A study of Urophora affinis (Diptera : Tephritidae) released on spotted knapweed in Western Montana
by Jim Maynard Story

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Entomology
Montana State University

Abstract:
A gall-producing fly, Urophora affinis Frfld., was introduced into western Montana for the biological control of spotted knapweed (Centaurea maaulosa Lam.). Releases were made in 1973, 1974, and 1975 on spotted knapweed infestations. In 1973, 150 u. affinis were released into a field cage, while 279 u. affinis were field released. The u. affinis population within the field cage was found to have increased significantly over a two-year period, u: affinis galls were found at a distance of 50 m from the initial release point after two years; the adults were found throughout the field in very small numbers. A spider, Dietyna major Menge, was found preying on U. affinis adults; the impact of the spider on the U. affinis population was not determined. It is concluded that u. affinis successfully overwintered and became established at the primary study site in western Montana. The life history of V. affinis was found to be closely synchronized with the flower head development of its host plant, spotted knapweed. An increase in the number of v. affinis galls was found to decrease spotted knapweed seed production. Pronounced variation for morphological traits occurred among spotted knapweed plants. Phenology of spotted knapweed generally agreed with previous reports.

STATEMENT OF PERMISSION TO COPY

In presenting this thesis in partial fulfillment of the requirements for an advanced degree at Montana State University, I agree that the Library shall make it freely available for inspection. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by my major professor, or, in his absence, by the Director of Libraries. It is understood that any copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Signature Jim M. Story

Date May 24, 1976

A STUDY OF *UROPHORA AFFINIS* (DIPTERA: TEPHRITIDAE) RELEASED ON SPOTTED KNAPWEED IN WESTERN MONTANA

by

JIM MAYNARD STORY

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Entomology

Approved:

Norman L. Anderson
Chairperson, Graduate Committee

James M. Pickett
Head, Major Department

Henry L. Parsons
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

May, 1976

ACKNOWLEDGMENT

I am extremely grateful to my major professor, Dr. Norman L. Anderson, for his interest, advice and assistance throughout the course of this study and for his constructive criticisms of the manuscript. I am also very grateful to Professor Laurence Baker, Dr. Stephen Chapman and Mr. Don Merkley for their assistance during the study and for their critical review of the manuscript. I wish to thank Donald Graham for his technical advice, Lynda Frost for her assistance, and Steven Baril for his excellent artwork. I am grateful to Mr. Roscoe Hall for the use of his property. My wife, Marleen, deserves special acknowledgment for her patience and encouragement, her artwork, and the numerous hours she spent counting seeds and recording data. Finally, I wish to thank the Biological Control of Weeds Laboratory in Albany, California for providing the insects used in the study.

The investigation was supported by the Western Area Weed Advisory Council, and a research assistantship from the Montana State Agricultural Experiment Station, Project 812.

TABLE OF CONTENTS

LIST OF TABLES

TABLE Page

LIST OF FIGURES

ABSTRACT

A gall-producing fly, *Urophora affinis* Frfld., was introduced into western Montana for the biological control of spotted knapweed (*Centaurea maculosa* Lam.). Releases were made in 1973, 1974, and 1975 on spotted knapweed infestations. In 1973, 150 *U. affinis* were released into a field cage, while 279 *U. affinis* were field released. The *U. affinis* population within the field cage was found to have increased significantly over a two-year period. *U. affinis* galls were found at a distance of 50 m from the initial release point after two years; the adults were found throughout the field in very small numbers. A spider, *Dictyna major* Menge, was found preying on *U. affinis* adults; the impact of the spider on the *U. affinis* population was not determined. It is concluded that *U. affinis* successfully overwintered and became established at the primary study site in western Montana. The life history of *U. affinis* was found to be closely synchronized with the flower head development of its host plant, spotted knapweed. An increase in the number of *U. affinis* galls was found to decrease spotted knapweed seed production. Pronounced variation for morphological traits occurred among spotted knapweed plants. Phenology of spotted knapweed generally agreed with previous reports.

INTRODUCTION

Spotted knapweed (*Centaurea maculosa* Lam.), a member of the Compositae family, is a serious problem in pastures, rangeland, and waste areas of western Montana. The plant is described by Watson and Renney (1974) thus:

> Spotted knapweed is a biennial or short-lived perennial, reproducing by seeds; stems erect or ascending, branched, pubescent, 30-100 cm high; leaves alternate, much divided, upper leaves linear; flower heads eradiate, 6mm diam., 16-20 mm high, mainly terminal, numerous, corymbs or corymbose panicles, bracts with a black-fringed tip 1-2 mm long; flowers tubular, purple, rarely white; achenes brownish, 3 mm long; pappus of simple bristles, 1-2 mm long, persistent.

The plant was first introduced into North America in the nineteenth century and has since spread to many parts of the United States and Canada (Fletcher and Renney, 1963). Moore (1972) reported that spotted knapweed occurs in all areas of the United States except possibly the Southeast. Watson and Renney (1974) showed that spotted knapweed can be found in the Canadian provinces of British Columbia, Alberta, Ontario, New Brunswick, Quebec, and Nova Scotia. The plant was first collected in Canada in 1893 at Victoria, British Columbia (Watson and Renney, 1974). The earliest collection of spotted knapweed in the Montana State University herbarium was made in 1927 in Gallatin County, Montana. The first herbarium specimen from western Montana was collected in 1933 and a note accompanying this specimen stated that the weed was probably introduced from states east of Montana. In 1975, a survey based on estimates by the County Extension

Agents and weed supervisors in those Montana counties having spotted knapweed infestations showed that approximately 647,511 ha (1.6 million acres) are infested with spotted knapweed in Montana. The majority of the infestation occurs west of the continental divide but it is rapidly spreading eastward into many areas of the State. It is so common in western Montana that it is referred to locally as "Bitterroot alfalfa." In Ravalli and Missoula Counties, spotted knapweed can be found on almost any unattended ground, especially on dry waste areas where the soil has at one time been disturbed. Spotted knapweed can be found on a wide variety of soil types (Watson and Renney, 1974) and it apparently requires very little moisture. The prevalence of spotted knapweed along the high mountain trails in the Bitterroot Mountains apparently is not unusual as Watson and Renney (1974) reported observations of the plant at altitudes over 1200 m in British Columbia.

Watson and Renney (1974) and Renney and Hughes (1969) report that spotted knapweed is an undesirable plant due to its unsuitability as a forage plant for livestock and its tendency to suppress desirable plant species. They report that the mature plant has a high fiber content, has very little nutritional value, and has a bitter taste all of which make the plant unacceptable to livestock except in overgrazed areas. Observations in the Bitterroot Valley were in agreement with the aforementioned statement with one exception. Sheep were observed

to not only eat the plant but to actually seek it out in pastures where abundant grass and other forage were available.

Spotted knapweed's tendency to suppress other vegetation is due to its dense overstory and its production of a substance inhibitory to other plant species (Watson and Renney, 1974). The inhibitor has been partially characterized as an indole, probably an indole alkaloid or an auxin precursor (Fletcher and Renney, 1963).

The suppression of vegetation by spotted knapweed was evident in western Montana. Study Site B (see page 8) was a good example of an area where gradual suppression by spotted knapweed had resulted in the complete elimination of all other competing vegetation. The economic losses due to spotted knapweed can be significant. Watson and Renney (1974) have described range in good condition and the adverse affects of spotted knapweed on range productivity. They cited the discussion by McLean and Marchand (1968) in which it was pointed out that: "'Bluebunch wheatgrass-rough fescue' range in 'good' condition produces, on the average, 896.8 kg/ha (800 lb/acre) of forage and would have a stocking rate of 0.61 ha (1.5 acre) per animal unit month.'" Watson and Renney (1974) report that: "Knapweed-infested range may produce only 112 kg/ha (100 lb/acre) of forage resulting in a stocking rate of 4.86 ha (12.0 acre) per animal unit month."

The beneficial aspects of spotted knapweed according to Watson and Renney (1974) are: (1) the plant serves as a valuable pioneer

species due to its rapid establishment which prevents soil erosion; (2) the plant serves as an important source of nectar for domestic bees; and (3) the plant has an esthetic value due to its attractive purple flowers.

Although chemical control has been effective against spotted knapweed (Furrer and Fertig, 1965; Renney and Hughes, 1969) it is limited to those infestations which are readily accessible and not located near waterways and livestock. Since spotted knapweed is found in a wide variety of habitats and soil types (Watson and Renney, 1974) control methods are needed which can be effectively used against the plant in all of its habitats and geographical locations.

Goeden (1975) states that biological weed control is the deliberate use of natural enemies (predators, parasites, or pathogens) to reduce weed densities to more acceptable levels. Since this control technique is environmentally safe and, under certain situations, more practical than other control methods, it is being considered as a possible alternative to the chemical control of spotted knapweed.

Urophora affinis Frfld. is a fly (Diptera: Tephritidae) that attacks the flower heads of *Centaurea maculosa* and *Centaurea diffusa* Lam. Like its host plants, the fly is native to Europe and probably western Asia (Zwölfer, 1970; Watson and Renney, 1974). Zwölfer (1970) describes the biology of *U. affinis* thus:

> If the flower head is accepted for oviposition the eggs are deposited singly or in small groups (2-5) on the small, undeveloped tubular flowers; between the tubular flower and the interior bracts; into the tissue of the receptacle. Up to 35 and 40 eggs may be deposited by an individual female per day, but the average number of eggs deposited per day seems to be much lower (5-10). After 3-4 days the first instar-larva hatches and penetrates into the ovariole of the undeveloped tubular flower, where it mines and causes the latter to develop into a fusiform gall deeply rooted in the receptacle and open at the apical end. Larval development takes several weeks during which time the walls of the gall become lignified. There are usually one to three galls per flower head but in some cases up to 8 galls had been found within an individual flower head. Varying proportions of larvae pupate without diapause and give rise to an additional generation. Most larvae, however, having reached maturity (i.e. third instar) remain in diapause within their galls until early summer when the diapause ends. Before a larva pupates it turns within the gall so that its head is orientated against the distal opening of the gall, the position in which pupation takes place. The adults emerge after two to three weeks and force their way through the opening of the gall by using their ptilinum.

Zwölfer further states that:

> The effect of *U. affinis* upon its host plant consists in the destruction of achenes and in the deformation of the receptacle of the capitulum which leads to a reduction of the production of viable seeds.

After being tested to insure its safety for release, the insect has been released into Canada and in the United States in Montana, Idaho, Oregon, and Washington (Harris and Hubbard, 1970; Andres, 1975).

The purposes of the present study were to: (1) study the behavior and life history of *U. affinis* in conjunction with the phenology of spotted knapweed and to determine if the relationship between the two organisms is affected in any way by environmental factors in western

Montana; (2) measure the ability of *U. affinis* to successfully overwinter, increase its population, and disperse at the initial (1973) release site in western Montana.

Field work was conducted from May to September, 1974 and from May to September, 1975 at the Western Agricultural Research Center at Corvallis, Montana.

DESCRIPTION OF STUDY AREA

All of the sites used for this study are located in or near the Bitterroot Valley of Western Montana. The Bitterroot Valley is approximately 104 km (65 miles) from north to south and 16 km (10 miles) wide. It extends from Lolo, Montana, on the northern boundary to Connor, Montana, where the East Fork of the Bitterroot River and the West Fork of the Bitterroot River merge to form the Bitterroot River. The valley is bordered on the west by the Bitterroot Mountains and on the east by the foothills leading to the Sapphire Mountains. The soils of the valley vary from highly calcareous on some east-side benches to moderately acid on west-side benches. Soil textures range from loamy coarse sand to clay loam (U.S. Department of Agriculture, 1959).

A waste field containing a heavy infestation of spotted knapweed was selected as the primary study site. The field was approximately 5000 m^2. This field will be referred to as "Site A" throughout the remainder of this paper. The field was located near the Western Agricultural Research Center at Corvallis, Montana, 46^{o} 20' N. and 114^{o} 4' W., at an elevation of 1,096 m (3,597 feet). A soil survey of the Bitterroot Valley reports the soil at Site A as Burnt Fork Loam and is described as "deep permeable soils that are high in natural fertility and have good water-holding capacity" (U.S. Department of Agriculture, 1959). The field was generally dry although the eastern half was usually more moist as a result of seepage from a nearby irrigation

ditch. Consequently, the vegetation in the eastern half was much taller. In August 1975, the absolute densities of spotted knapweed and kentucky bluegrass (*Poa pratensis* L.) in the moist half of the field were 107.92 and 24.50 shoots/m^2, respectively while the absolute densities of the same plants in the dry half were 201.53 and 92.67 shoots/m^2 (see page 20). The field was bordered on the west by an alfalfa-hay field, on the south and east by a pasture, and on the north by a garden.

Table 1 summarizes the weather data at the Western Agricultural Research Center during the 1973-1975 period. The highest temperature recorded at the Center over the three summers was 39 C (102 F) in July 1973. High temperatures of 36 C (97 F) and 37 C (99 F) were recorded for the summers of 1974 and 1975, respectively. The coldest temperature recorded at the Research Center during the 1973-1975 period was -32 C (-26 F) in January 1974; for an 11 day period in January 1974, the mean minimum temperature was -25 C (-13 F). The coldest temperature recorded during 1975 was a January reading of -26 C (-15 F).

Site B, the only study site located outside the boundaries of the Bitterroot Valley was located near Missoula, Montana, a distance of 80 km (50 miles) north of Site A. Spotted knapweed, the only plant inhabiting the area, was recorded at an absolute density of 60.65 shoots/m^2.

Table 1. Monthly maximum and minimum temperatures (in degrees Celcius) and precipitation recorded at the Western Agricultural Research Center from June 1973-Sept. 1975. (Converted from U.S. Weather Bureau Climatological Data.)

Date	Temperature					Precipitation (in cm)
	Avg. Mean	Avg. Max.	Avg. Min.	High Temp.	Low Temp	
June 1973	15	23	7	34	0	4.85
July 1973	18	30	8	38	3	.38
Aug. 1973	18	28	8	35	3	1.47
Sept. 1973	12	20	4	31	0	4.24
Oct. 1973	7	14	1	23	-7	3.43
Nov. 1973	0	3	-4	12	-20	5.38
Dec. 1973	0	3	-4	13	-14	2.46
Jan. 1974	-6	-1	-10	12	-32	3.78
Feb. 1974	1	7	-3	13	-8	.41
Mar. 1974	2	8	-3	19	-15	2.49
Apr. 1974	7	15	0	25	-6	.51
May 1974	8	18	1	24	-6	3.07
June 1974	17	26	7	36	0	2.49
July 1974	18	28	8	32	5	2.31
Aug. 1974	16	26	7	31	3	5.00
Sept. 1974	13	23	3	29	-2	.89
Oct. 1974	8	17	0	25	-8	.86
Nov. 1974	2	7	-3	16	-11	.86
Dec. 1974	-1	2	-5	10	-15	.51
Jan. 1975	-3	1	-8	10	-26	3.23
Feb. 1975	-5	0	-10	8	-25	2.49
Mar. 1975	1	6	-4	11	-17	1.50
Apr. 1975	3	10	-2	17	-7	5.16
May 1975	8	16	2	28	-3	5.33
June 1975	13	21	5	26	0	2.54
July 1975	21	30	11	36	6	-
Aug. 1975	16	25	7	33	2	5.64
Sept. 1975	12	22	2	28	-2	.76

Site C was located 4.8 km (three miles) northwest of Site A. Plant densities were not recorded at this site.

Site D was located 16 km (10 miles) southwest of Site A. The absolute density of spotted knapweed at this site in 1975 was 62.29 shoots/m^2. The rest of the vegetation was not measured.

Site E was located 6.4 km (four miles) south of Site A. The absolute density of spotted knapweed at this site in 1975 was 73.17 shoots/m^2. The rest of the vegetation was not measured.

Field cages were placed on Study Sites A, B, and C.

MATERIALS AND METHODS

A total of 1,329 *U. affinis* adults was received from the Biological Control of Weeds Laboratory (U.S.D.A., A.R.S.) in Albany, California from 1973-1975. The insects were released on spotted knapweed infestations immediately after they were received. The dates and locations of the releases are shown in Table 2. Of the total, 659 *U. affinis* were field-released at Sites A and C while 550 *U. affinis* were released into 3.6 m long x 1.8 m wide x 1.8 m high field cages placed on heavy infestations of spotted knapweed at Sites A, B, and C. A field cage is shown in Fig. 1A. The cages consisted of a wooden frame enclosed by a light colored, No. 32-mesh, nylon net. The cages were used to aid in studying the behavior of *U. affinis* adults since their small size (2.5-5 mm long) and protective coloration made them not only difficult to observe but also difficult to locate in a typical spotted knapweed infestation. In 1974, the field cage at Site A was removed in late July at the onset of flowering by spotted knapweed. The cages were not removed from the other sites until September. The only cage used in 1975 was the one at Site A and, again, it was removed in late July.

The remaining 120 *U. affinis* were released into three small cages placed around single spotted knapweed plants located in the western half of Site A. The three small cages will be referred throughout the paper as mini-cage A, mini-cage B, and mini-cage C. These cages are

Table 2. Date, number released, and location of *U. affinis* releases.

Dates of *U. affinis* releases	Number of *U. affinis* released	Release Sites
June 12, 1973	150	Site A-field cage
June 12, 1973	279	Site A-field
July 10, 1974	200	Site B-field cage
July 12, 1974	200	Site C-field cage
July 12, 1974	200	Site C-field
July 9, 1975	180	Site A-field
July 9, 1975	120	Site A-mini cages
Total	1,329	