THE EFFECT OF CORN POPULATION AND SEEDING DATE ON THE GROWTH OF YELLOW NUTSEDGE (*CYPERUS ESCULENTUS* L.)

by

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Short title

EFFECTS OF CORN MANAGEMENT ON YELLOW NUTSEDGE GROWTH

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ABSTRACT

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THE EFFECT OF CORN POPULATION AND SEEDING DATE ON THE GROWTH OF YELLOW NUTSEDGE (<u>CYPERUS ESCULENTUS</u> L.)

Yellow nutsedge is one of the most serious perennial weeds in corn production. The possibility of reducing the competitive ability of yellow nutsedge in corn through management practices of seeding date and planting density were investigated. These studies were conducted in a naturally infested field. None of the five different dates of seeding (1st, 2nd, 3rd and 4th week of May and 1st week of June) had any significant effect on the total yellow nutsedge above ground biomass and tuber production. In this study final seedbed preparation occurred just prior to the planting date and thus cultivation stimulated dormant tubers to sprout. As a result, a large population of yellow nutsedge emerged with the corn at all seeding dates. However, from this study the optimum seeding date was the 3rd week of May when the highest corn yield was obtained and the lowest yellow nutsedge above ground biomass and tuber production were also recorded. Increasing corn population from 33,333 to 133,333 plants per hectare significantly reduced total yellow nutsedge above ground biomass, tuber number, tuber dry weight and yellow nutsedge height at the end of the growing season, and significantly increased corn yield. The average photosynthetically active radiation (PAR) below corn canopies at different corn populations was significantly correlated with yellow nutsedge above ground biomass, tuber dry weight and tuber production. The reduction in PAR corresponded with the reduction of yellow nutsedge growth. These results suggested that available light may be a major factor in yellow nutsedge competition in corn. The size of tubers was significantly affected by corn population and seeding date. However, tuber dry weight in different size classes was not significantly altered by the treatments in either of the studies. The effect of each individual treatment on tuber size classes had either a normal distribution or a linear response due to increasing tuber size classes. In both studies, data on yellow nutsedge growth parameters obtained from within corn rows were always significantly greater than those obtained from between corn rows.

RESUME

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L'EFFET DE LA DENSITE DE POPULATION ET DE LA DATE DE SEMIS DU MAIS SUR LA CROISSANCE DU SOUCHET

Le souchet (Cyperus esculentus L.) est la mauvaise herbe vivace causant le plus de problèmes dans la production du maïs. La possibilité de réduire la capacité de compétition du souchet dans le maïs via une régie de la densité et de la date de semis a été étudiée. Ces deux expériences furent conduites dans un champ naturellement infesté. Aucune des 5 différentes dates de semis (1°, 2°, 3° et 4° semaine de mai et 1° semaine de juin) n'a eu d'effet significatif sur la biomasse aérienne totale du souchet et sur la production de tubercules. Dans cette expérience, la préparation finale du lit de semence se fait juste avant la date du semis; l'utilisation du motoculteur stimule la germination des tubercules dormants. Comme résultat, une forte population de souchet apparaît avec le maïs à chaque date de semis. La date de semis optimale de cet essai fut la 3° semaine de mai, alors que le plus fort rendement de maïs était obtenu et que la biomasse aérienne et la production des tubercules du souchet étaient les plus faibles. Augmenter la densité de population du maïs de 33,333 à 133,333 plants/hectare a diminué significativement la biomasse aérienne, le nombre de tubercules et la hauteur du souchet à la fin de la saison de croissance, et a accru de façon significative le rendement du maïs. Les radiations active dans la photosynthèse (RAP) moyenne au-dessous du feuillage du maïs aux différentes densités de population est significativement corrélée à la biomasse aérienne du souchet, au poids sec des tubercules et à la production de tubercules. La réduction de la RAP correspond à la réduction de croissance du souchet. Ces résultats suggèrent que la lumière disponible peut être un facteur majeur dans la compétition du souchet dans le maïs. La grosseur des tubercules de souchet a été significativement affectée par la densité de population et la date de semis. Toutefois, le poids sec des tubercules dans les différentes classes de grosseur ne fut significativement modifié par les traitements dans aucune des deux expériences. L'effet de chaque traitement individuel sur les classes de grosseur des tubercules est representé ~~soit~~ par une distribution normale, soit par une réponse linéaire fonction de l'accroissement des classes de grosseur des tubercules. Dans les deux expériences, les données des paramètres de croissance du souchet furent toujours significativement plus grandes lorsqu'obtenues sur le rang de maïs que lorsque prises entre les rangs de maïs.

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I. INTRODUCTION

Yellow nutsedge (Cyperus esculentus L.) is native to North America and Eurasia. It occurs in a wide range of soil types and can be found from southeastern Canada southwards to Florida and Texas as well as on the Pacific coast (Hauser 1968). Yellow nutsedge chiefly reproduces by tubers and rhizomes, and the biology of this plant has been reviewed by Mulligan and Junkins (1976).

Yellow nutsedge is one of the most serious perennial weeds in many crops, including corn, and its infestation seems to be increasing in agronomic crops in the United States and parts of Canada. A recent estimate indicates that about 2.5 million hectares of corn were infested with yellow nutsedge in the north central region of the United States (Armstrong 1975). Yellow nutsedge infestations reduce crop yield and increase the cost of production due to weeding. Corn yields have been reduced as much as 8 per cent for every 100 shoots/m^2 of yellow nutsedge infestation. When initial infestations of yellow nutsedge were 300 tubers/m^2 and 1200 tubers/m^2, corn yields were decreased by 17 and 41 per cent, respectively (Stoller et al. 1979). In addition, yellow nutsedge presence at the 5 to 6-leaf stage of corn tends to increase the magnesium, boron and zinc content of the corn, while at the silking stage of corn, nitrogen, phosphorus, potassium and zinc contents are reduced. Yellow nutsedge accumulates 1.5 to 2 times more calcium, magnesium and zinc than corn (Farwell et al. 1975).

Several control methods had been investigated to reduce yellow nutsedge infestations to tolerable levels. The use of chemical herbicides has been partly effective and research on biological control using natural enemies of nutsedge is not advanced. Cultural control methods, such as tillage, have been utilized for the control of yellow nutsedge. Fallow was also known to reduce yellow nutsedge tuber production (Bell et al. 1962; Tumbleson and Kommedahl 1962). Crop rotation has been shown to suppress the growth of yellow nutsedge by utilizing different crop species that could compete with the weed.

Other possible methods of cultural suppression of yellow nutsedge are to increase corn population densities and to establish the crop early in the growing season. Early rapid establishment of the crop could adversely suppress the development of the generally late establishing yellow nutsedge infestation. Also, increasing the corn population densities could reduce the competitive ability of yellow nutsedge.

The objectives of this study were to determine the effect of corn population densities and the effect of seeding dates of corn on yellow nutsedge growth.

II. BIOLOGY OF YELLOW NUTSEDGE

2.1 Plant description

Cyperus esculentus L. is known by numerous common names including yellow nutsedge, northern nutgrass, rust nut, yellow galingalls, earth almond, coco sedge and chufas (Muenschor 1952). The accepted common names in Canada are yellow nutsedge and souchet comestible (Alex *et al*. 1980). It is a perennial weed with rhizomes terminating in tubers or leafy shoots. The plant has a shiny appearance and grows to a height of 15 to 80 cm. The stem is triangular and unbranched. The leaves are mostly basal, except for the leaf-like bracts at the flower head. These grass-like leaves are less than 1 cm wide and about 60 cm long with a prominent heavy mid-vein. The inflorescence is umbelliform and becomes golden brown at maturity. The tubers are angular to oval in shape and are borne at the ends of rhizomes.

Another nutsedge species, *Cyperus rotundas* L. (purple nutsedge) is very closely related to yellow nutsedge and native to the tropics. Both of these species are found growing together in warmer regions of the United States (Hauser 1968). However, purple nutsedge can be easily distinguished from yellow nutsedge by the color of its inflorescence which is purple to brown and by its black tubers which are formed in chains on the rhizomes (Day and Russell 1955). These two *Cyperus* species combined represent perhaps the most serious weed problems in the world (Holm 1969).

2.2 Distribution and habitat requirements

Yellow nutsedge is native to North America and Eurasia. In North America it is common in the eastern regions from southern Canada to Florida and Texas, and is also found in the Pacific coast regions (Peck 1941; Muenschor 1952; Hauser 1968). Yellow nutsedge is a serious problem in many crops and occurs in a wide range of soil types from sand and sandy-gravel to clay (Tumbleson and Kommedahl 1961; Mulligan and Junkins 1976).

2.2.1 Edaphic factors

Several edaphic factors affect the growth of yellow nutsedge. Soil type and soil structure do not seem to limit the growth since yellow nutsedge occurs in a wide range of soil types and textures. However, the number of shoots produced from tubers in peat or sandy silt loam were more than in sand, and tubers in peat produced more shoots than did tubers in sandy silt loam (Tumbleson and Kommedahl 1961). In general, yellow nutsedge infestations in heavy soils produce more shoots than those in lighter soils.

The growth of yellow nutsedge is directly related to soil moisture with the number of tubers increasing as soil moisture increases to 100 per cent (Bell *et al*. 1962). When the tubers were exposed to the soil surface for 2 days, tuber survival was reduced from

90 per cent to 10 per cent (Tumbleson and Kommedahl 1962). Apparently soil moisture interacts with soil temperature regulating tuber survival in the soil. Thomas (1969) reported that duration of desiccation did not influence tuber survival at low temperature. Tubers of yellow nutsedge that overwinter in less than 5.1 cm depth of soil were more susceptible to winter killing than tubers at lower levels, probably because of the difference in soil temperature at these levels during cold periods. Under laboratory conditions, 100 per cent and 50 per cent of the tubers were killed when exposed to low temperature of -10°C and -7°C, respectively (Stoller and Wax 1973).

Fertilization also influences the growth of yellow nutsedge. Addition of 19-28-14 fertilizer from 250 to 500 lb/ac (280 to 560 kg/ha) significantly increases the number of tubers produced (Bell et al. 1962). However, at high nitrogen levels tuber formation is inhibited and at low nitrogen levels more tubers are formed, especially when combined with low temperature (Garg et al. 1967). Tuberization is not affected by soil pH (Bell et al. 1962).

2.2.2 Climatic factors

Climatic factors such as light, temperature and moisture can influence the growth and development of yellow nutsedge. Low temperature and high moisture enhanced germination and establishment of the plant. Effects of temperature and moisture seem to be more prominent in the soil and these have been discussed earlier under edaphic factors.

Light is an important climatic factor on yellow nutsedge growth, as the life cycle of the weed is closely related to photoperiod (Bundy et al. 1960; Bell et al. 1962; Garg et al. 1967; Jansen 1968). Under 12 hours alternating light-dark periods, crown development was rapid, but continuous darkness greatly delayed crown formation (Garg et al. 1967). Vegetative growth and production of rhizomes and peripheral shoots were greatly enhanced by day length greater than 14 hours, while development of peripheral plants was inhibited under an 8-hour photoperiod (Bell et al. 1962; Jansen 1968). Flowering was also induced under a 12 to 14-hour day length (Jansen 1968). According to Bundy et al. (1960) and Bell et al. (1962) nutsedge is sensitive to photoperiod under low light intensities, and high light intensities stimulate tuberization and vegetative growth by overcoming the requirement of photoperiod. Plants grown for 12 weeks under 48 per cent normal greenhouse light resulted in 82 per cent reduction in dry matter production. Similarly, under conditions of continuous shade in the field, the number of tubers and basal bulbs produced by purple nutsedge was reduced by 10 to 57 per cent (Hauser 1962). These results suggest that competition with crop plants for light would greatly inhibit nutsedge growth.

The competitive ability of plants is partly governed by their efficiency in utilizing the amount of light present. Cyperus species are considered by Black et al. (1969) to be photosynthetically efficient plants in which they continue to fix increasing amounts of CO_2 as light intensity increases to nearly full sunlight. If nutsedge plants are very competitive and efficient at high light intensities, rapid shading should decrease their photosynthetic rates and suppress their growth. The influence of shading from plant canopies of different crops has been shown by several investigators to affect the growth and development of nutsedge (Bell *et al*. 1962; Botha 1971; Lewis 1972; William and Warren 1975; Keeley and Thullen 1978). Some of the crops that have been shown to suppress the growth of nutsedge by shading are alfalfa, velvet beans, jack beans and lima beans. Lima beans spaced 5.0 cm apart were superior competitors with yellow nutsedge to beans spaced 10 to 15 cm apart (Loustalot *et al*. 1954; Bell *et al*. 1962; Botha 1971; Keeley *et al*. 1979). According to Keeley and Thullen (1978), the average number of shoots, tubers and total dry matter of yellow nutsedge increased directly proportional to increasing light.

2.2.3 Biotic factors

There are several insects and plant pathogens that have been reported on yellow nutsedge. These natural enemies are associated with the leaves, flowers, tubers or basal bulbs (Babcock 1916; Summerville 1933; Satterthwait 1942; Poinar 1964; Bird and Hogger 1973; Minton *et al*. 1973; Hogger and Bird 1976; Johnson and Brinkerhoff 1976; Mulligan and Junkins 1976; Beisler *et al*. 1977; Hollis 1977). Listings of natural enemies found on yellow nutsedge are given in Tables 1 and 2. Further discussion of biotic factors is included in the section on biological control (4.2).

2.3 Growth and development

Shoots may develop either from seeds or tubers but not from the basal bulbs (Bell et al. 1962; Hill et al. 1963; Bendixen 1970). The tubers generally give rise to a single shoot but some may produce as many as seven shoots. The number of shoots which sprout per tuber is influenced by temperature, soil properties and also by certain herbicides (Tumbleson and Kommedahl 1962; Hauser 1963). The development of crown and the rhizomes at the base of the primary shoots is originated from the root system. The tips of these rhizomes may develop into tubers or secondary shoots as a result of reduced internode elongation. Each indeterminate rhizome, ranging in size from 2 to 60 cm long, has a series of 4 to 33 internodes, nodal scale leaves (0.5 to 1.0 cm in length) and a terminal bud (Jansen 1971).

Foliar application of hormones can alter the morphology of yellow nutsedge by transformation of the rhizome tip. Bendixen (1970) found that repeated application of 1000 ppm gibberellic acid induced rhizomes to grow erect, thereby protruding above the soil surface. Gibberellic acid also suppressed rhizome initiation and rhizome transformation into either shoots or tubers, and triiodobenzonic acid induced transformation to shoots causing a tuft-like growth. Since gibberellic acid inhibits tuber formation (Garg et al. 1967) and tuberization occurs as a result of low levels of reducing sugar in the shoots, tuber formation is not merely due to excess carbohydrate in the plant, but it may be controlled by a gibberellic-like compound that is regulated in the plant under specific conditions of photoperiod and temperature (Garg et al. 1967).

Under field conditions at Ste-Anne-de-Bellevue, Quebec, growth and formation of tubers were rapid in July and August, with tuberization commencing in the first week of July (Abd.Ghafar 1977). In August, vegetative growth was greatly reduced and tuber formation was enhanced as photoperiod, temperature and light intensities decreased.

2.4 Reproduction

Reproduction of yellow nutsedge is chiefly by tubers and rhizomes (Tumbleson and Kommedahl 1961; Jansen 1971; Stoller _et al_. 1972; Bendixen 1973; Thullen and Keeley 1975; Mulligan and Junkins 1976). Several workers also indicated that seeds of yellow nutsedge play an important role in reproduction (Bellue 1946; Justice and Whitehead 1946; Bell _et al_. 1962; Hill _et al_. 1963). Others claim that seeds are not important in reproduction of yellow nutsedge (Thullen and Keeley 1975; Mulligan and Junkins 1976).

2.4.1 Seed production

There is controversy as to whether yellow nutsedge produces viable seed. Mulligan and Junkins (1976) reported seed set is very variable throughout its range in Canada. The amount of seed set varies from year to year with many stands of yellow nutsedge not producing seeds. In 1975, no seed was produced at 13 stations in eastern Ontario and adjacent Quebec. However, in eastern United States there is ample evidence that yellow nutsedge produces abundant seeds. These seeds are viable 2 to 3 weeks after the start of flowering (Justice and Whitehead 1946; Bell _et al_. 1962; Hill _et al_. 1963).

Seed germination is influenced by the weight of the seed, seed maturity, temperature, photoperiod and ethylene (Justic and Whitehead 1946; Bell and Larssen 1960; Bell _et al_. 1962).

2.4.2 Tuber production

The production of new tubers from a single tuber of yellow nutsedge is very great. A single tuber is capable of producing 6,900 tubers to a depth of 23 cm in a patch 21 dm diameter in one growing season (Tumbleson and Kommedahl 1961). These tubers are equivalent to 8.3 tons of fresh weight per acre. In greenhouse conditions, a single tuber could produce 146 tubers and basal bulbs in 14 weeks. These new tubers were produced between 3 and 4 weeks after planting in the field and about 8 weeks in the greenhouse (Jenkins and Jackman 1941; Tumbleson and Kommedahl 1961; Stoller _et al_. 1972).

The depth of tuber production in the soil varies at different locations. In the United States, at Oregon, most of the tubers of yellow nutsedge were in the upper 8 inches (20.32 cm) of the soil, with none below 12 inches (30.48 cm) (Jenkins and Jackman 1941); at Arizona Agricultural Experimental Station, tubers were found between 4 and 10 inches (10.16 and 25.4 cm) (Davis and Hawkins 1943), and at Rhode Island Agricultural Experimental Station, most tubers were found in the top 6 inches (15.25 cm) of soil (Bell _et al_. 1962). Tumbleson and Kommedahl (1961) found that 99 per cent of the tubers were in the upper 10 inches (25.4 cm) of the soil and none at the depth below 18 inches (45.72 cm). In Canada, at Ste-Anne-de-Bellevue, Quebec, most of the tubers were in the upper 15 cm of the soil (Abd.Ghafar 1977).

Tubers are formed either at apical ends of indeterminate or determinate rhizomes. Jansen (1971) and Mulligan and Junkins (1976) reported that a tuber is formed at the apical end of an indeterminate rhizome, but Stoller _et al_. (1972) reported that a tuber is formed at the apical end of determinate rhizomes which grow directly towards the soil surface and the original tubers may remain alive and attached to a primary basal bulb just below the surface for as long as 12 weeks. At the tip of determinate rhizomes, scale leaves elongate, the basal bulb enlarges, and a new tuber is initiated.

The tubers of yellow nutsedge are white when first formed and gradually turn brown to nearly black at maturity. Tubers have a hard tough lignified epidermal layer, have an oblong and slightly flattened shape, have well developed buds, a vascular system and roots; have an average weight of 209 mgm and contain 40 to 60 per cent moisture (Tumbleson and Kommedahl 1961; Bendixen 1973; Mulligan and Junkins 1976).

The number of buds per tuber ranges from 2 to 7, with 4 or 5 buds appearing 76 per cent of the time (Thullen and Keeley 1975). These buds are generally grouped in a single cluster at the six most apical nodes with 1/3 phyllotaxy. The oldest bud is the largest and most basipetal. Buds have never been observed along rhizomes. Adventitious roots which protrude from the surface of the tuber indicate no apparent arrangement with respect to buds (Bendixen 1973).

2.4.3 Tuber germination

The tuber dormancy of yellow nutsedge has received considerable study. The ability of tubers to remain dormant demonstrates a high degree of adaptation to environmental conditions and thus indicates the difficulty to eradicate the weed. Seasonal variation influences tuber sprouting and tuber dormancy. Sprouting is probably in response to warm temperature that promotes the formation of many basal bulbs, indeterminate rhizomes and leafy shoots (Jansen 1971). Freshly dug tubers appeared to be dormant and neither constant nor daily alternating temperatures in the range of 50°F to 95°F induced germination (Bell et al. 1962).

Tuber germination was greatly enhanced by storage for several months at low temperature, as low temperature helps to break tuber dormancy (Tumbleson and Kommedahl 1962; Taylorson 1967; Thomas and Hanson 1968; Stoller and Wax 1973). Tuber dormancy of yellow nutsedge can also be released by certain chemical compounds such as potassium thiocyanide, ethylene, chlorohydrin, thiourea and ethyl ether (Bell et al. 1962). Washing fall-harvested tubers increased sprouting from 75 to 95 per cent compared with unwashed tubers with 5 to 9 per cent germination (Tumbleson and Kommedahl 1962).

The sprouting of buds depends on their position on the tuber. Usually the largest outer triangular bud will sprout first, and in most cases two buds will break dormancy and sprout. The inhibition of apical end buds to sprout is due to the basal portion of the tuber. Tumbleson and Kommedahl (1962) detached the basal half of the tuber and found that the buds in the apical end broke dormancy and sprouted. The number of sprouted buds also depends upon how soon the sprouts were removed. For example, Thullen and Keeley (1975) removed the first sprout and found that 50 to 90 per cent of the tubers resprouted after 2 to 8 weeks and buds continued to sprout randomly until 95 per cent had sprouted after 64 weeks. They concluded that removing the sprouts every 2 weeks did not increase mortality. Bendixen (1973) found that 6 buds will sprout within 4 days depending on how often the sprouts were removed.

III. WEEDINESS OF YELLOW NUTSEDGE

3.1 Spread and establishment

The widespread use of herbicides in agricultural land has been effective in controlling most annual weeds. However, conditions are then favorable for the growth and development of many perennial weeds, such as yellow nutsedge, due to the reduced competition from other weeds. As a result of annual use of herbicides in cotton production in the United States, yellow nutsedge has greatly increased as a weed in cotton areas (Bird and Hogger 1973). The use of farm machinery may also be an important factor contributing to the rapid distribution of yellow nutsedge from field to field.

Yellow nutsedge is a rapidly growing plant. Once the plant is established, it can increase at an average rate of 3.7 to 23.5 plants per day and spread at a rate of up to 10.16 cm per day over a single season. It is not surprising to find that in one growing season a single tuber could produce 1900 plants, 6900 tubers and cover an area of 34 square feet (3.163 m²) (Tumbleson and Kommedahl 1961). The ability of yellow nutsedge to produce large quantities of tubers and the potential of buds to resprout make the plant a dominant weed in many fields.

3.2 Detrimental effects

Yellow nutsedge is a persistent weed in many fields of vegetables, corn, oats, beans, tomatoes, peppers, alfalfa, potatoes, ornamentals, small fruits, tree fruits and nurseries (Bell et al. 1962; U.S.D.A. 1968). The weed reduces yield, lowers crop quality, and increases the cost of production due to increased cultivation, hand weeding, harvesting and processing (Bell et al. 1962). Heavy infestation of yellow nutsedge in Minnesota, mainly at Hollandale and Maple Plain, has rendered peat land unproductive for truck crops and some farmers were taken out of production because of yellow nutsedge infestation (Tumbleson and Kommedahl 1961). The weed reduces yields of soybean, cotton seed, potatoes and onion as much as 29, 34, 48.6 and 100 per cent, respectively (Wax et al. 1972; Hogue 1975; Keeley and Thullen 1975).

In corn fields, medium and high densities of yellow nutsedge infestations significantly decreased corn yield by 17 to 41 per cent, and for every 100 shoots per meter square of the weed, corn yield was decreased by 8 per cent (Farwell and Hawf 1975; Stoller et al. 1979). Yellow nutsedge seems to compete with corn for nutrients and moisture but not for light because the corn grows taller than the weed. Increasing yellow nutsedge population in corn at 5 to 6-leaf stage tends to increase manganese, boron and zinc content of corn. Whereas when corn is in the silking stage, nitrogen, phosphorus, potassium and zinc are decreased. Nitrogen, potassium, calcium, magnesium, manganese and zinc were also accumulated in yellow nutsedge. The accumulation of

1.5 to 2.0 times more calcium, magnesium and zinc in the weed than in corn shows a possibility for severe competitive effects to corn (Farwell and Hawf 1975).

The allelopathic effect of yellow nutsedge on various crops has been investigated by several researchers (Tames _et al_. 1973; Drost and Doll 1980). Methanol extracts of yellow nutsedge tubers inhibited the growth of oats coleoptile section and germination of _Beta vulgaris_ L., _Lotus corniculatus_ L., _Lolium perenne_ L., _Pisum sativum_ L., _Trifolium repens_ L., _Lactuca sativa_ L., and _Lycopersium esculentum_ Ludwig. (Tames _et al_. 1973). The allelopathic effects of yellow nutsedge extracts and residue on soybeans and corn has also been reported (Drost and Doll 1980).

3.3 Beneficial uses

Yellow nutsedge has been used for a variety of purposes in other parts of the world. In some parts of the United States, yellow nutsedge or chufa is grown as food for hogs (Satterthwait 1942), although cattle and horses occasionally were allowed to graze off the tops of the plants before hogs were released (Killinger and Stokes 1946). Yellow nutsedge was also regarded as a valuable source of food and shelter for wildlife (Poinar 1964). Mulligan and Junkins (1976) reviewed some of the beneficial uses of chufa tubers which include: (i) production of beverage, vegetable oil and cellulose, (ii) ground as a substitute for coffee, and (iii) roasted tubers as «earth almonds.» In Italy and Egypt, the tubers have been extracted and the oil used as a food or for making soap (Power and Chestnut 1923).

IV. CONTROL OF YELLOW NUTSEDGE

Yellow nutsedge became a critical problem in eastern United States after 1958 and has only become a prominent weed in Canada during the last twenty years (Hauser 1968; Mulligan and Junkins 1976). Tuber dormancy and the tremendous reproductive potential of yellow nutsedge makes it difficult to control. Several control methods have been investigated in attempts to reduce the population of yellow nutsedge to economic levels. The use of herbicides has been only partly effective and research on biological control using natural enemies of nutsedge is not advanced. Cultural control methods, such as tillage, have also been utilized for the control of yellow nutsedge.

4.1 Chemical control

The ideal herbicides for yellow nutsedge control would not only kill the plants but would also persist in the soil and kill the dormant tubers. Since yellow nutsedge is a perennial, the opportune time for chemical control may be between the time when overwintering tubers sprout and the time when new tubers are produced, but it is nearly impossible to kill tubers buried in the soil (Stoller et al 1972) unless the herbicide is translocated and accumulated in the tubers in sufficient quantity. Several herbicides have been used to control yellow nutsedge, including some triazines, some thiocarbamates, alachlor, metolachlor, glyphosate, bentazon, and others.

4.1.1 Triazine

Atrazine, 2-chloro-4-ethylamino-6-isopropyl amino-s-triazine, has been extensively studied in corn fields infested with yellow nutsedge due to its selectivity properties in corn. Yellow nutsedge is very susceptible to atrazine at 4.48 kg/ha. When applied as preplant incorporation treatment, nutsedge stands were reduced up to 88 per cent (Vengris 1963; Parochetti 1974). This is due to the greater activity of this chemical in the more moist environment of the root zone and the effectiveness of atrazine increases as soil moisture increases up to field capacity (Fertig 1961; Vengris 1961; Bell and Gardiner 1962; Hargan et al. 1963). Since atrazine is translocated in the xylem, it is more widely distributed within the plant when soil applied than when foliage applied (Donnally and Rahn 1961). Atrazine interferes with photosynthesis and it does not enter and kill dormant tubers, but rather acts on the emerging sprout (Day 1953; Bundy et al. 1960; Bell et al. 1962; Keeley and Thullen 1974).

Atrazine may also be applied as preemergence herbicide but its effectiveness is reduced in controlling yellow nutsedge as compared with preplant treatments (Vengris 1963), especially in soil with high organic matter (Cole et al. 1962). However, disking after emergence may increase control (Hardcastle et al. 1966). Preemergence application of atrazine as wettable powder gave better control than when a granular formulation was used (Cole et al. 1962). Post emergence applications of atrazine seem to provide better control than preemergence treatment (Durfee et al. 1960), especially with the addition of oil (Colby 1967; Parochetti 1968; Brown and Mindreboe 1968).

In eastern Canada, split application of atrazine at 2.25 kg/ha incorporated to a depth of 5 to 8 cm plus second application of 2.25 kg/ha when nutsedge is about 15 cm high is recommended for yellow nutsedge control in corn (Ontario Ministry of Agriculture and Food 1981).

Two other s-triazine chemicals that have been found to be effective against nutsedge are cyanazine and cyprazine at 3.36 kg/ha (Hist and Ilnicki 1970; McAvoy and Ilnicki 1973).

4.1.2 Thiocarbamates

EPTC (s-ethyl dipropylthiocarbamate) gives excellent control of yellow nutsedge (Gentner 1973; Keeley and Thullen 1974). Preplant incorporation of EPTC at 4.48 to 6.72 kg/ha gave adequate control of nutsedge, due to its even distribution in the soil through incorporation rather than leaching of the herbicide into the soil (Rahn 1959; Holt et al. 1962; Bandeen 1968; Wax et al. 1972; Riley and Smith 1974). The effectiveness of emulsifiable and granular formulations of EPTC is slightly different in that the granular formulation has a longer residual effect (Antognini et al. 1959; Holt et al. 1962).

Since EPTC is a very volatile compound, it must be incorporated immediately following application and it should not be applied to a wet soil (Antognini et al. 1959; Havis et al. 1959; Holt et al. 1962). Further, incorporation of EPTC below the soil surface by blade injection technique seems to give better yellow nutsedge control than with disk incorporation (Hauser et al. 1966).

Translocation of EPTC is similar to atrazine in nutsedge (Donnalley and Rahn 1961). Even though EPTC does not penetrate the epidermis of dormant tubers and does not kill tubers (Bell et al. 1962; Holt et al. 1962; Parker et al. 1969; Ray and Wilcox 1969; Wax et al. 1972; Keeley and Thullen 1974), it does inhibit cell division and elongation of emerging shoots, delay sprouting of tubers, and reduce tuber germination up to 60 per cent (Rizk et al. 1967; Keeley and Thullen 1974).

EPTC in combination of either 2,4-D or atrazine at 1.12 kg/ha gave enhanced control of yellow nutsedge in corn (Worsham et al. 1964; Brown and Midreobe 1967).

In addition to EPTC, other thiocarbamates (pebulate, butylate and cycloate) could also suppress yellow nutsedge and are recommended for yellow nutsedge control in eastern Canada (Ontario Ministry of Agriculture and Food 1980).

4.1.3 Alachlor

Alachlor (2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide) was reported to be phytotoxic to yellow nutsedge and reduce shoot growth when placed near tubers in the soil (Ingle and Worsham 1971; Wax et al. 1972). In petri dish studies, alachlor inhibited growth, shoot elongation and killed newly emerging shoots, but did not inhibit sprouting of yellow nutsedge tubers (Armstrong et al. 1973a; Cornelius et al. 1978).

The time and method of application of alachlor may influence the herbicidal activity. In some studies preemergence application gave better control than preplant incorporation (Armstrong _et al_. 1973a; Ahrens 1975; Lange _et al_. 1977; Boyles and Murray 1979), and in other studies the incorporated application provided better control when compared with surface applications (Benson _et al_. 1969; Wilson _et al_. 1971; Clark and Fawcett 1977; Cornelius _et al_. 1978). Because alachlor is primarily translocated acropetally, post emergence application may not control yellow nutsedge due to insufficient translocation of the herbicide to the growing point and due to limited basipetal movement. Further, the main site of uptake of soil applied alachlor by yellow nutsedge plants is the portion of the plant above the tuber, and alachlor is metabolized rapidly in yellow nutsedge to at least one water-soluble metabolite. However, alachlor absorption by yellow nutsedge seedlings through the shoot or rhizome below the basal bulbs and subsequent translocation to the growing point appears responsible for reduced emergence of shoot, shoot height and eventual death of the young plant (Armstrong _et al_. 1973b).

In eastern Canada, preplant incorporation of alachlor at 3.25 to 4.5 kg/ha to a depth of 2.5 to 5.0 cm is recommended for yellow nutsedge control in corn (Ontario Ministry of Agriculture and Food 1981).

4.1.4 Metolachlor

Metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide) is a selective preplant incorporated and preemergence herbicide that is reported to be more effective than alachlor in controlling yellow nutsedge (Higgins et al. 1976; Hahn 1978). Metolachlor gave excellent long term control by maintaining more than 60 per cent control of yellow nutsedge even after 161 days post treatment (Brashears et al. 1976; Dixon et al. 1978; Obrigawitch et al. 1978; Selleck and Greider 1978; Warholic and Sweet 1978). Metolachlor inhibited shoot elongation but did not inhibit tuber sprouting (Cornelius et al. 1978).

Several researchers found that metolachlor, when incorporated before sowing, gave better control of yellow nutsedge than when applied as preemergence (Higgins et al. 1976; Clark and Fawcett 1977; Cornelius et al. 1978; Hill et al. 1978; Slack and Hayes 1978). Others claim that metolachlor provided good nutsedge control when applied either as incorporated preemergence or as surface applied (Clarkson and Van Geluwe 1975; Kurtz and Stroube 1975; Selleck and Webber 1976; Lange et al. 1977; McMahon et al. 1979; Obrigawitch et al. 1979; Saunders et al. 1979).

Metolachlor activity was considered to be high in sandy loam and silt loam soil, consistent on dry coarse textured soil, but low in silty clay loam (Dixon et al. 1978; Hill et al. 1978; Selleck 1978). It seems that metolachlor is very mobile in soil with low percentages of clay and organic matter (Cornelius et al. 1978). This may be one of the reasons why rainfall after application of metolachlor reduces its toxicity (Jooste et al. 1978; Jooste and Van Biljon 1979).

In eastern Canada, metolachlor at 2.0 to 2.5 kg/ha incorporated to a depth of 10 cm is recommended for yellow nutsedge control in corn (Ontario Ministry of Agriculture and Food 1981).

4.1.5 Glyphosate

Glyphosate (N-(phosphonomethyl) glycine) is a non-selective herbicide which shows promise against many perennial weeds including yellow nutsedge (Baird et al. 1971; Tweedy et al. 1972; Ahrens 1974). Glyphosate, a foliar applied herbicide, is actively translocated from leaf and stem tissue to underground parts primarily in the phloem with the photo-assimilates following the established source to sink relationship (Baird et al. 1971; Large 1973; Sprankle et al. 1975).

Several climatic factors such as temperature, photoperiod and light intensity influence the effectiveness of glyphosate to control yellow nutsedge. As the temperature, photoperiod and light intensity increase, glyphosate activity in yellow nutsedge is increased. On the other hand, increased soil moisture does not increase glyphosate activity (Tharawanich and Linscott 1975; Suwanketnikom and Penner 1976) because glyphosate has little or no residual activity in the soil (Sprankle et al. 1975; Hance 1976).

The effectiveness of glyphosate is also influenced by the growth stage of yellow nutsedge. Maximum shoot emergence is required for effective control by glyphosate, with optimum time of application being when the nutsedge is 7.6 to 25.0 cm tall (Penner 1975; Tharawanich and Linscott 1975; Suwanketnikom and Penner 1976).

Glyphosate, at low rates, may stimulate tuber formation (Linscott and Hagin 1973); however, the number of non viable tubers and the percentage of dormant tubers did not significantly increase (Appleby and Paller 1978).

In eastern Canada, glyphosate is recommended as a spot treatment at 1.75 to 2.25 kg/ha in 200 to 300 litres of water for yellow nutsedge control in corn (Ontario Ministry of Agriculture and Food 1981).

4.1.6 Bentazon

Bentazon (3-isoproply-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide) is a selective post emergence herbicide that is capable of controlling yellow nutsedge with rates of 0.75 to 1.5 kg/ha (Jagschitz 1979; Santos and Cruz 1979). Low rates of bentazon are effective in controlling yellow nutsedge even though the plants were not completely killed and may recover rapidly from herbicide injury (Stoller and Wax 1972; Parochetti and Hall 1975; Fretz and Sheppard 1979). As a result, repeated application of bentazon is required for effective control and single applications are usually not satisfactory for yellow nutsedge control (Tweedy et al. 1976; Bingham 1977; Jagschitz 1979). However, Ellison et al. (1978) and Kern et al. (1978) reported that single applications of bentazon are as effective as split applications and under favorable growing conditions gave 85 to 99 per cent control.

Time of application of bentazon has an effect on yellow nutsedge growth as the herbicide must be applied to actively growing yellow nutsedge if control is to be achieved (Hawf 1975; Jagschitz 1975, 1977, 1979; Ahrens 1979).

The effectiveness of bentazon on yellow nutsedge is influenced by environmental factors such as light intensity, soil moisture and temperature as well as plant growth stage. Bentazon was more effective for nutsedge control under low light intensity, high soil moisture, warm weather and on young and short plants (Stoller et al. 1975; Orr and Carter 1976; Suwanketnikom and Penner 1976; Orr et al. 1977). The optimum stage for treating yellow nutsedge in soybean and maize occurs when the nutsedge is 15 to 20 cm high and actively growing (Greulach et al. 1976; Zarecor et al. 1976; Paker 1978; Slack and Hayes 1978).

Several surfactants have been used to increase the phytotoxicity of bentazon on yellow nutsedge. Some surfactants appear to be beneficial while others do not (Hawf 1975; Boswell et al. 1976; Greulach et al. 1977; Suwanketnikom and Penner 1977, 1978; Ahrens 1979).

The translocation and adsorption of bentazon was demonstrated by several researchers (Abernathy and Wax 1973; Mahoney and Penner 1975; Stoller et al. 1975). Bentazon is translocated acropetally and basipetally from the site of application and is extensively diffused through the leaf (Mahoney and Penner 1975). It is not adsorbed to soil particles. Bentazon moved with the water front on soil thin layer plates as well as through soil columns (Abernathy and Wax 1975). Since foliage application of bentazon resulted in slow acropetal translocation of the herbicide, good coverage of the foliage by bentazon spray is essential because bentazon frequently kills the foliage contacted by the spray (Stoller et al. 1975). Although bentazon does not kill the parent tubers, it stops the production of new rhizomes from the basal bulb and kills the adventitious roots (Hawf 1975; Penner 1975; Stoller et al. 1975).

For the control of yellow nutsedge in corn, split application of bentazon is recommended at 0.85 to 1.20 kg/ha when corn is at the 1 to 5-leaf stage, plus a second application of the same rates 10 days later (Ontario Ministry of Agriculture and Food 1981).

4.1.7 Other chemicals

Other herbicides that gave satisfactory control of yellow nutsedge include buatachlor, methazole, prometryne, linuron, amitrol, dichlobenil, arsonates (AMA and DSMA), uracils (terbacil and bromacil) and certain combinations of herbicides (Hampshire 1969; Ray and Wilcox 1969; Duble and Holt 1970; Wax et al. 1972; Ahrens 1974; Keeley and Thullen 1974; Ontario Ministry of Agriculture and Food 1980).

In eastern Canada, linuron is recommended at 1.2 to 2.24 kg/ha in oil water emulsion at low pressure in 168 to 336 litres water as a directed spray and amitrol at 4.48 kg (active) as a spot treatment for yellow nutsedge control in corn (Ontario Ministry of Agriculture and Food 1980).

4.2 Biological control

Biological control of weeds is defined as the deliberate use of natural enemies - parasites, predators and pathogens - in reducing the population of a weed density to non-economic levels. In some instances these natural enemies can be manipulated to influence the abundance of their host plants. Weed-feeding insects have resulted in the control of a wide range of weed pests in many parts of the world. For example, Cactoblastic cactorum (Berg), the cactus-feeding moth, imported from

Argentina to Australia, greatly reduced the population of prickly pear cactus, Opuntia species (Dodd 1940), and the control of Hypericum perforatum L. by Chrysolina quadrigemina (Suffr.) imported from Europe (Huffaker and Kennett 1959).

In many cases insects have received particular attention for biological control of weeds, partly due to their size, their high rate of reproduction and their high degree of host specificity. However, studies are broadening to include plant pathogens as biological weed control agents (Wilson 1969; Inman 1971; Templeton and Tebeest 1979; Watson 1979).

There are differences in biological control approaches: (a) the classical biological control is aimed to suppress the growth and establishment of an introduced weed species by importation of its exotic natural enemies; (b) the augmentation approach is achieved by synchronizing the attack and the abundance of already present natural enemies in the weed habitat in order for the bioagent to be effective; (c) microherbicide approach is to employ microbes as herbicides by applying them to target native weeds in a manner similar to chemical herbicides. Both augmentation and microherbicide approaches seem to be possible biological control methods of yellow nutsedge in Canada because yellow nutsedge is native to North America.

4.2.1 Insects

Interest in biological control prompted a survey of the existing native insects on yellow nutsedge and purple nutsedge in California and in Mississippi. There are approximately 55 insect species in 7 orders representing 22 families that have been recorded on yellow nutsedge (Table 1). Some of these insects have shown association with yellow nutsedge plants either on leaves, stems, flowers, tubers or basal bulbs (Babcock 1916; Summerville 1933; Satterthwait 1942; Poinar 1964; Frick and Garcia 1975; Bersler et al. 1977).

The most promising insects found on nutsedge are moths in the genus Bactra. Nine species of this worldwide genus attack plants only in Cyperaceae. Within this genus, B. verutana Zeller has been found to be the most common insect attacking yellow nutsedge and it seems to be host specific (Poinar 1964; Keeley et al. 1970; Frick and Garcia 1975; Frick et al. 1979).

The percentage of B. verutana infestation on yellow nutsedge varies depending on plant growth stage. The earliness of the infestation of parent plants accompanied by a high infestation rate of daughter plants seems to be important factors contributing injury to the plants. Moreover, larval infestation at high plant density reduced dry weight, plant height, number of tubers and inflorescences of yellow nutsedge (Keeley et al. 1970; Frick et al. 1979).

Since B. verutana is native to North America, its potential to suppress yellow nutsedge in its native geographical range is limited due to the presence of its natural enemies. Moreover, it is rare that more than one larva develops per shoot and the larvae do not feed on the tubers. The feeding in the basal bulbs is limited. Therefore, a higher percentage of basal bulbs survives and produces new aerial

TABLE 1. Insects that were recorded on yellow nutsedge in North America

Order and Family	Species	Reference
Coleoptera		
Cuculionidae	Calendra callosa (Oliv.)	Satterthwait 1942
	C. destructor (Chitt.)	"
	C. cariosa (Oliv.)	"
	C. parvula (Gyll.)	"
	C. venatus (Say)	"
	Barinus squamolineatus (Casey)	"
	Sibariops confusa (Boh)	"
	Barilepis grisea (Lec.)	"
	Sphenophorous zeae (Walsh)	Babcock 1916
	S. phoeniciensis (Chittenden)	Poinar 1964
Coccidae	Antonina australes (Green)	Summerville 1933
	Chorizoccus rostellum Hoke	Poinar 1964
Anthribidae	Trigonorhinus sticticus (Boh.)	Beisler et al. 1977
Bruchidae	Althaeus hibisci (Oliver)	"
Buprestidae	Taphrocerus schaefferi Nicolay & Weiss	"
Chrysomelidae	Chactonema denticulata Ill.	"
	C. pulicaria Melsh	"
	Diabrotica undecempuncatata howardi Barber	"
Crytophagidae	Toramus sp.	"
Cucujidae	Telephanus velox Hald.	"
Nitidulidae	Megelethes sp.	"
Orthoperidae	Orthoperus sp.	"
Phalacridae	Phalacris politus Melsh	"
	Stilbus apicalis Melsh	"
	S. pallidus Casey	"
Scarabacidae	Pleurophorus sp.	"
Diptera		
Anthomyzidae	Anthomyza sp.	"
	Mumetopia occipitalis Mel.	"
	Stenomicra angustata Cog.	"
Chloropidae	Chlorops sp.	"
	Elachiptere nigriceps (Loew)	"
	Elliponeura debilis (Loew)	"
	Oscinella carbonaria (Loew)	"
	O. coxendix (Fitch)	"
	O. frit L.	"
	O. soror (Macquart)	"
	O. umbrosa (Loew)	"
	Stenoscinis atriceps (Loew)	"
	Thaumatomyia glabra (Meigen)	"
Otitidae	Chaetopsis fulvifrous (Macquart)	"

(table continued)

TABLE 1 (continued)

Order and Family	Species	Reference
Hemiptera		
Corimelaenidae	Corimelaena pulicaria (Germar)	Beisler *et al*. 1977
Miridae	Halticus bracteatus (Say)	"
	Megaloceroea recticornis (Geoffroy)	"
Homoptera		
Aphididae	Carolinaia cyperi Ainslie	Poinar 1964
	Rhopalosiphum maidis (Fitch)	Beisler *et al*. 1977
	R. rufiabdominalis (Sasaki)	"
Cicadellidae	Graminella nigrifrons (Forbes)	"
	Sanctanus sanctus (Say)	"
Delphacidae	Delphacodes basivitta (Van Duzee)	"
	Liburniella ornata (Stal)	"
Hymenoptera		
Tenthredinidae	Pachynematus corniger Norton	"
Lepidoptera		
Glyphipterygidae	Glyphidteryx impigritella (?)	"
Olethreutidae	Bactra verutana Zeller	Poinar 1964

shoots. In addition, climatic requirements for B. verutana to complete its life cycle are not synchronized with the growth cycle of yellow nutsedge in temperate climates. Thus in Central Mississippi and in Central California, there is a delay of about four months before the damaging population of this moth appears on yellow nutsedge (Poinar 1964; Keeley et al. 1970; Andres and Davis 1973; Frick and Garcia 1975).

Periodic release of B. verutana seems to be a logical step in controlling yellow nutsedge infestations. Mass rearing of this moth using artificial diets has proven to be effective for up to 35 generations, with good adult recovery and resulting mating and high fecundity without loss of vigor (Sieckett et al. 1974; Garcia and Frick 1975).

The main limitation would be the cost of producing these insects in the laboratory.

4.2.2 Pathogens

Plant pathogens are the most common natural enemies of plants and may often be destructive to their host populations. Fungi, nematodes, viruses, bacteria and mycoplasms may be considered for use as weed biological control agents (Charudattan 1975). Fungi and nematodes are the main pathogens associated with yellow nutsedge and some of these organisms may be considered as possible biological agents of yellow nutsedge. Approximately 13 pathogens have been reported from yellow nutsedge (Table 2). This list is probably far from complete as no concerted effort to survey yellow nutsedge for plant pathogens has

TABLE 2. Plant pathogens associated with Cyperus esculentus L.

Pathogen	Location found	Nature of association	Reference
Fungi			
Ascochyta sp.	Georgia, U.S.	on leaves	USDA 1963
Phyllachora cyperi Rehm.	S. Carolina	-	"
Puccinia cacaliculata Schrw. Lagerh	Quebec, Ontario, Mass. to Florida, Cal., Wisc.	-	USDA 1963; Conners 1967
Ustilago scitaminea Sydow	S. Africa	attacks apical bud and the inflorescence	Anonymous 1947
Verticillium dahliae Kelb.	-	caused slight discoloration in roots and lower stem	Johnson and Brinkerhoff 1976
Nematoda			
Criconemoides onoensis Luc	U.S. Gulf Coast region	injury to root tissue	Hollis 1977
Heterodera cyperi Golden, Rau & Cobb.	Florida	-	Schlindler and Golden 1965; Minton et al. 1973
H. mothi n.sp.	Georgia	abundant on roots but not on nuts	Khan and Husain 1965
Hoplolaimus columbus Sher.	Georgia	in roots	Minton et al. 1973

(table continued)

TABLE 2 (continued)

Pathogen	Location found	Nature of association	Reference
Nematoda (cont)			
Meloidogyne sp.	Florida, N.Carolina	life cycle completed in roots	Bird and Hogger 1973; Hogger and Bird 1976
M. incognita (Kofoid & White) Chit.	Georgia	life cycle completed in roots	USDA 1963; Bird and Hogger 1973; Hogger and Bird 1976
Pratylenchus brachyurus (Godfrey) Filipjev & Schuurmans Stekhoven	Georgia	-	Bird and Hogger 1973
Trichodorus sp. (Allen)	Georgia	-	"

been made. The usefulness of these pathogens as biological control agents of yellow nutsedge has not been assessed. It is possible that some of these pathogens or others not yet recorded could be used as bioherbicides.

4.3 Cultural control

Cultural weed control could be defined as any agronomic practice in farm production that suppresses the growth and development of weeds in the field. This may include: (1) physical control methods such as tillage operation, mowing, mulching and flooding, (2) preventive weed control such as sanitary practices to prevent the spread of yellow nutsedge tubers and rhizomes from field to field through contaminated farm machinery, and (3) habitat management by utilizing plant competition in a cropping system which includes fertilization, crop rotation, plant population density and seeding date.

Some of these cultural techniques have been investigated for the control of yellow nutsedge. Tillage has long been used to combat yellow nutsedge by exposing the tubers on the soil surface. Two days after tillage, tuber germination was reduced by as much as 80 per cent, and repeated tillage for 3 months at a depth of 12 inches (30.48 cm) under dry conditions reduced the tuber population to a very low level (Davis and Hawkins 1943; Tumbleson and Kommedahl 1961). At Ste-Anne-de-Bellevue, Quebec, triple tillage (June, July and August) at 8 to 10 cm depth in one growing season gave the best control of yellow nutsedge in reducing both plant population and tuber production. Tuber germination was only 35 per cent compared with 67.5 per cent for non-tilled plots (Abd.Ghafar 1977). Even though tillage implements destroy the above ground biomass, tillage does not eradicate the weed because the tuber population is not destroyed. Tillage of infested fields in the fall has little effect as most tubers are dormant (Taylorson 1967; Stoller et al. 1972). Perhaps, to ensure that no new tubers are formed, tillage should be done as soon as tubers sprout in the spring and should continue throughout the growing season as long as the tubers continue to sprout. Tumbleson and Kommedahl (1962) reported that 2 years of mechanical fallow reduces viable tubers in the soil by as much as 90 per cent. Mechanical disturbance of the soil has been shown to increase tuber sprouting, especially early in the spring (Abd.Ghafar 1977). This suggests that all potential shoots might be stimulated to germinate at approximately the same time and subsequent control practices could be more effective.

Crop rotation has been shown to suppress the growth of yellow nutsedge (Keeley et al. 1979). Crop rotation also provides an opportunity to use different herbicides and crops that could compete with nutsedge (Keeley and Thullen 1978). Since shading and competition from other plant species are inhibitory to nutsedge growth (Hauser 1962; Worsham et al. 1964), the use of competitive crops should be an effective means of reducing nutsedge populations.

There are several limitations on the use of cultural control methods. For example, tillage could also help the dispersal of tubers within infested fields and contaminated farm implements may transport tubers from infested fields to clean fields. If a fallow system is utilized for weed control, the land is not productive. In many weed-crop associations the optimum fertilizer and moisture levels for the crop are also advantageous for the weed population.

V. CULTURAL PRACTICES OF CORN

Corn yields are significantly reduced by nutsedge interference (Farwell and Hawf 1975; Stoller et al. 1979) and corn plants become short and lighter in color due to yellow nutsedge infestations (Tumbleson and Kommedahl 1961). Yellow nutsedge seems to compete, not only for nutrients, but also for the available space. Therefore, in fields heavily infested with yellow nutsedge, management practices of corn may alter the crop-weed interaction.

5.1 Fertilization

Corn yield generally increases with fertilization and the amount of fertilizer required will vary from location to location. White (1978) listed the general fertilizer requirements and recommendations for corn in various Canadian provinces.

Among all the nutrients required by corn, nitrogen and phosphorus seem to be the important elements for increasing corn yield. The addition of 45 to 90 kg/ha of N increases corn yields by 88 to 95 per cent. However, little or no benefit has been found by side dressing and applying N at planting in the Maritimes (White 1978). Similarly, the addition of phosphorus is not merely to increase yields, but also to improve maturity and the relative whole plant dry matter (White

1978). In New Brunswick, banded P was required for early corn growth even though the soil had been well supplied with P in prior years (Grant et al. 1972).

5.2 Corn population

It has been demonstrated that by increasing the plant population from a low density to a high density usually resulted in increased plant yield to a maximum level, and beyond this level an additional increase in population will decrease the yield. The relationship between plant density and yield components depends on the vegetative and reproductive phases of the plant. The yield per plant is represented by an asymptotic curve for the vegetative phase and a parabolic curve for the reproductive phase (Holliday 1960).

Early competition in corn will reduce plant growth rate. As the corn population increases, dry matter per plant and size of ear decreases but total grain yield increases (Donald 1963). In order to obtain the maximum silage and the highest grain yield contribution to silage production, optimum population densities of 55,000 to 80,000 plants per hectare were required (Rutger and Crowder 1967; Martin 1977). Generally, as corn population increases, the yield increases provided moisture is adequate (Giesbrecht 1969; Nunez and Kamprath 1969; Hunter et al. 1970; Bolton 1971; Baynes 1972).

Planting pattern in relation to different corn population densities has been shown to have some effect on grain yield. For example, Hoff and Mederski (1960) used 107 cm rows versus equidistant spacing with five plant densities ranging from 19,768 to 59,304 plants per hectare. Their results showed that equidistant spacing increased mean yield of grain by 370 to 673 kg/ha, but there was no significant difference due to the planting system. However, Yao and Shaw (1964) clearly demonstrated that an equidistant spacing of 53 cm was significantly superior to 81 cm and 107 cm spacings. In addition, closer spacing of 53 cm showed the greatest efficiency in water use. The advantage of equidistant spacing over other planting systems was probably due to less competition for light.

There is some controversy on the effect of increasing corn population density on plant height. Giesbrecht (1969) reported that increasing population density will increase plant height, whereas Bonaparte (1971) stated the opposite. These different findings may be due to differences in growing conditions.

5.3 Date of planting

Planting date of corn varies from area to area with the optimal date of seeding at Ste-Anne-de-Bellevue, Quebec, being between the 1st and the 15th of May. Seeding after the 15th of May will result in reduced yield and increased moisture percentage at harvest (Martin 1977). However, different planting dates of corn at Iowa did not show any significant effect on the number of leaves formed per plant and the average yield. On the other hand, plant height and shank length increased at successive planting dates, especially if adequate moisture was available (Eik and Hanway 1965; Genter and Jones 1970).

The main effect of planting date is reflected in flowering date. Several researchers have pointed out that by delaying the date of planting, flowering is delayed but the number of days required to flower is also reduced. This reduction in the number of days to flower varied with corn planted early in the season, when the reduction was much larger than if planting dates were later in the growing season (Grogan et al. 1959; Eik and Hanway 1965; Schmidt and Hallauer 1966; Stauber et al. 1968; Zuber 1968). There is linear relationship between planting dates and days to tassel. A five-day delay in planting will reduce one day to tassel (Stauber et al. 1968).

VI. EXPERIMENTAL

6.1 Introduction

Early establishment of competitive crops is one of the prime factors to combat weed infestations. Corn can be established relatively early and is one of the most rapidly growing annual crops. This early establishment and growth of corn should produce a competitive advantage for the crop over late emerging weeds such as yellow nutsedge. Therefore, planting corn early in the spring should result in the early establishment of the crop with a concomitant competitive advantage over weed populations that establish after the crop.

In southwestern Quebec corn is normally planted at 75 cm between rows and 20 cm between plants in the rows. These wide planting distances may provide adequate space for yellow nutsedge to grow and establish, and may provide the weed a competitive advantage over the crop. Probably, the weed-crop competition can be altered by crop density. Increasing corn population densities to a maximum level should be advantageous to the crop under severe yellow nutsedge competition. The amount of light penetrating below the corn canopy at different population densities should decrease as corn population densities increase, and the space available for yellow nutsedge will decrease. Therefore, increasing the corn population should be detrimental to yellow nutsedge growth.

The overall goal of this research program was to determine the effect of increasing corn population and different dates of seeding on the growth and development of yellow nutsedge. Two field experiments were conducted:

Experiment 1. Effect of corn population on yellow nutsedge.

Experiment 2. Effect of corn seeding date on yellow nutsedge.

6.2 Location

Field experiments were conducted on the Macdonald College Farm, Macdonald Campus of McGill University, Ste-Anne-de-Bellevue, Quebec (45°26'N, 73°56'W) during two growing seasons (1980 and 1981). The soil in the experimental areas was a sandy loam with 3.49 per cent organic matter and heavily infested with yellow nutsedge.

6.3 Material and methods

Each year, the field was ploughed in the fall and harrowed in the spring. At harrowing, 560 kg/ha of 5:20:20 fertilizer was applied to the soil. Prior to seeding the corn cultivar CO-OP S 265 (2650 heat units) the field was rotovated. At seeding, 28 kg/ha of 18:46:0 fertilizer was applied along the corn rows as a starter fertilizer. Split application of 366 kg/ha of ammonium nitrate was used as a side dressing. The first application of 168 kg/ha was done at the 5-6-leaf stage of corn and the second application was done 2-3 weeks later. Weeds other than yellow nutsedge were removed by hand, resulting in a severe infestation of yellow nutsedge (approximately 1600 shoots/m^2) (D.Cloutier, personal communication) throughout the growing season.

6.4 Treatments

6.4.1 Experiment 1 - Corn population

Twelve treatments were arranged in a randomized complete block design with 3 replications. The treatments consisted of combinations of 3 different distances between rows and 4 distances within the corn rows, with resulting corn populations varying from 33,333 to 133,333 plants per hectare as shown in Table 3. All plots were 3 m x 6 m. All plots were seeded on the same date (1980.5.12; 1981.5.15) utilizing a manual «adjustable corn punch» system.

6.4.2 Experiment 2 - Seeding date

Five different dates of seeding were assigned at one-week intervals as the five treatments. The first seeding date was in early May (1980.5.8; 1981.5.5) and the fifth seeding date was in early June (1980.6.5; 1981.6.2). Three rows of corn were planted in plots 2.25 meters x 6 meters at 75 cm between rows and 20 cm within corn rows (66,667 p.p.h.). Treatments were arranged in a randomized complete block design with three replications. Prior to each seeding date, the plots were rotovated at 8 to 10 cm depth. Seeding was done manually as described above.

TABLE 3. Treatments in Experiment 1

Treatment number	Planting distances (cm)		Population densities (pl/ha)
	Between rows	Within rows	
1	50	15	133,333
2	50	20	100,000
3	50	25	80,000
4	50	30	66,667
5	75	15	88,889
6	75	20	66,667
7	75	25	53,333
8	75	30	44,444
9	100	15	66,667
10	100	20	50,000
11	100	25	40,000
12	100	30	33,333

6.5 Data collection

6.5.1 Plant height

Plant height for both corn and yellow nutsedge was recorded from three random locations in each plot during the second week of July (Experiment 1). This date was chosen due to yellow nutsedge tuber formation. Plant height was also recorded at the end of the growing season prior to sampling yellow nutsedge biomass in 1981.

6.5.2 Light intensity

Light intensity below the corn canopy at the yellow nutsedge canopy was taken every week starting the second week of July to the second week of August. These measurements were taken between 1 p.m. and 2 p.m. Three different readings were recorded along the middle rows: one from the centre and two from near the ends of the rows.

The Lamba LI-185 instrument with quantum sensor was used to measure quanta in the Photosynthetically Active Radiation (PAR) spectrum between 400 and 700 nm (visible wave length) range received on a plane surface. This measurement is in microeinsteins (m^{-2} sec^{-1}) where one microeinstein equals 6.023×10^{17} photons.

The light intensity measurements were only done in Experiment 1.

6.5.3 Leaf Area Index

In 1981 in Experiment 1, Leaf Area Index of yellow nutsedge was calculated by measuring the leaf area to leaf weight ratio. This ratio was proportional to the dry weight of the total mass/0.1 m^2 (Radford 1967). The yellow nutsedge leaves were assumed to be rectangular and ten 20-cm lengths were cut and the width was measured at each sampling period, as described by William and Warren (1975).

6.5.4 Yellow nutsedge yield

Fresh weight and dry weight of yellow nutsedge were determined using quadrats of 30 cm x 30 cm and 20 cm x 45 cm placed between and within corn rows, respectively. Six samples were taken at random from each plot with three samples from between the rows and three samples within the corn rows. These samples were taken in the second week of August 1980 and 1981.

Yellow nutsedge tubers were collected at the end of the growing season with a 15-cm^3 sampler (Gutman and Watson 1980). Six soil samples were taken at random from each plot (3 samples from between rows and 3 samples from within corn rows). Tubers were separated, washed and dried. Only firm tubers were retained in the sample. The number and the weight of tubers were recorded. These tubers were then separated into different size classes by sieving them through a series of mesh screens of different sizes ranging from less than 2.8 mm to greater than 6.0 mm. The number of tubers in the different size classes was recorded with the weight of each class also recorded in 1981.

6.5.5 Corn yield

Ear length was measured just prior to harvesting the corn, for both experiments (1980 and 1981), but for Experiment 2 measurement was done only in 1981. The middle row of corn from each plot was harvested during the second week of September. Alternating plants from these rows were measured either as a silage or as ear yield. Subsamples of both silage and ear yield were chopped and oven dried to determine the dry weight.

6.6 Analysis of data

In all cases the yield of yellow nutsedge between the corn rows and within corn rows was analyzed separately as individual parameters (both experiments). The data were analyzed as a 3 x 4 factorial to evaluate the effects of planting distance between and within corn rows (Experiment 1). Duncan's Multiple Range Test was used to locate significant differences among the treatments.

Experiment 1 was also treated as non-factorial design by considering all the 12 different planting distance combinations as in individual treatments. Analysis of variance was conducted and Duncan's Multiple Range Test was used to locate significant differences between those 12 treatments.

Since some of the treatments had the same corn population per plot (planting distance of 50 cm x 30 cm; 75 cm x 20 cm; and 100 cm x 15 cm), the means yield from these populations and the yields from other treatments were used in regression analysis to determine the effect of different corn populations on the parameters measured. Different tuber size classes were considered as non-parametric and the χ^2 K-independence analysis was used to evaluate the effects of treatments on the tuber size classes. The Contingency Coefficient was also calculated to determine the relationship between the treatments and tuber size classes.

In order to gain more information on the tuber size classes, each different size class was considered as another variable. Analysis of variance as well as Duncan's Multiple Range Test was calculated.

The 't' test was also performed to evaluate the effect of treatments on yellow nutsedge harvested between and within the corn rows. This test was done for all the treatments combined and for each individual treatment.

Correlation analysis was conducted to determine the effect of treatments on yellow nutsedge and corn parameters. Correlation analysis was also conducted on silage yield and light intensity in comparison with yellow nutsedge parameters. Correlation, factorial and population analysis was not conducted in Experiment 2.

VII. RESULTS

7.1 Experiment 1 - Corn population

The yield of yellow nutsedge from between corn rows and from within corn rows were analyzed separately as individual parameters. A summary of the results obtained from the ANOVA is presented in Appendix 1.

7.1.1 Yellow nutsedge above ground biomass

Corn planting distance significantly altered yellow nutsedge biomass within corn rows. The lowest nutsedge yield was obtained from the closest planting distance of 50 cm between corn rows and 15 cm between corn plants within the rows (Appendix 2). Yellow nutsedge harvested from within corn rows decreased as the planting distance decreased either between the rows or within corn rows. A planting distance of 50 cm between rows in combination with planting distance of 15, 20, 25 or 30 cm within the rows tended to reduce yellow nutsedge biomass when compared with other planting distances between rows (alone or in combination within row distances) (Figure 1).

Corn planting distance did not significantly alter yellow nutsedge biomass between corn rows (Appendix 2). Nevertheless, the lowest overall yellow nutsedge biomass was obtained from between corn rows. The comparison 't' test was made on yellow nutsedge biomass between those samples obtained from between corn rows and those obtained from within corn rows (Table 4). There was significantly more yellow nutsedge biomass obtained from within corn rows than from between corn rows.

Corn planting distance of 50 x 30, 75 x 20 and 100 x 15 cm had the same corn population, but their effects on nutsedge biomass were slightly different (Figure 1). In general, the effect of increasing corn population corresponded to a linear decrease in yellow nutsedge above ground biomass (Figure 2).

<u>Yellow nutsedge height</u>.--The effect of corn population on yellow nutsedge height was not great (Figures 3 and 4). Nevertheless, there was a significant linear increase in yellow nutsedge height as the corn population increased when measured on July 18, 1980, but a decrease as corn population increased when measured on August 6, 1981 (Figure 3). There was no significant effect of corn population on yellow nutsedge height when measured on July 8, 1981 (Figure 4).

<u>Yellow nutsedge leaf area index (LAI)</u>.--The LAI of yellow nutsedge ranged from 0.27 at the lowest corn population (33,333 plants per hectare) to 0.47 at the highest corn population of 133,333 plants per hectare (p.p.h.).

TABLE 4. The comparison 't' values on yellow nutsedge parameters between and within corn rows as affected by corn planting distance

Corn planting distance	Dry weight above ground biomass		Tuber number		Tuber dry weight	
	1980	1981	1980	1981	1980	1981
50 cm between rows						
15 cm within row	-3.3158**	-1.34 NS	-1.7771 NS	-0.93 NS	-0.8925 NS	-0.45 NS
20 cm within row	-2.4519*	-1.53 NS	-0.4997 NS	-6.26**	-0.1483 NS	-4.24**
25 cm within row	1.5567 NS	-3.77**	-1.4178 NS	0.40 NS	-0.5321 NS	0.11 NS
30 cm within row	-3.2222**	-1.57 NS	-2.0794 NS	-0.54 NS	-0.9078 NS	-0.86 NS
75 cm between rows						
15 cm within row	-1.0420 NS	-4.27**	-2.7539*	-2.12 NS	-2.6841*	-2.23*
20 cm within row	-4.6808**	-4.57**	-1.0073 NS	-1.41 NS	-1.9841 NS	-3.07**
25 cm within row	-1.8188 NS	-4.98**	-2.2996*	-2.30*	-2.4697*	-1.87 NS
30 cm within row	-4.4404**	-11.85**	-3.0066**	-3.93**	-3.0277**	-2.04 NS
100 cm between rows						
15 cm within row	1.8107 NS	-4.78**	-0.5917 NS	-2.40*	-1.1960 NS	-3.39**
20 cm within row	-4.9542**	-4.53**	-2.4200*	-1.17 NS	-3.0274**	-2.33*
25 cm within row	-7.3970**	-4.64**	-3.7435**	-1.76 NS	-4.8929**	-2.85*
30 cm within row	-3.0228**	-3.81**	-3.6485**	-5.90**	-3.4089**	-5.34**
Over all treatments	-4.5445**	-8.85**	-4.1420**	-5.17**	-3.8520**	-7.19**

* Significant at 5 per cent level
** Significant at 1 per cent level
NS Not significant

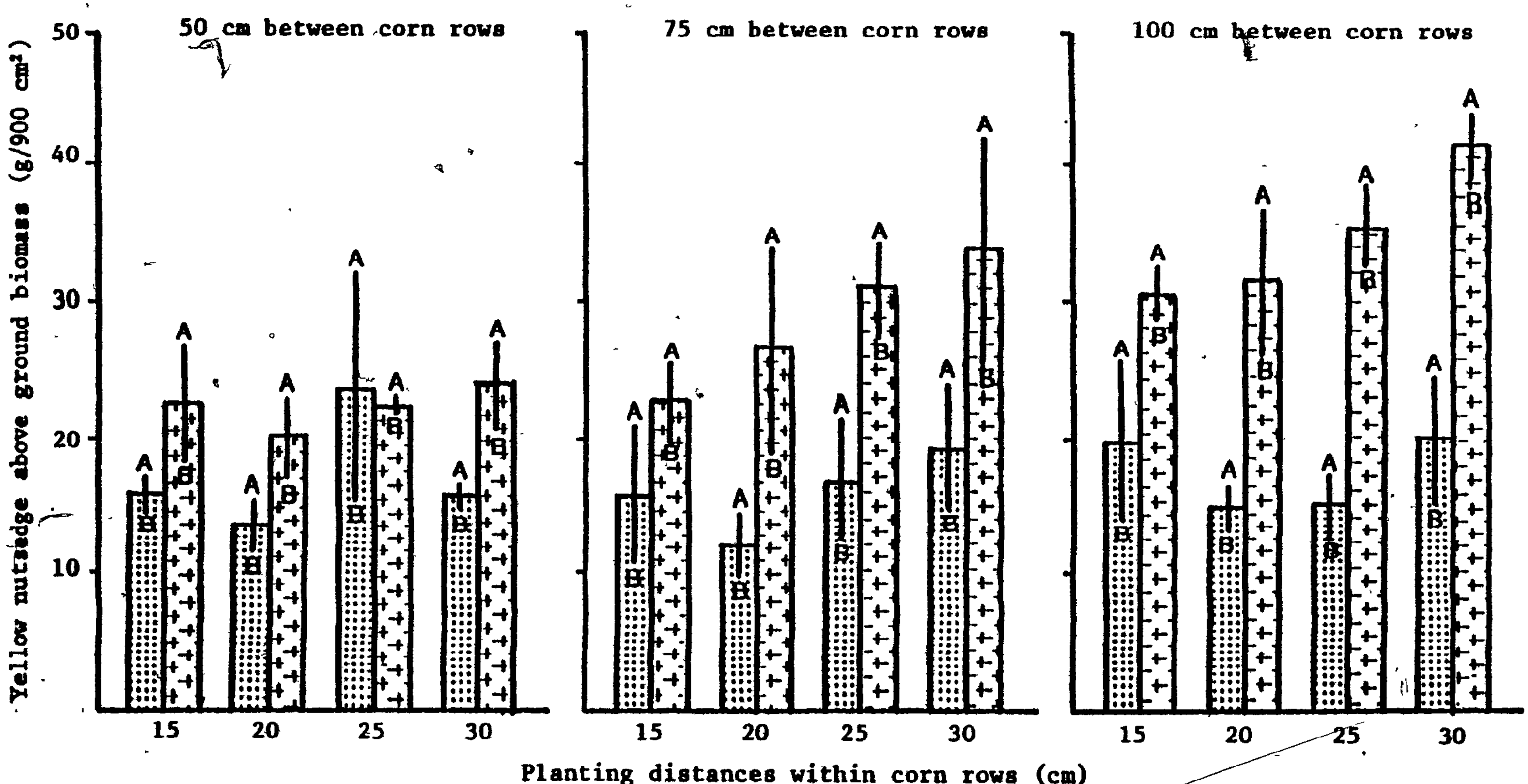


Figure 1. Effect of corn planting distances on yellow nutsedge above ground biomass.

Samples obtained from between corn rows

Samples obtained from within corn rows

A = 1980 data

B = 1981 data

Figure 2. Effect of corn population on yellow nutsedge biomass, tuber number and tuber dry weight.

Nutsedge biomass within corn rows. 1980.

$Y = 45.9 - 2.0 \times 10^{-4} X$

Nutsedge biomass within corn rows, 1981.

$Y = 37.1 - 1.8 \times 10^{-4} X$

Number of nutsedge tubers within corn rows, 1980.

$Y = 177.4 - 7.8 \times 10^{-4} X$

Number of nutsedge tubers within corn rows, 1981.

$Y = 134.7 - 7.0 \times 10^{-4} X$

Dry weight of nutsedge tubers within corn rows, 1980.

$Y = 11.8 - 6.6 \times 10^{-5} X$

Dry weight of nutsedge tubers within corn rows, 1981.

$Y = 9.6 - 6.1 \times 10^{-5} X$

Number of nutsedge tubers between corn rows, 1981.

$Y = 74.9 - 2.7 \times 10^{-4} X$

Note: Only significant nutsedge growth parameters were presented in the figure.

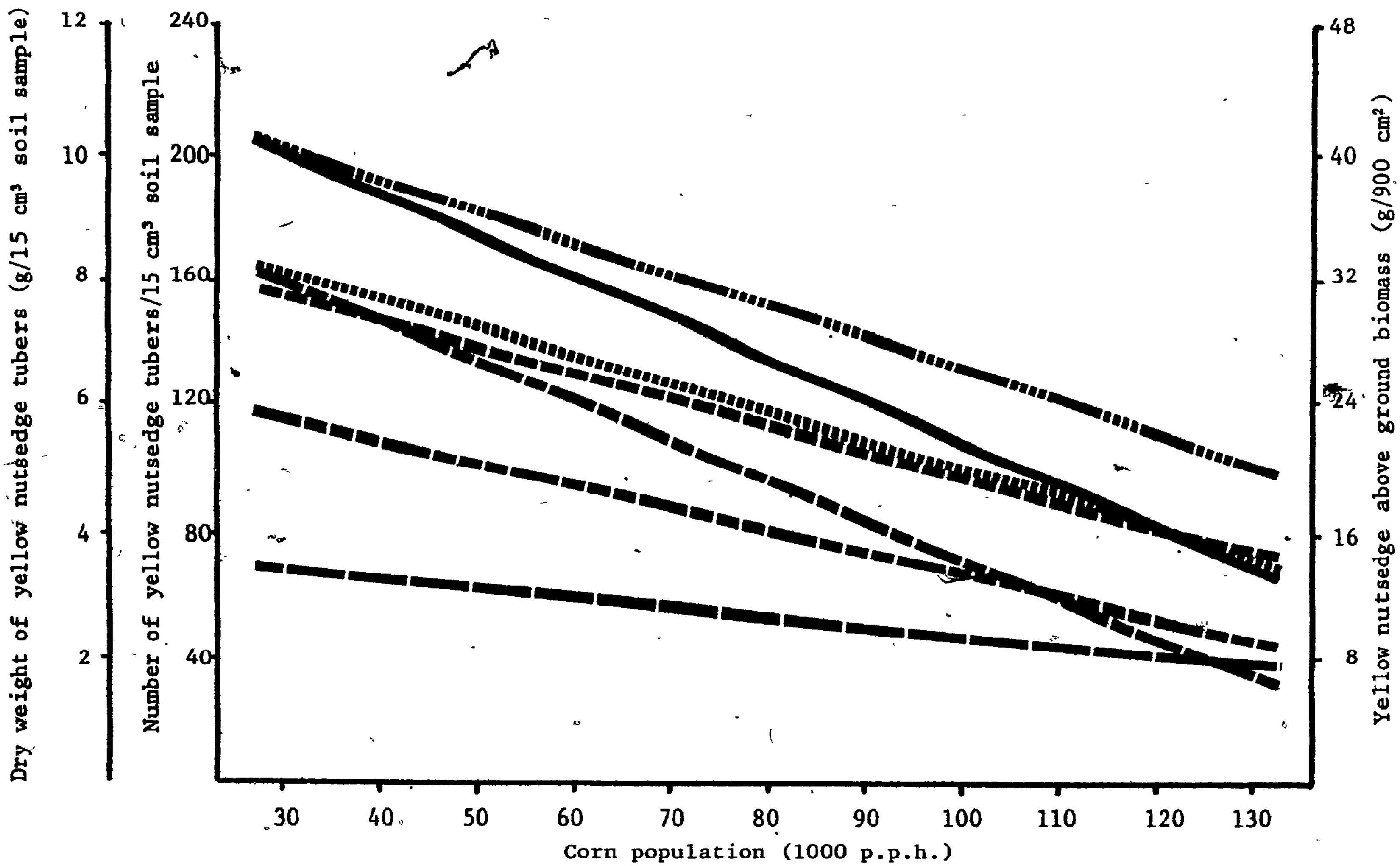

Dry weight of yellow nutsedge tubers (g/15 cm³ soil sample)
2
4
6
8
10
12
Number of yellow nutsedge tubers/15 cm³ soil sample
40
80
120
160
200
240
Yellow nutsedge above ground biomass (g/900 cm²)
8
16
24
32
40
48
30
40
50
60
70
80
90
100
110
120
130
Corn population (1000 p.p.h.)

Figure 2

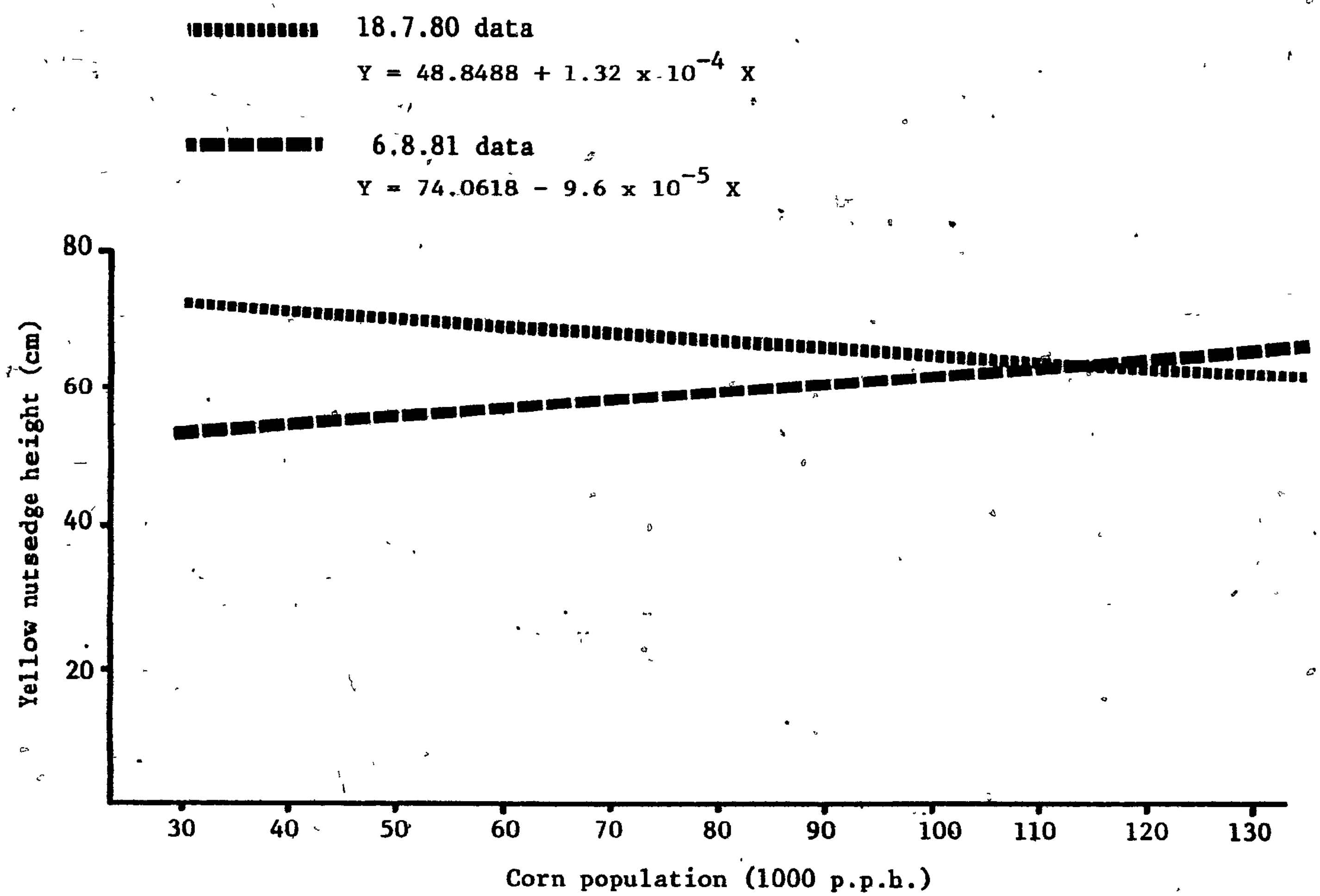


Figure 3. Effect of corn population on yellow nutsedge height.

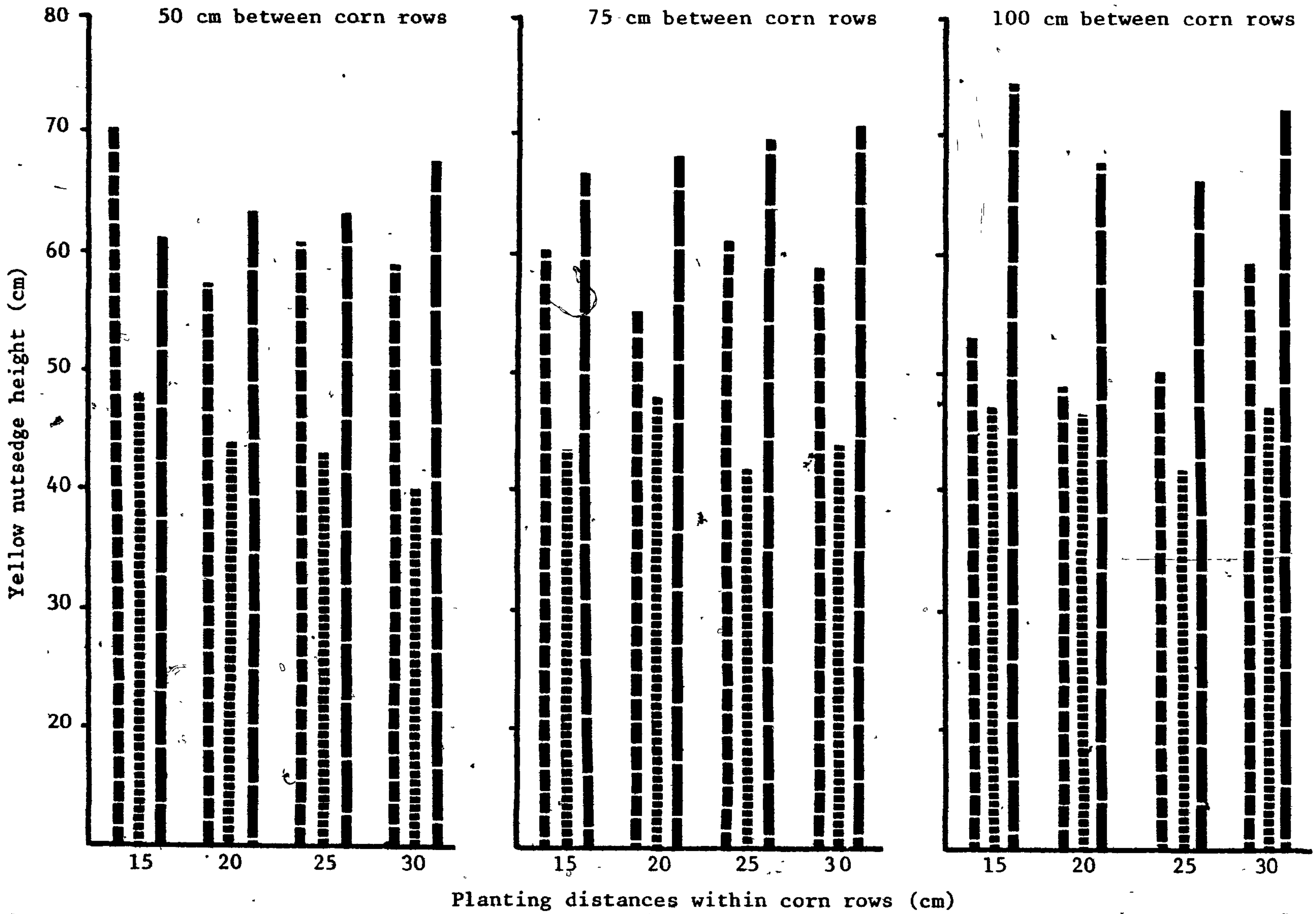


Figure 4. Effect of corn planting distances on yellow nutsedge height.

18.7.80 data   8.7.81 data   6.8.81 data

7.1.2 Tuber production of yellow nutsedge

7.1.2.1 Tuber number

The numbers of yellow nutsedge tubers produced from between corn rows and from within the rows were significantly affected by the corn planting distance between the rows but not by the distance within corn rows (Appendix 3). The lowest and highest number of tubers produced were obtained at the planting distance of 50 and 100 cm between corn rows, respectively. There were significantly more tubers produced from within corn rows than from between the rows (Table 4).

The overall effect of planting distance of corn on number of tubers produced is given in Figure 5. It appears that planting corn 20 cm between plants within the rows seems to result in fewer tubers within the corn rows regardless of the planting distances between the rows. In general, increasing corn population significantly decreased yellow nutsedge tuber number (Figure 2). However, the decrease in tuber number from between the corn rows was not significant in 1980.

The number of yellow nutsedge tubers from the different size classes was significantly affected by the planting distance of corn in each year. The Chi-square K-independent analysis and the contingency coefficient values of tuber numbers in different size classes are given in Table 5. The number of tubers in different size classes had either a normal distribution or a linear response due to individual corn populations (Figures 6 and 7). Only the lowest (33,333 p.p.h.), medium (66,667 p.p.h.) and the highest (133,333 p.p.h.)

TABLE 5. The values of χ^2 K-independent analysis and the contingency coefficient of tuber size classes affected by corn planting distance

	χ^2 K-independent				Contingency coefficient			
	Between rows		Within rows		Between rows		Within rows	
	1980	1981	1980	1981	1980	1981	1980	1981
Tuber number	217.5**	323.2**	361.17**	698.4**	0.8028	0.8540	0.7113	0.9238
Tuber weight	-	14.9 NS	-	37.7 NS	-	0.3323	--	0.4889

** highly significant at 1 per cent level

NS not significant

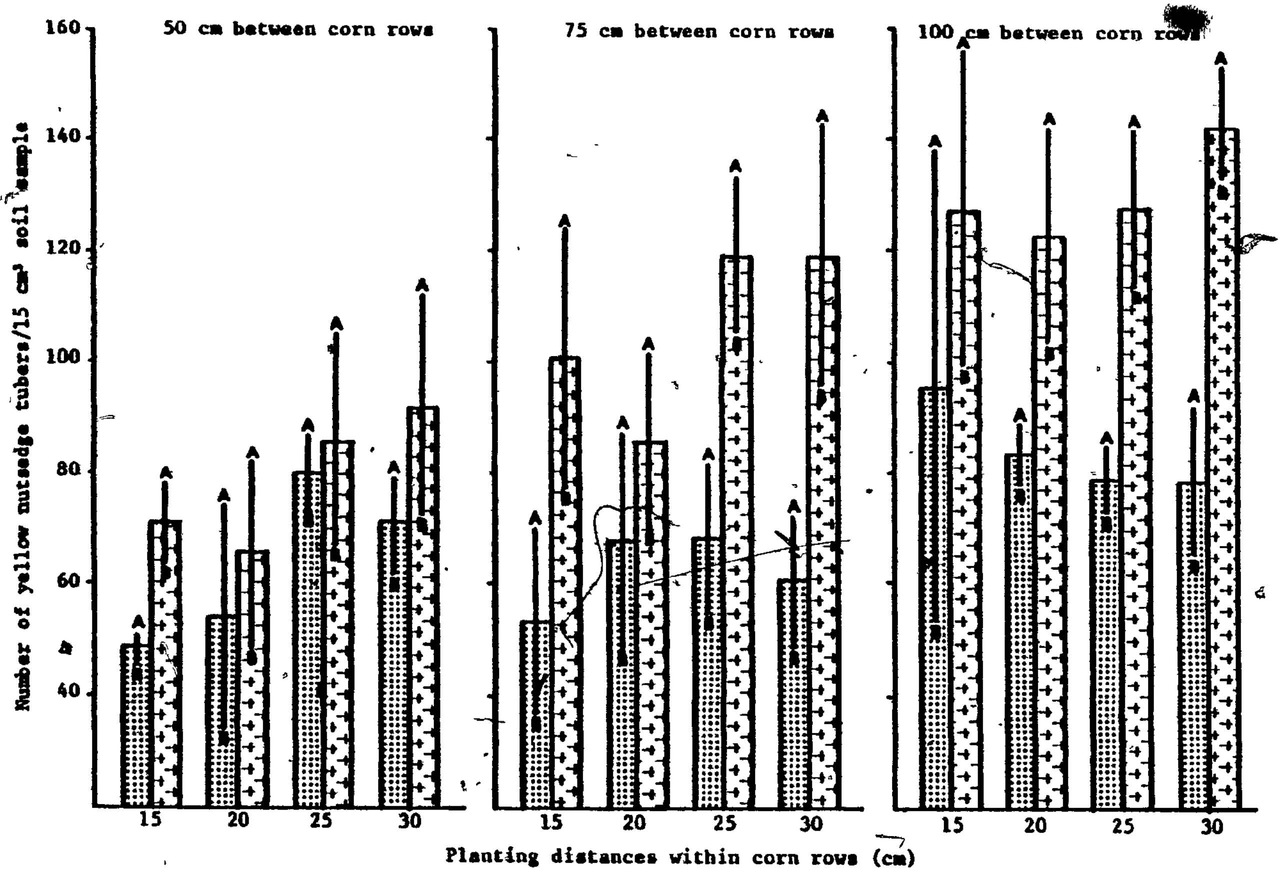


Figure 5. Effect of corn planting distances on yellow nutsedge tuber number.

Samples obtained from between corn rows. A = 1980 data

Samples obtained from within corn rows. B = 1981 data

Figure 6. Effect of corn population on yellow nutsedge tuber number in different size classes in 1980.

Tuber size classes (mm in diameter)

C1 = less than 2.8	C6 = 4.4-4.8
C2 = 2.8-3.2	C7 = 4.8-5.2
C3 = 3.2-3.6	C8 = 5.2-5.6
C4 = 3.6-4.0	C9 = 5.6-6.0
C5 = 4.0-4.4	C10 = greater than 6.0

▬▬▬ Nutsedge samples obtained from between corn rows.

P.1 = Corn population of 133,333 p.p.h.
$Y = 5.6056 + 5.1296\ X - 0.4836\ X^2$

P.5 = Corn population of 66,667 p.p.h.
$Y = 23.2278 + 12.5992\ X - 1.3573\ X^2$

P.10 = Corn population of 33,333 p.p.h.
$Y = 31.0944 + 2.4366\ X - 0.4129\ X^2$

▪▪▪▪ Nutsedge samples obtained from within corn rows.

P.1 = Corn population of 133,333 p.p.h.
$Y = 2.8944 + 12.0801\ X - 1.1957\ X^2$

P.5 = Corn population of 66,667 p.p.h.
$Y = 12.1222 + 16.7450\ X - 1.5278\ X^2$

P.10 = Corn population of 33,333 p.p.h.
$Y = 13.7389 + 14.2851\ X - 1.2210\ X^2$

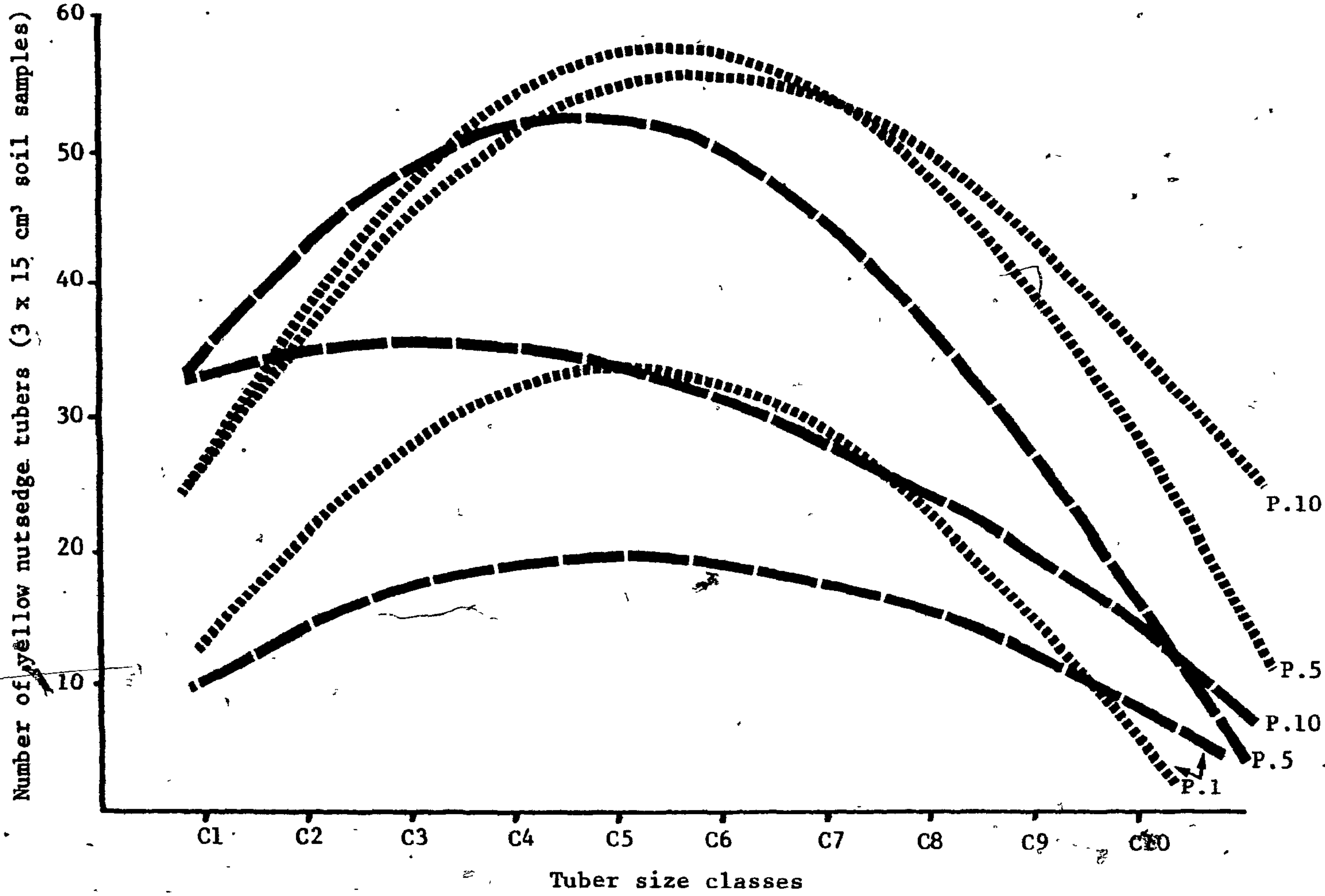

Number of yellow nutsedge tubers (3 x 15 cm³ soil samples)
60
50
40
30
20
10
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes
P.10
P.5
P.10
P.5
P.1

Figure 6

Figure 7. Effect of corn population on yellow nutsedge tuber number in different size classes in 1981.

Tuber size classes (mm in diameter)

C1 = less than 2.8	C6 = 4.4–4.8
C2 = 2.8–3.2	C7 = 4.8–5.2
C3 = 3.2–3.6	C8 = 5.2–5.6
C4 = 3.6–4.0	C9 = 5.6–6.0
C5 = 4.0–4.4	C10 = greater than 6.0

▬▬▬▬ Nutsedge samples obtained from between corn rows.

P.1 = Corn population of 133,333 p.p.h.
$Y = 23.3556 - 1.6525\ X$

P.5 = Corn population of 66,667 p.p.h.
$Y = 34.9111 - 3.4747\ X$

p.10 = Corn population of 33,333 p.p.h.
$Y = 39.2222 - 3.5616\ X$

▪▪▪▪▪▪ Nutsedge samples obtained from within corn rows.

P.1 = Corn population of 133,333 p.p.h.
$Y = 20.8889 + 3.9879\ X - 0.6162\ X^2$

P.5 = Corn population of 66,667 p.p.h.
$Y = 7.9556 + 10.9232\ X - 1.0000\ X^2$

P.10 = Corn population of 33,333 p.p.h.
$Y = 7.6056 + 11.8184\ X - 0.8573\ X^2$

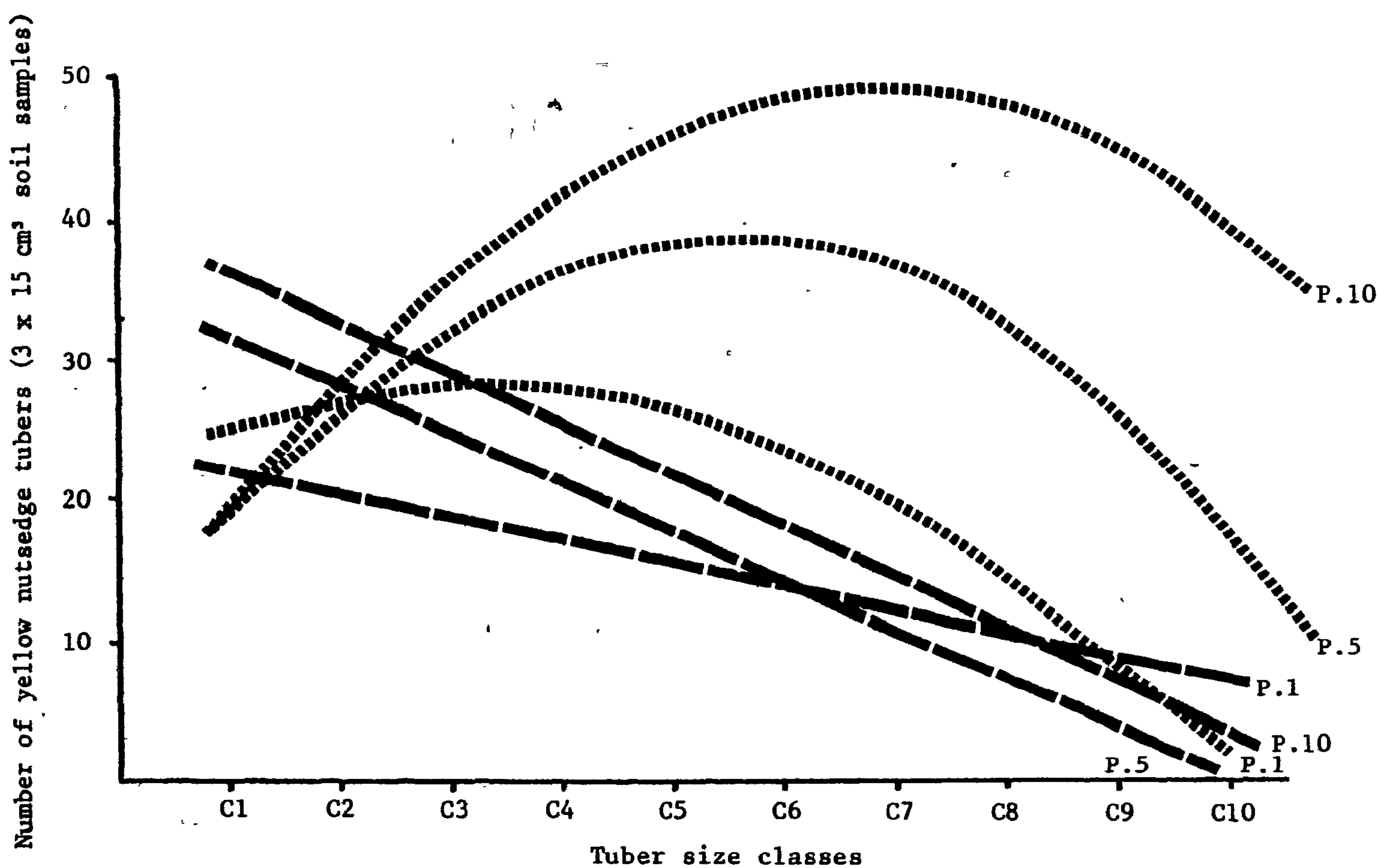

Number of yellow nutsedge tubers (3 x 15 cm³ soil samples)
50
40
30
20
10
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes
P.10
P.5
P.1
P.10
P.5
P.1

Figure 7

corn populations are presented in Figures 6 and 7 to avoid over-crowding. The majority of tubers obtained from within corn rows were in the range of 3.6 to 5.2 mm in diameter, while those tubers obtained from between corn rows were 2.8 to 4.0 mm in diameter.

7.1.2.2 Tuber dry weight

Tuber dry weight of yellow nutsedge was significantly affected by corn planting distance between the rows but not by planting distances within the corn rows (Appendix 3). The lowest and highest tuber dry weights were obtained from planting distances of 50 cm and 100 cm between corn rows, respectively, except in 1981 for tubers obtained from between corn rows. The dry weight of nutsedge tubers from within corn rows tends to decrease as the planting distance decreases (Figure 8). This trend was not apparent for tubers obtained from between the rows.

Tuber dry weight obtained from within corn rows was significantly greater than the weight obtained from between corn rows (Table 4). Increasing corn population significantly decreased tuber dry weight obtained from within corn rows in each year (Figure 2).

The effect of corn population on tuber weight in different size classes was not significantly different for both samples obtained from between and within corn rows. Similarly their contingency coefficients were low (Table 5). Nevertheless, when each individual corn population was analyzed for its effect on tuber size classes, significant effects were obtained for each specific population. Figure 9 shows the response

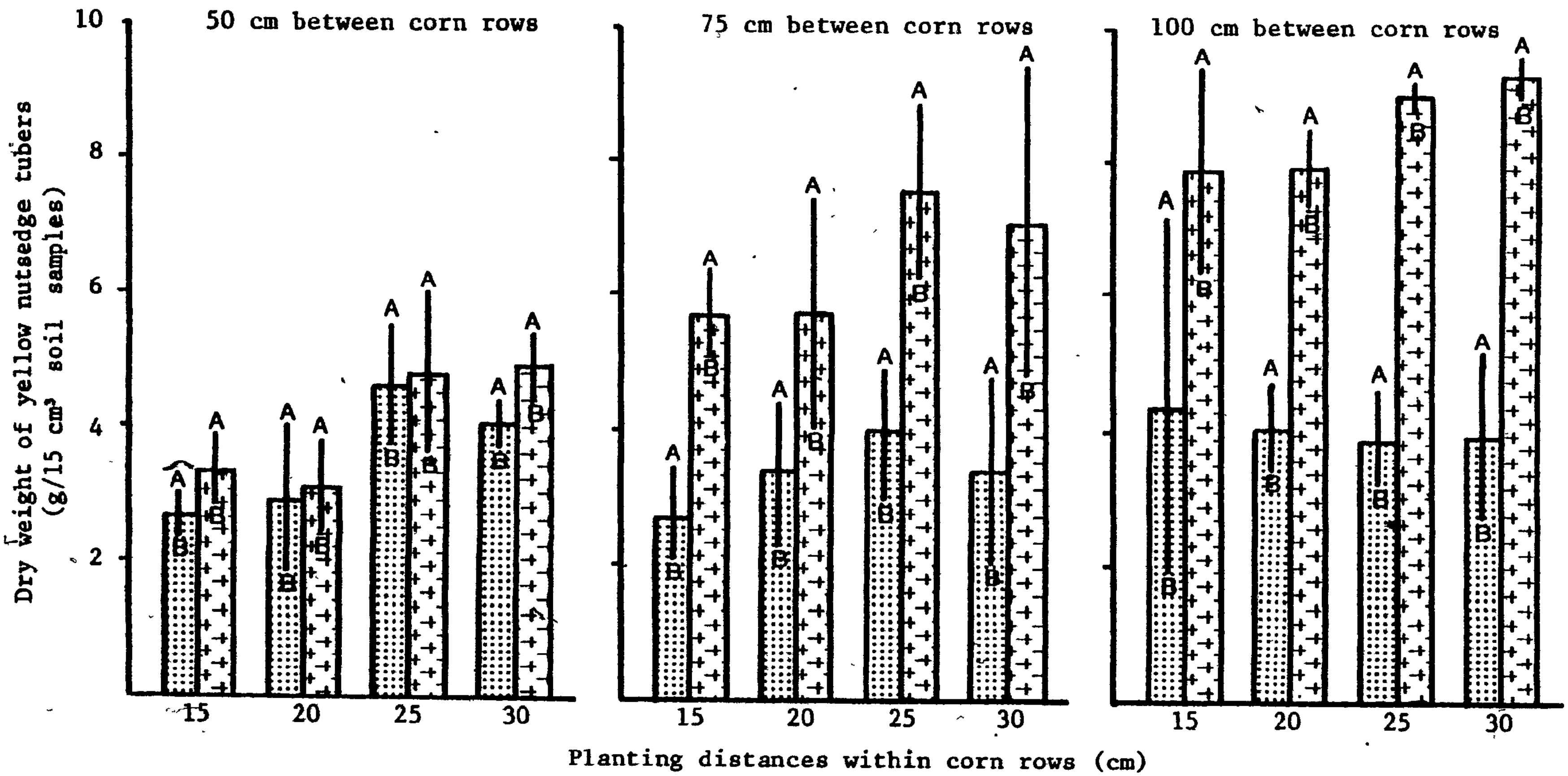


Figure 8. Effect of corn planting distances on yellow nutsedge tuber dry weight.

Samples obtained from between corn rows.

Samples obtained from within corn rows.

A = 1980 data

B = 1981 data

Figure 9. Effect of corn population on yellow nutsedge tuber dry weight in different size classes.

Tuber size classes (mm in diameter)

C1 = less than 2.8	C6 = 4.4–4.8
C2 = 2.8–3.2	C7 = 4.8–5.2
C3 = 3.2–3.6	C8 = 5.2–5.6
C4 = 3.6–4.0	C9 = 5.6–6.0
C5 = 4.0–4.4	C10 = greater than 6.0

Nutsedge samples obtained from between corn rows.

P.1 = Corn population of 133,333 p.p.h.
$Y = 0.3422 + 0.0735\ X$

P.5 = Corn population of 66,667 p.p.h.
$Y = 0.1900 + 0.2160\ X - 0.0199\ X^2$

P.7 = Corn population of 50,000 p.p.h.
$Y = 0.0428 + 0.4019\ X - 0.0317\ X^2$

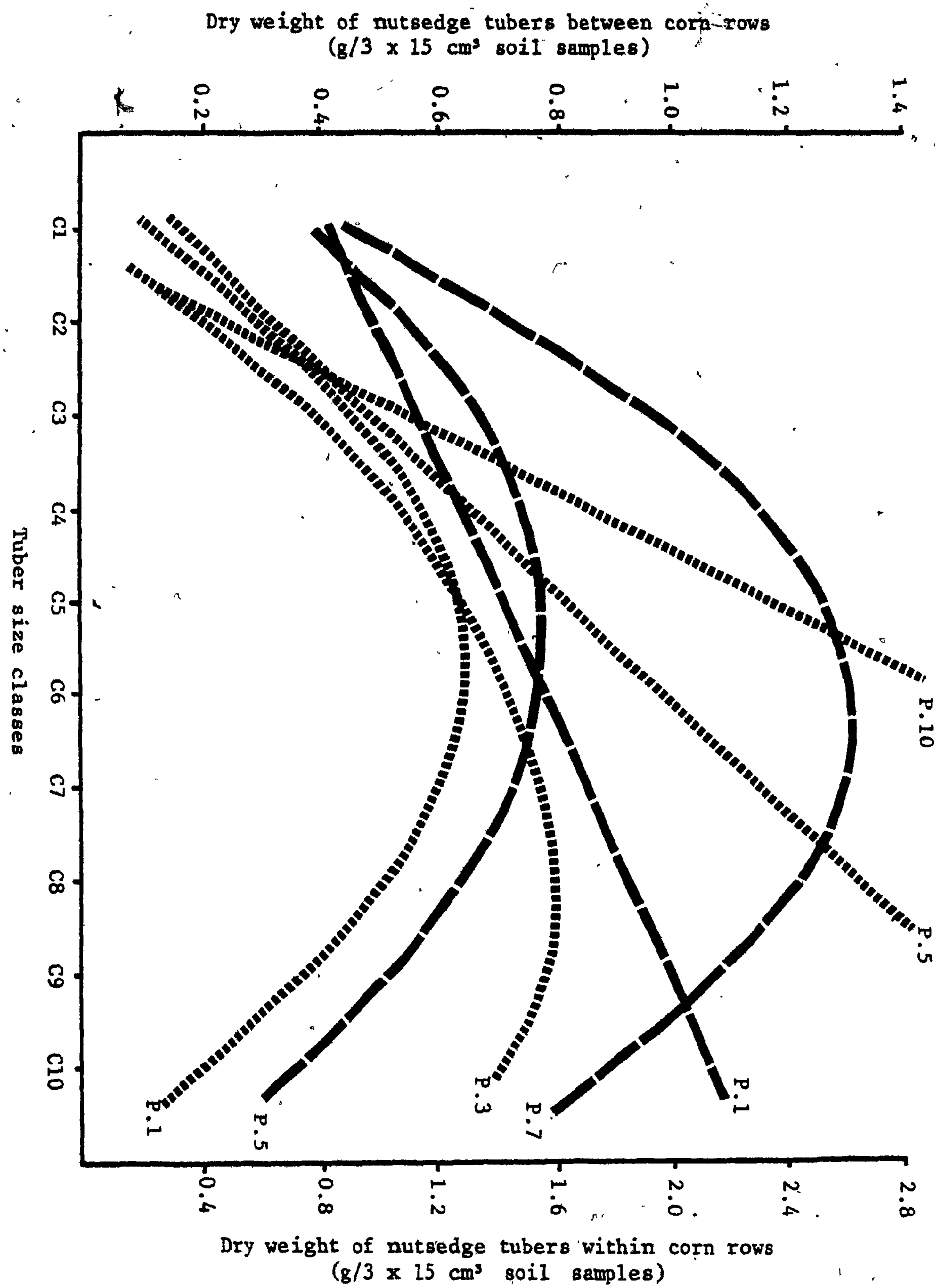
Nutsedge samples obtained from within corn rows.

P.1 = Corn population of 133,333 p.p.h.
$Y = -0.2972 + 0.5507\ X - 0.0484\ X^2$

P.3 = Corn population of 88,889 p.p.h.
$Y = 0.4450 + 0.4899\ X - 0.0294\ X^2$

P.5 = Corn population of 66,667 p.p.h.
$Y = 0.0111 + 0.3271\ X$

P.10 = Corn population of 33,333 p.p.h.
$Y = -0.7978 + 0.6317\ X$



Dry weight of nutsedge tubers between corn rows
(g/3 x 15 cm³ soil samples)
0.2
0.4
0.6
0.8
1.0
1.2
1.4
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes
P.10
P.5
P.1
P.7
P.3
P.5
P.1
0.4
0.8
1.2
1.6
2.0
2.4
2.8
Dry weight of nutsedge tubers within corn rows
(g/3 x 15 cm³ soil samples)

Figure 9

curve of different tuber size classes affected by each individual corn population. In the illustration (Figure 9) only corn populations of 33,333 p.p.h., 44,444 p.p.h., 66,667 p.p.h., 88,889 p.p.h., and 133,333 p.p.h. were represented to avoid over-crowding. The response curves obtained were again either a normal distribution or linear.

7.1.3 Light intensity

The amount of light (Microeinsteins/m^2/sec) intercepted by the yellow nutsedge canopy increased as the planting distance of corn increased (Appendix 4). There were significant linear decreases in the amount of light (PAR) received by yellow nutsedge canopies due to increasing corn population as measured in July and August for both years (Figure 10).

7.1.4 Corn yield

Corn yields tended to decrease as the planting distance of corn between and within the rows increased (Appendix 5). For the planting distance of 50 cm between corn rows, the corn yield (fodder and ear dry weight) decreased as planting distances within corn rows increased (Figure 11). These decreasing trends were not observed for planting distance of 75 cm nor of 100 cm between corn rows (Figure 11).

Increasing corn population significantly increased fodder dry weight and ear dry weight (Figure 12). The percentage of ear dry weight contribution to fodder dry weight slightly increased in 1981. It varied from 23.9 to 29.0 per cent in 1980, and 27.1 to 36.9 per cent in 1981.

Figure 10. Effect of corn population on light intensity (photosynthetic active radiation) received at yellow nutsedge canopies.

July 18, 1980
$Y = 218.5 - 4.4 \times 10^{-4} X$

July 25, 1980
$Y = 273.1 - 1.0 \times 10^{-3} X$

August 1, 1980
$Y = 616.4 - 3.0 \times 10^{-3} X$

August 8, 1980
$Y = 623.9 - 3.2 \times 10^{-3} X$

July 8, 1981
$Y = 236.3 - 4.7 \times 10^{-4} X$

July 15, 1981
$Y = 285.4 - 1.1 \times 10^{-3} X$

July 22, 1981
$Y = 173.5 - 6.1 \times 10^{-4} X$

July 30, 1981
$Y = 156.2 - 5.5 \times 10^{-4} X$

August 6, 1981
$Y = 507.3 - 2.6 \times 10^{-3} X$

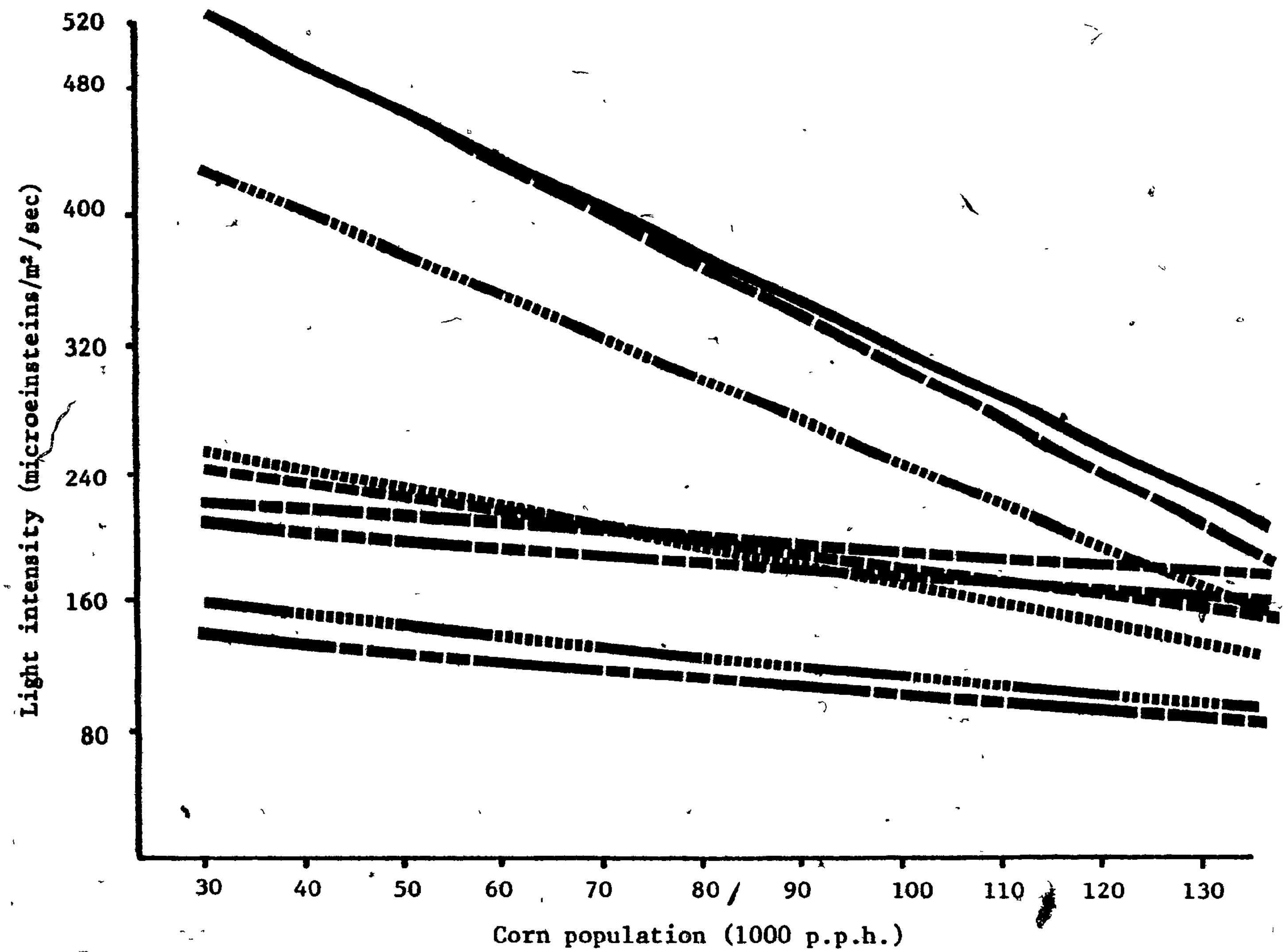

Light intensity (microeinsteins/m²/sec)
520
480
400
320
240
160
80
30
40
50
60
70
80
90
100
110
120
130
Corn population (1000 p.p.h.)

Figure 10

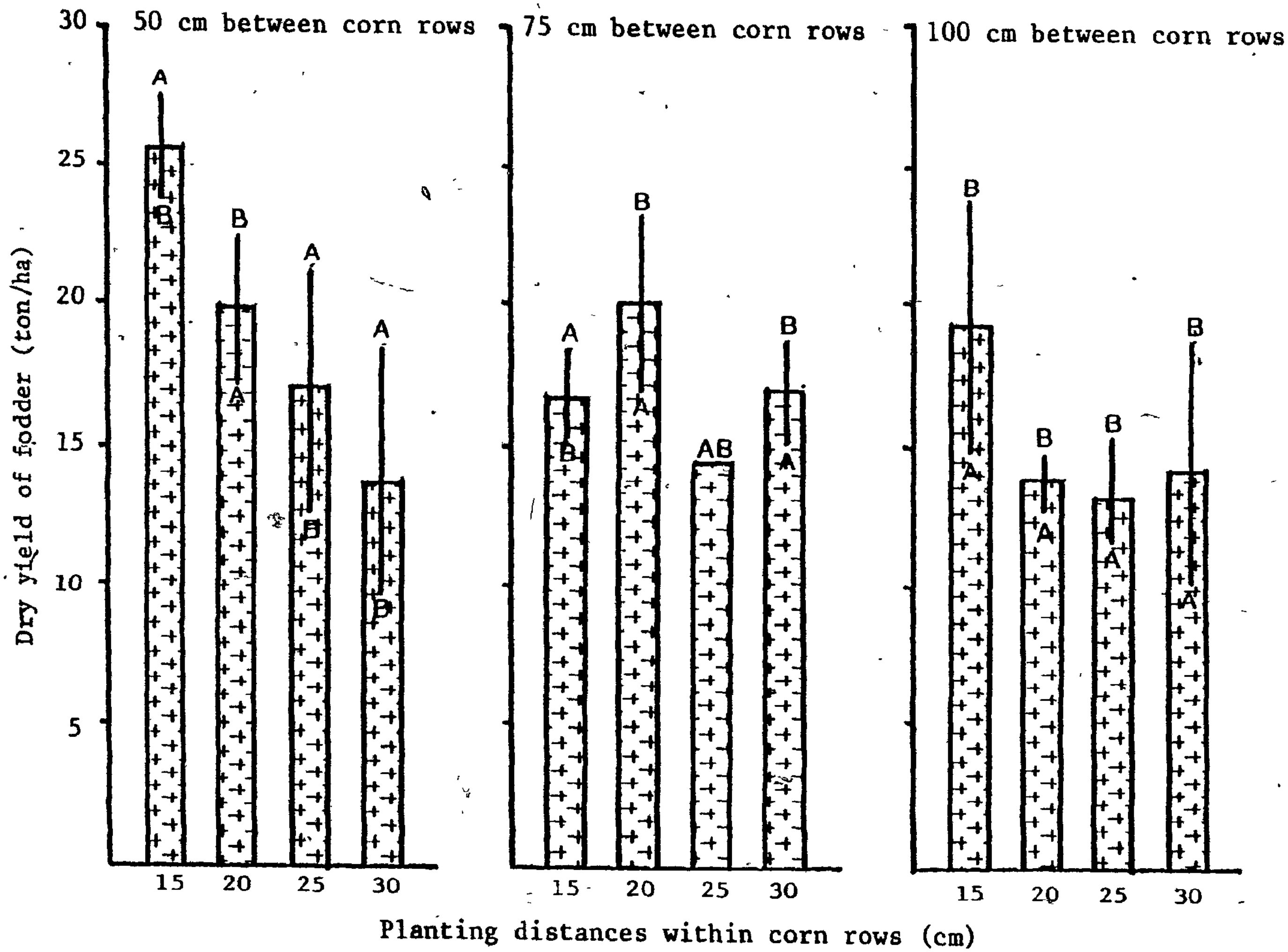


Figure 11. Effect of corn planting distances on fodder dry matter yield.
A = 1980 data B = 1981 data

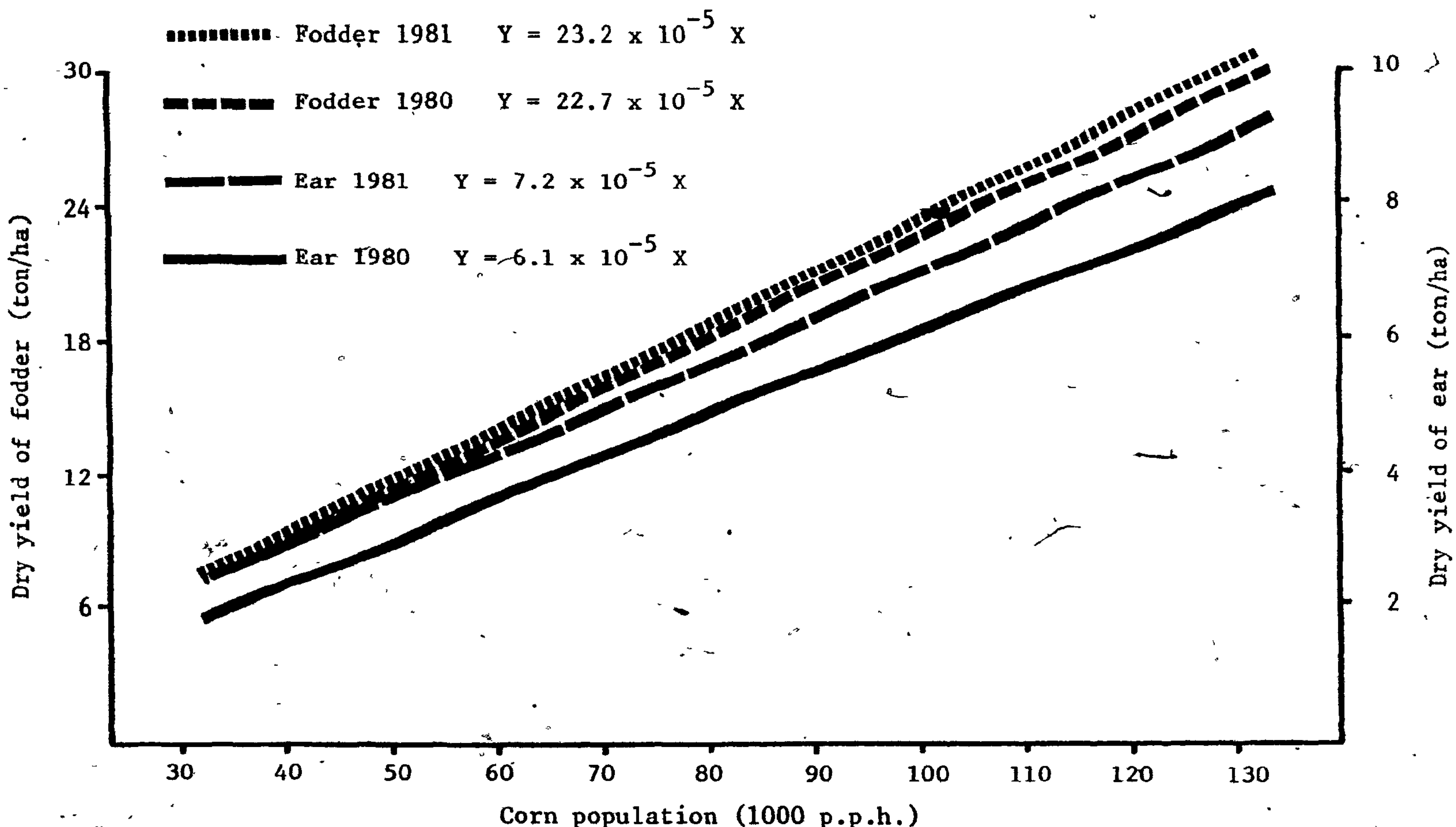


Figure 12. Effect of corn population on corn dry matter yield.

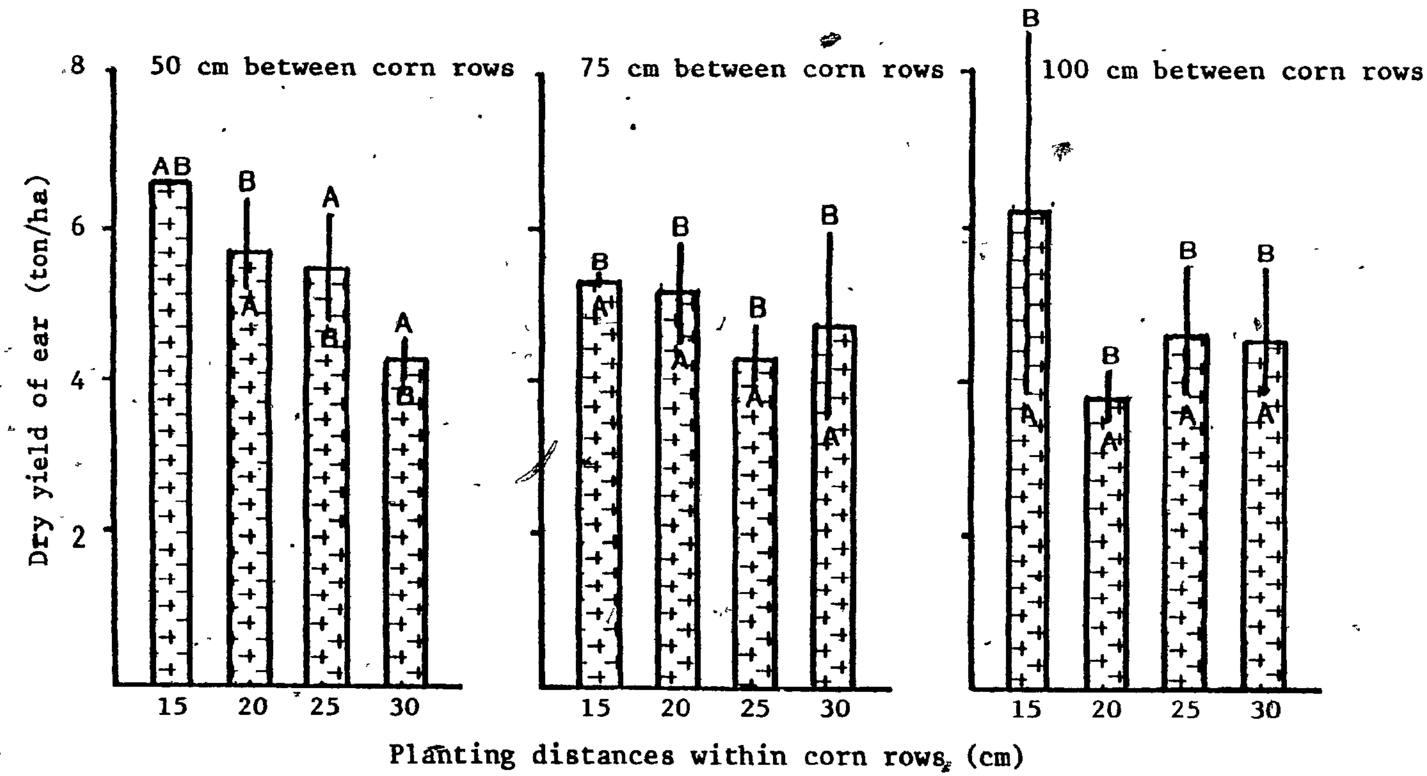


Figure 13. Effect of corn planting distances on ear dry matter yield.

A = 1980 data B = 1981 data

The effect of corn planting distance on ear length is shown in Figure 14. All planting distances between corn rows regardless of their distances within the rows tend to increase ear length due to increasing planting distances. The shortest ear length was obtained from planting distance of 50 x 15 cm, while the longest was obtained from planting distance of 100 x 30 cm.

In this study there was no significant effect of corn planting distance on corn height (Figure 15).

7.1.5 Correlation analysis

The correlation analysis between planting distances of corn, fodder dry weight and mean light intensity were conducted with various yellow nutsedge growth parameters as shown in Table 6. These results demonstrate that planting distance of corn was significantly correlated with yellow nutsedge above ground biomass, tuber number and tuber dry weight for those parameters measured from within corn rows but not from between the corn rows. However, there were still positive correlations on the above yellow nutsedge parameters measured from between corn rows. These results were similar for both years. Yellow nutsedge height in 1980 showed significant negative correlation with planting distance, but in 1981 showed positive correlation. These correlations were not significant, however.

Fodder yields were negatively correlated with all the yellow nutsedge growth data parameters except for tuber dry weight sampled from within corn rows in 1980, and yellow nutsedge height for both

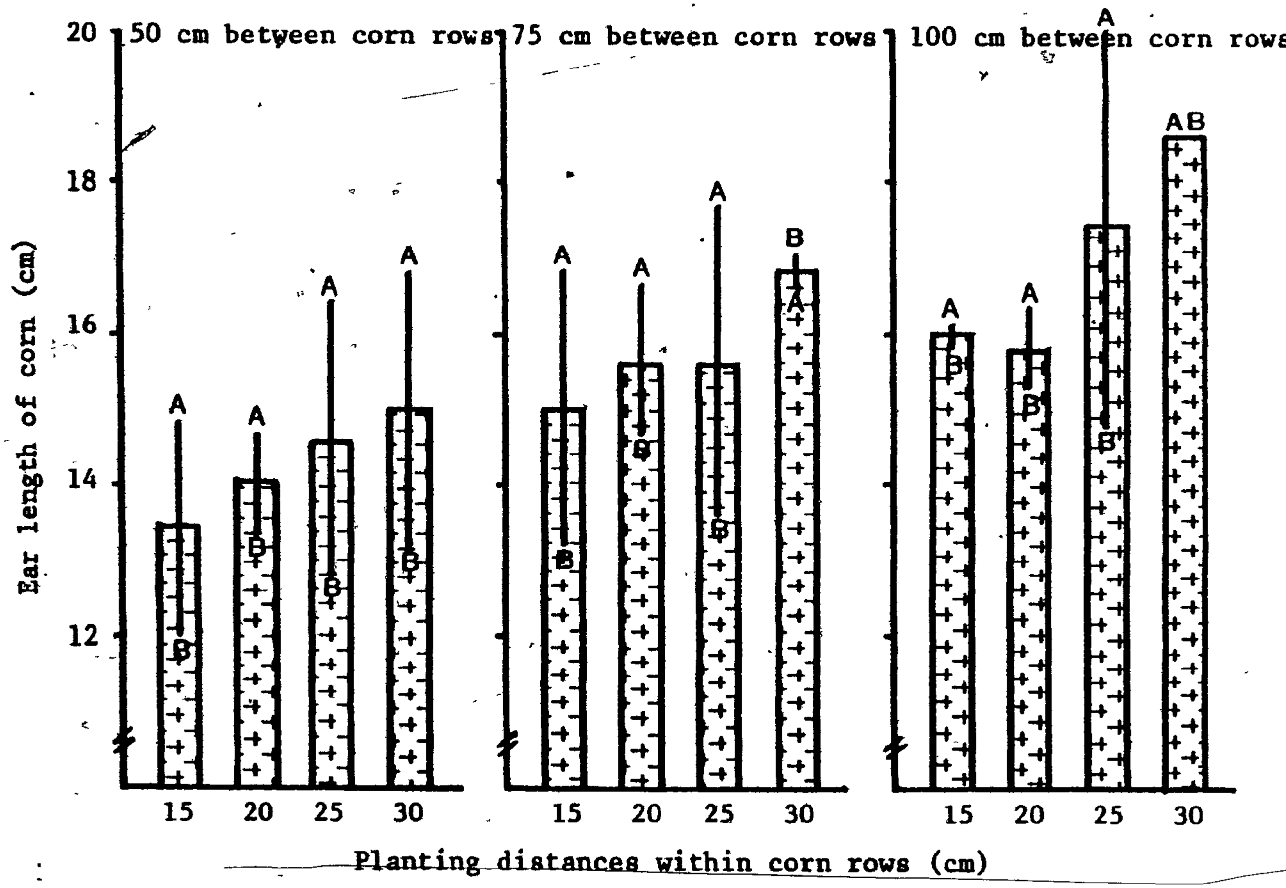


Figure 14. Effect of corn planting distances on ear length.

A = 1980 data B = 1981 data

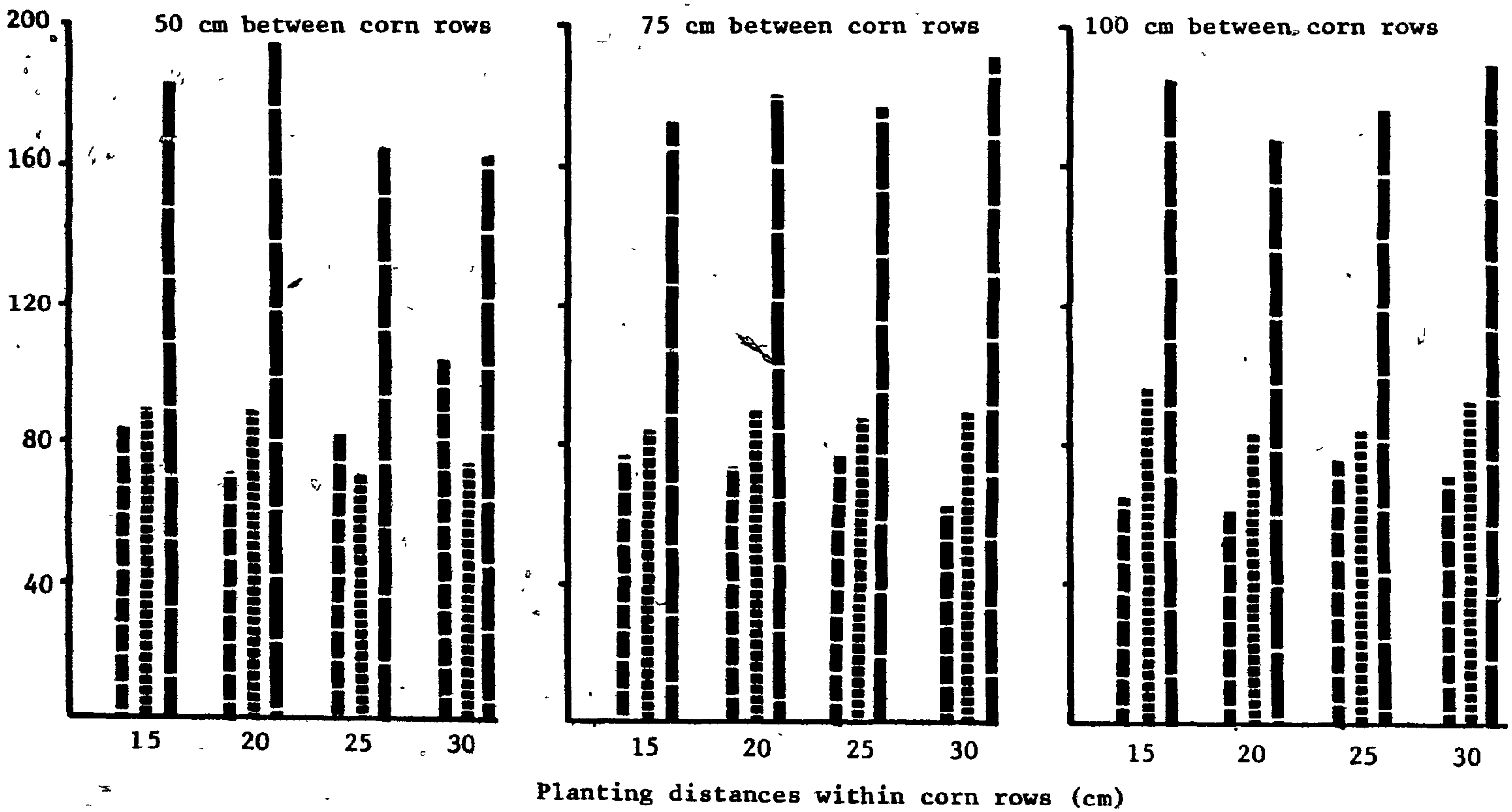


Figure 15. Effect of corn planting distances on plant height.

18.7.80 data   8.7.81 data   6.8.81 data

TABLE 6. Correlation coefficients of yellow nutsedge parameters

Yellow nutsedge parameters	Planting distances of corn		Fodder yield (dry weight)		Mean light intensity	
	1980	1981	1980	1981	1980	1981
Above ground biomass dry wt.						
a. between rows	0.14971 0.6424 †	0.04739 0.8837	-0.05410 0.8674	-0.13455 0.6767	0.01312 0.9677	0.31078 0.3255
b. within rows	0.86491** 0.0003	0.89581** 0.0001	-0.74337** 0.0056	-0.13155 0.6836	0.74809** 0.0051	0.62015* 0.0315
Tuber number						
a. between rows	0.51118 0.0894	0.51240 0.0885	-0.45250 0.1397	-0.58836* 0.0442	0.42861 0.1645	0.83904** 0.0006
b. within rows	0.92748** 0.0001	0.93638** 0.0001	-0.80768** 0.0015	-0.14436 0.6544	0.80608** 0.0015	0.63368** 0.0269
Tuber dry weight						
a. between rows	0.52435 0.0801	0.09915 0.7592	-0.47379 0.1197	-0.8554** 0.0004	0.43839 0.1540	0.79074** 0.0022
b. within rows	0.92968** 0.0001	0.94193** 0.0001	0.82633** 0.0009	-0.2311 0.4699	0.76148** 0.0040	0.68172* 0.0146
Plant height	-0.64564* 0.0233	0.14988 0.6420	0.71253 0.0093	0.7701** 0.0034	-0.72986** 0.0070	-0.46938 0.1237

* Significant at 5 per cent level
** Significant at 1 per cent level
† Probability level

years. Mean light intensity was positively correlated with all yellow nutsedge growth parameters measured except nutsedge height.

Correlation between planting distance of corn and fodder dry yield with corn growth parameters are shown in Table 7. In 1981, both planting distance of corn and fodder yield were positively correlated with corn parameters. However, in 1981, negative correlations were found between planting distance of corn with ear dry weight and with corn height. In the same year, fodder yield was negatively correlated with ear length and with ear contribution to fodder yield.

7.2 Experiment 2 - Corn seeding date

7.2.1 Yellow nutsedge above ground biomass

Planting date of corn did not significantly alter yellow nutsedge biomass either between corn rows or within the rows (Figure 16). However, there was significantly more nutsedge biomass obtained from within corn rows than from between the rows (Table 8).

Yellow nutsedge height.--Yellow nutsedge height decreased from the first seeding date (1st week of May) until the fourth date (4th week of May), then increased dramatically when corn was seeded in the first week of June (Figure 17).

TABLE 7. Correlation coefficients of corn parameters

Corn parameters	Planting distance of corn		Fodder yield (dry weight)	
	1980	1981	1980	1981
Ear dry weight	-0.91106**	0.02579	0.94488**	0.86839**
	0.0001 †	0.9366	0.0001	0.0002
Ear length	0.75213**	0.82223**	-0.69418*	0.83153**
	0.0048	0.0010	0.0123	0.0008
Plant height	-0.74248**	0.33900	0.80067**	0.18019
	0.0057	0.2811	0.0078	0.5752
Ear contribution to silage	0.40905	0.04403	-0.55276	0.66719*
	0.1867	0.8919	0.0623	0.0178

* Significant at 5 per cent level
** Significant at 1 per cent level
† Probability level

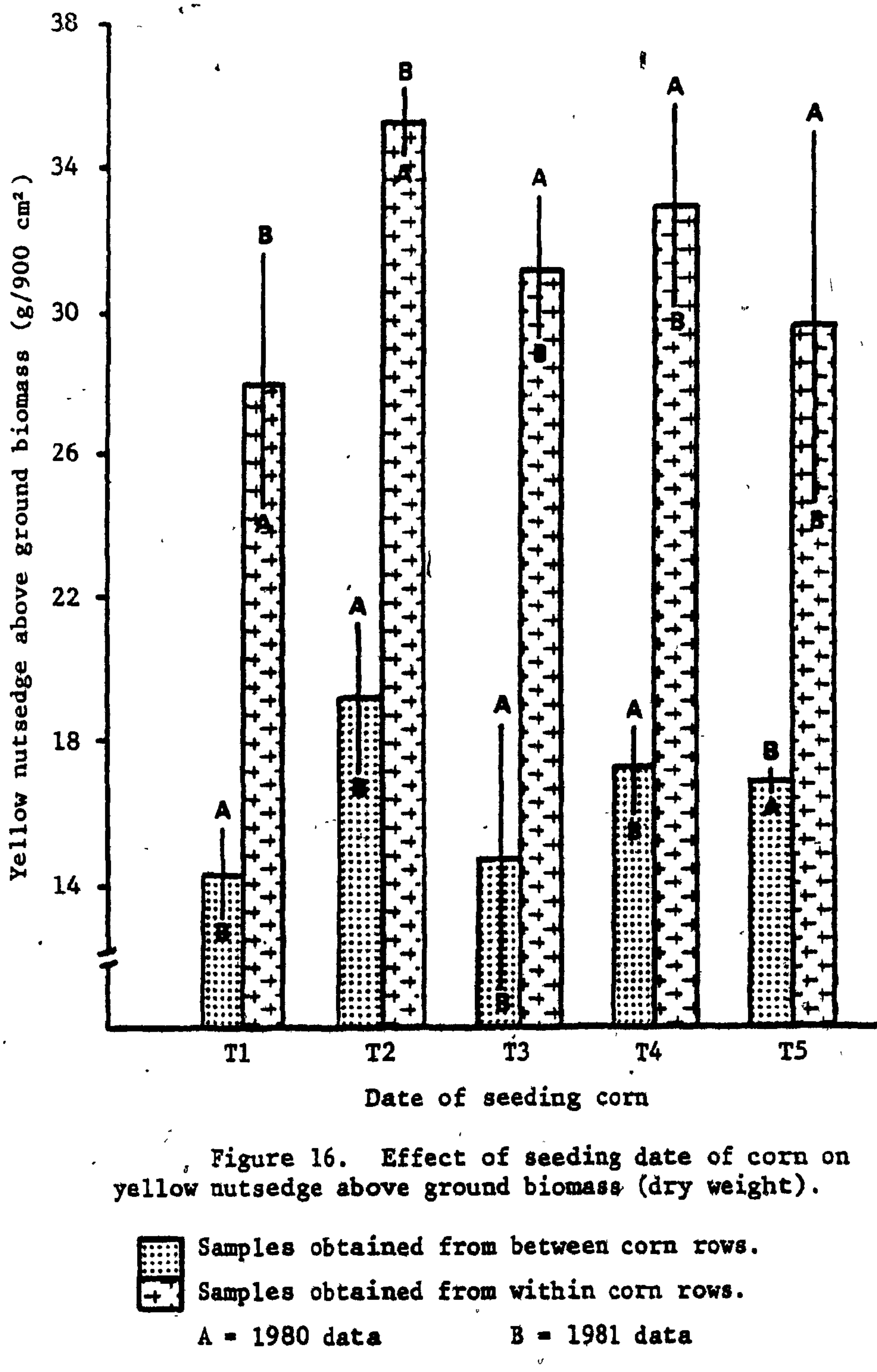


Figure 16. Effect of seeding date of corn on yellow nutsedge above ground biomass (dry weight).

Samples obtained from between corn rows.

Samples obtained from within corn rows.

A = 1980 data B = 1981 data

TABLE 8. The 't' values comparison on yellow nutsedge parameters between and within corn rows due to seeding date of corn

Seeding date of corn	Yellow nutsedge biomass dry weight		Yellow nutsedge tuber dry weight		Yellow nutsedge tuber number	
	1980	1981	1980	1981	1980	1981
1st week of May	-2.2419*	-5.41**	-2.8501**	-5.20**	-3.3020**	-1.34 NS
2nd week of May	-4.7952**	-3.20**	-6.5266**	-4.36**	-7.6614**	-3.32**
3rd week of May	-3.0701**	-12.83**	-1.9910 NS	-3.06**	-2.0698 NS	-1.23 NS
4th week of May	-4.943**	-5.31**	-2.2145**	-0.76 NS	-1.7616 NS	-0.30 NS
1st week of June	-4.7041**	-8.60**	-2.5807**	-3.80**	-3.6918**	-5.34**
Over all treatments	-8.1378**	-8.55**	-6.6777**	-4.69**	-7.0458**	-2.82**

* Significant at 5 per cent level

** Significant at 1 per cent level

NS Not significant

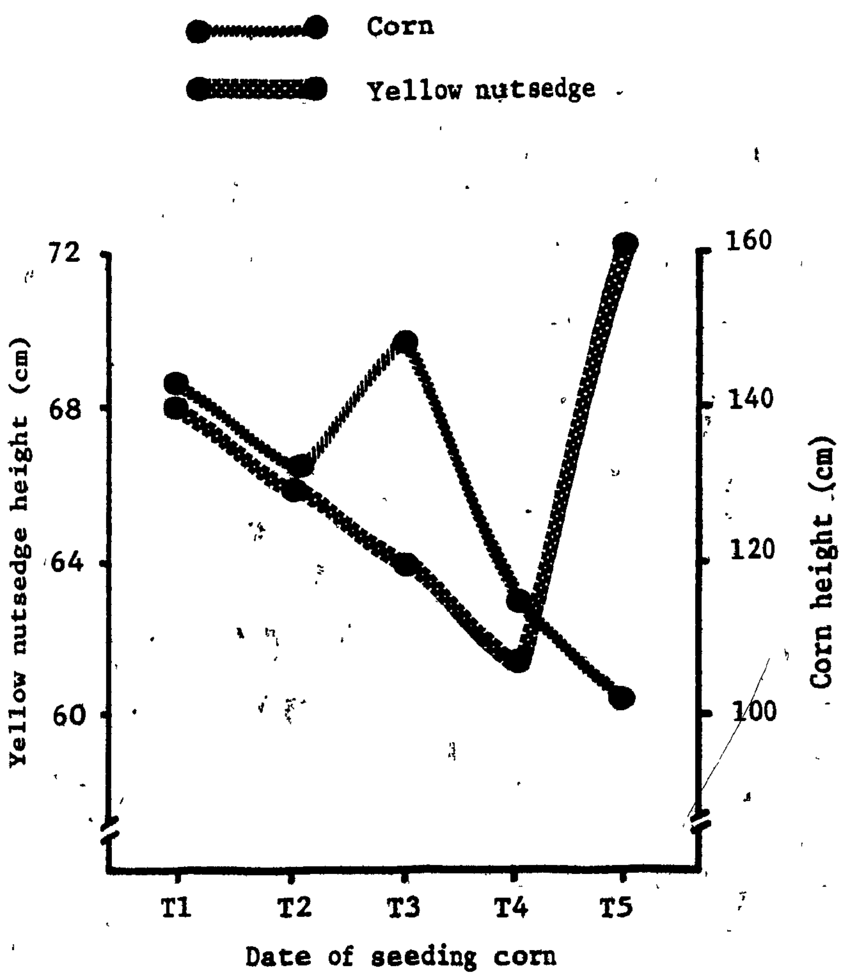


Figure 17. Effect of seeding date of corn on plant height.

7.2.2 Yellow nutsedge tuber production

7.2.2.1 Tuber number

There was no significant effect on yellow nutsedge tuber number due to seeding date of corn. The number of tubers produced from between corn rows tended to increase as the seeding date of corn was delayed until the fourth week of May, then decreased at the 1st week of June seeding (Figure 18). The number of tubers from within corn rows did not indicate any trends. However, there were significantly more yellow nutsedge tubers produced within corn rows than between the rows (Table 8).

Tuber numbers in different size classes were significantly affected by the seeding date of corn. Their Chi-square and contingency coefficient values are given in Table 9. The number of tubers in different size classes as affected by each seeding date of corn produce normal distribution curves in each year (Figures 19a and 19b) for tubers collected within corn rows. Tubers obtained from between corn rows tended to have normal distribution curves in 1980 (Figure 20a), and mainly decreasing trends in 1981 (Figure 20b).

7.2.2.2 Tuber dry weight

Yellow nutsedge tuber dry weight was not significantly affected by the seeding date of corn. However, significantly heavier tubers were found within the rows than from between the corn rows (Table 8).

The dry weight of yellow nutsedge tubers obtained from between corn rows had a tendency to increase until the fourth week of seeding,

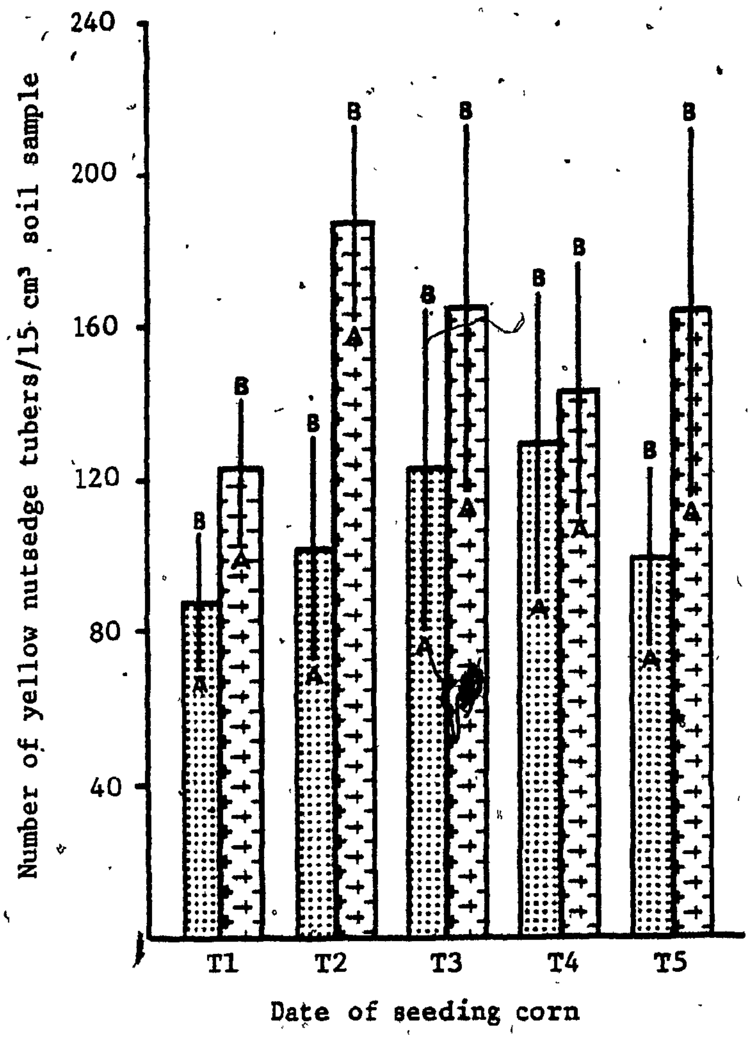


Figure 18. Effect of seeding date of corn on yellow nutsedge tuber number.

Samples obtained from between corn rows
Samples obtained from within corn rows
A = 1980 data B = 1981 data

TABLE 9. The values of χ^2-K independent analysis and the contingency coefficient of tuber size classes affected by planting date of corn

	χ^2-K independent values				Contingency coefficient values			
	Samples taken from between rows		Samples taken from within rows		Samples taken from between rows		Samples taken from within rows	
	1980	1981	1980	1981	1980	1981	1980	1981
Number of yellow nutsedge tubers	104.8**	83.3**	106.0**	157.5**	0.825	0.791	0.824	0.871
Dry weight of yellow nutsedge tubers	-	5.5 NS	-	7.4 NS	-	0.315	-	0.359

** Significant at 1 per cent level

NS Not significant

Figure 19a. Effect of seeding date of corn on yellow nutsedge tuber number in different size classes (within corn rows, 1980).

Tuber size classes (mm in diameter)

C1	=	less than 2.8	C6	=	4.4-4.8
C2	=	2.8-3.2	C7	=	4.8-5.2
C3	=	3.2-3.6	C8	=	5.2-5.6
C4	=	3.6-4.0	C9	=	5.6-6.0
C5	=	4.0-4.4	C10	=	greater than 6.0

1st week of seeding corn in May

$$Y = -3.1667 + 12.1399\,X - 0.8763\,X^2$$

2nd week of seeding corn in May

$$Y = 18.2111 + 16.0924\,X - 1.5278\,X^2$$

3rd week of seeding corn in May

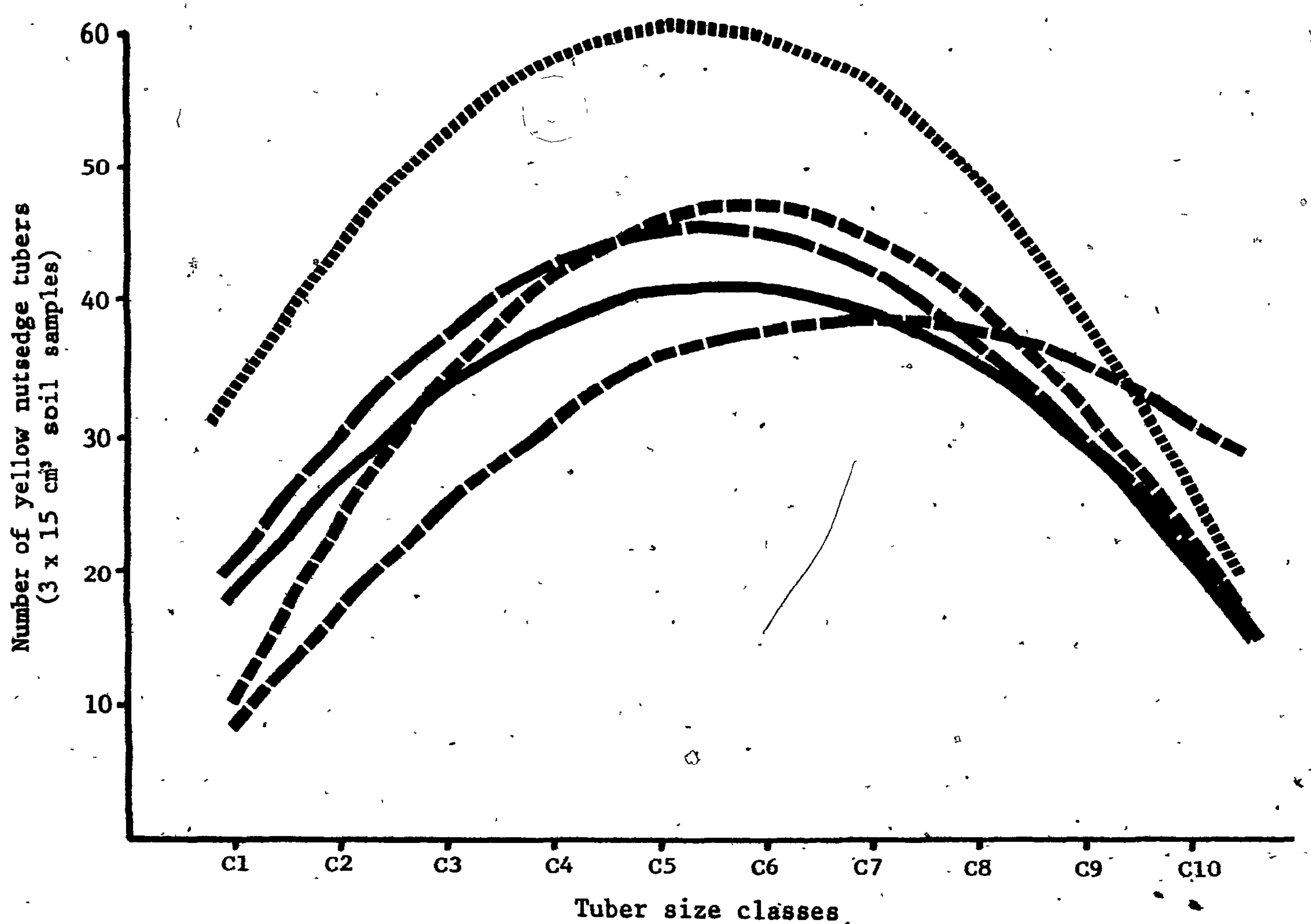
$$Y = 7.8444 + 13.7111\,X - 1.2525\,X^2$$

4th week of seeding corn in May

$$Y = 6.9000 + 12.2793\,X - 1.0884\,X^2$$

1st week of seeding corn in June

$$Y = -6.7778 + 18.3869\,X - 1.5606\,X^2$$



60
50
40
30
20
10
Number of yellow nutsedge tubers
(3 x 15 cm³ soil samples)
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes

Figure 19a

Figure 19b. Effect of seeding date of corn on yellow nutsedge tuber number in different size classes (within corn rows, 1981).

Tuber size classes (mm in diameter)

C1 =	less than 2.8	C6 =	4.4-4.8
C2 =	2.8-3.2	C7 =	4.8-5.2
C3 =	3.2-3.6	C8 =	5.2-5.6
C4 =	3.6-4.0	C9 =	5.6-6.0
C5 =	4.0-4.4	C10 =	greater than 6.0

1st week of seeding corn in May

$$Y = 18.5389 + 12.9487 X - 1.2361 X^2$$

2nd week of seeding corn in May

$$Y = 31.8833 + 18.5240 X - 1.8346 X^2$$

3rd week of seeding corn in May

$$Y = 40.2611 + 16.4896 X - 1.7538 X^2$$

4th week of seeding corn in May

$$Y = 37.0556 + 13.5258 X - 1.5328 X^2$$

1st week of seeding corn in June

$$Y = 79.8416 + 3.9216 X - 1.0132 X^2$$

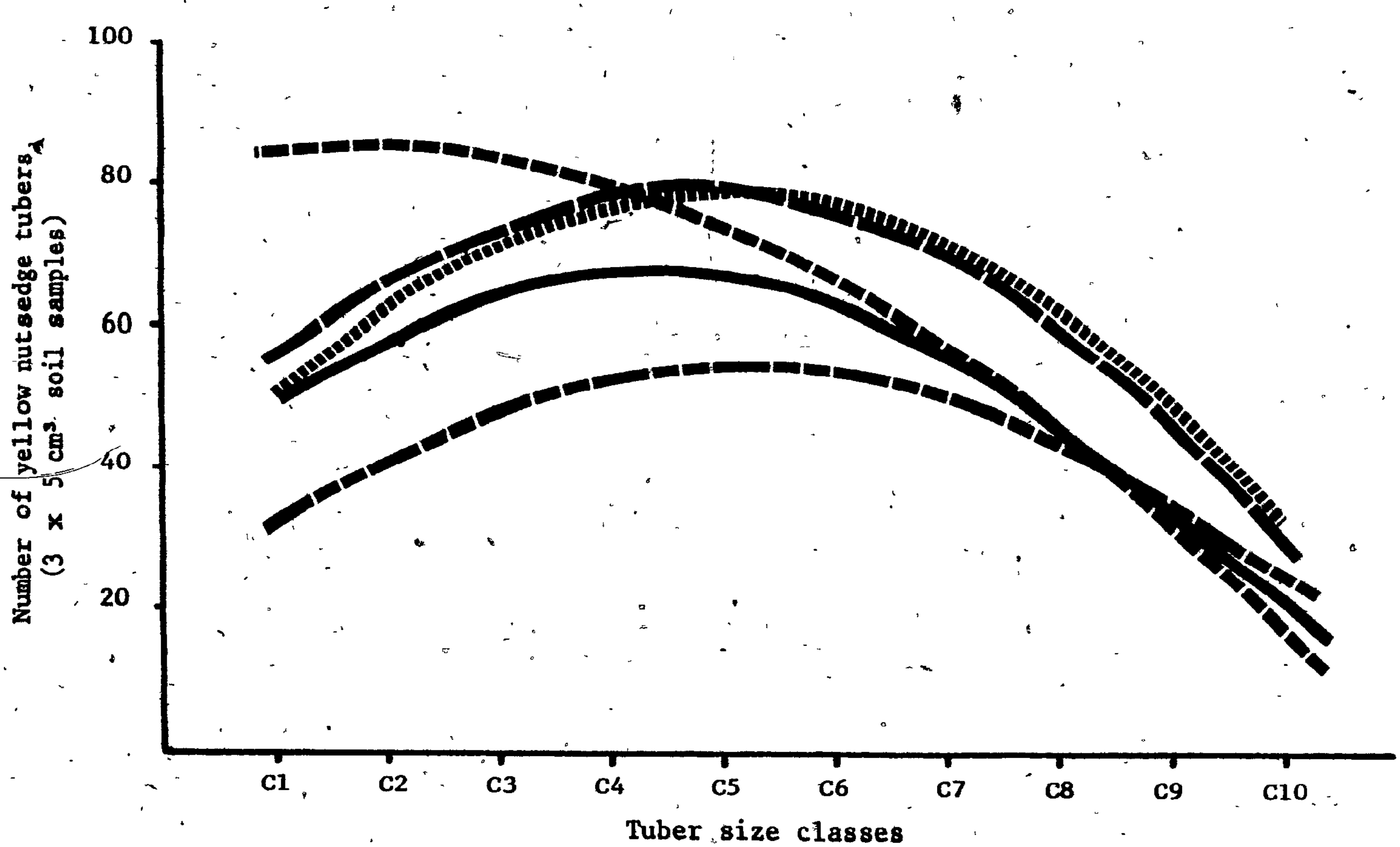

100
80
60
40
20
Number of yellow nutsedge tubers
(3 x 5 cm³ soil samples)
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes

Figure 19b

Figure 20a. Effect of seeding date of corn on yellow nutsedge tuber number in different size classes (between corn rows, 1980).

Tuber size classes (mm in diameter)

C1	=	less than 2.8	C6	=	4.4-4.8
C2	=	2.8-3.2	C7	=	4.8-5.2
C3	=	3.2-3.6	C8	=	5.2-5.6
C4	=	3.6-4.0	C9	=	5.6-6.0
C5	=	4.0-4.4	C10	=	greater than 6.0

▬▬▬▬▬ 1st week of seeding corn in May

$$Y = 6.5556 + 6.2889\,X - 0.5657\,X^2$$

▪▪▪▪▪▪▪ 2nd week of seeding corn in May

$$Y = 9.9889 + 5.9631\,X - 0.6793\,X^2$$

▬▬▬▬ 3rd week of seeding corn in May

$$Y = 11.1667 + 7.3086\,X - 0.729\,X^2$$

━━━━━ 4th week of seeding corn in May

$$Y = 17.1056 + 4.8977\,X - 0.4912\,X^2$$

▬▬▬▬▬▬ 1st week of seeding corn in June

$$Y = 11.8167 + 4.0806\,X - 0.2942\,X^2$$

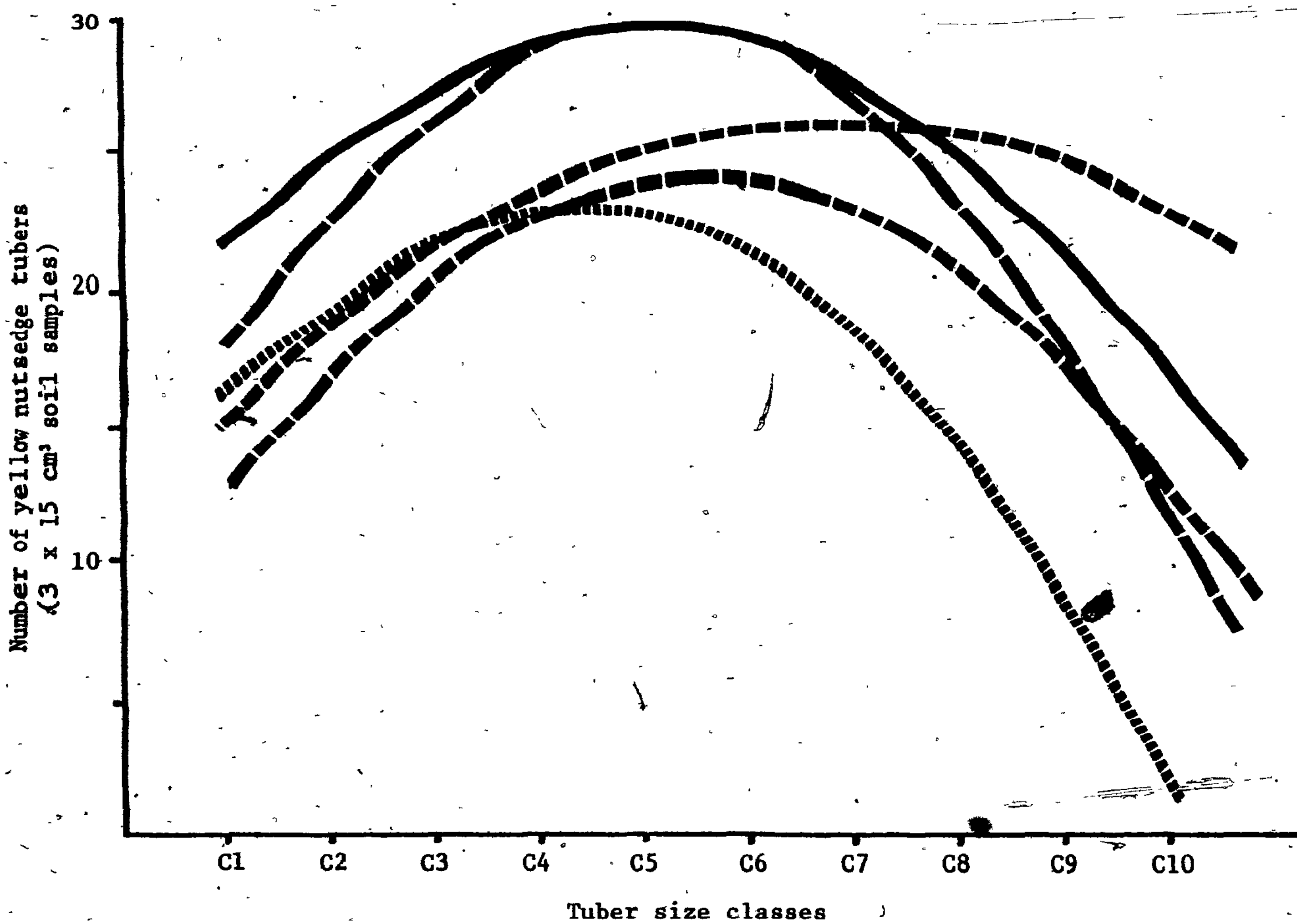

Number of yellow nutsedge tubers
(3 x 15 cm³ soil samples)
30
20
10
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes

Figure 20a

Figure 20b. Effect of seeding date of corn on yellow nutsedge tuber number in different size classes (between corn rows, 1981).

Tuber size classes (mm in diameter)

C1	=	less than 2.8	C6	=	4.4-4.8
C2	=	2.8-3.2	C7	=	4.8-5.2
C3	=	3.2-3.6	C8	=	5.2-5.6
C4	=	3.6-4.0	C9	=	5.6-6.0
C5	=	4.0-4.4	C10	=	greater than 6.0

1st week of seeding corn in May

$$\hat{Y} = 58.3778 - 4.8384\ X$$

2nd week of seeding corn in May

$$Y = 71.2667 - 5.7697\ X$$

3rd week of seeding corn in May

$$Y = 95.5111 - 8.5111\ X$$

4th week of seeding corn in May

$$Y = 82.2444 - 5.8929\ X$$

1st week of seeding corn in June

$$Y = 40.2250 + 5.6284\ X - 0.9034\ X^2$$

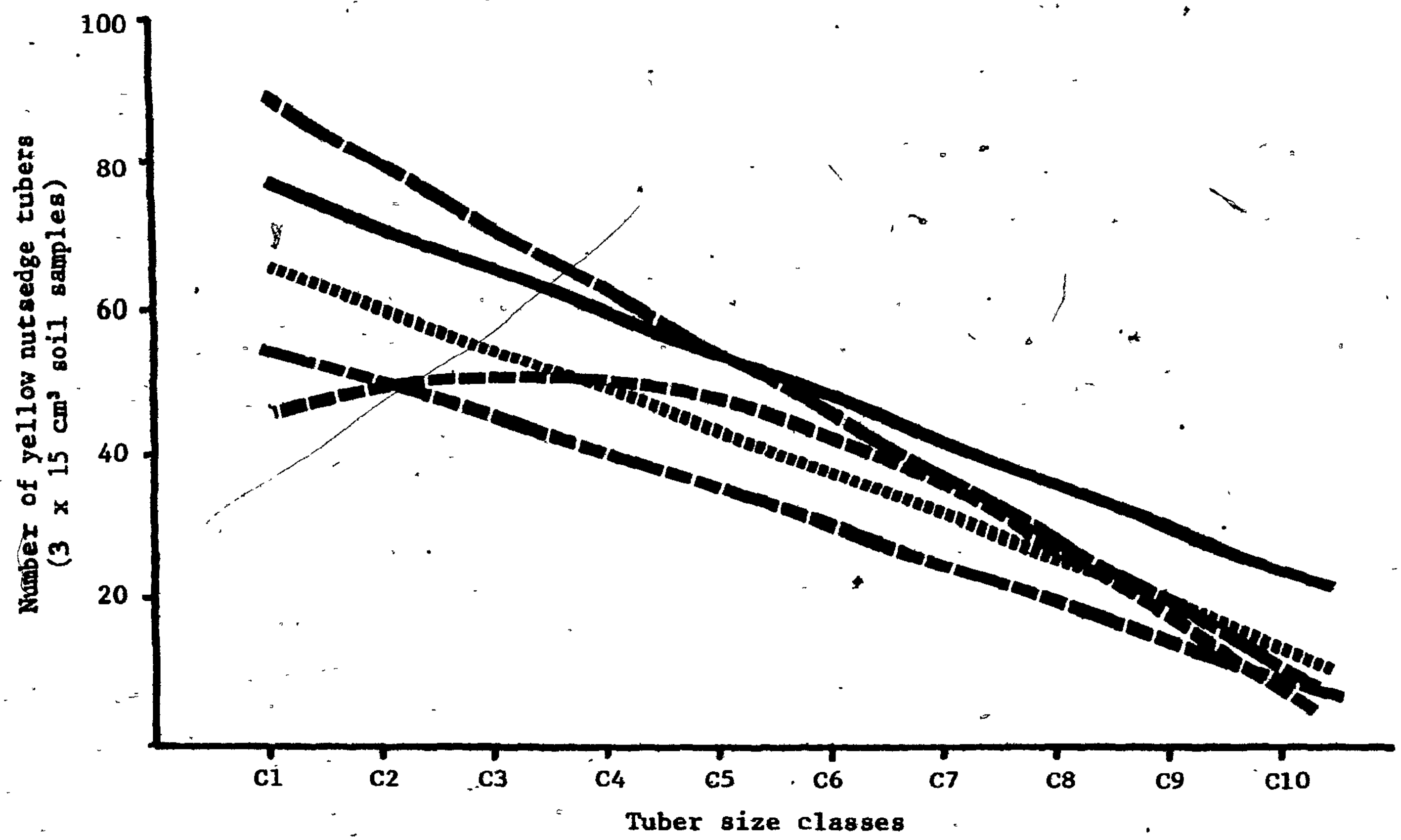

100
80
60
40
20
Number of yellow nutsedge tubers
(3 x 15 cm³ soil samples)
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes

Figure 20b

corn in May, then decreased slightly on the last date of seeding corn (1st week of June) (Figure 21). However, tubers obtained from within corn rows tended to increase in weight to the second week of seeding in May, then the tuber weight decreased with successive seeding dates.

Tuber dry weight in different size classes was not significantly affected by seeding date of corn (Table 9). Nevertheless, each individual seeding date of corn significantly altered tuber dry weight in different size classes. As illustrated in Figure 22a, tubers obtained from between corn rows tended to have normal distribution curves, while tubers obtained from within corn rows tended to indicate linear response in the first and second week of seeding corn in May, and normal distributions at the later seeding dates (Figure 22b).

7.2.3 Corn yield

The effect of seeding date of corn on fodder dry matter and ear dry weight are shown in Figure 23. The highest corn yields were obtained at the third week of seeding in May and the lowest yields were obtained at the first week of seeding in June. The percentages of ear contribution to fodder dry weight were 35.4 to 39.9 per cent. The corn height was greatest when corn was planted in the third week of May and decreased sharply when planted later (Figure 17). Ear length was significantly affected by seeding date of corn. The longest (15.6 cm) and the shortest (10.5 cm) ear lengths corresponded to the maximum and minimum height obtained for corn.

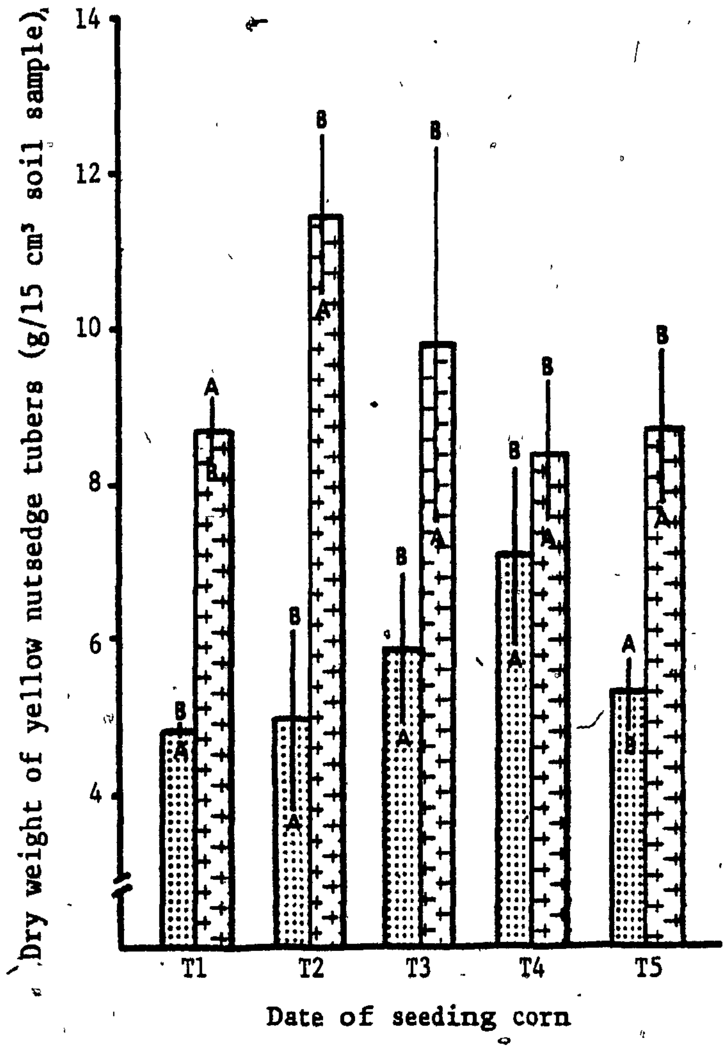


Figure 21. Effect of seeding date of corn on yellow nutsedge tuber dry weight.

Samples obtained from between corn rows
Samples obtained from within corn rows
A = 1980 data B = 1981 data

Figure 22a. Effect of seeding date of corn on yellow nutsedge tuber dry weight in different size classes (between corn rows, 1981).

Tuber size classes (mm in diameter)

C1 =	less than 2.8	C6 =	4.4-4.8
C2 =	2.8-3.2	C7 =	4.8-5.2
C3 =	3.2-3.6	C8 =	5.2-5-6
C4 =	3.6-4.0	C9 =	5.6-6.0
C5 =	4.0-4.4	C10 =	greater than 6.0

1st week of seeding corn in May

$$Y = 0.0078 + 0.5367\,X - 0.0396\,X^2$$

2nd week of seeding corn in May

$$Y = -0.3428 + 0.8289\,X - 0.0628\,X^2$$

3rd week of seeding corn in May

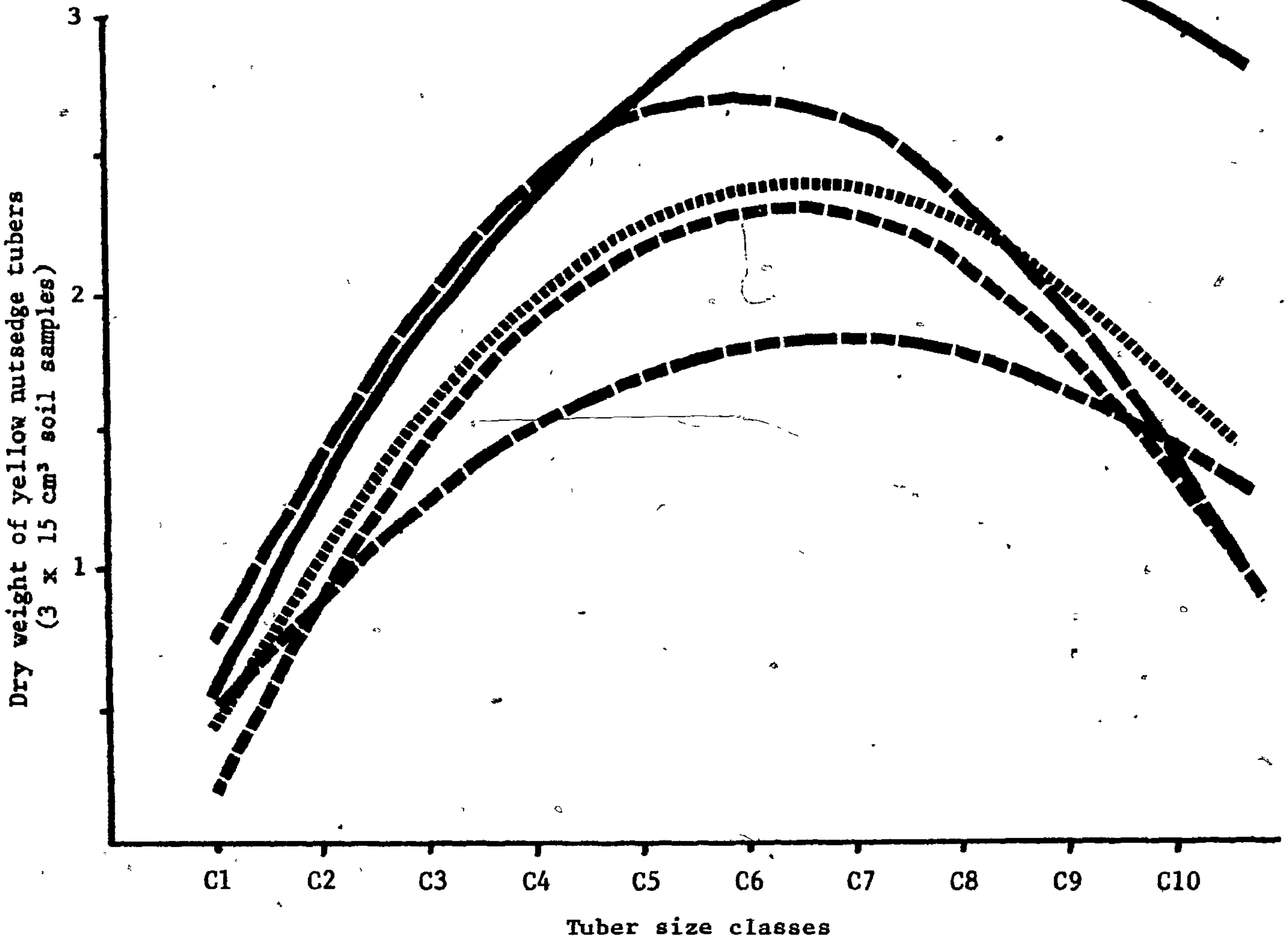
$$Y = -0.1600 + 0.9691\,X - 0.0818\,X^2$$

4th week of seeding corn in May

$$Y = -0.2717 + 0.8709\,X - 0.0547\,X^2$$

1st week of seeding corn in June

$$Y = -0.7108 + 0.9547\,X - 0.0752\,X^2$$



Dry weight of yellow nutsedge tubers
(3 x 15 cm³ soil samples)
1
2
3
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes

Figure 22a

Figure 22b. Effect of seeding date of corn on yellow nutsedge tuber dry weight in different size classes (within corn rows, 1981).

Tuber size classes (mm in diameter)

C1 =	less than 2.8	C6 =	4.4-4.8
C2 =	2.8.3.2	C7 =	4.8-5.2
C3 =	3.2-3.6	C8 =	5.2-5.6
C4 =	3.6-4.0	C9 =	5.6-6.0
C5 =	4.0-4.4	C10 =	greater than 6.0

1st week of seeding corn in May

$$Y = 0.0289 + 0.4384 X$$

2nd week of seeding corn in May

$$Y = -0.0444 + 0.6802 X$$

3rd week of seeding corn in May

$$Y = -1.0078 + 1.3126 X - 0.0684 X^2$$

4th week of seeding corn in May

$$Y = -1.1539 + 1.2939 X - 0.0840 X^2$$

1st week of seeding corn in June

$$Y = -0.5982 + 1.1908 X - 0.0806 X^2$$

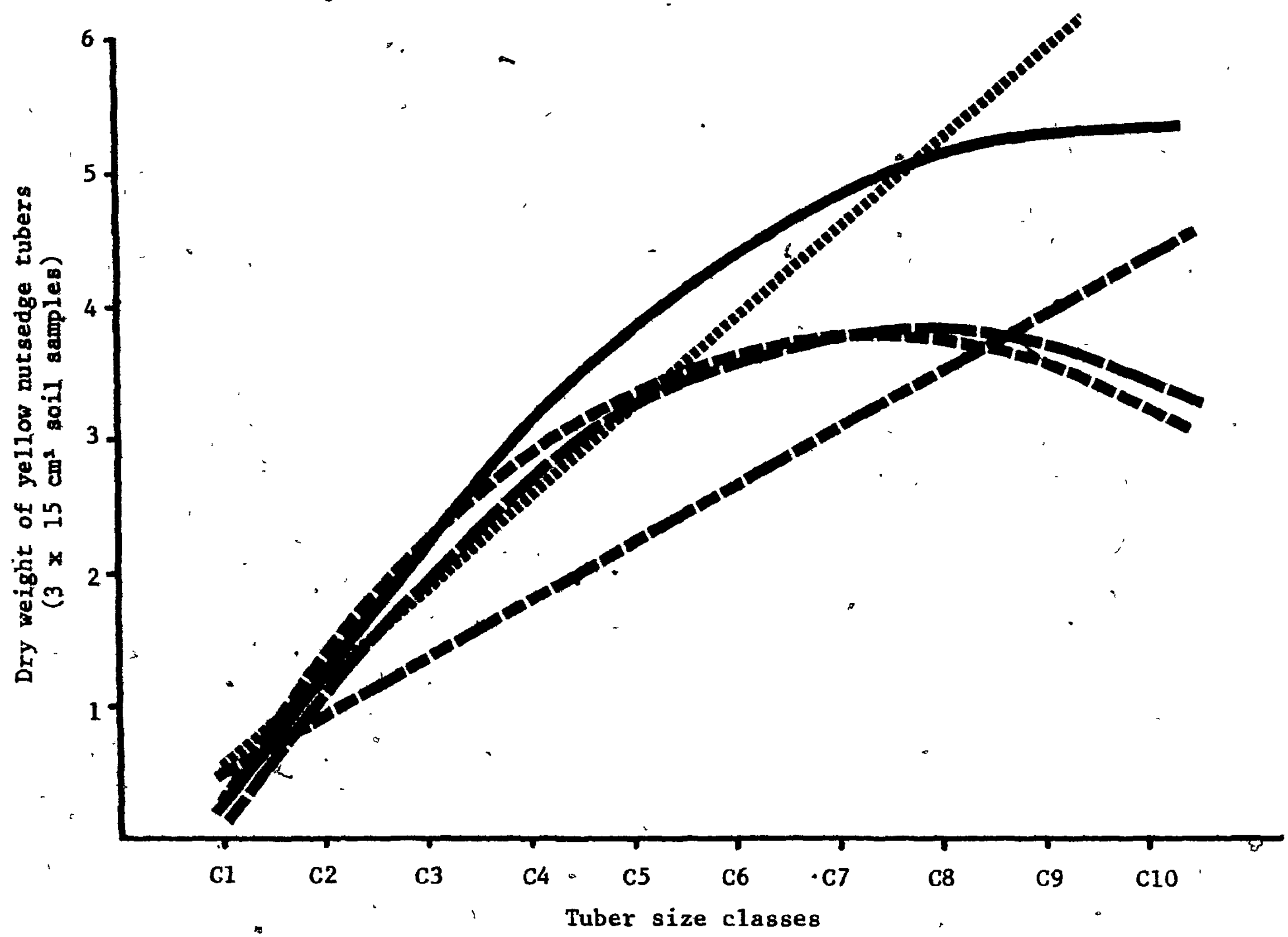

Dry weight of yellow nutsedge tubers
(3 x 15 cm³ soil samples)
6
5
4
3
2
1
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
Tuber size classes

Figure 22b

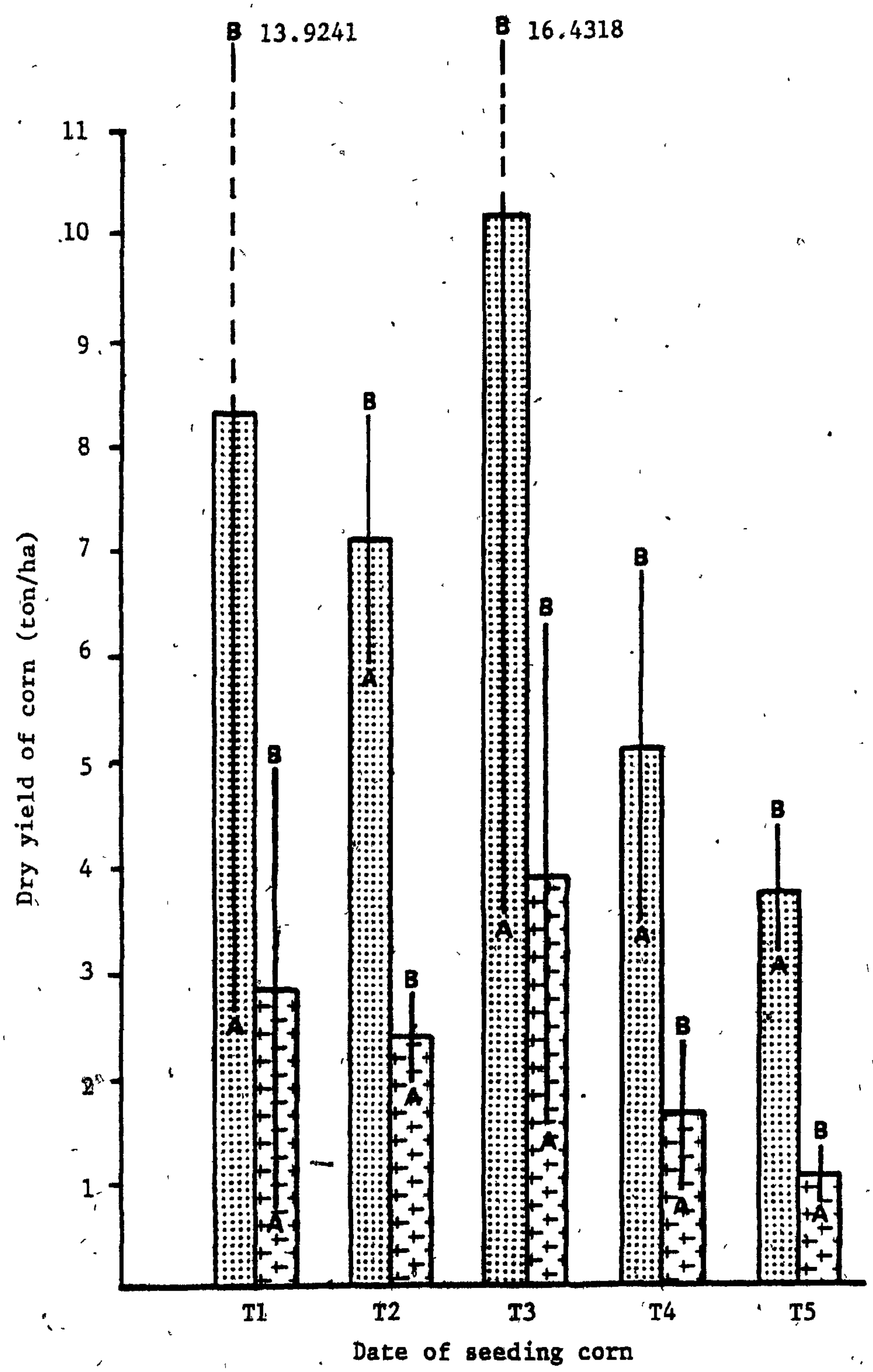


Figure 23. Effect of seeding date of corn on fodder and ear dry weight.

Fodder dry weight A = 1980 data

Ear dry weight B = 1981 data

VIII. DISCUSSION

8.1 Experiment 1 - Corn population

8.1.1 Yellow nutsedge above ground biomass

The above ground biomass of yellow nutsedge sampled from between corn rows was not affected by the planting distance of corn. These results suggest that wide planting distance between corn rows provides enough space for yellow nutsedge to grow and establish, and less competition from the crop. However, the effect of corn planting distance on yellow nutsedge sampled within the corn rows showed significant differences. These significant effects could be due to the different amounts of space available for yellow nutsedge growth and development, and increased competition from the crop as the corn planting distances within the rows were reduced.

There was significantly more yellow nutsedge biomass obtained within the corn rows than between the rows. This increase was due to the fertilizer applied within the corn rows as a starter and side dressing. Bell *et al*. (1962) and Garg *et al*. (1967) have reported that fertilization increases the growth of yellow nutsedge. Visual observation indicated that yellow nutsedge between corn rows was lighter in color when compared with that within the corn rows, which was a greener color. The reduction of yellow nutsedge biomass between corn rows suggested that yellow nutsedge was competing for nutrients. The significant reduction of yellow nutsedge above ground biomass due to increasing corn population clearly demonstrated competitive advantage for corn at high corn planting densities.

Yellow nutsedge height.--Plant height is considered to be one of the important factors in plant competition for light. During the vegetative growth phase, yellow nutsedge height tended to increase linearly with an increasing corn population (Figure 3). These results suggest that a strong competition between corn and yellow nutsedge occurred during the early phase of development. In some cases, yellow nutsedge plants were taller than corn in plots of less dense corn population. However, at the end of the growing season, yellow nutsedge height tended to decrease linearly due to increasing corn population. These results indicate the competitive advantage of the taller corn plants.

Yellow nutsedge Leaf Area Index (LAI).--The leaf area index of yellow nutsedge was calculated by measuring the leaf area to leaf ratio (Radford 1967) and this measurement could also be considered as a measurement of the rate of photosynthesis. The average LAI of yellow nutsedge varied from 0.27 to 0.47 as the corn population increased from 33,333 to 133,333 plants per hectare. Since LAI of this plant was less than 1, it would not be considered a strong competitor for light (Radford 1967; William and Warren 1975). Moreover, yellow nutsedge height was never greater than corn except in some plots of low corn population during the very early phases of development. Nevertheless, yellow nutsedge LAI tended to increase as the corn population densities increased. These results suggest that nutsedge responded to reduced light by stem elongation and leaf expansion.

8.1.2 Tuber production of yellow nutsedge

8.1.2.1 Tuber number

Yellow nutsedge is mainly reproduced by tubers. The ability of a single tuber to produce numerous tubers in a single growing season and their resprouting potential indicates the weediness of this plant in the field (Tumbleson and Kommedahl 1961).

The significant linear effect of increasing corn population in reducing yellow nutsedge tuber numbers (Figure 2), clearly demonstrates the competitive ability of corn at higher population. In Quebec, corn is often planted at 66,667 plants per hectare (S. Lussier, personal communication). Therefore, the reduction of tuber number due to increasing the corn population to 133,333 plants per hectare was 71.3 per cent. Conversely, a reduction of the corn population to 33,333 plants per hectare increased the production of tubers by 43.6 per cent.

The significant increase in tuber numbers within the corn rows when compared with between rows was mainly due to fertilizer application along the corn rows.

The number of yellow nutsedge tubers in different size classes was significantly affected by corn planting distance. The high contingency coefficient values for tuber number in different size classes (Table 5) indicated a strong relationship between corn population and tuber size classes. Further, regression analyses were performed for each selected population (low, medium and high) to represent the effect of corn population on the distribution of tuber size classes (Figures 6 and 7). Two different trends were indicated in 1981. Tubers sampled within the corn rows produced normal distribution curves, while tubers sampled from between corn rows decreased linearly as tuber size increased. However, in 1980, normal distribution curves were obtained for both samples between and within corn rows.

The different trends of response in 1981 were probably due to the fact that competition from between corn rows for nutrients occurred. The majority of tubers formed were small as compared with those tubers within the corn rows (which were fertilized).

8.1.2.2 Tuber dry weight

Yellow nutsedge tuber dry weight within the corn rows was significantly decreased due to increasing corn population. Tuber weight from between corn rows was not significantly affected by the increasing corn population and did not produce the same size as those tubers within corn rows. Besides, tuber dry weight within corn rows was significantly greater than tubers sampled from between corn rows. The increased tuber dry weight within corn rows was again contributed by the fertilizer applied as starter and side dressing.

It was interesting to note that total tuber dry weight in different size classes was not significantly affected by corn population. The low contingency coefficient (Table 5) indicated that there was no apparent relationship between total tuber dry weight in different size classes and corn population. However, there was a significant effect of each individual corn population on tuber dry weight in different size classes (Figure 9). Tubers obtained from within corn rows were represented by two different response curves. The two lowest corn populations (33,333 and 44,444 p.p.h.) produced normal distribution curves, while with the medium (66,667 p.p.h.) and the highest corn populations (133,333 p.p.h.) total tuber dry weight increased linearly with increasing tuber size classes. However, the opposite response curves were indicated for tubers obtained from between corn rows. The lowest corn population produced linear increases in tuber dry weight with increasing tuber size. As the corn population increased, the trends changed to normal distribution curves. Even though total tuber dry weight in different size classes was not significantly affected by corn population (from Chi-square analysis), regression analysis of individual corn populations demonstrated significant differences. However, this variation from between corn rows in two populations (T-11 and T-12) was not significant. The majority of the tubers between corn rows were small with few large tubers being produced.

8.1.3 Light intensity

The competitive ability of plants is partly governed by their efficiency in utilizing the amount of light present. Black et al. (1969) considered Cyperus species to be photosynthetically efficient plants. This information suggests that at low light intensities nutsedge growth would be reduced and competition with crop plants under low light conditions would greatly suppress growth and development of yellow nutsedge in the field.

In this experiment, the amount of light received by yellow nutsedge canopies was significantly reduced as the corn population increased (Figure 10). These results demonstrate the ability of corn at high planting densities to intercept light and provide rapid shading over nutsedge. Furthermore, yellow nutsedge was not able to grow taller than corn except for the first few weeks of crop establishment in some plots of the lowest corn population.

The importance of light for yellow nutsedge growth has been shown by several investigators (Bundy et al. 1960; Bell et al. 1962; Garg et al. 1967; Jensen 1968; Botha 1972; Lewis 1972; William and Warren 1975; Keeley and Thullen 1978). In this study, the mean light intensity (measured on PAR) was positively correlated with yellow nutsedge above ground biomass and tuber production, while yellow nutsedge height was negatively correlated with mean light intensity (Table 10). The reduction in the amount of light received by nutsedge canopies corresponded with the reduction of yellow nutsedge above ground biomass and tuber production. The same trends were shown by Keeley and Thullen (1978) where the average number of shoots, tuber and total dry matter of yellow nutsedge increased directly proportional to increasing light.

The average amount of light (PAR) intercepted by corn populations of 33,333, 66,667 and 133,333 plants per hectare was 84.9, 88.6 and 91.3 per cent, respectively. According to Keeley and Thullen (1978), corn intercepted more than 90 per cent of the photosynthetically active radiation.

8.1.4 Corn yield

Increasing plant population will result in successive increases in yield to a maximum level and beyond this level an additional increase in plant population would not add to the yield. Rutzer and Crowder (1967) and Martin (1977) suggested that optimum corn populations of 55,000 to 80,000 plants per hectare were required to obtain the maximum silage yields and the highest grain yield contribution to silage production.

In this experiment, the corn population varied from 33,333 to 133,333 plants per hectare. The results indicated that under local growing conditions, the optimum corn population may reach up to 133,333 plants per hectare in order to obtain the maximum corn yield (Figure 12). The highest fodder yield and ear yield were 25.8 and 6.6 tons per hectare, respectively. The ear dry weight contribution to fodder yield varied from 23.9 to 36.9 per cent. At the Ste. Anne de Bellevue, Quebec, location, average fodder and ear yields at corn populations of 66,667 plants per hectare were 13.5 and 7.7 tons per hectare, respectively, with ear contribution about 57 per cent (S. Lussier - personal communication).

Even though the ear contribution to fodder yields were low compared with the normal ear contribution obtained at the Macdonald Campus farm, fodder yield obtained in this experiment was approximately twice that of the normal yields. This will undoubtedly compensate for the lower ear contribution to total fodder yield. Ear length of corn tends to be reduced as the corn population increases. This response indicates that ear development was affected by high corn populations and explains the low ear contribution to fodder yield. Corn height was not significantly affected by the corn population which suggests that intraspecific competition for light did not occur in corn.

8.2 Experiment 2 - Seeding date

8.2.1 Yellow nutsedge

Yellow nutsedge above ground biomass and tuber production were not significantly affected by seeding date of corn. This was probably due to the effect of rotovation (final seedbed preparation) prior to each seeding date. Rotovation tends to expose the dormant tubers onto the soil surface, which stimulates the tubers to sprout. Although differences were not significant, the lowest number of tubers produced were obtained from the first seeding date of corn. These results demonstrated that early seeding of corn helps to reduce tuber production of yellow nutsedge.

The numbers of tubers in different size classes were significantly affected by the seeding date of corn. Their high contingency coefficients (0.79 to 0.83) suggested that there was a strong relationship between tuber size classes and seeding date of corn. However, tuber dry weight in different size classes was not significantly different due to the seeding date of corn. Low contingency coefficients (0.32 to 0.36) indicated that there was no apparent relationship between tuber weight in different size classes as affected by corn seeding date.

The distribution curves of tubers in different size classes for each seeding date of corn showed significant differences. These results suggested that each individual seeding date of corn influenced tuber size. The majority of tubers were in the medium size class of 3.6 to 4.8 mm in diameter.

Yellow nutsedge biomass and tuber production obtained from within the corn rows were significantly more than those obtained from between corn rows. This difference was due to the effect of fertilization as discussed earlier.

8.2.2 Corn

The effect of corn seeding date on corn yield (Figure 23) indicates that the optimum date of seeding corn in this area was in the third week of May. Planting after this date will result in decreased yields. The same response was obtained by Martin (1977). However, this type of response varies from location to location

(Eik and Hanway 1965; Genter and Jones 1970) and from year to year. Seeding corn in the third week of May also produced the tallest plants and the longest ear length. The opposite results were reported by Genter and Jones (1970) where plant height increased at successive planting dates. These different results are probably due to the difference in location and environmental factors.

The results obtained in this experiment suggest that the optimum seeding date of corn at the Macdonald Campus location was in the third week of May in order to obtain the maximum corn yield.

8.2.3 Response of yellow nutsedge to corn seeding date

Comparison between the trends of yellow nutsedge above ground biomass within corn rows and fodder yield is presented in Figure 24. In general, variation in seeding dates of corn did not significantly affect yellow nutsedge growth. However, the third week of seeding corn in May produced maximum corn yields. Furthermore, at this date, yellow nutsedge above ground biomass was reduced when compared with the second and the fourth seeding dates in May. These same trends of response were found for tuber production, except that there was a reduction in tuber production at the third week of May seeding and a slight increase at the first week of June seeding.

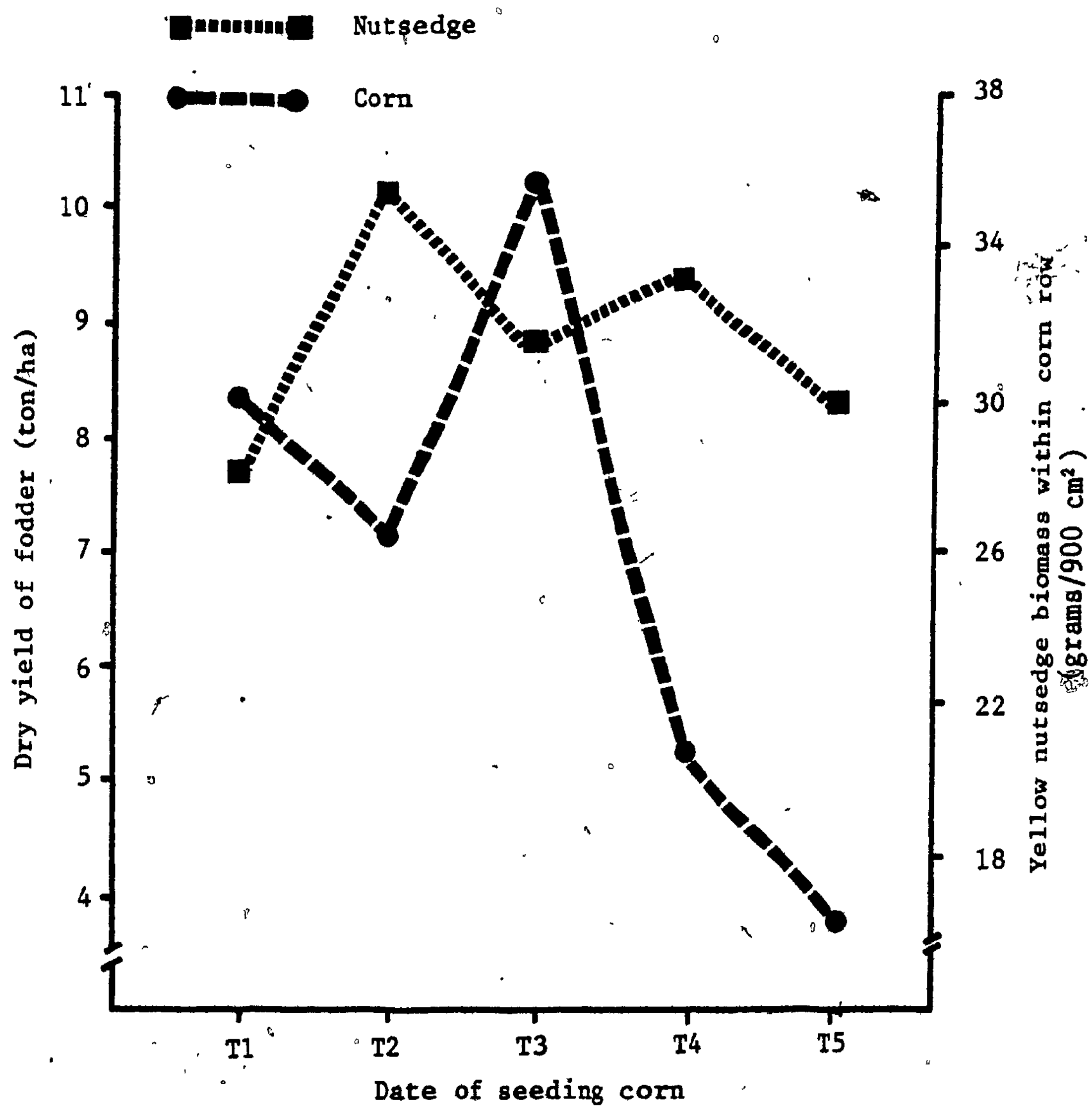


Figure 24. Effect of seeding date of corn on yellow nutsedge above ground biomass and corn yield.

IX. CONCLUSIONS

The following conclusions may be drawn from the results of this experiment.

1. Increasing corn population results in a reduction in the amount of photosynthetically active radiation (PAR) received by yellow nutsedge due to corn canopy interception.

2. The reduction of PAR tends to reduce yellow nutsedge above ground biomass, tuber dry weight, tuber number and yellow nutsedge height at the end of the growing season.

3. Leaf area index (LAI) of yellow nutsedge increases as corn population increases. LAI was less than one, suggesting that yellow nutsedge was not a strong competitor for light. Competition with corn probably was for available space and nutrients.

4. Tuber numbers in different size classes were significantly altered due to corn population and seeding date. There was a strong relationship between tuber numbers in different size classes and the treatments. However, tuber dry weight in different size classes was not significantly altered by the treatments. Their low contingency coefficient indicated that there was no relationship between tuber weight in different size classes with the corn population and seeding date.

5. Corn yields were significantly increased as the corn population was increased. Ear contribution to fodder yield was low for all planting densities. However, the increase in fodder yield compensated for the low ear contribution.

6. The third week of May was the optimum seeding date of corn in order to obtain the maximum corn yield. However, yellow nutsedge biomass, tuber number and tuber dry weight were not significantly affected by seeding dates.

APPENDICES

APPENDIX I. Table of significance - Experiment 1. Corn population. Effect of corn planting distance between rows and within rows on yellow nutsedge

Source of variation	df	Parameters taken from between corn rows (mean square)					
		Biomass dry weight above ground		Tuber number		Tuber dry weight	
		1980	1981	1980	1981	1980	1981
Block	2	112.7531	24.0508	197.0586	547.6944	0.2791	4.2608
Between rows (B)	2	3.6512	21.5158	2701.1142	1271.3611	5.3689	1.0208
Within rows (W)	3	109.1605	15.2462	43.9866	710.5463	0.8340	2.5974
B * W	6	102.8488	2.6751	1396.9619	345.7685	4.1265	1.2505
Error	22	132.0527	17.8975	804.3213	413.6338	2.4927	1.1823

table continued

APPENDIX 1 (continued)

Source of variation	df	Parameters taken from within corn rows (mean square)					
		Biomass dry weight above ground		Tuber number		Tuber dry weight	
		1980	1981	1980	1981	1980	1981
Block	2	92.8364	44.8603	1606.6759	1813.5277	10.7531	18.0503
Between rows (B)	2	508.3920**	454.5878**	26793.2870**	7301.444 **	61.0020**	62.9653**
Within rows (W)	3	141.2428*	122.2995*	2853.6882	1336.7685	6.5438	6.7299
B * W	6	44.5607	16.9804	880.1882	189.7407	1.5607	1.5771
Error	22	38.9980	28.8406	2131.0187	871.1035	3.5231	3.9476

* Significant at 5 per cent level
** Significant at 1 per cent level

APPENDIX 2. Effect of corn planting distance on yellow nutsedge above ground biomass ($g/900\ cm^2$)

Corn planting distance	Samples taken from between corn rows				Samples taken from within corn rows			
	Fresh weight		Dry weight		Fresh weight		Dry weight	
	1980	1981	1980	1981	1980	1981	1980	1981
Between rows								
50 cm	90.94A*	59.42A	20.08A	14.24A	112.17B	80.58B	25.14B	19.63B
75 cm	101.39A	48.92A	20.33A	11.73A	151.97A	96.08B	33.89A	23.04B
100 cm	98.39A	58.92A	21.14A	13.80A	161.92A	132.83A	37.86A	31.58A
Within rows								
15 cm	93.11a	52.56a	21.11a	13.11a	121.63b	91.22bc	28.47b	21.97b
20 cm	73.56a	45.78a	15.56a	11.74a	133.19b	88.33c	31.19b	21.21b
25 cm	109.67a	55.78a	23.67a	13.26a	144.00ab	111.67ab	31.78ab	27.37a
30 cm	111.30a	68.89a	21.74a	14.92a	169.26a	121.44a	37.81a	28.44a

*Means sharing the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

APPENDIX 3. Effect of corn planting distance on yellow nutsedge tuber production (15 cm³ soil sample).

Corn planting distance	Tuber number				Tuber dry weight (g)			
	Sample taken between rows		Sample taken within rows		Sample taken between rows		Sample taken within rows	
	1980	1981	1980	1981	1980	1981	1980	1981
Between rows								
50 cm	72.89 B*	54.00 AB	94.39 B	62.42 B	4.24 A	2.9 A	4.83 B	3.3 C
75 cm	77.78 AB	47.08 B	128.00 A	86.92 AB	4.37 A	2.4 A	8.02 A	5.1 B
100 cm	100.97 A	67.33 A	148.42 A	111.75 A	5.46 A	2.8 A	9.19 A	7.8 A
Within rows								
15 cm	86.37 a	45.89 a	119.26 a	80.11 a	4.56 a	2.1 a	6.63 a	4.7 a
20 cm	83.52 a	53.22 a	112.11 a	73.67 a	4.34 a	2.5 a	6.60 a	4.6 a
25 cm	84.56 a	67.00 a	127.00 a	94.56 a	5.03 a	3.4 a	8.02 a	6.3 a
30 cm	81.07 a	58.44 a	136.04 a	99.78 a	4.82 a	2.8 a	8.15 a	6.0 a

*Means sharing the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

APPENDIX 4. Means of light intensities (microeinsteins/m²/sec) measured at yellow nutsedge affected by corn planting distance

Planting distance	Date sampled								
	18.7.80	25.7.80	1.8.80	8.8.80	8.7.81	15.7.81	22.7.81	30.7.81	6.8.81
Between rows									
50 cm	177.17B*	172.92B	309.92B	291.50C	205.00A	192.92B	126.75A	108.42A	278.33B
75 cm	182.92B	206.92A	432.50A	420.58B	206.00A	197.50B	125.75A	117.92A	303.08B
100 cm	204.08A	229.92A	487.25A	498.67A	201.08A	230.75A	141.92A	128.00A	403.25A
Within rows									
15 cm	176.44a	178.11a	348.22b	334.78b	174.00b	168.89b	111.00b	101.56b	262.33c
20 cm	197.89a	205.78ab	404.78ab	417.11a	200.00ab	185.22b	113.44b	106.44b	291.11bc
25 cm	181.67a	203.33ab	429.22a	426.11a	210.44a	232.67a	146.00a	138.78a	394.89a
30 cm	196.22a	225.78a	457.33a	436.33a	232.33a	241.44a	155.44a	125.67ab	364.56ab

*Means sharing the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

APPENDIX 5. Effect of corn planting distance on corn yield (ton/ha)

Planting distance of corn	Fodder yield				Ear yield				Ear length (cm)	
	Fresh weight		Dry weight		Fresh weight		Dry weight			
	1980	1981	1980	1981	1980	1981	1980	1981	1980	1981
Between rows										
50 cm	70.48A*	46.67A	21.13A	17.15A	13.14A	10.33A	5.62A	5.36A	15.52B	12.93B
75 cm	51.37B	49.36B	15.96B	17.72A	9.39B	9.82A	4.29B	5.42A	16.66A	14.80A
100 cm	39.93C	51.88C	12.18B	18.26A	7.59B	10.50A	3.49B	5.95A	16.93A	16.14A
Within rows										
15 cm	66.01a	61.15a	20.06a	21.90a	12.04a	12.58a	5.22a	6.77a	15.64b	13.92b
20 cm	52.27b	52.63ab	15.73ab	19.26ab	10.29ab	10.22ab	4.39ab	5.47a	15.64b	14.58ab
25 cm	52.16b	39.14b	15.89ab	14.04b	9.88ab	8.99b	4.65ab	4.98a	17.75a	13.74b
30 cm	45.26b	44.29ab	14.01b	15.64b	7.95ab	9.07b	3.60b	5.09a	17.12a	16.26a

*Means sharing the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

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