INSECT PEST PROBLEMS OF SUNFLOWER WITH PARTICULAR REFERENCE TO THE SUNFLOWER BEETLE, *ZYGOGRAMMA EXCLAMATIONIS* (FABRICIUS), IN MANITOBA

by

Yakub Daud Deedat

A THESIS

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This thesis is dedicated to my beloved mother, Khatija Daud Deedat, and my late father, Daud Hussien Deedat.

May it also serve as a source of inspiration to my nephews, Daud, Mohmed and Zubair; and my nieces, Zainub, Summayya, Amina and Khatija.

Deedat, Yakub Daud, Ph.D.
The University of Manitoba; 1987

Insect Pest Problems of Sunflower with Particular Reference to the Sunflower Beetle, _Zygogramma exclamationis_ (Fabricius), in Manitoba.

Major Professor: Dr. P.A. MacKay

ABSTRACT

Data for this study were collected during the summers of 1983 to 1985. Field and grower surveys were conducted to determine the status of the sunflower-insect pest complex as well as their management by growers. Sunflower beetle, sunflower midge, sunflower maggot, banded sunflower moth and sunflower moth were the most prevalent species and found in at least 10 of the 12 fields that were surveyed. However, pests of primary concern to growers were the sunflower beetle, the sunflower midge and cutworms. Cultural control did not play a major role in the management of these pests. More than 80% of the growers indicated that they use economic thresholds when available. However, data from the field survey on sunflower beetle showed that growers applied insecticides at well below the currently recommended threshold values.

Insect densities were manipulated on individual plants in caged and open studies to determine the effect of defoliation of sunflower by sunflower beetle. Head

diameter, yield and seed weight decreased, whereas oil content increased with increasing beetle densities. A curvilinear relationship between pest density and yield was obtained for adults and larvae. These quadratic polynomial regressions were used to estimate the economic thresholds which ranged from 2-3 adults and 5-10 larvae per plant.

Sunflower plants were artificially defoliated at five growth stages using four levels of defoliation to simulate time of damage and time of insecticide application in relation to the sunflower beetle. Growth and yield components generally decreased with increasing levels of defoliation. Plants in their early growth stages (V4-V8) were most sensitive to defoliation. Plants showed compensation at low levels of defoliation. Depending on the duration of defoliation, a linear or a quadratic relationship between yield and defoliation was obtained. These relationships were used to calculate defoliation thresholds for individual growth stages.

A sequential decision plan for the control of sunflower beetle larvae was developed from studies of larval dispersion in growers' fields. Iwao's patchiness regression technique was used as a basis for the sequential model since it provided a consistently good fit to the data. The plan should minimize sampling efforts and provide a reliable method of assessing whether control is required.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 3, SECTION III:

Table:

CHAPTER 3, SECTION IV:

Table:

LIST OF FIGURES

CHAPTER 3, SECTION I:

CHAPTER 3, SECTION IV:

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 PROBLEMS

Commercial sunflower, *Helianthus annuus* var. *macrocarpus* (Decandolle) Cockerell, is one of the four most important annual crops grown for edible oil (Putt 1978). Sunflower ranked tenth as a world source of vegetable oil in 1930 (Cobia 1976) and is currently third only to soybean and palm (Anonymous 1986). In recent years, production has undergone rapid expansion, particularly in North America. Since 1966, production has increased more than tenfold in Canada and the U.S.A. (Cobia 1978; Putt 1978). The development of high yielding disease-resistant hybrids was the major factor contributing to the increase in sunflower production in these countries (Heiser 1978; Campbell 1979).

In Canada, sunflower was initially grown in Saskatchewan and Alberta, but later, production shifted almost entirely to the Red River Valley region of south-central Manitoba (Putt 1978). From 1976 to 1985 an average of 82,200 hectares were sown to sunflower in Manitoba (Anonymous 1986). Although sunflower hectarage has declined significantly since 1980, Manitoba has continued to be the most important producer in Canada, contributing more than 80% to the total Canadian production of sunflower (Anonymous 1986).

Sunflower is native to North America (Heiser 1978) and a large number of insect species are associated with it. Over 150 species of phytophagous insects have been recorded from wild and cultivated varieties of H. annuus L. in North America north of Mexico (Hilgendorf and Goeden 1981). Although the number of species is large, pests of economic importance are relatively few. The life cycles, seasonal activity, damage characteristics, host preference, and control of the more important head-infesting, foliage and stem-feeding, and root-infesting species have been discussed (Schulz 1978; McMullen 1985). Pertinent references on economically important insect pests of sunflower have also been published (Rogers 1979).

With increased production there has been a corresponding increase in insect infestation. Insect depredation has been an important deterrent to sunflower production both in Canada and the U.S.A. (Schulz 1978). In the U.S.A., a different species occurred in outbreak numbers in each year from 1970 to 1975 (Schulz and Oseto 1979). In North Dakota alone, over 15 species are of current concern (McBride et al. 1985b). Several of these insects have caused moderate to severe yield reductions in recent years (Cobia and Zimmer 1978; Schulz 1982). In Manitoba, insect damage to sunflower has been restricted to about five species (Westdal and Barrett 1955; Westdal 1975). The occurrence, as well as economic significance of these pests, has fluctuated from year to year (Westdal 1975; Anonymous

1987). In recent years there has been no systematic documentation of the insect pests that attack sunflower in Manitoba; neither is there any information to indicate the importance of these insects to growers or how growers manage these pests.

The sunflower beetle, *Zygogramma exclamationis* (F.), is considered one of the five most important insect pests of commercial sunflower in Manitoba (Westdal and Barrett 1955) and one of the six most important sunflower pests in North Dakota (Schulz and Lipp 1969). In Manitoba, extensive use of insecticides was required to control the outbreaks of this pest on three occasions: 1952, 1957-59, and 1971 (Westdal 1975). Although no major outbreaks have been reported in recent years, the beetle is present annually. Both adults and larvae defoliate plants. Even moderate defoliation may result in delayed maturity and seed losses of up to 8 percent (Westdal *et al*. 1976).

Chemical control is the only method currently used for the control of the sunflower beetle. But, the effectiveness of chemical control is dependent upon, among other things, well documented economic thresholds. Economic thresholds for adults and larvae have been reported. However, the adult threshold levels in Manitoba (Westdal *et al*. 1976) are at variance with those in North Dakota (McBride *et al*. 1985b). There are no reports from either region to indicate the basis for the difference in these thresholds; neither is there any published information on how the thresholds were developed.

Insecticides used for the control of adults are also effective for the control of larvae (Anonymous 1987). If properly timed, one application is adequate to obtain control of either the adults or the larvae (Westdal et al. 1976). Timing of application is critical since the insecticides for the control of adults must be applied before the eggs are laid, and for the larvae, after all the eggs have hatched (Westdal et al. 1976).

Neill (1982) emphasized larval control and proposed the mid-point in the development of the second instar as the optimal time for control. At that time most eggs will have hatched and little foliar damage will have been done by the larvae. The mid-point in the larval development occurs 21 days after the first egg hatch is noted. Determining the date of first hatch is not only difficult but also time consuming since the grower is required to monitor the field at three to four day intervals.

Neill's (1982) method of determining the optimal time of control is based on larval phenology. But, plants differ in susceptibility to insect damage depending on the growth stage at the time of infestation (Bardner and Fletcher 1974). Thus, for practical application, Neill's (1982) recommendation must be supplemented with information on the plant's phenology. There are no reports to indicate the stage of crop development at which insecticides should be applied to minimize damage; neither is there any information on the critical stage of plant growth and infestation level at which damage occurs.

The effectiveness of chemical control is dependent upon efficient and practical monitoring systems. The recommended procedure for monitoring the sunflower beetle is to sample randomly 100 plants in an "X" pattern, starting 30 m away from the field margins (McBride et al. 1985b). There are no reports in the literature to show how this sampling procedure was developed. What growers need is a rapid and statistically reliable method of classifying populations into those that require control and those that do not. This objective can be met through the use of sequential decision plans (Waters 1955; Iwao 1975). No studies have attempted to develop such a sampling technique for the sunflower beetle. Thus, there is little reliable information which growers can use to make sound management decisions with regard to the control of sunflower beetle.

1.2 OBJECTIVES

The study was designed to achieve the following objectives:

i) To evaluate the status of sunflower insect pests and their management by growers in Manitoba.

Information on the type of insect pests and their importance to growers would be useful in developing pest management programs. It would aid researchers and extension personnel in identifying current and future research needs.

ii) To determine the effect of defoliation of sunflower by the sunflower beetle and develop economic thresholds.

Economic thresholds would enable growers to apply insecticides only when necessary. This would prevent prophylactic sprays and in turn reduce production costs and increase farm net income.

iii) To determine the stage of plant growth most sensitive to defoliation in relation to the sunflower beetle.

Information on the level of defoliation at various growth stages of the plant would lead to the determination of defoliation thresholds. This knowledge would also help researchers to determine the optimum time of control and identify the plant stage at which insecticide should be applied.

iv) To establish the spatial dispersion of sunflower beetle larvae in growers' fields and develop a sequential sampling plan.

Information on the spatial dispersion of the larvae could lead to the development of a sequential sampling scheme, thus enabling growers to determine rapidly and efficiently whether a particular population warrants control. Knowledge on the dispersion pattern would also aid in determining whether the entire field must be sprayed or if only border treatments are necessary.

1.3 THESIS ORGANIZATION

The results reported in this thesis are from experiments conducted during the summers of 1983, 1984 and 1985. The status of sunflower insect pests and their management by growers was determined using field and grower surveys. Damage assessment studies were conducted at the Glenlea Research Station, using field cages. Studies on economic thresholds were done by artificially infesting individual plants in plots at Glenlea. The critical stage of plant growth and the optimum time of control were determined by artificially defoliating the plants in plots at Glenlea. Growers' fields were used to establish the distribution of the larvae by systematically sampling entire fields along eight transects.

The thesis is written in chapters, each covering a separate aspect of the research. In Chapter 1 the problems are identified. Chapter 2 reviews the literature pertaining to the crop and the sunflower beetle. Chapter 3 describes the experimental studies and is written in four sections in a style suitable for publication as a series of scientific papers. Results of field and grower surveys are reported in Section I. Economic threshold studies and damage assessment experiments are presented in Section II. Damage simulation studies are reported in Section III, while Section IV covers the studies on spatial dispersion and sampling. Chapter 4 provides a general discussion and Chapter 5 presents conclusions.

CHAPTER 2

LITERATURE REVIEW

2.1 THE SUNFLOWER PLANT

2.1.1 Domestication and Development

The origins and early history of the sunflower plant including its introduction, distribution and adoption as a commercial crop in Europe and North America have been reviewed (Heiser 1978; Putt 1978). Sunflower is among the few food plants to have been domesticated in prehistoric times on the North American continent (Heiser 1978). It has been part of the culture of North American Indians for 30 centuries or more (Heiser 1955). The Indians utilized the plant not only for food but also for ceremonial and medicinal purposes (Heiser 1951).

Using carbon-14 dating, archaeologists have found evidence of sunflower in the Mississippi-Missouri basin 2,800 years ago (Lees 1965 in Putt 1978). It is thought that sunflower may have been domesticated before corn (*Zea mays* L.) was introduced to North America (Whiting 1939 in Putt 1978). It is not clear whether the sunflower was independently domesticated in several places or domesticated in one place and then radiated to several areas.

The sunflower was initially introduced into Europe via Mexico and Spain during the early 16th century (Zukovsky

1950 in Putt 1978). By the end of the 18th century, sunflower began to be cultivated on a commercial scale in Russia. Russian varieties of sunflower were subsequently introduced to North America. Most sunflower historians agree that the present cultivated sunflower was established in North America after 1880 following introduction of improved varieties developed in Russia; however, the precise date or route of the introduction is not clear (Heiser 1978).

During the early 1900's, sunflower was grown mainly for silage, both in Canada and the U.S.A. (Geise 1974). Commercial production of sunflower as an oilseed crop began in Canada in 1943 and in the U.S.A. in 1947 (Geise 1974). Since the first introduction of the crop, a number of oilseed cultivars have been grown in Canada. Early breeding work at Saskatoon, using Russian varieties of sunflower, resulted in the release of cultivars Mennonite and Sunrise, and the hybrids Advance, Advent and Admiral (Putt 1978). In 1964, production for oil gained new interests with the introduction of Russian cultivars such as Peredovik and Krasnodarets. The oil content of these cultivars had been increased from about 28% to over 40%, rendering the earlier cultivars obsolete (Putt 1978).

Another major advancement during this period was the discovery of cytoplasmic male sterility and fertility restorer genes (Fick 1978). These discoveries provided a practical method of producing hybrid sunflower. The first hybrids produced by the cytoplasmic male sterility and genetic fertility restorer system were released for commercial production in the U.S.A. in 1972. By 1976, these hybrids accounted for over 90% of the sunflower production in the U.S.A. (Fick 1978). In Canada, the first of these hybrids was licensed in 1978 (Dedio *et al*. 1980) and within four years, accounted for 95% of the plantings (Anonymous 1981).

The new hybrids yielded an average of 25% more than the Russian cultivars and still maintained a high oil content of 40-50%. Further, most of these hybrids were resistant to three of the major diseases of sunflower, namely rust (*Puccinnia helianthi* Schw.), downy mildew [*Plasmopara halstedii* (Farl.) Berl and de Toni], and Verticillium wilt (*Verticillium dahliae* Kleb.) (Fick 1978). Thus, the production of hybrids, and of types resistant to diseases along with the increase in oil content were among the notable developments which have made sunflower economically competitive with other crops (Heiser 1978). These developments along with other agronomic improvements in the culture of sunflower, enabled growers to obtain yields 30 to 50% higher than those of the 1960's with open-pollinated cultivars, making the latter obsolete (Dedio *et al*. 1980).

2.1.2 Culture and Production

Robinson (1978) provided a detailed account on the agronomic characteristics and cultural requirements of sunflower. Sunflower performs well in most temperate zones and the same cultivars are grown on all five continents (Robinson 1978). It is a long-season crop requiring 115 to 130 days to mature. The length of the growing season is the most important factor used in identifying production areas (Geise 1974; Campbell 1979). Sunflower can be grown in soils ranging in texture from sand to clay as it does not require high fertility soils to produce satisfactory yields. Sunflower is not highly drought tolerant, but it often performs well when other crops are drought damaged, because of its extensive and heavily branched tap root system which has a potential lateral spread and depth exceeding two meters (Robinson 1978).

Sunflower is either solid seeded or planted as a row crop at a depth of 3 to 10 cm, depending on the moisture content of the soil. For northern U.S.A. and Canada, planting is recommended from 1 to 20 May (Robinson 1978). Although seedlings are relatively frost resistant up to the four leaf stage (Anonymous 1983), planting in April is not advised in parts of northern U.S.A. and Canada where frost may occur in late May or early June (Robinson 1978).

Sunflower planted in May is usually ready for harvest in late September or October. Plants are mature when the back of the head turns yellow (Browne 1978; Robinson 1983) or the bracts of the head become brown (Schneiter and Miller 1981). At this stage the moisture content of the heads ranges from 40 to 80% (Robinson 1983). Thus, physiological maturity usually occurs before the heads are dry enough to be harvested. Harvesting can be enhanced by applying dessicants (Schuler et al. 1978). To reduce shattering losses during harvest and loss of seeds from birds, sunflower is harvested at moisture contents ranging as high as 20-25% (Campbell 1979). The seed is then dried to a moisture content of approximately 9% for long term storage (Schuler et al. 1978).

Sunflower is third only to palm and soybean in world vegetable oil production (Anonymous 1986). Worldwide, a total of 14.431 million hectares were sown to sunflower in 1985. With an average yield of 1313 kg per hectare, a total of 18.944 million tonnes of sunflower seed was produced in that year (FAO 1986). Europe is the largest producer, contributing more than 50% of the world production. Among individual countries, the U.S.S.R. has consistently been the leading producer, contributing over 30% of world production. Argentina and the U.S.A. are the second and third largest producers contributing more than 13 and 12% respectively, toward the world total. Among the major producing countries, Canada was ranked last in the 1985-86 world production forecast (Anonymous 1986).

In the last 15 to 20 years, production in the U.S.A. and Canada has increased more than tenfold (Cobia 1978). Manitoba is the leading producer of sunflower in Canada. From 1976 to 1985 an average of 104,600 tonnes of sunflower was produced in Manitoba, with a high of 208,700 tonnes in

1979 (Anonymous 1986). The tremendous increase in sunflower production in 1979 was probably due in part to farmers shifting almost completely from open-pollinated cultivars to hybrids. Sunflower production in Canada has decreased significantly since the record high in 1979. The production for 1985 (77,100 tonnes) represented a drop of 63% from 1979. The decline in production was attributed to disease problems, depressed prices, increased flax-seed production and a reduction in contracting. The sunflower midge may also have contributed to the decline in production.

2.1.3 Uses and Future

Two types of sunflower are grown. One type called oilseed sunflower, produces a small, well filled, round, thin-hulled seed which is used for the extraction of edible oil. Seeds of oilseed cultivars contain between 40-50% oil on a whole seed basis. The second type, called nonoilseed or confectionery sunflower, produces a large, long seed with a thick, heavy hull and is used primarily for direct human consumption and as bird feed (Putt 1978). Seeds of confectionery cultivars generally contain less than 30% oil on a whole seed basis.

Sunflower oil is used primarily as a premium salad oil because of its light color and bland flavour. It is also useful as a cooking oil because of its high smoke point (Geise 1974). Eighty percent of the sunflower produced in Canada is sold as a salad oil and most of it is marketed as pure rather than as blended oil. In the U.S.A., the oil is usually blended with soybean oil to increase the level of unsaturation. Of the vegetable oils produced in North America, only safflower oil exceeds Canadian sunflower oil in the content of linoleic acid, a desirable polyunsaturated fatty acid (Dedio et al. 1980).

After the oil is removed the meal is most commonly used as a protein supplement for livestock feed. The meal contains from 38 to 46% protein and 8 to 12% fibre, and although low in lysine, it is high in thiamin and niacin. The hulls, which contain about 3% oil and 3-4% protein, are pelleted and fed to livestock while unpelleted hulls are used as chicken litter (Geise 1974).

Seed of confectionery type sunflower is roasted and used as a snack or dehulled and incorporated into candy, cookies or cereals. Further details on the use of sunflower can be found in Dorrell (1978) and Lofgren (1978).

With world population and global per capita consumption of fats and oils increasing, the demand for edible vegetable oils will continue to rise. Sunflower oil, because of its unusual combination of nutritional and storage qualities is capable of meeting the demand (Dotty 1978). Sunflower can still be further improved. Most cultivars have a potential seed yield exceeding 3000 kg per hectare, but average yields in North America are less than 1500 kg per hectare (Robinson 1978). Considerable unexplored genetic material exists for improving sunflower

(Heiser 1978) and plant breeders will most certainly develop improved and more productive cultivars in the future.

In Canada, sunflower has been grown primarily in the Red River Valley region of southern Manitoba (Putt 1978) where corn and soybean have not performed well, because of either a short growing season, or lack of rainfall during critical periods (Cobia 1978). Research trials conducted in southern Alberta and Saskatchewan have shown that sunflower can be profitably grown over a much wider area than has been generally recognized (Campbell 1979). Thus, there is potential for regional expansion.

Most of the sunflower produced in Canada and the U.S.A. is exported to Europe. In the past, restricted delivery opportunities, low cereal prices, along with strong demand for sunflower oil in Europe provided excellent marketing opportunities for sunflower. Future production in North America will depend on these factors and particularly on improved export demand. Sunflower, because of its yield potential and superior agronomic characteristics (Robinson 1978), is likely to become a more important economic crop (Dotty 1978). With an increase in sunflower production it is only logical to assume that sunflower associated insects will also increase. The question is what impact will the insect pests have on increased sunflower hectarage and/or increased yield potential.

2.2 THE SUNFLOWER BEETLE

2.2.1 Geographic Distribution and Status

The sunflower beetle, *Zygogramma exclamationis* (F.), is an oligophagous insect which feeds on a few members of the genus *Helianthus*. The most important member within the genus is the cultivated sunflower *H. annuus* (Rogers and Thompson 1978, 1980). Like its principal host, the sunflower beetle is native to North America (Wilcox 1972; Heiser 1978). The beetle has been recorded from most states and provinces of the Great Plains area of North America, including the Canadian prairies (Criddle 1922; Westdal and Barrett 1955), the northern Great Plains states of the U.S.A. (Schulz 1978), Montana (Cooley 1918), Arizona (Brisley 1925), Nebraska (Powell 1932), Texas (Rogers 1977), Kansas (Walker 1936) and Utah (Knowlton and Smith 1935).

As Criddle (1922) predicted, the sunflower beetle has spread from native plants to cultivated sunflower. It is the most important defoliating species of sunflower pest in Manitoba (Westdal and Barrett 1955) and the northern sunflower-growing region of the U.S.A., that is, North Dakota, South Dakota and Minnesota (Schulz 1978). However, it is not an economically important pest in the southern sunflower-growing regions of the U.S.A. (Cobia and Zimmer 1978; Rogers and Thompson 1980).