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ORIGINAL PAPER

Allelopathic effect of *Nepeta meyeri* Benth. extracts on seed germination and seedling growth of some crop plants

Salih Mutlu · Ökkeş Atici

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Abstract In order to evaluate the allelopathic potential of *Nepeta meyeri* Benth., the effects of aqueous extracts (0.125, 0.25, 0.5, 1, 2.5 and 5%) prepared from roots and leaves of *N. meyeri* were studied on the seed germination and seedling growth of several economically important crops (barley, wheat, canola, safflower, and sunflower). Both the root and leaf extracts of *N. meyeri* caused a general phytotoxic effect on the seed germination and seedling growth of barley and sunflower at all concentrations. However, both the root and leaf extracts significantly increased the seedling growth of wheat, especially at the lower concentrations 0.125, 0.25 and 0.5%, whereas the higher concentrations had a neutral effect. The seed germination and the seedling growth of canola and safflower were also generally improved by both extracts, especially at lower concentrations. However, these advantages were not observed at higher concentrations, at which the extracts mostly had a phytotoxic effect on canola and safflower. The Allelopathic activity of *N. meyeri* depended on whether the extract was derived from the leaf or root parts of the plant. The maximum allelopathic effect occurred with leaf extracts. The results demonstrate that the aqueous extracts from *N. meyeri* have allelopathic potential and should be evaluated as an allelopathic species, presenting a risk or advantage to seed germination and seedling growth of crop or weed plants.

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S. Mutlu · Ö. Atici (✉)
Department of Biology, Science and Art Faculty,
Atatürk University, 252540 Erzurum, Turkey
e-mail: oatici@atauni.edu.tr

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Introduction

Most plants exhibit allelopathic effects on seed germination, growth and development of other plants by releasing allelochemicals into the soil, either as exudates from living organs or by decomposition of plant residues (Narwal 1999; Singh et al. 2003; Noguchi and Ino 2005). Allelochemicals are present in almost all plants and their tissues such as leaves, stems, roots, flowers, seeds, bark, and buds (Weston and Duke 2003). Allelopathic plant interactions can have either a harmful or beneficial effect and are generally evaluated by testing some physiologic mechanisms that result in the inhibition/stimulation of seed germination, plant growth and development due to the presence of another plant (Suman et al. 2002; Weston and Duke 2003).

The genus *Nepeta* (family *Lamiaceae*) contains approximately 280 species, which are widely distributed in Central and Southern Europe, and South-West, Central and Southern Asia (Dabiri and Sefidkon 2003). Previous research on *Nepeta* species indicate that it is represented by 44 taxa, including 22 endemic to Turkey (Aytac and Yildiz 1996; Dirmenci 2005). The endemic and non-endemic species are commonly found in East Anatolia and the Taurus Mountains (Dirmenci 2005). Some *Nepeta* species have antioxidant properties (Dapkevicius et al. 1998) and significant effects on viruses, bacteria, fungi and acarus (Bourrel et al. 1993; Nostro et al. 2001; Çalmaşur et al. 2006). Through our numerous field observations, it was determined that *N. meyeri* has not permitted the germination of other wild plant species into its natural environment.

Such inhibition zones around dominant plants species can provide an important ecological context for studies of allelopathy (Inderjit and Callaway 2003). Therefore, it has been hypothesized that *N. meyeri* has significant allelopathic potential.

In this study, aqueous extracts from roots and leaves of *Nepeta meyeri* were studied for their allelopathic effect on seed germination and early seedling growth of five economically important crop plants: barley, wheat, canola, sunflower and safflower.

Materials and methods

Preparation of aqueous extracts from roots and leaves of *Nepeta meyeri*

Nepeta meyeri plants during the flowering stage were collected from various zones between Erzurum and Kars provinces in East Anatolia, Turkey. The plant material was dried and was separated into roots and leaves. The dried samples were cut into 1-cm pieces and ground in a blender (Dapkevicius et al. 1998). A measure of 5 g of dry powder was stirred (125 rpm) in 100 ml of distilled water for 8 h at 20°C. The resulting solution was filtered through four layers of cheesecloth to remove debris, and centrifuged at $5{,}000 \times g$ for 30 min. The supernatant was then filtered through one layer of filter paper (Whatman no. 1). The filtered solutions (stock solution) were held for a short time at 4°C until bioassayed. The extracts used for bioassay were performed by diluting the stock solution (5% w/v) at concentrations including 0.125, 0.25, 0.5, 1.0, 2.5 and 5.0 g of the dried powders per 100 ml of distilled water (Yu et al. 2003).

Plant materials

Plant seeds of barley (*Hordeum vulgare* cv. Tokak), wheat (*Triticum aestivum* cv. Dogu-88), canola (*Brassica napus* cv. Oleifera), safflower (*Carthamus tinctorius* cv. Dincer) and sunflower (*Helianthus annuus* cv. AS-508) were obtained from the Agriculture Faculty of Atatürk University, Turkey. Before germination tests, the plant seeds were surface-sterilized with 10:1 water/bleach (commercial NaOCl) solution for 5 min and then washed six times with distilled water.

Seed germination and seedling growth

Germination tests were performed for each of the root and leaf extracts from *N. meyeri* as follows: According to seed size, 25 or 50 the sterilized seeds were evenly placed on two layers of filter paper in sterile Petri dishes (9 cm). Ten ml of the extract solutions at five concentrations of stock solution (0.125, 0.25, 0.5, 1.0, 2.5 and 5.0%) were added to each Petri dish, and distilled water was used as the control. The Petri dishes were placed in a growth chamber (25°C, 70% humidity and continuously dark). Treatments were arranged in a completely randomized design with four replications. Germination was determined by counting the number of germinated seeds at 24-h intervals over a 5-day period. After 5 days, root and shoot length, and dry matter weight of the plants was calculated. Final germination was expressed as percentage after statistical analyses were performed on the raw data. Data were analyzed using a one-way ANOVA test in SPSS 11.0, and means were compared using Duncan's multiple range test at the 1 or 5% confidence level.

Results and discussion

Previous researches have studied the composition and content of the essential oils in *Nepeta* species including *N. meyeri*, because of the interesting biological activities of the *Nepeta* species and their use in traditional medicine. Most oils of *Nepeta* species contain nepetalactones as the main components, but different oil compositions have been detected in several *Nepeta* species (Baser et al. 1998; Sajjadi and Khatamsaz 2001; Sefidkon and Shaabani 2004; Esmaeili et al. 2006). In the present study, however, we were interested in the allelopathic potential of the aqueous extracts from *Nepeta* meyeri in Turkey. The effects of aqueous extracts (0.125, 0.25, 0.5, 1, 2.5 and 5%) from the roots and the leaves of *N. meyeri* were determined on seed germination and early seedling growth (root and shoot length, and dry matter weight) of several crop plants (barley, wheat, canola, safflower and sunflower). The root and leaf extracts from *N. meyeri* had an ameliorative effect on seed germination and early seedling growth of some of the crop plants studied while having an inhibitory effect on others.

Effect of *Nepeta meyeri* extracts on seed germination

The root and leaf extracts of *N. meyeri* significantly ($P < 0.01$) inhibited seed germination of barley and sunflower, compared to respective controls (Table 1). The determined inhibitions were higher for leaf extracts than root extracts, and were more pronounced at increasing concentrations of the leaf extract. The seed germinations of barley and sunflower, for instance, were inhibited by 87 and 60%, respectively, by the application of leaf extract at 5% concentration, and were inhibited by 83 and 46%, respectively, by the application of root extract (again at 5% concentration). Oueslati (2003), who studied the allelopathic effects of wheat varieties also suggested that leaf extracts appeared to have a more pronounced phytotoxic

Table 1 The effect on final germination percentages of some crops seeds of aqueous extracts in different concentrations prepared from roots and leaves of *Nepeta meyeri* Benth

Extract (%)	Barley		Wheat		Canola		Safflower		Sunflower	
	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE
0.0	92^{a}	92^{a}	98^{a}	98^{a}	86^{b}	86^{b}	75^{bc}	75^{bc}	87^{a}	87^{a}
0.125	90^{a}	72^{b}	98^{a}	100^{a}	88^{a}	92^{a}	77^{b}	77^{b}	82^{b}	80^{b}
0.25	90^{a}	48^{c}	100^{a}	98^{a}	90^{a}	90^{a}	77^{b}	85^{a}	77^{c}	80^{b}
0.5	90^{a}	38^{d}	100^{a}	100^{a}	90^{a}	88^{a}	83^{a}	70^{c}	74^{cd}	70^{c}
1.0	82^{b}	20^{e}	98^{a}	100^{a}	90^{a}	90^{a}	70^{c}	70^{c}	72^{d}	64^{d}
2.5	56^{c}	16^{ef}	100^{a}	98^{a}	82^{bc}	76^{c}	75^{bc}	75^{bc}	60^{e}	61^{e}
5.0	16^{d}	12^{f}	100^{a}	96^{a}	80^{c}	64^{d}	50^{d}	30^{d}	47^{f}	34^{f}

Means within each column followed by the same letter are not significantly different at the 1% level as determined by Duncan's multiple range test

RE root extract, *LE* leaf extract

effect than roots extracts. In contrast, the germination of canola and safflower seeds was increased by both leaf and root extracts of *N. meyeri* at low concentration while that of wheat seeds was not affected at even the highest extract concentration (Table 1). The results show that allelochemicals in the extracts of *N. meyeri* could have a beneficial, harmful or harmless effect on seed germination of the crops.

Effect of *Nepeta meyeri* extracts on early seedling growth

The extracts from roots and leaves of *N. meyeri* significantly ($P < 0.01$) inhibited the root length of germinating barley and sunflower seedlings, compared to respective controls (Fig. 1). The inhibitions were relatively enhanced with the increasing amount of both extract concentrations. The leaf extracts proved to have more effective allelopathic effect than the roots extracts. On the contrary, the root lengths of wheat, canola and safflower seedlings were promoted by 0.125, 0.25, 0.5 and 1% concentrations of both extracts while showing a slight inhibition at 2.5 and 5% concentrations (Fig. 1). It can be concluded that the low concentrations of the extracts could stimulate the root elongation of wheat, canola and safflower, but the same concentrations had harmful effects on barley and sunflower root elongation. The results obtained from root elongation tests also support the findings from germination tests (Table 1, Fig. 1). Nojavan (1990), who studied the allelopathic effect of *N. meyeri* on wheat, also reported a similar result. In addition, the extracts did not affect the germination of wheat while increasing root elongation. Some allelochemicals can stimulate the growth of plants while having neither harmful nor beneficial effects on the seed germination (Macias et al. 1999).

The extracts from *N. meyeri* significantly inhibited shoot length and dry matter weight of barley seedlings but the same extracts generally stimulated shoot growth of wheat, canola, safflower and sunflower seedlings (Figs. 2, 3). It is interesting that the extracts had an inhibitory effect on germination and root elongation of sunflower while having an ameliorative effect on shoot elongation and dry weight (Table 1, Figs. 1, 2, 3). However, the shoot length and dry weight results obtained from the crops studied were comparable with the findings from germination to root length tests of the same crops. The results show that

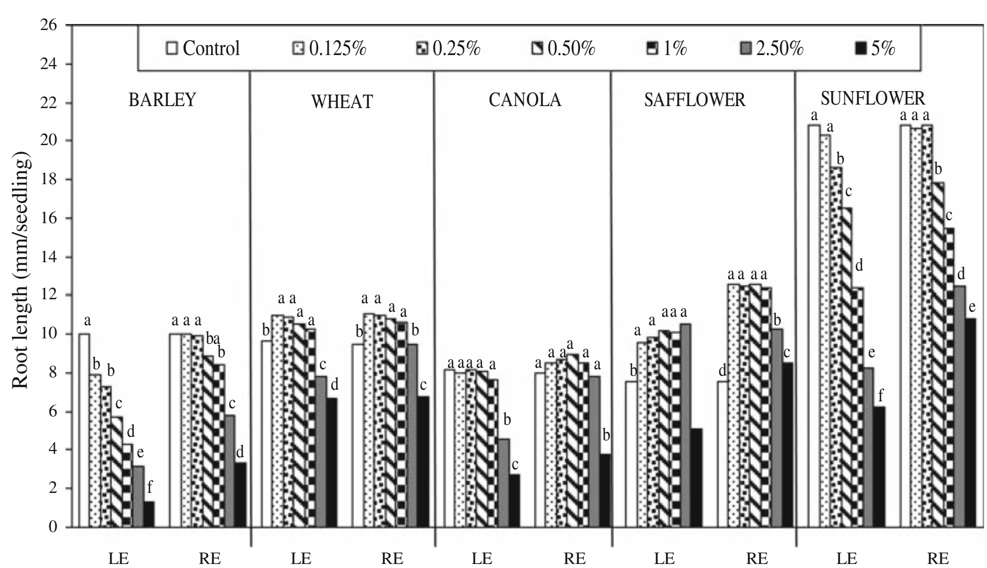
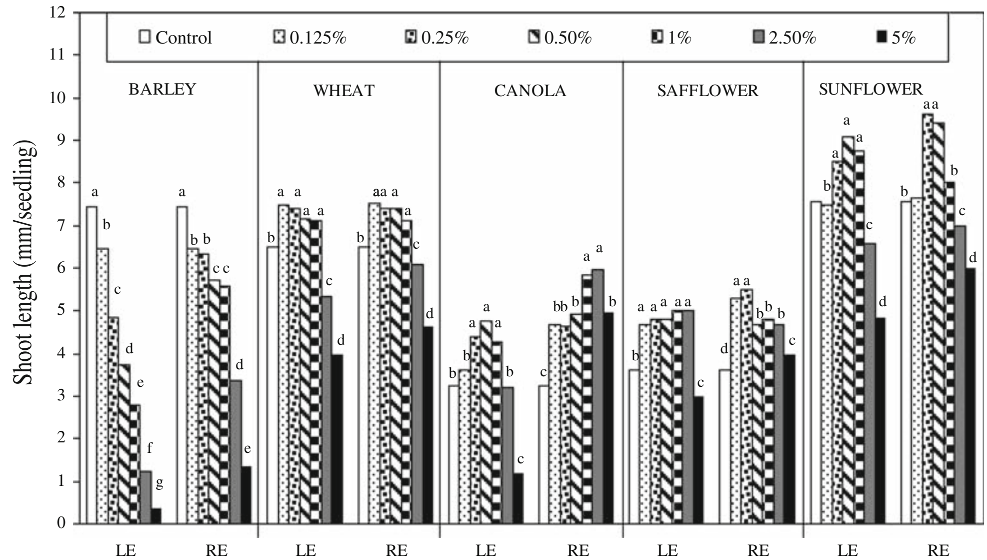


Fig. 1 Effect of root and shoot extracts of *Nepeta meyeri* on the root lengths of barley, wheat, canola, safflower and sunflower. *LE* leaf extract, *RE* root extract. Means followed by the same letter are not significantly different at the 1% level as determined by Duncan's multiple range test

Fig. 2 Effect of root and shoot extracts of *Nepeta meyeri* on the shoot lengths of barley, wheat, canola, safflower and sunflower. *LE* leaf extract, *RE* root extract. Means followed by the same letter are not significantly different at the 1% level as determined by Duncan's multiple range test



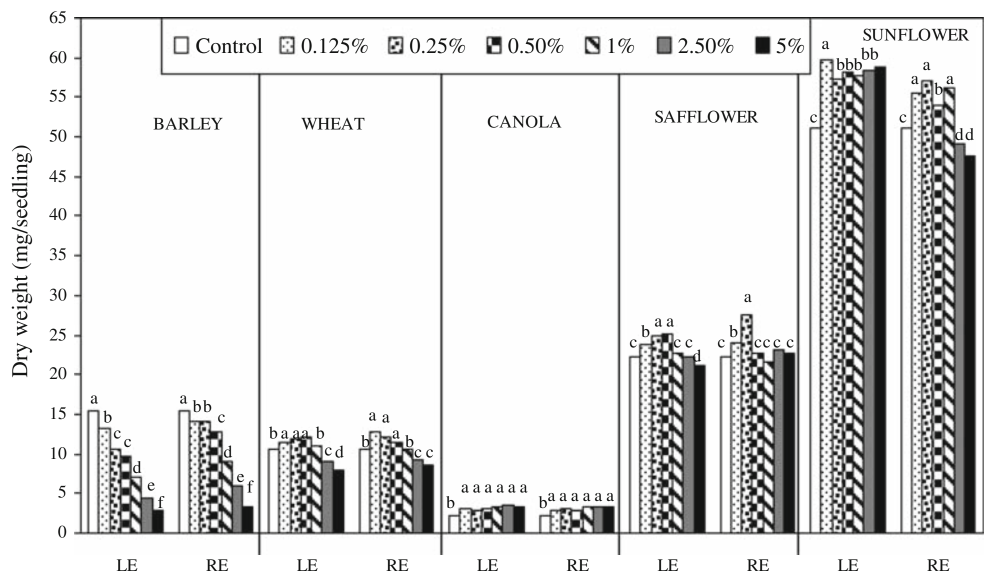


Fig. 3 Effect of root and shoot extracts of *Nepeta meyeri* on the dry matter weights of barley, wheat, canola, safflower and sunflower. *LE* leaf extract, *RE* root extract. Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test

allelochemicals in the extracts of *N. meyeri* could have both beneficial and harmful effects on growth of the crops.

It was determined that the aqueous extracts from *N. meyeri* leaf and root parts exhibited variable allelopathic activity on seed germination and seedling growth of the five food crops. Allelopathic activity depended on both the concentration levels of the extracts and the parts (leaf or root) of *N. meyeri* from which the extract was derived. This might be ascribed to differential allelopathic strength provided by constitutional variability of allelochemicals in *N. meyeri*. Differential response of various allelopathic compounds and/or their concentrations has been reported in previous findings (Wu et al. 1998, 2000; Om et al. 2002). The maximum reduction or induction generally occurred with leaf extracts. The advantages registered by low concentrations of the extracts from *N. meyeri* could not be observed at higher concentration (2.5 and 5%). High concentrations (2.5 and 5%) often inhibited both seed germination and seedling growth, except in the case of germination of wheat seeds. Similar findings were reported in studies of the allelopathic activities of *Parthenium hysterophorus* (Tefera 2002) and *Chenopodiaceae* extracts (Jefferson and Pennacchio 2003).

Overall, the phytochemicals having allelopathic properties in extracts of *Nepeta meyeri* are both species-specific and plant part (root and leaf)-dependent. The effects of the extracts cannot be categorized as only a phytotoxic effect because its extracts have both stimulatory and inhibitory effects on the crops studied. *N. meyeri* must be considered as an allelopathic species, presenting both risk and advantage to seed germination and growth of crop plants. Further research is required in order to define in detail the allelopathic characteristics of *N. meyeri*.

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References

Aytac Z, Yildiz G (1996) A new record for the Flora of Turkey. Turk J Bot 20:385–386

Baser KHC, Demircakmak B, Duman H (1998) Composition of the essential oils of *Nepeta sulfuriflora* P·H. Davis. J Essent Oil Res 10:179–181

Bourrel C, Perineau F, Michel G, Bessiere JM (1993) Catnip (*Nepeta cataria* L.) essential oil: analysis of chemical constituents, bacteriostatic and fungistatic properties. J Essent Oil Res 5:159–167

Çalmaşur O, Aslan I, Sahin F (2006) Insecticidal and acaricidal effect of three Lamiaceae plant essential oils against *Tetranychus urticae* Koch and *Bemisia tabaci* Genn. Ind Crops Prod 23:140–146. doi:10.1016/j.indcrop.2005.05.003

Dabiri M, Sefidkon F (2003) Chemical composition of the essential oil of *Nepeta racemosa* Lam. from Iran. Flavour Fragr J 18:157–158. doi:10.1002/ffj.1151

Dapkevicius A, Venskutonis R, van Beek R, Linssen JPH (1998) Antioxidant activity of extracts obtained by different isolation procedures from some aromatic herbs grown in Lithuania. J Sci Food Agric 77:140–146. doi:10.1002/(SICI)1097-0010(199805)77:1<140::AID-JSFA18>3.0.CO;2-K

Dirmenci T (2005) A new subspecies of *Nepeta* (Lamiaceae) from Turkey. Bot J Linn Soc 147:229–233. doi:10.1111/j.1095-8339.2005.00355.x

Esmaeili A, Rustaiyan A, Masoudi S, Nadji K (2006) Composition of the essential oils of *Mentha aquatica* L. and *Nepeta meyeri* Benth. from Iran. J Essent Oil Res 18:263–265

Inderjit Callaway RS (2003) Experimental designs for the study of allelopathy. Plant Soil 256:1–11

Jefferson LV, Pennacchio M (2003) Allelopathic effects of foliage extracts from four *Chenopodiaceae* species on seed germination. J Arid Environ 55:275–285. doi:10.1016/S0140-1963(03)00028-4

Macias FA, Oliva RM, Varela M, Torres A, Molinillo MG (1999) Allelochemicals from sunflower leaves cv. Peredovick. Phytochemistry 52:613–621. doi:10.1016/S0031-9422(99)00141-7

Narwal SS (1999) Allelopathy update, basic and applied aspects, vol 2. Science Publishers Inc., New Hampshire, pp 200–254

Noguchi HK, Ino T (2005) Possible involvement of momilactone B in rice allelopathy. J Plant Physiol 162:718–721. doi:10.1016/j.jplph.2004.11.009

Nojavan AM (1990) An Investigation of allelopathic effects of catnip (*Nepeta meyeri* L.) on seed germination and seedling growth of wheat and radish. Res J Esphahan Univ Fall

Nostro A, Cannatelli MA, Crisafi G, Alonzo V (2001) The effect of *Nepeta cataria* extract on enzyme production of *Staphylococcus aureus*. Int J Antimicrob Agents 18:583–585. doi:10.1016/S0924-8579(01)00452-6

Om H, Dhiman SD, Kumar S, Kumar H (2002) Allelopathic response of *Phalaris minor* to crop and weed plants in rice–wheat system. Crop Prot 21:669–705. doi:10.1016/S0261-2194(02)00025-X

Oueslati O (2003) Allelopathy in two durum wheat (*Triticum durum* L.) varieties. Agric Ecosyst Environ 96:161–163

Sajjadi SE, Khatamsaz M (2001) Volatile constituents of *Nepeta heliotropifolia* Lam. J Essen Oil Res 13:204–205

Sefidkon F, Shaabani A (2004) Essential oil composition from *Nepeta meyeri* Benth from Iran. Flavour Fragr J 19:236–238. doi:10.1002/ffj.1294

Singh HP, Batish DR, Kohli RK (2003) Allelopathic ınteractions and allelochemicals: new possibilities for sustainable weed management. Crit Rev Plant Sci 22:239–311. doi:10.1080/713610858

Suman A, Shahi HN, Singh P, Guar A (2002) Allelopathic influence of *Vigna mungo* (black gram) seeds on germination and radical growth of some crop plants. Plant Growth Regul 38:69–74. doi:10.1023/A:1020943011207

Tefera T (2002) Allelopathic effects of *Parthenium hysterophorus* extracts on seed germination and seedling growth of *Eragrostis tef*. J Agron Crop Sci 188:306–310. doi:10.1046/j.1439-037X.2002.00564.x

Weston LA, Duke SO (2003) Weed and crop allelopathy. Crit Rev Plant Sci 22:367–389. doi:10.1080/713610861

Wu L, Guo X, Harivandi MA (1998) Allelopathic effects of phenolic acids detected in buffalograss (*Buchloe dactyloides*) clippings on growth of annual bluegrass (*Poa annua*) and buffalograss seedlings. Environ Exp Bot 39:159–167. doi:10.1016/S0098-8472(97)00040-3

Wu H, Haig T, Pratley J, Lemerle D, An M (2000) Distribution and exudation of allelochemicals in wheat *Triticum aestivum*. J Chem Ecol 26:2141–2154. doi:10.1023/A:1005520500110

Yu JQ, Ye SF, Zhang MF, Hu WH (2003) Effects of root exudates and aqueous root extracts cucumber (*Cucumis sativus*) and allelochemicals, on photosynthesis and antioxidant enzymes in cucumber. Biochem Syst Ecol 31:129–139. doi:10.1016/S0305-1978(02)00150-3