  | 5.6 ab           | 5.7 a           | 1.25 a                 | 0.81 a                 |
|                                   | 3                            | 3.9 a                     | -13.3 | 6.5 a           | 5.0 ab           | 1.50 a                 | 0.79 a                 |
|                                   | 4                            | 3.6 ab                    | -20.0 | 5.5 ab           | 4.3 b           | 1.18 a                 | 0.65 ab                |

Abbreviations: PIS, Percentage Inhibition or Stimulation of sprouting of rhizome fragments.

The means in a column followed by the same letter are not significantly different at the 5% level by Fisher’s protected LSD test.

distribution (Gomez and Gomez, 1984), and retransformed data were presented in the results.

4. Statistical analysis

Computations were performed using SPSS software (SPSS, 2001). All data were analyzed by ANOVA, and the treatments means were separated using the Least Significant Difference (LSD) test at 5% level of significance.

Results and Discussion

1. Inhibitory effects of alfalfa residues mixed into soil on rhizome sprouting

AGAB highly inhibited sprouting of rhizome fragments and growth of mugwort seedlings regenerated from rhizome fragments. The sprouting of rhizome fragments was totally inhibited or regenerated seedlings were soon killed in the soil containing the highest concentration of AGAB (Table 1). Sozeri (2003) reported similar effects of soil incorporated alfalfa plant materials on sprouting of root buds of Russian knapweed (Acroptilon repens (L.) DC.), and the seedlings regenerated from root fragments were also killed as observed in our experiments. Alfalfa has been reported to have inhibitory effects on some other perennial noxious weeds, such as bladygrass (Imperata cylindrica L. Beauv.) (Abdul-Rahman and Habib 1989), and Waller et al. (1993) for dandelion (Taraxacum officinale Weber) and coffeeweed (Daubentonia punicea (Cav.) D. C.).

Gradual seedling leaf discoloration (yellowing) was observed with increasing amount of AGAB mixed into soil as observed in the field experiment by Onen (1999). The leaf color became whitish at the highest and next highest dose. Significant differences were observed between AGAB application and control in L* value and hue angle (Figs. 1 and 2). However, sprouting of mugwort rhizome fragments...
and growth of seedlings were not negatively affected by UGAB mixed into soil, and leaf discoloration was not observed (Table 1 and Fig. 1).

2. Impacts of alfalfa extracts applied by foliar spray on seedlings

Alfalfa extracts did not significantly influence the growth of mugwort seedlings (Table 2). However, mugwort seedlings were slightly affected by alfalfa extracts. Some lesions occurred on the leaf margin of seedlings after AGAB extract application. The lesions began as small yellow speckles and later became necrotic symptoms. The extract from UGAB also discolored (yellowing) the leaves; however lesions did not become necrotic symptoms. The lesions on the younger leaves were produced after the application of extract.

3. Inhibitory effects of alfalfa extracts on seed germination

Water extracts of both AGAB and UGAB significantly reduced the seed germination and seedling growth of mugwort in the petri dishes experiments. At the highest concentration, seed germination of mugwort was inhibited 97% by AGAB extract, whereas only 36% of the seeds were affected by the UGAB extract application. Hypocotyl and radicle lengths, and total fresh weights of seedlings were all negatively affected especially by 25 and 50% concentrations of AGAB and the highest concentration of UGAB extracts (Table 3 and Fig. 3). However, the inhibitory effect of the extracts on radicle growth was severer than that on hypocotyl growth of mugwort seedlings. Mean germination time (MGT) was also negatively affected by the extracts, and the impact was progressively increased with increasing extract concentrations.

| Alfalfa Extract | Seedling length (cm) | Leaf number per seedling | Fresh shoot weight (g) | Fresh root weight (g) |
|-----------------|----------------------|-------------------------|------------------------|-----------------------|
|                 | Mean  SD             | Mean  SD                | Mean  SD               | Mean  SD             |
| Control (dis. water) | 4.6 n.s. 1.7 | 5.7 n.s. 1.9 | 0.14 n.s. 0.06 | 0.13 n.s. 0.03 |
| Above-ground biomass | 3.5 1.2 | 4.2 1.3 | 0.11 0.06 | 0.11 0.06 |
| Under-ground biomass | 4.0 1.2 | 4.8 1.3 | 0.11 0.05 | 0.11 0.05 |

n.s. : Not significant across the treatments.

| Alfalfa Extract | Extract concentration (%) | PG | PIS | MGT (Day) | Hypocotyl length (mm) | Radicle length (mm) |
|-----------------|---------------------------|----|-----|-----------|-----------------------|---------------------|
| Control (dis. water) | 0 | 87 a | – | 2.4 e | 9.9 a | 10.7 a |
| AGAB            | 5 | 83 a | –5 | 2.4 de | 10.9 a | 4.9 c |
|                 | 10 | 84 a | –4 | 2.8 d   | 10.3 a | 2.9 d |
|                 | 25 | 25 d | –71| 3.9 b   | 2.4 d   | 1.0 e |
|                 | 50 | 3 c  | –97| 5.0 a   | 0.0 f   | 0.5 e |
| UGAB            | 5 | 83 a | –5 | 2.4 e   | 11.4 a  | 8.2 b |
|                 | 10 | 72 b | –17| 2.4 c   | 9.9 a   | 2.6 d |
|                 | 25 | 67 b | –23| 2.7 d   | 7.8 b   | 1.3 e |
|                 | 50 | 56 c | –36| 3.3 c   | 5.1 c   | 1.2 e |

Abbreviations: PG, Percentage Germination; PIS, Percentage Inhibition or Stimulation of seed germination; MGT, Mean Germination Time; Above Ground Alfalfa Biomass (AGAB); Under Ground Alfalfa Biomass (UGAB).

The means in a column followed by the same letter are not significantly different at the 5% level by LSD test.
The MGT was doubled with the highest dose of AGAB extract (Table 3). Our findings in petri dish experiments were consistent with those reported elsewhere for different weeds and crop species in a variety of plant families (Chung and Miller, 1995a; Kocacaliskan and Ogutcu, 1999; Sozeri, 2003).

The allelochemicals responsible for such interactions were not identified in this study. However, water-soluble allelochemicals such as saponins (Miller, 1983, 1996; Bialy et al., 1999), medicarpin (Dornbos et al., 1990), chlorogenic acid (Chung et al., 2000), and among the several phenolic compounds coumarin and trans-cinnamic acid were reported contributing to autotoxicity and/or allelopathy (Hedge and Miller, 1992). Alfalfa was also reported containing allelochemicals in all fresh or dry plant parts (Miller et al., 1988; Chung and Miller, 1995b; Miller, 1996), and such chemicals accumulate in the soil where the crops grown (Read and Jensen, 1989; Jennings and Nelson, 1998, 2002).

However, the inhibitory effects of AGAB extracts were greater than that of UGAB as observed in greenhouse and laboratory experiments. Thus, observations and data obtained indicated that AGAB may have some allelochemicals that are highly inhibitory on seed germination, sprouting of rhizome fragments and seedling growth of mugwort. The greater inhibitory effects of AGAB were also reported by other investigators (Chung and Miller, 1995c; Hedge and Miller, 1992). Increased amount of soil incorporated AGAB or AGAB extracts resulted in greater inhibition due to increased allelochemicals concentrations. In general, root growth of tested plant is reported more sensitive than shoot growth or seed germination to alfalfa extracts or phenolics compounds of alfalfa (Chung and Miller, 1995b; Chon et al., 2002) as observed in our experiments.

Conclusions

The results conducted under controlled conditions indicated a drastic decrease in mugwort stem number in the field which was not only due to the competitive characteristics and harvesting regime of alfalfa but also allelopathic effects of alfalfa. Although the existence of reports on reestablishment problems related to autotoxicity and negative effects of alfalfa on other plants, the allelochemicals responsible for the interaction and influence of allelochemicals have not been clearly identified. Therefore, experiments related to allelochemicals involved are needed to illuminate the possible allelopathic interference.

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References

Abdul-Rahman, A.A. and Habib, S.A. 1989. Allelopathic effect of alfalfa (Medicago sativa) on bladegrass (Imperata cylindrica). J. Chem. Ecol. 15: 2289-2300.
Andersen, W.P. 1999. Characteristics and Identification of Selected Herbaceous Species. In Perennial Weeds. Iowa State University Press, Ames, IA, USA. 19-21.
Bialy, Z., Jurzysta, M., Oleśzek, W., Piaceń, S. and Piazza, C. 1999. Saponins in alfalfa (Medicago sativa L.) root and their structural elucidation. J. Agric. Food. Chem. 47: 3185-3192.
Bing, A. 1983. Problems in mugwort control in lawns. Proceedings of the 37th Annual Meeting of the Northeastern Weed Science Society. 76.
Bradley, K.W. and Hagood, E.S. Jr. 2002. Influence of sequential herbicide treatment, herbicide application timing, and mowing on mugwort (Artemisia vulgaris) control. Weed Technol. 16: 346-352.
Chon, S.U., Choi, S.K., Jung, S., Jang, H.G., Pyo, B.S. and Kim, S.M. 2002. Effects of alfalfa leaf extracts and phenolic allelochemicals on early seedling growth and root morphology of alfalfa and barnyard grass. Crop Prot. 21: 1077-1082.
Chung, I.M. and Miller, D.A. 1995a. Natural herbicide potential of alfalfa residue on selected weed species. Agron. J. 87: 920-925.
Chung, I.M. and Miller, D.A. 1995b. Effect of alfalfa plant and soil extracts on germination and seedling growth of alfalfa. Agron. J. 87: 762-767.
Chung, I.M. and Miller, D.A. 1995c. Differences in autotoxicity among seven alfalfa cultivars. Agron. J. 87: 596-600.
Chung, I.M., Seigler, D., Miller, D.A. and Kyoung, S.H. 2000. Autotoxic compounds from fresh alfalfa leaf extracts: Identification and biological activity. J. Chem. Ecol. 26: 315-327.
Dornbos, D.L.Jr., Spencer, G.F. and Miller, R.W. 1990. Medicarpin delays alfalfa seed germination and seedling growth of alfalfa. Crop Sci. 30: 162-166.
Ells, J.E. and McSay, A.E. 1991. Allelopathic effects of alfalfa plant residues on emergence and growth of cucumber seedlings. Hortic. Sci. 26: 368-370.
Farooq, M., Jabran, K., Cheema, Z.A., Wahid, A. and Siddique, K.H.M. 2011. Role of allelopathy in agricultural pest management. Pest Manage. Sci. 67: 494-506.
Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. 2nd edition. John Wiley & Sons, New York.
Guncan, A. 1982. Artemisia vulgaris: Its Biology and Control in Tea and Hazelnut Plantations in Turkey. TUBITAK, Ankara, Turkey. 517 (TOAG-276): 45*.
Hedge, R.S. and Miller, D.A. 1990. Allelopathy and autotoxicity in alfalfa: characterization and effects of preceding crops and residue incorporation. Crop Sci. 30: 1255-1259.
Hedge, R.S. and Miller, D.A. 1992. Concentration dependency and stage of crop growth in alfalfa autotoxicity. Agron. J. 84: 940-946.
Hoffmann, B. and Herrmann, K. 1982. Flavonol glycosides of wormwood (Artemisia vulgaris), tarragon (Artemisia dracunculus L.), and absinthe (Artemisia absinthium L.). Z. Lebensm. Unters. Forsch. 174: 211-215.
Holm, L., Doll, J., Holm, E., Pancho, J. and Herberger, J. 1996. Natural Histories and Distribution. In World Weeds. John Wiley & Sons, New York.

Holm, L., Plucknett, D., Pancho, J. and Herberger, J. 1977. Distribution and Biology. In The World’s Worst Weeds. The University Press of Hawaii, Honolulu.

Inderjit and Foy, C.L. 1999. Nature of the interference mechanism of mugwort (Artemisia vulgaris). Weed Technol. 13: 176-182.

Inderjit and Bhowmik, P.C. 2002. The importance of allelochemicals in weed invasiveness and the natural suppression. In Inderjit and A.U. Mallik eds., Chemical Ecology of Plant: Allelopathy of Aquatic and Terrestrial Ecosystems. Birkhauser Verlag AG, Basel. 187-192.

Jennings, J.A. and Nelson, C.J. 1998. Influence of soil texture on alfalfa autotoxicity. Agron. J. 90: 54-58.

Jennings, J.A. and Nelson, C.J. 2002. Rotation interval and pesticide effects on establishment of alfalfa after alfalfa. Agron. J. 94: 786-791.

Kamatbe, W.J., Ungar, I.A. and Mitchell, J.P. 1998. Effect of salinity on germination and seedling growth of two Atriplex species (Chenopodiaceae). Ann. Bot. 82: 167-175.

Kocacaliskan, I. and Ogutcu, H. 1999. Allelopathic effects of alfalfa extracts on germination and seedling growth of some plant seeds. Dumlupınar Üniversitesi Fen Bilimleri Dergisi 1: 39-49.

Onen, H. and Ozer, Z. 1999. The effects of dried mugwort (Artemisia vulgaris L.) leaves and rhizomes on germination and seedling growth of some crop species. Türkiye Herboloji Dergisi 2: 22-30.

Onen, H. and Ozer, Z. 2002. Study of Allelopathic influence of mugwort (Artemisia vulgaris L.) on several crops. Z. Pflanzenk. Pflanzen. – J. Plant. Dis. Protect. 18: 339-347.

Onen, H., Ozer, Z. and Telci, I. 2002. Bioherbicidal effects of some plant essential oils on different weed species. Z. Pflanzenk. Pflanzen. – J. Plant. Dis. Protect. 18: 597-605.

Onen, H. 2006. The influence of temperature and light on seed germination of mugwort (Artemisia vulgaris L.). Z. Pflanzenk. Pflanzen. – J. Plant. Dis. Protect. 20(Special Issue): 393-399.

Onen, H. 2007. Autotoxic potential of mugwort (Artemisia vulgaris). Allelopathy J. 19: 323-335.

Ozer, Z. and Onen, H. 2002. Untersuchungen über die Wirkung der mechanischen Unkrautbekämpfung bei Beifuß (Artemisia vulgaris L.). Z. Pflanzenk. Pflanzen. – J. Plant. Dis. Protect. 18: 653-660.

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