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Northeast Asia as a Source of Biological Control Agents for North American Weeds

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Abstract

Many weeds introduced to North America occur as native plants in Northeast Asia (China, Japan, Korea, and the Soviet Orient). These include well known Asian plants such as kudzu (*Pueraria lobata*), Eurasian water milfoil (*Myriophyllum spicatum*), and multiflora rose (*Rosa multiflora*). Weeds that are less recognized to occur as native plants in the region include: *Halogeton glomeratus, Kochia scoparia,* Russian thistle (*Salsola pestifer* = *S. australis*) and *Tamarix ramosissima* which are usually thought of as Middle Eastern or Central Asian species; plants usually regarded as European such as bindweed (*Convolvulus arvensis*), dyer's woad (*Isatis tinctoria*), *Carduus crispus,* leafy spurge (*Euphorbia esula*) and purple loosestrife (*Lythrum salicaria*); and a few plants usually associated with warmer climates such as *Hydrilla verticillata.* Many important North American weeds, of unknown origins, also occur commonly in Northeast Asia. The distributions in Northeast Asia are given for twenty-five North American weeds. The potential for finding useful natural enemies for American weeds in Northeast Asia appears to be good. Preliminary field surveys of kudzu in Japan and Korea, and leafy spurge in China have revealed rich and diverse complexes of natural enemies associated with both weeds. The region has a great variety of climates and biotic zones, including many of which are excellent matches with North American environments. This should allow the selection of natural enemies that are preadapted to North American habitats, including cold grasslands and steppes where many of the problem weeds of rangelands occur.

Introduction

Northeast Asia, defined as China, Japan, Korea, and the Soviet Union east of Lake Baikal, appears to be a potentially important source of natural enemies for weeds that are problems in North America. These weeds include both those which are native to Northeast Asia and others of uncertain origin that occur widely in the region. The only agents from Northeast Asia to be thus far employed outside the region for weed control are three carp fishes (Cyprinidae), introduced to many countries for aquatic weed management (Julien 1987). Except for some preliminary field surveys for natural enemies of kudzu (*Pueraria lobata* [Willd.] Ohwi; Fabaceae), and leafy spurge (*Euphorbia esula* L.; Euphorbiaceae) (Pemberton and Wang 1989), the region is virtually unexplored for natural enemies of American weeds. Northeast Asia has not been examined because most of the area (China and the Soviet Orient) has not been accessible and because the region's potential as a source has not been well recognized. A limited awareness that many American weeds occur in Northeast Asia as native plants is probably the principal reason for not recognizing the region's potential as a source for biological control agents.

The purpose of this paper is to give and indication of this potential by communicating information on: (1) the occurrence of North American weeds in Northeast Asia; and (2) the rich assemblages of natural enemies associated with two of these weeds. Information on the occurrence of weeds in Northeast Asia was obtained from published floras of the region, and to a lesser degree from field observations. Information from field surveys of leafy spurge and kudzu is used to indicate the potential of finding promising natural enemies in the area.

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Results and Discussion

The Plants

Table 1 shows some of the American weeds known to occur in Northeast Asia as native plants. These include well known Asian plants such as Eurasian water milfoil (*Myriophyllum spicatum* L.; Haloragaceae), Japanese honeysuckle (*Lonicera japonica* Thunb.; Caprifoliaceae), kudzu and multiflora rose (*Rosa multiflora* Thunb.; Rosaceae). These weeds, which are problems in the eastern and southeastern United States (Reed and Hughes 1970) occur in the moist environments of Japan, Korea and China. Weeds that are usually thought of as Middle Eastern species but which occur as native plants in the region include: halogeton (*Halogeton glomeratus* [M. Bieb.] C.A. Meyer; Chenopodiaceae), Russian thistle (*Salsola pestifer* A. Nels. = *S. australis* R. Br.; Chenopodiaceae) and tamarix (*Tamarix ramosissima* Ledeb. (Tamaricaceae). These plants, which are pests in the arid western United States (Pemberton 1986, Reed and Hughes 1970, Kerpez and Smith 1987), range from the Middle East through Central Asia east to Mongolia and northwestern China (Sinkiang Province), which are dry zones. Also occurring as native plants in Northeast Asia are weeds such as leafy spurge (*E. esula*) and purple loosestrife (*Lythrum salicaria* L.; Lythraceae), usually considered to be European species. Leafy spurge is a pest of the rangelands of the northern Great Plains region of North America (Watson 1985). It occurs sporadically in Japan and Korea and commonly in the grasslands of northern China and Mongolia. Loosestrife is a problem in wetland areas of the northern United States (Thompson *et al.* 1987). It occurs widely in wet areas of Northeast Asia from central China to the Soviet Orient and through Korea and Japan. Hydrilla (*Hydrilla verticillata* Royle; Hydrocharitaceae), a submersed aquatic weed of the southeastern United States northward to Delaware and California (Steward and Van 1987) is an Old World tropical species which ranges northward to China, Korea and Japan.

Viewing American weeds that are native to Eurasia as being limited to Europe or the Middle East has been a common occurrence. Many Eurasian plants may have been originally introduced to North America from the European parts of their ranges with the transfer of European agriculture. These introductions are often reported as "naturalized from Europe" in published floras and weed guides (Munz and Keck 1970, Reed and Hughes 1970, etc.). While this may, in many cases, be historically accurate, the weeds may appear to readers of the books to be European instead of Eurasian in distribution. A similar impression can be gained from the *Flora Europa* (Tutin *et al.* 1964-76) and other European floras, which often do not indicate the occurrence of Eurasian species in Asia. Actually a large portion of plants that are native to Europe also occur in Northeast Asia. Matthews (1937) reported that 480 of the 1500 higher plants of Britain range into temperate Asia. These plants constitute, in part, the Euro-Siberan floristic province of Good (1953).

Table 2 shows the occurrence in Northeast Asia of some North American weeds, whose origins are uncertain. Although most have been considered to be European in origin, many are probably Eurasian. These weeds grow in disturbed situations and have, to some degree, been selected by agriculture (Harper 1960). All of these plants occur in Europe as well as Asia and North America, many being pests in all three regions (Holm *et al.* 1977). Linnaeus described 12 of 14 of these weeds, an indication that they were probably common in Europe in his time (1700s). Some of these plants such as *Chenopodium album* L. (Chenopodiaceae) have been temperate zone weeds, of uncertain origins, for many years (Bassett and Crompton 1979). Other weeds have been thought to be native of many different areas. *Datura stramonium* L. (Solanaceae) has been reported as native to: tropical America (Munz and Keck 1970), the area between India and the Caspian Sea (Haselwood and Motter 1966), the tropics (Parker 1972), Eurasia and Africa (Reed and Hughes 1970) and Asia (Fernald 1950). The difficulty of determining the origins of these and many other weeds is expressed by the following disclaimer in the introduction of *Flora Europa* (Tutin *et al.* 1964-76), "all data on native established or casual status relating to weeds or other palaeosynantropic plants must be regarded only as approximate".

Table 1. North American weeds native to Northeast Asia.

Weed species	Japan	Korea	Soviet Far East	Mongolia	W. China (Sinkiang)	N.E. China (Manchuria)	N. China (Beijing)	C. China (Yangtze V.)	S. China (Canton-HK)
Euphorbia esula L. leafy spurge (Euphorbiaceae)	1, 12	1, 2, 12	1	4, 12	E	13	5, 6	7	
Halogeton glomeratus (M. Bieb.) C.A. Meyer halogeton (Chenopodiaceae)				11	3				
Hydrilla verticillata Royle hydrilla (Hydrocharitaceae)	1, 10	2, 10, 12				13	6	7	8, 9
Kochia scoparia (L.) Schrad. kochia (Chenopodiaceae)	1, 3	1	3	4	E	13	5, 6		
Lonicera japonica Thunb. Japanese honeysuckle (Caprifoliaceae)	1, 12	1, 12			E		6	7	8
Lythrum salicaria L. purple loosestrife (Lythraceae)	1, 10, 12	12	3	4		13	5, 6	7	
Myriophyllum spicatum L. Eurasian water milfoil (Haloragaceae)	1, 10, 12	1, 10, 12	3	4		E	6	7	8
Pueraria lobata (Willd.) Ohwi kudzu (Fabaceae)	1, 10, 12	1, 12				E	5, 6	7	9, 12
Rosa multiflora Thunb. multiflora rose (Rosaceae)	1, 3					E	5, 6	7	8
Salsola pestifera A. Nels. (= *S. australis* R. BR.) Russian thistle (Chenopodiaceae)		3	3, 4		E	13	6		
Tamarix ramosissima Ledeb. tamarix (Tamaricaceae)			3, 4	12	E				

[1] Sources of the records: 1. *Flora of Japan* (Ohwi 1965); 2. *Illustrated Flora of Korea* (Lee 1979); 3. *Flora USSR* (Komarov *et al.* 1934-1964); 4. *Flora Intramongolica* (Ma *et al.* 1979-1985), 5. *Flora of Beijing* (Hua *et al.* 1984); 6. *Claves Planarum Pekinensis* (Hua *et al.* 1986); 7. *Manual of Vascular Plants of the Lower Yangtze Valley* (Stewart 1958); 8. *Flora of Canton* (Choa 1956); 9. *Checklist of Hong Kong Plants* (Lau and Wong 1978); 10. *Geographic Atlas of World Weeds* (Holm *et al.* 1979); 11. Fu Hiang-chian, Inner Mongolian Agricultural College, pers. commun. 1987; 12. Pemberton, unpubl. field observations, 1986 and 1987; 13. *Weeds of Liaoning Province* (Guan *et al.* 1982). Numbers refer to record sources below, E = Expected.

Table 2. North American/Cosmopolitan weeds occurring in Northeast Asia.

Weed species	Japan	Korea	Soviet Far East	Mongolia	W. China (Sinkiang)	N.E. China (Manchuria)	N. China (Beijing)	C. China (Yangtze V.)	S. China (Canton-HK)
Abutilon theophrasti Medik. velvetleaf (Malvaceae)	1				13	5, 6		7	
Acroptilon repens (L.) DC. Russian knapweed (Asteraceae)				4	11				
Capsella bursa-pastoris (L.) Medik. Shepherd's purse (Brassicaceae)	1, 10	10, 12	3	4		13	5, 6	7	8, 9
Cardaria pubescens (C.A. Meyer) Jarmol. hairy whitetop (Brassicaceae)			4	4	E				
Carduus crispus L. (Asteraceae)	1			4		13	6	7	
Chenopodium album L. lambsquarters (Chenopodiaceae)	1, 10	10	3	4	E	13	5, 6, 10, 12	7	9
Convolvulus arvensis L. bindweed (Convolvulaceae)	10			4, 12	E	13	6		
Datura stramonium L. jimsonweed (Solanaceae)		10		4		13	6		9
Echinochloa crus-galli (L.) Beauv. barnyardgrass (Gramineae)	1 , 10	1, 10		4		13	6	7	8, 9
Eleusine indica (L.) Gaertn. goosegrass (Gramineae)	1, 10	10				13	6	7	8, 9
Isatis tinctoria L. dyer's woad (Brassicaceae)	1	1	4				5, 6		
Portulaca oleracea L. purselane (Portulacaceae)	1, 3, 10	10	3	3, 4	3	13	5, 6	7	9
Sonchus oleraceus L. sow thistle (Asteraceae)	1, 10	10		4		13	6	7	8
Tribulus terrestris L. puncture vine (Zygophyllaceae)	10	10	3	4, 12	3	13	6	7	

[1] The sources for the records are the same as in Table 1. Numbers refer to record sources below, E = Expected.

Many of the weeds listed in Table 2 are well integrated into the human cultures of Northeast Asia, suggesting longtime residence in the region. *Capsella bursa - pastoris* (L.) Medik (Brassicaceae), *Portulaca oleracea* L. (Portulacaceae), *C. album* and *Sonchus oleraceus* L. (Asteraceae) are used as human food in China (Stewart 1958). *Isatis tinctoria* L. (Brassicaceae) is used to make a popular tea in China (Wang, R., pers. comm., 1987). In China, bindweed (*Convolvulus arvensis* L.; Convolvulaceae) is called "Chinese convolvulus" (Ma *et al.* 1980).

Plants of long residence in the area could be expected to have natural enemies associated with them. Most of these weeds of both native and uncertain origins, except for hydrilla and *Acroptilon repens* (L.) DC. (Asteraceae), have congeneric relatives in Northeast Asia, which should increase the number of associated natural enemies.

The Natural Enemies

One would expect that these weeds, particularly the species native to Northeast Asia, to have specialized pathogens and insects associated with them in Northeast Asia. Since there has been little research on the natural enemies of these weeds in Northeast Asia, I will report findings from preliminary field surveys on leafy spurge (*E. esula*) and kudzu (*P. lobata*) to indicate the potential of Northeast Asia as a source for natural enemies for American weeds.

In 1986 kudzu populations were examined for natural enemies near Seoul and western South Korea; near Tokyo, Nagoya and Yamaguchi on Honshu Island, Japan; and on the northeastern portion of Kyushu Island, also in Japan. Kudzu was common in all of these areas but the vines were usually smaller than those in the southeastern United States. Most kudzu populations were attacked by numerous natural enemies, and insects were found feeding on most parts of the plant. The flowers and developing fruits were being fed upon by a number of Lepidoptera, including larvae that were probably *Lampides boeticus* Korot (Lepidoptera: Lycaenidae). The leaves were frequently mined by an agromyzid fly, a beetle (*Trachys auricollis* E. Saunders; Coleoptera: Buprestidae) and various Lepidoptera. *Liocrobyla lobata* Kuroko (Gracillaridae) and *Microthauma* sp. (Lyonetiidae) have been noted to mine kudzu's leaves in Japan (Yano, K. pers. comm., 1986). Other Lepidoptera observed were leaf folders (possibly *Charema* sp.; Pyralidae), leaf rollers, leaf skeletonizers and general defoliators, including a *Clanis* sp. (Sphingidae). The leaves in many kudzu populations were severely galled by a fly, probably *Calopedila pueraiae* Shinji (Diptera: Cecidomyiidae). Larvae of an unknown borer were found in the growing shoot tips of the vines. The woody stems of the plant were commonly attacked by a large weevil (*Mesalcidodes trifidas* [Puscoe]; Coleoptera: Curculionidae), which formed spherical galls 3 to 6 cm in diameter. A smaller weevil (*Eugnathus distinctus* Roelofs; Coleoptera: Curculionidae) is known to feed on the roots of kudzu (Morimoto, K., pers. comm., 1986). This weevil is thought to be common in Japan, Korea and China. In addition to these insects, an unknown rust was observed on the leaf blades and petioles, and what appeared to be a mosaic virus was seen infecting the leaf blades. These organisms were found during a few weeds of part-time field work, in only part of the plant's range. Many other insects and diseases would probably be discovered with more effort, particularly in China where almost nothing is known about the natural enemies associated with the *Pueraria* spp. that occur there.

In 1986 a several-week survey for leafy spurge and its natural enemies was made in Korea and Japan. Populations of the plant were difficult to locate and had few natural enemies associated with them. A few Lepidoptera (including unknown Geometridae and Psychidae), Homoptera and a rust (probably *Melampsora euphorbiae* [Schub.] Cast. (Teliomycetes) were infecting the leaves. None of these organisms appeared to be damaging.

In 1987, China permitted me to do survey work in northern China (in the Beijing area and Lioaning Province) and in the Inner Mongolian Autonomous Region. Dr. Ren Wang of the Chinese Institute for Biological Control, Chinese Academy of Agricultural Science hosted and worked with me during the survey. The leafy spurge population were morphologically varied, but included forms that were similar to those that are problems in North America. These forms were growing on the Inner Mongolia grasslands, which also had the greatest

abundance and diversity of natural enemies. The plants were often common, particularly in Inner Mongolia, but did not appear to be problematic (leafy spurge is not considered to be a problem in China, Wang, R., pers. comm., 1987). The plants were, in some areas, attacked by large populations of *Aphthona* flea beetles (Coleoptera: Chrysomelidae). These included *A. chinchihi* Chen and *A. seriata* Chen. The adult feeding of these beetles defoliated the plants at some sites. Species and groups of insects previously known from Europe were also found in Inner Mongolia. These included *Oberea* probably *erythrocephala* Schrank (Coleoptera: Cerambycidae), *Hyles* probably *euphorbiae* L. (Lepidoptera: Sphingidae) and *Chamesphecia* sp. (Lepidoptera: Aegeriidae). *Oberea* was found boring the stems of up to 97% of the plants in some areas. The plants were commonly infested with two aphid species and almost a dozen unidentified Lepidoptera were seen feeding on the flowers and leaves. A leaf miner (Diptera: Agromyzidae) was common in the leaves and flower bracts. A number of pathogens were observed, including a powdery mildew and what is probably *M. euphorbiae* which appeared, in some locations, damaging to the plants. One of the most impressive organisms seen on the survey was an *Endophyllum* rust (Teliomycetes) which distorted and killed plants. If this rust will attack North American leafy spurge, it could have great potential as a biological control agent of the weed. It is noteworthy that not only does leafy spurge have a Eurasian distribution, but so does much of its "European" insect fauna. Leafy spurge and its natural enemies occur in much colder situations in Asia than they do in Europe. Insects and diseases attacking the plants in the cold grasslands of Inner Mongolia should be preadapted to the similar cold grasslands of North America, where leafy spurge is a problem.

Access to Northeast Asia

Both Korea and Japan have good access for foreign biological control specialists. To my knowledge, foreign biological control of weeds workers have not done field work in the Soviet Orient. There have been some exchanges of natural enemies for weed control between the USSR and USA (Julien 1987, USDA-ARS, Albany CA., unpubl. records) and several successful field surveys for *Halogeton* and *Salsola* insects were made in the western and central parts of the USSR in 1965 and 1977 (Andres, L.A., pers. comm., 1988). My 1987 leafy spurge survey of northern China and Inner Mongolia was the first field survey in China by a foreign biological control of weeds worker. There has also been exchanges of biological control materials between the U.S. and China, including the alligator weed flea beetle (*Agasicles hygrophila* Selman and Vogt; Coleoptera: Chrysomelidae) recently sent to China from Florida (Buckingham, G., pers. comm., 1988).

Conclusions

Many North American weeds occur in Northeast Asia as both native and introduced species. Surveys of leafy spurge and kudzu revealed rich complexes of natural enemies associated with both weeds. This suggests that Northeast Asia could be an important source for natural enemies for these and other North American weeds. Northeast Asia's great climatic and environmental diversity should allow for the selection of agents that are preadapted to North American environments. Whether or not Northeast Asia becomes an important source for natural enemies of American weeds will depend upon an increased recognition of the region's potential and upon the growth of scientific cooperation between nations.

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NOTE ADDED IN PROOF: In 1988 the Sino/American Biological Control Laboratory was formed in Beijing, China, by the Chinese Academy of Agricultural Sciences and ARS, USDA. Leafy spurge, hydrilla and Eurasian water milfoil currently are the principal weeds under study by the laboratory (R. Wang, pers. comm., 1990).