TECHNOLOGY DEVELOPMENT PROPOSAL

PROJECT STATUS: New

PROJECT NUMBER: R1-1999-01

PROJECT TITLE: A Demonstration and Evaluation of the Effects of Interactions Between Biological Control Agents and Chemical, or Fire Treatments for Managing Spotted Knapweed

SUBJECT: Noxious Weed Biological Control

PROJECT OBJECTIVES:

1. Evaluate the effects of chemical applications (Tordon and Transline) on the survival over time of two root-feeding biological control agents, Agapeta zoegana and Cyphocleonus achates.
2. Determine whether different densities of knapweed, achieved through different chemical treatments, affect the ability of biological control agents to establish and increase in population size.
3. Determine whether fire has an effect on population size of root-feeding biological control insects and the knapweed seedbank.
4. Develop a set of recommendations to assist land managers in determining the best treatment or combination of treatments, for spotted knapweed based upon our findings from biological, chemical and prescribed fire trials.

BRIEF DESCRIPTION OF PROJECT:

This project consists of two interlinked studies. In the first study, we will test two hypotheses: the first is that biological control insects can survive in areas treated with low concentrations of herbicides. The assumption is that at low concentrations, not all knapweed plants are killed, thus leaving refugia for the insects. A preliminary study found strong evidence of the ability of A. zoegana to survive in knapweed plants remaining in skips (areas missed by the herbicide) and surrounding untreated areas following an aerial application of a herbicide (Sturdevant, Six, Vander Meer, unpublished data). The second hypothesis is that lowering densities of knapweed in areas where it is well established will help optimize conditions for biological control insect establishment and efficacy. Our experiments are designed to assess which densities of knapweed might be optimal for the biological control insects and determine what herbicide concentrations will be necessary to achieved these densities. We will focus our efforts on two herbicides: Tordon, a commonly utilized herbicide in management of

knapweed, and Transline, which unlike Tordon can be used in forested areas because it has no or little effect on trees. By assessing both herbicides, we will be able to develop data supporting weed management programs in a wide range of situations.

In the second study we will also test two hypotheses: the first is that biological control agents feeding in the roots can survive the direct effects of burning. The effects of a low versus a high intensity burn will be evaluated on the root-feeding insects. The second hypothesis is that fire has a negative effect on the knapweed seedbank and therefore an indirect effect on insects over time. The burning project will be done in a forested area that has been recently logged and is infested with spotted knapweed. Some logging slash must remain on the ground to facilitate the fire and therefore have an effect on the spotted knapweed seedbank, otherwise without some slash, fire in knapweed acts like a crown fire and never results in high enough temperatures to affect the seedbank. Woody debris will be added or removed to simulate the two treatments of a low and high intensity fire.

Both studies are conducive to use as demonstration projects for displaying the effects of an integrated management approach in managing spotted knapweed.

FHP PERSON WHO WILL LEAD THE PROJECT:
Nancy Sturdevant, FHP, Missoula Field Office.

JUSTIFICATION:
The invasion of exotic weeds is one of the greatest threats to natural ecosystems in the western United States. Exotic weeds often dominate the natural vegetation where they become established. This results in lower diversity and abundance of native plants, which greatly alters the biological community.

Invasive noxious weeds are difficult to manage. The effectiveness of herbicides is well known, however, herbicides often remove native plants along with the target weed and are short term in their effects. Biological control, the utilization of natural enemies in the management of pest organisms, is an approach that holds much promise for the control of weeds in natural environments. Unlike chemical control that must be periodically reapplied, biological control is long-term in its effects and poses few risks to the nontarget organisms and the environment. In situations where biological control alone does not provide a desired level of control of the pest, it can still provide an important tool as a part of an integrated pest management program.

Prescribed fire is a treatment that is being widely and increasingly used to manage western forest vegetation. In certain instances, spotted knapweed infestations are also burned as part of a larger land management plan. In areas where biological control agents have already been released, land managers do not always have the option of altering the management plans and not burn, to protect their biological control releases. Therefore information is needed to determine the effects of Fire on the biological control agents and spotted knapweed.

Currently, and increasingly so in the future, an integrated approach to knapweed management will be the choice of land managers for economic and environmental reasons. Each treatment individually has its benefits and drawbacks, integrating treatments will, in certain circumstances, be the only choice for land managers. An example of this would be a forested area where biological control agents had been previously released but now will be burned as part of a larger land management plan. We need to know what the effects are on the biological control agents to make informed land management decisions.

URGENCY:
Spotted knapweed, Centaurea maculosa, is a perennial aggressive weed that has invaded nearly three million hectares in nine western state and Canada (Davis and other 1993) with over two million hectares invaded in Montana alone (Chicoine and others 1985). The Office of Technology Assessment (OTA-F-565, Sept. 1993) states that "a ballpark figure for total direct non-indigenous weed costs is $3.6 billion to $5.4 billion annually." Spotted knapweed is a perennial forb that reproduces by seeds and can produce up top 1000 seeds per plant (Watson and Renney 1974). These seeds may remain viable for many years in the soil (Davis and others 1993). Therefore, spotted knapweed presents a serious management challenge. Areas where spotted knapweed were established are characterized by reduced livestock and wildlife forage (Spoon and others 1983), increased erosion (Lacey and others 1989) and lowered biodiversity (Tyser and Key 1988).

Historically, the invasion and spread of spotted knapweed has been left unchecked or treated with a variety of herbicides. Cultural methods, including mowing and grazing, have also been tried by small land owners and ranchers. At present, most efforts at controlling spotted knapweed have focused on the use of herbicides, and to a lesser degree biological control agents, though seldom in conjunction with each other. At present, most biological control efforts are focused on the distribution of two promising insects, a moth, Agapeta zoegana and a weevil, Cyphocleonus achates.

Forest and district personnel have been releasing biological control agents for spotted knapweed over the past decade or more. Spotted knapweed is continuing to encroach into previously uninfested forested areas. Reducing spotted knapweed levels will probably require an integrated approach using biological, chemical and cultural tools (Roches and other 1986; Story 1989). A combination of treatments such as biological control insects with herbicides may be more effective and provide more long-term control than either treatment alone. Further, the use of one treatment may increase the efficacy of another. For example, particular site characteristics, including host plant density, are essential to the successful establishment and reproductive success of biological control agents. Altering a knapweed community to fit the needs of the biological control agents may be an important step in minimizing establishment time and their ability to impact the host plant.

LINK TO NATIONAL FHP TECHNOLOGY DEVELOPMENT STEERING COMMITTEE PRIORITIES:

There is currently no steering committee on biological control of weeds. However, this proposal has been strongly recommended by a committee consisting of R-1 FHP personnel, Forest Insect and Disease Research, University of Montana and Montana State University scientists, R-1 Forest Rangeland Management, and botanists, wildlife biologists, and range conservationists from R-1, that are involved in biological control efforts of weeds. Noxious weed management has been recognized nationally by the Forest Service (Chief's Natural Resource Agenda and the SPF Action Strategy) as an area of concern. Issuance of the President's Executive Order on Invasive Species also indicates a high level of national priority.

SCOPE OF APPLICATION:
Spotted knapweed is found throughout much of the United States and western Canada. The most serious infestations occur in Idaho, Montana, Oregon, and Washington. Products of this study will be applicable anywhere knapweed grows and is treated with biological control agents, chemical or burning applications.

RESEARCH BASIS:
The basis for this project became evident during studies conducted in a previous TDP (Developing monitoring tools, determining impact and developing a risk rating system for biological control agents of spotted knapweed) by the proposing authors. We found that many sites where biological control agents were released were then either treated with chemicals or burning. This occurred because land managers did not view the biological control agents as having an impact on the knapweed (this was largely because they did not have adequate monitoring methods to assess establishment and impact) or that the time required for biological control to become effective was too long.

In recent field observations, larval and adult Agapeta zoegana were present in skips (areas missed during chemical application) and in the surrounding area of a release site that had been sprayed with Tordon (Sturdevant, Six, Vander Meer, unpublished data). We hypothesize that the early summer application of Tordon allowed the insects to finish development, emerge and move onto the adjacent knapweed. This situation increases the insect density on the unsprayed knapweed causing greater impact. In the proposed study herbicides and fire would be used to lower the density of the knapweed while increasing stress on the plants, which in combination with the insect stress, pushes the competitiveness of the knapweed below the threshold that allows it to remain dominant.

Few biological control insects perform optimally in monocultures of their host plants. This may be true with knapweed insects for whom releases are recommended to be made on sites where knapweed is moderately dense rather than dense (J. Story, pers. communication). Therefore, optimizing site conditions for biological control insects for knapweed management might be achieved by first using herbicides to reduce knapweed to densities to those most optimal for insect establishment and efficacy.

Sheley and Jacobs (1997) have shown that in simulations using competitive coefficients derived from a 90% reduction in knapweed a plant community would be put on a trajectory toward grass domination. With the additional stress placed on knapweed by

biological control agents this shift might occur at less than a 90% reduction or take place more rapidly.

McCullough et al (1998) showed that soil arthropod populations decreased following a fire, followed by a rapid colonization period (6 months to 2 years). We hypothesize that the two root feeding biological control agents will survive the impact of fire because of the insulation of feeding in the roots. We also need information on the indirect effects of the fire on the insect populations over time and the impact on the resultant vegetation.

METHODOLOGY:
Objectives

1. Evaluate the effects of a chemical application (Tordon and Transline) on the survival over time of two root feeding biological control agents, Agapeta zoegana and Cyphocleonus achates.

2. Determine if different densities of knapweed, accomplished by chemical treatments, affect the biological control agent's ability to establish and increase in population size.

Agapeta zoegana and Cyphocleonus achates are the two root feeding biological control insects that will be used in this project. We propose to look at the effects of herbicides on these insect's establishment and reproductive success following separate applications of three different strengths of picloram (Tordon) and clopyralid (Transline); each applied at 0.125, 0.0625 and 0.03 lbs ae/acre.

The sites will be located on Plum Creek land in the Cramer Creek drainage, 25 miles east of Missoula, MT. The site is approximately a 10 acre parcel of rangeland with a moderate to heavy infestation of spotted knapweed. Both insects have already been released and established at this site for several years. We will also augment the insect populations to have a more even distribution of both insects across the site.

Spring of 1999
Thirty-five, 10 x 10m plots will be staked out with sufficient buffers of 4 m between plots. Seven treatments will be applied and replicated 5 times in a randomized complete block design (7 treatments x 5 replications = 35 treatment plots). We might block either insect or knapweed densities based upon our preliminary assessment of these parameters across the plots.

Pretreatment densities of adult insects using a non-destructive sampling technique will be measured on all plots. Destructive larval sampling techniques will be done around each treatment plot and along transects in the buffers between plots. The insect monitoring will be done using already established techniques in use by Western Agricultural Research Center and the US. Forest Service (J. Story technique for measuring adult populations; and N. Sturdevant and S. Kegley-larval technique developed in R1-97-2 Technology Development Proposal).

Summer 1999

Augmentation of the insect populations on each plot will take place in July of 1999 for Agapeta and late August 1999 for Cyphocleonus if needed. Forty insects of each species will be added to each plot. Each plot will be sectioned into quarters and the insects will be placed at each center to insure a more evenly distributed insect population across treatment plots. Insects to augment populations will be purchased from the Western Montana Experiment Station, Corvallis, MT.

Fall 1999

Pretreatment evaluations of the knapweed will be conducted by randomly selecting five-individual, square meters per plot. Data on the following parameters will be collected: site characterization including: soil and slope characterizations; knapweed measurements including: densities, seedhead production, seedling and mature plant numbers, heights and stalk number, crown width of mature plants, and number of viable versus non-viable seedheads. We will assess the non-knapweed plant community components by species and percent ground that each species occupies.

Year 2000

Chemical treatment plots will be sprayed in the spring by Dow AgroScience with either picloram (Tordon) or clopyralid (Transline) at the three concentrations. Dow AgroScience has agreed to supply and apply all chemicals, and provide their senior scientist as a project consultant throughout the duration of the project.

Post-treatment evaluations of both larval and adult populations will be done using the same pretreatment techniques mentioned above.

Post-treatment evaluations on the plot vegetation will be done using the same methods as described for the pre-treatment survey. Data will again be collected on both the knapweed and non-knapweed plant community components.

Summer of 2001

Second year final data collection on the above described parameters in the post-treatment evaluation. At this time we will excavate a number of knapweed plants/plot to determine the survival and reproductive success of the insect populations.

Study 2:

Objective 3. Determine whether fire has an effect on population size of root-feeding biological control insects and the knapweed seedbank.

Spring of 1999

Fifteen, 1/20 acre plots will be staked out with sufficient buffers of 4 m between plots. These plots will be located at a different site than the chemical treatment study. The site will have an already established population of both Agapeta and Cyphocleonus. Three treatments will be applied and replicated in a randomized complete block design 5 times

(3 treatments x 5 replications = 15 treatment plots). The treatments consist of a control-no burning, a low intensity burn and a high intensity burn.

Pre-treatment densities of the insects and of the knapweed seedbank will be performed. The insect population monitoring will include estimates of larval and adult insects. The insect monitoring will be done using already established techniques in use by Western Agricultural Research Center and the US. Forest Service as mentioned above. The natural seedbank density and viability monitoring will done using already established methods described by Davis et al (1993). A bulb planter is used to remove soil cores containing knapweed seeds; the samples are sieved down to 0.6 mm squared, and then the seeds are removed by hand, counted and planted in germination trials.

Summer 1999
Augmentation of the insect populations on each plot will take place in July of 1999 for Agapeta and late August, 1999 for Cyphocleonus. This will be done to assure a more evenly distributed insect population across treatment plots.

Fall 2000
Dr. Ronald Wakimoto from the School of Forestry at the University of Montana will conduct burning applications using a drip torch so intensity can be controlled. The burning will be done in the Spring of 2000 when conditions are suitable for achieving the desired burning outcome.

Shortly after the fire, post-treatment evaluations of both larval and adult populations of the two root-feeding insects and the knapweed seedbank will evaluated. One-year post treatment evaluations of the knapweed seedbank will also be done the evaluate the effects of fire on the overwintering survival of burned seed. The percent of viable seed will be determined by germination tests of a select number of randomly collected seeds from pre-fire, post-fire and one year post-fire soil core collections in the greenhouse at the University of Montana. Also at this time, the survival of the insects will be remeasured and their reproductive success. This will be continued following the completion of the TDP by the University of Montana.

MEASURE OF SUCCESS:
The development of a set of recommendations to assist land managers in determining effective spotted knapweed treatments integrating biological control agents with either Fire or chemical treatments. Establishment of demonstration areas illustrating integrated management techniques to control knapweed.

COOPERATORS:
Dr. Diana Six, University of Montana, School of Forestry , Missoula, MT.

Dr. Ronald Wakimoto, University of Montana, School of Forestry, Missoula, MT.

Mary Halstvedt, Dow AgroSciences, Billings, MT.

Dr. George Markin, Biological Control Lab, US Forest Service, Intermountain Station, Bozeman, MT.

Dr. Ronni L. Korol, US Forest Service, Intermountain Station, RWU-4151, Missoula, MT.

Jim Olivarez, US Forest Service, R-1, Forest and Rangeland Management, Missoula, MT.

Jim Story, Montana State University Western Agricultural Center, Corvallis, MT.

Alan Knudsen, Weed Coordinator, Missoula County Weed Board, Missoula, MT.

Andy Kulla, Resource Forester, US Forest Service, R-1, Lolo Ranger District, Missoula, MT.

Plum Creek Timber Company Inc. Missoula, MT.

PRODUCTS:

1. Develop a set of recommendations to assist land managers in determining the best treatment or
combination of treatments, for spotted knapweed based upon our findings from biological, chemical and prescribed fire trials.

2. A demonstration area to display and educate interested parties on the effects and benefits of integrated weed management.

PUBLICATIONS: The results of this project will be published as a Forest Service technical report and in one or more scientific journals.

TECHNOLOGY TRANSFER:
Results of this project will be transferred to users through the development of recommendations on the appropriate rates of herbicides to be used in conjunction with the implementation of biological control agents. This information will be transferred through technical reports, training sessions, and informational leaflets. The plots established as part of this project will be used as demonstration areas to illustrate the results and promote the integrated management of spotted knapweed using biological control agents. There is a high level of support for this information from the Regional Noxious Weed program manager, from ARS, and from County Weed Management boards.

PROJECT DURATION: 2 years.

BUDGET REQUEST: Year One-1999

	ITEM	Requested FHP STDP Funding	Other Sources amount	Organization Name
Admin items:	Salary			
	PhD Student	$14,500	$6,400	Univ of Montana
				Dow Chemical
	Univ Faculty	$ 2,000	$6,680	Univ of Montana
				Dow Chemical
	FS Employee		$3,537	Lolo NF
	FHP		$6,155	FHP
	Seasonals	$10,930		
	Overhead	$ 4,849		
	Travel	$12,960	$ 2,500	
FHP Procurements:	Contracting	$ 2,000		
Statistics				
	Equipment			
	Supplies	$ 6,100		
	Other			
Total		$53,339	$25,272	

TOTAL FY 1999 Budget: $78,611

Year Two: 2000

	ITEM	Requested FHP STDP Funding	Other Sources amount	Organization Name
Admin items:	Salary			
	PhD Student	$14,500	$6,400	Univ of Montana
				Dow Chemical
	Univ Faculty	$ 2,000	$6,680	Univ of Montana
				Dow Chemical
	FS Employee		$3,537	Lolo NF
	FHP		$6,155	FHP
	Seasonals	$ 7,286		
	Overhead	$ 4,274		
	Travel	$12,960	$ 2,500	
FHP				

Procurements:	Contracting		
	Equipment		
	Supplies	$ 3,000	
	Other	$ 3,000	
Total		$47,020	$25,272

TOTAL FY 2000 Budget: $72,292

Benefit Cost Analysis:
Potential benefits of the proposed project include a substantial long-term reduction in weed management costs including the costs of herbicides, a reduction in the impact of herbicides on native plant diversity and abundance, and other negative impacts on the ecosystem; better efficacy and a shorter establishment time for the biological control insects; and increases in wildlife and domestic animal forage in affected areas. If the insects survive either the chemical or Fire applications, repeat releases of insects should be greatly reduced. Further, the acceptance by the public of lowered concentrations of herbicides applied across the landscape to control knapweed is immeasurable.

Project Cost: All chemicals and application of chemicals on plots will be provided by Dow AgroSciences. The Forest Service and University of Montana are providing approximately 4 months of salary for two researchers, Nancy Sturdevant, FS, and Diana Six, University of Montana over a two year period. Plum Creek is providing us use of their land. The University of Montana has agreed to do the burning. The primary cost of the project will be to hire a Ph.D. student from the University of Montana, and three seasonal employees for 10 weeks the summer of 1999 and two seasonal employees during the summer of 2000 for installing plots and collecting the data.

Background:
The cost of the herbicides are as follows:
Tordon-$90/gallon at 0.25ae/ac = $11.25ae/ac, at .125 ae/ac = $ 5.63/ac, at .0625ae/ac = $2.81/ac, at .03ae/ac = $1.41/ac.
Transline-$348/gallon at 0.25ae/ac = 29/ac, at .125ae/ac = $14.50/ac, at .0625ae/ac = $7.25/ac, at .03ae/ac = $3.63/ac.

-The cost of the biological control agents are:
Agapeta = @ .50/ unit when bought in quantity
Cyphocleonus = @ $1.00/unit when bought in quantity
-25 Agapeta and 10 Cyphocleonus will be released/acre

Assumptions:
-Assuming treating 30,000 acres/year throughout the state of Montana for knapweed reduction
-Assuming that it will take 66 years to treat the knapweed infestation just in the state of Montana.

-Assuming that Transline and Tordon will need to be reapplied every ten years for control of knapweed.
-Assuming that the reduced concentrations of herbicides and the release of the biological control agents will only be done once.

Economic Calculations:

We will use Transline only for these calculations and at the middle concentration rate. We will also use the figures just for Agapeta. We did not do an economic analysis for burning because we are not proposing burning as a treatment for knapweed, we are only evaluating the effects of already proposed burning treatments on the biological control agents.

Expenditure and Output Values without Project
($14.50/acre for Transline x 30,000 acres sprayed per year x 66 years to spray the knapweed infestation in MT) x 6 repeated applications of herbicides over the 66 year period for each acre origianlly sprayed =$172,260,000/(1.04)66 = $12,941,483

Expenditure and Output Values with Project
($7.25/ac for Transline x 30,000 acres sprayed per year x 66 years to spray the knapweed infestation in MT)/(1.04)66 + ($375,000/(1.04)66 for Agapeta purchase and release) + ($157,095 the cost of the TDP project) = $1,263,725

Benefit Attributable to Project = $ 12,941,483 - $1,263,725 = $11,677,758

Benefit/Cost Ratio = $11,677,758/$150,903 = 77.4

Benefit Attibutable to STDP Funds = 77.4 x $7,767,787 = $7,767,787

PNV of Project: $11,677,758 - $150,903 = $11,526,855

PNV of STDP: $7,767,787 - $100,359 = $7,667,428

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