Impact of *Conyza canadensis* on its Co-occurring Plant Species in its Non-native Region

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Abstract
The paper reports about the impact of *Conyza canadensis* on species that co-occurs with it in invaded and un-invaded plots at the various sites located in Kashmir Himalayas. These invaded and un-invaded plots supports diverse plant species varying in their status like native and non-native species which were at different stages of invasion, including invasive species, naturalised species, casual alien and cultivated un-escaped alien. Various ecological factors, such as disturbance and pollution have caused prominent changes in the dynamics and distribution of the native species of Kashmir Himalayas. The paper highlights the adverse impact of the invasive species on its co-occurring native species and facilitative role to non native aliens. Higher number and better performance of alien species in invaded than un-invaded plots in comparison to higher number and better performance of native species in un-invaded plots indicates invasion meltdown.
Keywords: Invasive species, naturalised species, casual alien, cultivated un-escaped alien, invasion meltdown

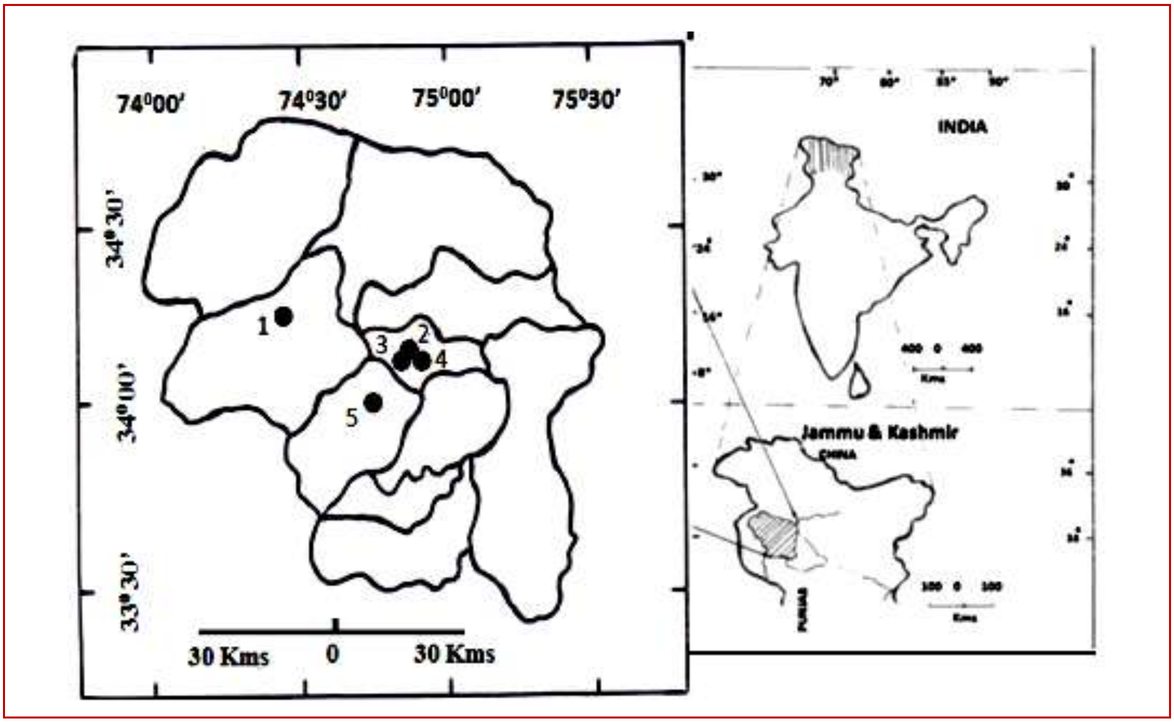
Introduction

Plant invasion is one of the most severe threats to the biodiversity on Earth (Chapin *et al.*, 2000; Werner *et al.*, 2010) as exotic plant invaders appear to achieve disproportional dominance in their nonnative ranges through many mechanisms (Hierro *et al.*, 2005; Callaway *et al.*, 2008; Lankau *et al.*, 2009; Lankau, 2012). Various studies on these invasive species have reported that these species are rare at home and abundant or even superabundant in introduced communities (Bruce *et al.*, 1997; Paynter *et al.*, 1998; Memmot *et al.*, 2000), such observations remain largely anecdotal without any support based on quantitative data. Thus it is clear that those plants which are vulnerable to become superabundant only in the introduced range must be 'doing something different' in recipient communities that enables them to attain such dominance. Crawley (1987) was one of the first researchers who found that non native often were larger in size than their native conspecifics. Similarly Grosholz and Ruiz (2003) have observed the same pattern for marine invertebrates. Further, Jakobs *et al.* (2004) in his survey of 46 native and 45 introduced populations of *Solidago gigantea*, found that total plant biomass was larger among exotic than native plants. Callaway *et al.* (2011a) found that the abundance of *Acroptilon repens* in North America, where it is invasive, was almost twice that in Uzbekistan, where it is native. This difference in impact corresponded with inherently stronger competitive and allelopathic effects of *A. repens* on North American species than on species native to Uzbekistan (Ni *et al.*, 2010). Similar comparisons between native and nonnative ranges have been reported for the allelopathic effects of other invasives, including *Ageratina adenophora* (Inderjit *et al.*, 2011), *Centaurea stoebe* (Thorpe *et al.*, 2009), *Centaurea diffusa* (Callaway and Aschehoug, 2000), *Prosopis juliflora* (Kaur *et al.*, 2012), *Foeniculum vulgare* (Colvin and Gliessman, 2011), the red algae *Bonnemaisonia hamifera* (Svensson *et al.*, 2013), *Chromolaena odorata* (Qin *et al.*, 2013).

In this context, the present study was conducted to assess the impact of the native North American plant, *Conyza canadensis* (Asteraceae, *Erigeron canadensis*, commonly known as Canadian horseweed), on its co occurring plant species in Kashmir Himalayas; where it is highly invasive plant species. Studies of invasive species often focus on species that undergo dramatic increases in abundance in their nonnative ranges (Inderjit *et al.*, 2011; Kaur *et al.*, 2012). We tackled this issue through field studies at the various sites located in Kashmir Himalayas so as to evaluate the impact of *Conyza canadensis* on its neighbours that co-occur with it at the invaded plots with reference to un-invaded plots.

Material and Methods

In Kashmir Himalaya, India, five sites (Site 1: Khawajabagh-Baramulla; Site 2: Mirzabagh; Site 3: Kashmir University Botanical Garden; Site 4: Nigeen and Site 5: Garend-Berwah) (Figure 1) which were invaded by *Conyza canadensis* varying in the level of soil disturbance, spread over three districts were selected in Kashmir Himalaya representing diverse habitat types viz., terrestrial open habitat with low soil disturbance (LSDH), terrestrial open habitats with intermediate level of soil disturbance (ISDH), and riparian habitats. Within each site invaded and comparable un-invaded (control) plots were located. Criteria for site selection were that the survey should include range of habitats varying in the level of soil disturbance. For instance, the sites included terrestrial open habitats with low soil disturbance, terrestrial open habitat with intermediate level of soil disturbance and riparian habitat, (established several years ago and with a dense vegetation cover) (Table 1). The selected sites varied widely in the density or cover of *C. canadensis* and its co-occurring neighbours. At all the selected sites, *C. canadensis* stands formed distinct patches of one to several meters diameter within the vegetation. In this study, plots at the selected sites with either no or negligibly small number of individuals of *C. canadensis* were considered as “un-invaded or control plots”, and stands with huge number of *C. canadensis* were called “invaded plots”, although invaded plots also contained few native species. Plant species along with the *Conyza canadensis* were recorded quarterly during summer season.



1= Baramulla; 2= Mirzabagh; 3= Kashmir University; 4= Nigeen; 5= Budgam

Figure 1: Map of the study area showing distribution of sampling sites for different field studies in Kashmir Himalaya.

Table 1: Description of the sites in Kashmir selected for the study of *Conyza canadensis* and its co-occurring neighbours during the present study.

Sites	Site name/ Sampling location	District	Habitat type	Latitude N	Longitude E	Altitude m.a.s.l
S1	Khwajabagh	Baramulla	Open, dry, less disturbed	34˚13´09"	72˚22´42"	1598
S2	Mirzabagh	Srinagar	Dry, exposed, moderately disturbed or Intermediate	34˚ 07´46"	74˚ 49´54"	1590
S3	KUBG	Srinagar	Open, Dry, protected	34˚ 08´50"	74˚50´ 11"	1580
S4	Nigeen	Srinagar	Open, Slightly Moist, highly disturbed	34˚07´20"	74˚50´00"	1580
S5	Garend-Beruwah	Budgam	Open, riparian, highly disturbed	34˚03´07"	74˚40´49"	1600

Results and Discussion

Field studies revealed that plant species growing in association with *Conyza canadensis* at the five selected sites of Kashmir Valley comprised 74 species belonging to 60 genera and 25 families (24 dicot and 2 monocot families). Family Asteraceae (18 species) and Poaceae (11 species) contribute maximum number of plant species distributed in 15 genera of Asteraceae and 10 genera of Poaceae (Table 2 and 3). Alien plant species belonging to Asteraceae were the worst alien species among all due to their fertility and unique seed structures which make them a very powerful colonizer in new environments especially in case of *C. canadensis*. Moreover, it was found that all of these *C. canadensis* invaded plots suffer from serious invasion. The surveyed plant species growing in association with *C. canadensis* in the Kashmir Valley included both native and non-native species which were at different stages of invasion, including 37 Invasive species (widespread and dominant), 14 naturalised species (established with self sustaining populations), 1 casual alien (occasional species with no self replacing populations), and 1 cultivated un-escaped alien (Figure 2). Besides, 21 native species of Kashmir Himalaya were recorded growing in association with *C. canadensis.* Most of these alien plants in the present checklist 31 were natives to Europe followed by Africa 16, (Asia 13, South America 5 and North America 3 respectively. Two probable reasons for such high number of European species in the alien flora of Kashmir Himalaya could be: (a) successful introduction due to more or less similar climate, and (b) European colonial past that could have facilitated the transport of plant propagules from Europe to this region with men and machinery.

Out of 74 species, the invaded and un-invaded plots harboured 58 and 62 species, respectively. In case of invaded plots out of 58, 47 plant species (1causal, 12 Naturalised, 34 invasive) were alien and only 11 were native while in case of un-invaded plots out of 62, 42 plant species (1 causal, 1cultivated, 8 naturalised, 32 invasive) were alien and only 20 were native. Therefore, an increase in the number of plant species was observed in case of un-invaded plots compared to invaded plots. The number of invasive species is higher in invaded plots compared to un-invaded plots (Figure 3). Our results are consistent with the results of with many other studies (Bimova *et at*., 2004; Dunbar and Facelli, 1999; Kohli *et al.*, 2004; Dogra *et al.*, 2009 a, b) which reported negative impact of exotic species on species diversity. In case of *Lantana camara*, Dobhal *et al.* (2011) also reported a decrease in species number and diversity in invaded localities as compared to un-invaded ones and thus such study is also in conformity with our results. Similar results have been obtained by Rascher *et al.* (2011) who reported decrease in species number and diversity by upto 50% in invaded compared to un-invaded areas of *Acacia longifolia.*

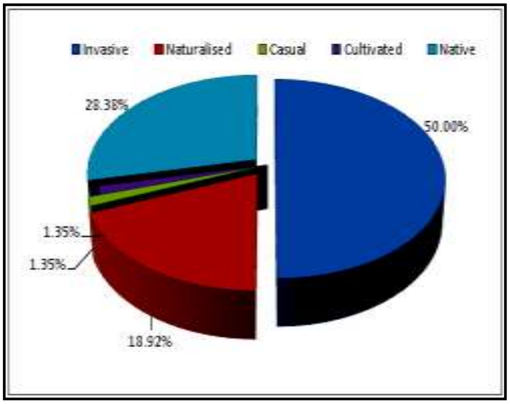


Figure 2: Distribution of the total plants species growing in association with *Conyza canadensis* in the invaded and un-invaded plots.

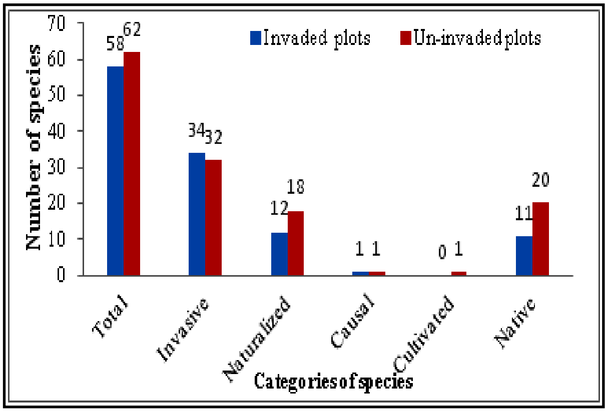


Figure 3: Impact of invasion by *Conyza canadensis* on the number of native and alien species in invaded and un-invaded plots.

Table 2: Conspectus of the alien plant species, families, origin, status, group, growth form and occurrence in plots invaded and un-invaded by *Conyza canadensis.*

Family/ plant species	Origin	Status	Group	Growth form	Mode/purpose of introduction	Occurrence	
						Inv	Un
Amaranthaceae							
Amaranthus caudatus L.	AMS	In	Dicot	A	Fd	+	+
Apiaceae							
Conium maculatum L.	EU	Nt	Dicot	B	Fd	+	+
Daucus carota L.	AF;EU	In	Dicot	B	Ui	+	+
Eryngium billardieri Del.	AF;EU	In	Dicot	P	Ui	+	+
Torilis japonica DC.	AS	Nt	Dicot	A	Ui	+	-
Asteraceae							
Achillea millefolium L.	EU	In	Dicot	P	Md	+	+
Anthemis cotula L.	EU	In	Dicot	B	Ui	+	+
Arctium lappa L.	EU	In	Dicot	P	Md	+	+
Artemisia absinthium L.	EU	In	Dicot	Ss	Md	+	+
Artemisia tournefortiana Reichb.	AS	Nt	Dicot	A	Ui	+	-
Cichorium intybus L.	EU	In	Dicot	P	Ui	-	+
Cirsium arvense Scop.	AS	In	Dicot	P	Ui	+	+
Galinsoga parviflora Cav.	AMS	In	Dicot	A	Ui	+	+
Taraxacum officinale F.H.Wigg.	AF	In	Dicot	P	Ui	+	+
Xanthium spinosum L.	AF	In	Dicot	A	Ui	-	+
Xanthium strumarium L.	AMN	In	Dicot	A	Ui	+	+
Brassicaceae							
Capsella bursa-pastoris Medic.	EU	In	Dicot	A	Ui	-	+
Sisymbrium loeselii L.	AF; EU	In	Dicot	A	Ui	+	+
Cannabiaceae							
Cannabis sativa L.	AS	In	Dicot	A	Ui	+	+
Chenopodiaceae							
Chenopodium album L.	EU	In	Dicot	A	Fd	+	+
Convolvulaceae							
Convolvulus arvensis L.	EU	In	Dicot	P	Ui	+	+
Cyperaceae							
Cyperus globosus All.	AF; EU	In	Monocot	A	Ui	+	-

Family/ plant species	Origin	Status	Group	Growth form	Mode/purpose of introduction	Occurrence	
						Inv	Un
Euphorbiaceae							
Euphorbia helioscopia L.	AS; EU	In	Dicot	A	Ui	+	-
Fabaceae							
Medicago polymorpha L.	AF; EU	In	Dicot	A	Fr	+	+
Medicago sativa L.	AF; EU	Nt	Dicot	B	Fr	+	+
Robinia pseudoacacia L.	AMN	In	Dicot	T	Pl	+	-
Trifolium pratense L.	EU	In	Dicot	P	Fr	+	+
Trifolium repens L.	EU	In	Dicot	P	Fr	+	+
Lamiaceae							
Marrubium vulgare L.	AS; EU	In	Dicot	P	Ui	+	-
Mentha longifolia L.	AF; EU	In	Dicot	P	Ui	+	+
Nepeta cataria L.	EU	Nt	Dicot	P	Ui	+	+
Malvaceae							
Althaea rosea Cav.	AS	Cs	Dicot	B	O	+	+
Onagraceae							
Oenothera rosea Ait.	AMS	In	Dicot	A	Ui	+	+
Plantaginaceae							
Plantago lanceolata L.	AF; EU	In	Dicot	P	Ui	+	+
Plantago major L.	EU	In	Dicot	P	Ui	+	+
Poaceae							
Boyhriochloa ischaemum Keng.	AF	In	Monocot	P	Ui	+	+
Bromus japonicas Thunb.	EU	Nt	Monocot	A	Fr	+	+
Echinochloa crus-galli Beauv.	AS	Nt	Monocot	Aq	Ui	+	-
Lolium perenne L.	AS; EU	Nt	Monocot	P	Fr	-	+
Oryza sativa L.	AS	Cl	Monocot	A	Fd	-	+
Phragmites australis Trin.	AMS	In	Monocot	P	Fr	+	-
Setaria viridis P. Beauv.	AS; AF	In	Monocot	A	Fr	+	+
Sorghum halepense Pers.	EU	In	Monocot	P	Fr	+	+
Sorghum vulgare Pers.	AF	Nt	Monocot	A	Fr	+	-
Polygonaceae							
Polygonum hydropiper L.	EU	In	Dicot	A	Fd	+	+
Rumex dentatus L.	AF; EU	Nt	Dicot	A	Md	+	+
Portulacaceae							
Portulaca oleracea L.	AF;	Nt	Dicot	A	Fd	+	+
Rosaceae							
Fragaria nubicola Lindel. ex.	EU	Nt	Dicot	P	Fd	+	-
Potentilla reptans L.	AS; EU	Nt	Dicot	P	Ui	-	+
Rubus ulmifolius Schott.	EU	In	Dicot	S	Ld	+	+
Rubiaceae							
Rubia cordifolia L.	AS; AF	Nt	Dicot	C	Ui	+	-
Solanaceae							
Datura stramonium L.	AMN	In	Dicot	A	In	+	+
Urticaceae							
Urtica dioica L.	AF; EU	In	Dicot	P	Ui	+	+

Abbreviations:

Origin: AMN = North America; AMS = South America; EU = Europe; AF = Africa; AU = Australia; AS = Asia (excluding the Indian sub-continent);

Growth form: A = Annual herb; B = Biennial herb; P = Perennial herb; Ss = Sub shrub; S = Shrub; T = Tree; Aq = Aquatics; C = Climber

Mode of introduction: Fd = Food; Fr = Fodder; Ld = Landscaping; Md = Medicinal; O = Ornamental; Ui = Unintentional

Invasion status: Cl= Cultivated un-escaped aliens; Cs = Casual aliens; Cn = Casual or naturalized aliens; Nt = Naturalized aliens; In = Invasive alien, Inv= invaded plots, Unv = uninvaded plots

Table 3: Conspectus of the family wise native plant species, growth form, group and occurrence in plots invaded and un-invaded by *Conyza canadensis.*

Family/ plant species	Growth form	Group	Occurrence	
			Inv	Un
Asteraceae				
Artemisia dubia Wall. ex besser.	P	Dicot	-	+
Carpesium cernuum L.	P	Dicot	-	+
Cotula anthemoides L.	A	Dicot	-	+
Myriactis nepalensis Less.	A	Dicot	-	+
Lactuca serriola L.	B	Dicot	+	+
Leucanthemum vulgare Lam.	P	Dicot	+	+
Tragopogon kashmirianus G.S.	B	Dicot	+	+
Boraginaceae				
Cyanoglossum glochidiatum Wall. ex Benth.	A	Dicot	+	+
Myosotis arvensis L.	P	Dicot	+	+
Fabaceae				
Melilotus albus Medik.	A	Dicot	+	+
Geraniaceae				
Geranium nepalense Sweet.	A	Dicot	-	+
Malvaceae				
Malva sylvestris L.	A	Dicot	+	+
Apiaceae				
Eryngium caeruleum M. Bieb.	P	Dicot	+	+
Poaceae				
Cynodon dactylon L.	P	Monocot	+	+
Hordeum murinum L.	A	Monocot	-	+
Polygonaceae				
Polygonum lapathifolium L.	A	Dicot	-	+
Polygonum plebejum R.Br.	A	Dicot	-	+
Rosaceae				
Potentilla arvensis L.	P	Dicot	+	-
Potentilla nepalensis Hook.	P	Dicot	-	+
Scrophulariaceae				
Veronica agrestis L.	A	Dicot	-	+
Solanaceae				
Solanum nigrum L.	A	Dicot	+	+

Growth form: A = Annual herb; B = Biennial herb; P = Perennial herb.

In the plots invaded by *Conyza canadensis* the highest percentage of aliens were found to be in invaded plots of every study site and minimum in un-invaded plots. Amongst the natives, the highest percentage was observed in the un-invaded plots of each study site as compared to invaded plots. Reason for such an increase of alien species is due to "invasion meltdown" a process by which a group of non-indigenous species facilitate one another's invasion in various ways thereby increase the likelihood of survival and/or of ecological impact and possibly the magnitude of impact (Simberloff and Von Holle, 1999). Some of the plant species which have been found to facilitate invasion by other alien species are *Myrica faya* in Hawaii, where it has altered soil nutrients by invading very nitrogen poor volcanic soils (Vitousek and Walker, 1989). *Mesembryanthemum crystallinum,* African Crystalline ice plant, that modifies the environment to favour other introduced species in California (Philbrick, 1972; Vivrette and Muller, 1977) and Australia (Kloot, 1983). Highly disturbed habitats which provide "windows of opportunity" for the entrance of alien propagules (Myster, 1993) may increase the quantity of available space for establishment and growth of alien species (Davis *et al.*, 2000), other likely reasons for having higher number of aliens as compared to number of natives in invaded plots. Altered competitive interactions between the species caused by anthropogenic activities operating at small scale create new niche opportunities for recruitment and establishment of species and as a result of such altered competitive interactions might have reduced biotic resistance and facilitated the establishment of exotic species (Verdu and Valiente-Banuet, 2008; Altieri *et al.*, 2010).

Moreover, the findings of our study also revealed higher number of invasive species in plots invaded by *C. canadensis.* It could be due to soil modification done by invasive species by employing various ways that facilitate invasion by other species as well. It is well known fact that invasive species alter physical chemical attributes of soil including cycling of nutrients and other elements (Haubensak *et al.*, 2004; Hawkes *et at*., 2005), pH (Kourtev *et al.*, 2003), soil organic matter and soil particle aggregation (Saggar *et al.*, 1999). Other findings have reported more direct effect on the biotic composition of invaded soil, e.g., alteration of soil food web (Duda *et al.*, 2003). Total soil microbial communities (Kourtev *et al.*, 2003) mutualistic fungi (Mummey and Rilling, 2006; Jordan *et al.*, 2008) are also reported to be altered by invasive species which in turn facilitates invasion directly or via cross facilitation of other invasive species. Our results are also consistent with McIntyre *et al.* (1988); McIntyre and Lavorel (1994a); Hoffmann (1998), who also revealed that high species richness of alien plants is coupled with low species richness of native plants in man-dominated habitats and with high richness in natural habitats.

Higher percentage of other co-occurring non-natives /aliens in the plots invaded by *Conyza canadensis* than native plant species indicates potential role of *C. canadensis* in the success and spread of its co-occurring aliens in the disturbed habitats of the Kashmir Himalaya (Figure 4). Our results are consistent with the results of many other studies (di Castri, 1989; Kornas, 1990; McIntyre and Lavorel, 1994b; FaliNski, 1998; Pysek, 1998; Sukopp, 1998; McKinney, 2002) who also reported that ecosystems with anthropogenic disturbances, contain high numbers of aliens, whereas natural or near-natural ecosystems display a certain ecological resistance against the introduction of alien species (FaliNski, 1998). McIntyre and Lavorel, (1994b); Hoffmann (1998), have revealed that high species richness of alien plants is coupled with low species richness of native plants in man-dominated habitats and with high richness in natural habitats. Likewise low community resistance against invading non-native species is caused due to less number of native plant species thereby indicating that native plant species increases community resistance against invading non-native species (Levine, 2000), at least as long as disturbance levels are low (Cornell and Karlson, 1997).

These results add to the growing body of literature reporting *Conyza canadensis* does have a negative relationship with native species richness in its non native range, and it significantly decreases native species richness in its non-native (Kashmir Himalaya). It is pertinent to mention that Shah *et al.* (2014) recently demonstrated through transcontinental field studies, green house experiments and individual based models that *C. canadensis* significantly reduces the native plant diversity in non-native ranges but not at home.

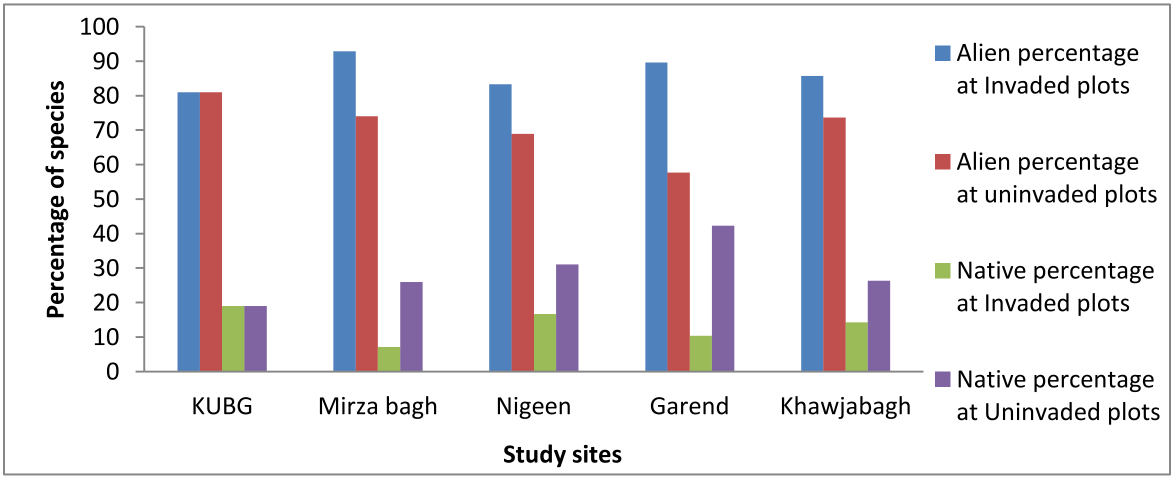


Figure 4: Percentage comparison of co-occurring aliens and native plant species in plots invaded and un-invaded by *Conyza canadensis.*

References

Altieri, A. H., Van Wesenbeeck, B. K., Bertness, M. D. and Silliman, B. R. 2010. Facilitation cascade drives positive relationship between native biodiversity and invasion success. ***Ecology*. 91:** 1269-1275.

Bimova, K., Mandak, B. and Kasparova, I. 2004. How does *Reynoutaria* invasion fit the various theories of invasibility. ***Journal of Vegetation Science*. 15:** 495–504.

Bruce, K. A., Cameron, G. N., Harcombe, P. A. and Jubinsky, G. 1997. Introduction, impact on native habitats, and management of a woody invader, the Chinese tallow tree, *Sapium sebiferum* (L.) Roxb. ***Natural Areas Journal*. 17:** 255–260.

Callaway, R. M. and Aschehoug, E. T. 2000. Invasive plants versus their new and old neighbours: a mechanism for exotic invasion. ***Science.* 290:** 521–523.

Callaway, R. M., Cipollini, D., Barto, K., Thelen, G. C., Hallett, S. G., Prati, D., Stinson, K. and Klironomos, J. 2008. Novel weapons: invasive plant suppresses fungal mutualists in America but not in its native Europe. ***Ecology.* 89:** 1043–1055.

Callaway, R. M., Schaffner, U., Thelen, G. C., Khamraev, A., Juginisov, T. and Maron, J. 2011. Impact of *Acroptilon repens* on co-occurring native plants is greater in the invader's non-native range. ***Biological Invasions*. 14:** 1143–1155.

Chapin, F. S. I., Zavaleta, E. S., Eviner, V. T., Naylor, R. L., Vitousek, P. M., Reynolds, H. L.,Hopper, D. U., Lavorel, S., Sala, O. E., Hobbie, S. E., Mack, M. C and Diaz, S. 2000. Consequences of changing biodiversity. ***Nature*. 405:** 234-242.

Colvin, W. I. and Gliessman, S. R. 2011. Effects of fennel (*Foeniculum vulgare* L.) interference on germination of introduced and native plant species. ***Allelopathy Journal*. 28:** 41–52.

Cornell, H. V. and Karlson, R. H. 1997. Local and regional processes as controls of species richness. p. 250–268. In: ***Spatial Ecology*** (D. Tilman and P. Kareiva, eds). Princeton University Press, Princeton, New Jersey, USA.

Crawley, M. J. 1987. What makes a community invasible? p 424–453. In: ***Colonization, Succession and Stability*** (A. J. Cray, M. J. Crawley and P. J. Edwards, eds.). Blackwell Scientific Publications, Oxford.

Davis, M. A., Grime, J. P. and Thompson, K. 2000. Fluctuating resources in plant communities: a general theory of invasibility. ***Journal of Ecology*. 88:** 528–534.

di Castri, F. 1989. History of biological invasions with special emphasis on the old world. p. 1–30. In: ***Biological Invasions: a Global Perspective*.** (J. A. Drake, H. A. Mooney, F. di Castri, R. H. Groves, F. J. Kruger, M. Rejmánek and M. Williamson, eds.). John Wiley and Sons, New York.

Dobhal, P. K., Kohli, R. K. and Batish, D. R. 2011. Impact of *Lantana camara* L. invasion on riparian vegetation of Nayar region in Garhwal Himalayas (Uttarakhand, India). ***Journal of Ecology and the Natural Environment.* 3(1):** 11-22.

Dogra, K. S., Kohli, R. K. and Sood, S. K. 2009a. An assessment and impact of three invasive species in the Shivalik hills of Himachal Pradesh, India. ***International Journal of Biodiversity and Conservation*. 1(4):** 4-10.

Dogra, K. S., Kohli, R. K., Sood, S. K. and Dobhal, P. K. 2009b. Impact of *Ageratum conyzoides* L. on the diversity and composition of vegetation in the Shivalik hills of Himachal Pradesh (Northwestern Himalaya), India. ***International Journal of Biodiversity and Conservation*** 1**(4):** 135-145.

Duda, J. J., Freeman, D. C., Emlen, J. M., Belnap, J., Kitchen, S. G., Zak, J. C., Sobek, E., Tracy, M. and Montante, J. 2003. Differences in native soil ecology associated with invasion of the exotic annual chenopod, *Halogeton glomeratus*. ***Biology and Fertility of Soils.* 38:** 72–77.

Dunbar, K. R. and Facelli, J. M. 1999. The impact of a novel invasive species, *Orbea variegate* African carrion flower, on the chenopod shrublands of south Australia. ***Journal of Arid Environment*. 41:** 37–41.

Falinski, J. B. 1998. Invasive alien plants and vegetation dynamics. p. 3-21. In: ***Plant Invasions: Ecological Mechanisms and Human Responses.* (**U. Starfinger, K. Edwards, I. Kowarik and M. Williamson, eds.). Backhuys Publishers, Leiden.

Grosholz, E. D. and Ruiz, G. M. 2003. Biological invasions drive size increases in marine and estuarine invertebrates. ***Ecology Letters*. 6:** 705–710.

Haubensak, K. A., Antonio, D. C. M. and Alexander, J. 2004. Effects of nitrogen-fixing shrubs in Washington and coastal California. ***Weed Technology***. **18:** 1475–1479.

Hawkes, C. V., Wren, I. F., Herman, D. J. and Firestone, M. K. 2005. Plant invasionalters nitrogen cycling by modifying the soil nitrifying community. ***Ecological Letters***. **8:** 976–985.

Hierro, J. L., Maron, J. L. and Callaway, R. M. 2005. A biogeographic approach to plant invasions: The importance of studying exotics in their introduced and native range. ***Ecology.*** **93:** 5–15.

Hoffmann, J. 1998. Assessing the effects of environmental changes in a landscape by means of ecological characteristics of plant species. ***Landscape and Urban Planning***. **41:** 239–248.

Inderjit, Evans, H., Crocoll, C., Bajpai, D., Kaur, R., Feng, Y. L., Silva, C., Carreon, J. T., Valiente-Banuet, A., Gershenzon, J. and Callaway, R. M. 2011. Volatile chemicals from leaf litter are associated with invasiveness of a neotropical weed in Asia. ***Ecology.*** **92:** 316–324.

Jakobs, G., Weber, E. and Edwards, P. J. 2004. Introduced plants of the invasive *Solidago gigantean* (Asteraceae) are larger and grow denser than conspecifics in the native range. ***Diversity and Distributions***. **10:** 11–19.

Jordan, N. R., Larson, D. L. and Huerd, S. C. 2008. Soil modification by invasive plants: effects on native and invasive species of mixed-grass prairies. ***Biological Invasions***. **10:** 177-190.

Kaur, R., Gonzales, W. L., Llambi, L. D., Soriano, P. J., Callaway, R. M., Rout, M. E,, Gallaher, T. J. and Inderjit. 2012. Community impacts of *Prosopis juliflora* invasion: Biogeographic and congeneric comparisons. ***PLoS One***. **7 (9):** e44966. doi:10.1371/journal.pone.0044966.

Kloot, P. M. 1983. The role of common iceplant (*Mesembryanthemum crystallinum*) in the deterioration of medic pastures. ***Australian Journal of Ecology***. **8:** 301–306.

Kohli, R. K., Dogra, K. S., Batish, D. R. and Singh, H. P. 2004. Impact of invasive plants on the structure and composition of natural vegetation of north western Indian Himalayas. ***Weed Technolnology.*** **18:** 1296-1300.

Kornas, J. 1990. Plant invasions in Central Europe: Historical and ecological aspects. p. 19–36. In: ***Biological Invasions in Europe and the Mediterranean Basin***. (F. di Castri, A .J. Hansen and M. Debussche, eds.). Kluwer Academic Publishers, Dordrecht.

Kourtev, P. S., Ehrenfeld, J. G. and Haggblom, M. 2003. Experimental analysis of the effect of exotic and native plant species on the structure and function of soil microbial communities. ***Soil Biology and Biochemistry.*** **35:** 895-905.

Lankau, R. A. 2012. Coevolution between invasive and native plants driven by chemical competition. ***Proceedings of the National Academy of Sciences,*** *USA.* **109:** 11240–11245.

Lankau, R. A., Nuzzo, V., Spyreasa, G. and Davis, A. S. 2009. Evolutionary limits ameliorate the negative impact of an invasive plant. ***Proceedings of the National Academy of Sciences***. **106:** 15362–15367.

Levine, J. M. 2000. Species diversity and biological invasions: relating local process to community pattern. ***Science***. **288:** 761 -763.

McIntyre, S. and Lavorel, S. 1994a. How environmental and disturbance factors influence species composition in temperate Australian grasslands. ***Vegetation Science.*** **5:** 373–384.

McIntyre, S. and Lavorel, S. 1994b. Predicting richness of native, rare, and exotic plants in response to habitat and disturbance variables across a variegated landscape. ***Conservation Biology***. **8:** 521–531.

McIntyre, S., Ladiges, P. Y. and Adams, G. 1988. Plant species richness and invasion by exotics in relation to disturbance of wetland communities on the Riverine Plain, NSW. ***Australian Journal of Ecology***. **13:** 361–373.

Mckinney, M. L. 2002. Urbanization, biodiversity and conservation. ***BioScience***. **52:** 883–890.

Memmott, J., Fowler, S. V., Paynter, Q., Sheppard, A. W. and Syrett, P. 2000. The invertebrate fauna on broom, *Cytisus scoparius* in two native and two exotic habitats. ***Acta Oecologica***. **21:** 213–222.

Mummey, D. L. and Rillig, M. C. 2006. The invasive plant species *Centaurea maculosa* alters arbuscular mycorrhizal fungal communities in the field. ***Plant and Soil***. **288:** 81–90.

Myster, R. W. 1993. Tree invasion and establishment in old fields at Hutchenson Memorial Forest. ***The Botanical Review.*** **59:** 251–572.

Ni, G., Schaffner, U., Peng, S., Callaway, R. M. 2010. Acroptilon repens, an Asian invader, has stronger competitive effects on species from America than species from its native range. ***Biological Invasions.*** **12:** 3653–3663.

Paynter, Q., Fowler, S. V., Memmott, J. and Sheppard, A. W. 1998. Factors affecting the establishment of *Cytisus scoparius* in southern France: implications for managing both native and exotic populations. ***Ecology.*** **35:** 582–595.

Philbrick, R. N. 1972. The plants of Santa Barbara Island, California. ***Madrono.*** **21:** 329–393.

Pysek, P. 1998. Is there a taxonomic pattern to plant invasions? ***Oikos***. **82:** 282–294.

Qin, R., Zheng, Y., Valiente-Banuet, A., Callaway, R. M., Barclay, G. F., Pereyra, C. S. and Feng, Y. 2013. The evolution of increased competitive ability, innate competitive advantages, and novel biochemical weapons act in concert for a tropical invader. ***New Phytologist***. **197:** 979–988.

Rascher, K. G., Große-Stoltenberg, A., Maguas, C., Meira-Neto, J. A. A. and Werner, C. 2011. *Acacia longifolia* invasion impacts vegetation structure and regeneration dynamics in open dunes and pine forests. ***Biological Invasions***. **13:** 1099–1113.

Saggar, S., McIntosh, P., Hedley, C. and Knicker, H. 1999. Changes in soil microbial Biomass, metabolic quotient and organic matter turnover under *Hieracium pilosella* L. ***Biol. Fertil. Soils***. **30:** 232–238.

Shah, M. A., Callaway, R. M., Shah, T., Houseman, G. R., Pal, R. W., Xiao, S., Luo, W., Rosche, C., Reshi, Z. A., Khasa, D. P. and Chen, S. 2014. *Conyza canadensis* suppresses plant diversity in its nonnative ranges but not at home: a transcontinental comparison. ***New Phytologist***. **202:** 1286-1296.

Simberloff, D. and Von Holle, B. 1999. Positive interactions of non-indigenous species: invasional meltdown? ***Biological Invasions***. **1:** 21-32.

Sukopp, H. 1998. On the study of anthropogenic plant migrations in central Europe. p. 43-56. In: ***Plant Invasions: Ecological Mechanisms and Human Responses*** (U. Starfinger, K. R. Edwards, I. Kowarik and M. Williamson, eds.), Backhuys Publishers, Leiden.

Svensson, J. R., Nylund, G., Cervin, G., Toth, G. and Pavia, H. 2013. Novel chemical weapon of an exotic macroalga inhibits recruitment of native competitors in the invaded range. ***Journal of Ecology***. **101:** 140–148.

Thorpe, A. S., Thelen, G. C., Diaconu, A. and Callaway, R. M. 2009. Root exudate is allelopathic in invaded community but not in native community: field evidence for the novel weapons hypothesis. ***Journal of Ecology.*** **97:** 641–645.

Verdu, M. and Valiente-Banuet, A. 2008. The nested assembly of plant facilitation networks prevents species extinctions. ***The American Naturalist***. **172:** 751-760.

Vitousek, P. M. and Walker, L. R. 1989. Biological invasion by *Myrica faya* in Hawaii: plant demography, nitrogen fixation, and ecosystem effects. ***Ecological Monographs***. **59:** 247–265.

Vivrette, N. J. and Muller, C. H. 1977.Mechanism of invasion and dominance of coastal grassland by *Mesembryanthemum crystallinum*. ***Ecological Monographs***. **47:** 301–318.

Werner, C., Zumkier, I., Beyschalg, W. and Maguas, C. 2010. High competitiveness of a resource demanding invasive *Acacia* under low resource supply. ***Plant Ecology***. **206 (1):** 83-96.