Competitive Interaction between *Hedera helix* and Native Riparian Vegetation

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Abstract

The perennial vine, *Hedera helix*, is perceived as an aggressive and noxious invader from Eurasia. There are hypotheses and predictions that describe *H. helix* as capable of killing host trees by shading and inhibiting recruitment of herbaceous species, however, they remain untested. The purpose of this study was to establish if competition exists between *H. helix* and native riparian plant species and how such interspecific competition might alter riparian assemblages. We found that different native plants exhibited different growth responses when grown with ivy. Some plants decreased both root and shoot length in the absence of ivy and others increased growth in the presence of ivy. Then there were plants that increased or decreased only shoot or only root length but never both in the absence and presence of ivy. The study also examined the toxic effects that *H. helix* may have on soil. Native wildflowers seeds watered with ivy extract showed 16% germination, and soil pH for ivy treatments were more acidic than were control treatments. This suggested that ivy has the potential to exclude indigenous plant species germination by actively releasing allelopathic chemicals, thereby maintaining dominance by changing the chemical traits of soils.

Introduction

Non-indigenous riparian plant species have continually increased their presence in aquatic ecosystems throughout California by intentional or non-intentional human dispersal, or a combination of both (Dudley and Collins 1995). As the rate of introduction and disturbance increases within and between these regions due to human activity, the likelihood of introducing species to new environments also increase (Brock et al 1994) . Increases in non-indigenous species either directly impact individual native species or alter the ecosystem, indirectly affecting the native biodiversity of the community, especially animal and plant species dependent on the area for food and habitat resources. Examples of problem plants in the San Francisco Bay Area include Cape ivy (*Delairea odorata*) and Himalayan blackberry (*Rubus discolor*)(Dudley and Collins 1995).

One non-indigenous plant that poses a serious threat to riparian communities is *Hedera helix*, or English ivy, which can establish in either wet or dry environments (Carter and Teramura 1988). *H. helix*, a member of the Araliaceae family, is a woody evergreen vine of Eurasian origin which was probably introduced to the United States in colonial times and now has become widely established in North America as garden ornamentals. *H. helix* possesses certain attributes of successful invaders. This includes the ability for quick regeneration following cutting, the large production of adventitious roots, and the potential to alter site conditions, by which it can displace native species and prevent further interspecies growth (Luken and Thieret 1997). English ivy is also capable of spreading its roots expansively into the soil and its stems just below the surface to form a dense, creeping, flat groundcover (B. Ertter, UC Herbarium, pers. comm.). The connecting structures may allow the translocation of resources from ivy growing in spatially favorable habitats to clonal ivy segments growing in spatially unfavorable patches (Stuefer and Hutchings 1994). Ivy is common in both deep shade and full sun environments, and thus may possess a broad intraspecific physiological and morphological plasticity (e.g. hardiness to extreme temperatures and specific root length) that strongly affects survival, growth, and competitive ability (Aerts 1999, Viougeas et al. 1995, Hutchings and Steufer 1994, Carter and Teramura 1988).

The potential threat of invasive plants in natural ecosystems is often assessed or predicted by considering the life history characteristics of the invading species, the attributes of the invaded system, and the facilitating factors that may modify system or invader attributes (Luken and Thieret 1997). Without knowing the characteristics of the species and of the ecosystem (i.e. its physical and chemical characteristics) it is not possible to predict the rate of invasion, the mechanisms controlling invasion, or the impact of invasion on native abundance within the community (D'Antonio 1993, Luken and Thieret 1997). There exist few quantitative data showing the competitive relationship between *H. helix* and natural riparian vegetation. *H. helix* is thought to be damaging to adjacent vegetation by competing for light and below ground nutrients (Gough and Grace 1997). This report is intended to establish whether competition exists between *H. helix* and native riparian plants, and if so, what are the effects of competition on growth and form in native species in the presence of *H. helix*. We hypothesized that ivy can alter site chemistry by releasing secondary/inhibitory chemicals that discourage herbivory and thereby facilitate the displacement of native species.

Study Site/Methods

The study was conducted at the University of California Gill Tract Agricultural Research Facility in Albany (Alameda Co.). Outdoor field experiments at the facility were adjacent to a stream channel that carries primarily urban run-off. Experimental plots were on a gradually sloping bank of the stream channel underlain with well-drained riparian soil and organic matter.

Field Study The experimental treatments were conducted within 1m x 1m plots with a 0.5 m buffer strip surrounding each to minimize edge effects. The three treatments were 1) addition of native species after ivy removal, 2) addition of native species among ivy, and 3) addition of natives where ivy was absent. Each treatment was replicated three times to yield nine experimental plots. The following native species were selected based on their presence in riparian systems and also on availability and capability to grow quickly. The plants included: California blackberry (*Rubus vitifolius*), mugwort (*Artemesia douglasiana*), bee plant (*Scrophularia californica*), fringe cups (*Tellima grandiflora*), pitcher sage (*Salvia spathacea*), California fuschia (*Zauchneria californica/ Epilobium canum*), inside-out-flower (*Vancouveria planipetala*), yarrow (*Achillea millefolium*), red sorrel (*Rumex* sp.), wild ginger (*Asarum caudatum*) and a variety of wildflower seeds from a commercial native wildflower mix. Field planting included both seedlings and cuttings that had already established rootlets following stem harvesting. From February through April, observations were made to analyze above ground plant growth and morphological changes due to possible competitive interactions.

Greenhouse study The greenhouse study consisted of planting one native plant with one *H. helix* plant in 6 inch pots. The experimental variable was the addition of *H. helix.* Treatments involved the following plants: California blackberry (*Rubus vitifolius*), wood fern (*Dryopterus arguta*), rush (*Juncus effusus*), bee plant (*Scrophularia californica*), fringe cups (*Tellima grandiflora*), peppermint (*Mentha sp*.), redtwig dogwood (*Cornus sericea*), yarrow (*Achillea millefolium*), and wildflower seeds. Each planting and seeding treatment had three replicates, including control pots with the native species a native species planted by itself. Air temperatures remained at ca. 65-70 C. Plants were given 1.3 l. of water every seven days. After three months, plants were collected.

Different sampling schemes were used to document root distributions for *H. helix* and native species due to differences in size and morphology of individual plants. The lengths of the tallest three stems and the longest root segment of each plant were measured to determine the root-shoot growth rate. The relationships between shoot and root growth rate between and among ivy and natives were compared by analysis of statistical means. All roots were also examined for any significant morphological abnormalities in spatial patterns relative to the control plant roots. Following shoot and root measurements, plants were rinsed free of soil, dried at 55 C. for two weeks, and weighed.

Seed Germination Study To study allelopathic inhibition, individual wildflower seeds were grown in the absence and presence of ivy extract. First, 250 g of young and old ivy leaves were pureed in a blender and then mixed with 6 l of water. The solution was then filtered to obtain an ivy extract. The containers were watered every seven days with 1.0 l. of ivy extract water solution. After four weeks, wildflowers seedlings were uprooted, measured, then cleaned, dried and weighed. One random core sample of 2 cm of soil was taken in fixed locations from each plant control and experimental to measure pH. Soil pH was determined by mixing soil with de-ionized water, sieving solution to obtain soil extract, and measuring the extract with a pH meter to test the above hypothesis of soil chemistry alterations.

Results

Field study When grown in the absence of ivy all nine native plants survived the four-month experiment. Each control plant showed similar or slightly better shoot growth than compared to their test counter-plant. All of the control plants survived. In addition native plants in the control plot showed no physical changes, such as discoloration and herbivory, due to environmental stress. The shoots of *S. spathacea* showed greatest growth at 65 cm (Table 1).

Species	No ivy	Ivy removed	With ivy
Asarum caudatum	24.5	0	0
S. californica	18	23	50
Z. californica	29	18	0
Rumex sp.	10.5	9	3
A. douglasiana	13.5	3	10
T. grandiflora	55	41	63
F. californica	17	4	0
S. spathacea	65	24	10
V. planipetala	32	14	0

Table 1. Shoot growth (cm) of native field plants grown in the absence of *H. helix*, after the removal of *H. helix*, and in the presence of ivy.

Plant survivorship was 67% for the nine native plants grown in areas where ivy was removed. In contrast, survivorship for native plants grown in the presence of ivy plots was 55%. Discoloring and the appearance of water log stress were observed among native plants in both experimental plots. Wild ginger, *Z. californica*, *F. californica*, and *V. planipetala* displayed shriveled, yellowish brown leaves. We expected all native plants grown without ivy to exhibit greater shoot growth. *S. spathacea* and *A. douglasiana*, regardless of the type of treatment, conclusively grew better without ivy present. Shoot growth difference for *S. spathacea* and *A. douglasiana* in the absence and presence of ivy were 70% and 30 % respectively (Table 1). *S. californica* and *T. grandiflora*, however, did not follow expected trends. In fact, *S. californica* grew better by 64% and *T. grandiflora* by 18% with ivy.

Greenhouse study Native plant shoot growth was greater in the absence of ivy for *R. vitifolius, A. millefolium,* and *F. californica* (Table 2). Shoot growth increases for *R. vitifolius, A. millefolium,* and *F. californica* without ivy were 20%, 42%, and 28% respectively. In contrast, *J. effusus, S. spathacea, and S. californica* shoots grew better with ivy (Table 2). These native plants increased shoot length by 7%, 20%, and 48% respectively.

Species	Root:Shoot ratio – No ivy	Root:Shoot ratio – w/ Ivy
J. effusus	21.33/58.33	34.50/63.50
R. vitifolius	13.33/41.66	15/33.66
A. millefolium	43/50	25.33/28.66
S. spathacea	46.66/36.33	41.33/45.66
D. arguta	14.66/38.66	14.50/35
C. sericea	13/32.33	19.50/39
Mentha sp.	41.66/78.67	34.33/33
F. californica	18.33/12.50	15/56
T. grandiflora	5.50/59.33	15.66/46.33
S. californica	23.41/44.95	21.50/87

Table 2. Native plant root:shoot growth ratio (cm) with and without *H. helix*.
Standard error was extrapolated from 6 samples of each native plant.

Table 2 shows that *A. millefolium***,** *D. arguta,* and *Mentha sp.* increase in both root and shoot length when grown without ivy. Meanwhile, *J. effusus*, *C. sericea*, and *S. californica* grew better with ivy. *R. vitifolius, S. spathacea, F. californica,* and *T. grandiflora* did not display this unidirectional root and shoot growth. These native plants displayed variations of increases and declines in root or shoot growth that made it difficult to find a growth trend.

The field study indicated that shoot length for *S. spathacea* and *A. douglasiana* increased in the absence of ivy. The greenhouse study showed that shoot growth was greater for *R. vitifolius*, *A. millefolium,* and *F. californica*. There was no correlation between field and greenhouse shoot growth. However, some trends were distinctly exhibited in the greenhouse study. Table 3 shows the native plants that displayed better shoot and root growth and biomass accumulation in the absence of ivy. These native plants showed greater growth in two or more of the three categories.

Shoot growth	Root growth	Biomass
R. vitifolius	*A. millefolium*	*R. vitifolius*
F. californica	*F. californica*	*F. californica*
A. millefolium	*S. spathacea*	*S. spathacea*
-	*Mentha sp.*	*Mentha sp.*

Table 3. Native plants that grew better in the categories of shoot growth, root growth, and biomass accumulation when grown in the absence of *H. helix*.

Native plant biomass for *R. vitifolius*, *S. spathacea*, *C. sericea*, *Mantha sp.,* and *F. californica* showed slightly to significantly greater increases when grown without ivy (Table 4).

Species	Growth without ivy	Growth with ivy
J. effusus	18.79	39.57
R. vitifolius	3.68	2.70
A. millefolium	8.94	17.53
S. spathacea	8.06	4.29
D. arguta	11.10	22.11
C. sericea	2.92	1.94
Mantha sp.	32.01	7.15
F. californica	12.03	3.43
T. grandiflora	6.70	6.60
S. californica	2.88	3.60

Table 4. Native plant biomass (g) with and without *H. helix*

Inhibition study Only 1.6% of the wildflower seeds watered with ivy extract germinated. The single seedling had a root 3 cm long with a 7 cm in shoot. In contrast, control treatments produced 73% germination, the seedlings averaging 8 cm in root growth and 15 cm in shoot growth. Soil pH for ivy controls averaged 6.35 while pH for ivy-watered soil was 6.81.

Discussion

The ability of *H. helix* to invade and flourish in riparian corridors is not yet well documented. However, numerous studies have identified some mechanisms that make exotics successful competitors, while taking into account different environmental and physiological factors such as disturbance, ratio of natives to non-natives, proximity of plants, habitat structure, and species characteristics (D'Antonio 1993). These mechanisms include the rate of vegetative regeneration, extension of root system, and site altering capacity (D'Antonio 1993, Zimdahl 1980).

The results of this study indicated that native plants exhibit certain trends when grown with and without *H. helix*. Some native plants grew longer roots and shoots and accumulated more biomass while other native plants did not survive or show increased growth when grown without ivy. Then there were native plants that increased shoot length but not root length and vice versa with and without ivy. This category of native plants showed significant growth variations in the field and greenhouse studies. The lack of an overall trend in this experiment shows that to effectively understand the competitive impacts on native plant growth by *H. helix*, we must understand the mechanisms and responses of small groups of individual native plants that share similar physiological characteristics. We cannot use large groups of native plants with wide ranging physiological characteristics to extrapolate conclusive trends pertaining to competitive effects and resulting responses.

The length of the study was quite short, but still produced certain growth trends. We speculate that native plants that displayed greater growth in both root and shoot length in the absence of ivy did well because of the lack of competition for resources such as light, space, nutrients, and water. The field study suggests that native plants grown without ivy had greater access to resources than those grown in close proximity to ivy, and as a result they were comparatively smaller in size.

The growth differences between the same native plants in the field and in the greenhouse were also examined. We speculate that the experimental variations may be caused by the controlled versus the non-controlled components of the experiments. These components include daily watering and stable temperature control for the greenhouse plants. Other factors are the differences in soil nutrient content and the availability of the nutrients to the native plants. Furthermore, seasonality may have played a role in determining growth. Certain plants grow better in certain times of the year. We cannot establish whether the native plants used would all successfully grow well during the start of the experiment. Life cycles of certain native plants may also have attributed to how well they grew. Some plants invest all their energy into root or shoot output and not necessarily both.

Many plant species produce allelopathic chemical compounds in all parts of plants that can inhibit seed germination and growth. Although some of these chemicals may have an inhibitory effect at high concentrations, they may have no toxicity or even exhibit a stimulatory effect at low concentrations. Another major concern is whether inhibition is caused by individual phytotoxins or mixtures of chemicals (Yun and Maun 1997). In addition, allelopathy may also inhibit the growth of important microbes that facilitate nutrient cycling. Rice (1984) found that pioneer weed species inhibited bacteria that fixed nitrogen, thus reducing the nitrogen availability in the soil. He also showed that plants may release allelopathic substances into their immediate environment through leaf litter, release of volatile substances, release of metabolites by the roots into the rhizosphere, and by the leaching of organic and inorganic metabolites in above ground plant parts by rain or dew. The allelopathic potential of *H. helix* on native plants has not been determined. We tested the effects of aqueous extracts of all ivy plant parts on native.

Our study suggests that *H. helix* may be able to inhibit plant growth. The role of soil pH was examined to determine the magnitude of allelopathic effects of inhibitory compounds, such as phenolic acids, in ivy (Blum 1996). There was evidence that native plants watered with the aqueous ivy extract failed to germinate. A single test plant grew out of the six plants used in the experimental portion of the germination study. We also found a significant growth difference between the test plant and the control plants. The short length and small scale of the germination study provide a limited and incomplete examination of ivy's allelopathic potential and its impact on native vegetation.

Failure by the test plants to germinate may have been due to factors other than allelopathy. But before we can explicitly determine if allelopathy is a major contributor to the native plants' ability to grow in the presence of ivy, we must identify the possible inhibitory metabolites and volatiles contained in *H. helix*. More research also needs to be done on the levels of chemicals required for inhibition of germination and seedling growth in laboratory bioassays. Field soils may contain a variety of phenolic acids as well as other toxic and non-toxic organic compounds that may or may not play a significant role in plant inhibition. Another factor that needs to be investigated is which specific plant part, such as the roots, leaves, or stem, contain allelopathic chemicals. This is important in determining the source of chemical release and where the chemicals would impact first. Moreover, when testing for allelopathy we failed to associate the ecological component between the field and greenhouse studies. The extract concentration given to test plants may have exceeded the level of inhibitory chemicals released in the natural biotic setting.

The ecological implications of this study suggest allelopathy may play an important role in the survival and reproduction of native plant species. However our focus was on the allelopathic potential of ivy on native plants. D'Antonio (1993) suggested that the ability to alter site conditions is an important competitive mechanism that perennial alien species use to take over space. The significant lack of germination and root-shoot elongation in seed pots that were watered with ivy extract support our hypothesis that allelopathy plays a role in competition. Our data showed that ivy has the allelopathic potential to inhibit seed germination and overall growth by releasing inhibitory chemical compounds like phenolic acids (Viles and Reese 1995). Secondary compounds when released from leaf litter can theoretically lead to longer dominance of a species (Aerts 1999). Evergreen plants like ivy have low litter decomposability thus allelochemicals are retained longer in the soil. Alellochemicals can also be bound and made unavailable by soil organic matter and clays (Weidenhammer 1996). We speculate that release of high concentrations of lignin and phenolics stored in ivy may lead to higher fitness due to long term effects on soil fertility. This may give ivy a competitive advantage over native plant species. Studies identifying specific allelochemicals and metabolite rates of release/uptake need to be further addressed before we can conclude that *H. helix* possesses allelopathic agents.

This study demonstrated that competition may exist between *H. helix* and native riparian plant species but more research needs to be done using similar groups of native plants in order to establish conclusive results. We also showed that *H. helix* has the potential to inhibit seed germination by releasing allelochemicals.

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