United States Department of Agriculture

Forest Service

Forest Health Technology Enterprise Team

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Enclosure 2

Special Technology Development Program

New Project Proposal

PROJECT NUMBER : **R1-2002-03**

PROJECT TITLE: Develop techniques to Quantify Impact of *Agapeta zoegana* and *Cyphocleonus achates* on Spotted (*Centaurea maculosa)* and Diffuse Knapweed (*Centaurea diffusa*) Populations and further Evaluate Site and Plant Characteristics that are Important to the Success of Biological Control Agents of Knapweeds.

PROJECT STATUS: New

EXPECTED PROJECT DURATION: **2 years**

EXPECTED COMPLETION DATE OF THE PROJECT:**2004**

SUBJECT (This is a hierarchical table that helps us understand our financial investment. Please indicate percentage of funding for all that apply; total percentage for numbers 1-6 should equal 100):

1. Total Suppression/Prevention Technology	%		2. Survey and Monitoring Technology	%	
a. Total Biological Control i. Microbial % ii. Parasitoides % iii. Synthetic hormones/pheromones % iv. Other %	**85**	%	a. Advancements in Detection Technology		%
			b. Landscape Level Assessment Technology i. Data Visualization		%
b. Total Modeling i. Pesticide (Insecticide) Application % ii. Disturbance % iii. Growth and Yield % iv. Organism % v. Population % vi. Terrain %		%	c. Remote Sensing i. Aerial % ii. Hyperspectral % iii. Satellite %		%
			d. Other		%
c. Genetic, Cultural and Silvicultural Interactions		%	3. Assessment Technology	%	

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Silvicultural Innovations For Controlling Pest Species i. Fire % ii. Methyl Bromide Alternatives % iii. Thinning/Regeneration Techniques and other Silvicultural Guidelines % iv. Resistance, Screening, and Breeding %			a. GIS % b. Spatial Analysis % c. Landscape Analysis % d. Decision Support % Risk and Hazard % Expert Systems %		
d. Pesticide Application (Spray) Technology i. Equipment innovations % ii. Methods and Guidelines %		%	4. Social Values	%	**15**
			5. Technology Transfer Innovations	%	
e. Other		%	6. Other	%	

Enclosure 2 continued

STATUS OF SUBJECT SPECIES : non-native invasive

PROJECT OBJECTIVES :

- Develop a sequential sampling system for evaluating larval populations of root-feeding biological control agents.
- Refine the recommendations for using several "key" plant and site characteristics to improve establishment of *A. zoegana* and *C. achates*.
- Evaluate impact of *A. zoegana* and *C.achates* on spotted and diffuse knapweed across primarily Montana, and in Idaho and Washington.
- Refine the set of management recommendations developed from a previously related knapweed STDP for improving the establishment of biological control agents of knapweed and integrating biological control with other management methods.

BRIEF DESCRIPTION OF PROJECT:

2002

- Remeasure knapweed plant populations and densities of *A. zoegana* at 44 sites (approximately ½ of the original sites measured in a 97-98 STDP). Evaluate selected site characteristics: weather data including average summer and winter temperatures and

precipitations annually since release, disturbance factors, current land use, % bare soil and % of top five plants other than knapweed, including grasses and forbs.

- Remeasure knapweed plant populations and densities of *C. achates* at 23 sites (approximately ½ of the original sites measured in a 97-98 STDP). The same plant population and site characteristics outlined for *A. zoegana* above will also be measured for *C. achates*.
- Develop a sequential sampling system for measuring larval populations of *C. achates.*
- Determine densities of *A. zoegana* and *C. achates* and the diffuse knapweed population at six sites in western Montana.

2003

- Remeasure knapweed plant populations and densities of *A. zoegana* at 42 sites (approximately the other ½ of the original sites). Evaluate selected site characteristics: weather data including average summer and winter temperatures and precipitations annually since release, disturbance factors, current land use, % bare soil and % of top five plants other than knapweed, including grasses and forbs.
- Remeasure knapweed plant populations and densities of *C. achates* at 22 sites (approximately the other ½ of the original sites). The same plant populations and site characteristics outlined for *A. zoegana* above will also be measured for *C. achates*.
- Determine densities of *A. zoegana* and *C. achates* and the diffuse knapweed population at an additional six sites in western Montana.
- Further develop a sequential sampling system for measuring larval populations of *C. achates.*
- Summarize and analyze data.
- Produce a FHP Report outlining describing a larval sequential sampling system for root-feeding biological control agents.
- Produce a FHP Report refining our recommendations for selecting site and plant characteristics for improving establishment and impact of *A. zoegana* and *C. achates.*

2004

- Produce several journal articles reporting our results and conclusions.

FHP LEAD CONTACT

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FHP LEAD INVOLVEMENT (add lines as necessary)**:**

	Role	Time Commitment
N. Sturdevant	Project Supervisor and Cooperator	20%
S. Kegley	Project Supervisor and Cooperator	15%

PRINCIPAL INVESTIGATOR(S) (add lines as necessary)**:**

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
Janelle Corn	Montana State University	(406) 961-3025
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PRINCIPAL INVESTIGATOR(S) INVOLVEMENT (add lines as necessary)**:**

Name	Role	Time Commitment
Janelle Corn	Project Cooperator	20%

COOPERATORS (contributing to, but not leading, the project) (add lines as necessary):

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax

Jim Story jstory@montana.edu	Montana State University	(406) 961-3025
Jim Olivarez joliverez@fs.fed.us	R1 Range Specialist	(406) 329-3621
Alan Knudsen	Missoula County Weed Coordinator	(406) 829-0946
Range Specialists	R1-Helena, Lolo, Kootenai, Bitterroot, B-D Forests	

COOPERATOR INVOLVEMENT (add lines as necessary)**:**

Name	**Role**	**Time Commitment**
Jim Story	Project consultant	5%
Jim Olivarez	Project consultant	5%
Alan Knudsen	Field Assistance & Project Consultant	5%
Range Specialists (from 5 R1-Forest)	Field Assistance & Project Consultant	5% each

JUSTIFICATION:

The data we collected during the earlier knapweed TDP represents the "only" data set of this size and detail and will be essential in determining the impact of *A. zoegana* and *C. achates* on knapweed. Further work on using plant and site characteristics is needed to fully understand the role they play in establishment of the insects and their associated impact on knapweed.

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 are of concern. Issuance of the President's Executive Order on Invasive Species also indicates a national high level of priority.

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.

Currently, and increasingly so in the future, biological control of knapweed will be the choice of land managers for economic and environmental reasons. Knapweed is increasing over the western landscape at an alarming rate. Biological control in remote areas or over expansive knapweed infestations where other control methods are not economically feasible will be the only solution. We need to know if the biological control agents are reducing knapweed populatons 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 to 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 we 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.

NATIONAL FHP TECHNOLOGY DEVELOPMENT PRIORITY

Priority 1: _X_ Priority 2: __ Priority 3: __ Priority 4: __

This project 1) evaluates impact of the two most promising biological control agents of spotted knapweed, 2) develops a sequential sampling scheme for a promising biological control agent, and 3) refines the set of site and plant characteristics that were recommended based on the results of our earlier TDP.

TECHNICAL COMMITTEE DEVELOPMENT PRIORITY (check at least one and describe how proposed work addresses the priorities):

Priority 1: __ Priority 2: __ Priority 3: __ Priority 4: __

Priority 5: __ Priority 6: __ Priority 7: __ Priority 8: __ Priority 9: _X_

This project 1) evaluates impact of the two most promising biological control agents of spotted knapweed, 2) develops a sequential sampling scheme for a promising biological control agent, and 3) refines a set of site and plant characteristics that were recommended based on the results of our earlier TDP.

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.

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. From the previous TDP we established a baseline for biological control agent populations and knapweed densities. Also, we identified a set of site and plant characterisitics that were important to the establishment of *A. zoegana* and *C. achates*. As part of the 2001 proposed TDP, we will remeasure 131 releases of A. zoegana and C.achates and compare them to the baseline data collected in 97-98. More intensive measurements of several of the "key" site and plant characteristics will be taken in the proposed TDP to fully understand their role in establishment of the insects and their impact on knapweed.

Results from our 97-98 STDP showed that for both *A. zoegana* and *C. achates* the percentage of infested roots increased with root diameterOther physical factors that were not statistically significant when analyzed separately, but had *P* values high enough to merit further consideration in multi-factor models, were slope, precipitation, and the presence of disturbance factors (Clark *et al* 2001).

Biological control offers the most promise for permanent control of this noxious weed over large areas of forest and rangeland. Thirteen species of herbivorous insects have been introduced into North America against spotted knapweed (Rees et al. 1996; Julien and Griffiths, 1998). Of

these, eight species attack the seed heads and three feed inside the roots. This study concerns two of these root-feeding species, *A. zoegana* and *C. achates*.

Management of project activities can be improved by knowing how factors affect the probability of establishment, so that future releases can be made at favorable sites, using the most effective release techniques. Gaining information about factors affecting success in the release process requires information about the relative efficacy of different sampling methods available to detect released insects and thus demonstrate success or failure of establishment at particular sites.

METHODS:

Hypothesis I: There has been a significant and measureable decrease in spotted and diffuse knapweed densities where *A. zoegana* and *C. achates* have been released for 5 years or more.

To determine impact of *A. zoegana* and *C. achates* on knapweed populations, we will use three sampling methods: root dissection for *C. achates* larvae, visual counts of adult *A. zoegana* resting on plants, and sweep net sampling for adults of both species.

Larval Sampling. Larvae of *C. achates* will be sampled by dissecting 52 spotted knapweed roots from each site. Each root will be dissected and number and species of all recovered larvae recorded. **Visual Sampling for *A. zoegana***. In July, August or September (depending upon location and elevation) we revisit all sites to sample adult *A. zoegana*. **Sweep Net Sampling**. Because land managers are familiar with the use of sweep net sampling to detect the presence of insects, we will includ this procedure in our evaluations. Also, it gives us a second measusrment of insect densities and our previous work has shown it to be effective.

Knapweed Densities. Spotted knapweed densities at all sites will be measured in July and August when plants are in the flowering stage. We will use exactly the same methods as were used in the 97-98 STDP. In both time periods, plant density will be determined by placing 0.09 m^2 hoops at points 3.0, 6.0, 9.0 and 12.1 meters from the plot's center (the original insect release point) aligned in the cardinal directions. A total of sixteen samples will be taken at each site per year, and all data were converted to numbers per $m^{2.}$

The same methodology for assessing knapweed densities and insect numbers will be used for evaluating impact on diffuse knapweed. We do not have baseline data for the diffuse knapweed sitess. Instead, we will compare insect numbers and knapweed densities that we measure with data taken at the time the insects were originally released.

Paired t-tests will be used to compare plant density in the first period (1997 & 1998) to densities in 2002 and 2003. A Chi-Square test was used to determine if the change in knapweed density was affected by the presence and or abundance of the root-feeding biological control insects. The percentage change in knapweed density will be regressed against the number of *A. zoegana* and *C. achates* released and measured at each site.

Sequential Sampling System for Measuring Larval Populations of *C. achates*. A subset of 25 sites for *C. achates* will be selected to develop a sequential sampling system. At each site, examining a smaller number of roots sequentially, will be compared to the number of larvae found examining the standard 52 roots per site. The percent infestation rate will determine the number of roots sampled per site.

Hypothesis II: Several plant and site characteristics are essential to the establishment of *A. zoegana* and *C. achates* and their impact on knapweed.

Plant Stand Features at the Site. The size of the spotted knapweed infestation at each site will be recorded as <1.0, 1.0-2.4, 2.5-4.0, or > 4.0 ha. The area of the original weed infestation will be taken from notes recorded by the land managers in the year of the first release or, if this information was not available, from our own assessment at the time of this study. Plotting the infestation boundaries on a topographic map checked accuracy of patch size assessments

The density of spotted knapweed at each site will be categorized as <5, 6 to 10, or >10 posst rosette plants per 0.09 m^2. The density will be measured by counting the number of spotted knapweed plants that had an erect stem within an area defined by a 0.09-m^2-wire hoop. Sixteen samples will be taken per site, located at each of four distances (3.0, 6.0, 9.0, and 12.1 m) from the release point at the center of the site (marked by a reference stake) along lines arranged in cardinal directions.

Physical Characteristics at the Release Site.

Disturbance Factors. Grazing, logging, presence of roads, fire, cultivation, flooding, or construction will be noted for analysis as present or absent at each site.

Land Use Category. Land use will be categorized for analysis as grazing, timber production, wildlife-use, rights-of-way, wetlands, recreational, or mining.

% Bare Soil. The % bare soil will be determined visually for a 3.6-meter radius plot around the release point.

Annual Precipitation. Site average annual precipitation will be taken as the 25 year average

from the closest weather station.

Mean Annual Summer and Winter temperatures-will be taken from the closet weather station.

Statistics. We will first analyze our data at the level of individual variables, some of which are categorical, while others are quantitative. For the categorical variables, we will create contingency tables that related the number of cases in each category of the variable to the number of cases of presence or absence of the two root-feeding insects. These tables were then analyzed using Chi-Square or Fisher's exact tests. For the quantitative variables we will perform logistic regressions between the variable and the presence of these insects.

After assessing variables individually, we will construct models to test combinations of site, and plant stand variables to determine which combinations best predict the abundace of the biological control agents.

MEASURES OF SUCCESS: MEASURE OF SUCCESS:

Standard of Success: We will know we are successful if land managers request and utilize the tools and information produced from this TDP.

Expected Outcomes: Development of a sequential sampling scheme for larval populations of *C. achates*. Recommendations on selecting sites based on a set of site and plant characteristics that are important to both the establishment and impact of *A. zoegana* and *C. achates* on knapweed infestations. A determination of impact of *A. zoegana* and *C. achates* on spotted and diffuse knapweed populations.

Implementation of Products/methods:

Immediate use of recommendations for selecting sites based on "key" knapweed and site characteristics. Accepting and expanding the use of biological control as a part of an integrated weed management program for spotted and diffuse knapweed.

PRODUCTS AND DUE DATES:

- 2003-Produce a FHP Report refining our recommendations for selecting site and plant characteristics for improving establishment and impact of *A. zoegana* and *C. achates.*
- 2003-Produce a FHP Report on the sequential sampling system we develop.
- 2004-Produce several journal articles reporting our results and conclusions.

PUBLICATIONS: Results will merit publication in government reports and scientific journal articles. We will pursue the journal, "Biological Control" where we published the results from our 97-98 STDP.

TECHNOLOGY TRANSFER All land managers involved in biological control of knapweed will readily use any technology we develop. Private land owners will also benefit from our findings. Forest and county weed coordinators will participate in collecting the data and will directly benefit from learning our sampling methods and our results.

PRODUCT LEVERAGING; This proposal builds on the results of our 97-98 STDP. The data we collected during the earlier knapweed TDP represents the "only" data set of this size and detail and will be essential in determining the impact of *A. zoegana* and *C. achates* on knapweed. Impact can only be determined if the plots are remeasured

LONG-TERM BUDGET REQUEST: (estimates by fiscal year and funding, both monetary and in-kind, excluding FHP base funding and salaries) (extend table as necessary)**:**

	Item	**Requested FHP STDP Funding**	**Other-Source Funding**	**Source**
FY 2002				
Administration	Salary	20,480	Montana State Univ.	5,000
	Overhead	2,200		
	Travel	8,550		1,000
	vehicle	5,000		
Procurements	Contracting			
	Equipment			
	Supplies	750		
YEAR TOTALS		36,980		6,000

FY 2003				

Administration	Salary	21,299	Montana State Univ.	5,000
	Overhead	2,200		
	Travel	8,550		1,000
	vehicle	5,000		
Procurements	Contracting			
	Equipment			
	Supplies	750		
YEAR TOTALS		37,799		6,000

FY 2004				
Administration	Salary			
	Overhead			
	Travel			
Procurements	Contracting			
	Equipment			
	Supplies			
YEAR TOTALS				
PROJECT TOTALS		74,779		12,000

LONG-TERM BUDGET REQUEST EXPLANATION: none:

BENEFITS: Tools for acurately measuring populations of *C. achates* will be devleoped which will aid in the success of biological control programs. This methodology can be applied to sampling other root-feeding biological control agents. Sites for releasing *A. zoegana* and *C. achates* will be selected based on criteria which are crucial to their establishment and impact. Integrated weed management programs incorporating biological control will be accepted and become more widely used if we can demonstrate impact of these insects on knapweed.

LITERATURE, CITATIONS, ATTACHMENTS, etc.:
REFERENCES:

Chicoine, T. K., P. K. Fay and G. A. Nielsen. 1985. Predicting weed migration from soil and climate maps. Weed Sci. 34:57-61.

S. E. Clark, R. G. Van Driesche, N. Sturdevant, J. Elkinton, and J. P. Buonaccorsi. 2001. Effects of Site Characteristics and Release History on Establishment of *Agapeta zoegana* (Lepidoptera: Cochylidae) and *Cyphocleonus achates* (Coleoptera: Curculionidae), Root-feeding Herbivores

of Spotted Knapweed,

Davis, E. S., P. K. Fay, T. K. Chicoine and C. A. Lacey. 1993. Persistence of spotted knapweed (Centaurea Maculosa) seed in soil. Weed Science. 41:57-61.

Lacey, J. R., C. B. Marlow, and J. R. Lane. 1989. Influence of spotted knapweed (*Centaurea maculosa*) on surface runoff and sediment yield. Weed Technol. 3:627-630.

Tyser, R. W. and C. H. Key. 1989. Spotted knapweed in natural area fescue grasslands: an ecological assessment. Northwest Sci. 62:151-160.

Watson, A. K., and A. J. Renney. 1974. The biology of Canadian weeds, *Centaurea diffusa* and *C. maculosa.* Can. J. Plant Sci. 54:169-183.