EFFICACY AND ECONOMICS OF YELLOW NUTSEDGE (*Cyperus esculentus* L.) MANAGEMENT SYSTEMS

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YELLOW NUTSEDGE (*Cyperus esculentus* L.) MANAGEMENT SYSTEMS

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RESUME

M.Sc. MARYSE LEBLANC Plant Science

EFFICACITE ET RENTABILITE DE DIFFERENTS PROGRAMMES DE REGIE CONTRE LE SOUCHET COMESTIBLE (*CYPERUS ESCULENTUS* L.)

La répression du souchet comestible a été évaluée dans neuf régies culturales différentes à l'intérieur de deux expériences en champs, une initiée en 1987 et l'autre en 1988. Les systèmes culturaux étaient les suivants: maïs + atrazine + EPTC/dichlormid, maïs + atrazine + métolachlore, maïs + atrazine + bentazone, maïs + EPTC/dichlormid intercallé de trèfle rouge enfoui à l'automne ou récolté l'année suivante, luzerne + EPTC, soya + métolachlore + métribuzine, sorgho utilisé comme engrais vert suivi du blé d'automne et orge de printemps + diclofop-méthyl + bromoxynil. Le souchet en peuplement pur ou sa répression totale constituaient les deux témoins. Suite à deux saisons de croissance dans la première expérience, les populations de tubercules ont diminué de 40 à 92%. Aucune différence significative a été notée entre les systèmes culturaux à l'exception de la luzerne qui avait un nombre de tubercules significativement plus élevé que dans les systèmes de maïs, de soya et d'orge. La population de souchet a été réduite à 9% de la population originale dans le témoin désherbé tandis qu'elle a triplé dans le témoin enherbé. Suite à une première saison de croissance dans la partie traitée de la deuxième expérience, seul le maïs intercallé de trèfle rouge a réduit de façon significative la population de souchet de 17 %. Dans la partie non traitée, le nombre de tubercules a augmenté de 41 à 180%. La production de tubercules était en fonction de la densité et la biomasse aérienne des tiges de souchet, de feuilles larges et de graminés. En réunissant toutes les données provenant des deux expériences, une relation significative a été trouvée entre la densité de tiges de souchet et sa production de tubercules. Cette fonction mathématique pourrait servir d'outil dans l'évaluation d'un programme de répression contre le souchet comestible. Du coté économique, la monoculture du maïs était la plus rentable à court terme

alors que la luzerne une fois établie était aussi avantageuse. L'orge était le système cultural le moins économique. Dans la partie non traitée de la deuxième expérience, seul le maïs intercallé de trèfle rouge pouvait être rentable. Malgré que tous les systèmes de régie culturale évalués n'étaient pas tous économiquement rentables, ils pourraient être utilisés dans un programme de rotation.

ABSTRACT

M.Sc. MARYSE LEBLANC Plant Science

EFFICACY AND ECONOMICS OF YELLOW NUTSEDGE (*CYPERUS ESCULENTUS* L.) MANAGEMENT SYSTEMS

Two field experiments were conducted to evaluate nine different cropping systems along with two control treatments. One experiment was initiated in 1987 and the other in 1988. The cropping systems were: corn + atrazine + EPTC/dichlormid; corn + atrazine + metolachlor; corn + atrazine + bentazon; corn + EPTC/dichlormid intercropped with red clover as green manure or managed as forage crop in the following year; alfalfa + EPTC; soybean + metolachlor + metribuzin; sorghum as green manure followed by winter wheat; and spring barley + diclofop-methyl + bromoxynil. The two control treatments were yellow nutsedge growing in a pure stand and complete yellow nutsedge control (bare ground). After two growing seasons in experiment #1, the tuber population had decreased in all cropping systems. The reduction ranged between 40 and 92 % of the initial population. There were no significant differences between cropping systems except for alfalfa which had a significantly greater tuber population than the corn, soybean and barley systems. Yellow nutsedge was reduced to 9% of the initial population under perfect control while it tripled in the pure stand. After the first growing season in the second experiment, only corn intercropped with red clover significantly reduced yellow nutsedge population by 17%. When the systems were not treated with herbicides, the yellow nutsedge population increased between 41 to 180% in all cropping systems. There was a significant relation between yellow nutsedge, broadleaf weed and grass densities and yellow nutsedge tuber production but it differed from year to year. By pooling data from both years and experiments, yellow nutsedge shoot densities were related to the number of tubers produced. This mathematical function could provide a tool to assess the fall tuber production in the field and to plan nutsedge control programs. Although all cropping systems

were equally effective in reducing tuber population within two years, economic aspects differed. Corn was the most profitable cropping system. However, alfalfa in its second year was as profitable as corn. The least economically advantageous cropping system was barley. Only corn intercropped with red clover was profitable when no chemical and mechanical controls were used. Despite the fact that some systems were less profitable, all of the systems evaluated can be used alternatively in a crop rotation.

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INTRODUCTION

Yellow nutsedge (*Cyperus esculentus* L.) is a perennial that is known as one of the worst weed pests. Holm *et al.* (1977) listed yellow nutsedge as the sixteenth world's worst weed. It infests crop production areas in tropical and temperate climates, causing severe losses in crop yield (Bendixen and Nandihalli, 1987). Wider distribution of this weed has been associated both with the use of herbicides that are more effective against annual weeds and with the shifts in farming practices from hand hoeing to mechanization (Hauzer, 1968; Mulligan and Junkins, 1976). In Canada, this agressive, noxious weed is persistent in many crops. It causes yield reductions and cannot be eradicated using present methods (Mulligan and Junkins, 1976). In Québec, Doyon and Bouchard (1981) reported that this indigenous plant was responsible for severe field infestations.

1.1 Description

The literature abounds with reports on description, morphology, and biology of yellow nutsedge (e.g. Bendixen, 1973; Jansen, 1971; Mulligan and Junkins, 1976; Stoller, 1981; Stoller *et al.*, 1972; Tumbleson and Kommedahl, 1961; Wills, 1987; Wills *et al.*, 1980). It is a member of the Cyperaceae family and belongs to the *Cyperus* genus. *Cyperus esculentus* alias yellow nutsedge known as souchet comestible in French is characterized by 3-ranked leaves with one-third phyllotaxy and the leaves have closed sheaths around the triangular fascicle. The rachis is terminated by a yellowish-brown umbel which consists of several erect short rays and two to nine strongly ascending longer rays. The umbel is surrounded at the same level with 3 to 9 involucral leaves which are considerably longer than the longest rays of the umbel. The inflorescence on each stalk consists of simple to compound spikelets pinnately arranged along an elongated axis. The spikelets are strongly flattened, golden-brown, about 0.5 to 3 cm long and 1.5 to 3 mm wide. Individual seeds are borne as achenes which are yellowish-brown, three-angled and 1.2 to 1.5 mm long. Justice and Whitehead (1946) found that yellow nutsedge may produce 2000 seeds per inflorescence with an average germination of 75%. Hill *et al.* (1963) obtained 605 million seeds/ha or 2500 seeds per inflorescence with an average germination of 46%. Thullen and Keeley (1979) reported that yellow nutsedge produced an average of 209 to 1137 seeds per inflorescence where 78% of the seed germinated. Although the seeds are viable, they are insignificant in propagating these species in most cultivated areas primarily due to inadequate seedling vigor (Stoller and Sweet, 1987; Thullen and Keeley, 1979).

The vegetative propagation of yellow nutsedge is characterized by basal bulbs, rhizomes and tubers. In the spring, when the soil temperature increases, some tubers are stimulated to germinate. In Québec, shoot emergence begins in May. Emergence is delayed as the tuber depth in the soil increase. When a tuber germinates, one or more slender rhizomes elongate vertically from the buds at the terminal end of the tuber. The rhizomes express a negative geotropic response upon germination. As the rhizome reaches the soil surface, the rhizome tip encounters sunlight and diurnal temperature fluctuations which are the principal factors in stimulating basal bulb formation (Stoller and Woolley, 1983). The basal bulb region contains meristems for roots, secondary rhizomes, leaves and the flower stalk. Later in the season, rhizomes differentiate into tubers instead of basal bulbs (Jansen, 1971). In Québec, the production of tubers usually begins at the end of June when daylength is maximum. The differentiation into a basal bulb or a tuber is regulated by several factors of which photoperiod is considered to be the most important. However, environmental conditions, interference from other plants and management techniques also affect differentiation. Short photoperiod is reported to stimulate tuber production and long photoperiod to stimulate basal bulb formation but some biotypes are reported to be photoperiod insensitive (Matthiesen, 1976; Mulligan and Junkins, 1976; Stoller, 1981). Of the various vegetative parts of yellow nutsedge, only tubers overwinter in the soil. Some of them remain dormant and viable for at least four years (Stoller and Wax, 1973). This long dormancy contributes to perpetuating field infestations. Tubers are found to a depth of 46 cm in soil but more than 80% of the tubers occur in the upper 15 cm (Stoller and Sweet, 1987). The tubers are white when initiated but they darken as they mature. There are between 4 to 7 buds on a tuber. Because of the presence of numerous buds, a tuber can germinate several times, as well as produce several shoots at one time. The first shoot consumes most of the food reserves, leaving subsequent shoots with reduced vigor (Stoller *et al.*, 1972; Thullen and Keeley, 1975).

1.2 Distribution

In North America, yellow nutsedge is found in Nova Scotia, New-Brunswick, Québec, Ontario, Manitoba, Alaska, and all of the contiguous United States (Bendixen and Nandihalli, 1987; Wills, 1987). Geographic distribution of yellow nutsedge can be related to variation in climatic factors. Stoller and Wax (1973) found that 50% of yellow nutsedge tubers were killed at -6.5°C. This tuber mortality due to cold winter temperatures may account for the limited range of *Cyperus esculentus* in Canada (Mulligan and Junkins, 1976).

1.3 Habitat

Yellow nutsedge occurs in a wide range of soil types: sand, sandy-loam, sandy-gravel, loam, clay-loam, clay and muck. In its natural habitat, the soil is always flooded in the spring whereas in cultivated fields, it often grows in drier soil (Mulligan and Junkins, 1976).

1.4 Detrimental effects

Yellow nutsedge is a poor competitor. It proliferates when cultural practices reduce competition from crops and other weeds. Either frequent cultivations or repeated herbicide applications remove competing vegetation, thereby allowing space for nutsedge development (Stoller, 1981; William and Bendixen, 1987). Keeley (1987) reported on the interference of nutsedge with crops and reported yield losses in 17 different crops. Stoller *et al.* (1979) reported an 8% corn yield reduction for every 100 shoots/m^2. Keeley *et al.* (1983) found that 40 shoots/m^2 reduced cotton yield by 12 to 36%. Soybean yield was reduced by 29% when 128 shoot/m^2 were present (Wax *et al.*, 1972). Yellow nutsedge competes for light, nutrients and soil moisture (Keeley, 1987) and is recognized as having allelopathic potentiel which affects interaction between different plant species (Drost and Doll, 1980).

1.5 Control

1.5.1 Chemical

No single measure adequately supresses yellow nutsedge during the growing season. However, intensive use of costly herbicides is the primary approach used to control this weed. Pereira *et al.* (1987) has summarized nutsedge response to herbicides which were grouped by their mode of action within plants. Among these herbicides, only those available in Québec will be discussed (C.P.V.Q., 1989). Atrazine, which is known to interfere with photosynthesis, does not inhibit sprouting of tubers, but kills shoots after emergence. In addition to controlling vegetative growth, the photosynthetic inhibitor kills tubers by rapidly exhausting the food reserves of the storage organs (Keeley and Thullen, 1974). However, inconsistent control of yellow nutsedge with atrazine may be due to differences in nutsedge biotypes and size of tubers. More consistent control has been achieved with split applications of soil incorporated and directed postemergence treatments of atrazine [6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine] along with combinations of herbicides such as metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide], EPTC (*S*-ethyl dipropylcarbamothioate), or butylate [*S*-ethyl bis(2-methyl propyl)carbamothioate]. Also the addition of non phytotoxic oil enhances postemergence control with atrazine. Metolachlor alone, can delay tuber sprouting and kills shoots of yellow nutsedge but fails to kill tubers (Keeley and Thullen, 1974; Dixon and Stoller, 1982). However, Cornelius *et al.* (1985) reported that metolachlor fails to prevent yellow nutsedge tuber sprouting. Linuron [*N*'(3,4-dichlorophenyl)-*N*-methoxy-*N*-methyl urea], an other photosynthetic inhibitor, reduces growth of nutsedge but provides only marginal control while bentazon [3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide] selectively controls yellow nutsedge in many crops particularly when applied twice, 5 to 10 days apart, to growing nutsedge plants at the 4- to 6-leaf stage. Evidence suggests that parent tubers are controlled with bentazon although repeated annual treatments are needed (Stoller *et al.*, 1975). Control of nutsedge with paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) is inconsistent. Paraquat quickly desiccates the foliage and stops new tuber production but effects are temporary and new sprouts emerge from parent tubers, or basal bulbs. EPTC and other thiocarbamate herbicides have been used extensively to suppress nutsedge during early growth stages. However, butylate and vernolate [*S*-propyl dipropyl carbamothiate] are less active against yellow nutsedge than EPTC. They readily enter roots but must translocate to the meristematic regions where cell division and expansion is inhibited. Because these herbicides inhibit shoot growth only and do not kill tubers, repeat applications might be required to maintain satisfactory control (Keeley and Thullen, 1974). Diclormid (R-25788) is used as an antidote to the phytotoxicity of the thiocarbamate herbicide EPTC protecting corn from injury by this herbicide. It does not affect the degree of weed control normally obtained with the herbicide (Anderson, 1983). Dichlobenil (2,6-dichlorobenzonitrite) kills germinating seeds and inhibits mitosis within young seedlings and sprouts of nutsedge (Hardcastle and Wilkinson, 1968; Ray and Wilcox, 1969). Of the numerous non-selective postemergence herbicides tested for yellow nutsedge, glyphosate [*N*-(phosphonomethyl)-glycine] has shown the greatest potential in suppressing resprouting of parent tubers (Keeley *et al.*, 1986; Pereira and Crabtree, 1986). Glyphosate decreases tuberization of yellow nutsedge when applied before tuber initiation. Translocation studies suggest that glyphosate accumulates in the meristematic regions of foliage, roots, rhizomes, and tuber in a typical source-to-sink pattern and interferes with amino acid metabolism.

1.5.2 Cultural

High densities of competitive crops cause shading which reduces nutsedge growth and reproduction (Keeley, 1987; Keeley and Thullen, 1978; Bell and Larssen, 1960). Several researchers have observed that corn and/or soybeans compete favorably with nutsedge (Keeley, 1987). In most crops, the first 4 to 8 weeks are the most critical period of weed competition. The time required by crops to produce canopies which reduce growth and reproduction of yellow nutsedge varies but generally is between 4 and 16 weeks (Glaze, 1987). Corn is one of the most rapidly developing canopies which intercept 90% or greater of incident light within 8 to 9 weeks. About 12 weeks were required for 80% of interception light in sorghum. Alfalfa intercepted about 90% within 2 to 3 weeks after each cut (Keeley and Thullen, 1978). Maintaining a continuous stand of alfalfa for 2 or more years, which is common practice, provides considerable shading to yellow nutsedge during the normal growing period of this weed. Soybean canopies are reported to intercept more light than canopies of many other crops (Wax *et al.*, 1972) and therefore, it is very effective in suppressing yellow nutsedge by shading. Yellow nutsedge dry matter and tuber production increases in direct proportion to increases in amounts of available light. As little as 30% shade reduces dry matter and tuber production by 32%, and 80% shade reduces dry matter and tuber production by 80%. However, some tubers are produced even under 94% shading (Bell and Larssen, 1960; Keeley *et al.*, 1983; Stoller, 1981). Although yellow nutsedge will not be eliminated by dense shading, shading can substantially reduce the effort required to prevent propagation of the weed.

Among the crop management practices that enhance the competitive ability of crops against yellow nutsedge, sometimes, early planting will increase the competitiveness of crops. Ghafar and Watson (1983) reported that the optimum seeding date of corn at Macdonald campus location was the third week of May when the highest corn yield was obtained and yellow nutsedge growth was generally reduced. Crop density could also interfere with yellow nutsedge development. The same researchers reported that increasing the corn population from 33,000 to 133,300 plants per hectare in the field reduced yellow nutsedge above-ground biomass, tuber number, tuber weight, tuber size and yellow nutsedge height at the end of growing season, and significantly increased corn yield. Silage corn which is usually planted at a higher density than grain corn could be an alternative crop to help in reducing yellow nutsedge populations. Generally, narrow crop row spacings are more desirable than wide spacings because of the earlier shading of yellow nutsedge (Doll, 1981). Row spacing of 45 to 60 cm for corn and 19 to 38 cm for soybean resulted in superior control of yellow nutsedge at harvest when compared to spacing of 90 and 76 cm, respectively (Chappel and Leasure, 1980; Choudhary, 1981). Planting crops in narrow rows that do not permit cultivation requires total dependence on herbicides. Narrow row seeding is usually the practice used for soybean production in Québec while 75 cm row spacing is used in corn. Cereals which are usually seeded in narrow rows can also reduce yellow nutsedge populations.

1.5.3 Mechanical

Cultivation is a necessary component of a nutsedge control program (Glaze, 1987). The reduction of mechanical cultivation has enhanced nutsedge proliferation. Cultivation, although expensive, reduces soil surface crusting, increases water penetration and aeration, and controls weeds. Cultivation during the growing season plus timely herbicide use will apply enough pressure to maintain nutsedge population at manageable levels (Glaze, 1987; Hauzer, 1962; Hauzer *et al.*, 1974).

Preplant tillage stimulates germination and moves tubers to the surface where they are subjected to desiccation and/or cold injury (Day and Russel, 1955; Glaze, 1987; Thomas, 1967 and 1969; Tumbleson and Kommedahl, 1961; Stoller, 1981; Stoller and Wax, 1973).

1.5.4 Miscellaneous

Crop rotation is usually an excellent approach in reducing yellow nutsedge in cultivated areas as the cropping system affects the long-term tuber population (Hauzer *et al.*, 1974; Keeley and Thullen, 1978; Keeley *et al.*, 1979 and 1983; Stoller *et al.*, 1979). Growing competitive crops in rotation systems should complement other control practices (Hauser, 1968; Keeley and Thullen, 1978). This practice also provides the opportunity to use different herbicides. Corn or soybean rotating with other crops is advisable, since chemical control and competition from these crops will reduce the infestation of yellow nutsedge (Stoller *et al.*, 1979).

The harmful effects of corn monoculture has raised interest in the use of catch crops and intercrops. These techniques prevent erosion, improve the soil's physical properties and prevent wilting because forage plants enormously enhance evapotranspiration (Parent, 1989). Water absorption and soil aeration also improve. The use of legume plants will significantly increase nitrogen levels, especially where manure is unavailable. Catch crops and intercrops are reported to compete little with main crops (Parent, 1989). Red clover is promising because it is better at covering the ground and it provides greater dry matter and nitrogen per hectare than alfalfa (Scott *et al.*, 1987). Red clover can either be kept the following year for hay crop, green manure, green chop or it can be plowed under after harvest.

Despite considerable effort to develop biocontrol agents for yellow nutsedge, that control method is not yet ready for producer use. Phatak *et al.* (1987) listed insects and pathogens which have potentiel to control nutsedges. Research on *Puccinia canaliculata* to control yellow nutsedge has been successful (Phatak *et al.*, 1987).

1.5.5 Integrated nutsedge control

As with most weeds, an integrated yellow nutsedge program involving several control methods should be the most effective (Stoller, 1981; William and Bendixen, 1987). The program should take into account: yield potential, well adapted varieties that resist yellow nutsedge competition, timely and appropriate fertilizer application for maximum crop growth and minimum weed growth. It should also include preplanting seedbed tillage, effective seedbed preparation, optimum plant populations per hectare, including close spacing in the row and close spacing between the rows; and the use of crops that form a canopy for shading early in the growing season to discourage yellow nutsedge growth. Timely and appropriate cultivation, crop rotation, crop diversification, field sanitation, use of biological agents such as insects and pathogens, as well as effective chemical methods should all be employed (Glaze *et al.*, 1984; Miller, 1982).

1.5.6 Economics

Very few studies have been done on the economics of yellow nutsedge control in different cropping systems. In California, Keeley *et al.* (1979) compared four cropping systems and reported that alfalfa treated with EPTC or double cropping barley with corn was most profitable and reduced considerably yellow nutsedge tubers (96%). The same researchers in 1983, analysed six additional cropping systems and reported that the most economical and efficient systems were cotton plus fluridone {1-methyl-3-phenyl-5-[3-(tri-fluoromethyl)phenyl]-4(1*H*)-pyridinone} and cotton plus hoeing. However, production of crops in small research plots may not be typical of large-scale farms. Furthermore, prices fluctuate from year to year. Therefore, choosing the preferable system for the control of yellow nutsedge will depend on the crop production potential of a given farm as well as the price expected for crops.

1.6 Goal and objectives

My research is concerned with the development and evaluation of an integrated weed management system against yellow nutsedge. The program is based on the combination of cultural and chemical weed control methods and relies on understanding nutsedge biology. Data accumulated from the literature and from previous experiments conducted at Macdonald College of McGill University on the biology of yellow nutsedge have been used to assist in the selection of crop management systems that should reduce yellow nutsedge populations in Québec.

The objectives of this study were to evaluate the efficiency of nine different cropping systems in repressing yellow nutsedge at the farm level and to estimate the costs and benefits of each cropping system.

Chapter 2

MATERIALS AND METHODS

Field experiments were conducted in 1987 and 1988 on the Macdonald College Farm of McGill University, at Ste-Anne-de-Bellevue, Quebec (45°26'N, 73°56'W). The soil in the experimental area was a St-Amable sandy loam and tested 3.8% organic matter, a pH of 5.9, and an average of 400 kg/ha of P_2O_5 and 200 kg/ha of K_2O. The site was naturally and relatively uniformly infested with yellow nutsedge. The field was plowed in the fall and harrowed in the spring before the establishment of the experiments. One experiment was initiated in 1987 and replanted in 1988 and a second experiment was initiated in 1988.

2.1 Experimental design

In 1987, the first experiment was established using a randomized complete block design with three replications. Nine different cropping systems and two control treatments were evaluated. The treatments with annual crops were plowed after harvest and replanted with the same crop and in the same plots in 1988.

In 1988, a second experiment (experiment #2) was initiated in an adjacent area in the same field. The same cropping systems and control treatments were evaluated in this second experiment, but the experimental design was a split-plot with the split consisting of using weed control methods or not using weed control against yellow nutsedge. The untreated plots were hand weeded once a week to remove all other weed species in order to have only yellow nutsedge. Each subplot was randomized within each main plot and all main plots were randomized within each of the three replications.

The plot width was choosen to accomodate farm machinery. The dimension of the main plots was 4.5 m wide by 20 m long but only the center of the plot was harvested and sampled: 2.5 m by 6 m for experiment #1 and 2.5 m by 5 m for experiment #2. The shorter length in the latter was due to the extra guard space needed because of the sprayer equipment. There was a path of 1.5 m between each plot and a 5 m roadway between each block.

2.2 Cropping systems and control treatments

Nine cropping systems, selected for their potential for controlling nutsedge, were evaluated along with two control treatments (Table 2.1). All field operations were conducted with farm machinery. In the first five cropping

Table 2 1 Cropping systems evaluated for controlling yellow nutsedge.

NO	CROP[1]	SEEDING RATE	HERBICIDE[2]	RATE (kg a.i./ha)	TYPE OF APPLICATION[4]	DATE EXP #1 1987	DATE EXP #1 1988	DATE EXP #2 1988	FIELD OPERATIONS	DATE EXP #1 1987	DATE EXP #1 1988	DATE EXP #2[3] 1988
1	Corn	88,000 pl/ha (75 cm between rows, 15 cm between plants)	EPTC/dichlormid + atrazine	6 8 1 8	PPI	13/5	17/5	17/5	corn seeding cultivating harvesting plowing	14/5 30/6 11/9 6/10	18/5 23/6 22/9 4/10	18/5 23/6 22/9 4/10
2	Corn	88,000 pl/ha	metolachlor + atrazine	2 64 1 75	PPI	13/5	17/5	17/5	same as cropping system 1			
3	Corn	88,000 pl/ha	bentazon/ atrazine + oil/surfactant	0 8 0.8 2 l/ha	POST	13/6	31/5	31/5	same as cropping system 1			
4	Corn + red clover	88,000 pl/ha 14 kg/ha	EPTC/dichlormid	6 8	PPI	13/5	17/5	17/5	corn seeding rototilling clover seeding raking/rolling corn harvesting plowing	14/5 26/6 26/6 26/6 11/9 6/10	18/5 9/6 10/6 10/6 22/9 4/10	18/5 9/6 10/6 10/6 22/9 4/10
5	Corn + red clover	88,000 pl/ha 14 kg/ha	EPTC/dichlormid	6 8	PPI	13/5	——	17/5	corn seeding rototilling clover seeding raking/rolling corn harvesting clover 1> harvesting 2>	14/5 26/6 26/6 26/6 11/9 —— ——	—— —— —— —— —— 2/6 25/7	18/5 9/6 10/6 10/6 22/9 —— ——
6	Alfalfa	12 kg/ha	EPTC	3 36	PPI	13/5	——	10/5	alfalfa seeding alfalfa 1> harvesting 2> 3>	14/5 17/7 —— ——	—— 13/6 18/7 29/8	10/5 18/7 —— ——
7	Soybean	100 kg/ha	metolachlor + metribuzin	2.64 0 4125	PPI	13/5	17/5	17/5	soybean seeding soybean harvesting plowing	13/5 30/9 6/10	19/5 30/9 4/10	19/5 30/9 4/10
8	Sorghum/ winter wheat	25 kg/ha 120 kg/ha	—— ——	—— ——	—— ——	—— ——	—— ——	—— ——	sorghum seeding sorghum chopping plowing harrowing 1> (triple K) 2> wheat seeding wheat harvesting	29/5 4/8 6/8 4/9 15/9 15/9 ——	—— —— 29/7 26/8 15/9 15/9 26/7	1/6 28/7 29/7 26/8 15/9 15/9 ——
9	Spring barley	120 kg/ha	diclofop-methyl + bromoxynil	0.795 0.28	POST	4/6	31/5	31/5	barley seeding barley harvesting plowing	13/5 6/8 6/10	6/5 8/8 4/10	6/5 8/8 4/10
10	Pure stand of yellow nutsedge		diclofop-methyl + bromoxynil	0.795 0 28	POST	13/6	31/5	31/5	plowing	6/10	4/10	4/10
11	Bare ground		paraquat	2 0	POST	4-5 times/season			plowing	6/10	4/10	4/10

[1] see appendix 1 for cultivars used in this experiment. [2] see appendix 2 for chemical and trade names. [3] treated split only. [4] PPI = pre-plant incorporated, POST = postemergence

systems, corn was planted with a precision planter[1] at 15 cm spacing between plants within corn rows and 75 cm between rows (88,000 plants/ha). The two middle rows of each plot were harvested. Plants were counted and harvested within each row and cobs of one row were counted and weighed. Corn yield was expressed as the mean of the two harvested rows. Corn quality was indicated by harvest index[2].

In the first cropping system, EPTC/dichlormid plus atrazine were tank mixed and incorporated the day before planting. In cropping system 2, only the herbicides changed. Metolachlor plus atrazine were applied as a soil incorporated tank mixed treatment. In cropping system 3, the formulated mixture of bentazon and atrazine was applied postemergence. These three systems were cultivated with tractor mounted sweeps at the end of June and were plowed after harvest. In 1988, the same treatments were applied in both experiment #1 and experiment #2.

In cropping system 4, EPTC/dichlormid was preplant incorporated. When the corn was 20 cm high, a between row soil strip 50 cm wide was rototilled and raked. Red clover was hand seeded at a rate of 14 kg/ha in this soil strip and

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[1]GASPARDO SP250

[2] Harvest index= cob dry weight/whole plant dry weight.

then rolled. The plots were plowed in the fall and red clover was used as green manure.

Cropping system 5 was similar to cropping system 4 except that red clover was kept as a forage crop in 1988. In experiment #1, red clover was not harvested the year of establishment but it was harvested twice in the second year. The dimensions of the harvested area were 2.25 by 6 m. In experiment #2, red clover was not harvested since it was its year of establishment.

In cropping system 6, EPTC was preplant incorporated and alfalfa was seeded using a Brillion seeder at a rate of 12 kg/ha and was harvested as a hay crop. The alfalfa was cut once the first year and three times the second year. The harvested areas were 2.5 by 6 m for experiment #1 and 2.5 by 5 m for experiment #2. Legumes were analysed as feed for lifestock.

Soybean was the crop used in system 7. It was planted with a cereal planter[3] at a seeding rate of 100 kg/ha. Metolachlor plus metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one] tank mixed were applied as a preplant incorporated treatment. The plots were plowed after harvest. In experiment #1, thirteen rows, 6 m in length were harvested with a plot combine, while the harvested length was 5 m in experiment #2.

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[3] INTERNATIONAL 510 semi-mounted

In cropping system 8, sorghum was planted with the cereal planter at a rate of 25 kg/ha at the beginning of June. The plots were plowed in early August and kept as fallow until early September (two harrowings were required). Winter wheat was seeded September 15, 1987 at a rate of 120 kg/ha. The crop was harvested in July 1988 using a plot combine. The harvested area was the same as for soybean. Plant height, hectoliter weight and 1000 grain weight were taken as quality indicators. The cropping practices done in 1987 were repeated in experiment #2.

Spring barley at 120 kg/ha plus diclofop-methyl {methyl 2-[4-(2,4-dichlorophenoxy)phenoxy] propanoate} plus bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) applied postemergence were evaluated in cropping system 9. The harvested area and the yield quality indicators were the same as those for winter wheat. The same treatments were repeated in 1988 in both experiments.

There were two control treatments. The first one was yellow nutsedge growing in a pure stand. Diclofop-methyl and bromoxynil were applied to control broadleaf species and grasses at the same rate and date as in barley. This treatment was used to compare the efficacy of the cropping systems with a situation where yellow nutsedge was not controlled.

The other control treatment was complete yellow nutsedge control. Paraquat was applied when needed to keep the ground bare: one application at two to three week intervals starting in mid June. This treatment was used as 100% control against which the cropping system could be compared. Both control treatments were plowed in the fall.

Crop fertilization was done according to the soil analysis results and followed the Conseil des Productions Végétales du Québec (C.P.V.Q.) recommendations (Table 2.2). In spring 1987, part of the fertilizer (200 kg/ha of 5-20-20) was applied with machinery (earlier date in Table 2.2) while the other part was hand broadcasted onto each plot before harrowing the soil. In 1988, all of the fertilizers were applied with machinery. Herbicides and/or fertilizers were incorporated into the soil with a field cultivator[4] immediately after herbicide application.

2.3 Sampling methodology

Yellow nutsedge tubers were collected in the spring before planting operations and in the fall after harvest. Underground sampling was done using the soil sampler described by Gutman and Watson (1980). The sample dimensions were 15 by 15 by 15 cm. Six samples per plot for experiment #1 and five samples per subplot for experiment #2 were taken at random.

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[4] TRIPLE K, which is a Danish tine followed by rolling baskets.

Table 2.2. Fertilizers and lime applied for each crop and growing season

1987 — EXPERIMENT #1

CROPPING SYSTEM	CROP REQUIREMENT	FERTILIZERS & AMENDMENT	RATE (kg/ha)	DATE
1, 2, 3, 4, 5	corn 180-70-80	34-0-0	478	9/5
		0-0-60	17	9/5
		5-20-20	350	7,9/5
6	alfalfa 30-50-140	34-0-0	59	9/5
		0-0-60	133	9/5
		0-15-30	67	9/5
		5-20-20	200	7/5
7	soybean 35-40-40	34-0-0	74	9/5
		5-20-20	200	7/5
8	sorghum 130-100-100	34-0-0	309	9/5
		5-20-20	500	7,9/5
	winter wheat 40-20-60	10-20-20	400	14/9
9	spring barley 110-60-40	34-0-0	271	9/5
		5-20-20	200	7/5
		18-46-0	44	9/5
CONTROLS 10, 11	87-24-40*	34-0-0	238	9/5
		0-0-60	27	9/5
		5-20-20	320	7/5
AMENDMENT				
All	3000	lime ($CaCO_3$)	3300	1/10

1988 — EXPERIMENT #1

CROPPING SYSTEMS	CROP REQUIREMENT	FERTILIZERS & AMENDMENT	RATE (kg/ha)
1, 2, 3	corn 180-40-120	34-0-0	500
		0-0-60	133
		5-20-20	200
6	alfalfa 30-20-130	34-0-0	74
		0-0-60	183
		5-20-20	100
		boron	2
7	soybean 45-45-75	34-0-0	99
		0-0-60	50
		5-20-20	225
8	winter wheat 40-20-60	34-0-0	88
		0-0-60	67
		10-20-20	100
9	spring barley 70-20-30	34-0-0	191
		0-0-60	17
		5-20-20	100
CONTROLS 10, 11	81-31-89*	34-0-0	218
		0-0-60	96
		5-20-20	156

1988 — EXPERIMENT #2

CROPPING SYSTEM	CROP REQUIREMENT	FERTILIZERS & AMENDMENT	RATE (kg/ha)	DATE
1, 2, 3, 4, 5	corn 180-60-180	34-0-0	485	3/5
		0-0-60	200	3/5
		5-20-20	300	3/5
6	alfalfa 30-20-165	34-0-0	74	3/5
		0-0-60	242	3/5
		5-20-20	100	3/5
		boron	2	3/5
7	soybean 45-45-85	34-0-0	99	3/5
		0-0-60	67	3/5
		5-20-20	225	3/5
8	sorghum 80-40-80	34-0-0	208	3/5
		0-0-60	67	3/5
		5-20-20	200	3/5
	winter wheat 40-20-60	34-0-0	88	14/9
		0-0-60	67	14/9
		10-20-20	100	14/9
9	spring barley 70-20-60	34-0-0	191	3/5
		0-0-60	67	3/5
		5-20-20	100	3/5
CONTROLS 10, 11	81-37-117*	34-0-0	211	3/5
		0-0-60	128	3/5
		5-20-20	185	3/5
AMENDMENT (1987)	4500	lime ($CaCO_3$)	4500	1/10

* based on the average fertilization of the cropping systems

The soil samples were washed by running water as described by Gutman and Watson (1980). The material retained in the sieve was dried in a forced air oven (65°C) for 48 hours. Afterwards, tubers were sorted, counted, and dried to a constant weight in the same oven, and weighed.

The above-ground biomass of yellow nutsedge and other weeds were taken before crop harvest. Quadrats 25 cm by 25 cm were placed at random. The shoots were cut at ground level, grouped as yellow nutsedge, broadleaf weeds and grasses, counted, and dried to a constant weight in an oven (65°C) for 24 hours.

Five above-ground samples per plot were taken for experiment #1 and four above-ground samples per subplot for experiment #2. This operation was done at each cut in alfalfa and red clover plots. In corn, two or three samples were taken on the rows and three between the rows.

2.4 Economic analysis

Economics of the various cropping systems studied were analysed. The gross margin was obtained by subtracting the variable costs from the crop value.

2.4.1 Variable costs

The variable costs differed for each cropping system evaluated. It included costs of all crop operations such as seeding, plowing, fertilizing, herbicide spraying, harrowing, cultivating and harvesting. The costs per hectare multiplied by the number of times the operations were done gave the yearly costs. Cultural practices costs, seed, and fertilizer prices were obtained from the "Comité de références économiques en agriculture du Québec" and herbicide prices were obtained from the "Coopérative fédérée du Québec" which is a major retailer in Québec.

2.4.2 Crop value

Crop value for each cropping system was obtained by multiplying crop yields by crop prices. Values of corn, red clover, alfalfa, soybean, winter wheat, and spring barley harvested were based on crop prices in 1987 and 1988. Crop prices were recorded from the "Comité de références économiques en agriculture du Québec" (soybean), the "Office des provendes du Canada" (cereal), and from personnal communications (forage crops). Crop prices of forage crops such as red clover or silage corn were reported on their respective dry matter basis.

2.5 Statistical analysis

The data were subjected to analysis of variance using the Statistical Analysis System (SAS; Anonymous, 1985). Tuber number, tuber dry weight, and average dry weight per tuber were recorded. All of the nutsedge tuber data required a square root transformation plus one-half (Steel and Torrie, 1960). The presented data means were all retransformed to the original unit by squaring the transformed means and substracting one-half. The T-test and the least significant difference at the 5% level of probability (LSD 0.05) were used to compare means over time. The Waller-Duncan t test was used to determine the statistical difference between cropping systems (Chew, 1976). All data were expressed as a percentage of the first initial sampling date except when all cropping systems were compared; they were then expressed as percentage of the initial population of their respective season. Treatment means under 100% indicate that there was a reduction in the original tuber population level. Regressions were fitted to raw data to describe the relationship between tuber production and above-ground plant parts of yellow nutsedge and other weeds. Economic data were not statistically analysed.

Chapter 3

RESULTS AND DISCUSSION

Results and discussion will be presented under two aspects: biological and economical.

3.1 BIOLOGICAL ASPECTS

3.1.1 Effect of cropping systems on yellow nutsedge populations

This first sub-section includes the effect of nine different cropping systems on yellow nutsedge populations. Each cropping system will be discussed separately and a comparison between all of them will follow. The studied variables are tuber number, tuber dry weight, and average dry weight per tuber.

Cropping system 1: CORN + atrazine + EPTC + cultivation.

In the first cropping system evaluated, populations of yellow nutsedge tubers declined with time when herbicide application and cultivation were done (Figure 3.1.1 A, B, C).

After 18-months management in experiment #1, tuber number and biomass were reduced to 7.6% and 7.1% respectively of the initial tuber population (Figure 3.1.1 A, B). Reductions were significant for each sampling date. Between the sixth and the twelfth month, fall plowing and winter conditions put additional pressure on the nutsedge by increasing tuber mortality. After each growing season (6 and 18 months), the average dry weight per tuber tended to be greater than the initial spring one (Figure 3.1.1 C). This increase might indicate that a larger number of small tubers died during the growing season or that heavier tubers were produced in greater number. Small tubers which had less reserve (Stoller and Weber, 1975) might have lost their viability faster than the larger ones (Stoller and Wax, 1973). During the winter, the inverse phenomenon was observed. This might be attributed to plowing which by turning over the soil, might have exposed large tubers (often distributed deeper in soil [Cloutier,1986]) to weather extremes on the soil surface while small tubers might be buried deeper in the soil and therefore be better protected against weather extremes until the next growing season. However, Stoller and Weber (1975) observed that among various biotypes of yellow nutsedge collected in different states, tuber size

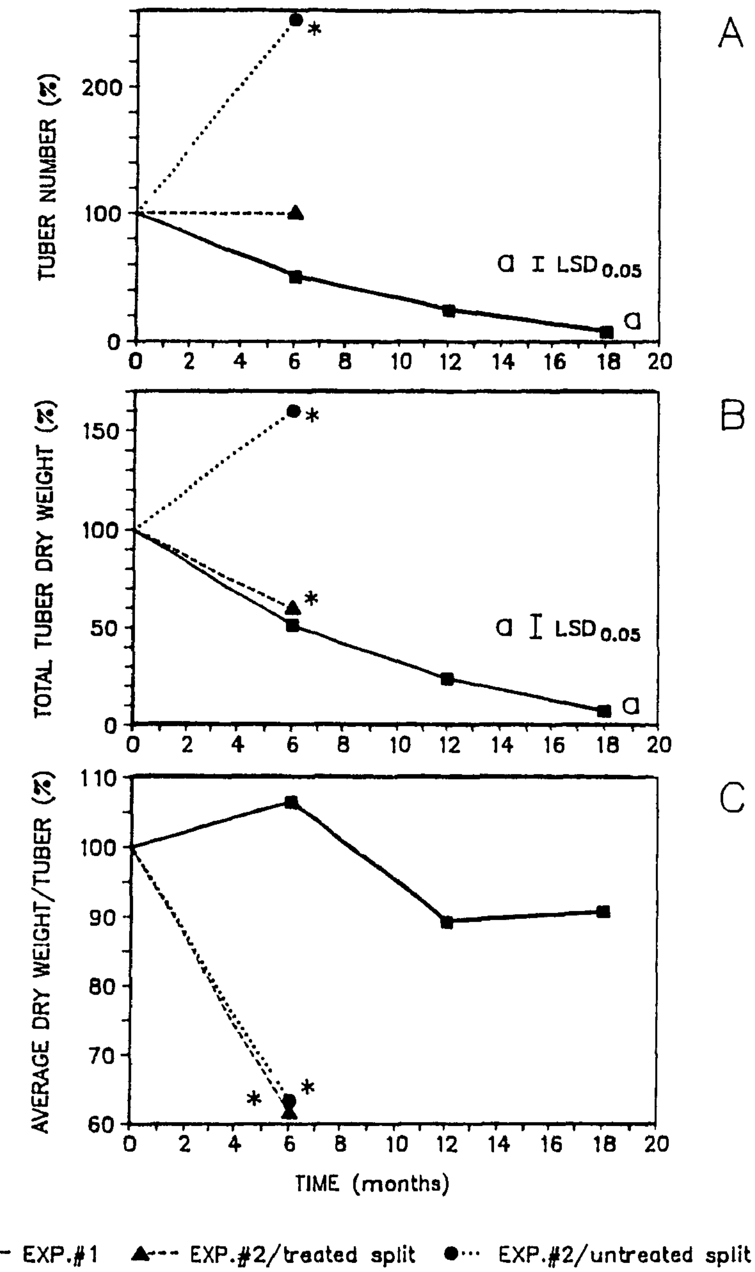

Figure 3.1.1. Changes in yellow nutsedge tuber variables during the growing season in corn system 1. Where summer= 0-6, 12-18 months, winter= 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

decreased and moisture percent increased as tuber cold-hardiness increased. They also recorded that cold treatment increased starch, sugar and lipid content in most cold resistant yellow nutsedge tubers.

Yellow nutsedge might compete for water, nutrients, light and space. For both growing seasons, fertilizers were broadcasted and no side-dressing was applied. In 1987, rain was abundant while in 1988, water was scarce due to a drought lasting all summer. No significant difference at the 5% level of probability was noted between tuber populations within or between corn rows in experiment #1. However, they tended to be higher between rows after the first growing season and higher within rows the second growing season (Table 3.1.1). Cultivation did not reduce yellow nutsedge populations between rows when compared to within rows the first year, probably because water was not a limiting factor. However, cultivation probably compounded the effect of drought which caused a decrease of yellow nutsedge populations between rows the second year compared to within rows. When water was available, light and space remained factors which might have affected yellow nutsedge growth. Both were more available between rows. Within rows, light was reduced by corn canopy shading and the underground space was mainly occupied by corn roots. Consequently, less tubers might be produced and/or more tubers died. In 1988, the drought seemed to be the main factor which affected tuber production and distribution. Between rows, tubers were more exposed to the sun and to desiccation especially after cultivation between rows. Consequently, less tubers were produced and/or

Table 3.1.1. Tuber populations between or within corn rows.

No. of exp.	cropping system[1]	between (B) or within (W) rows	tuber number (%)	total tuber dry weight (%)	average dry weight per tuber (%)	No. of exp.	cropping system	between (B) or within (W) rows	tuber number (%)	total tuber dry weight (%)	average dry weight per tuber (%)
1-87	1	B	57.7	55.5	93.4	2-88u	1	B	217.8	135.4*	62.2
		W	43.5	47.4	117.1			W	302.7	194.8*	64.8
	2	B	76.7	68.9	87.9		2	B	203.1	118.0	57.7
		W	55.5	54.4	98.2			W	237.1	140.0	58.6
	3	B	48.6	49.1	94.7		3	B	235.6*	144.4	61.8
		W	44.8	41.5	93.0			W	347.8*	233.5	68.2
	4	B	75.3	70.0	93.8		4	B	110.8	70.8	63.9
		W	70.0	70.2	100.5			W	183.7	142.8	75.4
	5	B	69.2	71.0	104.1		5	B	171.7*	115.7*	67.2
		W	72.9	72.8	95.2			W	270.4*	157.2*	57.3
1-88	1	B	26.8	26.0	108.9	2-88t	1	B	74.1	49.5	67.8*
		W	31.7	30.0	94.5			W	134.7	74.0	55.5*
	2	B	48.0	60.8	142.0		2	B	89.6*	54.0	60.3
		W	39.9	37.9	93.2			W	191.2*	106.2	54.1
	3	B	35.3	56.9	145.5		3	B	102.5	60.6	59.0
		W	125.7	222.8	166.1			W	156.8	112.3	71.0
	4	B	112.4	141.8	126.2		4	B	69.6*	43.2	62.2
		W	153.3	209.1	152.6			W	104.0*	65.2	62.6
							5	B	84.7	55.9	65.4
								W	118.1	71.4	61.2

[1] 1= CORN + atrazine + EPTC
2= CORN + atrazine + metolachlor
3= CORN + atrazine +bentazon
4= CORN + CLOVER + EPTC (plowed)
5= CORN + CLOVER + EPTC

* significant difference between and within rows.

Where u= untreated split, t= treated split. All means were detransformed and expressed as percentage of the initial spring population of its respective year and experiment number. The T-test at 0.05 level of significance was used to compare means between and within rows for each corn system.

more tubers died due to drought.

In experiment #2, which was initiated in 1988, the fall tuber population in the treated split remained at the same level as that of the initial population (Figure 3.1.1 A). Tuber production was therefore approximately the same as tuber mortality. However, tuber biomass declined with time to reach 60% of the initial one and might indicate that tubers produced were smaller and/or that tubers which died were bigger (Figure 3.1.1 B). Tuber number and tuber dry weight from the untreated split were significantly higher than the initial ones and, respectively reached 250 and 160% of the spring population. The decline in average dry weight per tuber for both splits might indicate that some new smaller tubers were produced or that tuber weight decreased during the growing season through respiration (as in generally reported for plants [Salisbury and Ross, 1978; Tumbleson and Kommedahl, 1962]) (Figure 3.1.1 C). This different population response might be due to the demographic profile of the tuber population in experiment #2 which was different than in experiment #1. Tuber number, total tuber dry weight and average weight per tuber were higher in experiment #2 (Appendix 3). This second experiment was prepared in 1987 by allowing nutsedge to grow freely. Therefore, the 1988 spring tuber population was composed mostly of first-year tubers. These young tubers might have been more physiologically active and consequently, might have had a higher respiration level which increased weight loss. Moreover, the drought probably increased tuber metabolism as in generally reported for plants (Salisbury and Ross, 1978).

In the untreated split, there was no signicant difference between tuber number within or between corn rows but it tended to be greater within rows (Table 3.1.1). Total tuber dry weight was significantly higher within rows than between rows. For the treated split, the number and biomass of tubers tended to be higher within rows. Average weight per tuber was significantly lower within rows than between rows. That indicates that tubers might be smaller within rows, probably because of corn shoot and root competition. The lesser number of tubers found between rows might be attributed to the reasons mentioned above, and to a higher soil compaction between rows reducing tuber production. In the case of the treated split, cultivation between rows might have pushed soil containing tubers to each side of the corn plant and it might have contributed to the increase in the tuber population within row. In the untreated split, yellow nutsedge shoot number was high and favoured etiolation of nutsedge plants which were more subjected to lodging. Corn plants within rows might have acted as support for yellow nutsedge plants, therefore avoiding lodging. Their leaves remained green and consequently, they remained physiologically active longer to produce more tubers than the plants between rows.

Cropping system 2: CORN + atrazine + metolachlor + cultivation.

In the first experiment, tuber number and tuber dry weight declined with time as in cropping system 1 but the reduction was less and reached 15 and 16 % of the initial population, respectively (Figure 3.1.2 A, B). Plowing and/or winter cold increased tuber mortality between the sixth and twelth months. There was no significant difference between the average dry weight per tuber of each sampling date (Figure 3.1.2 C). Average dry weight per tuber tended to be similar the first year between spring and fall sampling and increased after the second growing season. It might be that by providing a continuous pressure on yellow nutsedge, bigger tubers survived more than smaller ones. There was no significant difference in tuber population between or within rows but tuber number, total tuber dry weight and average weight per tuber tended to be higher between rows in the first and the second growing seasons (Table 3.1.1). Light was probably more available between rows allowing nutsedge growth. Within rows, corn plants might provide enough shade and might occupy enough space by their shoot and roots to reduce yellow nutsedge growth.

In experiment #2, tuber number increased in both the treated and untreated split but the augmentation was significantly higher in the untreated split (Figure 3.1.2 A). However, tuber biomass in the treated split tended to decline, indicating that some smaller tubers were produced (Figure 3.1.2 B). Average dry weight per tuber decreased after the first growing season indicating that either

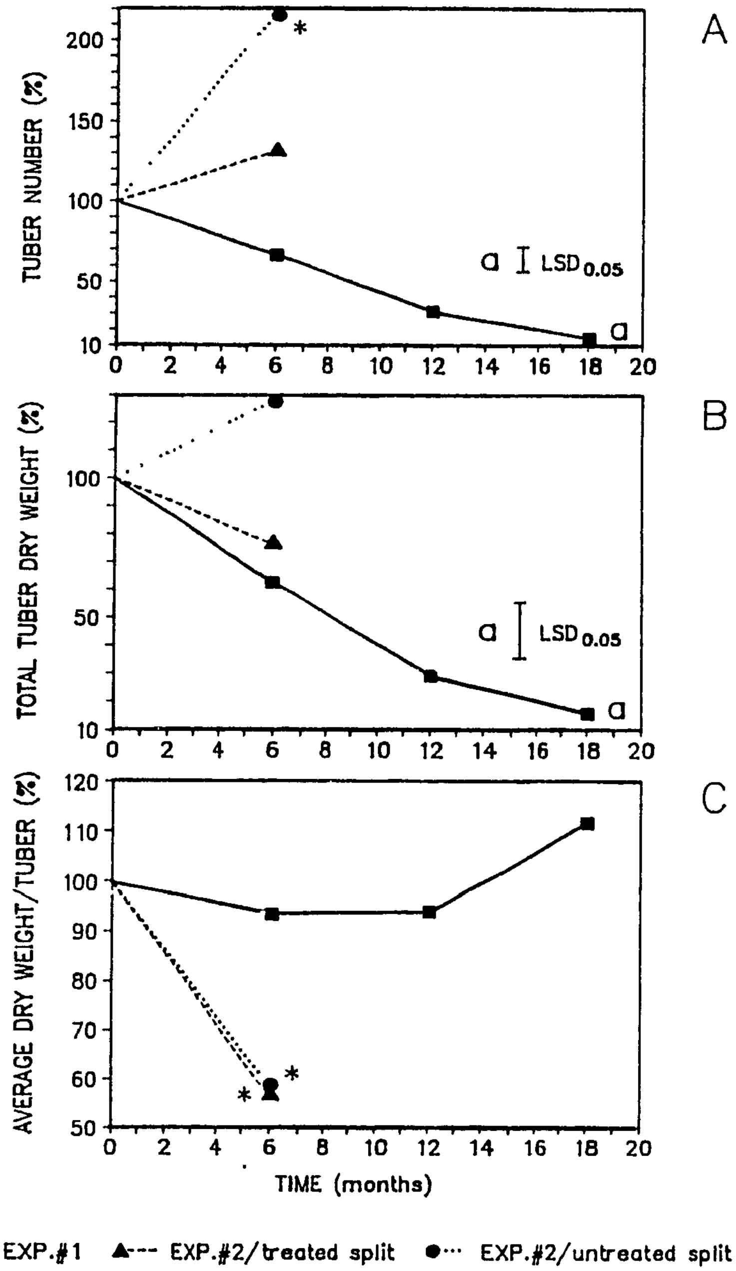

Figure 3.1.2. Changes in yellow nutsedge tuber variables during the growing season in corn system 2. Where summer= 0-6, 12-18 months, winter= 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

tubers produced were smaller than the initial population or that the weight of some was reduced as discussed for cropping system 1.

Tuber number (%) tended to be higher within rows than between rows (Table 3.1.1). The difference was significant in the treated split. Tuber dry weight (%) tended to be higher within rows for both splits. Since the results were similar to that observed in corn system 1, the discussion will not be repeated here.

Cropping system 3: CORN + atrazine + bentazon + cultivation.

In experiment #1, tuber number and tuber dry weight decreased with time as in corn systems 1 and 2 (Figure 3.1.3 A, B). The reduction was less than in the two first systems. Number and biomass of tubers reached 20 and 29% of the initial population, respectively (Figure 3.1.3 A, B). During the six last months, tuber number remained at the same level while tuber dry weight and average dry weight tended to increase (Figure 3.1.3 C). That might indicate that some yellow nutsedge escaped chemical and mechanical control and produced bigger tubers and/or that more smaller tubers died during the growing season. During the winter (6 to 12 months), bigger tubers died because tillage might have exposed more bigger tubers to the soil surface. There were no significant differences

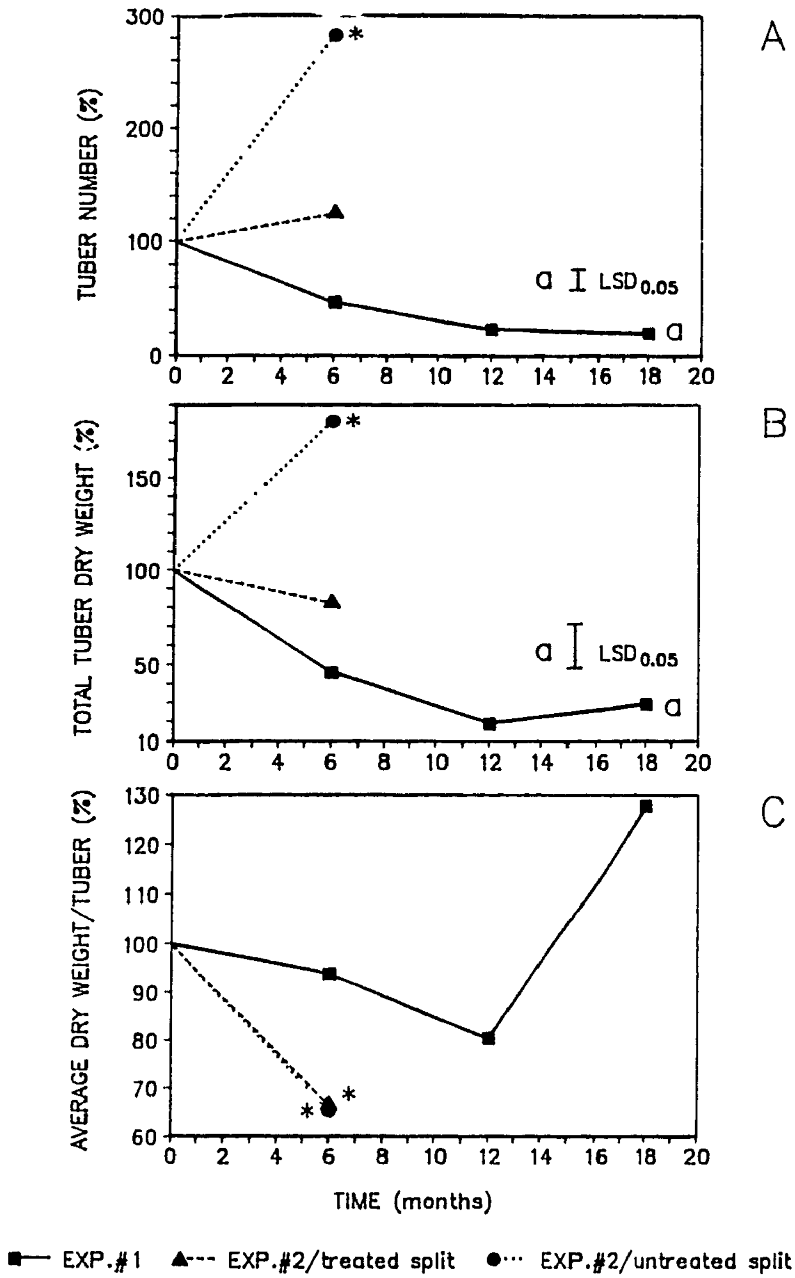

Figure 3.1.3. Changes in yellow nutsedge tuber variables during the growing season in corn system 3. Where summer= 0-6, 12-18 months, winter= 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

between variables obtained within or between rows but they tended to be greater within rows the second growing season (Table 3.1.1). Postemergence herbicides might have not reached yellow nutsedge plants within rows, because of protection afforded by the corn canopy.

In the second experiment, tuber number (%) tended to increase while total tuber dry weight and average dry weight per tuber decreased in the treated split (Figure 3.1.3 A, B, C). Apparently the tubers produced were smaller than the initial ones. In the untreated split, tuber number and tuber biomass increased while average dry weight per tuber declined indicating that numerous new smaller tubers were produced or that tubers lost weight, probably due to higher levels of metabolism (respiration).

Tuber number and tuber biomass tended to be higher within rows than between rows for the same reasons cited above (Table 3.1.1). For the untreated split, tuber number was significantly higher within rows. Average dry weight per tuber tended to be higher within rows. As explained in cropping system 1, the corn plants might have acted as support for the yellow nutsedge, therefore avoiding lodging and allowing them to produce more tubers.

Cropping systems 4: CORN/RED CLOVER + EPTC (plowed).

5: CORN/RED CLOVER + EPTC.

The difference between cropping systems 4 and 5 was that in the latter, red clover was kept as forage the following growing season. In experiment #1, after the first growing season, tuber number and tuber dry weight were reduced by 30% in both systems while average dry weight per tuber remained relatively stable (Figure 3.1.4 A, B, C). There were no significant differences between variables taken within or between rows but tuber production in system 4 tended to be higher between rows the first growing season while it tended to be higher within rows the second growing season as in system 1 and 3 (Table 3.1.1). In system 5, it also tended to be higher within rows the first growing season. This might be explained by mechanical operations done to rotovate soil between rows before clover planting which helped in reducing tuber population between rows. The presence of weeds could have also influenced the yellow nutsedge tuber population found between rows. During the winter interval, the tuber population, biomass and average tuber weight decreased more in the plowed treatment than in the unplowed treatment (Figure 3.1.4 A, B, C). The tuber weight decrease was probably due to tillage which exposed larger tubers on the soil surface. During the second growing season, in system 5, red clover exerted a continuous pressure on yellow nutsedge and reduced tuber number and tuber biomass to 25% and 24% of the initial population. Tuber population and total tuber dry weight from corn intercropped with red clover (system 4) tended to increase during the second

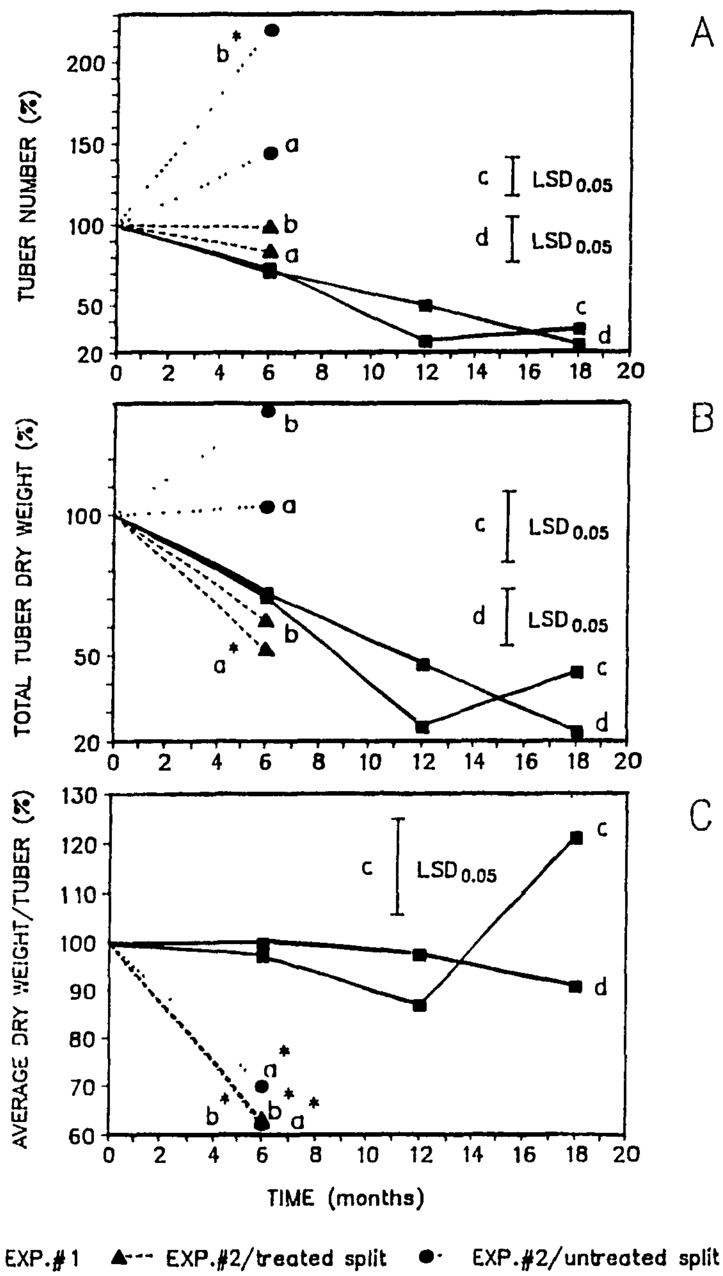

Figure 3.1.4. Changes in yellow nutsedge tuber variables during the growing season in corn intercropped with red clover. Where system 4= a, c; system 5= b, d; summer= 0-6, 12-18 months; winter= 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

year of this management probably due to the drought which reduced herbicide efficacy and crop growth. The average dry weight per tuber was significantly higher after the second growing season in this system indicating that larger tubers were produced and/or that smaller tubers died during the second growing season.

In experiment #2, tuber number and tuber biomass from the treated split followed trends similar to those noted in experiment #1 (Figure 3.1.4 A, B). However, average dry weight per tuber declined significantly (Figure 3.1.4 C). These results supported that experiment #2 had a demographic profile different from experiment #1. Tuber number and tuber biomass tended to be higher within rows. In system 4, tuber number was significantly higher within rows than between rows for the treated split (Table 3.1.1). In the untreated split, tuber number and tuber biomass increased significantly while average weight per tuber decreased significantly indicating that numerous smaller tubers were probably produced. In both systems, tuber number and total tuber dry weight were significantly higher within rows than between rows.

Cropping system 6: ALFALFA + EPTC (first growing season).

In experiment #1, tuber number and tuber dry weight increased after the first growing season (Figure 3.1.5 A, B). Average dry weight indicated that smaller tubers were produced (Figure 3.1.5 C). This system was not plowed and during the winter, tuber mortality increased. This may have been due to smaller tubers closer to soil surface that were more exposed to winter cold. During the second growing season, tuber number and biomass continued to decrease to reach respectively 62 and 59% of the initial population and lighter tubers closer to the soil surtace had increased mortality (Figure 3.1.5 A, B, C).

In experiment #2, tuber number and tuber dry weight for the untreated split increased and smaller tubers were produced (Figure 3.1.5 A, B). In the treated split, the number of tubers tended to increase while tuber dry weight tended to decrease indicating that smaller tubers were produced or that bigger ones died. For both splits, lower average dry weight per tuber might indicate that tubers lost weight during the dry weather conditions of the growing season which could be explained by higher respiration as discussed in cropping system 1 (Figure 3.1.5 C).

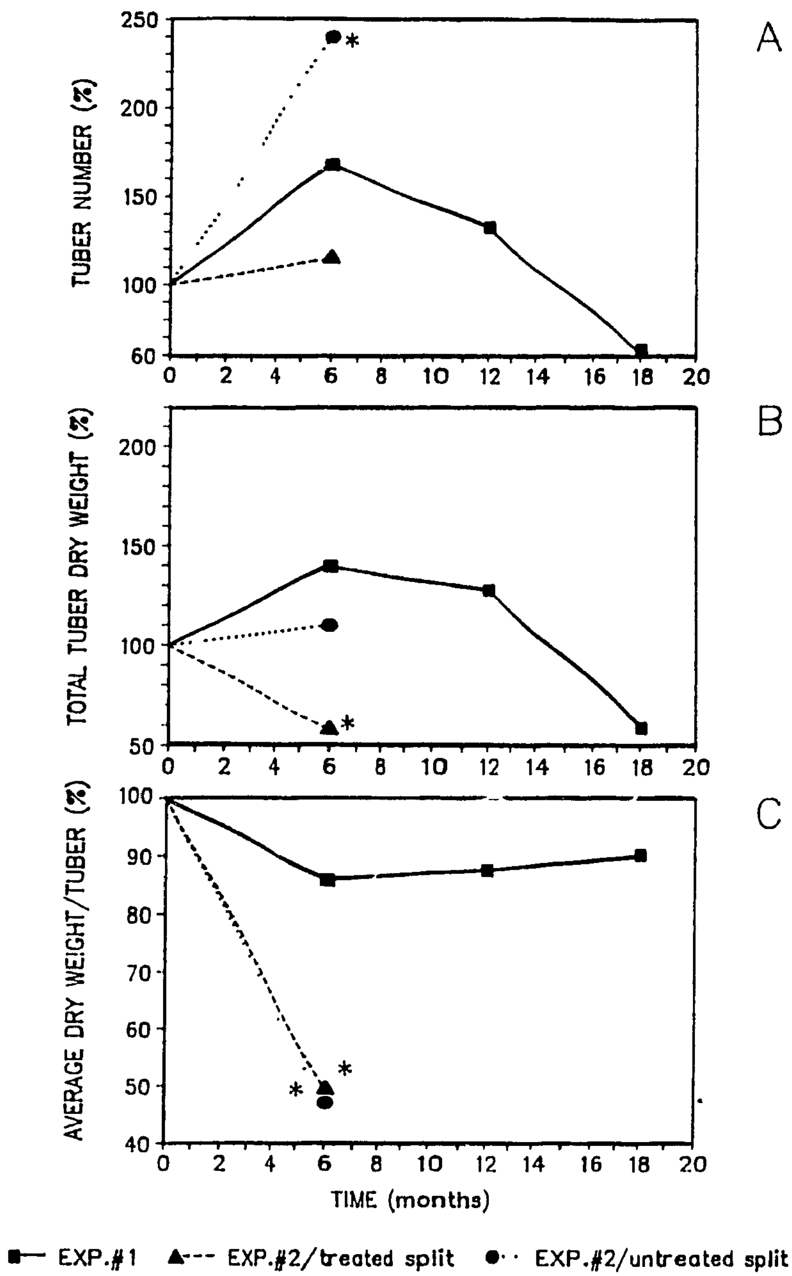

Figure 3.1.5. Changes in yellow nutsedge tuber variables during the growing season in the alfalfa system. Where summer = 0-6, 12-18 months, winter = 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

Cropping system 7: SOYBEAN + metribuzin + metolachlor.

In experiment #1, tuber number and tuber biomass declined with time and reached 24 and 26% respectively of the initial population (Figure 3.1.6 A, B). After the first growing season, the average dry weight per tuber decreased in the fall possibly because they were more active and respired more, or because of a greater mortality of the heavier tubers, or more smaller tubers were produced. During the winter, tuber number, total tuber dry weight and average weight per tuber decreased as in the plowed corn system (Figure 3.1.6 A, B, C). The average dry weight per tuber tended to increase probably because a lot of smaller tubers died during the last growing season and that the population was now composed of large tubers.

In experiment #2, the same trend was observed for both the untreated and the treated splits (Figure 3.1.6 A, B, C). Tuber number and tuber dry weight increased while the average dry weight per tuber decreased. This could be attributed to the fact that smaller tubers were produced and/or that tubers present lost weight due to a greater respiration rate brought on by drought (Salisbury and Ross, 1978). More smaller tubers were produced in the untreated split.

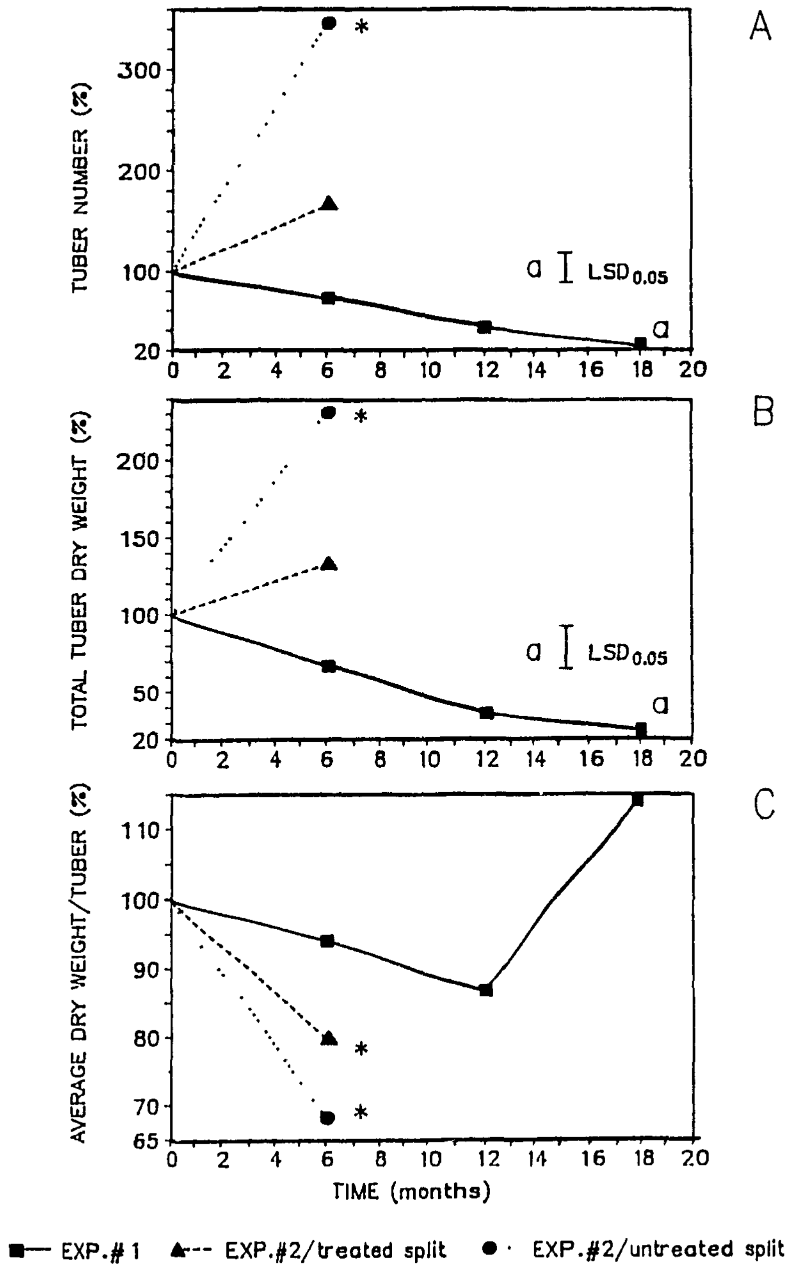

Figure 3.1.6. Changes in yellow nutsedge tuber variables during the growing season in the soybean system. Where summer= 0-6, 12-18 months, winter= 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

Cropping system 8: SORGHUM/WHEAT.

In experiment #1, sorghum was planted in the spring of the first growing season. Tuber number and tuber dry weight increased while average dry weight per tuber decreased indicating that smaller tubers were produced (Figure 3.1.7 A, B, C). Winter conditions helped to decrease tuber population (Figure 3.1.7 A). Winter mortality might be enhanced by plowing and harrowing during fall which might expose tubers on the soil surface. Smaller tubers died more than larger ones because they have less reserves (Stoller and Wax, 1973) and new shoot emergence during the fall might have decreased their reserves which then made them more sensitive to winter cold. During the second growing season, wheat decreased tuber number and tuber biomass to levels of 38% and 32% of their initial population, respectively. Without herbicide, larger tubers survived the winter and produced smaller tubers the following year. Tubers might also have lost weight due to higher respiration rates during dry periods of the second growing season.

In experiment #2, sorghum was not effective in controlling yellow nutsedge since the population increased to 160% and 193% of the initial population respectively in the treated and untreated treatments.

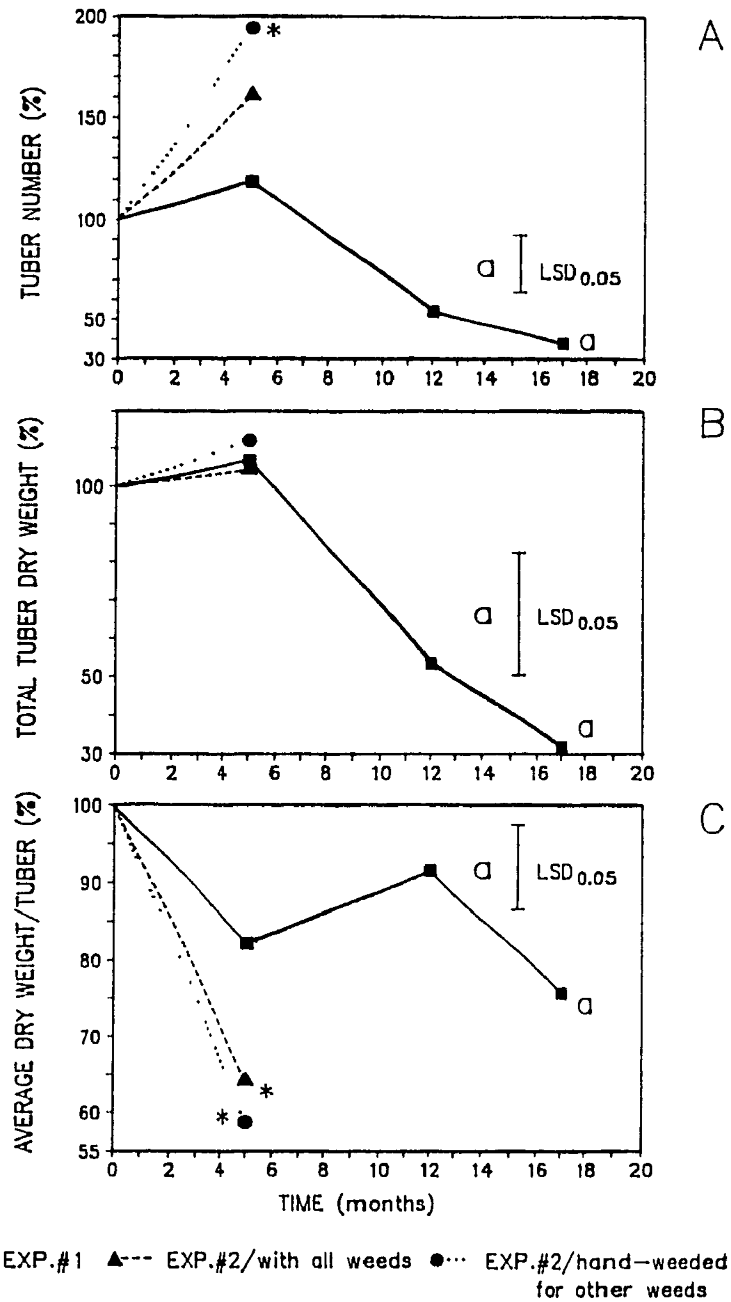

Figure 3.1.7. Changes in yellow nutsedge tuber variables during the growing season in the sorghum/wheat system. Where summer= 0-6, 12-18 months, winter= 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

Cropping system 9: BARLEY + bromoxynil + diclofop-methyl.

Herbicides applied in this system did not seem to affect yellow nutsedge growth. In experiment #1, tuber number and tuber biomass declined with time to reach 19 and 22% of the initial population (Figure 3.1.8 A, B). During the growing season, the tubers produced were larger or a lot of smaller tubers died (Figure 3.1.8 C). In winter, larger ones may have died due to plowing as reported for corn systems in the same experiment.

In experiment #2, herbicides and weed competition seemed to affect yellow nutsedge growth. Tuber number and biomass increased in the treated split while tuber number was greater in the untreated split and the biomass decreased (Figure 3.1.8 A, B). The untreated split was hand-weeded for weeds other than yellow nutsedge. In both cases, the average dry weight per tuber decreased although it was greater in the treated split.

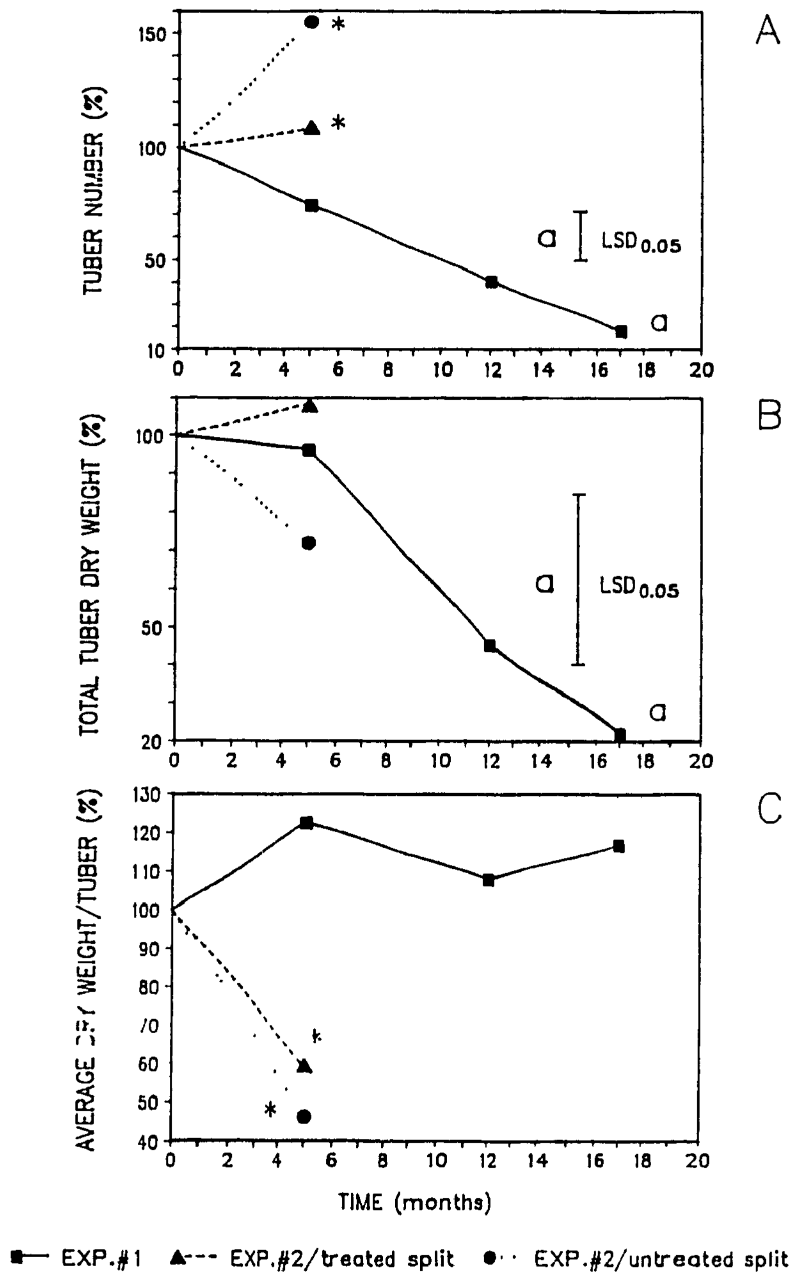

Figure 3.1.8. Changes in yellow nutsedge tuber variables during the growing season in the barley system. Where summer= 0-6, 12-18 months, winter= 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

Control 10: Pure stand of yellow nutsedge.

11: Bare ground + paraquat.

In the pure stand, the lack of yellow nutsedge control allowed the tuber population and biomass to triple during the growing season (Figure 3.1.9 A, B). In experiment #1, after the first and the second growing season, tuber populations increased respectively to 295% and 244% of the spring populations of their respective growing season. Winter reduced populations by 54%. Average weight per tuber increased indicating that tubers produced were larger than the initial ones (Figure 3.1.9 C). A lot of the new tubers produced in the fall of 1987 probably had the same size and were distributed equally due to intraspecific competition. When a crop was present, a few large tubers might be produced at greater soil depth due to the crop root exploration of the shallow soil. In this control, a great number of tubers were produced and might be equally distributed in the soil and fall plowing had probably no effect on the distribution of the tuber size in the soil depth. A large proportion of tubers succumbed to the winter cold but the average weight per tuber tended to increase indicating that smaller tubers tended to be more sensitive to winter conditions.

In experiment #2, tuber number increased between 279 to 372% of the initial population (Figure 3.1.9 A). Tubers produced after the first growing season were smaller than the initial ones probably because of the growing conditions (Figure 3.1.9 B, C).

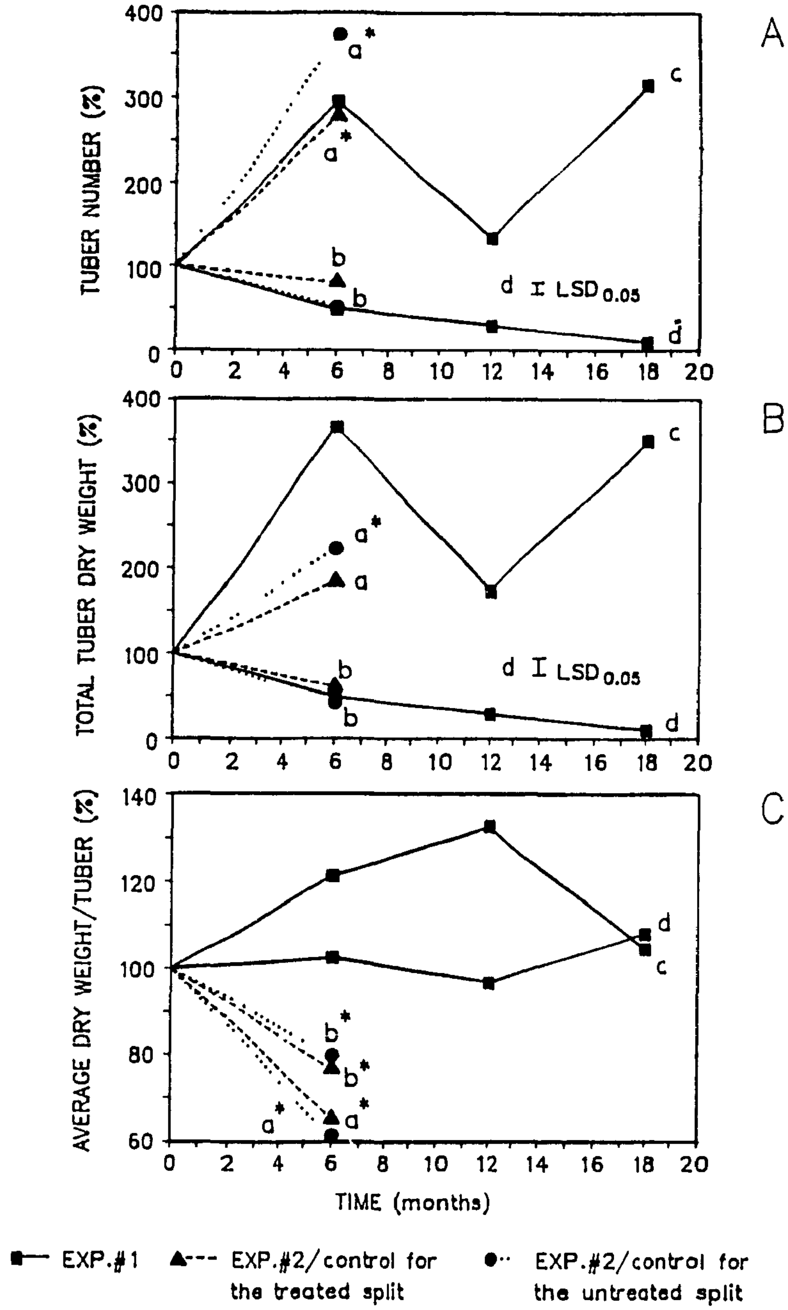

Figure 3.1.9. Changes in yellow nutsedge tuber variables during the growing season in control treatments. Where pure stand= a, c; bare ground= b, d; summer= 0-6, 12-18 months; winter= 6-12 months. Values are expressed as percentage of the first sampling time. The LSD at 0.05 level of probability was used to compare means of experiment #1 over time when significant. T-test was used to compare both spring and fall means in experiment #2.

*significantly different at the 0.05 level according to T-test.

In the bare ground treatment, the yellow nutsedge population declined with time (Figure 3.1.9 A, B, C). In experiment #1, the first year, a reduction of 51% was recorded for both tuber number and biomass. After two years of continuous and perfect weed control, the number and biomass of tubers were respectively reduced to 9 and 10% of the initial population. Plowing and winter conditions reduced the tuber population by 41%. Smaller tubers died during the growing season and bigger ones died during winter but the differences were not significant. Similar trends were observed in most cropping systems in experiment #1 except in systems which were not plowed such as alfalfa, red clover or winter wheat where the average weight per tuber did not decrease during winter. In experiment #2, tuber number and biomass were reduced to 53 and 42% of the initial spring population which were similar to results obtained in experiment #1 after the first growing season.

All cropping systems

Combined results of all cropping systems are shown in Table 3.1.2 and comparisons between them will be discussed in this section. Means are expressed as percentage of the initial population within their respective season.

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Good growing conditions with abundant rain prevailed in 1987. In experiment #1, the average original tuber population was 3300 tubers/m^2 (Appendix 3). After this first growing season, the yellow nutsedge population decreased by 51% under perfect control while it tripled in the pure stand. Reductions observed for the bare ground treatment were slightly lower than those reported by other researchers. Tuber viability has been reported to decrease by 60 to 86% the first year (Bell *et al.*, 1962; Cloutier, 1986; Doty, 1973; Stoller and Wax, 1973). These differences might be due to the various methods used to keep the ground bare. In most of the cropping systems evaluated, the population of yellow nutsedge tubers declined. Reductions between 27% and 53% were recorded but none were significantly different.

There were no significant differences between the three first corn systems and the corn intercropped with red clover but tuber number and total tuber dry

Table 3.1.2. Comparison of nine croppping systems and two control treatments for yellow nutsedge control.

cropping[1] systems		EXPERIMENT #1 F87/S87	EXPERIMENT #1 S88/F87	EXPERIMENT #1 F88/S88	EXPERIMENT #1 F88/S87	EXPERIMENT #2 F88/S88 split treated	EXPERIMENT #2 F88/S88 split untreated
tuber number	1	50.7d	48.5abc	29.4d	7.5d	98.6bcd	252.4abc
	2	66.3cd	46.2abc	44.6cd	14.4cd	130.2bc	217.2abc
	3	46.9d	53.1abc	81.0bc	19.4cd	124.3bc	280.6abc
	4	72.7cd	36.6c	133.7b	34.5bcd	83.3cd	140.6c
	5	71.1cd	67.0ab	53.3cd	24.9cd	98.2bcd	211.6abc
	6	160.9b	72.4a	53.7cd	60.1b	114.6bc	238.9abc
	7	72.3cd	57.3abc	62.9cd	23.7cd	158.1b	342.1ab
	8	118.2bc	43.3bc	71.4cd	37.4bc	160.4b	193.2bc
	9	73.3cd	54.8abc	46.8cd	18.5cd	155.0b	176.4c
	10	294.0a	45.9abc	239.0a	311.8a	275.0a	367.2a
	11	49.1d	58.4abc	30.0d	9.2cd	52.7d	____
total tuber dry weight	1	51.5cd	47.6ab	28.3c	7.0c	59.4cd	159.3ab
	2	61.7cd	47.9ab	50.1bc	15.6bc	75.0bcd	127.9ab
	3	45.4d	44.4ab	141.7a	28.6bc	82.0bcd	180.4ab
	4	70.1cd	33.9b	176.1a	43.2bc	52.1cd	100.2b
	5	71.9cd	64.7ab	49.6bc	23.2bc	62.1cd	132.4ab
	6	135.6b	75.3a	58.6bc	57.1b	57.3cd	110.2b
	7	66.6cd	53.3ab	77.7b	25.9bc	126.5ab	228.7a
	8	105.8bc	47.2ab	62.7bc	31.2bc	103.4bc	112.1b
	9	93.4bcd	47.7ab	50.5bc	21.9bc	71.7bcd	105.6b
	10	361.7a	48.9ab	191.9a	335.9a	180.7a	220.1a
	11	49.2cd	58.9ab	32.6bc	9.9c	42.1d	____
average dry weight /tuber	1	105.5	88.6	102.1bcde	90.8ab	61.3bc	63.2
	2	93.2	103.1	119.1abcd	111.6ab	56.6bc	58.9
	3	93.9	85.8	158.7a	126.9a	66.1ab	65.1
	4	97.2	89.4	139.4ab	120.8ab	62.5abc	70.0
	5	99.7	97.8	94.2cde	90.7ab	63.1ab	61.8
	6	85.8	100.7	105.3bcde	89.7ab	49.3bc	46.9
	7	94.1	92.1	129.5abc	113.4ab	79.8a	67.9
	8	82.1	111.6	83.0de	75.7b	64.0ab	58.7
	9	122.1	88.4	107.2bcde	115.9ab	46.1c	58.6
	10	121.2	108.5	78.3e	103.8ab	65.0ab	60.5
	11	102.5	94.4	112.0a	107.8ab	79.6a	____

[1] 1= CORN + atrazine + EPTC
2= CORN + atrazine + metolachlor
3= CORN + atrazine + bentazon
4= CORN + CLOVER + EPTC (plowed)
5= CORN + CLOVER + EPTC
6= ALFALFA + EPTC
7= SOYBEAN + metribuzin + metolachlor
8= SORGHUM/WHEAT
9= BARLEY + bromoxynil + diclofop-methyl
10= Pure stand of yellow nutsedge
11= Bare ground

Where S= spring, F= fall. All means were detransformed and expressed as percentage of the initial population of their respective season. Means followed by the same letter in the same column for each variables evaluated were not significantly different at P= 0.05 as determined by Waller-Duncan K-ratio t test.

weight tended to increase in the intercropped corn. This might be attributed to the fact that only one herbicide (EPTC) was used in the intercropped corn system while for all other corn treatments, combinations of two herbicides such as atrazine plus another one were applied. Alfalfa and sorghum/wheat cropping systems were less effective in suppressing weed growth and allowed the nutsedge tuber population to reach 161 and 118% respectively of the initial population. Total tuber dry weight also increased and reached respectively 135 and 105% of the initial tuber biomass of the alfalfa and the sorghum systems. Average weight per tuber tended to be lower in these systems indicating that tubers produced were smaller. The alfalfa system was significantly different from all of the other cropping systems tested while the sorghum/wheat system was significantly less effective than corn systems 1 and 3.

WINTER KILL

An average of 53% of the yellow nutsedge tuber population died during the winter. Plowing caused a greater decrease in the tuber population. The tuber population from the plowed treatments decreased between 42 and 63% while it decreased by only 28 and 33% respectively in alfalfa and red clover systems which were not plowed. Tillage operations that exposed more tubers to winter cold or other weather extremes caused increases in tuber mortality. Similar observations were reported by Cloutier (1986).

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The average spring population level was about 1450 tubers/m^2 in experiment 1 excluding the yellow nutsedge pure stand while it was 4225 tubers/m^2 in experiment #2 (Appendix 3).

During the second growing season in experiment #1, the alfalfa and wheat system exhibited the same control level on tuber population than the other cropping sytems. Corn intercropped with red clover was significantly less effective than other cropping systems and allowed the spring population to increase by 34%. However, it was not significantly different from cropping system 3 which is corn plus atrazine and bentazon applied postemergence.

The lack of control on nutsedge with intercropped corn might be attributed to the fact that red clover was seeded during very dry weather conditions. The drought lasted almost all summer. Consequently, the establishment of red clover was slow and it was less competitive against yellow nutsedge. In cropping system 3, herbicides were applied postemergence and were also less effective against yellow nutsedge.

Yellow nutsedge population increased by 139% compare to the spring population in the pure stand while it decreased by 70% in the bare ground control. Cloutier (1986) reported that a greater than 80% reduction in the population of tubers was obtained after the second growing season in a bare ground treatment.

In 1988, experiment #2 was in its first growing season. The untreated split was hand weeded and yellow nutsedge population increased in all cropping systems evaluated. Increases between 41 and 180% were recorded. The nutsedge population in the soybean system was significantly higher than corn intercropped with red clover, sorghum and barley systems. The nutsedge population in the intercropped corn (system 4) was significantly lower than corn systems 1 and 3. As expected, the total tuber dry weight was higher in the soybean system. This crop and the corn systems were not efficient against yellow nutsedge alone. In the untreated split, yellow nutsedge was very competitive and produced numerous tubers.

In the treated split, yellow nutsedge population decreased very slightly in three systems: corn systems 1, 4 and 5. The best control was obtained in systems in which EPTC was applied (systems 1, 4, 5, and 6). Drought lasting all summer might have reduced the efficacies of some herbicides and EPTC was possibly less affected. Cultivation helped to control nutsedge. In corn intercropped with red clover (systems 4 and 5), yellow nutsedge growth might have been interrupted by the tilling and raking that occurred immediately before clover seeding and this might explain their lower tuber number. The worst control systems were soybean, sorghum and barley which allowed nutsedge population to increase to 1.5 times of the initial spring population. In most of the cropping systems, tuber biomass declined except when grown with soybean and sorghum. Reductions between 28 and 43 % were recorded but none of the treatments were significantly different. Reductions were more accentuated in tuber weight than tuber number. This might be explained by the drought which increased weight loss due to higher tuber respiration (Salisbury and Ross, 1978). In the pure stand, tuber population tripled while it decreased by 47% in the bare ground.

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After 2 growing seasons in experiment #1, the tuber populations had decreased in all cropping systems evaluated. The reductions ranged between 40 and 92% of the initial population. In the pure stand, the complete lack of yellow nutsedge control allowed the tuber number population to reach 311% of the initial spring 87 population. The final population was 10,000 tubers/m^2 (Appendix 3).

Alfalfa seemed to be less effective than corn, soybean and barley systems. The yellow nutsedge population increased because alfalfa canopy was not developed as well as those cropping systems in the year of establishment. This poor control of yellow nutsedge during the first year of establishment of alfalfa and the lower winter mortality of nutsedge tubers contributed to these differences.

All of the systems evaluated could be alternatives to each of the other systems and it is possible to plan crop rotations with these cropping systems. Comparisons between experiment #1 and #2 in 1988 illustrate the importance of keeping infested fields under continuous pressure to maintain nutsedge population at manageable levels. Herbicide efficacy was severely reduced by the drought in 1988 and the nutsedge population level did not reach a detrimental level within that season in experiment #1 while it did in experiment #2.

3.1.2 Relationship between tuber production and above-ground plant parts of yellow nutsedge and other weeds present.

Data were analysed to determine the relative effects of shoot density and shoot biomass of yellow nutsedge, broadleaf weeds and grasses on tuber production.

Tuber production was found by using these following equations:

TP = FTO - TM   where   TP : tuber production.
FTO: fall tuber number observed.
TM : tuber mortality.

The number of tubers recorded in the fall was the result of the surviving soil tuber bank and the tuber production put together. No distinction could be made between them. Therefore, on the assumption that under perfect control no tubers were produced, the proportion of the initial spring tuber number recorded in the fall in the bare ground was the result of tuber mortality. This proportion was used to calculate the portion of the initial tuber population which died within each plot, for each experiment and each year. Tuber production was then obtained by subtracting this tuber mortality from the observed fall tuber number. When no tubers were produced, the portion of the spring tuber population which died equalled the number of tubers found after the growing season.

The effects of shoot density and shoot biomass of yellow nutsedge, broadleaf weeds and grasses on tuber production were tested for significance through multiple regression analysis and a polynomial was fitted to the significant terms (Table 3.1.3). In 1987, the number and biomass of grasses were not found to have any statistically significant effect on tuber production while shoot density and biomass of yellow nutsedge and broadleaf weeds were found to significantly affect tuber production. In 1988, all the effects were tested for both experiments. In experiment #1, shoot density of broadleaf weeds and grasses and shoot biomass of grasses were not found to have any statistically significant effect on tuber production while shoot density of nutsedge and shoot biomass of nutsedge and broadleaf weeds were found to significantly affect tuber production. In the untreated split of experiment #2, weeds other than yellow nutsedge were hand weeded and the use of multiple regressions were not applicable. However, in the split treatment of experiment #2, shoot density of yellow nutsedge and broadleaf weeds, biomass of broadleaf weeds and the interaction between the density of broadleaf weeds and the biomass of yellow nutsedge significantly affected tuber production while shoot density of grasses and shoot biomass of yellow nutsedge and grasses were not found to have any statistically significant effects. When all experiments and years were pooled, shoot density of broadleaf weeds and grasses and shoot biomass of grasses were not found to significantly affect tuber production.

Table 3.1.3. Regression equations of yellow nutsedge tuber production as a function of shoot density and biomass of yellow nutsedge, broadleaves and grasses.

Experiment number	Regression equations	R^2	Pr.
1. 1987	$TP = 2.00936(YN) - 0.00223(YN)^2 + 3.38768E\text{-}6(YN)^3 + 12.97954(YW) + 59.36641(BN) - 1.01899(BN)^2 + 0.00379(BN)^3 + 73.54673(BW) - 0.44822(BW)^2$	0.98	0.0001
1. 1988	$TP = 0.96283(YN) + 0.00675(YN)^2 - 6.81862(YW) + 0.03812(YW)^2 + 0.76019(BW)$	0.98	0.0001
2. 1988 (split treated)	$TP = 5.4501(YN) - 13.16031(BN) + 1.21980(BN)^2 - 0.01569(BN)^3 - 0.72370(BW) + 0.00607(BN{*}YW)$	0.85	0.0001
All	$TP = 8.19684(YN) - 0.00579(YN)^2 + 1.33303E\text{-}6(YN)^3 - 17.62776(YW) + 0.21254(YW)^2 - 0.21254(YW)^3 - 0.00039(BW) + 1.84162(BW)^2 + 0.365194E\text{-}6(BW)^3 + 0.00664(YN{*}YW) - 0.01942(YN{*}BN) - 0.01798(YN{*}BW) + 0.02708(YW{*}BW)$	0.91	0.0001

Where TP = yellow nutsedge tuber production
YN = shoot density of yellow nutsedge
YW = shoot biomass of yellow nutsedge
BN = shoot density of broadleaves
BW = shoot biomass of broadleaves
GN = shoot density of grasses
GW = shoot biomass of grasses
R^2 = coefficient of determination
Pr = level of significance of the regression

Table 3.1.4. Regression equations of yellow nutsedge tuber production as a function of shoot density of yellow nutsedge.

Experiment number	Regression equations	R^2	Pr.
1. 1987	$\ln(TP+1) = 1.26452 \ln(YN+1)$ or $TP = (YN+1)^{1.26452} - 1$	0.81	0.0001
1. 1988	$\ln(TP+1) = 1.21086 \ln(YN+1)$ or $TP = (YN+1)^{1.21086} - 1$	0.90	0.0001
2t. 1988	$\ln(TP+1) = 1.27593 \ln(YN+1)$ or $TP = (YN+1)^{1.27593} - 1$	0.99	0.0001
2u. 1988	$\ln(TP+1) = 1.29475 \ln(YN+1)$ or $TP = (YN+1)^{1.29475} - 1$	0.99	0.0001

Where t = treated split
u = untreated split
ln = natural log
TP = yellow nutsedge tuber production
YN = shoot density of yellow nutsedge.
R^2 = coefficient of determination
Pr. = level of significance of the regression.

It might be possible to predict fall tuber productions by placing quadrats in field and by counting, harvesting, or weighing all weeds present. But this method would involve several operations like shoot cutting, drying and weighing and would not give an immediate measure of tuber production. An effort has been made to find a simple relation between tuber production and yellow nutsedge shoot density. Significant logarithmic regressions were fitted for each experiment and year to express the relationship between the number of tubers produced and the yellow nutsedge shoot density (Table 3.1.4). A logarithmic equation was fitted on the combined data of both years and both experiments (Figure 3.1.10). The regression curve has a good fit (R^2 = 0.95) and describes relatively well the relation between tuber production and yellow nutsedge shoot density. There are no reports mentioning such a relation. The number of tubers produced increases as shoot density increases. However, in this figure, it seems that a maximum tuber production potential was not reached . This mathematical function provides a tool to predict the tuber production in field and the advantage of this data manipulation is that it gives an immediate measure of tubers produced by counting yellow nutsedge shoots/m^2 in the fall. For example, at 50 shoots/m^2, 2.9 tubers/shoot were produced while at 200 shoot/m^2, the rate of tuber production was 4.2 tubers/shoot. For both growing seasons in experiment #1, the best cropping systems (e.g. those which reduced the spring population) were those where less than 200 shoots/m^2 were present at harvest (Table 3.1.5). Unfortunately, dry weather conditions lasting all summer in 1988 reduced the efficacy of cropping systems in experiment #2 which did not significantly reduced

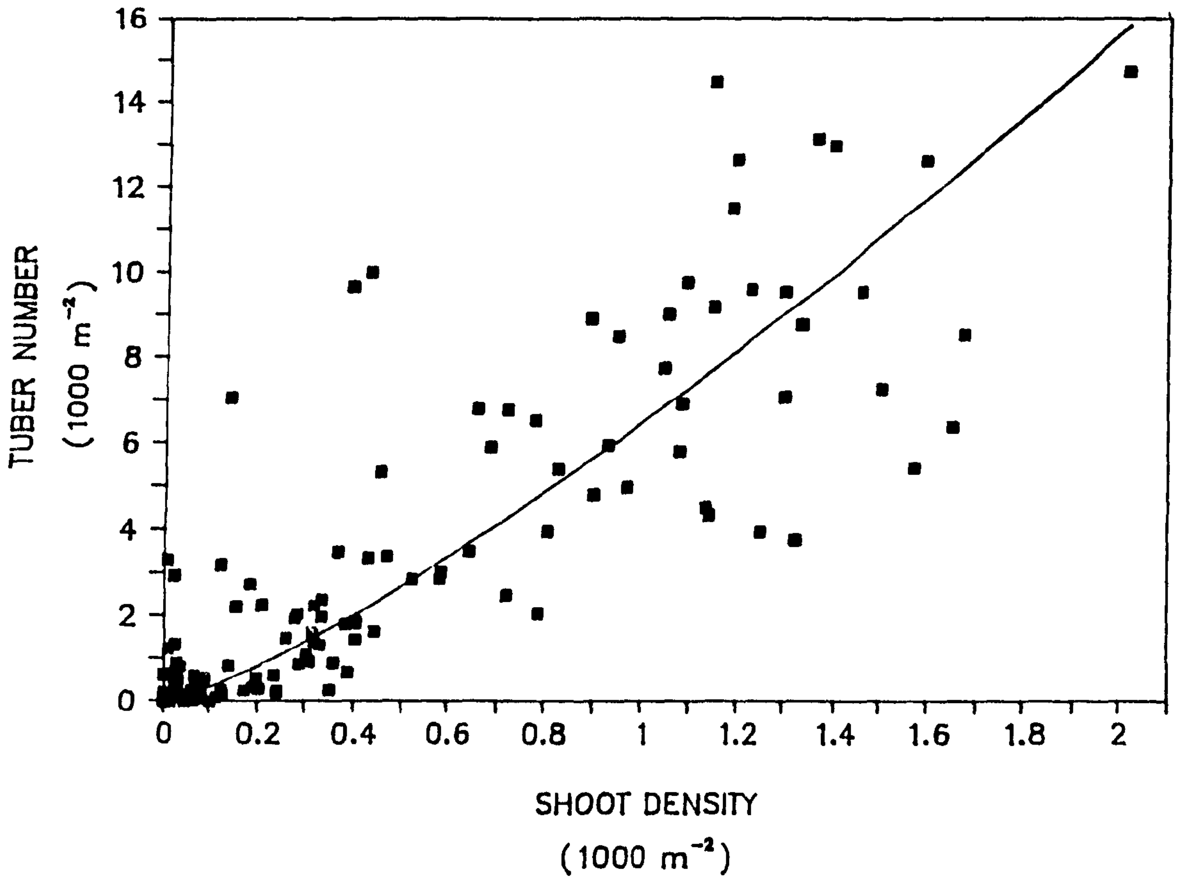

Figure 3.1.10. Yellow nutsedge tuber production as a function of shoot density. Where the regression $\ln(TP + 1) = 1.27061 * \ln(YN + 1)$ or $TP = (YN + 1)^{1.27061} - 1$. ($R^2 = 0.95$, Pr.= 0.0001, TP= tuber production, YN= shoot density, R^2= coefficient of determination, Pr.= level of significance).

Table 3.1.5. Relationship between tuber number and shoot density of yellow nutsedge.

No. of exp.	cropping systems[1]	F87/S87 tuber number (%)	F87/S87 shoot/m^2	F88/S88 tuber number (%)	F88/S88 shoot/m^2
1	1	50.7	34	29.4	65
	2	66.3	6	44.6	8
	3	46.9	13	81.0	126
	4	72.7	200	133.7	239
	5	71.1	215	53.3	81
	6	160.9	338	53.7	187
	7	72.3	3	62.9	47
	8	118.2	529	71.4	159
	9	73.3	126	46.8	125
	10	294.0	944	239.0	1002
2t	1			98.6	269
	2			130.2	205
	3			124.3	452
	4			83.3	344
	5			98.2	338
	6			114.6	326
	7			158.1	585
	8			160.4	952
	9			155.0	1241
	10			275.0	1452
2u	1			252.4	1144
	2			217.2	1107
	3			280.6	1076
	4			140.6	508
	5			211.6	867
	6			238.9	320
	7			342.1	1467
	8			193.2	1344
	9			176.4	1097
	10			367.2	1292

[1] 1= CORN + atrazine + EPTC
2= CORN + atrazine + metolachlor
3= CORN + atrazine + bentazon
4= CORN + CLOVER + EPTC (plowed)
5= CORN + CLOVER + EPTC
6= ALFALFA + EPTC
7= SOYBEAN + metribuzin + metolachlor
8= SORGHUM/WHEAT
9= BARLEY + bromoxynil + diclofop-methyl
10= Pure stand of yellow nutsedge
Where S = spring, F= fall, t= treated, u= untreated.
All tuber means were detransformed and expressed as percentage of the initial population of their respective seasons.

the initial population. Therefore, the number of shoots/m^2 was higher than 200 shoots/m^2 in all cropping systems of experiment #2.

Briefly, based on the results from the first experiment, a shoot density at harvest of less than 200 shoots/m^2 indicated that the treatment was efficient in controlling yellow nutsedge. Producers interested in knowing if their treatments used against nutsedge were efficient could count the number of yellow nutsedge shoots at harvest and calculate if the density was lower than 200 shoots/m^2.

3.2 ECONOMICAL ASPECTS

The economical aspects of using the various cropping systems against yellow nutsedge will be presented in this section. The effect of these alternative control methods on product quality and crop yield will be discussed first followed by the benefit/cost analysis.

3.2.1 Effect on product quality and on crop yield

Yellow nutsedge can reduce the quality of produce and crop yield but adequate integrated weed management might prevent it (Keeley, 1987). However, a producer's decision to control this weed is influenced by many uncertainties such as: the likely level of nutsedge infestation (this occurs because the decision to control it is often made before the tubers germinate and produce visible shoots); the effectiveness of control (related to weather conditions); the reinvasion risk and the crop sensitivity (Auld *et al.*, 1987; Miller, 1982). In this experiment, as a farmer, decisions were made to control yellow nutsedge and the effect on product quality and on crop yield have been taken into consideration.

C.P.V.Q. trials were used as reference to compare yield and quality within each crop harvested. Results from C.P.V.Q. variety trials are obtained under optimum crop growth conditions (i.e. appropriate soil, adequate fertilization and good weed control) but they do not necessarily reflect the reality of on farm production. Weeds cannot be perfectly controlled without considering implied cost. However, an effort was made to emulate an average farm.

The effects of yellow nutsedge management on product quality and crop yield are regrouped according to crops and will be presented within the following parts: silage corn, forage, soybean, sorghum and cereals.

SILAGE CORN

In 1987, corn yields obtained in the experiment were greater than the average ones reported from the C.P.V.Q. variety trials (Table 3.2.1). Percentage of moisture at harvest was higher but conformed to the norm which indicate that corn plants should not have less than 30% of dry matter because silage quality would be directly influenced by the percentage of dry matter of the crop sitting in the silo (C.P.V.Q., 1984). However, the harvest index was lower than the ones from C.P.V.Q. variety trials. This may be explained by wet weather conditions in 1987 which promoted vegetative growth of corn. In that year, corn plants grew to three meters in height without exibiting any mineral deficiency symptoms. Corn intercropped with red clover provided yield, percentage of dry matter, and a harvest index comparable to other corn systems. Red clover appears to have

Table 3.2.1. Crop yield and product quality in the corn systems.

No. of exp.	Corn system[1]	Dry matter yield (ton/ha)	% of moisture at harvest	Harvest index (%)
1-87	1	14.7	66.9	46.2
	2	14.8	68.1	48.3
	3	14.9	67.8	46.4
	4	15.4	65.3	49.8
	5	16.0	65.4	47.8
	$LSD_{0.05}$	N.S.	N.S.	N.S.
1-88	1	13.2	66.5	34.5
	2	15.2	61.2	46.9
	3	12.1	65.7	37.6
	4	11.2	65.6	40.0
	$LSD_{0.05}$	1.6	N.S.	N.S.
2-88u	1	4.6	75.2	37.4
	2	5.5	71.8	39.8
	3	4.8	75.2	35.2
	4	8.7	69.3	36.8
	5	10.2	64.6	46.9
	$LSD_{0.05}$	3.7	N.S.	N.S.
2-88t	1	13.1	66.0	38.5
	2	12.2	65.1	40.2
	3	10.9	64.8	50.3
	4	8.9	70.4	30.4
	5	10.5	70.7	22.2
	$LSD_{0.05}$	N.S.	N.S.	15.2
C.P.V.Q. variety trials (2700 H.U.) (COOP 2645)				
	1987	13.1	57.3	56.3
	1988	13.1	67.4	51.7

Where u= untreated split, t= treated split,
ton= metric ton, H.U.= heat unit,
N.S.= not significant at 0.05 level.

[1] 1= atrazine + EPTC
2= atrazine + metolachlor
3= atrazine + bentazon
4= clover + EPTC (fall plowed)
5= clover + EPTC

competed little with corn since there was no yield reduction. This combination actually tended to produce better yield although yellow nutsedge and other weeds were more abundant than in other corn systems (Table 3.2.2). Growing conditions in 1987 were exceptionally good for the promotion of crop growth and the avoidance of weed competition while soil herbicides were well incorporated by rain and their efficiency was enhanced.

In 1988, only corn yield from systems 1 and 2 of experiment #1 and from system 1 of the treated split of experiment #2 were higher or equivalent to C.P.V.Q. trials (Table 3.2.1). The difference with the previous year might be attributed to the drought which lasted most of the summer and which was accentuated by the sandy soil at the experimental site. Preplant incorporated herbicides (systems 1 and 2) seemed to perform better than postemergence herbicides (system 3). The number of yellow nutsedge and other weeds were higher in this system (Table 3.2.2). Also, the crop was slightly injured by the postemergence herbicides because corn was stressed by the drought. The lower yield of corn intercropped with red clover (system 4 and 5) compared to other corn systems was probably due to greater competition for water (Table 3.2.1). Yellow nutsedge and other weeds were also more abundant in these systems (Table 3.2.2). The same trends were observed for both experiments but yields were lower in experiment #2 because it had a higher yellow nutsedge population level and therefore, it required a greater effort to control it or to decrease its density.

Table 3.2.2. Plant density and above-ground biomass in the corn systems.

No. of exp.	corn system[1]	Density (shoots/m^2)				Above-ground biomass (g/m^2)[2]			
		clover	nutsedge	broadleaves	grasses	clover	nutsedge	broadleaves	grasses
1-87	1		33.8	7.1	6.2		1.78	0.58	0.73
	2		6.2	5.3	0.9		1.25	0.08	0.00
	3		13.3	3.6	87.1		0.65	0.60	35.68
	4	255.1	200.0	111.1	49.8	6.33	17.31	1.17	2.49
	5	225.8	215.1	89.8	29.3	4.20	15.23	7.00	1.30
	$LSD_{0.05}$	N.S.	64.0	25.0	49.3	N.S.	7.63	3.43	16.75
1-88	1		65.1	6.4	16.0		9.89	1.77	2.98
	2		7.5	4.3	8.5		1.86	13.38	0.52
	3		125.9	30.9	38.4		22.73	63.73	9.26
	4	87.5	238.9	17.1	22.4	0.85	53.10	122.83	11.41
	$LSD_{0.05}$		83.4	N.S.	N.S.		17.99	N.S.	N.S.
2-88u	1		1144.0	0.0	0.0		268.38	0.00	0.00
	2		1106.7	0.0	0.0		262.02	0.00	0.00
	3		1076.0	0.0	0.0		226.37	0.00	0.00
	4	105.3	508.0	0.0	0.0	2.19	167.95	0.00	0.00
	5	34.7	866.7	0.0	0.0	0.56	264.14	0.00	0.00
	$LSD_{0.05}$	N.S.	277.4			N.S.	71.23		
2-88t	1		269.3	9.3	10.7		75.38	0.59	4.12
	2		205.3	10.7	0.0		66.06	0.54	0.00
	3		452.0	24.0	17.3		139.65	20.60	22.90
	4	101.3	344.0	40.0	2.7	3.64	46.84	21.85	0.08
	5	146.6	338.7	42.7	0.0	4.41	81.14	66.67	0.00
	$LSD_{0.05}$	N.S.	N.S.	N.S.	13.2	N.S.	N.S.	N.S.	15.05

Where u= untreated, hand-weeded for broadleaves and grasses, t= treated,
N.S.= not significant at 0.05 level.

[1] 1= atrazine + EPTC
2= atrazine + metolachlor
3= atrazine + bentazon
4= clover + EPTC (fall plowed)
5= clover + EPTC

[2] 100% dry matter

In the untreated split of experiment #2, corn yields of the three first systems were reduced by more than 50% compared to the treated split (Table 3.2.1). Corn without weed control was not competitive against yellow nutsedge and therefore, most of the corn plants were small (often less than one meter) with white, small, soft and aborted grains. Corn yields from system 4 and 5 which were intercropped with red clover were similar whether they were treated or not. Both treatments were rotovated between corn rows prior to clover seeding, which seems to have reduced yellow nutsedge competition and might be similar to cultivation. Despite the fact that the management of corn systems 4 and 5 were identical during the first growing season, corn yield tended to be greater in system 5 than in system 4. Density and biomass of yellow nutsedge were significantly higher in the untreated split of system 5 (Table 3.2.2). In the treated split, the broadleaf weeds tended to be larger in system 5 than in system 4. This might be explained by unequal soil texture and fertility across the field.

FORAGE

C.P.V.Q. variety trials cannot be used as reference to compare forage yields since their yields are expressed as percentage of one variety of alfalfa or red clover. Provincial means established by "Régie des assurances agricoles du Québec" were used.

In both years of establishment, alfalfa (cropping system 6) was cut only once and both cuts gave similar yields which were lower than provincial means (Table 3.2.3). However, in 1987, alfalfa quality was better since yield was composed of 58% of alfalfa while in 1988, it was only composed of 24% of alfalfa in the treated split of experiment #2. The lack of water was probably the main reason for the reduction in alfalfa growth. In the untreated split, yield was slightly lower and was mainly composed of yellow nutsedge. Density of alfalfa was also reduced compared to the treated split.

In Table 3.2.4, plant analysis revealed that the percentage of crude protein was higher in alfalfa than in yellow nutsedge which has a crude protein contents similar to cereal (C.P.V.Q., 1986). The percentage of calcium and magnesium was less in the yellow nutsedge plant than in the alfalfa plant while phosphorus contents remained the same in both species. Total digestible nutrients, net energy of lactation, gain or maintenance recorded for alfalfa and yellow nutsedge were similar. Fiber contents was also the same in both species.

The percentage of crude protein was higher in alfalfa from the untreated split than from the treated split while the inverse phenomenon was observed for yellow nutsedge (Table 3.2.4). The percentage of crude protein of forages is related to the maturity of the plant (C.P.V.Q., 1986). Yellow nutsedge which is a monocotyledon and alfalfa which is a dicotyledon did not reach the same stage of maturity at the same time (C.P.V.Q., 1986; Heat *et al.*, 1985). In the untreated

Table 3.2.3. Crop yield, botanical composition and plant density in the forage systems.

No. of exp.	CROP	CUT	YIELD 100%d.m. (ton/ha)	Botanical composition (%)[1]				Density (shoots/m²)			
				crop	nutsedge	broadleaves	grasses	crop	nutsedge	broadleaves	grasses
1-87	alfalfa	1	2.8	58.1	25.9	12.6	3.4	314.7	833.1	87.5	89.6
1-88	alfalfa	1	4.6	98.3	0.2	1.5	0.0	614.4	150.4	17.1	3.2
		2	3.0	99.2	0.6	0.1	0.0	702.9	196.3	65.1	34.1
		3	2.4	94.5	4.3	0.3	0.9	643.2	186.7	25.6	84.3
	red	1	0.8	85.9	0.3	13.6	0.1	403.2	163.2	69.3	32.0
	clover	2	1.7	67.7	0.6	31.4	0.3	602.7	83.2	90.7	24.5
2-88u	alfalfa	1	2.4	6.7	93.3	0.0	0.0	233.3	2046.7	0.0	0.0
2-88t		1	2.9	24.1	22.9	53.0	0.0	336.0	648.0	54.7	0.0
PROVINCIAL MEANS[2]											
	hay	1 cut	3.5								
		2 cuts	6.5								
		3 cuts	8.0								

Where u= untreated split, t= treated split, ton= metric ton.

[1] 100% dry matter.
[2] Régie de l'assurance agricole du Québec.

Table 3.2.4. Forage analysis.

No. of exp.	cut	analysed crop/weed	dry matter (%)	N.E. lact. (MCal/kg)	crude protein (%)	Ca (%)	P (%)	Mg (%)	fiber A.D.F. (%)	T.D.N (%)	N.E. gain (MCal/kg)	N.E. m. (MCal/kg)
1-87	1	Alfalfa	100	1.18	16.1	1.20	0.33	0.19	39.8	54.1	0.58	1.28
		Nutsedge	100	1.17	11.2	0.48	0.46	0.14	40.1	53.8	0.57	1.27
		Broadleaves	100	1.13	16.3	1.78	0.42	0.44	42.1	52.1	0.53	1.23
		Grasses	100	1.24	15.4	0.43	0.38	0.18	37.5	56.1	0.62	1.32
		C.F.S.[1]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-88	1	Alfalfa	100	1.28	14.9	1.07	0.18	0.19	35.9	57.4	0.65	1.35
		C.F.S.	100	1.17	12.6	0.99	0.19	0.18	40.5	53.5	0.56	1.26
	2	Alfalfa	100	1.19	18.0	1.12	0.27	0.21	39.1	55.0	0.58	1.28
		C.F.S.	100	1.20	17.3	1.14	0.27	0.21	39.0	54.8	0.59	1.29
	3	Alfalfa	100	1.34	17.2	1.18	0.26	0.19	33.1	59.8	0.70	1.40
		C.F.S.	100	1.34	18.2	1.17	0.26	0.19	33.0	59.9	0.71	1.41
	1	Red clover	100	1.40	20.4	1.70	0.22	0.37	23.6	68.0	0.88	1.58
		C.F.S.	100	1.40	20.9	1.61	0.27	0.35	29.0	63.3	0.78	1.48
	2	Red clover	100	1.40	17.3	1.41	0.23	0.31	31.0	61.6	0.74	1.44
		C.F.S.	100	1.39	15.5	1.36	0.26	0.31	31.0	63.1	0.75	1.45
2-88u	1	Alfalfa	100	1.3	18.1	1.51	0.31	0.27	35.2	58.0	0.66	1.36
		Nutsedge	100	NA	9.8	0.75	0.25	0.15	31.1	NA	NA	NA
		C.F.S.	100	NA	11.4	0.96	0.29	0.22	33.7	NA	NA	NA
2-88t	1	Alfalfa	100	1.29	16.9	1.61	0.29	0.26	35.5	57.7	0.66	1.36
		Nutsedge	100	NA	12.0	0.70	0.26	0.18	34.0	NA	NA	NA
		C.F.S.	100	1.36	16.8	1.40	0.32	0.36	32.6	60.2	0.71	1.41

[1]Combined forage sample.
Where NA= not available, u= untreated split, t= treated split,
N.E. lact.= net energy for lactation, N.E. gain = net energy for gain,
N.E. m.= net energy for maintenance, T.D.N.= total digestible nutrients,
A.D.F.= acid-detergent fiber.

split, yellow nutsedge density was greater than in the treated split while alfalfa density was greater in the treated split than in the untreated split (Table 3.2.3). Therefore, the maturity of the plants which were at low density might be delayed due to interspecific competition. At harvest time, alfalfa plants in the untreated split were less developed than in the treated split. Nutsedge plants in the treated split were smaller than in the untreated split. In the combined forage sample, the percentage of crude protein, calcium and magnesium was higher when the split was treated. Based on these results, the presence of yellow nutsedge appeared to have reduced the quality of the alfalfa crop.

In 1988, in the first experiment, alfalfa was in its second year and 3 cuts were taken, giving a higher yield than the provincial means (Table 3.2.3). Alfalfa was almost exclusively the main component of the stand. Yellow nutsedge plants were still present but at a lower level. Percentage of crude protein contained in combined forage sample was above average in the last two cuts (Table 3.2.4).

Red clover (system 5) had a very poor yield even though it was cut twice but its quality was superior to alfalfa (Table 3.2.3, 3.2.4). At the first cut, red clover had less fiber and had better percentage of crude protein than alfalfa. At the second cut, crop density had increased while nutsedge density had decreased. Red clover had higher energy values and its nutrients were better balanced than alfalfa. The problem with red clover is that it is a short lived perennial. This crop should not be kept more than two years and could be excellent in rotation with corn but the yield is too low. Planting red clover at corn planting might improve red clover establishment and increase its density in the fall. However, weed growth would not be interrupted as when red clover was planted in this experiment, therefore a mowing might be required between corn rows for weed control. Another possibility might be to plant a cereal on the row space occupied previously by corn plants after corn harvest. Since approximately one third of the area was lost due to corn rows the previous year, this practice might increase forage yield and the combination of red clover and cereal would make it easier to dry. Red clover alone is difficult to harvest as hay because it contains a high water level. However, a means should be found to remove the corn stalks left by the forage harvester.

SOYBEAN

In 1987, soybean yield was lower than C.P.V.Q. cultivar trials but very close to provincial means (Table 3.2.5). Yellow nutsedge was well controlled because of the soybean canopy which covered the ground well and shaded the yellow nutsedge that escaped chemical control. Broadleaf weeds were not numerous but they were large and probably reduced soybean yield and contaminated the harvest. Some postemergence applications of herbicide would be necessary to avoid growth of broadleaf weeds during the growing season. Soybean is sensitive to many herbicides. Their judicious use is important in order

Table 3.2.5. Crop yield, weed density and above-ground biomass in the soybean system.

No. of exp.	YIELD[1] (ton/ha)	Density (shoots/m²)			Above-ground biomass (g/m²)[1]		
		nutsedge	broadleaves	grasses	nutsedge	broadleaves	grasses
1-87	2.0	2.7	2.7	0.0	0.47	88.20	0.00
1-88	0.9	46.9	14.9	57.6	27.86	688.58	51.96
2-88u	0.09	1466.7	0.0	0.0	325.53	0.00	0.00
2-88t	0.6	585.3	16.0	0.0	226.69	713.39	0.00
C.P.V.Q. variety trials (+2500 H.U.) (MAPLE ARROW)							
	4.7						
PROVINCIAL MEANS[2]							
	2.1						

Where u= untreated split, t= treated split, ton= metric ton, H.U.= heat unit.

[1]100% dry matter.
[2]Régie de l'assurance agricole du Québec.

Table 3.2.6. Height, botanical composition and plant density in the sorghum system.

No of exp.	height (cm)	Botanical composition (%)[1]					Density (shoot/m2)				
		sorghum	YN	BL	G	BL+G	sorghum	YN	BL	G	BL+G
1-87	170.8	78.8	7.8	NA	NA	13.4	181.3	529.3	NA	NA	180.0
2-88h	96.8	47.8	52.2	0.0	0.0	0.0	90.7	1344.0	0.0	0.0	0.0
2-88	93.5	29.8	35.3	34.8	0.1	34.9	81.3	952.0	52.0	1.3	53.3

Where NA= not available, h= hand-weeded for broadleaves and grasses,
YN= yellow nutsedge, BL= broadleaves, G= grasses.

[1]100% dry matter.

not to injure the crop.

In 1988, soybean germination was very low due to the drought. In experiment #1, yellow nutsedge remained at a low density despite the fact that herbicides did not work as well as expected. This is probably due to the excellent yellow nutsedge repression in 1987 and to competition by the other weeds in 1988. Broadleaf weeds were more numerous than in 1987 and were larger, which reduced yield. In experiment #2, in the treated split, yellow nutsedge density was very high and broadleaf weeds were very large. Yield was lower than in experiment #1 because yellow nutsedge was more numerous and probably competed more with soybean. In the untreated split, yellow nutsedge, which was 2.5 times more numerous than in the treated split, caused a 85% yield reduction compared to that obtained in the treated split.

In 1988, no crop was harvested by machine due to poor yield and to the numerous and large broadleaf plants in the treated plots. Soybean was harvested by hand to obtain an idea of its yield and for comparison between the treated and untreated splits.

SORGHUM

In 1987, the sorghum crop was tall and competed relatively well with nutsedge (Table 3.2.6). However, in 1988, sorghum did not grow as well as in 1987 and its height was reduced by half. At the beginning of the 1988 season, sorghum had some difficulties to become established because it was seeded during the drought and consequently, its density was reduced.

Sorghum was seeded on May the 29th in 1987 and June the 1st in 1988 and was cut at the beginning of August. A first cut at the begining of July might reduce yellow nutsedge and other weed growth. The chopped plants could be harvested or left on the soil to act as a mulch. An extra cut means a higher cost and its benefit remains to be evaluated. However, green manure would increase organic matter in the soil and improve soil structure which is very important.

CEREALS

Yields from harvested cereal were considerably lower than the values reported from the C.P.V.Q. variety trials (Table 3.2.7). It might be attributed to the seeding rate which was 120 kg/ha instead of the 160 kg/ha used by the C.P.V.Q. (1988) which are based on the % of the seed germination of the barley (Laurier) and the winter wheat (Frankenmuth). It might also be due to the

Table 3.2.7. Crop yield, height and product quality in the cereal systems.

No. of exp.	crop	yield[1] (ton/ha)	height (cm)	1000 grain weight (g)	hectoliter weight (g)	kernel (%)	whole grain (%)	hull (%)
1-87	barley	2.1	88.4	38.6	56.7			
1-88	barley	1.5	53.7	38.1	57.6			
1-88	wheat	3.3	84.5	37.8	80.9	98.42	1.57	0.02
2-88u	barley	1.9	56.7	44.3	59.4			
2-88t	barley	1.0	50.9	36.2	54.4			
C.P.V.Q. variety trials (means 87-88)								
	barley (Laurier)	3.8	80.0	42.2	60.6			
	wheat (Frankenmuth)	4.9	93.0	37.3	75.5			
PROVINCIAL MEANS[2]								
	barley	3.1						
	wheat	3.2						

Where u= untreated split, t= treated split, ton= metric ton.

[1]100% dry matter.
[2]Régie de l'assurance agricole du Québec.

seeding date which was later than the optimum date. Also, the sandy soil of the experimental area is not the ideal soil for cereals.

In 1987, barley plants were taller than that reported from the C.P.V.Q. variety trials but grains were lighter (Table 3.2.7). There was some lodging in the middle of July due to a violent rain fall which probably reduced yield and quality of this cereal. In 1988, the quality was also less than that of the C.P.V.Q. variety trials. Dry weather conditions were probably responsible for these differences. In experiment #2, barley from the untreated split had a better quality than in the treated split. Postemergence herbicides applied to control broadleaf weeds and grasses in barley injured the crop which was stressed by the drought and therefore, yields and quality of the treated split were reduced.

Despite the fact that some ice spots were present, winter wheat had a higher yield than the provincial means (Table 3.2.7). It also showed a quality of grain with 1000 grain weight and hectoliter weight similar to the C.P.V.Q. variety trials results. More than 98% of the harvest were kernels. Winter wheat has usually a better yield than spring wheat cereal. The rotation sorghum-winter wheat could be profitable if winter wheat which was harvested the second year provided enough yield to cover the variable costs accumulated since sorghum seeding. Winter wheat yield might have been better on a rich soil with higher pH and, in a site well covered by snow during the winter and protected from wind.

3.2.2 Benefit/cost analysis

The decision to control weeds in a field should ideally be made in the context of the overall management strategy for the farm, and the aims and objectives in managing the farm (Auld *et al.*, 1987). The goal of the majority of producers is profit maximization. Therefore, choosing the best cropping systems for control of yellow nutsedge will depend largely on the costs and the gross margin resulting from each of them. The cropping systems will be compared and discussed in these two following parts: fixed and variable costs, gross margin and yield equivalence table.

Fixed and variable costs

The fixed costs of a farm operation such as: land costs, hired labour, depreciation, loan interest, taxes and, overhead expenses (upkeep, electricity, phone, book-keeping, insurances) are not taken into account because they vary too much from one farm to another. These costs are constant within the same farm regardless of the crop and they do not add anything to yield or product quality. The only factors which could improve yield or yield quality are included in variable costs: seed quality, preparation of seedbed, seeding rate, optimal fertilization, adequate protection against diseases and weeds etc.

Variable costs of production accumulated in experiment #1 and #2 have been grouped together in Appendix 4. The first year of each experiment, corn had the greatest cost of production while alfalfa was the cheapest to produce.

The second year of experiment #1, corn was still more expensive to produce while wheat and red clover had the lowest costs because the establishment costs were assumed the first year. Alfalfa was less expensive to produce than in the year of establishment but some fertilizers were applied, therefore increasing costs.

The greatest proportion of variable costs came from fertilizers and lime but the costly systems did not necessarily have the least gross margin. In general, prices increased from 1987 to 1988 and consequently costs also. However, by comparing the two years of experiment #1, total cost decreased from 1987 to 1988. This is due mostly to the application of lime the first year and not the second year. Liming once for several years is recommended and reduces operational costs.

Gross Margin

This was obtained by subtracting the variable costs from the crop value, where crop value is the crop price multiplied by the crop yield. The crop price is assumed to have three levels: low, medium and high (Appendix 5). The medium level represented the current crop price established within its respective year of production. The high and low levels had 15% added or subtracted respectively from the medium level. The range obtained this way should reflect most crop price variations within each experiment year. Crop yield had also three levels (Appendix 6). The medium yield was the yield obtained in this experiment and is expressed on its respective dry matter basis. The 95% confidence interval was either added or subtracted from this yield. The interval included between low and high yield varied depending on yield uniformity between replications. The gross margin had often a negative value when price or yield decreased. Therefore, the risk of losing money is greater in such systems if price or yield are low. In 1988, the difference between low and high yields were clearly greater and were probably due to the type of soil combined with the drought. Soil texture was not even in the field and probably accounted for the high variability in crop yield.

It could be profitable to treat yellow nutsedge in a field provided that the cost of doing so is less than the value of the product obtained with the treatment. In 1987, in experiment #1, all corn systems including intercropped corn were more profitable than the others (Table 3.2.8). Corn value was more than enough

Table 3.2.8. Gross margin as a function of crop yield and price in experiment #1 in 1987.

PRODUCT	PRICE[1]	YIELD[2] low	YIELD[2] med	YIELD[2] high
1-corn silage	low	448.87	588.00	727.12
	med	620.45	783.77	947.10
	high	792.03	979.55	1167.07
2-corn silage	low	484.61	615.62	746.62
	med	659.17	812.95	966.74
	high	833.72	1010.29	1186.86
3-corn silage	low	619.70	646.37	673.05
	med	813.35	844.66	875.98
	high	1007.00	1042.95	1078.91
4-corn silage	low	261.68	546.78	831.87
	med	416.84	751.52	1086.20
	high	571.99	956.26	1340.52
5-corn silage	low	387.11	613.14	839.18
	med	561.79	827.13	1092.48
	high	736.46	1041.12	1345.78
6-alfalfa hay	low	-157.83	-62.31	33.22
	med	-128.87	-16.07	96.74
	high	-99.91	30.18	160.26
7-soybean grain	low	9.80	166.85	323.91
	med	74.06	259.04	444.02
	high	138.32	351.22	564.12
8-sorghum green manure	low	-523.12	-523.12	-523.12
	med	-523.12	-523.12	-523.12
	high	-523.12	-523.12	-523.12
9-barley grain	low	-236.47	-170.64	-104.81
	med	-213.35	-136.41	-59.48
	high	-188.57	-99.74	-10.91

[1]see appendix 5.
[2]Gross margin values were calculated with a greater crop yield precision than the values shown in appendix 6.

to cover the higher costs of production. Soybean gross margin at medium price and yield corresponded to the lowest gross margin which could be obtained with corn intercropped at the lowest price and yield. There were no comparisons possible between alfalfa and corn since alfalfa was not profitable enough in the first year of establishment. The reasons for this have been already discussed. Barley was not profitable either, even under high price and high yield. Sorghum could not be profitable because no crop was harvested and consequently, there was no crop value in monetary terms and the values in Table 3.2.8 represent variable costs only. However, it is difficult to give a value either to green manure or to the long-term benefit of legume rotation or intercropping on soil conservation, but these values will positively contribute to following crops.

In 1988, corn remained the most profitable crop in experiment #1 (Table 3.2.9). However, alfalfa offered a gross margin equivalent or superior to corn gross margin even at low yield and low price. The risk of losing money was more accentuated in the corn intercropped with the red clover system because of the additional cost of the red clover seeding with no improved gross margin if yield was low (negative value of gross margin). Although red clover had a lower yield than alfalfa in its first year of establishment, the high forage price in 1988 made red clover profitable. Gross margin obtained from wheat cropping was good but because of costs incurred in 1987, the net gross margin after two year was relatively low. As in 1987, barley was risky and not profitable but at least, there was some positive gross margin at medium yield and price. From 1987 to 1988,

Table 3.2.9. Gross margin as a function of crop yield and price in experiment #1 in 1988.

		YIELD[2]		
PRODUCT	PRICE[1]	low	med	high
1-corn silage	low	310.37	729.40	1148.42
	med	454.91	948.76	1442.61
	high	599.45	1168.12	1736.80
2-corn silage	low	506.62	941.89	1377.17
	med	682.88	1195.88	1708.88
	high	859.13	1449.86	2040.59
3-corn silage	low	303.16	677.39	1051.63
	med	437.87	878.93	1319.99
	high	572.58	1080.47	1588.35
4-corn silage	low	-178.61	451.75	1082.10
	med	-105.05	637.87	1380.79
	high	-31.48	824.00	1679.49
5-clover hay	low	155.39	192.60	229.81
	med	191.32	235.09	278.86
	high	227.24	277.58	327.92
6-alfalfa hay	low	740.39	917.95	1095.52
	med	909.63	1119.18	1328.73
	high	1078.86	1320.40	1561.94
7-soybean grain	low	-201.47	-46.46	108.56
	med	-181.90	0.84	183.58
	high	-162.77	47.06	256.90
8-wheat grain	low	403.10	538.33	673.57
	med	478.91	637.59	796.27
	high	554.73	736.85	918.97
9-barley grain	low	-194.62	-21.68	151.26
	med	-185.77	18.25	222.27
	high	-176.91	58.18	293.28

[1]see appendix 5.
[2]Gross margin values were calculated with a greater crop yield precision than the values shown in appendix 6.

the barley price increase made it profitable although its yield was lower due to drought and the use of postemergence herbicides. Soybean was harvested by hand and the result could not be considered since farm machinery would not have been able to harvest it due to the numerous large broadleaf weeds present in the field. These results were presented to provide an idea of the gross margin of this crop even though its yield was very low.

In experiment #2 which had a greater yellow nutsedge density than experiment #1, the risk to lose money was higher and the gross margin was lower (Table 3.2.10). Despite the fact that at low yield, there was a monetary loss, corn gave the most certain income. By maximizing yield and price, intercropped corn was more profitable in the untreated split than in the treated split but income was more uncertain if yield was low (Table 3.2.11). Alfalfa was more profitable treated than untreated. Barley was not profitable except when it competed alone with yellow nutsedge without any herbicide use.

Table 3.2.10. Gross margin as a function of crop yield and price in the untreated split of experiment #2 in 1988.

		YIELD[2]		
PRODUCT	PRICE[1]	low	med	high
1-corn silage	low	-519.47	-113.93	291.62
	med	-515.13	-37.17	440.79
	high	-510.79	39.59	589.97
2-corn silage	low	-624.42	-27.56	569.29
	med	-638.92	64.62	768.06
	high	-653.22	156.80	966.82
3-corn silage	low	-169.87	-99.05	-28.23
	med	-103.10	-19.64	63.83
	high	-36.34	59.78	155.89
4-corn silage	low	-192.37	159.23	510.83
	med	-110.63	303.76	718.15
	high	-28.89	448.28	925.46
5-corn silage	low	-351.68	310.52	972.71
	med	-300.70	479.74	1260.19
	high	-249.72	648.97	1547.67
6-alfalfa hay	low	-79.18	-39.72	-0.26
	med	-39.13	7.44	54.01
	high	0.92	54.59	108.27
7-soybean grain	low	-317.61	-302.72	-287.82
	med	-317.15	-299.59	-282.03
	high	-316.69	-296.53	-276.37
8-sorghum green manure	low	-431.41	-431.41	-431.41
	med	-431.41	-431.41	-431.41
	high	-431.41	-431.41	-431.41
9-barley grain	low	-177.72	-12.13	153.46
	med	-157.36	37.99	233.34
	high	-136.99	88.11	313.21

Where u= untreated split.
[1]see appendix 5.
[2]Gross margin values were calculated with a greater crop yield precision than the values shown in appendix 6.

Table 3.2.11. Gross margin as a function of crop yield and price in the treated split of experiment #2 in 1988.

		YIELD[2]		
PRODUCT	PRICE[1]	low	med	high
1-corn silage	low	405.88	594.34	782.80
	med	591.37	813.48	1035.60
	high	776.85	1032.62	1288.39
2-corn silage	low	46.87	524.04	1001.22
	med	164.91	727.30	1289.69
	high	282.96	930.56	1578.15
3-corn silage	low	-81.40	435.16	951.72
	med	8.53	617.33	1226.13
	high	98.45	799.50	1500.54
4-corn silage	low	-82.09	106.08	294.26
	med	32.60	254.38	476.15
	high	147.29	402.67	658.05
5-corn silage	low	-188.23	267.87	723.97
	med	-94.81	442.74	980.29
	high	-1.39	617.61	1236.60
6-alfalfa hay	low	-64.98	-16.72	31.53
	med	-16.15	40.79	97.74
	high	32.67	98.31	163.95
7-soybean grain	low	-381.58	-243.58	-105.57
	med	-376.57	-213.88	-51.20
	high	-371.67	-184.86	1.94
8-sorghum green manure	low	-431.41	-431.41	-431.41
	med	-431.41	-431.41	-431.41
	high	-431.41	-431.41	-431.41
9-barley grain	low	-244.01	-197.75	-151.49
	med	-224.90	-170.32	-115.75
	high	-205.78	-142.90	-80.01

Where t= treated split.
[1]see appendix 5.
[2]Gross margin values were calculated with a greater crop yield precision than the values shown in appendix 6.

Yield equivalence table

Different tables were generated to show the crop yields equivalent to the same gross margin within each experiment and year (Tables 3.2.12, 3.2.13, 3.2.14). Gross margins of the cropping systems were obtained by subtracting variable cost from product value which was the crop price multiplied by crop yield. These tables could be very useful for farmers who want to know which cropping system will allow them to reach sufficient levels of gross margin. Equivalent yield is horizontally read on the same line as the chosen gross margin. The farmer could use these to find out how much to improve crop yield to get gross margin equivalent to their objective. Bold numbers between brackets indicate the closest value to the provincial means while underlined numbers indicate the average crop yield obtained in this experiment. For example, 29 to 31 tons/ha of corn, or 34 tons/ha of corn intercropped with clover, or 6.2 tons/ha of alfalfa, or 2.5 tons/ha of soybean, or 6.9 tons/ha of barley have to be produced to obtain a gross margin of $300/ha in 1987. Four tons more of corn should be produced when corn is intercropped to be as profitable as corn alone. A yield of 6.2 tons of alfalfa was inconceivable the year of establishment and barley could not be considered mainly because of the lower market price in 1987.

In 1987, it was impossible to obtain a positive gross margin with alfalfa and barley even by using provincial means (Table 3.2.12). Costs were too high in relation to crop prices which were too low. In both experiments in 1988, all

Table 3.2.12. Yield equivalence in experiment #1 in 1987.

EXPERIMENT #1, 1987

CROP. SYSTEM	1	2	3	4	5	6	7	8	9
VAR. COSTS ($/ha)	538	519	494	630	617	318	352	523	374
CROP PRICE ($/ton)	27	27	27	27	27	100	265	NA	97
GROSS MARGIN ($/ha)	(ton/ha)								2.4
0	19.9	19.2	18.3	23.4	22.9	[3.2]	1.3	NA	[3.9]
100	23.6	22.9	22.0	27.1	26.6	4.2	1.7	NA	4.9
200	27.3	26.6	25.7	30.8	30.3	5.2	2.1	NA	5.9
300	31.0	30.3	29.4	34.5	34.0	6.2	[2.5]	NA	6.9
400	34.7	34.0	33.1	[38.2]	[37.7]	7.2	2.8	NA	8.0
500	[38.4]	[37.7]	[36.8]	[41.9]	[41.4]	8.2	3.2	NA	9.0
600	[42.1]	[41.4]	[40.5]	45.6	45.1	9.2	3.6	NA	10.0
700	45.8	45.2	44.2	49.3	48.8	10.2	4.0	NA	11.1
800	49.5	48.9	47.9	53.0	52.5	11.2	4.3	NA	12.1
900	53.2	52.6	51.6	56.7	56.2	12.2	4.7	NA	13.1
1000	57.0	56.3	55.3	60.4	59.9	13.2	5.1	NA	14.2
1100	60.7	60.0	59.0	64.1	63.6	14.2	5.5	NA	15.2
1200	64.4	63.7	62.7	67.8	67.3	15.2	5.9	NA	16.2
1300	68.1	67.4	66.4	71.5	71.0	16.2	6.2	NA	17.3
1400	71.8	71.1	70.1	75.2	74.7	17.2	6.6	NA	18.3
1500	75.5	74.8	73.8	78.9	78.4	18.2	7.0	NA	19.3
1600	79.2	78.5	77.5	82.6	82.1	19.2	7.4	NA	20.3
1700	82.9	82.2	81.3	86.3	85.8	20.2	7.7	NA	21.4
1800	86.6	85.9	85.0	90.0	89.5	21.2	8.1	NA	22.4
1900	90.3	89.6	88.7	93.7	93.2	22.2	8.5	NA	23.4
2000	94.0	93.3	92.4	97.4	96.9	23.2	8.9	NA	24.5
2100	97.7	97.0	96.1	101.1	100.6	24.2	9.3	NA	25.5
2200	101.4	100.7	99.8	104.8	104.3	25.2	9.6	NA	26.5
2300	105.1	104.4	103.5	108.5	108.0	26.2	10.0	NA	27.6
2400	108.8	108.1	107.2	112.2	111.8	27.2	10.4	NA	28.6
2500	112.5	111.8	110.9	115.9	115.5	28.2	10.8	NA	29.6

Where ton= metric ton, NA= non applicable
1= corn + atrazine + EPTC + cultivation
2= corn + atrazine + metolachlor + cultivation
3= corn + atrazine + bentazon + cultivation
4= corn + red clover + EPTC (plowed)
5= corn + red clover + EPTC
6= alfalfa + EPTC
7= soybean + metribuzin + metolachlor
8= sorghum
9= barley
Bold number between brackets= closest value to the provincial means
Underlined number= closest value to the experimental's yield

Table 3.2.13. Yield equivalence in experiment #1 in 1988.

EXPERIMENT #1, 1988

CROP. SYSTEM	1	2	3	4	5	6	7	8	9
VAR. COSTS ($/ha)	499	480	451	591	48	199	311	557	244
CROP PRICE ($/ton)	33	33	33	33	100	120	290	176	151
GROSS MARGIN ($/ha)					(ton/ha)				
0	15.1	14.6	13.7	17.9	0.5	1.7	1.1	3.2	1.6
100	18.2	17.6	16.7	20.9	1.5	2.5	1.4	[3.7]	2.3
200	21.2	20.6	19.7	24.0	2.5	3.3	1.8	4.3	2.9
300	24.2	23.6	22.8	27.0	3.5	4.2	2.1	4.9	[3.6]
400	27.2	26.7	25.8	30.0	4.5	5.0	[2.5]	5.4	4.3
500	30.3	29.7	28.8	33.0	5.5	5.8	2.8	6.0	4.9
600	33.3	32.7	31.9	36.1	[6.5]	6.7	3.1	6.6	5.6
700	36.3	35.8	34.9	[39.1]	7.5	[7.5]	3.5	7.1	6.3
800	[39.4]	[38.8]	[37.9]	[42.1]	8.5	[8.3]	3.8	7.7	6.9
900	[42.4]	[41.8]	[40.9]	45.2	9.5	9.2	4.2	8.3	7.6
1000	45.4	44.9	44.0	48.2	10.5	10.0	4.5	8.8	8.2
1100	48.5	47.9	47.0	51.2	11.5	10.8	4.9	9.4	8.9
1200	51.5	50.9	50.0	54.3	12.5	11.7	5.2	10.0	9.6
1300	54.5	54.0	53.1	57.3	13.5	12.5	5.6	10.6	10.2
1400	57.5	57.0	56.1	60.3	14.5	13.3	5.9	11.1	10.9
1500	60.6	60.0	59.1	63.4	15.5	14.2	6.2	11.7	11.5
1600	63.6	63.0	62.2	66.4	16.5	15.0	6.6	12.3	12.2
1700	66.6	66.1	65.2	69.4	17.5	15.8	6.9	12.8	12.9
1800	69.7	69.1	68.2	72.4	18.5	16.7	7.3	13.4	13.5
1900	72.7	72.1	71.2	75.5	19.5	17.5	7.6	14.0	14.2
2000	75.7	75.2	74.3	78.5	20.5	18.3	8.0	14.5	14.9
2100	78.8	78.2	77.3	81.5	21.5	19.2	8.3	15.1	15.5
2200	81.8	81.2	80.3	84.6	22.5	20.0	8.7	15.7	16.2
2300	84.8	84.3	83.4	87.6	23.5	20.8	9.0	16.2	16.8
2400	87.8	87.3	86.4	90.6	24.5	21.7	9.3	16.8	17.5
2500	90.9	90.3	89.4	93.7	25.5	22.5	9.7	17.4	18.2

Where
ton= metric ton
1= corn + atrazine + EPTC + cultivation
2= corn + atrazine + metolachlor + cultivation
3= corn + atrazine + bentazon + cultivation
4= corn + red clover + EPTC (pl wed)
5= red clover
6= alfalfa
7= soybean + metribuzin + metolachlor
8= wheat
9= barley
Bold number between brackets= closest value to the provincial means
Underlined number= closest value to the experimental's yield

Table 3.2.14. Yield equivalence in experiment #2 (treated) in 1988.

EXPERIMENT #2, 1988

CROP. SYSTEM	1	2	3	4	5	6	7	8	9
VAR. COSTS ($/ha)	633	614	585	724	711	336	410	431	350
CROP PRICE ($/ton)	33	33	33	33	33	120	290	NA	151
GROSS MARGIN ($/ha)	(ton/ha)								
							0.7		1.2
0	19.2	18.6	17.7	22.0	21.6	2.8	1.4	NA	2.3
100	22.2	21.6	20.8	25.0	24.6	[3.6]	1.8	NA	3.0
200	25.2	24.7	23.8	28.0	27.6	4.5	2.1	NA	[3.6]
300	28.3	27.7	26.8	31.0	30.6	5.3	[2.4]	NA	4.3
400	31.3	30.7	29.8	34.1	33.7	6.1	2.8	NA	5.0
500	34.3	33.8	32.9	37.1	36.7	7.0	3.1	NA	5.6
600	37.4	36.8	35.9	[40.1]	[39.7]	7.8	3.5	NA	6.3
700	[40.4]	[39.8]	[38.9]	[43.2]	[42.8]	8.6	3.8	NA	7.0
800	43.4	[42.9]	[42.0]	46.2	45.8	9.5	4.2	NA	7.6
900	46.4	45.9	45.0	49.2	48.8	10.3	4.5	NA	8.3
1000	49.5	48.9	48.0	52.3	51.9	11.1	4.9	NA	8.9
1100	52.5	51.9	51.1	55.3	54.9	12.0	5.2	NA	9.6
1200	55.5	55.0	54.1	58.3	57.9	12.8	5.6	NA	10.3
1300	58.6	58.0	57.1	61.3	61.0	13.6	5.9	NA	10.9
1400	61.6	61.0	60.2	64.4	64.0	14.5	6.2	NA	11.6
1500	64.6	64.1	63.2	67.4	67.0	15.3	6.6	NA	12.3
1600	67.7	67.1	66.2	70.4	70.0	16.1	6.9	NA	12.9
1700	70.7	70.1	69.2	73.5	73.1	17.0	7.3	NA	13.6
1800	73.7	73.2	72.3	76.5	76.1	17.8	7.6	NA	14.2
1900	76.8	76.2	75.3	79.5	79.1	18.6	8.0	NA	14.9
2000	79.8	79.2	78.3	82.6	82.2	19.5	8.3	NA	15.6
2100	82.8	82.2	81.4	85.6	85.2	20.3	8.7	NA	16.2
2200	85.8	85.3	84.4	88.6	88.2	21.1	9.0	NA	16.9
2300	88.9	88.3	87.4	91.6	91.3	22.0	9.3	NA	17.6
2400	91.9	91.3	90.5	94.7	94.3	22.8	9.7	NA	18.2
2500	94.9	94.4	93.5	97.7	97.3	23.6	10.0	NA	18.9

Where ton= metric ton, NA= non applicable
1= corn + atrazine + EPTC + cultivation
2= corn + atrazine + metolachlor + cultivation
3= corn + atrazine + bentazon + cultivation
4= corn + red clover + EPTC (plowed)
5= corn + red clover + EPTC
6= alfalfa + EPTC
7= soybean + metribuzin + metolachlor
8= sorghum
9= barley
Bold number between brackets= closest value to the provincial means
Underlined number= closest value to the experimental's yield

cropping systems were profitable when provincial means were used (Tables 3.2.13, 3.2.14). Corn systems and alfalfa in its second year always gave the best gross margins.

By predicting variable costs and crop prices, these tables could be a tool in the farmer's decision making process to choose profitable cropping systems to control yellow nutsedge or to improve gross margins. The best cropping systems which might lead the greatest level of gross margin were the three first corn systems: corn plus atrazine, EPTC and cultivation; corn plus atrazine, metolachlor and cultivation; and corn plus atrazine plus bentazon and cultivation. Their average gross margins were $850/ha.

Chapter 4

CONCLUSION

The objective of this study was to assess the efficacy and economics of nine different cropping systems in controlling yellow nutsedge at the farm level. All cropping systems used were helpful in controlling yellow nutsedge with time.

After two growing seasons in experiment #1, the tuber population had decreased in all cropping systems. The reduction ranged between 40 and 92 % of the initial population. There were no significant differences between cropping systems except for alfalfa which had a significantly greater tuber population than the corn, soybean and barley systems. Yellow nutsedge was reduced to 9% of the initial population under perfect control while it tripled in the pure stand.

After the first growing season in the treated split of experiment #2, only corn intercropped with red clover reduced yellow nutsedge population by a slight average of 9%. When splits were not treated, yellow nutsedge populations increased between 141 to 280% of the initial population in all cropping systems. Dry weather conditions in 1988 reduced the efficacy of the cropping systems especially in experiment #2 where initial tuber population was high.

Effects of above-ground plant parts of yellow nutsedge, broadleaf weeds and grasses on tuber production were significant but differed from year to year. By pooling data from both years and experiments, a relation was found between yellow nutsedge shoot density and the number of tubers produced. This mathematical function provides a tool that can be used to assess the tuber production in the field and in evaluating and planning nutsedge control programs. However, the results obtained in this experiment are specific to one biotype of yellow nutsedge, a type of soil and a microclimate.

Although all cropping systems were about equal in reducing tuber populations within two years, the economic aspect was different. Corn was the most profitable cropping system. However, alfalfa in its second year was as profitable as corn. The least economically advantageous cropping system was barley. When splits were untreated, only corn intercropped with red clover gave a positive gross margin.

Since some tubers remained after two years of continuous pressure on the weed populations, control of yellow nutsedge would still be required in succeeding crops to maintain nutsedge populations at manageable levels. This is suggested in order to prevent detrimental increase in nutsedge population level in cases where herbicide efficacy would be reduced under unfavorable growing conditions such as drought or excessive rain after application. Despite the fact that some systems were less profitable, all of the systems evaluated can be used alternatively and it is possible to plan crop rotations using these cropping systems. The corn systems seemed to be more profitable but continuous corn has resulted in reduced yields where it has been practiced for any length of time. The advantage of crop rotation are difficult to assess economically but are undeniable.

The suggestions for future research are:

- to evaluate other cropping systems such as:

  » corn with other herbicides since atrazine is residual in the soil for over one year and it is difficult to use it in rotation;

  » corn intercropped with legumes with improved techniques of seeding and harvesting;

  » cereals with different rates of seeding;

  » other competitive crops such as buckwheat;

  » sorghum cut at different times;

  » winter cereals with better protection against winter conditions such as artificial or natural wind breaks;

  » improved techniques of cultivating or mowing between the rows of row crops.

- to determine the relation between shoots and tubers with greater accurancy in various crops, with different biotypes of yellow nutsedge, on different soil types, and under different climatic conditions.

- to determine the critical nutsedge shoot density threshold in the spring to decide whether to treat or not in various crops, nutsedge biotypes, soil types and climates.

- and finally, to develop a model combining both biological and economical aspects of the cropping systems that can be used by producers in assessing and planning their integrated control of yellow nutsedge in the context of their aims and objectives in managing the farm.

APPENDICES

Appendix 1. Crops and cultivars used in this experiment.

CROP	LATIN NAME	CULTIVAR
Corn	*Zea mays* L.	Coop 2645
Red clover	*Trifolium repens* L.	Tristan
Alfalfa	*Medicago sativa* L.	Saranac
Soybean	*Glycine max* (L.) Merr.	Maple Arrow
Sorghum	*Sorghum bicolor* (L.) Moench	Sorghum-sudan
Winter wheat	*Triticum aestivum* L.	Frankenmuth
Barley	*Hordeum vulgare* L.	Laurier

Appendix 2. Common, chemical and trade names of herbicides used in this study.

Common name	Chemical name	trade name
atrazine	6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine	AATREX(R)
atrazine/bentazon	6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine/ 3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide	LADDOK(R)
bromoxynil	3,5-dibromo-4-hydroxybenzonitrile	PARDNER(R)
diclofop-methyl	methyl 2-[4-(2,4-dichlorophenoxy)phenoxy] propanoate	HOE-GRASS(R)
EPTC	S-ethyl dipropylcarbamothioate	EPTAM(R)
EPTC/dichlormid	S-ethyl dipropylcarbamothioate/2,2-dichloro-N,N-di-2-propenylacetamide	ERADICANE(R)
metolachlor	2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide	DUAL(R)
metribuzin	4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one	LEXONE(R)
oil/surfactant		ASSIST(R)
paraquat	1,1'-dimethyl-4,4'-bipyridinium ion	GRAMOXONE(R)

Appendix 3. Original tuber population.

No. of exp.	cropping system	tuber number (m^{-2})	total tuber dry weight (g/m^2)	average dry weight per tuber (g)
1[1]	1	3687	108.7	0.030
	2	3558	111.0	0.031
	3	2354	73.6	0.032
	4	2246	67.0	0.029
	5	3351	102.2	0.030
	6	2754	84.6	0.030
	7	3202	120.4	0.034
	8	3068	95.3	0.030
	9	3798	101.6	0.027
	10	3527	120.7	0.035
	11	4851	131.8	0.028
2u[2]	1	4092	262.3	0.065
	2	4425	317.2	0.072
	3	4215	262.4	0.062
	4	3240	230.7	0.071
	5	4025	249.2	0.062
	6	4852	306.8	0.064
	7	4631	300.8	0.066
	8	3535	247.7	0.070
	9	4877	298.5	0.061
	10	3899	251.3	0.065
	11	3493	242.7	0.070
2t[3]	1	4013	281.5	0.070
	2	3358	263.8	0.079
	3	3797	229.5	0.061
	4	4185	265.0	0.064
	5	3942	273.1	0.069
	6	4198	271.7	0.065
	7	4202	269.3	0.064
	8	3713	231.5	0.063
	9	4732	331.5	0.071
	10	4870	300.2	0.062
	11	3388	225.6	0.064

[1]refered to initial tuber sampling in spring 1987.
[2]refered to initial tuber sampling in spring 1988, where u= untreated split.
[3]refered to initial tuber sampling in spring 1988, where t= treated split.

Appendix 4. Variable costs of production.

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 1 YEAR: 1987
PRODUCT: corn EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.35	1	4.35	
fertilizer spreading	2.75	1	2.75	
herbicide spraying	2.50	1	2.50	
harrowing (triple K)	3.95	1	3.95	
corn seeding	6.40	1	6.40	
cultivating	2.25	1	2.25	
corn harvesting	42.65	1	42.65	
plowing	13.20	1	13.20	
				78.05

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	86.00	88000	94.60	
				94.60

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	248.00	0.47794	118.53	
0-0-60	196.00	0.0167	3.27	
5-20-20	255.00	0.35	89.25	
lime($CaCO_3$)	21.07	3.3	69.53	
				280.58

HERBICIDES		$/l	l/ha	$/ha	
ATRAZINE 480L	(l)	3.15	3.75	11.81	
ERADICANE 8E	(l)	8.55	8.5	72.68	
					84.49

========

TOTAL/ha 537.72

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 2 YEAR: 1987
PRODUCT: corn EXPERIMENT: 1

CROP OPERATIONS		$/ha	time	$/ha	
harrowing (disk)		4.35	1	4.35	
fertilizer spreading		2.75	1	2.75	
herbicide spraying		2.50	1	2.50	
harrowing (triple K)		3.95	1	3.95	
corn seeding		6.40	1	6.40	
cultivating		2.25	1	2.25	
corn harvesting		42.65	1	42.65	
plowing		13.20	1	13.20	
					78.05
SEED		$/80000gr	grain/ha	$/ha	
corn(COOP 2645)		86.00	88000	94.60	
					94.60
FERTILIZERS+LIME		$/ton	ton/ha	$/ha	
34-0-0		248.00	0.47794	118.53	
0-0-60		196.00	0.0167	3.27	
5-20-20		255.00	0.35	89.25	
lime(CaCO3)		21.07	3.3	69.53	
					280.58
HERBICIDES		$/l	l/ha	$/ha	
ATRAZINE 480L	(l)	3.15	3.75	11.81	
DUAL 960E	(l)	19.65	2.75	54.04	
					65.85
					========
				TOTAL/ha	519.08

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 3 YEAR: 1987
PRODUCT: corn EXPERIMENT: 1

CROP OPERATIONS		$/ha	time	$/ha	
harrowing (disk)		4.35	1	4.35	
fertilizer spreading		2.75	1	2.75	
herbicide spraying		2.50	1	2.50	
harrowing (triple K)		3.95	1	3.95	
corn seeding		6.40	1	6.40	
cultivating		2.25	1	2.25	
corn harvesting		42.65	1	42.65	
plowing		13.20	1	13.20	
					78.05
SEED		$/80000gr	grain/ha	$/ha	
corn(COOP 2645)		86.00	88000	94.60	
					94.60
FERTILIZERS+LIME		$/ton	ton/ha	$/ha	
34-0-0		248.00	0.47794	118.53	
0-0-60		196.00	0.0167	3.27	
5-20-20		255.00	0.35	89.25	
lime(CaCO3)		21.07	3.3	69.53	
					280.58
HERBICIDES		$/l	l/ha	$/ha	
LADDOK	(l)	9.15	4	36.60	
ASSIST	(l)	1.98	2	3.96	
					40.56
					========
				TOTAL/ha	493.79

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 4 YEAR: 1987
PRODUCT: corn EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.35	1	4.35	
fertilizer spreading	2.75	1	2.75	
herbicide spraying	2.50	1	2.50	
harrowing (triple K)	3.95	1	3.95	
corn seeding	6.40	1	6.40	
r. clover seeding	5.80	1	5.80	
corn harvesting	42.65	1	42.65	
plowing	13.20	1	13.20	
				81.60

SEED	$/80000gr $/kg	grain/ha kg/ha	$/ha	
corn(COOP 2645)	86.00	88000	94.60	
red clover(TRISTAN)	7.12	14	99.68	
clover innoculum	0.096	14	1.34	
				195.62

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	248.00	0.47794	118.53	
0-0-60	196.00	0.0167	3.27	
5-20-20	255.00	0.35	89.25	
lime(CaCO3)	21.07	3.3	69.53	
				280.58

HERBICIDES	$/l	l/ha	$/ha	
ERADICANE 8E (l)	8.55	8.5	72.68	
				72.68

========

TOTAL/ha 630.48

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 5 YEAR: 1987
PRODUCT: corn EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.35	1	4.35	
fertilizer spreading	2.75	1	2.75	
herbicide spraying	2.50	1	2.50	
harrowing (triple K)	3.95	1	3.95	
corn seeding	6.40	1	6.40	
r. clover seeding	5.80	1	5.80	
corn harvesting	42.65	1	42.65	
				68.40

SEED	$/80000gr $/kg	grain/ha kg/ha	$/ha	
corn(COOP 2645)	86.00	88000	94.60	
red clover(TRISTAN)	7.12	14	99.68	
clover innoculum	0.096	14	1.34	
				195.62

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	248.00	0.47794	118.53	
0-0-60	196.00	0.0167	3.27	
5-20-20	255.00	0.35	89.25	
lime($CaCO_3$)	21.07	3.3	69.53	
				280.58

HERBICIDES	$/l	l/ha	$/ha	
ERADICANE 8E (l)	8.55	8.5	72.68	
				72.68

========

TOTAL/ha 617.28

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 6 YEAR: 1987
PRODUCT: alfalfa EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.35	1	4.35	
fertilizer spreading	2.75	1	2.75	
herbicide spraying	2.50	1	2.50	
harrowing (triple K)	3.95	1	3.95	
alfalfa seeding	5.80	1	5.80	
alfalfa harvesting	14.45	1	14.45	
twine $/ton ton/ha	2.08	3.0828	6.41	
transport	3.07	1	3.07	
				43.28
SEED	**$/kg**	**kg/ha**	**$/ha**	
alfalfa(SARANAC)	5.88	12	70.56	
innoculum	0.096	12	1.15	
				71.71
FERTILIZERS+LIME	**$/ton**	**ton/ha**	**$/ha**	
34-0-0	248.00	0.05882	14.59	
0-0-60	196.00	0.13333	26.13	
0-15-30	227.00	0.06667	15.13	
5-20-20	255.00	0.2	51.00	
lime(CaCO3)	21.07	3.3	69.53	
				176.39
HERBICIDES	**$/l**	**l/ha**	**$/ha**	
EPTAM 8E (l)	7.85	4.2	32.97	
				32.97
				========
			TOTAL/ha	324.35

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 7 YEAR: 1987
PRODUCT: soybean EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.35	1	4.35	
fertilizer spreading	2.75	1	2.75	
herbicide spraying	2.50	1	2.50	
harrowing (triple K)	3.95	1	3.95	
soybean seeding	5.80	1	5.80	
soybean harvesting	28.30	1	28.30	
transport	3.07	1	3.07	
plowing	13.20	1	13.20	
				63.92

SEED	$/kg	kg/ha	$/ha	
soybean(MAPLE ARROW)	0.5375	100	53.75	
innoculum	0.06	100	6.00	
				59.75

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	248.00	0.07353	18.24	
5-20-20	255.00	0.2	51.00	
lime(CaCO3)	21.07	3.3	69.53	
				138.77

HERBICIDES		$/l $/kg	l/ha kg/ha	$/ha	
DUAL 960E	(l)	19.65	2.75	54.04	
LEXONE DF	(kg)	64.00	0.55	35.20	
					89.24
					========
				TOTAL/ha	351.67

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 8 YEAR: 1987
PRODUCT: sorghum as green manure EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.35	1	4.35	
fertilizer spreading	2.75	2	5.50	
harrowing (triple K)	3.95	3	11.85	
sorghum seeding	5.80	1	5.80	
sorghum chopping	5.20	1	5.20	
wheat seeding	5.80	1	5.80	
plowing	13.20	1	13.20	
				51.70

SEED	$/kg	kg/ha	$/ha	
sorghum	1.00	25	25.00	
wheat(FRANKENMUTH)	0.55	120	66.00	
				91.00

FERTILIZERS+LIME		$/ton	ton/ha	$/ha	
34-0-0	s87	248.00	0.30882	76.59	
5-20-20	s87	255.00	0.5	127.50	
lime(CaCO3)		21.07	3.3	69.53	
10-20-20	f87	267.00	0.4	106.80	
					380.42
					========
				TOTAL/ha	523.12

Where s = spring
f = fall

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 9 | YEAR: 1987
PRODUCT: barley | EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.35	1	4.35	
fertilizer spreading	2.75	1	2.75	
herbicide spraying	2.50	1	2.50	
harrowing (triple K)	3.95	1	3.95	
barley seeding	5.80	1	5.80	
barley harvesting	28.30	1	28.30	
transport	3.07	1	3.07	
plowing	13.20	1	13.20	
				63.92
SEED	**$/kg**	**kg/ha**	**$/ha**	
barley(LAURIER)	0.396	120	47.52	
				47.52
FERTILIZERS+LIME	**$/ton**	**ton/ha**	**$/ha**	
34-0-0	248.00	0.27109	67.23	
5-20-20	255.00	0.2	51.00	
18-46-0	382.00	0.04348	16.61	
lime(CaCO3)	21.07	3.3	69.53	
				204.37
HERBICIDES	**$/l**	**l/ha**	**$/ha**	
HOE-GRASS 284EC (l)	16.05	2.8	44.94	
PARDNER (l)	12.81	1	12.81	
				57.75
				========
			TOTAL/ha	373.56

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 1 YEAR: 1988
PRODUCT: corn EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
cultivating	2.56	1	2.56	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				90.64

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
				95.70

FERTILIZERS	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.5	141.50	
0-0-60	233.00	0.13333	31.07	
5-20-20	276.00	0.2	55.20	
				227.77

HERBICIDES		$/l	l/ha	$/ha	
ATRAZINE 480L	(l)	3.27	3.75	12.26	
ERADICANE 8E	(l)	8.55	8.5	72.68	
					84.94

========

TOTAL/ha 499.04

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 2 YEAR: 1988
PRODUCT: corn EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
cultivating	2.56	1	2.56	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				90.64

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
				95.70

FERTILIZERS	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.5	141.50	
0-0-60	233.00	0.13333	31.07	
5-20-20	276.00	0.2	55.20	
				227.77

HERBICIDES		$/l	l/ha	$/ha	
ATRAZINE 480L	(l)	3.27	3.75	12.26	
DUAL 960E	(l)	19.65	2.75	54.04	
					66.30
					========
				TOTAL/ha	480.41

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 3
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 1

CROP OPERATIONS		$/ha	time	$/ha	
harrowing (disk)		4.49	1	4.49	
fertilizer spreading		2.42	1	2.42	
herbicide spraying		1.56	1	1.56	
harrowing (triple K)		3.49	1	3.49	
corn seeding		8.06	1	8.06	
cultivating		2.56	1	2.56	
corn harvesting		55.10	1	55.10	
plowing		12.96	1	12.96	
					90.64
SEED		**$/80000gr**	**grain/ha**	**$/ha**	
corn(COOP 2645)		87.00	88000	95.70	
					95.70
FERTILIZERS		**$/ton**	**ton/ha**	**$/ha**	
34-0-0		283.00	0.5	141.50	
0-0-60		233.00	0.13333	31.07	
5-20-20		276.00	0.2	55.20	
					227.77
HERBICIDES		**$/l**	**l/ha**	**$/ha**	
LADDOK	(l)	8.30	4	33.20	
ASSIST	(l)	1.95	2	3.90	
					37.10
					========
				TOTAL/ha	451.21

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 4 YEAR: 1988
PRODUCT: corn EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
r. clover seeding	5.10	1	5.10	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				93.18

SEED	$/80000gr $/kg	grain/ha kg/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
red clover(TRISTAN)	7.12	14	99.68	
clover innoculum	0.11	14	1.57	
				196.95

FERTILIZERS	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.5	141.50	
0-0-60	233.00	0.13333	31.07	
5-20-20	276.00	0.2	55.20	
				227.77

HERBICIDES	$/l	l/ha	$/ha	
ERADICANE 8E (l)	8.55	8.5	72.68	
				72.68
				========
			TOTAL/ha	590.57

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 5
PRODUCT: red clover

YEAR: 1988
EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
r.clov.harvesting silage	24.09	2	48.18	
				48.18
				========
			TOTAL/ha	48.18

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 6
PRODUCT: alfalfa

YEAR: 1988
EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
fertilizer spreading	2.42	1	2.42	
alfalfa harvesting	15.56	3	46.68	
twine $/ton ton/ha	2.08	11.1791	23.25	
transport	2.81	3	8.43	
				80.78

FERTILIZERS	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.07353	20.81	
0-0-60	233.00	0.18333	42.72	
5-20-20	276.00	0.1	27.60	
boron	25.20	2	50.40	
				141.52
				========
			TOTAL/ha	222.31

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 7 YEAR: 1988
PRODUCT: soybean EXPERIMENT: 1

CROP OPERATIONS		$/ha	time	$/ha	
harrowing (disk)		4.49	1	4.49	
fertilizer spreading		2.42	1	2.42	
herbicide spraying		1.56	1	1.56	
harrowing (triple K)		3.49	1	3.49	
soybean seeding		5.10	1	5.10	
soybean harvesting		22.28	1	22.28	
transport		2.57	1	2.57	
plowing		12.96	1	12.96	
					54.87
SEED		**$/kg**	**kg/ha**	**$/ha**	
soybean(MAPLE ARROW)		0.59375	100	59.38	
innoculum		0.07	100	7.00	
					66.38
FERTILIZERS		**$/ton**	**ton/ha**	**$/ha**	
34-0-0		283.00	0.09926	28.09	
0-0-60		233.00	0.05	11.65	
5-20-20		276.00	0.225	62.10	
					101.84
HERBICIDES		**$/l $/kg**	**l/ha kg/ha**	**$/ha**	
DUAL 960E	(l)	19.65	2.75	54.04	
LEXONE DF	(kg)	61.40	0.55	33.77	
					87.81
					========
				TOTAL/ha	310.89

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 8 — YEAR: 1988

PRODUCT: wheat — EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
wheat harvesting	18.95	1	18.95	
plowing	12.96	1	12.96	
transport	2.40	1	2.40	
				34.31
				========
			TOTAL/ha	34.31

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 9 | YEAR: 1988
PRODUCT: barley | EXPERIMENT: 1

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
barley seeding	5.10	1	5.10	
barley harvesting	18.95	1	18.95	
transport	2.40	1	2.40	
plowing	12.96	1	12.96	
				51.37

SEED	$/kg	kg/ha	$/ha	
barley(LAURIER)	0.41	120	49.20	
				49.20

FERTILIZERS	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.19118	54.10	
0-0-60	233.00	0.01667	3.88	
5-20-20	276.00	0.1	27.60	
				85.59

HERBICIDES		$/l	l/ha	$/ha	
HOE-GRASS 284EC	(l)	16.05	2.8	44.94	
PARDNER	(l)	12.81	1	12.81	
					57.75

========

TOTAL/ha 243.91

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 1
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				86.52

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
				95.70

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55
				========
			TOTAL	543.77

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 2
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				86.52

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
				95.70

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.52	
				361.55
				========
			TOTAL	543.77

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 3
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				86.52

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
				95.70

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55
				========
			TOTAL	543.77

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 4
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
r. clover seeding	5.10	1	5.10	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				91.62

SEED	$/80000gr $/kg	grain/ha kg/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
red clover(TRISTAN)	7.12	14	99.68	
clover innoculum	0.11	14	1.57	
				196.95

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55
				========
			TOTAL	650.12

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 5
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
r. clover seeding	5.10	1	5.10	
corn harvesting	55.10	1	55.10	
				78.66

SEED	$/80000gr $/kg	grain/ha kg/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
red clover(TRISTAN)	7.12	14	99.68	
clover innoculum	0.11	14	1.57	
				196.95

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55
				========
			TOTAL	637.16

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 6
PRODUCT: alfalfa

YEAR: 1988
EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
harrowing (triple K)	3.49	1	3.49	
alfalfa seeding	5.10	1	5.10	
alfalfa harvesting	15.56	1	15.56	
twine $/ton ton/ha	2.08	2.619809	5.45	
transport	2.81	1	2.81	
				39.32

SEED	$/kg	kg/ha	$/ha	
alfalfa(SARANAC)	5.56	12	66.72	
innoculum	0.11	12	1.34	
				68.06

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.07353	20.81	
0-0-60	233.00	0.24167	56.31	
5-20-20	276.00	0.1	27.60	
lime(CaCO3)	21.07	4.5	94.82	
boron	9.00	0.002	0.02	
				199.55
				========
			TOTAL	306.93

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 7
PRODUCT: soybean

YEAR: 1988
EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
harrowing (triple K)	3.49	1	3.49	
soybean seeding	5.10	1	5.10	
soybean harvesting	22.28	1	22.28	
transport	2.57	1	2.57	
plowing	12.96	1	12.96	
				53.31

SEED	$/kg	kg/ha	$/ha	
soybean(MAPLE ARROW)	0.59375	100	59.38	
innoculum	0.07	100	7.00	
				66.38

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.09926	28.09	
0-0-60	233.00	0.06667	15.53	
5-20-20	276.00	0.225	62.10	
lime(CaCO3)	21.07	4.5	94.82	
				200.54
				========
			TOTAL	320.22

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 8 YEAR: 1988
PRODUCT: sorghum as green manure EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS		$/ha	time	$/ha	
harrowing (disk)		4.49	1	4.49	
fertilizer spreading		2.42	2	4.84	
harrowing (triple K)		3.49	3	10.47	
sorghum seeding		5.10	1	5.10	
sorghum chopping		5.54	1	5.54	
wheat seeding		5.10	1	5.10	
plowing		12.96	1	12.96	
					48.50
SEED		$/kg	kg/ha	$/ha	
sorghum		0.92	25	23.00	
wheat(FRANKENMUTH)		0.55	120	66.00	
					89.00
FERTILIZERS+LIME		$/ton	ton/ha	$/ha	
34-0-0	s88	283.00	0.20588	58.26	
0-0-60	s88	233.00	0.06667	15.53	
5-20-20	s88	276.00	0.2	55.20	
lime(CaCO3)	f87	21.07	4.5	94.82	
34-0-0	f88	283.00	0.0882	24.96	
0-0-60	f88	233.00	0.0667	15.54	
10-20-20	f88	296.00	0.1	29.60	
					293.91
					========
				TOTAL	431.41

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 9
PRODUCT: barley

YEAR: 1988
EXPERIMENT: 2
SPLIT: untreated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
harrowing (triple K)	3.49	1	3.49	
barley seeding	5.10	1	5.10	
barley harvesting	18.95	1	18.95	
transport	2.40	1	2.40	
plowing	12.96	1	12.96	
				49.81

SEED	$/kg	kg/ha	$/ha	
barley(LAURIER)	0.41	120	49.20	
				49.20

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.19118	54.10	
0-0-60	233.00	0.0667	15.54	
5-20-20	276.00	0.1	27.60	
lime(CaCO3)	21.07	4.5	94.82	
				192.06
				========
			TOTAL	291.07

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 1
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
cultivating	2.56	1	2.56	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				90.64

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
				95.70

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55

HERBICIDES		$/l	l/ha	$/ha	
ATRAZINE 480L	(l)	3.27	3.75	12.26	
ERADICANE 8E	(l)	8.55	8.5	72.68	
					84.94
					========
				TOTAL	632.83

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 2
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
cultivating	2.56	1	2.56	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				90.64

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
				95.70

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55

HERBICIDES		$/l	l/ha	$/ha	
ATRAZINE 480L	(l)	3.27	3.75	12.26	
DUAL 960E	(l)	19.65	2.75	54.04	
					66.30
					========
				TOTAL	614.19

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 3
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
cultivating	2.56	1	2.56	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				90.64

SEED	$/80000gr	grain/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
				95.70

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55

HERBICIDES		$/l	l/ha	$/ha	
LADDOK	(l)	8.30	4	33.20	
ASSIST	(l)	1.95	2	3.90	
					37.10
					========
				TOTAL	584.99

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 4
PRODUCT: corn

YEAR: 1988
EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
r. clover seeding	5.10	1	5.10	
corn harvesting	55.10	1	55.10	
plowing	12.96	1	12.96	
				93.18

SEED	$/80000gr $/kg	grain/ha kg/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
red clover(TRISTAN)	7.12	14	99.68	
clover innoculum	0.11	14	1.57	
				196.95

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55

HERBICIDES	$/l	l/ha	$/ha	
ERADICANE 8E (l)	8.55	8.5	72.68	
				72.68
				========
			TOTAL	724.36

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 5 YEAR: 1988
PRODUCT: corn EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
corn seeding	8.06	1	8.06	
r. clover seeding	5.10	1	5.10	
corn harvesting	55.10	1	55.10	
				80.22

SEED	$/80000gr $/kg	grain/ha kg/ha	$/ha	
corn(COOP 2645)	87.00	88000	95.70	
red clover(TRISTAN)	7.12	14	99.68	
clover innoculum	0.11	14	1.57	
				196.95

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.48529	137.34	
0-0-60	233.00	0.2	46.60	
5-20-20	276.00	0.3	82.80	
lime(CaCO3)	21.07	4.5	94.82	
				361.55

HERBICIDES	$/l	l/ha	$/ha	
ERADICANE 8E (l)	8.55	8.5	72.68	
				72.68
				========
			TOTAL	711.40

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 6
PRODUCT: alfalfa

YEAR: 1988
EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS		$/ha	time	$/ha	
harrowing (disk)		4.49	1	4.49	
fertilizer spreading		2.42	1	2.42	
herbicide spraying		1.56	1	1.56	
harrowing (triple K)		3.49	1	3.49	
alfalfa seeding		5.10	1	5.10	
alfalfa harvesting		15.56	1	15.56	
twine $/ton	ton/ha	2.08	3.195512	6.65	
transport		2.81	1	2.81	
					42.08
SEED		$/kg	kg/ha	$/ha	
alfalfa(SARANAC)		5.56	12	66.72	
innoculum		0.11	12	1.34	
					68.06
FERTILIZERS+LIME		$/ton	ton/ha	$/ha	
34-0-0		283.00	0.07353	20.81	
0-0-60		233.00	0.24167	56.31	
5-20-20		276.00	0.1	27.60	
lime(CaCO3)		21.07	4.5	94.82	
boron		9.00	0.002	0.02	
					199.55
HERBICIDES		$/l	l/ha	$/ha	
EPTAM 8E	(l)	7.85	4.2	32.97	
					32.97
					========
				TOTAL	342.66

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 7
PRODUCT: soybean

YEAR: 1988
EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
soybean seeding	5.10	1	5.10	
soybean harvesting	22.28	1	22.28	
transport	2.57	1	2.57	
plowing	12.96	1	12.96	
				54.87

SEED	$/kg	kg/ha	$/ha	
soybean(MAPLE ARROW)	0.59375	100	59.38	
innoculum	0.07	100	7.00	
				66.38

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.09926	28.09	
0-0-60	233.00	0.06667	15.53	
5-20-20	276.00	0.225	62.10	
lime(CaCO3)	21.07	4.5	94.82	
				200.54

HERBICIDES		$/l $/kg	l/ha kg/ha	$/ha	
DUAL 960E	(l)	19.65	2.75	54.04	
LEXONE DF	(kg)	61.40	0.55	33.77	
					87.81
					========
				TOTAL	409.59

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 8
PRODUCT: sorghum as green manure

YEAR: 1988
EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS		$/ha	time	$/ha	
harrowing (disk)		4.49	1	4.49	
fertilizer spreading		2.42	2	4.84	
harrowing (triple K)		3.49	3	10.47	
sorghum seeding		5.10	1	5.10	
sorghum chopping		5.54	1	5.54	
wheat seeding		5.10	1	5.10	
plowing		12.96	1	12.96	
					48.50
SEED		**$/kg**	**kg/ha**	**$/ha**	
sorghum		0.92	25	23.00	
wheat(FRANKENMUTH)		0.55	120	66.00	
					89.00
FERTILIZERS+LIME		**$/ton**	**ton/ha**	**$/ha**	
34-0-0	s88	283.00	0.20588	58.26	
0-0-60	s88	233.00	0.06667	15.53	
5-20-20	s88	276.00	0.2	55.20	
lime(CaCO3)	f87	21.07	4.5	94.82	
34-0-0	f88	283.00	0.0882	24.96	
0-0-60	f88	233.00	0.0667	15.54	
10-20-20	f88	296.00	0.1	29.60	
					293.91
				TOTAL	========
					431.41

VARIABLE COSTS OF PRODUCTION

CROPPING SYSTEM: 9
PRODUCT: barley

YEAR: 1988
EXPERIMENT: 2
SPLIT: treated

CROP OPERATIONS	$/ha	time	$/ha	
harrowing (disk)	4.49	1	4.49	
fertilizer spreading	2.42	1	2.42	
herbicide spraying	1.56	1	1.56	
harrowing (triple K)	3.49	1	3.49	
barley seeding	5.10	1	5.10	
barley harvesting	18.95	1	18.95	
transport	2.40	1	2.40	
plowing	12.96	1	12.96	
				51.37

SEED	$/kg	kg/ha	$/ha	
barley(LAURIER)	0.41	120	49.20	
				49.20

FERTILIZERS+LIME	$/ton	ton/ha	$/ha	
34-0-0	283.00	0.19118	54.10	
0-0-60	233.00	0.0667	15.54	
5-20-20	276.00	0.1	27.60	
lime(CaCO3)	21.07	4.5	94.82	
				192.06

HERBICIDES		$/l	l/ha	$/ha	
HOE-GRASS 284EC	(l)	16.05	2.8	44.94	
PARDNER	(l)	12.81	1	12.81	
					57.75

========
TOTAL 350.38

Appendix 5. Crop price.

		CROP PRICE[1] ($/ton)		
year	product	low	med	high
1987	corn silage	23	27	31
	alfalfa hay	85	100	115
	soybean grain	225	265	305
	barley grain	83	97	112
1988	corn silage	28	33	38
	clover hay	85	100	115
	alfalfa hay	102	120	138
	soybean grain	246	290	333
	wheat grain	150	176	202
	barley grain	128	151	174

Where ton= metric ton.

1 low = -15% of medium price

med = corn, clover, alfalfa: forage price (personnal communication from Serge Lussier Agr.)
soybean price (C.R.E.A.Q.)
cereal price (Office des provendes du Canada)

high= +15% of medium price

Appendix 6. Crop yield.

No. of exp.	year	PRODUCT	YIELD[1,2] (ton/ha) low	med	high
1	1987	1-corn silage	42.9	48.9	55.0
		2-corn silage	43.6	49.3	55.0
		3-corn silage	48.4	49.6	50.7
		4-corn silage	38.8	51.2	63.6
		5-corn silage	43.7	53.5	63.3
		6-alfalfa hay	1.9	3.1	4.2
		7-soybean grain	1.6	2.3	3.0
		8-sorghum	NA	NA	NA
		9-barley grain	1.7	2.4	3.2
1	1988	1-corn silage	28.9	43.9	58.8
		2-corn silage	35.3	50.8	66.3
		3-corn silage	26.9	40.3	53.7
		4-corn silage	14.7	37.2	59.7
		5-clover hay	2.4	2.8	3.3
		6-alfalfa hay	9.4	11.2	13.0
		7-soybean grain	0.4	1.1	1.7
		8-wheat grain	2.9	3.8	4.7
		9-barley grain	0.4	1.7	3.1
2	1988	1-corn silage	0.9	15.4	29.8
		2-corn silage	0.0	18.4	39.8
(untreated)		3-corn silage	13.4	15.9	18.4
		4-corn silage	16.3	28.9	41.5
		5-corn silage	10.2	33.8	57.5
		6-alfalfa hay	2.2	2.6	3.0
		7-soybean grain	0.0	0.1	0.1
		8-sorghum	NA	NA	NA
		9-barley grain	0.9	2.2	3.5
2	1988	1-corn silage	37.1	43.9	50.6
		2-corn silage	23.6	40.7	57.7
(treated)		3-corn silage	18.0	36.4	54.9
		4-corn silage	22.9	29.7	36.4
		5-corn silage	18.7	35.0	51.3
		6-alfalfa hay	2.7	3.2	3.7
		7-soybean grain	0.1	0.7	1.2
		8-sorghum	NA	NA	NA
		9-barley grain	0.8	1.2	1.6

Where ton= metric ton, NA= not available.
[1] low = -95% confidence interval

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