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The ecological significance of allelopathy in the community organization of *Alhagi graecorum* Boiss.

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Abstract

Field study revealed that species diversity index of the community was 0.597. The data of interspecific association index of *Alhagi graecorum* and each of its associates, *Chenopodium murale, Glinus lotoides* and *Malva parviflora,* were 0.35, 0.41 and 0.33, respectively. Therefore, a net negative association and low diversity among the species were the main characters of the community. Laboratory experiments verified the role played by competition and allelopathy in this community organization. The bioassay results indicated that *A. graecorum* exhibited phytotoxic activity on the tested species. Accordingly, water-borne allelopathic compounds may be released from *A. graecorum* into the environment and suppress the growth of its associates where they were not able to compete with *A. graecorum* in the field, so the latter species become dominant.

Additional key words: allelochemicals, association index, diversity index, *Chenopodium murale, Glinus lotoides, Malva parviflora,* resource competition.

Introduction

The community is merely an assemblage of population in a given area. Its structure, functioning, and dynamics are governed by various kinds of positive, negative or indifferent interactions between the species, besides their interactions with the environment. Since Darwin (1859), competition has been the subject of innumerable investigations and considerable discussion in ecology (*e.g.* Keddy 1989, Grace and Tilman 1990). Therefore, most ecologists have attempted to explain the pattering of vegetation and the general distribution of plants largely on the basis of competition. In a survey conducted by the British Ecological Society, competition was ranked the fifth among the fifty most important ecological concepts (Cherrett 1989).

Recently, allelopathy and resource competition are the two mechanisms proposed to explain plant interference (Rice 1984, Putnam and Tang 1986, Grace and Tilman 1990, Hegazy 1997, El-Khatib 1997a, El-Khatib and Hegazy 1999). However, many studies have been done to separate between resource competition and allelopathy to demonstrate which is the probable cause of an observed growth pattern (Nilsson 1994, Thijs *et al.* 1994, Macharia and Peffley 1995, Inderjit and Moral 1997), but it is very difficult to do this under natural systems (Williamson 1990).

The present study addresses the finding of El-Khatib *et al.* (1999) who reported that *Alhagi graecorum* develops a well-developed community at the fallow land habitat, where a pure stand and poor associates were the characteristic features. From the ecological point of view, this finding is of prime interest and would be favourable subject to study the role-played by allelopathy in this community.

Materials and methods

Field experiments were conducted at the arable non-cultivated land of Sohag area, Upper Egypt (31 - 32 °E, 26 - 27 °N). The climate of this area is extremely arid with a marked hot and dry summer (May to August, temperature 23 - 45 °C), and dry and relatively cool winter (December to February, temperature 10 - 21 °C). Rainfall

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is negligible (mean annual rainfall = 2.25 mm) and occurs in winter. However, occasional short rainy storms may take place anytime on the eastern site of Sohag area (El-Khatib 1997b).

Sampling, and field study: The botanical composition of the study area was determined by the quadrate method. One hundred quadrates (1 × 1 m each) were randomly used. Identification and nomenclature of the species were done according to Boulos (1995). Species diversity of the community was computed by using the Shannon-Wienner index (Shannon and Wienner 1949). In addition, a measure of the degree of association of *A. graecorum* and each of the species with which it coexists was made according to Schluter's VR test (1984).

Plants of *Alhagi graecorum* Boiss. collected from the study area were separated into root and shoot tissues, and air-dried (at room temperature). Seeds of associate species, *Malva parviflora* L., *Chenopodium murale* L. and *Glinus lotoides* L. were collected from the natural stands to be used in the bioassay.

Three-rhizosphere soil samples (2 kg each) were collected from underneath *A. graecorum*. Control soil samples were collected from areas covered with dense growth of *M. parviflora, C. murale,* and *G. lotoides* and not infested previously by *A. grecorum*. All these samples were taken at 20-cm depth, and were prepared for chemical analyses according to the United State Salinity Laboratory Staff (1954), and to the bioassays.

Competition experiment: In a random block design, seeds of *A. graecorum* and the above mentioned species were sown alone and by mixing the seeds of each associate with seeds of *A. graecorum* in a 1:1 ratio in a tray 40 × 37 cm for each. The trays were filled with soil taken from area far from *Alhagi*-dominated microhabitat and moisture kept at its field capacity during the whole period of the experiment. Three densities, 50, 100, and 150 seeds per tray were employed. Trays were placed side by side in a growth chamber (temperature of 22 ± 2 °C, air humidity 80 % and photon flux density 170 μmol m^{-2} s^{-1} during a 11-h photoperiod). Seedling biomass was determined 60 d after sowing.

Soil monoculture bioassay: The seeds of the test species were sown each alone in trays filled with soil (moisture kept at its field capacity through the period of the experiment) collected from the community of *A. graecorum*. The trays were completely randomized (three replicates) in the growth chamber. Emergence value of each was determined against control soil (*Alhagi*-free soil) according to the equation of Maluf and Tigchelaar (1980):

$$EI = \sum (TD + 1 - D)(E_D) / PLS$$

where PLS = number of pure live seeds of each species tested, TD = number of days from beginning of the experiment, D = numerical position of the surveyed day, E_D = number of seedling emerged at D-day.

Effect of aqueous extracts on seed germination and seedling growth: Aqueous extraction of shoot and root of *A. graecorum* parts was prepared according to the method of El-Khatib (1997a,b) and El-Khatib and Abd-Elaah (1998). 50 g of each tissue type were mixed with 1 dm^3 deionized water to prepare 5 % (m/v) aqueous extracts. The purified extracts were adjusted to pH 6.8 with 1 M HCl (Rice 1967). The extracts were bioassayed at different concentrations (1 %, 3 % and 5 %) to determine the phytotoxicity according to Wardle *et al.* (1993). All the bioassay experiments were conducted in growth chamber to assess allelopathic potential of the material against seeds collected from wild populations of its associated species. The germination value (GV) of the different test species was calculated according to Czabator (1962):

$$GV = PV \times MDG$$

where, PV = the maximum germination in one day through the time of the experiment and MDG = the mean daily germination.

Percentage seedling length inhibition of the test species (PLI) was calculated between 5-d interval from seed germination and a maximum 25 d. Vokou (1992) formula was used:

$$PLI = [(\Delta L_C - \Delta L_R) / \Delta L_C] \times 100$$

where ΔL_C = difference of mean initial seedling length from mean final seedling length of the respective control, ΔL_R = difference of mean initial seedling length from mean final length of the treated species.

Statistical analysis: Three replicates of all analyses were made. All data were subjected to analysis of variance (*ANOVA*) using the *Statistical Analysis System* (*SAS*) program (1985). Comparisons of main effects were performed using the least significant differences (LSD) test at $P < 0.05$.

Results and discussion

Floristic composition of the studied community revealed that Shannon-Wienner index was 0.597 reflecting low species diversity within the community. The data of interspecific association index of *A. graecorum* and each of its associates, *C. mural, G. lotoides* and *M. parviflora,* were 0.35, 0.41 and 0.33, respectively. Therefore, a net negative association among the species was a main character of the community.

Results of the competitive capacity experiment (Fig. 1) clarified that in both control and mixed trays, the seedling biomass of the tested species was not significantly different at the beginning of the experiment. This is evidence of no competition during the initial stage of germination. Nevertheless, during further growth significant differences were recorded, reflecting low survival rate for the tested species in the mixed trays. Because non-significant variations in the emergence at different densities it could be suggested that the reduction in seedling biomass was not attributed to the intraspecific competition.

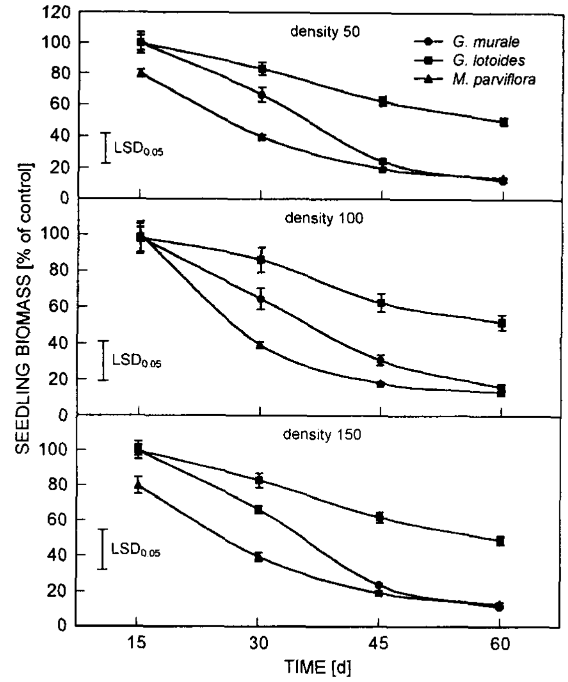

Fig. 1. Biomass of the tested species seedlings grown alone at different densities (controls) or mixed with *A. graecorum* (the same density ratio) at different time intervals.

For monoculture, a significant reduction in the emergence value of the test species was recorded when the seeds of each species sowed alone in trays filled with soil collected from the rhizosphere of *A. graecorum*. The reduction in the emergence value decreases as plant density increases (Fig. 2). Since this observation was at low but not at high densities and it is inconsistent with a hypothesis of resource competition (Thijs *et al.* 1994, Tilman 1994, Wedin and Tilman 1993, Grace 1995, Badger and Ungar 1990), it constitutes a strong evidence for the presence of toxin in the soil. To establish the ecological relevance of this toxin in the observing reduction in the emergence value of the test species and to verify its effects from the soil nutrients, physico-chemical characteristics were analyzed. They clarified that null hypothesis is not rejected when considering the physico-chemical characteristics of the soil taken from *A. graecorum* community and those of sparse growth of the test species (Table 1). Consequently, there is no dissimilarity in the environmental requirements between species.

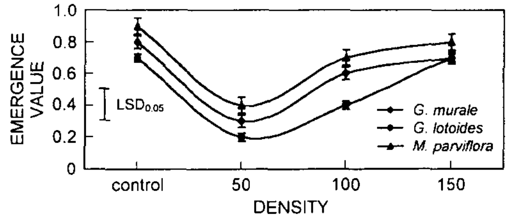

Fig. 2. Emergence values of the test species. Seeds were sown alone in control soil or in soil collected from the community with *A. graecorum* at densities 50, 100, and 150 seeds per tray.

Table 1. Some of physico-chemical characteristics of soil samples collected from *A. graecorum* community and areas of dense growth of its associate species. Means are not significantly different at $P < 0.05$, except those of moisture content.

Soil characteristics	*A. graecorum*	*C. murale*	*G. lotoides*	*M. parviflora*
pH	7.9 ± 0.3	8.0 ± 0.4	7.8 ± 0.2	7.7 ± 0.3
Moisture content [mg kg^{-1}]	180 ± 70	280 ± 80	140 ± 30	160 ± 40
Electrical conductivity [dS m^{-1}]	225 ± 65	222 ± 20	229 ± 32	219 ± 24
Cl^- content [mg kg^{-1}]	0.08 ± 0.01	0.07 ± 0.01	0.09 ± 0.02	0.08 ± 0.01
PO_4^{3-} content [mg kg^{-1}]	48 ± 8	53 ± 10	45 ± 6	49 ± 4
Na^+ content [mg kg^{-1}]	188 ± 21	150 ± 26	150 ± 30	170 ± 20
K^+ content [mg kg^{-1}]	230 ± 40	220 ± 28	210 ± 32	240 ± 22
Ca^{2+} content [mg kg^{-1}]	1220 ± 110	1230 ± 180	1120 ± 120	1180 ± 100
Mg^{2+} content [mg kg^{-1}]	340 ± 58	370 ± 88	400 ± 120	350 ± 93

Based on the above-mentioned results, it could be approved that a factor other than competition controls the interaction between *A. graecorum* and its associates. Allelopathy was, therefore, the remaining mechanism for interpretation. Accordingly, water-born allelochemicals may be produced by *A. graecorum* in the environment and suppress growth of their neighboring species. Consequently, the tested species (associates) have no ability to compete with *A. graecorum* under field conditions and so the latter species was dominant. One can thought that this organization might be related to the recorded significant difference in the soil water content (Table 1). Even though this thought is right, it supported the argument of Grime (1979) who reported that stress not only excludes competitive species but also reduces the importance of competition as a force in the structuring of plant community. However, there is evidence that stress may induce allelopathy as a force in such structuring and enhance the production of allelopathic compounds (Einhellig 1989, Gershenzon 1984, Richardson and Bacon 1993, Tang *et al.* 1995).

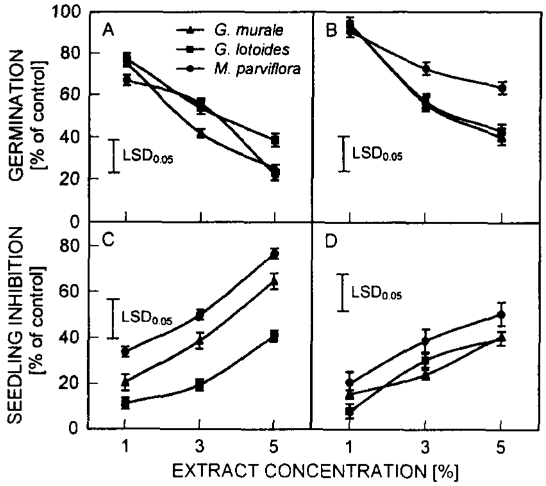

Fig. 3. Effect of concentration of extract from shoot (*A*,*C*) or root (*B*,*D*) tissue of *A. graecorum* on germination value (*A*,*B*) and the percentage seedling inhibition (*C*,*D*) of the different test species.

Indoor bioassays (Fig. 3) showed a significant increase in mortality and reduced growth of the tested species seedlings when watered with different concentrations of aqueous tissue extracts of *A. graeccorum,* especially with shoot extract. Both germination value (GV) and percentage of seedling inhibition (PLI) were a function of extract concentration. So, the results provide empirical evidence of a possible allelopathic inhibition by *A. graecorum* on its associates (test species). Therefore, the recorded reduction in both diversity and association index under field conditions could be the result of them.

In conclusion, we can say that, when the seeds of the associate species land on the upper soil surface in an *Alhaghi*-dominated microhabitat, they come in direct contact with newly fallen toxic litter and are exposed to phytotoxins released from the green foliage of *Alhagi.* During the imbibition, the seeds absorb water, and if the water contains toxins from *Alhagi,* the germination will be delayed or totally inhibited, depending on the concentrations. Also, before rooting occurs, the early radicle may be affected in the same way. In their study on *Ledum groenlandicum*, Inderjit and Mallik (1996) reported that *Ledum* has the potential to leach water-soluble phenolics to its immediate organic soil. Although the evidence is strong that some kind of allelopathy is the chief agent in the growth inhibition, there is pressing need to investigate resource competition and allelopathy interactions under field conditions that need development of a satisfactory methodology.

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