Intercropping and mechanical weeding: effects on insects of *Zea mays*

by

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ABSTRACT

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A study was undertaken from 1993 to 1994 to determine the effects of intercropping (with *Glycine max* L. Merr., *Lupinus* sp., *Trifolium pratense* L.-*Lolium multiflorum* Lam., or *Secale cereale* L.) and mechanical weeding (with a rigid tines cultivator, Danish tines cultivator or ridge cultivator) on the population dynamics of insect pests (*Diabrotica longicornis* Say, *Lygus lineolaris* Palisot de Beauvois, *Ostrinia nubilalis* Hübner, and *Pseudaletia unipuncta* Haworth) on corn (*Zea mays* L.) in L'Assomption and Sainte-Anne-de-Bellevue, Quebec, Canada.

D. longicornis or *P. unipuncta* populations did not increase.

In 1994, intercropping with *T. pratense-L. multiflorum* (Sainte-Anne-de-Bellevue) or weeding with the Danish tines cultivator (L'Assomption) increased *L. lineolaris* populations.

In 1994, intercropping with *S. cereale* (L'Assomption) or *T. pratense-L. multiflorum* (Sainte-Anne-de-Bellevue) increased *O. nubilalis* populations.

RÉSUMÉ

M.Sc. Francine Brunet Entomologie

La polyculture et le sarclage mécanique: les effets sur des insectes de *Zea mays*

Une étude a été entreprise de 1993 à 1994 pour déterminer les effets de la polyculture (avec *Glycine max* L. Merr., *Lupinus* sp., *Trifolium pratense* L.-*Lolium multiflorum* Lam. ou *Secale cereale* L.) et du sarclage mécanique (avec herse-peigne, sarcloir à dents danoises ou sarcloir billonneur) sur la dynamique des populations d'insectes ravageurs (*Diabrotica longicornis* Say, *Lygus lineolaris* Palisot de Beauvois, *Ostrinia nubilalis* Hübner et *Pseudaletia unipuncta* Haworth) sur le maïs (*Zea mays* L.) à L'Assomption et Sainte-Anne-de-Bellevue, Québec, Canada.

Les populations de *D. longicornis* et *P. unipuncta* n'ont pas augmenté.

En 1994, la polyculture avec *T. pratense-L. multiflorum* (Sainte-Anne-de-Bellevue) ou le sarclage avec le sarcloir à dents danoises (L'Assomption) ont augmenté les populations de *L. lineolaris*.

En 1994, la polyculture avec *S. cereale* (L'Assomption) ou *T. pratense-L. multiflorum* (Sainte-Anne-de-Bellevue) a augmenté les populations d'*O. nubilalis*.

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Field Experiment:

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Data Analysis:

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1. INTRODUCTION

Diabrotica longicornis Say, *Lygus lineolaris* Palisot de Beauvois, *Ostrinia nubilalis* Hübner, and *Pseudaletia unipuncta* Haworth are herbivorous insects commonly found on corn (*Zea mays* L.) in Quebec (Beirne, 1971a, 1971c & 1972; Boivin et al, 1986; Hudon, 1968; Hudon et al, 1992; Matin and Yule, 1984). With the use of nontraditional agricultural practices to reduce the use of chemical herbicides, such as polyculture and mechanical weeding, the incidence of these insects may be increased (Weber et al, 1990).

There is no general rule for predicting the effects that a polyculture will have on crop damage by herbivorous insects (Andow, 1991) although some hypotheses exist (Altieri, 1993). These effects may vary (Kennedy and Margolies, 1985) with many factors (Perrin and Phillips, 1978). For example, Martin et al (1989) observed less infestation of corn by *O. nubilalis* in a corn-*Glycine max* L. Merr. polyculture than in a corn monoculture. However, Tonhasca and Stinner (1991) observed no effect with the same polyculture.

The practice of mechanical weeding is little documented with respect to its influence on insect populations on corn. Mechanical weeders are cultivators that are used after the crop has been sown. Perhaps they could have effects similar to those of tillage done before sowing. Tillage is known to reduce the damage done to corn by *P. unipuncta* (Harrison et al, 1980), to increase damage done to corn by *D. longicornis* (Tyler and Ellis, 1974), to increase *O. nubilalis* population levels (Tonhasca and Stinner, 1991) and to reduce *L. lineolaris* population levels (Tonhasca and Stinner, 1991).

Part of a multidisciplinary project that aimed at developing alternative solutions to the use of herbicides in grain corn in Quebec, this study examined the effects of four polycultures (corn-*G. max*, corn-*Lupinus* sp., corn-*Secale cereale* L. or corn-*Trifolium pratense* L.-*Lolium multiflorum* Lam.) and of three mechanical weeders (rigid tines cultivator, Danish tines cultivator or ridge cultivator) on the population dynamics of the insects *D. longicornis*, *L. lineolaris*, *O. nubilalis*, and *P. unipuncta*. Only insect species described as pests of corn in the literature and commonly found in corn fields in Quebec were chosen. The number of insect species studied was limited to four to minimize the time required for observations. Other pests of corn in Quebec include *Heliothis zea* (Lepidoptera), *Hydroecia micacea* (Lepidoptera), *Hylemya platura* (Diptera), and *Rhopalosiphum maidis* (Homoptera) (Beirne, 1971a, 1971b & 1972; St-Pierre and Gendron, 1982). This study was conducted over two years (from 1993 to 1994 inclusive) and at two sites (L'Assomption and Sainte-Anne-de-Bellevue).

2. LITERATURE REVIEW

2.1 The Production of Grain Corn (*Zea mays*) and Associated Populations of Herbivorous Insects in Quebec

In Quebec (Canada) 1.87 millions of tons of grain corn (*Zea mays*) were produced in 1993 on a total planted area of 295 000 hectares (MAPAQ, 1994). This represents an average yield of 6.3 t/ha for 1993. Grain corn is usually grown as a monoculture and with the use of chemical herbicides. Dependence on chemical herbicides for weed control in corn in North America has increased and there exists the fear of underground water contamination by such products (Weber et al, 1990; Schweizer et al, 1992). More than 100 weed biotypes have developed a resistance to 14 herbicide classes during the last 25 to 30 years (Thill et al, 1994). Examples are *Stellaria media*, *Setaria viridis*, *Brassica kaber* and *Bromus tectorum* (Thill et al, 1994). These species occur in Quebec (Frère Marie-Victorin, 1964). These resistant weeds have developed in situations where chemical herbicides were the main or the only component in a weed control program and where an integrated weed management strategy was not used (Thill et al, 1994).

In an effort to reduce pollution while maintaining an adequate level of weed control, corn producers use reduced herbicide dosages, often in combination with post-emergent mechanical weeding (Weber et al, 1990). But the use of cultural practices other than monoculture, chemical herbicides and pre-sowing soil tillage for the control of weeds may increase insect damage (Weber et al, 1990).

Diabrotica longicornis Say (Coleoptera: Chrysomelidae; the Northern corn rootworm) (Beirne, 1971c; Matin and Yule, 1984), *Lygus lineolaris* Palisot de Beauvois (Hemiptera: Miridae; the tarnished plant bug) (Beirne, 1972), *Ostrinia nubilalis* Hübner (Lepidoptera: Pyralidae; the European corn borer) (Beirne, 1971a; Boivin et al, 1986; Hudon, 1968; Hudon et al, 1992), and *Pseudaletia unipuncta* Haworth (Lepidoptera: Noctuidae; the common armyworm) (Beirne, 1971a) are herbivorous insects that may be found on corn in Quebec. These pest insects of corn were chosen arbitrarily among others for this study. Other pests of corn in Quebec include *Heliothis zea* (Lepidoptera), *Hydroecia micacea* (Lepidoptera), *Hylemya platura* (Diptera), and *Rhopalosiphum maidis* (Homoptera) (Beirne, 1971a, 1971b & 1972; St-Pierre and Gendron, 1982).

The Northern corn rootworm can cause a reduction of corn yield of 0.8-2 t/ha (Beirne, 1972). Based on the estimated average yield in Quebec in 1993, i.e. 6.3 t/ha (MAPAQ, 1994), this represents an estimated corn yield loss of 13-32%. *D. longicornis* is considered one of the most important corn pests in the U.S. (Foster et al, 1982). The economic threshold generally observed for *D. longicornis* is 10 larvae per plant (Chiang, 1973).

Although it is commonly found on the corn plants (especially on the silks) in Quebec (Beirne, 1972) and corn is considered as one of its many host plants (Young, 1986), *L. lineolaris* does not cause significant damage to corn (Beirne, 1972). Hemipterans are commonly found on corn plants. A study conducted in Guatemala in 1951 revealed the presence of Miridae on corn (Painter, 1955). However, there was no apparent damage (Painter, 1955).

Clower (1958) reported that adult *Nezara viridula* (Hemiptera; Southern green stink bug) severely damaged corn. Corn plants, attacked by the insect, showed light wilting and some were completely killed. On the older plants, the cobs were deformed, thus grain did not develop. This insect was found especially in the soil, on the corn plants and on the surrounding weeds (Clower, 1958).

Since its first appearance in Quebec in 1926 the European corn borer has spread to all regions of the province where corn is grown and is considered an insect with a high economic importance (Boivin et al, 1986; Hudon, 1968; Hudon et al, 1992). The reduction of photosynthesis rate is estimated at 11% (for 3 larvae per plant) and at 22% (for 5 larvae per plant) due to *O. nubilalis* larvae tunnelling in the stalks (Godfrey, Holtzer and Norman, 1991). The corn yield loss is estimated at 3% for an infestation of one larva per plant (Lynch et al, 1980; Lynch, 1980). Corn yield losses were estimated between 13 and 19% for an infestation of five larvae per plant (i.e. 3.2 cavity holes per plant) (Godfrey, Holtzer, Spomer and Norman, 1991).

Finally, the common armyworm, when present in great numbers, can completely destroy a corn field (Beirne, 1971a). However, severe and widespread outbreaks tend to occur at irregular intervals of 5 to 20 years and last only one season (Beirne, 1971a; Pedigo, 1989) because *P. unipuncta* is an immigrant species that does not usually survive the winter in Canada (Beirne, 1971a). It seems that the number of immigrants in May mainly determines the importance of the species as a pest in Canada each year (Beirne, 1971a). Normally, populations are small and attract little attention (Guppy, 1961).

2.2 The Effect of Interrow Vegetation (Weeds or Cultivated Plant Species) on Herbivorous Insects of Corn

The presence or absence of interrow vegetation (weed or cultivated species) may influence pest insect populations in corn (Weber et al. 1990). An increase in vegetational diversity[1] in an area can drastically reduce a specialized herbivorous insect's colonization efficacy and subsequently its population density (Tahvanainen and Root, 1972).

The pumpkin pest insect *Frankliniella occidentalis* (Thysanoptera: Thripidae) population level on pumpkin (*Cucurbita pepo*) was reduced in a pumpkin-corn-cowpea (*Vigna sinensis*) triculture, compared to a pumpkin monoculture (Létourneau and Altieri, 1983). *F. occidentalis*' s predator *Orius tristicolor* (Hemiptera: Anthocoridae) was more attracted to the triculture (Létourneau and Altieri, 1983).

A priori, three types of effects can result from the presence of interrow vegetation: exacerbation (due to the nursery crop phenomenon), amelioration (due to the trap crop phenomenon) and neutrality (Kennedy and Margolies, 1985).

In the exacerbation effect, the increase of vegetational diversity within the field increases the pest risk to the crop. The nursery crop phenomenon refers to a situation where large insect populations develop on a crop and subsequently disperse in great numbers towards other crops. For example,

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1 "Diversity" means "richness in species or structures" (Van Emden and Williams, 1974).

safflower (*Carthamus* sp.) and alfalfa (*Medicago sativa*) are nursery crops to *Lygus* spp. and impact on the extent of damage caused by *Lygus* spp. insects in cotton fields in California (U.S.) (Kennedy and Margolies, 1985).

In the amelioration effect, the increase of vegetational diversity within the field reduces the pest risk to the main crop. The trap crop phenomenon may be found in agricultural areas characterized by a diversified agriculture (i.e. where various crops or various growth stages of the same crop can be found) where plants that are more attractive than others to certain insect species can be found (Kennedy and Margolies, 1985). In North Carolina (U.S.) areas where potato (*Solanum tuberosum*) and grain corn fields are simultaneously present, potato fields act as trap crops for *O. nubilalis* (i.e. attracts the insect) and protect corn plants (Kennedy and Margolies, 1985).

In the neutrality effect, the increase of vegetational diversity within the field does not affect the pest risk to the crop. The neutrality effect would be the most common (Kennedy and Margolies, 1985).

The ultimate effect interrow vegetation will have on an insect is difficult to determine because one plant species may act as a nursery crop and as a trap crop for one insect species at different times (Kennedy and Margolies, 1985).

To determine the ultimate effect of the presence of interrow vegetation on insect pest population levels, the mechanisms of host selection of each insect must be known.

An insect may obtain information about its host with at least two mechanisms: (a) with peripheral sensory organs and (b) with a metabolic route (as when a toxin or a nutritional deficiency leads to a metabolic disequilibrium that is thereafter perceived by internal sensory organs) (Waldbauer and Friedman, 1991).

According to Richter's hypothesis, insects have an innate ability to detect the nutritional value of food items and have the capacity to recognize the needed nutritional elements with their senses (Waldbauer and Friedman, 1991). Herbivorous insects are influenced by the nutritional quality of plants and can modify their behaviour when encountering food sources of lesser quality (Buendgen et al, 1990; Wheeler and Slansky, 1991). *Ostrinia nubilalis*, preferring plants that are richer in soluble carbohydrates, selects the richer leaves without ingesting them (Fiala et al, 1990.).

Chemical compounds produced by plants are involved in the host selection and in the feeding behaviour of herbivorous insects (Tahvanainen and Root, 1972). The lipid content in plant cuticles can lead to the complete rejection of a plant (Espelie et al, 1991). The presence of phytotoxins can harm herbivorous insects (Kelsey et al, 1991).

For *O. nubilalis*, the host selection for egg deposition is accomplished with the help of a chemical communication system involving chemical substances emitted by the plant and detected by the insect: (a) volatile compounds (e.g., phenylacetaldehydes) help the insect in identifying and locating from a distance the host plants; and (b) other compounds that act on contact (e.g., soluble sugars) stimulate the egg deposition or not (Stockel et al, 1987; Fiala et al. 1985).

Many factors can influence host selection of herbivorous insects at any time. The quality (growth stages and plant species) of the interrow vegetation present at the time herbivores infest the field would generally determine if the crop will be protected (Perrin, 1977). In Zimbabwe and Sudan, corn has failed at protecting cotton (*Gossypium* sp.) probably because it was at an unattractive stage when the pest *Heliothis armigera* (Lepidoptera) was present in great numbers (Perrin, 1977). The plant quality can vary. The quantity of carbohydrates present at the corn leaf surface would vary with plant age, plant growth stage, hybrid or cultural conditions (Fiala et al, 1990).

The micro-climate (e.g., light, humidity, wind and temperature) in a polyculture would differ from that in a monoculture (similarly in a weedy monoculture compared to a weeded monoculture). Interrow plants could provide protection against wind or provide shade to pest insects and their natural enemies (Perrin, 1977; Létourneau, 1990; Andow, 1991).

Temperature and humidity influence the *O. nubilalis* egg hatchability (Godfrey and Holtzer, 1991). Temperature influences the nymphal development and viability of the eggs of *Lygus lineolaris* (Khattat and Stewart, 1977).

Light and humidity influence flower visitation by insects (Kevan and Baker, 1983). Certain phytotoxins are more effective in sunlight than in shade, others are effective in shade (Kelsey et al, 1991).

Light and temperature can modify the structure of chemical compounds (e.g. olfactory stimuli), their transfer rate from the plant to the insect, and their reactivity within the environment or the insect (Shapiro, 1991).

Wind influences the insects that fly (Kevan and Baker, 1983). The absence of wind (e.g. where there is protection provided by interrow vegetation) can limit the dispersal of organisms that cannot fly. The mite *Tetranychus urticae* uses wind dispersal (Brandenburg and Kennedy, 1982). Corn populations of *T. urticae* can be the source of subsequent infestations in surrounding peanut (*Arachis hypogea*) fields, as winds transport the mites towards peanut fields (Brandenburg and Kennedy, 1982). A light wind is required to guide the *O. nubilalis* male moth in its search of the female to mate (DeRozari et al, 1977).

Interrow vegetation can interfere with the olfactory stimuli emitted by the host crop that normally would guide the insect to find the crop (Perrin, 1977). The olfactory stimuli emitted by aromatic interrow plant species (e.g., *Allium* spp. and *Lycopersicon* sp.) can camouflage a host crop (Perrin, 1977; Perrin and Phillips, 1978).

Interrow vegetation can modify the visual stimuli that guide the pest insects to their host plants (Perrin, 1977). These stimuli are defined as spatiotemporal distributions of photon flux that differ in total energy and in frequency (Prokopy and Owens, 1983).

What would be perceived by the insect would depend on the nature of the surface looked at, on the optical background, on the nature of light, on the angle in which the object is looked at, and on the insect's sensitivity (Prokopy and Owens, 1983). The insect's vision[2] also depends on its past visual experience (Prokopy and Owens, 1983). A dense vegetational canopy could be unattractive to certain insects that respond better to spaced out plants and that clearly contrast with soil (Perrin, 1977). Other insects respond better to a dense vegetational canopy (Perrin and Phillips, 1978).

The quantity of natural light reaching an insect at any time and available to allow discrimination of plants (or their structures) may vary according to many environmental factors and the insect's position within a habitat (Prokopy and Owens, 1983). The visibility of a terrestrial object for an insect varies according to incidental solar light quantity and quality reaching the earth (Prokopy and Owens, 1983). The quality and abundance of light varies according to the time of day and year, the latitude, the longitude, the altitude and the turbidity (or quantity of water vapour or dusts) in the atmosphere (Prokopy and Owens, 1983). The reflected light under a plant canopy is richer in the green to red spectrum portion and poorer in blue (Prokopy and Owens, 1983).

An interrow vegetation that limits the development or the survival rate of insects can make the dispersal of a pest insect between two host plants or host rows difficult (Perrin, 1977; Perrin and Phillips, 1978). Trichomes act as a resistance mechanism against lepidopteran insect larvae that feed on *Glycine max* leaves (Lambert et al, 1992). *G. max* plants with trichomes could be an

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[2] "Vision" means "aptitude to perceive the photoluminescent patterns in the space" (Prokopy and Owens, 1983).

intercrop[3] that limits insect populations.

The capacity to limit dispersal would, in part, depend on the polycultural pattern used (Perrin, 1977; Prokopy and Owens, 1983). To limit insect movement could influence the angle from which the host plant is seen by the insect and, consequently, could influence the perception by the insect (Prokopy and Owens, 1983). Plant density will influence populations of herbivores (Pimentel, 1961). *Hylemya antiqua* (Diptera) lays more eggs at high *Allium* sp. plant densities (Chiang and Perron, 1980). The degree of contrast between the crop area and its environment can influence the dispersal rate of insects that disperse with the help of visual stimuli (Prokopy and Owens, 1983).

Interrow vegetation can modify the incidence of crop pests by acting on their natural enemies (Perrin, 1977). Parasitic insect population levels of the bean (*Phaseolus* sp.) pest *Heliothis armigera* (Lepidoptera: Noctuidae) increased with the increase in crop diversity (Abate, 1991). However, the study did not show a decrease in *H. armigera* population levels on the bean plants.

According to the hypothesis of Southwood, the action of natural enemies of herbivores is maximized with polyculture and, consequently, minimizes the population of herbivores (Perrin and Phillips, 1978).

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[3] "Intercrop" means "interrow cultivated plant species" (Andow, 1991).

However, the populations of natural enemies could be reduced with polyculture, particularly if they respond to the same visual and olfactory stimuli as their hosts or prey, and if they encounter the same dispersal problems (Perrin, 1977).

Natural enemies probably use both visual and olfactory (chemical) stimuli emitted by their hosts or prey (McClain et al, 1990; Gueldner et al, 1984), or emitted by the host plant of their hosts or prey (Shahjahan and Streams, 1973).

Parasitoids would first be attracted to a habitat that is likely to contain an acceptable insect host (Streams et al, 1968). The parasite of *Lygus* nymphs, *L. pseudopallipes* (Hymenoptera: Braconidae), is attracted by *Erigeron* plants (Shahjahan and Streams, 1973). These plants are hosts of *Lygus* insects (Shahjahan and Streams, 1973).

Although many factors influence the ultimate effect that interrow vegetation will have on herbivorous insects, there are at least two hypotheses for explaining decreases in pest population levels on crops: the Natural Enemies Hypothesis and the Resources Concentration Hypothesis (Risch, 1981; Altieri, 1993).

With the Natural Enemies Hypothesis, the increase of predatory and parasitic insect abundance in areas rich in plant species would result in the decrease in pest insect abundance (Risch, 1981). This is based on the assumption that an area rich in plant species provides more favourable conditions to natural enemies by reducing the probability that these natural enemies will have to leave the area to feed (Risch, 1981). These conditions include: (a) a better temporal and spatial distribution of pollen and nectar sources; and (b) an increased richness in alternative hosts or prey when the preferred hosts or prey are unavailable (Risch, 1981).

With the Resources Concentration Hypothesis, the decrease of resource concentration (e.g. crop) due to the presence of interrow vegetation, increases the difficulty of locating host plants (Risch, 1981). This is based on the assumption that an area rich in plant species provides more confusing stimuli to the insect compared to a simple area (Risch, 1981).

Risch et al (1983) suggested that diversification in agricultural habitats frequently reduces the pests population in these habitats. This is based on a literature review that revealed that : (a) 53% of the populations of studied herbivorous species were reduced following a diversification; (b) 18% were increased; and (c) 9% did not show an effect. Andow (1991) suggested that 52% of the population of studied herbivorous species were reduced following a diversification and 15% were increased.

It is, however, impossible to explain or predict the ultimate effects of interrow vegetation on herbivorous insects even with the suggested hypotheses (Stinner et al, 1983). Generalizations can only be done with more research (Stinner et al, 1983). The effect of interrow vegetation on herbivorous insects can also vary (i.e., be positive, negative or neutral) with the insect and plant species involved in the polyculture (Capinera et al, 1985; Kennedy and Margolies, 1985).

A better understanding of the involved mechanisms is necessary for a generalization (Risch et al. 1983). The study of each interaction existing between each living organism within an agroecosystem is unrealistic: a simple ecosystem, for example, composed of two plant species, six herbivorous species and six natural enemies species, would amount to at least 91 two-way potential interactions and 364 three-way potential interactions to study (Andow, 1991). A generalization may not exist (Andow, 1991).

Weeds as Interrow Vegetation- Insect damage on crops can be reduced with the increase in weed incidence.

The population levels of the Brussels sprouts (*Brcssica oleracea gemmifera*) pest insects *Aleyrodes brassicae* (Aleyrodidae), *Aphis fabae* (Aphididae), *Brevicoryne brassicae* (Aphididae), *Myzus persicae* (Aphididae), and *Pieris rapae* (Lepidoptera) were reduced with the increase in weed incidence in Brussels sprouts fields (Smith, 1976). *Chenopodium album*, *Polygonum persicaria*, *Raphanus raphanistrum*, *Sinapsis arvensis*, and *Spergula arvensis* were the dominant weeds (Smith, 1976).

The population of the corn pest *Dalbulus maidis* (Homoptera: Cicadellidae) was reduced on corn plants in weedy fields, compared to weeded fields (Power, 1987).

The number of *Diabrotica* larvae and adults on corn was reduced in weedy corn fields (dominated by the weed *Setaria* sp.), compared to weeded corn fields (Johnson et al, 1984). *Diabrotica* insects also emerged later in weedy corn fields (Johnson et al, 1984).

The damage done by the soya pest *Epilachna varivestis* (Coleoptera) was reduced with the increase in weed incidence (Shelton and Edwards, 1983).

Corn damage from *Heliothis zea* (Lepidoptera) was reduced in weedy fields, compared to weeded corn fields (18% versus 32% of plants damaged) (Altieri et al, 1985). *Amaranthus* sp., *Erodium cicutarium*, and *Spergula arvensis* were the dominant weeds (Altieri et al, 1985).

The number of *O. nubilalis* larvae and damage were reduced in corn weedy fields, compared to weeded fields (Pavuk and Stinner, 1991). The dicotyledonous weeds *Amaranthus retroflexus* and *Chenopodium album* were the dominant weeds (Pavuk and Stinner, 1991). Pavuk and Stinner suggested that weeded corn may be more attractive to *O. nubilalis* since this insect prefers tall and mature plants, and corn plants were shorter in weedy fields.

The increase in weed incidence can also have no effect on pest insects. Corn damage due to *Helicoverpa zea* (Lepidoptera) was not influenced by the increase in weed incidence (Weber et al, 1990).

The increase in weed incidence can also increase pest population levels. The infestation of sweet corn by *O. nubilalis* increased with an increase in weed incidence, at five weeks after corn emergence (Weber et al, 1990).

The damage to corn caused by *Pseudaletia unipuncta* was increased with the increase in weed incidence (Pavuk and Stinner, 1991).

There are relationships between insects and weeds. Some examples are stated below.

The weed *Setaria* sp., allowing the formation of dew and retention of rain drops, constitutes the ideal humid habitat for the reproduction activities and resting of *O. nubilalis* adults (DeRozari et al. 1977; Showers et al. 1980).

The weeds *Amaranthus* sp., *Ambrosia* sp., *Chenopodium* sp., *Digitalis* sp., *Panicum* sp., *Echinochloa crus-galli* and *Polygonum persicaria* are host plants to *Lygus lineolaris* (Young, 1986). These weeds grow in Quebec (Frère Marie-Victorin, 1964).

The flowers of weeds are a nutritive source that increases the parasitic activity of *Meteorus rubens* (Hymenoptera) against the corn pest *Agrotis ipsilon* (Lepidoptera: Noctuidae) (Foster and Ruesink, 1984).

The dicotyledonous weeds *Amaranthus retroflexus*, *Chenopodium album* would contribute more to the increase of corn damage done by *O. nubilalis* than the monocotyledonous weeds *Digitaria sanguinalis*, and *Panicum dichotomiflorum* (Weber et al, 1990).

Cultivated Plants Species (or Intercrops) as Interrow Vegetation- The growth of cultivated plant species in between the rows of a crop is the basic principle of polyculture[4]. For example, the presence of soya (*Glycine max*) in between the rows of corn is a corn-soya polyculture. Polyculture is an alternative method to the use of chemical herbicides to control weeds. The presence of interrow cultivated plant species (intercrops) could influence the incidence of herbivorous insects on the crop (Risch and Hansen, 1982).

[4] "Polyculture" is defined as one or a combination of various plant species intimately present in space and time (Andow, 1991).

The effect of intercrops on the corn pests *Diabrotica longicornis*, *Lygus lineolaris*, *Ostrinia nubilalis*, and *Pseudaletia unipuncta* is little documented.

Diabrotica longicornis- The effect of corn polycultures on *D. longicornis* is not documented. However, there was no effect of soya on *Diabrotica virgifera virgifera* (Coleoptera: Chrysomelidae) population levels on corn (Tonhasca and Stinner, 1991).

Many plants may influence *D. longicornis*. This insect can complete its larval development on 14 monocotyledonous species in addition to corn (Chiang, 1973). *D. longicornis* feeds on pollen from plant species of Gramineae, Compositae, Leguminosae and Cucurbitaceae (Chiang, 1973). Red clover and soya are host plants on which the beetle can feed (Cinereski and Chiang, 1968).

Lygus lineolaris- There was no effect of soya in corn fields on *L. lineolaris* population levels (Tonhasca and Stinner, 1991). The relationship between corn and *L. lineolaris* is not documented regarding whether the insect is more a predator or a herbivore in corn fields.

Many plants may influence *L. lineolaris*. Young (1986) counted 385 host plants for this insect. These plants include soya, rye (*Secale cereale*), red clover (*Trifolium pratense*) and corn, which are grown in Quebec (MAPAQ, 1994). *L. lineolaris* feeds on the fruit structures of soya (Broersma and Luckmann, 1970). The presence of clover near a corn field could influence the incidence of *L. lineolaris* because when clover fields are cut or dried in the field, the insect migrates to other crops (Beirne, 1972).

L. lineolaris can also feed on living and dead insects (Young, 1986; Cleveland, 1987). *L. lineolaris* can feed on Miridae (Hemiptera), Cicadellidae (Hemiptera), Aphididae (Hemiptera), Chrysomelidae (Coleoptera), Curculionidae (Coleoptera), Geometridae (Lepidoptera), Noctuidae (Lepidoptera), Agromyzidae (Diptera), Braconidae (Hymenoptera) and Formicidae (Hymenoptera) insects (Culliney et al, 1986; Young, 1986). *L. lineolaris* is a predator of *Heliothis* spp. (Lepidoptera: Noctuidae) eggs and larvae (Cleveland, 1987). *L. lineolaris* may be a predator of other herbivorous insects present in corn fields, such as *D. longicornis* (Coleoptera: Chrysomelidae), *O. nubilalis* (Lepidoptera: Pyralidae), and *P. unipuncta* (Lepidoptera: Noctuidae). The hemipteran *Orius insidiosus* (Anthocoridae), is a predator of *O. nubilalis* (Godfrey, Godfrey, Hunt and Spomer, 1991). However, the relation between *L. lineolaris* and *O. nubilalis*, *P. unipuncta* and *D. longicornis* is not documented.

Ostrinia nubilalis- The infestation of corn plants by *O. nubilalis* was lower in a corn-soya polyculture than in monocropped corn, in Eastern Ontario (Canada) (Martin et al, 1989).

There was no effect of soya on *O. nubilalis* infestation of corn, in Ohio (U.S.A.) (Tonhasca and Stinner, 1991).

The corn damage done by *O. nubilalis* was lower in a polyculture of corn-red clover than in monocropped corn, in Eastern Ontario (Lambert et al, 1987).

Pseudaletia unipuncta- There was no effect of soya on *P. unipuncta* infestation of corn, in Ohio (Tonhasca and Stinner, 1991).

2.3 The Effect of Tillage and Mechanical Weeding on Herbivorous Insects of Corn

The effect of mechanical weeding, as a weed control method, on corn insects in Quebec is not documented. Mechanical weeders are cultivators used after the crop has been sown. Because they disturb the soil, perhaps they have effects similar to those of tillage done before sowing.

Tillage influences insects and other invertebrates in at least three ways: (a) by mechanical disturbance; (b) by redistribution of the plant residues; and (c) by effects on weed populations (Stinner and House, 1990; Seal et al, 1992).

Tillage could modify the susceptibility of crops to pest insects, either via direct effects or via indirect effects on the insects (Andow, 1992). Tillage can indirectly influence crop pests population levels by acting on their natural enemies (e.g., soil and litter Carabidae, spiders, and acarids; plant foliage insect hemipterans and hymenopterans) (Stinner and House, 1990).

Certain soil nematodes can parasitize pest insects of crops. *Heterorhabditis heliothidis* can parasitize *Pseudaletia unipuncta* occurring at the soil surface (Morris and Converse, 1991). The *Aphelenchoides*, *Diplogasteridae*, *Panagrolaimidae* and *Rhabditidae* nematode population levels were higher in mechanically weeded corn fields (weeding done at 5 and 7 weeks after corn planting), compared to chemically weeded fields (Yeates et al, 1993).

A frequently tilled (disturbed) soil can leave insufficient openings in the soil for arthropods to nest (Altieri et al, 1985). For instance, *Diabrotica virgifera* (Coleoptera: Chrysomelidae) adults prefer big soil particles and cracks rather than soil aggregates to lay eggs (Kirk et al, 1968). In addition to modifying the quantity of residues at the soil surface, tillage modifies the soil thermal properties (Gray and Tollefson, 1988b).

The effect of tillage, carried out prior to sowing, on the corn pest insects *Diabrotica longicornis*, *Lygus lineolaris*, *Ostrinia nubilalis*, and *Pseudaletia unipuncta*, is documented.

Diabrotica longicornis- In Southern Ontario, the emergence rate of *D. longicornis* adults and the number of plants damaged by the insect increased with tillage carried out prior to corn sowing (Tyler and Ellis, 1974).

The population levels of soil predators of *D. longicornis* (i.e. the carabids *Agonum muelleri*, *Pterostichus lucublandus* and *Harpalus affinis*) were reduced with tillage carried out prior to corn sowing, in Southern Ontario (Tyler and Ellis, 1979).

Studies were also done on other *Diabrotica* species. *Diabrotica virgifera virgifera* population levels increased with tillage done prior to corn sowing, compared to no tillage (Tonhasca and Stinner, 1991; Gray and Tollefson, 1987).

The larval population levels and corn damage of *D. barberi* increased with tillage done prior to corn sowing, compared to no tillage (Gray and Tollefson, 1987).

The viable egg population levels of *Diabrotica virgifera virgifera* and *D. barberi* in the soil of corn fields were reduced with tillage done prior to corn sowing, compared to no tillage (Gray and Tollefson, 1988a).

Lygus lineolaris- In Ohio, *L. lineolaris* population levels were increased in corn fields with tillage done prior to corn sowing, compared to no tillage (Tonhasca and Stinner, 1991).

Ostrinia nubilalis- The predation levels of the neuropteran *Chrysopa* sp. on *O. nubilalis* eggs were reduced with tillage done prior to corn sowing, compared to no tillage in corn fields (Andow, 1992).

The carabid predation levels on *O. nubilalis* larvae were reduced with tillage done prior to corn sowing, compared to no tillage in corn fields (Brust et al, 1986).

The *O. nubilalis* population levels in corn increased with tillage done prior to corn sowing, compared to no tillage (Tonhasca and Stinner, 1991).

Pseudaletia unipuncta- The corn damage done by *P. unipuncta* was reduced with tillage done prior to corn sowing, compared to no tillage (Harrison et al, 1980). The reasons for this reduction were not established but: (a) the soil temperature was lower at 2.5 cm deep in the no tillage system, although there was no difference at the surface; and (b) the soil had a higher free water level in the no-tillage system.

The *P. unipuncta* population levels in corn were reduced with tillage done prior to corn sowing, compared to no tillage (Tonhasca and Stinner, 1991).

The carabid predation levels on *P. unipuncta* larvae in corn were reduced with tillage done prior to corn sowing, compared to no tillage (Brust et al, 1986).

3. MATERIALS AND METHODS

The study was conducted in Quebec (Canada) in 1993 and 1994 at the experimental farm of Agriculture and Agri-Food Canada at L'Assomption (45° 50' N, 73° 25' W) and at the experimental farm of Macdonald College (McGill University) at Sainte-Anne-de-Bellevue (45° 24' N, 73° 56' W) to determine the effects of four polycultures, three mechanical weeders, one weedy control and two weeded controls on herbivorous insects commonly found on corn. At L'Assomption, the trials were done on a sandy loam soil (Soulanges series). At Sainte-Anne-de-Bellevue, the trials were done on a clay loam soil (Chateaugay series). The preparation of the treatments and harvest operations were performed in part by the farm employees.

Treatments in 1993 and 1994- The studied treatments are shown in Table 1.

The mechanical weeders used in the treatments were a rigid tines cultivator (Rabewerk®), a Danish tines cultivator (Kongskilde®) and a ridge cultivator (Hiniker®) (Figure 1).

The rigid tines cultivator (Figure 1a) had a series of rows (3) with flexible teeth and one row of crow's-foot on a frame. These teeth were individually adjustable to three different levels of tension. One level allowed the teeth to be completely pulled up. The crow's-feet served the purpose of weeding in between the rows whereas the teeth allowed weeding near the crop's plants. This weeder brought little soil up to the soil surface.

The Danish tines cultivator is shown in Figure 1b. Each tine was in the shape of an "S" and was ended with a crow's-tooth. This cultivator weeded near the crop's plants while the crop was protected with rigid walls carried by the cultivator. The weeder brought little soil up to the surface, shook the soil and rooted out the weeds to dry out.

The ridge tines cultivator is shown in Figure 1c. Each toothed wheel was linked to the cultivator's rigid frame with springs. The springs gave the tension to the wheel while allowing it to adjust to the soil contour. The wheels' teeth resembled spoons. When the wheels spun at high speed, the spoons threw soil up in the air. Weeds in the interrow areas were rooted out and allowed to dry out. It also allowed the weeds located on the crop's rows to be buried with the soil thrown up from in between the rows.

Prior to corn sowing, in all treatments, the soil was tilled with a harrow in the spring. The fertilization plan used for each treatment is shown in Table 2. The cultural pattern (i.e. sowing density, number of rows, sowing date, ...) used for corn and each interrow plant species is shown in Table 3.

Experimental Design in 1993- The observations were taken in three experiments undertaken by other graduate students for the purpose of investigating intercropping and cultivation effects on pest insects of corn. Table 4 shows the experimental design and Figure 2 shows the spatial arrangement of the treatments.

The treatments 1 and 2 were observed in experiment C; the treatments 3 and 4 in experiment B; the treatments 5, 6 and 7 in experiment A; the treatments 8 and 9 in experiments A, B and C; and the treatment 10 in experiments A and B.

The treatments were arranged in completely randomized blocks (one per experiment). Each plot contained 4 corn rows and measured: 10 x 3 m^2 (experiment A), and 7 x 3 m^2 (experiments B and C). Spacing between corn rows was 0.76 m and spacing within the corn row was about 0.16 m.

Experimental Design in 1994- In 1994, to facilitate the comparison of the treatments, my experiment was undertaken with its own plots. Each plot, containing 4 corn rows, measured 7 x 3 m^2. Spacing between corn rows was 0.76 m and spacing within the corn row was about 0.16 m. All treatments were in a single completely randomized block and repeated four times at each site.

Corn Yield- The corn cobs were harvested manually October 25, 1993 and October 12, 1994 at L'Assomption, and October 22, 1993 and October 27, 1994 at Sainte-Anne-de-Bellevue. The cobs were harvested in the two centre rows of each plot, excluding one meter of row at each end of the plot. The cobs were shelled in a threshing machine, weighed, dried at 80°C to 15% moisture, and weighed again to obtain the dried grain yield.

Insect Populations- The subject insect populations (i.e. *Diabrotica longicornis* Say, Coleoptera, Chrysomelidae; *Lygus lineolaris* Palisot de Beauvois, Hemiptera, Miridae; *Ostrinia nubilalis* Hübner, Lepidoptera, Pyralidae; and *Pseudaletia unipuncta* Haworth, Lepidoptera, Noctuidae) were recorded by the visual counting of units of infestation on corn plants. The observations dates at L'Assomption were: 24/Sep/93, 1/Jul/94, 8/Jul/94, 20/Jul/94, 29/Jul/94, 7/Aug/94, 27/Aug/94, 11/Sep/94, 25/Sep/94 and 15/Oct/94. At Sainte-Anne-de-Bellevue, the observation dates were: 25/Sep/93, 1/Jul/94, 8/Jul/94, 29/Jul/94, 7/Aug/94, 27/Aug/94, 11/Sep/94, 25/Sep/94 and 27/Oct/94.

For the four insects, 10 corn plants were randomly selected (on each observation date) in the two centre rows of each plot, excluding one meter of row at each end of the plot to avoid edge effects, as did Bendell et al (1981). No insect counting was done on weeds, intercrops or flying insects. None of the insect infestation was man made. Visual counting was used by Altieri et al (1985) in a similar experiment where all insects present on corn plants were recorded. The difference is that, in the present study, all the plants were observed instead of just two leaves. Tonhasca and Stinner (1991) used a similar method to record *Lygus lineolaris*, *O. nubilalis*, *P. unipuncta* and *Diabrotica virgifera virgifera*, except that they selected 40 plants per plot. Their plots measured 18 x 16 m^2.

For *O. nubilalis*, the cavity holes in the corn plants, a broken cross (male inflorescence) and the larvae occurring on/in corn plants were recorded as units of infestation, as did Tonhasca and Stinner (1991). After the corn harvest in 1994. 10 corn plants per plot were dissected and the larvae counted.

The larvae of *P. unipuncta*, the nymphs and adults of *L. lineolaris* and, the adults of *D. longicornis* were recorded as units of infestation.

Incidence of Weeds- In 1994, percentages of plot area covered by weeds (total, monocotyledonous and dicotyledonous) were visually estimated at the time insect observations were done. Weeds were not recorded by species as in the study of Altieri et al (1985) where a fixed quadrat of 1 m^2 was randomly placed weekly in the weedy control plots. In the present study, the observer first went into the centre of the plot (while observing for insects). Then the observer established a ratio "monocotyledonous weeds/dicotyledonous weeds" by counting the weeds present in a quadrat delimited by 6 consecutive corn plants (randomly selected) and the 2 centre rows. This quadrat covered an area of about 0.76 m x 0.16 m x 5 (i.e. 0.61 m^2). Finally, the percentages of the plot area covered by all the weeds was estimated within this quadrat. This method was adapted from Altieri et al (1985) with the difference that, in the present study, all treatments were studied for weed incidence (not only the weedy control plots), I did not identify the weeds to species, and no fixed quadrat was used.

Statistical Analysis- Data were organized with the computer program Quattro Pro. Using the computer program SAS System 6.10 for Windows, data were submitted to Duncan's multiple-range test for means analysis ($\alpha = 0.05$) (SAS Institute Inc., 1985a, 1985b). Means were computed by the GLM (General

Linear Model) function of SAS. Martin et al (1989) and Weber et al (1990) performed this type of analysis in a similar study. The variables were also submitted to SAS for correlation analysis between insect population levels on corn and weed incidence. Data were computed by experiment, site and year.

4. RESULTS

4.1 The Effect of Weeds, Cultivated Plant Species (Intercrops) or Mechanical Weeding on the Corn Yield

The yields are shown in Table 5.

In 1993, in L'Assomption (L'As.), the corn yield was, although not significantly, lower in the rigid tines cultivator treatment than in the other mechanical weeding or control treatments ($F = 2.6$; $df = 5, 2$; $P = 0.0847$). In Sainte-Anne-de-Bellevue (St.A.), the yield was lower in the weedy control treatment than in the other treatments (experiment A; $F = 6.8$; $df = 5, 2$; $P = 0.0038$) (experiment B; $F = 5.3$; $df = 4, 3$; $P = 0.0058$). In St.A., the yield was lower in the Danish tines cultivator ($F = 6.8$; $df = 5, 2$; $P = 0.0038$) and the *Secale cereale*-corn polyculture ($F = 5.3$; $df = 4, 3$; $P = 0.0058$) treatments than in the chemically weeded control treatment.

In 1994, in L'As., the corn yield was lower in the *Lupinus* sp.-corn polyculture, the mechanical weeders (except the Danish tines cultivator) and the weedy control ($F = 2.2$; $df = 6, 9$; $P = 0.0356$) treatments than in the chemically weeded control treatment. There was no difference between the weedy control and the other non-control treatments. In St.A., the yield was lower in all the treatments than in the chemically weeded control treatment ($F = 6.6$; $df = 8, 9$; $P = 0.0001$). The yield was lower in the weeded control treatment than in the *Glycine max*-corn and the *S. cereale*-corn polyculture treatments, and the rigid tines cultivator treatment ($F = 6.6$; $df = 8, 9$; $P = 0.0001$).

4.2 The Effect of Weeds, Intercrops or Mechanical Weeding on the Herbivorous Insects of Corn

In 1993, *Ostrinia nubilalis* was the only insect studied. In 1994, data were collected on *Diabrotica longicornis*, *Lygus lineolaris*, *O. nubilalis*, and *Pseudaletia unipuncta*.

On August 27, 1994, in L'As., although not significantly, dicotyledonous weeds were the majority (Figure 3a) ($F = 1.2$; $df = 3, 9$; $P = 0.3151$). In St.A., although not significantly, monocotyledonous weeds were the majority (Figure 3b) ($F = 1.7$; $df = 3, 9$; $P = 0.1119$). *Elytrigia repens*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Asclepias* sp., *Chenopodium album*, *Echinochloa crusgalli*, *Helianthus* sp. and *Setaria viridis* were recorded at both sites. The incidence of these weed species was not established since weeds were not recorded by species. Their presence was only recorded as an additional observation. At both sites, there were more weeds in all the treatments than in the weeded control treatments, more weeds in the weedy control treatment than in all the other treatments, and more weeds in the mechanical weeder treatments than in the polyculture treatments (Figure 4) (L'As.; $F = 23.2$; $df = 3, 9$; $P = 0.0001$) (St.A.; $F = 32$; $df = 3, 9$; $P = 0.0001$).

4.2.1 The Effect on *Diabrotica longicornis*

Infestation levels of *D. longicornis* are shown in Table 6.

Weeds- In St.A., on August 7, 1994, the infestation was higher in the weedy control treatment than in all the other treatments ($F = 4.1$; $df = 3, 9$; $P = 0.0011$).

Polycultures and Mechanical Weeding- In 1994, no effect of intercrops or mechanical weeding on the infestation of corn by *D. longicornis* was observed.

4.2.2 The Effect on *Lygus lineolaris*

Infestation levels of *L. lineolaris* are shown in Table 7.

Weeds- In 1994, in St.A., no effect of weeds on the infestation of corn by *L. lineolaris* was observed. In L'As., on July 8, 1994, the infestation was higher in the weedy control treatment than in the manually weeded control treatment ($F = 2$; $df = 3, 9$; $P = 0.0707$). On August 27, 1994, the infestation was lower in the weedy control treatment than in the manually weeded control treatment ($F = 1.1$; $df = 3, 9$; $P = 0.3696$).

Polycultures- In L'As., on July 8 1994, the infestation was lower in the *Lupinus* sp.-corn polyculture than in the weedy control treatment (F = 2; df = 3, 9; P = 0.0707). On August 27, 1994, the infestation was lower in all the polyculture treatments (except the *Lupinus* sp.-corn) than in the manually weeded control treatment (F = 1.1; df = 3, 9; P = 0.3696).

In St.A., on August 27, 1994, the infestation was higher in the *Trifolium pratense-Lolium multiflorum*-corn polyculture treatment than in all the other treatments (F = 1.2; df = 3, 9; P = 0.3425).

Mechanical Weeding- In 1994, in St.A., no effect of mechanical weeding on the infestation of corn by *L. lineolaris* was observed. In L'As., on July 8, 1994, the infestation was higher in the Danish tines cultivator treatment than in the weeded control treatments (F = 2; df = 3, 9; P = 0.0707). On July 20, 1994, the infestation was still higher in the Danish tines cultivator treatment than in the chemically weeded control treatment. On July 20, 1994, the infestation was higher in the Danish tines cultivator than in the rigid tines cultivator treatment (F = 0.9; df = 3, 9; P = 0.5207).

4.2.3 The Effect on *Ostrinia nubilalis*

Infestation levels of *O. nubilalis* are shown in Table 8.

Weeds- In 1993, in L'As., the infestation was lower in the weedy control treatment than in the weeded control treatments in experiment B (F = 4.6; df =

4, 2; P = 0.0252). In experiment C, the infestation was higher in the weedy control treatment than in the manually weeded control treatment (F = 1.5; df = 3, 3; P = 0.2912). In 1993, in St.A., the infestation was higher in the weedy control treatment than in the manually weeded control treatment in experiment C (F = 3.1; df = 3, 3; P = 0.0621).

Polycultures- In 1993, in St.A., no effect of intercrops on the infestation of corn by *O. nubilalis* was observed. In L'As., on September 24, 1993, the infestation was lower in the *Lupinus* sp.-corn polyculture treatment than in the weedy control treatment (F = 1.5; df = 3, 3; P = 0.2912). In L'As., in 1993, the infestation was lower in the *S. cereale*-corn polyculture treatment than in the chemically weeded control treatment (F = 4.6; df = 4, 2; P = 0.0252). In L'As., in 1993, the infestation was lower in the *T. pratense-L. multiflorum*-corn polyculture treatment than in the weeded control treatments (F = 4.6; df = 4, 2; P = 0.0252).

On October 15, 1994 in L'As., the infestation was higher in the *S. cereale*-corn polyculture treatment than in the manually weeded control treatment, but the infestation was not different than in the chemically weeded control (F = 1.6; df = 3, 9; P = 0.1396).

In St.A., on September 11, 1994, the infestation was higher in the *T. pratense-L. multiflorum*-corn polyculture treatment than in the manually weeded control, but the infestation was not different than in the chemically weeded control treatment (F = 1.2; df = 3, 9; P = 0.3007).

Mechanical Weeding- No effect of mechanical weeding on the infestation of corn by *O. nubilalis* (Table 8) was observed.

4.2.4 The Effect on *Pseudaletia unipuncta*

No effect of weeds, intercrops or mechanical weeding on *P. unipuncta* was observed (Table 9). *P. unipuncta* was rarely recorded on corn plants (Table 9).

5. DISCUSSION

5.1 The Effect of Weeds, Cultivated Plant Species (Intercrops) or Mechanical Weeding on the Herbivorous Insects of Corn

The plot size was assumed sufficient to allow the observation of effects on the studied insects. The plot size was similar to that in other studies. In Eastern Ontario, Lambert et al (1987) used a size of 5 x 7 m^2 for a corn seed density lower than that in this study (i.e. 60 000 versus 80 000 grains per hectare). They observed effects. Weber et al (1980) used a plot size smaller than that in this study (i.e. 6 m x 3 rows versus 7 m x 4 rows) to study *Diabrotica longicornis*, *Ostrinia nubilalis* and *P. unipuncta*.

Contradictory results between years, sites, studies, treatments or dates could be due to differences in climate between years, sites, studies, treatments or dates. Meteorological data were, however, not collected in this study. The climate is known to directly and/or indirectly influence insects. For example, wind influences insects that fly (e.g., natural enemies, *D. longicornis*, *L. lineolaris*, *O. nubilalis* or *P. unipuncta* adults) (Kevan and Baker, 1983). Wind and light influence the *O. nubilalis* male moths in the search for females (DeRozari et al, 1977). Temperature and humidity influence *O. nubilalis* egg hatchability (Godfrey and Holtzer, 1991). The temperature also influences the nymphal development and viability of the eggs of *Lygus lineolaris* (Khattat and Stewart, 1977).

Also, since climate can influence natural enemies of pest insects (Perrin. 1977), and because there are several possible interactions between each species (e.g., plant, herbivorous and natural enemies species) in a crop system (Andow, 1991), contradictory results between years, sites, studies, treatments or dates can occur.

Moreover, adventitious fauna or flora can differ from one site to the other and, depending on natural outbreaks, from one year to the other (Altieri, 1993). The presence of non-host species can drastically reduce pest incidence on crops (Perrin, 1977). Recording the insects present on the weeds may have revealed correlations between weeds and insects.

Any neutral effect of weeds, intercrops, or mechanical weeding observed in this study does not present an isolated result. The neutral effect could be the most common effect where the weeds or intercrops are involved (Kennedy and Margolies, 1985).

Any comparison between studies on tillage and this study is partially feasible. In those studies, tillage is done before corn sowing whereas, in this study, mechanical weeding was done after corn sowing.

5.1.1 The Effect on *Diabrotica longicornis*

Weeds- In Sainte-Anne-de-Bellevue (St.A.), on August 7, 1994, the infestation of corn by *D. longicornis* was higher in the weedy control treatment than in the weeded corn treatments. The weeds could have acted as nursery crops for the insect. For instance, when the weeds became less attractive than corn. i.e. on August 7. 1994. the infestation level on corn increased. *D. longicornis* is known to be attracted to several monocotyledonous weed species (Chiang. 1973). and the majority of weeds in St.A. was monocotyledonous (Figure 3b). There was. however. no correlation between the weeds and *D. longicornis* (Table 10).

Intercrops- No effect of intercrops on the infestation of corn by *D. longicornis* (i.e., neutral effect) was observed, although *Trifolium pratense* and *Glycine max* are hosts of *D. longicornis* (Cinereski and Chiang. 1968). In Ohio, Tonhasca and Stinner (1991) observed the same effect for *Diabrotica virgifera virgifera*.

Mechanical Weeding- No effect of mechanical weeders was observed on *D. longicornis*, although tillage may influence *D. longicornis* (Tyler and Ellis, 1974). Tillage may influence *D. longicornis* by influencing soil temperature, soil humidity, and/or its natural enemies (Tyler and Ellis, 1974).

5.1.2 The Effect on *Lygus lineolaris*

The pest status (i.e. corn herbivorous insect, weeds or intercrops herbivorous insect, or predator) of *L. lineolaris* within a corn field could not be determined in this study. *L. lineolaris*, in addition to many host plants, can feed on living and dead insects (Hemiptera, Coleoptera, Lepidoptera, Diptera and Hymenoptera) (Culliney et al, 1986; Young, 1986; Cleveland, 1987). *L.*

lineolaris may be a predator of other corn pests (e.g. *O. nubilalis*, *P. unipuncta* and *D. longicornis*). This pest status could have influenced the results obtained in this study.

Weeds- On July 8, 1994, in L'Assomption (L'As.), the infestation of corn by *L. lineolaris* was higher in the unweeded control treatment than in the manually weeded control treatment (i.e. exacerbation effect), but the opposite (i.e. amelioration effect) was observed on August 27, 1994. The contradiction may be explained by a variation in time in the availability of weed species or structures (stages). Nevertheless, there was no correlation between the weeds and *L. lineolaris* (Table 10).

L. lineolaris is also highly mobile (Khattat and Stewart, 1980). A decreased attractiveness in a contiguous crop or weedy area may result in an invasion of a crop which was previously free of *L. lineolaris* (Khattat and Stewart, 1980).

Intercrops- In L'As., on August 27 1994, the infestation of corn by *L. lineolaris* was lower in the *G. max*-corn or *S. cereale*-corn polyculture treatments than in the manually weeded control treatment. On August 27, 1994, in St.A., the opposite effect was observed. *G. max* and *S. cereale* are hosts of *L. lineolaris* (Broersma and Luckmann, 1970; Young, 1986). These intercrops, or weeds present in the polycultures, could have acted as nursery crops until August 27, 1994. Then, they could have become less attractive than corn. There was, however, no correlation between the weeds and *L.*

lineolaris (Table 10). In Ohio, Tonhasca and Stinner (1991) observed no effect of the *G. max*-corn polyculture on *L. lineolaris*.

On August 27, 1994, in L'As., the infestation of corn by *L. lineolaris* was lower in the *T. pratense-L. multiflorum*-corn polyculture treatment than in the manually weeded control treatment. Both of the intercrop species, one of them, and/or the weeds present in the polyculture could have been more attractive than corn. *T. pratense*, several monocotyledonous and dicotyledonous weeds are hosts of *L. lineolaris* (Young, 1986). The hosts *Digitalis* sp., *Panicum* sp. and *Echinochloa crus-galli* were present in St.A. There was, however, no correlation between the weeds and *L. lineolaris* (Table 10).

No effect of the *Lupinus* sp.-corn polyculture treatment on the infestation of corn by *L. lineolaris* was observed (i.e. neutral effect). This is not surprising since *Lupinus* sp. is not a host of *L. lineolaris* (Young, 1986).

Mechanical Weeding- On July 8 and 20, 1994, in L'Assomption (L'As.), the infestation of corn by *L. lineolaris* was higher in the Danish tines cultivator treatment than in the weeded control treatments (however not significantly different from the manually weeded control on July 20, 1994). The Danish tines cultivator treatment plots were weedy (Figure 4). Part of the effect of this cultivator could be due to the presence of certain weeds. On July 8, 1994, the insect infestation in the Danish tines cultivator treatment was similar to the infestation in the weedy control treatment.

However, in July, 1994, the other two mechanical weeders showed no effect on the infestation by *L. lineolaris*, even if all three mechanical weeding treatments were as weedy as the weedy control treatment (Figure 4).

There may have been a difference in weed diversity between the three mechanical weeding treatments. Certain weeds could have been more attractive to *D. longicornis*. There was no correlation between weeds and *L. lineolaris* (Table 10).

The effect was not repeated on other dates. This may be due to variations in the available weed species or structures between dates. The effect was not repeated in St.A.

Another part of the effect may be due to a direct effect (mechanical injuries) on the prey of *L. lineolaris* (Andow, 1992; Altieri et al, 1985; Seal et al, 1992). The Danish tines cultivator could have injured fewer prey of *L. lineolaris* than the other mechanical weeders, resulting in more *L. lineolaris* individuals staying in the Danish tines cultivator treatment plots.

The effect observed is different than that observed in Ohio by Tonhasca and Stinner (1991). *L. lineolaris* populations decreased following the increase in soil tillage in corn fields. This may be explained by the difference between tillage and mechanical weeding.

5.1.3 The Effect on *Ostrinia nubilalis*

Weeds- In 1993, in L'As. and St.A., the infestation of corn by *O. nubilalis* was lower in the unweeded control treatment than in the weeded control treatments in experiment B. This agrees with Pavuk and Stinner (1991), but contradicts Weber et al (1990).

However, in 1993, at both sites, the infestation was higher in the weedy control treatment than in the manually weeded control treatments in experiment C. This agrees with Weber et al (1990).

The contradictory observations could be explained with a difference in the availability of weed species between studies and experiments. Specific weeds, more abundant in the plots of experiment C and less abundant in those of experiment B, could have attracted *O. nubilalis* and later be less attractive than corn.

In 1994, at both sites, no effect of weeds on *O. nubilalis* was observed (i.e. neutral effect). This does not agree or disagree with Pavuk and Stinner (amelioration effect) or Weber et al (exacerbation effect). Dicotyledonous weeds could have attracted fewer natural enemies of *O. nubilalis* than monocotyledonous weeds. There was, however, no correlation between the weeds and *O. nubilalis* (Table 10). Dicotyledonous weeds would favour the increase of corn damage done by *O. nubilalis* more than monocotyledonous weeds (Weber et al, 1990). Dicotyledonous weeds could also contribute to an increase of the incidence of natural enemies of pests in corn fields, and thus could influence *O. nubilalis* (Pavuk and Stinner, 1991).

Intercrops- In 1993, in L'As., the infestation was lower in the *Lupinus* sp-corn polyculture treatment than in the weedy control treatment (monocropped corn), but was not different than in the weeded control treatments. *Lupinus* sp. could have been less attractive than certain weeds in the weedy control treatment, and more attractive than corn. In 1993 (in St.A.) nor in 1994 (at both sites), the result was repeated.

In 1993, in L'Assomption, the infestation of corn was lower in the *S. cereale*-corn polyculture treatment than in the chemically weeded control treatment (monocropped corn). *S. cereale* could have acted as a trap crop for *O. nubilalis* and reduced the incidence of *O. nubilalis* on corn. However, in 1994, in L'As., the infestation was higher in the *S. cereale*-corn polyculture treatment than in the manually weeded control treatment.

In St.A., in 1994, the infestation was higher in the *T. pratense-L. multiflorum*-corn polyculture treatment than in the manually weeded control treatment (monocropped corn). This contradicts the result obtained by Lambert et al (1987) in Ontario. This contradiction could be due, in part, to the differences in the intercrop sowing dates used. In this study, *T. pratense* was sown 17 days after the corn emergence whereas in the Lambert et al study, it was sown at 10 days. The sowing date is important in the control of *O. nubilalis* (Lambert et al, 1987).

Their study did not use the second intercrop species *L. multiflorum* which this study did. The comparison between the two studies is therefore only partially feasible. If *L. multiflorum* did not have a neutral effect on *O. nubilalis*, attracting or repelling the insect or its natural enemies, there could have been a contradiction between the studies.

The attraction of an intercrop (e.g. *T. pratense*, *L. multiflorum*) to an insect also varies with the growth stage, the presence or absence of other plants (e.g. weeds) in the vicinity and the use of cultural practices that affect the growth of plants (Kennedy and Margolies, 1985). Lambert et al used a lower corn sowing density. Plant density can influence the colonization rate of *O. nubilalis* (Pimentel, 1961). Certain insects lay more eggs at high densities (e.g., Chiang and Perron, 1980). However, the *T. pratense* sowing rate was the same for both studies (i.e., 10 kg/ha). Moreover, in 1993, in L'As., the results agree with Lambert et al. The infestation was lower in the polyculture.

The *G. max*-corn polyculture treatment showed no effect on the infestation of corn by *O. nubilalis* (i.e. neutral effect). This agrees with Tonhasca and Stinner (1991). Martin et al (1989), however, observed an amelioration effect of the polyculture in Ohio. The infestation of corn by *O. nubilalis* was lower in the polyculture. However, their result varied with the years.

Mechanical Weeding- No effect of mechanical weeders was observed on the infestation of corn by *O. nubilalis*, although tillage may influence *O. nubilalis*. In Ohio populations of neuropteran predators of the *O. nubilalis* eggs decreased following tillage (done prior to corn sowing) (Andow, 1992). There was an increase of the *O. nubilalis* populations following tillage (done prior to corn sowing) (Tonhasca and Stinner, 1991). The result of this study may be due to the efficacy of the weeders at controlling weeds. The weeds could have been responsible for any effect observed.

5.1.4 The Effect on *Pseudaletia unipuncta*

In 1994, no effect of weeds, intercrops or mechanical weeding on *Pseudaletia unipuncta* was observed. This is not surprising. *P. unipuncta* was rarely recorded (Table 9), and normally, *P. unipuncta* populations are small and attract little attention (Guppy, 1961). Severe and widespread outbreaks tend to occur at intervals of 5 to 20 years (Guppy, 1961).

6. CONCLUSIONS

No effect on the infestation of corn by *D. longicornis* or *P. unipuncta* was observed. *P. unipuncta* was, however, rarely observed in the fields.

The results showed that infestations of corn by *Diabrotica longicornis*, *Lygus lineolaris*, and *Ostrinia nubilalis* can vary according to the site and the year. These variations could have been due, in part, to environmental factors (e.g., wind, precipitation, temperature, ...).

Also, the variations between two sites could have been due to differences in adventitious flora and/or fauna. In 1994, the adventitious flora was dicotyledonous in the majority in L'Assomption (L'As.) and monocotyledonous in Sainte-Anne-de-Bellevue (St.A.).

Although the results varied, they showed that the infestation of corn by *L. lineolaris* and *O. nubilalis* was influenced by the weed control method used (i.e. mechanical, polycultural or conventional).

In 1994, in L'As., the infestation of corn by *L. lineolaris* was lower in most of the polycultures (i.e. *Glycine max*-corn, *T. pratense-L. multiflorum*-corn, and *S. cereale*-corn) than in the manually weeded monocropped corn. In St.A., in 1994, the infestation by *L. lineolaris* was higher in the *T. pratense-L. multiflorum*-corn polyculture than in weeded monocropped corn. The infestation by *L. lineolaris* was higher in the Danish tines cultivator treatment than in chemically weeded monocropped corn.

In 1993, in L'As., the infestation by *O. nubilalis* was lower in the *Secale cereale*-corn and *Trifolium pratense-Lolium multiflorum*-corn polycultures than in weeded monocropped corn. In 1994, in St.A., the opposite was observed for *S. cereale*. In 1994, in St.A., the infestation by *O. nubilalis* was higher in the *Trifolium pratense-L. multiflorum*-corn polyculture.

Strictly from an entomological point of view, only the following weed control methods are acceptable since they did not show an infestation of corn by *D. longicornis*, *L. lineolaris*, and *O. nubilalis*, higher than chemically or manually weeded monocropped corn: a) the use of the intercrops *G. max* or *Lupinus* sp.; or b) the use of the rigid tines cultivator or the ridge cultivator. Note that maybe the Danish tines cultivator is also acceptable, although it showed a high infestation by *L. lineolaris*, if the pest status of *L. lineolaris* in corn fields is low or inexistent. *L. lineolaris* could be more a predator than a corn herbivore.

Considering the entomology and the yield quantity aspects, only the use of the intercrop *G. max* could be acceptable since it did not significantly decrease grain corn yields, compared to chemically weeded corn fields. However, this does not consider the profitability of using intercrops.

For instance, will the obtained corn yields be higher in polyculture than in monocropped corn? The "LER" ("Land Equivalent Ratio" or the relative area in monoculture required to produce the yield that would be obtained in polyculture) (Mead and Willey, 1980) indexes were not calculated because the intercrop yields were missing in the data. These indexes could allow the comparisons between the various polycultures studied (Mead and Willey, 1980).

It is necessary to extend this study for more than two years and on more than two sites prior to making recommendations since the effects can vary according to site and season.

Finally, in this study, attention was given to the incidence of only four herbivorous insects of corn. Other aspects should be studied in future to allow a better understanding of the observed effects.

For instance, the incidence of herbivorous insects should also be studied on the intercrops and weeds to determine specific relations.

The incidence of other organisms like nematodes, parasitic or predatory insects, and spiders, ..., should be studied for the determination of specific relations between these other organisms and the herbivorous insects of corn.

Studies in the laboratory, in greenhouses or in cages would be helpful to provide evidence of existing relations between corn herbivorous insects and weeds or intercrops.

A preference order should be determined within host plants (and stages) for each corn insect. This could be done with the method used by Chang et al (1986) for *Spodoptera frugiperda* (Lepidoptera) or the method used by Levine (1985) for *Papaipema nebris* (Lepidoptera).

Finally, the existing relations between each corn insect should be defined, especially the ones between *L. lineolaris* and the others.

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8. TABLES

Table 1. Treatments studied in 1993 and 1994 in L'Assomption (L'As.) and Sainte-Anne-de-Bellevue (St.A.)

Treatment Type	Treatment
Polycultures of corn (*Zea mays*)	Corn (Pioneer 3921; 2700 UTM) intercropped with ... 1. *Glycine max* L. Merr. cv Maple glenn[1] 2. *Lupinus* sp. cv Ultra[1] 3. *Trifolium pratense* L. cv Khun [1] and *Lolium multiflorum* Lam. cv Marshall [2] 4. *Secale cereale* L. cv Prima[2]
Mechanically weeded monocultures	Corn (Pioneer 3921; 2700 UTM) weeded at 0, 2 and 4 weeks in post-emergence with ... 5. a rigid tines cultivator 6. a Danish tines cultivator 7. a ridge cultivator
Controls	Corn (Pioneer 3921; 2700 UTM) ... 8. naturally weedy 9. manually weeded (weekly from June to September) 10. chemically weeded (a pre-emergence application of 1 kg/ha of atrazine and 1.9 kg/ha of metolachlor; a post-emergence brush application of glyphosate on *Elytrigia repens* in St.A. in 1994)

[1] Leguminosae. [2] Gramineae.

Table 2. Fertilization plan used per treatment and year for both sites

Treatment Type	Treatment	Fertilization at[1] (kg N/ha:kg P_2O_5/ha:kg K_2O/ha) 1993	1994
Corn polycultures	*G. max* and *Lupinus* sp.	180:100:140	180:100:140
	T. pratense-L. multiflorum and *S. cereale*	180:100:120	"
Mechanically weeded corn monocultures	All	180:80:140	"
Controls	All	180:100:140 (Experiment A) 180:100:120 (Experiment B) 100:80:140 (Experiment C)	"

[1] In 1994, fertilization was done according to AFEQ (1990) for grain corn. In 1993, fertilization was done according to the plans of the other graduate students who undertook the experiments A, B and C.

Table 3. Cultural pattern used for sown plant species at both sites

Species	Sowing Density (/ha)	Number of rows per plot or between two corn rows	Sowing Method	Sowing Date (day/month)			
				1993		1994	
				L'As	St.A	L'As	St.A
Corn	80 000 grains	4	With a 4 row precision sower (e.g., John Deere Max Emergence 7200®)	11/5	13/5	13/5	18/5
G. max and *Lupinus* sp.	250 000 plants	2	Manually, after two rigid tines cultivations[1]	8/6	11/6	8/6	16/6
T. pratense	10 kg	0 (broadcast)	"	"	"	"	"
L. multiflorum	8 kg	"	"	"	"	"	"
S. cereale	110 kg	"	Manually, after two rigid tines cultivations[1, 2]	"	"	"	"

[1] One and two weeks after corn sowing.
[2] In 1994, in St.A., one Danish tines cultivation was done also prior to the *S. cereale* sowing to loosen the soil.

Table 4. Experimental Design in 1993 at both sites

Treatment	Number of experiments observed		Number of repetitions observed by experiment					
	L'As.	St.A.	L'As.			St.A.		
			A	B	C	A	B	C
G. max	1	1	-	-	4	-	-	4
Lupinus sp.	1	1	-	-	4	-	-	4
T. pratense-L. multiflorum	1	1	-	3	-	-	4	-
S. cereale	1	1	-	3	-	-	4	-
Rigid tines cultivator	1	1	3	-	-	3	-	-
Danish tines cultivator	1	1	3	-	-	3	-	-
Ridge cultivator	1	1	3	-	-	3	-	-
Weedy control	3	3	3	3	4	3	4	4
Manually weeded control	3	3	3	3	4	3	4	4
Chemically weeded control	2	2	3	3	-	3	4	-

Table 5. Effects of treatments on grain corn yields

Treatment	Dried grain yield (t/ha) [1] by experiment							
	L'As.				St.A.			
	1993			1994	1993			1994
	A	B	C	-	A	B	C	-
G. max	-	-	8.2	6.8 abc	-	-	7.9 a	5.2 b
Lupinus sp.	-	-	8.5	6.4 bc			7.4 a	4.6 bc
T. pratense-L. multiflorum	-	7.4	-	7.1 abc	-	7.6 ab	-	4.7 bc
S. cereale	-	6.9	-	7.1 abc	-	7.1 b	-	5.3 b
Rigid tines cultivator	6.8 a	-	-	6.1 c	7.0 ab	-	-	4.9 b
Danish tines cultivator	7.9	-	-	6.9 abc	6.5 b	-	-	4.1 bc
Ridge cultivator	7.8	-	-	6.4 bc	7.0 ab	-	-	4.4 bc
Weedy control	7.3	-	7.2	5.7 bc	4.4 c	5.6 c	3.2 b	1.9 c
Manually weeded control	7.9	-	7.3	7.2 ab	7.8 ab	8.5 ab	8.2 a	5.3 a
Chemically weeded control	8.8	-	-	7.7 a	8.0 a	9.0 a	-	5.6 a

[1] Means followed by the same letter are not significantly different ($\alpha = 0.05$; Duncan's multiple-range test).

Table 6. Effects of weeds, intercrops or mechanical weeders on the infestation of corn by *D. longicornis* (NCR)

Treatment	Infestation by the NCR (units of infestation/100 corn plants)[1]					
	L'As.			Sainte-Anne-de-Bellevue		
	1/Jul/94	7/Aug/94	11/Sep/94	1/Jul/94	7/Aug/94	11/Sep/94
G. max	0.0	0.0	0.0	0.0	0.0 a	0.0
Lupinus sp.	0.0	0.0	0.0	0.0	0.0 a	0.0
T. pratense-L. multiflorum	0.0	0.0	0.0	0.0	7.5 a	2.5
S. cereale	0.0	7.5	0.0	0.0	2.5 a	2.5
Rigid tines cultivator	0.0	0.0	0.0	0.0	12.5 a	2.5
Danish tines cultivator	0.0	0.0	0.0	0.0	7.5 a	0.0
Ridge cultivator	0.0	0.0	0.0	0.0	10.0 a	5.0
Weedy control	0.0	0.0	0.0	0.0	35.0 a	0.0
Manually weeded control	0.0	0.0	0.0	0.0	5.0 b	0.0
Chemically weeded control	0.0	0.0	0.0	0.0	2.5 b	0.0

[1] Means followed by the same letter are not significantly different ($\alpha = 0.05$; Duncan's multiple-range test).

Table 7. Effects of weeds, intercrops or mechanical weeders on the infestation of corn by *L. lineolaris* (TPB)

Treatment	Infestation by the TPB (units of infestation/100 corn plants)[1]			
	L'As.			St.A.
	8/Jul/94	20/Jul/94	27/Aug/94	27/Aug/94
G. max	12.5 abc	5.0 ab	2.5 b	0.0 b
Lupinus sp.	2.5 bc	2.5 ab	12.5 ab	0.0 b
T. pratense-L. multiflorum	7.5 abc	2.5 ab	2.5 b	15.0 a
S. cereale	12.5 abc	5.0 ab	0.0 b	0.0 b
Rigid tines cultivator	5.0 abc	0.0 b	5.0 ab	0.0 b
Danish tines cultivator	17.5 a	15.0 a	12.5 ab	0.0 b
Ridge cultivator	10.0 abc	2.5 ab	7.5 ab	0.0 b
Weedy control	15.0 ab	2.5 ab	2.5 b	2.5 b
Manually weeded control	0.0 c	2.5 ab	25.0 a	2.5 b
Chemically weeded control	2.5 bc	0.0 b	12.5 ab	0.0 b

[1] Means followed by the same letter are not significantly different ($\alpha = 0.05$; Duncan's multiple-range test).

Table 8. Effects of weeds, cultivated plant species (intercrops) or mechanical weeders on the infestation of corn by *O. nubilalis* (ECB)

Treatment	Infestation by the ECB by experiment (units of infestation/100 corn plants)[1]				
	L'As.			St.A.	
	24/Sep/93		15/Oct/94	25/Sep/93	11/Sep/94
	B	C	-	C	-
G. max	-	47.5 ab	85.0 ab	105.0 ab	50.0 ab
Lupinus sp.	-	35.0 b	75.0 ab	130.00 ab	45.0 ab
T. pratense-L. multiflorum	10.0 a	-	125.0 ab	-	72.5 a
S. cereale	43.3 ab	-	135.0 a	-	45.0 ab
Rigid tines cultivator	-	-	65.0 ab	-	57.5 ab
Danish tines cultivator	-	-	97.5 ab	-	65.0 ab
Ridge cultivator	-	-	72.5 ab	-	45.0 ab
Weedy control	36.7 a	72.5 a	72.5 ab	152.5 a	27.5 ab
Manually weeded control	70.0 b	35.0 b	50.0 b	62.5 b	17.5 b
Chemically weeded control	86.7 c	-	62.5 ab	-	57.5 ab

[1] Means followed by the same letter are not significantly different ($\alpha = 0.05$; Duncan's multiple-range test).

Table 9. Effects of weeds, intercrops or mechanical weeders on the infestation of corn by *P. unipuncta* (CAW)

Treatment	Infestation by the CAW (units of infestation/100 corn plants)[1]					
	L'As.			St.A.		
	1/Jul/94	7/Aug/94	11/Sep/94	1/Jul/94	7/Aug/94	11/Sep/94
G. max	0.0	0.0	0.0	0.0	0.0	0.0
Lupinus sp.	0.0	0.0	0.0	0.0	0.0	0.0
T. pratense-L. multiflorum	0.0	0.0	0.0	0.0	0.0	0.0
S. cereale	0.0	0.0	0.0	0.0	0.0	0.0
Rigid tines cultivator	5.0	0.0	0.0	0.0	0.0	0.0
Danish tines cultivator	0.0	0.0	0.0	0.0	0.0	0.0
Ridge cultivator	0.0	0.0	0.0	0.0	0.0	0.0
Weedy control	0.0	0.0	0.0	0.0	0.0	0.0
Manually weeded control	0.0	0.0	0.0	0.0	0.0	0.0
Chemically weeded control	0.0	0.0	0.0	0.0	0.0	0.0

[1] Means followed by the same letter are not significantly different (alpha= 0.05; Duncan's multiple-range test).

Table 10. Correlation between the insect populations and the incidence of weeds ($\alpha = 0.05$)

Insect Population (units of infestation/ 100 corn plants)	Weeds (% plot area covered with)	L'As.		St.A.	
		r	n	r	n
Diabrotica longicornis	Monocotyledonous	0	32	0.4	32
	Dicotyledonous	0	32	0.4	32
	All	0	40	0.4	40
Lygus lineolaris	Monocotyledonous	0	32	0.3	32
	Dicotyledonous	0.2	32	0.2	32
	All	0.2	40	0.1	40
Ostrinia nubilalis	Monocotyledonous	0	32	0.4	32
	Dicotyledonous	0.2	32	0	32
	All	0.2	40	0.4	40
Pseudaletia unipuncta	Monocotyledonous	0	32	0	32
	Dicotyledonous	0	32	0	32
	All	0	40	0	40

9. FIGURES

Figure 1. a) Rigid tines cultivator used.

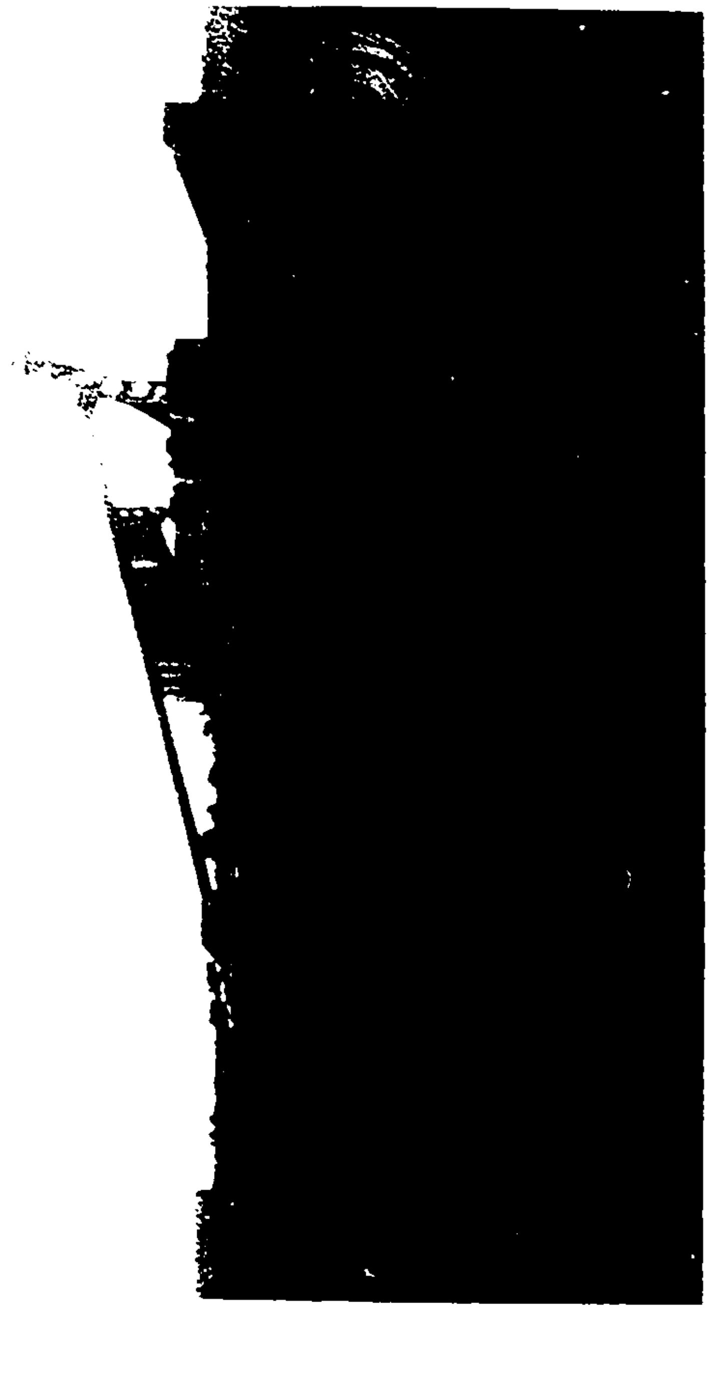


Figure 1. b) Danish tines cultivator used.

Figure 1. c) Ridge cultivator used.

Figure 2. Spatial arrangement of treatments in 1993.

Experiment A (Treatments 5, 6, 7, 8, 9 and 10):

3 m

10 m	5	6	7	8	9	10	Repetition 1
	8	5	10	9	8	6	Repetition 2
	10	7	9	8	6	5	Repetition 3

Experiment B (Treatments 3, 4, 8, 9 and 10):

3 m

7 m	3	4	8	9	10	Repetition 1
	10	8	9	4	3	Repetition 2
	4	10	3	8	9	Repetition 3

Experiment C (Treatments 1, 2, 8 and 9):

3 m

7 m	1	2	8	9	Repetition 1
	8	9	2	1	Repetition 2
	9	8	1	2	Repetition 3
	2	1	9	8	Repetition 4

Figure 3. a) Incidence of monocotyledonous and dicotyledonous weeds by treatment in L'As. on August 27, 1994. Treatments: 1 = *G. max*, 2 = *Lupinus* sp., 3 = *T. pratense-L. multiflorum*, 4 = *S. cereale*, 5 = rigid tines cultivator, 6 = Danish tines cultivator, 7 = ridge cultivator, 8 = weedy control, 9 = manually weeded control, 10 = chemically weeded control.

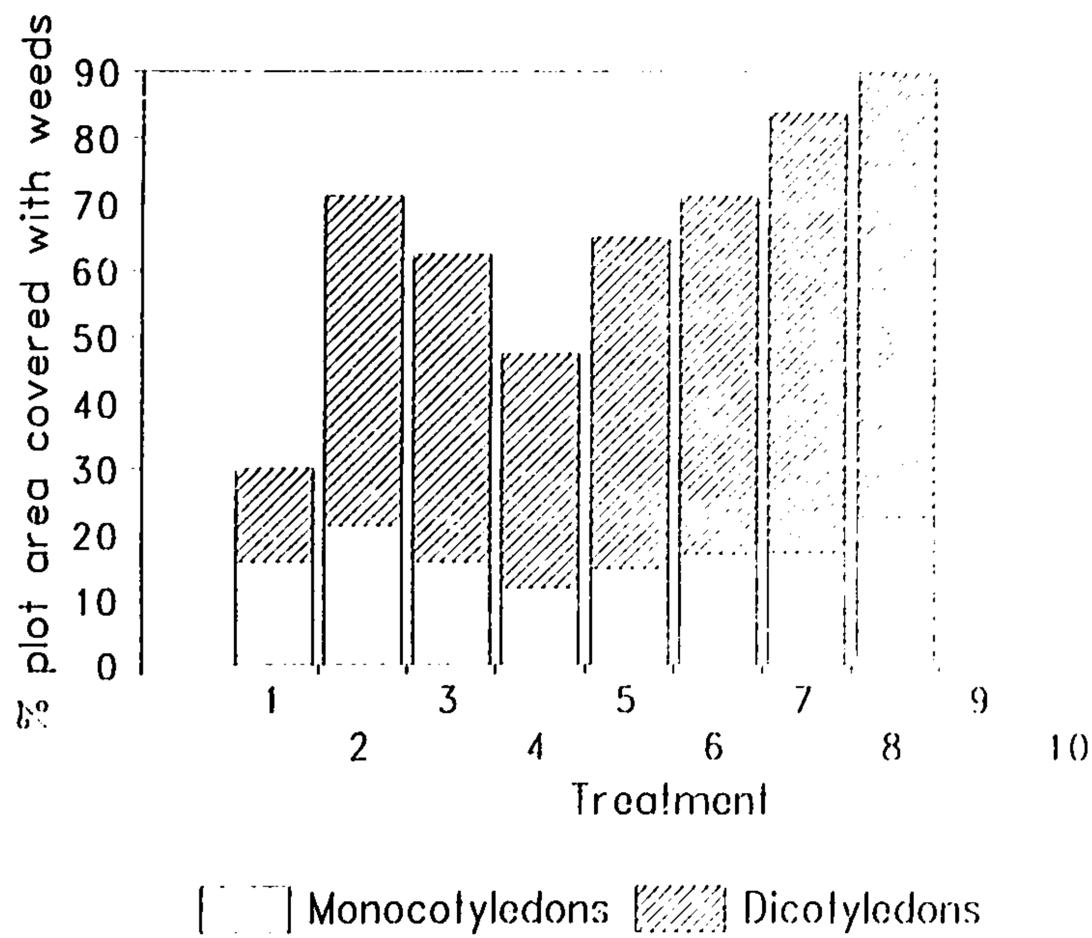

% plot area covered with weeds
0
10
20
30
40
50
60
70
80
90
1
2
3
4
5
6
7
8
9
10
Treatment
Monocotyledons
Dicotyledons

Figure 3. b) Incidence of monocotyledonous and dicotyledonous weeds by treatment in St.A. on August 27, 1994. Treatments: 1 = *G. max*, 2 = *Lupinus* sp., 3 = *T. pratense-L. multiflorum*, 4 = *S. cereale*, 5 = rigid tines cultivator, 6 = Danish tines cultivator, 7 = ridge cultivator, 8 = weedy control, 9 = manually weeded control, 10 = chemically weeded control.

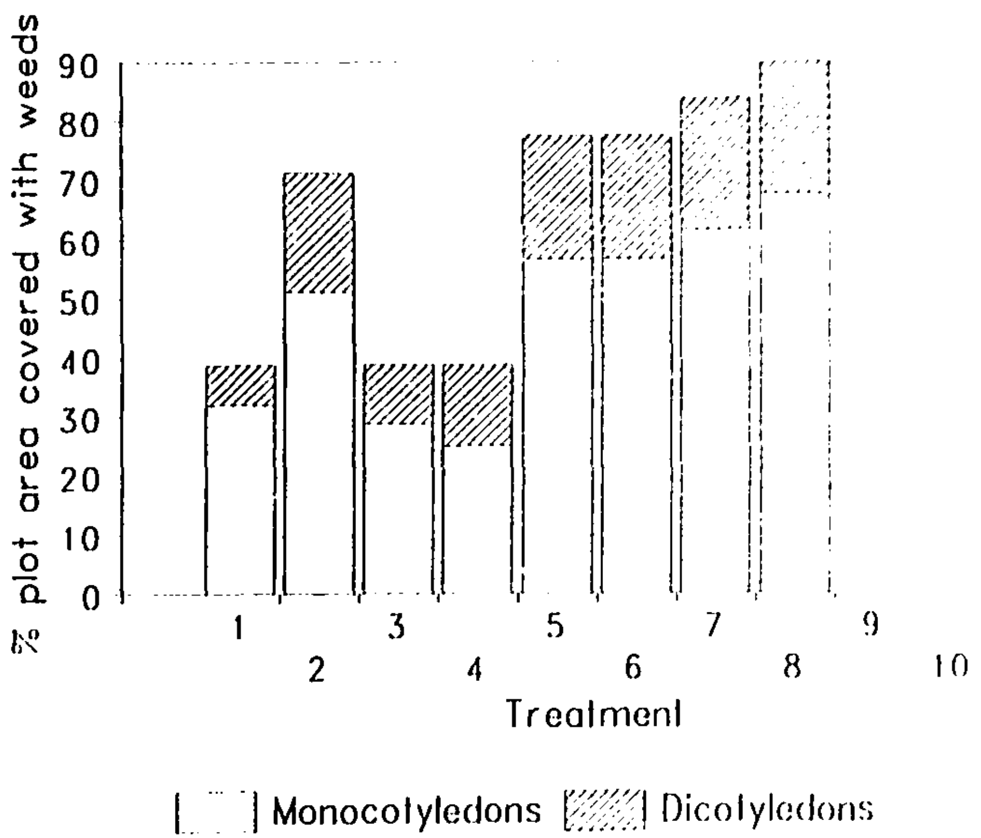
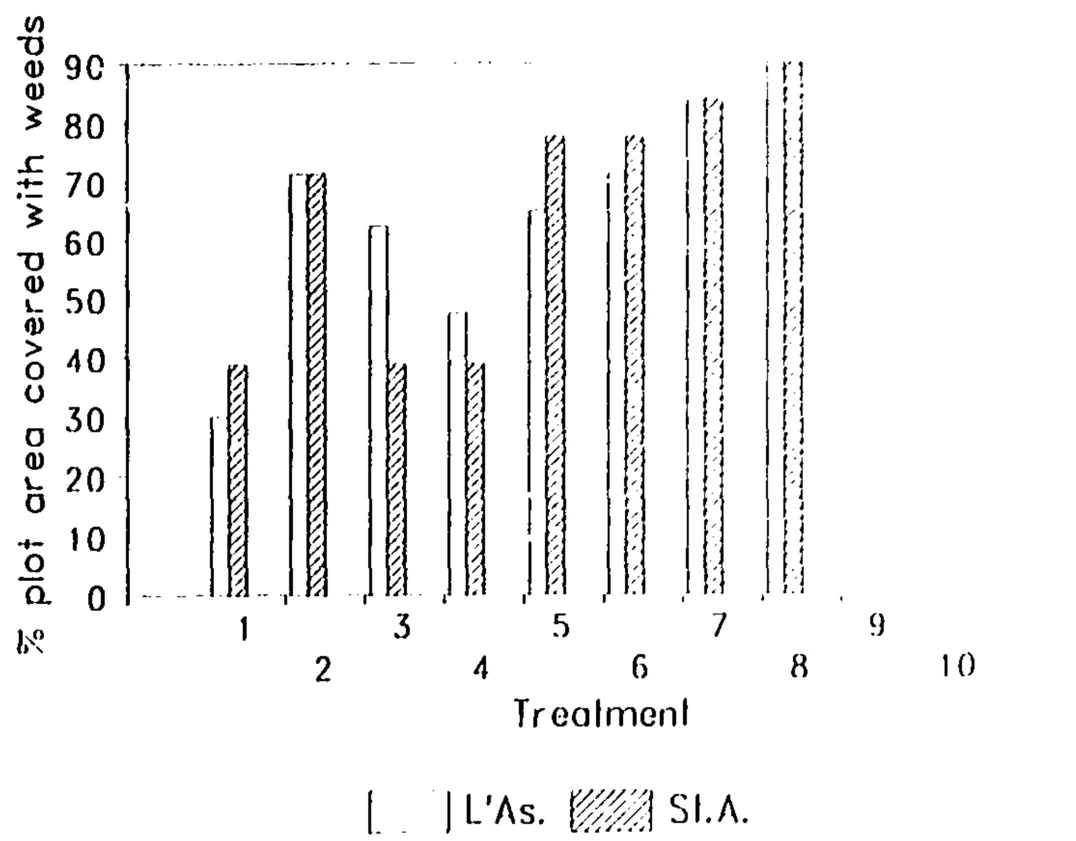

% plot area covered with weeds
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Treatment
Monocotyledons
Dicotyledons

Figure 4. Total incidence of weeds by treatment on August 27, 1994. Treatments: 1 = *G. max*, 2 = *Lupinus* sp., 3 = *T. pratense-L. multiflorum*, 4 = *S. cereale*, 5 = rigid tines cultivator, 6 = Danish tines cultivator, 7 = ridge cultivator, 8 = weedy control, 9 = manually weeded control, 10 = chemically weeded control.



% plot area covered with weeds
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Treatment
L'As.
Sl.A.