EFFECTS OF DIFFERENT LEVELS OF COMPETITION BY *CYPERUS ESCULENTUS* L. ON THE GROWTH AND SUCROSE YIELD OF IRRIGATED SUGARCANE (*SACCHARUM OFFICINARUM* L.) IN NORTHERN SWAZILAND

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DECLARATION

I declare that the results reported in this thesis are from my own original work except where acknowledged herein.

S.V.I. MANANA

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ABSTRACT

The study was undertaken to evaluate the interference of *Cyperus esculentus* (L.) with growth and quality of irrigated sugarcane (*Saccharum officinarum* (L.)) in northern Swaziland, and to quantify or characterise yield loss in relation to *C. esculentus* population and its control. The study comprised two field experiments on different soil types on plant, 1st, 2nd and 3rd ratoon sugarcane located at Mhlume (Swaziland) Sugar Company during the period 1988 to 1991. Three *C. esculentus* population levels were established at 1680 to 1833 plants m^{-2} (heavy), 1110 to 1205 plants m^{-2} (medium), and 550 to 582 plants m^{-2} (light). Medium and light infestation treatments were instituted through thinning by hand to populations of 67% and 33% of the original populations respectively. Four weed control methods were superimposed. These comprised two controls; a) no weed control (*C. esculentus* was left undisturbed throughout the growth of the crop), b) complete weed control by hand weeding throughout the season; and two levels of herbicide application rates, a recommended estate level, which was a mixture of 1.6 L MCPA (a.i.) ha^{-1} (2-methyl-4-chlorophenoxyacetic acid) (400 g a.i. L^{-1}) with 1.5 L ametryn (a.i.) ha^{-1} (2-methylthio-4-isopropylamino-s-triazine) (500 g a.i L^{-1}) and one-half the recommended herbicide application. A surfactant was added to the mixture at 0.5 L ha^{-1}. Both trials had 12 treatments arranged in a 3x4 rectangular lattice with five replications.

Significant sugarcane yield responses to weed control method were obtained on plant and 3rd ratoon sugarcane. For the plant sugarcane crop, the institution of the recommended herbicide rate and complete hand weeding gave yield increases of about 14% and 24%, respectively, compared to the no control treatment. The plant crop sucrose yield was significantly affected by weed control methods with the recommended herbicide and complete hand weeding giving 15% and 26% increase in sucrose yield, respectively, compared to the no control treatment. In the 3rd ratoon crop complete hand weeding gave an increase of 26% and 28% sugarcane and sucrose yield, respectively. Indications were that 1st and 2nd ratoon sugarcane displayed the most vigorous growth, and hence was highly competitive against the *C. esculentus* and suffered no yield or quality loss due to weed populations. The possible reason was that the 1st ratoon sugarcane crop grows more vigorously than the plant crop and would therefore achieve canopy earlier than in the plant sugarcane crop. Even though results under the

environmental conditions and time of regeneration of young ratoons used in this study indicated little, if any, benefit of weed control, this aspect would need further study at other times of the year before no weed control on young, vigorously growing ratoons could generally be recommended.

As sugarcane yield and quality were not affected by *C. esculentus* populations, it was not possible to establish a population level for economic control of the weed. However, regeneration of *C. esculentus* in subsequent years was shown to be a function of previous years' populations and control method imposed on that population. Final populations in the subsequent year were lower where weed control was instigated than where there was no weed control. The conclusion reached in this study is that weed control will not only affect competitive abilities of current *C. esculentus*, but also reduce future population levels of the weed. The lack of sugarcane yield and quality response to different levels of *C. esculentus* population made it impossible to conclusively determine the economic threshold of *C. esculentus* which caused sugarcane yield and quality loss in irrigated agriculture on these soils.

GENERAL INTRODUCTION

Sugar is Swaziland's main export commodity contributing about 30% to the gross national product (Thompson, 1991) and is commercially produced from sugarcane (*Saccharum officinarum L.*) in the eastern lowveld region.

Sugarcane is grown on a large area of the Swaziland lowveld that is characterised by hot and dry summers with temperatures exceeding 37°C and evaporation, exceeding 250 mm per month. Winters have relatively cool temperatures and are normally very dry. The characteristic trees (e.g. *Acacia nigrescens*) and shrubs of the lowveld are open Savannah (Acocks, 1953). Rainfall is restricted almost entirely to the spring and summer months, much of which falls in rainstorms of high intensity and short duration. Because the rainfall is erratic, unreliable, and of low efficiency, all commercial sugarcane in Swaziland is irrigated. Water is obtained from the Usuthu river in the south and Komati and Umbuluzi rivers in the north (Murdoch, 1968).

The altitude of the sugar growing areas varies between 50 m in the south to 200 m in the north. Topography is relatively flat. Soils are generally variable in depth and texture. Murdoch (1968) reported that the most common soil sets in the south are S, R, C and K (similar to Mayo, Shortlands, Canterbury and Arcadia soil series, respectively) and in the north T, H and R sets (similar to Tambankulu, Westleigh and Habelo soil series, respectively).

Throughout the years, weed control practices in the sugar industry have featured prominently as one of the most labour intensive operations and together with herbicides involve the sugar industry in an annual expenditure of approximately 3% of production costs[1]. A wide spectrum of weeds exists in the sugar producing areas. The most widespread broadleaved weeds include *Bidens pilosa* L., *Datura stramonium* L., *Amaranthus spinosus* L., *Commelina benghalensis* L., and *Portulaca oleracea* L. The most troublesome grass species in the sugar

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[1] Mr I.H.S. Moore, Mhlume (Swaziland) Sugar Company

industry include *Sorghum verticillifolium* L., *Panicum maximum* L., *Rottboelia exaltata* L. and *Cynodon dactylon L.*

The widespread occurrence and the difficulty of controlling sedges, yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*C. rotundus* L.) is a major concern in the sugar growing areas of Swaziland. These species are commonly abundant both in plant and ratoon sugarcane. The production of underground tubers which remain dormant in the soil, and are capable of carrying the plant through extreme environmental conditions are important characteristics of *Cyperus* spp. As a result even when small isolated pockets of these weeds survive in the field, the rapid regeneration and colonising habit of the species ensures a high infestation within one or two seasons (Fisher, 1966).

Cyperus esculentus is regarded as one of the world's worst weeds in a wide range of crops (Holm, Pancho and Herberge, 1977). The weed is widely known by the common names of nutsedge, nutgrass, or yellow nutsedge. Available literature shows that there has been more experimental work done on the competitive effects of *C.rotundus* on sugarcane than *C.esculentus*. (Holm *et.al.* 1977; Keeley, 1987).

The *Cyperus* spp. have been classified by their phenotypic characteristics (Wills, 1987), falling within the class of Angiospermae, subclass Monocotyledoneae, order Graminales and the family, Cyperaceae. Members of the Cyperaceae family resemble the Poaceae family (grass family), but Wills (1987) was also able to distinguish them from grasses by their three ranked leaves that have closed leaf sheaths, usually solid stems, absence of ligule and also that each flower is subtended by a single glume or scale. He further observed that the family Cyperaceae consists of about 75 genera containing more than 4000 species.

Stoller (1973) noted that yellow nutsedge tubers can survive in areas of low air and soil temperatures, partly because of the tuber's ability to harden in areas of extreme environmental conditions. This confirmed earlier studies by Ueki (1969) who reported that the purple nutsedge was more sensitive to cold than yellow nutsedge. He observed that purple nutsedge is restricted to areas where air temperatures are higher than -1°C, while yellow nutsedge can survive where air temperature is as low as -17°C.

Many crops are affected by yellow nutsedge competition (Holm *et al.*, 1977). In maize and cotton, yield losses of up to 75% and 34%, respectively, have been reported (Keeley and Thullen, 1978). This confirmed earlier findings by Fisher (1966) who noted that for maize such yield reductions were attained when yellow nutsedge was left uncontrolled for the first eight weeks of maize growth. He postulated that this was because yellow nutsedge made its greatest demands on water and nutrients during early growth.

Decreases in sugarcane yields due to purple nutsedge of 38% in Australia and 75% in Argentina have been reported (Holm *et al.*, 1977). It was suggested by Chapman (1966) that the cause for the severe yield reduction was as a result of competition for water at the time of tiller formation and as a result fewer cane shoots were produced. According to Chapman (1966) the weed also withdraws and retains large quantities of mineral nutrients into its underground structures which are therefore not made available to the associated crop.

Turner (1984) investigated the competitive effects of *C. rotundus* on sugarcane yields in South Africa. In a plant crop of cultivars N13 and N8 under rain grown conditions, competition from *C. rotundus* caused yield losses of up to 85%. He also observed that stalk elongation and tillering were slower in plots of plant sugarcane which contained *C. rotundus*.

In most literature cited it is not evident at which population level yellow nutsedge starts to affect yield loss. There can be no doubt, however, that yellow nutsedge at high population levels and of sufficient aggressiveness reduces yields of crops to a value that fully justifies chemical and other weed control practices. It is necessary to know the point at which cost of weed control is no longer remunerated by the enhanced value of the crop. In order for this concept to be fully accepted by farm management, there must be a change in the farm manager's thinking towards weeds. Unless proved otherwise, the presence of weeds in a field cannot be automatically judged as damaging, and therefore in need of control. Also, with the present financial squeeze in agriculture there is a greater need to look at weed control practices, especially herbicide application, more objectively (Ford and Pleasant, 1994).

The objective of this study was to evaluate the interference of *C. esculentus* with growth and quality of sugarcane in northern Swaziland and to quantify or characterise yield loss in relation to nutsedge population and its control. With such knowledge the farmer would not only be able to correctly time his weed control practices to the best advantage but also choose the most cost effective weed control measures. Little information is available on the competitive effects of *C. esculentus* on sugarcane and therefore literature on the competitive effects of the weed on tall statured crop species was included in the literature review.

CHAPTER 1

LITERATURE REVIEW

1.1 INTRODUCTION

Historically weed control practices have featured prominently in crop production. Because of their evident impact on crop yields, weeds have traditionally been considered unwanted plants. Consequently agriculturalists have concentrated their research on weed/crop competition with relatively little focus on the mechanisms involved (Alteri and Liebman, 1986). Generalization about crop yield losses due to weed competition apparently justified the development of season-long weed-free systems (Aldrich, 1984). However, farmers need a satisfactory way to relate levels of weed infestation to reductions in crop yield, to decide if weed control will be economical.

Studies have tried to identify the weed density at which reduction in crop yield first occurs (threshold level), assuming that there is some minimum weed density which does not reduce crop yield. Cousins (1985) challenged this assumption by showing that a rectangular hyperbola relationship best describes the relationship between weed infestation and crop yield reduction. He noted that there was no minimum number of weeds which the crop can tolerate. Alteri and Liebman (1986) argued against this assumption. They said that the implication made by Cousins (1985) would be correct only, if either the crop population level and spacing were sufficient to use the available resources, or if the supply of growth resources was insufficient to meet the requirements of both the weed and the crop plants.

While farmers may recognise the importance of knowing when a given weed density will reduce yield, there is far greater interest in information ascertaining weed levels where implementation of weed control practices are economical (Zimdahl, 1980; Swanton and Wise, 1991). Help in answering that question can come from an ability to forecast crop yield losses caused by weed competition (Chisaka, 1977). If weed control is necessary, the next step involves determining how intensive a control programme should be implemented. Zimdahl (1980) observed that, for many farmers around the world, reducing risk outweighs maximizing yield. He further noted that, farming for many people is a business where maximum profit is more important than maximum yield.

It is noteworthy that research in this subject is hampered by many problems. There are some difficulties in conducting such studies because it is important to assess the value of weed control practices over time, usually emphasizing the importance of weed seeds or tubers which are produced in a weedy crop, carrying forward to infest the crops in later years (Poole and Gill, 1987). Also, researchers are faced with the problem of separating the allelopathic effects of weeds from that of competition because methods are lacking (Aldrich, 1984).

1.2 THE BIOLOGY OF *C.ESCULENTUS*

1.2.1 General Description

Cyperus esculentus is an erect, perennial herb, with a triangular stem, 0,30 to 0,80 m tall. Leaves are 5 to 6 mm wide with a prominent mid-vein; the inflorescence is in more or less terminal umbels (an often flat topped inflorescence whose pedicels and peduncles arise from a common point) subtended by unequal leaflike bracts varying from 0,05 to 0,25 m long. Spikelets are yellowish brown or straw coloured, 0,01 to 0,03 m of length with several flowers (Holm *et al.*, 1977).

1.2.2 Seed propagation

Reports of *C.esculentus* seed production and viability are controversial, but there seems to be little doubt that large quantities of viable seed can be produced under favourable growing conditions (Holm *et al.*, 1977; Mulligan and Junkins, 1976). Hill, Lachman and Maynard (1963) in the eastern United States of America (U.S.A.) demonstrated in experimental plots that one seedling could develop a plant system in a single season capable of producing 90000 seeds having better than 50% viability. Justice and Whitehead (1946) found that in Maine plants produced 1500 seeds per inflorescence. While gathering seed lots from the north to the south of the U.S.A. they found that viability varied from 50% to 95%. Justice and

Whitehead (1946) further observed that dormancy is alleviated by storage at 10°C. After four months of storage at a temperature range of 20°C to 30°C, 80% of the seeds germinated.

1.2.3 Tuber propagation

When tubers germinate there are usually three sprouts produced from one determinate rhizome (Mulligan and Junkins, 1976). According to these researchers the determinate rhizomes grow directly towards the soil surface and form a primary haplocorm just below the surface. Each primary haplocorm produces a primary vegetative plant above the soil surface. The haplocorm produced by the original tuber also gives rise to many adventitious fibrous roots as well as indeterminate rhizomes originating from axillary buds (Jansen, 1971).

The vegetative system of yellow nutsedge is an interconnected, complex system of many tubers, rhizomes, haplocorms and above ground leafy plants (Mulligan and Junkins, 1976). During one growing season at Rosemount, Minnesota, a single parent tuber produced 1900 plants 6900 tubers to a depth of 0.23 m (Tumbleson and Kommendahl, 1962).

Stoller (1973) found that *C. esculentus* tubers survive in areas of low air and soil temperatures partly because of tubers' ability to harden in the cold and withstand low temperatures for long periods, and partly because the extreme coldness of the air on the soil surface is not usually transmitted down to the soil layers where some tubers reside. He found that 50% of *C. esculentus* tubers were killed at -6.5°C. He concluded that tuber mortality due to cold winter temperatures may account for the limited range of the weed in cold countries like Canada.

Bell, Lachman, Raffin and Sweet (1962) reported on the winter mortality of tubers in Delaware. In October of 1958 only 15% of tubers were soft and presumed dead whereas by April 1959, 75% were in this condition. Of the tubers overwintering in New York at the latitude of 42°N, >96% sprouted when buried 50 to 100 mm deep whereas only 40% of the tubers near the soil surface (<50 mm) sprouted.

Day length is the principal factor that stimulates tuber production in *C. esculentus* (Jansen, 1971). Long photoperiods (more than 14 h) stimulate vegetative growth while short photoperiods (14 h or less) stimulate tuber production (Bell *et al.*, 1962; Jansen, 1971; Williams, 1982)

1.2.4 Tuber dormancy

An understanding of factors affecting tuber dormancy in *C. esculentus* is essential in order to efficiently control plants and tuber sprouting with herbicides or through mechanical tillage (Holm *et al.*, 1977). Bell *et al.* (1962) found tubers to be completely dormant at different germination temperatures harvested during the growing season in the U.S.A. When held at 20°C and 25°C for 48 days a germination of 42% was obtained. If held for longer periods the percentage germination was higher. Tubers which had overwintered in the field, however, showed a high percentage of sprouting after 7 days at the same temperatures. Tumbleson and Kommedahl (1962) found 12% germination in winter harvested tubers and 95% in spring harvested tubers. They concluded that storage at 30°C promoted sprouting and also increased the number of shoots per tuber. This observation is important because tuber dormancy is one of the important features by which infestations are carried over from one season to the other.

1.3 COMPETITION

1.3.1 The importance of competition in crop production

Competition by weeds for light and soil factors (water and nutrients) is the primary cause of crop yield loss in intensive crop farming. The intensity of competition for these resources varies with the scarcity of the resource and the relative demand for the resource exerted by the crop and the weed (Sony and Ambasht, 1977; Tollenaar, Nissanka, Aguilera, Weise and Swanton, 1994).

Willey (1979) mentioned that it is possible for two component plants not to compete for exactly the same overall resources. He explained that the main way that this can happen is when the growth patterns of the different plants differ in time so that the plants make their major demands on resources at different times. This type of complementarity is said to give better temporal use of resources (Willey and Osiru, 1972).

In addition to temporal complementarity between competing plants, spatial complementarity may also be possible (Willey, 1979). For example, it is often suggested that a combined leaf canopy may make better spatial use of light or a combined root system may make better spatial use of nutrients and/or water. Willey (1979) however, mentioned the difficulty in distinguishing between temporal and spatial effects. In practice they are often inseparable.

Competitive ability of weeds has been conceived by Altieri and Liebman (1986) as being of a combination of characteristics which result in resource pre-emption from crops. In contrast Radosevich and Holt (1984) had difficulties in defining the competitiveness of plants in terms of the characteristics that confer it, since few studies have addressed the specific mechanisms of competition among weeds and plants. Competition can modify plant growth and reproduction (Aldrich, 1984). At the population level, it may result in mortality, affecting the number of survivors or reduce the size of survivors which in turn reduces consequent seed output or lowers the rate of vegetative reproduction of the population as a whole (Harper and Gajic, 1961; Palmblad, 1968).

1.3.2 Photosynthetic photon flux density (PPFD)

1.3.2.1 Importance of photosynthetic photon flux density (PPFD) in crop production

Donald (1961) emphasized that PPFD differed from other resources in that it could not be regarded as a reservoir from which demands could be made as required: PPFD is therefore instantaneously available and has to be instantaneously intercepted if it is to be used for photosynthesis. Because of this Willey and Roberts (1976) emphasized that PPFD was probably the most important factor when better temporal use of resources is achieved. Baker and Yusuf (1976) also considered PPFD of prime importance in plants of different maturities. If there is to be better spatial use of PPFD, this has probably to be achieved through more efficient use of PPFD rather than greater interception (Willey, 1979). This can occur if PPFD is better distributed over the leaves, because of better leaf inclination. Leaf inclination has been studied extensively in grass mixtures in which attempts have been made to produce a more ideal canopy by combining tall, erect leaved grass with a short, prostrate one (Trenbath, 1974). Consequently in intensive agriculture PPFD can be a limiting factor. One aim of cropping systems is therefore to make optimal use of PPFD. According to Steiner (1984) taller plants are normally dominant and intercept a greater proportion of the PPFD. Consequently the smaller dominated plant grows more slowly. Even slight differences in early height differentials can result in strong competitive advantages, resulting in relative yield enhancement of dominant plants (Steiner, 1984).

More efficient use of PPFD can be obtained when the dominated species has inclined leaves (Trenbath, 1976). According to Trenbath (1976) this not only allows a better use of PPFD by the dominant plant, but also increases the amount of PPFD available to the dominated plants.

1.3.2.2 Influence of artificial shading on growth of *C. esculentus*

If competitive plants such as *C. esculentus* are photosynthetically efficient at high light intensities (C4 plants), it is postulated that rapid shading would decrease their photosynthetic rates and suppress their growth. This postulate is apparently verifiable, as many researchers reported that shading by crop canopies suppressed the growth and development of the weed (Bell *et al.*, 1962; Holm *et al.*, 1977). A detailed investigation of light requirements of *C. esculentus* and the potential of certain crops to compete with *C. esculentus* for light was made by Keeley and Thullen (1978). They planted *C. esculentus* in rows 0.5 m apart, and plots were regularly watered to promote rapid sprouting of tubers and emergence of shoots. Plastic shade cloth intercepting various amounts of light (0, 47, 80, and 94%) was attached to coarse wire netting and erected over the plots one month after planting (about two weeks after emergence). The average number of shoots and tubers, and dry matter production increased in direct proportion to increased amounts of light (Figure 1.1).

These results were confirmed by Patterson (1982) who determined the effects of shade (0, 40, 70 and 85%) on dry matter production, leaf area and biomass partitioning in both *C. rotundus* and *C. esculentus* at a 32/26°C day/night temperature. He observed that shading significantly reduced the height of *C. esculentus* but not that of *C. rotundus*. Dry matter

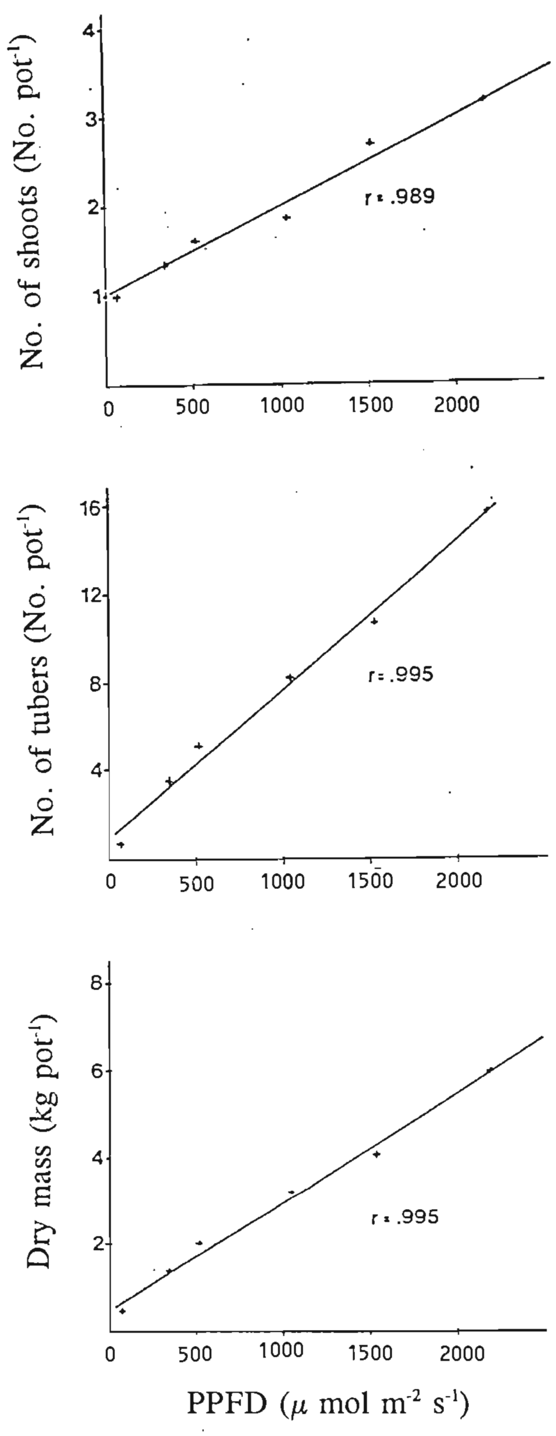


FIGURE 1.1 Effects of photosynthetic photon flux density (PPFD) on number of shoots and tubers and total plant dry mass of *C. esculentus* grown for 120 days under different levels of shading (After Keeley and Thullen, 1978).

production, leaf area production, rhizome and tuber formation of both *C. esculentus* and *C. rotundus* were significantly reduced by shading. According to Patterson (1982) *C. esculentus* can most effectively utilize light intensities approaching those of full sunlight, concurring with earlier findings by Black, Chen and Brown (1969).

1.3.3 Soil factors

The competition between roots of weeds and crops for nutrients can simultaneously decrease the amount of soil nutrients available to both (Crafts and Robbins, 1962). Further, the extent to which one root system may gain competitive advantage over another for a given supply of soil nutrient may depend upon production of exudates and allelochemicals which can either enhance or disrupt the nutrient uptake (Timonin, 1946).

The uptake of dissolved nutrients by a root surface tends to establish a concentration gradient down which further supplies of the substance diffuse toward the root (Nye, 1966; Dunhyam and Nye, 1974). The movement of substances by diffusion and by mass flow in water through the soil to the root depletes the soil of these substances in the vicinity of the roots (Trenbath, 1976). Because nitrate ions are more mobile in soil than potassium and phosphate (Bray, 1954; Barley, 1970) and are usually taken up at faster rates (Brewster and Tinker, 1970; Hanway and Weber, 1971) the zones of their depletion around active roots are expected to increase in size fastest and to overlap the soonest (Bray, 1954). Competition for nutrition does not occur until there is an overlapping of depletion zones of roots of the different component of plants (Bray, 1954).

Since mobile ions like NO_3^- are carried passively in moving soil water and through diffusion, their depletion zones will be as large as those for water, providing the ions are taken up as fast as they arrive at the root (Barber, 1962; Barley, 1970). If there is little transpiration from the shoots, there will be little flow of water to the roots and movement of nutrients will be mostly by diffusion.

Anions like PO_4^{3-} (and cations like NH_4^+, Ca^{2+} and K^+) being absorbed strongly onto the surfaces of soil particles, are of low concentrations in the soil water and therefore move almost exclusively by diffusion (Brewster and Tinker, 1970; Trenbath, 1976). Large reductions in uptake are expected where roots are clumped together rather than distributed at random. For the uptake of mobile nutrients, roots may easily become redundant if they are close together. For the uptake of nonmobile nutrients, however proximity has much less effect because the depletion zones are so much narrower. If the narrowness of the depletion zones for nonmobile nutrients tends to prevent interference between individual roots at anything but high root densities, it will tend also to prevent competition for these nutrients between root systems of different component plants (Bray, 1954; Baldwin *et al.*, 1972).

Since the same principles apply to competition between individual roots as apply to competition between whole plants, the spatial distribution of individual roots in regions that root systems overlap could influence the intensity of competition effects. As the degree of overlap between components' root-systems determines the intensity of competition effects (Cable, 1969), a knowledge of the distribution of density of competing plants becomes important. The variation of form of root-system between species has been studied by a range of methods (Baldwin *et al.*, 1971). A good correlation is often observed between root abundance and uptake activity (Barley, 1970).

Competition for nutrients and water will have two main types of effect on a less successful component plant. First, within the soil, the roots of the inferior component plant may develop less on the sides towards plants of the more aggressive component (Baldwin and Tinker, 1972). Adaptive effects in an unsuccessful competitor for nutrients and water may include an increased capacity for uptake by roots (Nye and Tinker, 1969; Gardener, 1960). Second, on the whole plant scale, plants affected by competition for nutrients and water are likely to show an increased root:shoot ratio (Crist and Stout, 1929). Competition for water may lead to wilting and growth depression due to water stress. Competition for nutrients may lead to visible symptoms of deficiency, reduced content of the competed for element (Snaydon, 1971; Trenbath, 1976) and physiological impairment of the plant (Murata,1969; Trenbath, 1976).

Interactions between weed root activity and available nutrient to the associated crop were investigated by Volz (1977), who cultivated *C. esculentus* in association with maize, tomato and soybean. He observed that *C. esculentus* infestation decreased the total dry mass and total N composition of maize, tomato fruit and soybean grain. Decreases were most severe in maize and a nitrogen balance revealed that N uptake by *C. esculentus* accounted for only 38% of the decrease in N composition of the weed infested maize. Volz (1977) suggested that in the absence of: a) inhibition of N uptake by limiting supplies of light; and b) water differential leaching of extractable mineral N; and c) allelochemical production by *C. esculentus* in maize; *C. esculentus* roots may decrease the availability of N to maize roots during the growing season by providing an environment more conducive to enhance denitrifying bacteria. This premise was supported by the observation that at the time of crop harvest the extractable soil mineral N level was less than would have been expected from component species uptake.

The conclusion made by Volz (1977) is tempered by the assumption that plant roots absorb nutrients from the soil horizons below 0,1 m depth during growth (Craft and Robbins, 1962; Newbould and Taylor, 1964; Russell and Ellis, 1968). However, substantial quantities are absorbed near the surface <0,3 m (Newbould and Taylor, 1964). Newbould and Taylor (1964) did not expect differential leaching of extractable N from the soil inhabited by maize roots alone compared with weed infested maize.

Uptake of water by *C. esculentus* was compared with that of *Eleusine indica*, and *Tagetes minuta*, grown with or without competition from maize by Fisher (1966). His objective was to establish whether or not *C. esculentus* transpired more water than the other plants during a given period of time. Six weed plants and six maize plants were grown per pot. The trial was terminated nine weeks after planting. The results showed that aerial growth of the *T. minuta* was poor. On the other hand *E. indica* grew very vigorously, forming a dense canopy over the soil surface. *Cyperus esculentus* tended to produce long leaves in contrast to the shorter upright forms normally produced under field conditions. It was noted in the same trial that *E. indica* was responsible for the lowest maize yields and produced the highest aerial stem height. The total water consumption remained constant. This evidence would strongly indicate that *E. indica* can under optimum nutrient conditions utilize, withdraw or prohibit the uptake of nutrients and water by the maize which in turn might influence directly or indirectly the uptake of soil water by this crop.

The results in the Fisher (1966) trial revealed that when the three weed species were grown in competition with maize, the total uptake of water for a given period over a given surface remained constant, irrespective of the weed species concerned. The depressing effect of the weed on the growth of maize, however, differed among the three weed species included in the study, *E. indica*, for example, was a far more serious competitor than an equal number of *C. esculentus* plants.

It is noteworthy that one should accept the results of Fisher (1966) with caution because in his studies, the comparisons were drawn from identical population densities which are not necessarily a true representation of field conditions.

1.4 ALLELOPATHY

1.4.1 Effects on crop growth

Rice (1974) defines allelopathy as any direct or indirect effect of one plant on the germination, growth or development of another through the production of chemical compounds. Putnam (1988) observed that chemicals with allelopathic potential are present in virtually all plants. *Cyperus esculentus* may be self-inhibitory (Stoller, Wax and Slife, 1979) and inhibitory to other plants through allelopathy. According to these researchers growth inhibitors have been found in both live and dead *C. esculentus* plants.

Mclaughlin (1977), cited by Drost and Doll (1980), grew maize and *C. esculentus* in connected pots, with nutrient solution being circulated between the pots. He observed that *C. esculentus* root exudates inhibited maize growth. In the same trial direct competition effects were eliminated by growing maize and *C. esculentus* in separate containers. Methanol soluble extracts from *C. esculentus* tubers inhibited *Avena* coleoptile elongation, and germination and radicle elongation of a number of crop plants (Drost and Doll,1980).

Tumbelson and Kommendahl (1962) tested 5-9 viable tubers of *C. esculentus* per 100 g of soil and found that they reduced the quantity of sprouting tubers as well as the number of sprouts per tuber. Because of observed reductions in tuber densities in non-herbicide treated plots over three years, Stoller *et al.* (1979), speculated that *C. esculentus* tuber densities may be regulated by self-allelopathy as well as that by other plants. However, according to these researchers the allelopathic effects of *C. esculentus* on crops and weeds are inconclusive, even though isolated cases have been reported.

Drost and Doll (1980) studied the effects of *C. esculentus* residue level, water extracts of tuber residue, soil texture and depth of residue incorporation on maize growth and development. Maximum contact between the *C. esculentus* residue and the maize or soybean plants was achieved by mixing the residue with the soil. *Cyperus esculentus* additions of 0; 0.125; 0.250; 0.375; 0.500 and 0.675 g of the tubers per 100 g soil were used in each study except for the residue placement study. The residue concentrations used by Drost and Doll (1980) were based on those concentrations that had been used by other researchers (Friedman and Horowitz, 1970; Bendall, 1975; Horsley, 1977) that gave allelopathic effects. It was observed that soybean shoot and root dry masses were significantly reduced by foliage residue additions above 0.25 g per 100 g soil. At equivalent concentrations, soybean shoots were less inhibited than their roots (Table 1.1). As the amount of foliar residue increased, growth reduction was generally greater. Soybean was more susceptible than maize to foliage residues (Table 1.1).

Several techniques have been used to extract growth inhibitors from plant residues encompassing; shaking in ethanol (Friedman and Horowitz, 1971); grinding in ethanol; Soxhlet extraction with ethanol; grinding in water or stirring and shaking in water (Guenzi, Mclalla and Norstadt, 1967; Jangaard, Sokert and Schieferstern, 1971). However, according to Drost and Doll (1980) the mentioned extraction procedures may not simulate field conditions because they employ organic solvents or physical manipulation in water. They recommended soaking the residues in water to simulate a more natural release of plant growth regulating chemicals. Plant extracts from *C. esculentus* contain a number of different phenolic compounds (Jangaard *et al.*,1971; Sanchez, Gesto and Vieitez, 1973) which have been implicated as allelopathic chemicals (Horsley, 1977). The allelopathically active phenolic compounds which have been isolated from *C. esculentus* include p-hydroxybenzoic, vanillic, syringic, ferulic and p-coumaric acids (Sanchez *et al.*, 1973). Jangaard *et al.*, (1971)

TABLE 1.1 **Influence of *C. esculentus* foliage and tuber residues on dry mass of maize and soybean (after Drost and Doll, 1980)**

C. esculentus residue	Foliage residues				Tuber residues			
	Soybeans		Maize		Soybeans		Maize	
	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots
(% w.w)[**]	%[*]							
0	100a[+]	100a	100a	100a	100a	100a	100a	100a
0.125	95ab	55b	93ab	91a	77a	61b	58b	76b
0.250	78bc	43b	93ab	111a	60b	46b	65b	66bc
0.375	72bc	39b	83ab	126a	65ab	58b	59b	70bc
0.500	65c	44b	81b	91a	58b	45b	56b	68bc
0.675	79bc	58b	83b	89a	60b	50b	54b	55c

* All data reported as percent of the untreated control

** Percentage based on 1 500 g silica sand

\+ Means within column followed by the same letter are not significantly different at the 95% confidence level as determined by Duncan's multiple range test.

verified the phenolic compounds isolated by Sanchez *et al.,* (1973). In addition they identified salicylic, protocatechuic and caffeic acids as well as eugenol.

Concentrations of *C. esculentus* foliage residues of 0.500 and 0.675 g per 100 g soil reduced the dry mass of maize shoots to 81 and 83% of the control respectively, but did not significantly reduce root dry mass (Table 1.1). However, these results differ from those obtained by Mclaughlin (1977); who found no effects on maize growth when 0.625 g dried *C. esculentus* leaves 100 g soil^{-1} were added to soil. Even though the residue amounts were similar, there were probably two differences in response between the studies due to incorporation of ground residue in silica sand (Drost and Doll, 1980), as opposed to the use of intact leaves applied to soil by Mclaughlin (1977). Drost and Doll (1980) firstly concluded that inhibiting chemicals could be released faster from the milled foliage than from intact leaves. Milling leaf material lead to greater inhibition or microbial degradative activity. Secondly, inactivation of toxins by soil components could reduce the inhibition of residues. Soybean growth and dry matter production were reduced more by tuber residues than foliage residue (Drost and Doll, 1980). Maize roots and shoot dry masses were reduced to 54 and 55% of the control (Table 1.1). Lucena and Doll (1976) reported a similar effect by the plant parts of *C. rotundus*. Roots of *C. rotundus* residues were more inhibiting to tomatoes (*L. esculentum*) than foliage residues.

In general, the below ground parts of many perennial weeds are found to be more detrimental to associated plant's growth than the above ground parts (Drost and Doll, 1980; Meissner, Nel and Smith, 1982).

Some researchers have reported the liberation of toxic substances to the soil from decaying plant parts (Bell and Koeppe, 1972; Bendall, 1975; Bieber and Hoveland; 1968; Friedman and Horowitz, 1970). In addition, toxins may remain active in the soil after the donor plant has been removed (Horowitz and Friedman, 1970). Drost and Doll (1980) mentioned that the fate of allelopathic compounds is not well understood, and the effects of different soil properties on allelopathy have not been thoroughly investigated.

1.4.2 Residue placement

Maize and soybean responded differently to the placement of *C. esculentus* foliage residues. Drost and Doll (1980) found that surface placement of foliage material had no effect on the dry mass of maize and soybean shoots. However, they observed that placement in the seed zone reduced maize and soybean yields by 21 and 32% respectively. If the foliage residues were placed below the seed, maize growth was unaffected, but soybean growth was reduced by 27%. As the amount of foliage residue increased, soybeans were inhibited to a greater extent than maize. Drost and Doll (1980) noted that in contrast to results with foliage residues, tuber residues reduced crop dry mass at all combinations of level and depth of incorporation (Figure 1.2).

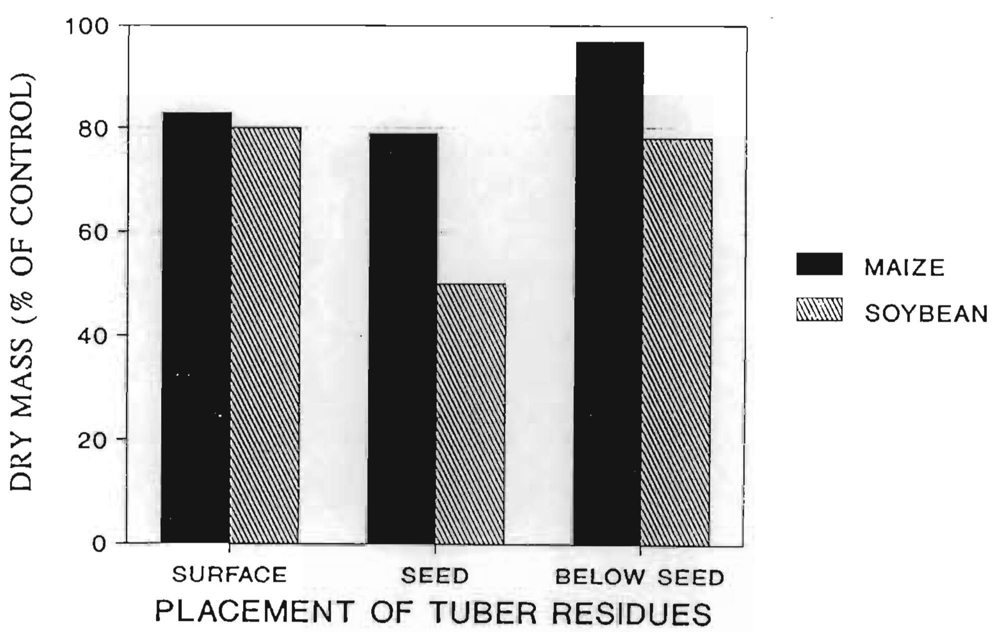


FIGURE 1.2 Response of maize and soybeans shoot dry mass at 14 days after planting as a % of control to depth of tuber residue (after Drost and Doll, 1980)

Patrick, Toussoun and Snyder (1963) also reported that the location of plant residues with respect to the location of associated plant roots had a direct effect on root growth. Plant and tuber residues caused injury if the residues were in contact with or in the immediate vicinity of plant roots.

1.4.3 Problems in studying allelopathy

Although a considerable amount of work has been done in the study of allelopathy, many researchers have admitted that allelopathy is a particularly difficult phenomenon to study (Drost and Doll, 1980; Aldrich, 1984). It has been found difficult for instance to separate the effects of allelopathy from those of competition because growth and yield may be influenced by each other. According to Aldrich (1984), the adverse effects on plant growth could be the result of a tie-up of large amounts of nutrients by micro-organisms involved or of the release of allelochemicals or both. Thus he advised allelopathy researchers to exclude competition as a factor, though not easy, because it too, often involves a complex of factors.

Aldrich (1984) further mentioned that another problem in the study of allelopathy is that in most cases, its effects are manifested in the soil environment. The soil environment inherently provides physical, chemical, and biological processes that may interact with allelochemicals and thus interfere with the study. The combined influence of competition and allelopathic effects is usually referred to as interference (Keeley, 1987).

1.5 CROP YIELD LOSS DUE TO COMPETITION

1.5.1 Yield loss prediction

The extent of crop yield loss is closely related to the number of competing weeds and their mass. Aldrich (1984) proposed a general relationship between weed density and crop yield (Figure 1.3). The relationship shown by the solid line in the graph is sigmoidal and simply means that single weeds at the sparse or low density end have less effect on yield than a single weed at the medial densities. This was thought to be due to the plasticity in plant form on the part of both the weed and the crop plant. According to Aldrich (1984) as the numbers of a given weed increased the size of each plant decreased. He further explained that the important point on the density yield curve is where the crop yield begins to fall rapidly. This is commonly called the threshold value.

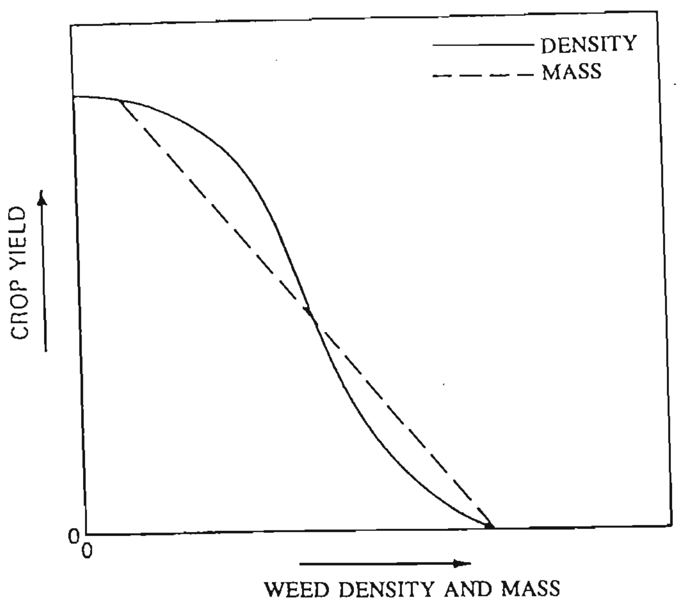


FIGURE 1.3 General relationship between weed density and crop yield (after Aldrich, 1984)

A way of predicting crop yield loss for a given weed infestation would help the producer decide if control was warranted (Harvey and Wagner, 1994). Attempts to develop mathematical equations for this purpose have made only modest progress.

Laphan (1987) reported on the population dynamics and competitive effects of *C. esculentus*. He related the yield loss of tobacco (*Nicotiana tabacum*) to *C. esculentus* tuber intensity by a rectangular hyperbolic function (Figure 1.4). The weed dynamics and the effects on tobacco yield were simulated over ten tobacco cropping seasons. Herbicide control combined with hand weeding was most beneficial in the dense infestation level (1225 tubers m^{-2}). Laphan (1987) was surprised to note that even in very light infestations (1.5 tubers m^{-2}), lack of control for one season reduced subsequent economic returns, indicating an economic optimum threshold of less than 1.5 tubers m^{-2}.

The most widely accepted model for competition was developed by De Wit (1960). He termed his model a "spacing formula" and he derived it from consideration of space available to a plant and the plant's ability to utilize that space. He considered two species grown in one field. Firstly, he assumed that the growth of one plant was not affected by the growth of

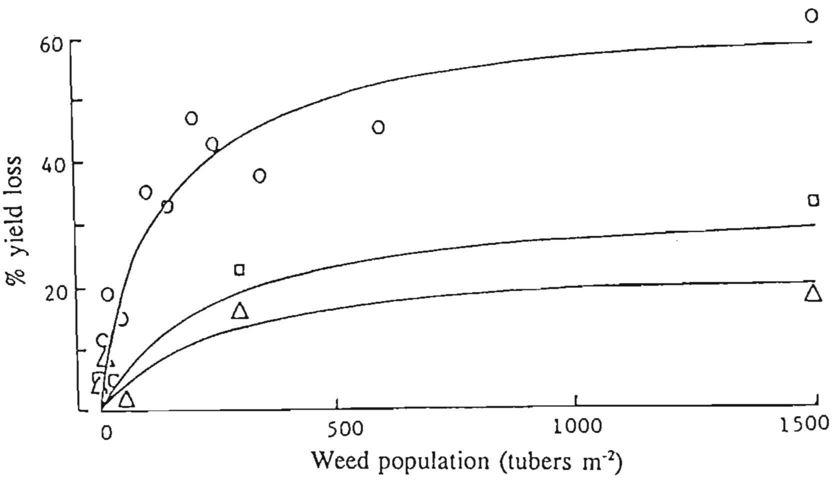


FIGURE 1.4 The rectangular hyperbolic function, relating percentage yield loss in tobacco to the *C. esculentus* population in three weed management systems (after Laphan, 1987)

another. However, De Wit (1960) pointed out that in practice this situation would only occur where the plant density was so low that there was no competition or where the competitive power of the species was equal. Secondly, De Wit (1960) developed his argument for the more practical situation where plants did compete. This situation is illustrated diagrammatically in Figure 1.5. It can be seen that the yields of species No.2 are relatively higher than the yields of species No.1. De Wit (1960) explained that this was because species No.2 dominated species No.1.

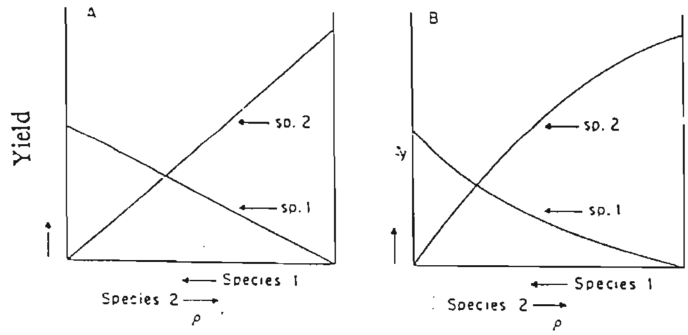


FIGURE 1.5 Diagrammatic representation of the yields of each of two species (sp.1, sp.2) grown in different mixtures: (A) where there is no competition between the species; and (B) where competition exists between the species. At any point on the *P* axis, all the squares of the homogeneous field contain a seed either from species 1 or 2 (after Willey and Health, 1969)

1.5.2 Sugarcane

Literature on the competitive effects of *C. esculentus* on sugarcane yield is limited. However, there have been a considerable number of studies undertaken on the effects of *C. rotundus* on the growth and yield of sugarcane. Rocheouste (1956) conducted experiments on the effects of *C. rotundus* on sugarcane in various climatic conditions in Mauritius. His data showed that in the humid zone the following quantities of nutrients may be taken up and assimilated in the weed: 171 kg N ha^{-1} 16 kg P ha^{-1} and 160 kg K ha^{-1}.

Supportive results have been obtained in several places in the world. Experiments in Argentina, for example have shown that in extreme cases the weed may reduce sugarcane yields by 75%, and sucrose yields by 65% (Holm *et al.*, 1977). In Australia sugarcane yields were reduced by 38% (Holm *et al.*, 1977). Chapman (1966) cited by Holm *et al.*(1977) suggested that the yield reduction was due to competition for soil water at the tillering stage.

Turner (1984) observed that *C. rotundus* reduced sugarcane yields (cultivars N8 and N13) by 85% in a rain grown plant crop in South Africa (Table 1.2). However, he thought that the severe effect on yield may have been exacerbated by water stress as the crop only received 60% of the long term mean rainfall during its growth period.

1.5.3 Maize

Crops that grow taller than *C. esculentus* and provide a full crop canopy of shade dominate this weed, and are therefore less susceptible to growth reduction. Fisher (1966) showed that lack of *C. esculentus* weed control during the first seven weeks after planting did not reduce grain yield of maize. He also observed that as from the 8th week after planting lack of *C. esculentus* control brought about a steady decline in grain production.

In another trial where a mixed population of *C.esculentus* and grass weeds were permitted to compete with maize for the first 6 weeks after planting and then removed, cob number and protein composition was not influenced, despite the apparent suppressive effect on initial maize growth (Fisher, 1966).

TABLE 1.2 The effects of *C. rotundus* on cane and sucrose yields of two sugarcane cultivars (after Turner, 1984)

Sugarcane cultivar	N13					N8				
Treatments	Sugarcane yield (Mg ha^{-1})	% Sucrose	Sucrose yield (Mg ha^{-1})	Stalk length (m)	Stalk popn. (1000-ha)	Sugarcane yield (Mg ha^{-1})	% Sucrose	Sucrose yield (Mg ha^{-1})	Stalk length (m)	Stalk popn. (1000-ha)
C. rotundus	5.3*	11.35	0.66*	0.57**	33.00	3.83**	10.02	0.40**	0.54**	37.00**
No *C. rotundus*	30.7	12.65	3.94	0.94	83.00	25.0	10.97	2.74	1.06	113.00

* Statistically significant at the 5% level

** Statistically significant at the 1% level.

The above results confirmed earlier trials conducted at Bapsfontein by Fisher and Steven (1958) in weeded and unweeded maize grown with a mixed stand of annual grasses. They observed that up to the sixth week after emergence of the *C.esculentus*, the dry matter production of maize was not significantly different from the clean weeded control, after which it dropped sharply in the unweeded maize. Furthermore, between the fifth and sixth weeks the weeds began to make their greatest demands on nutrients. A highly significant correlation was found between the depressed maize dry mass after the sixth week and the amounts of nutrients which the weeds took up after the sixth week (Fisher, 1966).

The relationship between *C.esculentus* population (shoots) and percentage yield reduction in maize was developed by Stoller *et al.* (1979) over a three year period (Figure 1.6). The regression predicts an 8% yield reduction per 100 shoots m^{-2}. In the same study there were occasions when *C. esculentus* densities of over 100 shoots m^{-2} would not affect yield, but there were times when densities less than 100 shoots m^{-2} caused up to 17% yield reductions. Stoller *et al.* (1979) believed that there was considerable variability from year to year in the yield reductions caused by *C. esculentus*. Stoller *et al.* (1979) postulated that *C. esculentus* rarely competes with maize for light because maize grows taller, but *C. esculentus* does compete for soil water and nutrients. Therefore yield reductions were postulated as probably being greater in lighter soils where soil water would more likely be limiting than in heavier soils. Jooste and Van Biljon (1980) indicated that *C. esculentus* was more competitive with maize on relatively moist (Avalon) than dry (Hutton) soils. However, this may be purely related to the large populations that can be supported on wet soils.

1.5.4 Sorghum

To establish the level of competition between *C. esculentus* and sorghum, Fisher (1966) planted increasing populations of *C.esculentus* (3 to 20 tubers pot^{-1}) together with a constant sorghum population of five sorghum seedlings per pot. Foliage mass of *C. esculentus* per pot of *C.esculentus* increased significantly with increased tuber populations up to 15 tubers per pot (Table 1.3).

Fisher (1966) further observed in the same trial that the fresh mass of sorghum stems was significantly lowered by an increased *C. esculentus* population. Increasing tuber population from 3 to 12 decreased the mass of sorghum from 5,62 to 1,80 g pot^{-1} (Table 1.3). A further increase in the number of tubers to 20 tubers per pot decreased the mass of sorghum by 0,55 g but did not significantly influence the foliage production of *C.esculentus* per pot.

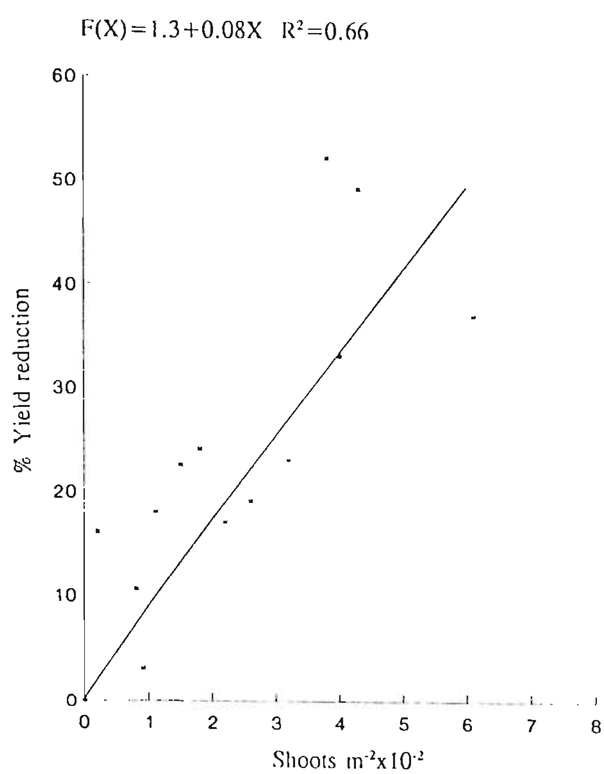


FIGURE 1.6 The regression of percentage yield reduction in Maize on *C. esculentus* shoot density (after Stoller *et al.*, 1979)

TABLE 1.3 Fresh mass of sorghum grown with or without *C.esculentus* competition ($g\ pot^{-1}$) (after Fisher, 1966)

Treatment pot^{-1}		Mass of sorghum		Mass of *C. esculentus*
		With *C. esculentus*	No *C. esculentus*	
1.	3 Tubers	5.62	21.8	17.07
2.	6 Tubers	3.02	24.0	21.35
3.	12 Tubers	1.80	23.0	22.17
4.	15 Tubers	1.75	23.4	29.00
5.	20 Tubers	1.20	23.9	28.10
	LSD	1.56	NS	6.06

An understanding of the biology, competitive effects and other related aspects of *C. esculentus* is important in determining and describing the threshold population of the weed.

CHAPTER 2
GENERAL METHODS

2.1 INTRODUCTION

The study comprised two field experiments located at Mhlume (Swaziland) Sugar Company during the period 1988 to 1991. Experiments were undertaken to investigate the effect of *C. esculentus* populations on growth and development of second and third ratoon (Experiment I) and on plant and first ratoon sugarcane (Experiment II) on fields 345/2 and 228/1, respectively.

2.2 DESCRIPTION OF SITES

Mhlume sugar estate is situated at a longitude of 30°55′ E and a latitude of 26°02′ S at an altitude between 150 and 600 m and lies in the Bushveld bioclimatic zone (Acocks, 1953; Murdoch, 1968).

Bushveld

Topography: Flat

Natural vegetation: *Themeda triandra* and *Acacia nigrescens*

Annual rainfall: 500 - 700 mm

2.2.1 Climatic description during the trials

In 1989, February, November and December had good rainfall (Appendix 3.3). The minimum rainfall for the year fell in July and August. January to April and August to December were hot months with the mean maximum monthly temperatures ranging from 28.2°C to 30.3°C.

The 1990 season began with above average rainfall (115.4 mm) in January. However, compared with the previous year this was a rather dry year with the overall mean monthly rainfall of 39.0 mm which is about half of what was received in 1989 (Appendix 3.4). In

1991, January and to a lesser extent February, had exceptionally high rainfall of 283.6 and 144.5 mm respectively (Appendix 4.2).

2.2.2 Soils

Experiment 1 on field 345/2 was located on a T soil set (equivalent to the Westleigh soil series) and was sprinkler irrigated. This soil is described by Nixon, Workman and Glendening (1986) as a dark greyish brown sandy loam to clay loam topsoil, over-lying a red, grey and olive brown clay loam to clay, which contains abundant soft and hard iron concretion and/or gravel. The soil depth is usually less than 1 m. According to these authors this soil is potentially fertile and productive but requires careful management under irrigation. A typical profile of a T set is shown on Plate 2.1.

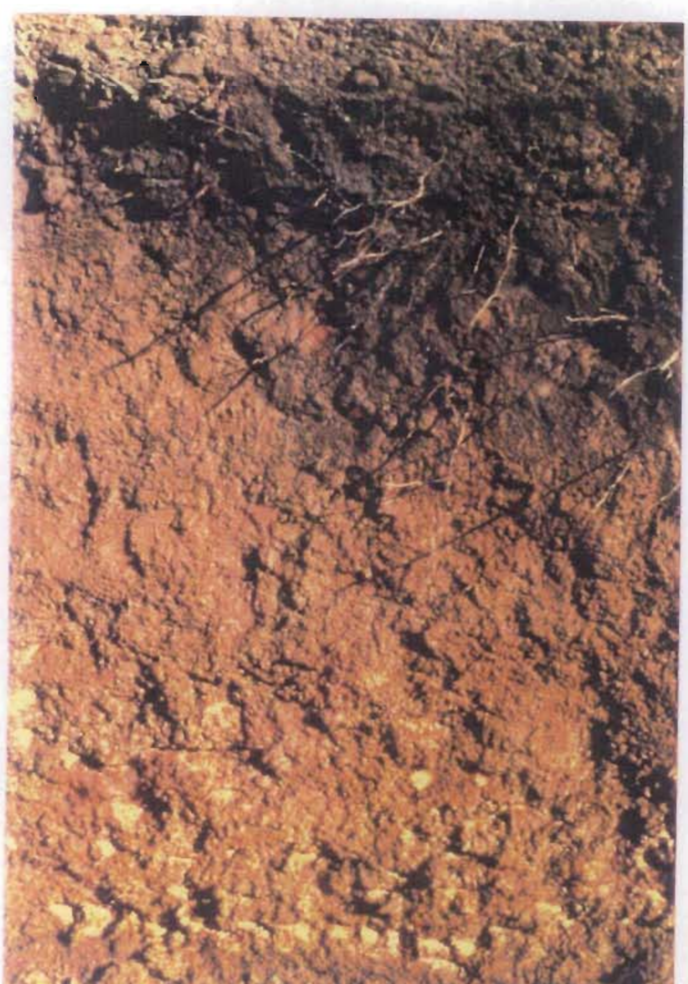


PLATE 2.1 Typical soil profile of the T soil set (Westleigh)

Experiment II on field 228/1 was located on an H_0 soil set (equivalent to the Zwide soil series) and was flood irrigated. This soil is described by Nixon *et al.* (1986) as having a dark brown sandy topsoil over a dense brown grey and olive prismatic or coarse blocky calcareous sandy clay, which may be mottled. A typical profile of the H_0 soil set is shown on Plate 2.2.

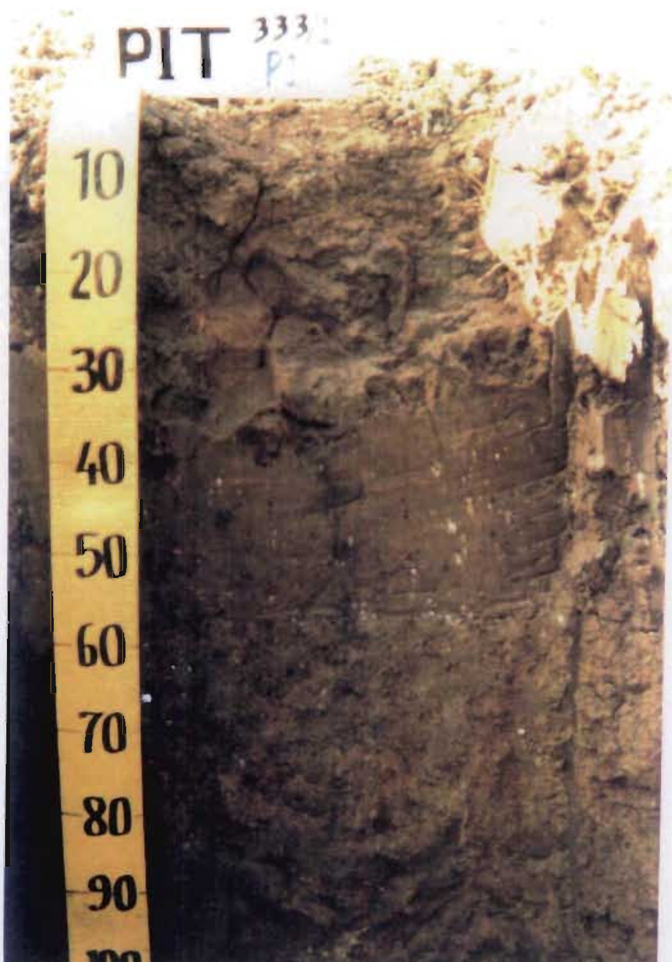


PLATE 2.2 Typical soil profile of the H_0 soil set

2.3 FIELD MANAGEMENT AND CULTURAL PRACTICES

2.3.1 Land preparation and establishment

2.3.1.1 Experiment I

Experiment I was undertaken on established sugarcane (cultivar NCO 376, spacing 1.5 m) under overhead sprinkler irrigation. The crop was fertilized as recommended by soil analysis (Tables 2.1 and 2.2) with 100 kg N ha^{-1}, 40 kg P ha^{-1} and 80 kg K ha^{-1} at planting using a compound fertilizer (5:2:4{25}). Fertilizer was applied as a slurry to all ratoon crops following harvest.

TABLE 2.1 Soil analysis for experimental sites in different years of the experiments (ppm)

	Experiment I Field 345/2		Experiment II Field 228/1	
	P	K	P	K
1988	16.2	70.1		
1989	10.0	99.4	18.0	115.4
1990	21.0	69.1	41.0	120.0

TABLE 2.2 Total mixtures of nutrients applied initially and topdressed to ratoon sugarcane (Experiment I and Experiment II) in different years of the experiments

	Experiment I			Experiment II		
	Mixture (kg ha^{-1})			Mixture (kg ha^{-1})		
	N	P	K	N	P	K
1988	160	20	100			
1989	160	20	200	160	40	80
1990	160	0	200	160	0	0

Nitrogen was applied as urea ammonium nitrate (32) while P was applied as diammonium phosphate (38) plus 0.5% zinc and K was applied as potassium chloride (25). The fertilizer mixture was applied on top of the sugarcane rows with an infield truck (Plate 2.3). The fertilizer was incorporated with irrigation. All plant and ratoon sugarcane in both experiments were topdressed with 60 kg N ha-1 applied as urea (46) at about 10 weeks after planting or cutting.

PLATE 2.3 Infield truck application of liquid fertilizer onto ratoon sugarcane

2.3.1.2 Experiment II

Preparations for planting on the flood irrigated land on which Experiment II was situated commenced after the harvesting of the previous crop. To achieve eradication of the old crop, the stool was lifted, shattered and left on the ground surface to desiccate by using shallow cultivation with a medium disc (0.60 m disc diameter). After the old crop was destroyed two discing operations were undertaken to produce a satisfactory seedbed. The first discing was undertaken using a heavy disc (0.90 m disc diameter) which operation was followed up by using a medium disc (0.60 m disc diameter) and a light land planing for levelling of the field.

The planting furrows were surveyed and drawn at a gradient of 1 in 200. The furrows were drawn by a tractor mounted ridger set to draw furrows approximately 0.25 m deep and 1.5 m apart with hoppers attached, so that fertilizer was banded at the bottom of the furrow during the operation. Seedcane of cultivar N17 was hand planted by placing the stalks in continuous double lines in the furrow using a seedcane planting rate of 8.0 Mg ha^{-1}. Sticks were cut into setts of 3 - 4 nodes in the furrow and the seedcane was then covered mechanically, leaving a furrow shape to optimise subsequent irrigations.

2.3.2 Irrigation

Experiment I undertaken in field 345/2 was sprinkler irrigated at a stand time of 4 h. The total application per irrigation cycle was 50 mm.

In Experiment II (the furrow irrigated field), water was delivered into the field by means of a concrete stepped canal with a capacity of about 60 L s^{-1}. Syphons (63 mm diameter) with a delivery rate of approximately 4.3 L s^{-1} were used to deliver water into individual sugarcane furrows.

A computer based system of irrigation scheduling was used for both experiments. This system used the cumulative class A pan evapotranspiration (ET) from the time of previous irrigation, estimated from evaporation and canopy cover (Table 2.4). The field was irrigated when estimated soil water deficit reached 40 mm.

TABLE 2.4 Total amounts of irrigation water supplied to the sugarcane at different stages of growth for different experiments.

	Experiment I Field 345/2		Experiment II Field 228/1	
Crop stage	Amounts of irrigation water (mm)		Amounts of irrigation water (mm)	
	1988/89	1989/90	1989/90	1990/91
Very young cane (VYC)	50	50	60	240
Immature cane (IMC)	150	100	300	360
Full canopy cane (FCC)	700	800	720	420
Total crop irrigation	900	950	1080	1020

2.3.3 Disease control

As a standard practice an intensive roguing programme for smut is employed at Mhlume. Roguing for smut was undertaken on all trials until the sugarcane was at full canopy.

2.4 EXPERIMENTAL PROCEDURES

2.4.1 Treatments and design

The standard herbicide treatment used in this study was that recommended for use on *C. esculentus* in the sugar industry in Northern Swaziland. It was a mixture of 1.6 L MCPA (a.i.) ha^{-1} (2-methyl-4 chlorophenoxyacetic acid) (400 g a.i. L^{-1}) with 1.5 L ametryn (a.i.) ha^{-1} (2-methylthio-4-ethylamino-6-isopropylamino-s-triazine) (500 g a.i. L^{-1}). A surfactant, Agrowett, was added to the mixture at 0.5 L ha^{-1}.

All levels of herbicide were applied in 400 L water ha^{-1} using a manually operated CP3 knapsack sprayer using a flood jet nozzle (TK 5) at a set pressure of 15 KPa. The spraying swath was 1.5 m and the nozzle height was about 0.5 m. The walking speed was kept at 0.5 m s^{-1}.

Three weed population levels of *C. esculentus* were established as 'heavy', 'medium' and 'light' infestation (Plates 2.4, 2.5 and 2.6). A field having a uniformly high population of *C. esculentus* was chosen for the experiments. Medium and light infestation treatments were instituted through thinning by hand to populations of 67% and 33% of the original populations, respectively.

Plate 2.4 A heavy infestation treatment of *C. esculentus*

Plate 2.5 A medium infestation treatment of *C.esculentus*

Four weed control treatments were superimposed on the weed population treatments. The weed control treatments were:

2 controls;
- a) no weed control (the *C. esculentus* was left undisturbed throughout the growth of the crop).
- b) complete weed control by hand weeding throughout the season.

2 levels of herbicide control;

- c) recommended herbicide application level, and
- d) one half the recommended herbicide application.

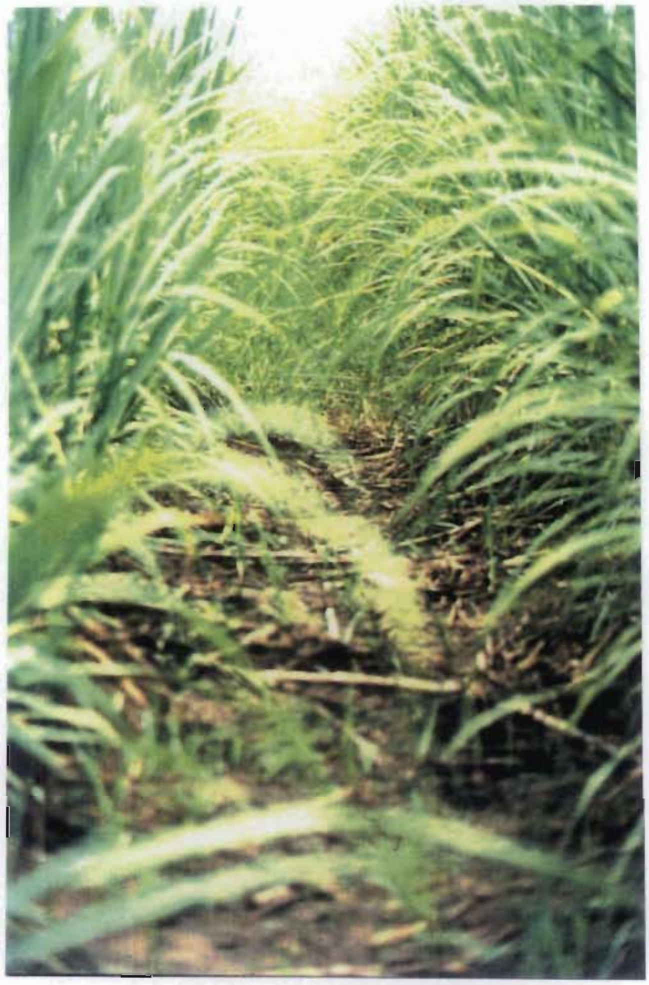


Plate 2.6 A light infestation treatment of *C.esculentus*

The 3 x 4 factorial trials of twelve treatments were arranged as a 3 x 4 rectangular lattice with six replications. One replication in both experiments had to be discarded due to low population levels of *C. esculentus* infestation. Each plot comprised six rows, 10 m long and 1.5 m apart. All weeds other than *C. esculentus* were removed by hand throughout the duration of experimentation.

2.4.2 Sampling for growth measurements and yield

2.4.2.1 Population

Weed counts on all the plots were sampled at the time of herbicide application and again three weeks after herbicide application. For sampling weed population levels, rectangular wooden frames measuring 0.20 m x 0.30 m were placed on plot diagonals at three different positions across each plot. The numbers of actively growing *C. esculentus* shoots were counted within each frame (Fisher, 1966; Ford and Peasant, 1994).

Monthly sugarcane stalk population samples were undertaken from four sample units within each plot. Each sample unit comprised two rows 2 m long placed randomly within each plot. The mean population counts from each sample were used to estimate the stalk population in stalk ha^{-1} in each plot.

2.4.2.2 Stalk height

Stalk height measurements were taken at the same time as the stalk population measurement. Measurements were made from the base of the sugarcane stalk at ground level to the topmost visible leaf collar. The measurements were taken from 10 different sites within each plot (10 representative stalks per plot). A mean stalk height per plot was determined from the measurements.

2.4.2.3 Sugarcane yield and quality

Sugarcane yield was determined from each net plot of four rows, 6 m long (24 m^2) by discarding the outer two rows and 2 m from each end of the plots (Appendices 3.1 and 4.1). The sugarcane was burnt and cut by hand and its mass was measured in the field with a tractor mounted grab scale. Fifteen stalks were randomly selected from each harvested net plot and taken to the laboratory for sucrose estimation. Percent sucrose refers to sucrose % sugarcane on a fresh weight basis. The sucrose percentages in association with stalk mass were used to compute the sucrose yield per hectare for each plot. As all the trials were harvested on an annual cycle the final yield is expressed as Mg ha^{-1} (equivalent to t ha^{-1} ann^{-1}).

2.4.3 Biometrical analysis

The loss of one replication necessitated analysing either three (triple lattice) or four (rectangular lattice) replications and ignoring the extra replications. Lattice analyses could not take into account the factorial treatment structure. The lattice designs were analysed using the MSTAC-C package. An alternative method of analysis involved regarding the design as an incomplete block design, and was analysed using the General Linear model facilities in Genstat 5 Release 2.2.

Results of the triple or rectangular lattice replication analyses were almost identical to those obtained from the Linear model. The comparative analysis are shown in Appendices 2.4 and 2.5. It was decided, therefore to analyse the design as an incomplete block design as this method had two major benefits.

1. All five replications could be analysed.
2. The factorial treatment structure of the experiment could be taken into account.

A preliminary analysis of the final yield of sugarcane showed that the results for each experiment had similar trends between the years. It was decided to undertake a combined analysis of the data over two years. The analysis was undertaken using the REML (Residual maximum likelihood). This analysis gives better adjusted means combined over years with the correct standard error of differences as compared with alternative statistical procedures (Robinson, 1987).

Two approaches within the framework of an incomplete block design were explored to analyse both sugarcane and weed population levels.

1. *Traditional approach*. Involves using a square root transformation to stabilize variances and then performing an ordinary analysis of variance (ANOVA). The advantage of this method is that it is familiar and easier to interpret since use is made of the ordinary ANOVA. On the other hand, the disadvantage of this approach is that table means must be made on the transformed square root scale.

2. *General Linear Model Approach*. We say that population is a count and can be modelled using an underlying Poisson distribution, therefore modelling was carried out using a Poisson error and identity link. The advantage of this method is that tables of means, and standard errors, are on the measured (population) scale. In this method we no longer look at F tables. Instead the Chi square (X^2) tests are used on the change in deviance and residual deviance.

The two methods gave similar results. To avoid unnecessary duplication it was decided to present the generalised linear model approach of analysis. Comparison of growth and stalk height and stalk population were undertaken using standard non-linear regression models. The benefit of this method was that it allowed an overall comparison of the growth curves for each treatment used in the study (Digby, Galwey and Lane, 1989; Dobson, 1990). Overall analysis of variance indicating whether or not the data can be represented with a single curve is presented.

2.5 RE-ESTABLISHMENT OF TREATMENTS ON SUBSEQUENT RATOONS AFTER HARVEST

The *C. esculentus* weed population levels that regenerated on the re-established plots were assessed using 0,20 m by 0,30 m wooden frames in all 60 plots immediately after the undisturbed first flush of *C.esculentus* had fully germinated (about four weeks after harvesting). The same weed control treatments on germinated *C. esculentus* populations indicated in 3.2 above were then superimposed on all 60 plots. Three weeks after the weed control treatments were executed, another count of actively growing *C. esculentus* was made.

2.6 GROWTH ANALYSIS

2.6.1 Design and treatments

In addition to the main experiments described, separate plots of 19.5 m by 19.5 m with selected treatments (Table 2.5) were used for growth analysis of sugarcane during the first year of study of each of the two experiments (Appendices 2.1 and 2.2). The treatments were replicated twice.

TABLE 2.5 Treatments used in the growth analysis trials

1.	Heavy infestation, zero control.
2.	Complete hand weeding of a light *C. esculentus* infestation.
3.	Heavy infestation of *C. esculentus* controlled with a standard rate of herbicide.
4.	Medium infestation controlled with ½ the standard rate of herbicide.

2.6.2 Sampling procedures and biometrical analysis

Seven 1.0 m sampling units of both the sugarcane and *C.esculentus* were sampled on the plot diagonals at each sampling date (Appendix 2.3). The first sampling was undertaken at the time of herbicide application and then fortnightly until the sugarcane was at full canopy. Then samplings were made monthly from full canopy to harvest.

The sample unit whose observed mass was closest to the mean of all sample units from each plot was selected and taken to the laboratory for dry matter analysis. This selective analysis of a sub sample was undertaken in order to reduce the number of sample units to a manageable level. In the laboratory the selected sample units were bagged and oven dried at 105°C until a constant mass was achieved.

The weed data were so variable that it was discarded and therefore was not used in the discussion of this study. For sugarcane the growth was observed to be sigmoidal and was described and interpreted by logistic growth curves of the form:

$$y = \frac{c}{1 + \exp(-b(x - m))}$$

where:

x is the time from regeneration;

y is the sugarcane dry matter yield m^{-2};

m is the point of inflection; and

bc is the maximum growth rate (at x = m).

Since sugarcane growth is sigmoidal, the parameters of the given growth curve describe the growth better than an average growth rate would. For each of the above parameters a one way analysis of variance was carried out to see if there were any differences between treatments.

CHAPTER 3

EXPERIMENT I: INTERFERENCE OF *CYPERUS ESCULENTUS* WITH SECOND AND THIRD RATOON SUGARCANE ON A WESTLEIGH SOIL

3.1 INTRODUCTION

The population levels of *C. esculentus* in sugarcane which have been observed to be increasing with time in Swaziland are viewed by agronomists with concern. Limited research has been conducted with regard to the competitive effects of *C. esculentus* in irrigated sugarcane and its potential effects on ratoon yield and quality. Intensive weed control programmes have been introduced in the industry without knowing the extent and importance of the problem. Turner (1984) showed that in South Africa competition from *C. rotundus* caused sugarcane yield losses of up to 85% under rain grown conditions.

The objective of weed control practices should be to maximise the economic return from its application (Elliot, 1982). Achieving this goal therefore requires precise knowledge of damage done by a particular weed (Cousens, 1985). While it is important to know when a given weed density will reduce yield, there is far greater interest in information that suggests whether or not to implement weed control practices (Zimdahl, 1980). Altieri and Liebman (1986) noted that before stressing the importance of weed control it should be made clear whether or not a particular weed is harmful in a given area. Information should be made available to assess the influence of control method on subsequent weed populations (Aldrich, 1984; Poole and Grill, 1987; Harvey and Wagner, 1994). From a commercial perspective this information is translated into the feasibility of instituting weed control programmes.

The aim of this project was, therefore, to investigate and describe the interference of *C. esculentus* on growth, yield and quality of 2nd and 3rd ratoon sugarcane grown under overhead irrigation in northern Swaziland so that an improved strategy for control of this weed could be determined under the prevailing conditions. The terminology of interference has been used to discuss results in this thesis as it was impossible to separate effects due to competition and/or allelopathy.

3.2 MATERIALS AND METHODS

The previous 1st ratoon sugarcane crop was harvested on 9 November 1988. Experiment I was established on 10 December 1988 and was monitored for two successive years (2nd and 3rd ratoon crop cycles).

During the 2nd ratoon crop the weed control treatments were instituted on the *C. esculentus* population levels which had previously been established by thinning (Chapter 2.4.1 and Table 3.1). In the 3rd ratoon crop, populations of *C. esculentus* on each plot were left to regrow from the previous year's treatments and the regenerations were used as weed population level treatments. Weed control methods used in the 3rd ratoon crop were the same as those used in the 2nd ratoon. Treatments in both the 2nd and 3rd ratoon crops were arranged in a 3 x 4 rectangular lattice design with six replications, though one replication had to be discarded due to low levels of *C. esculentus* populations (Chapter 2.4.1). Sampling and data processing were executed as described in Chapters 2.4.2 and 2.4.3 respectively.

TABLE 3.1 Population levels of *C. esculentus* established in second ratoon crop (Experiment I) - 1988/89

Population levels	Plant population (plants m^{-2})	
	Desired	Achieved
High	1680	1680
Medium	1126	1110
Light	555	550

In addition to the main experiment, separate plots with selected treatments were used for growth analysis during the 2nd ratoon crop (Table 2.5, Appendix 2.1). Sampling for growth and biometrical analysis for both the *C. esculentus* and sugarcane were performed as described in Chapter 2.6.2.

Uniform fertilization of the experiment was undertaken using methods described in Chapters

2.3.1.1 and 2.3.1.2. The field was routinely irrigated and standard practices of disease control were carried out (Chapters 2.3.2 and 2.3.3). The 2nd and 3rd ratoon crops were harvested on 11 November 1989 and 22 November 1990, respectively (Chapter 2.4.2.3)

3.3 RESULTS AND DISCUSSION

3.3.1 *Cyperus esculentus* populations

The analysis of treatment effects on *C. esculentus* were undertaken by fitting generalized linear models, using a Poisson distribution. The best model for the analysis was the use of separate lines which indicated that the regrowth *of C. esculentus* population levels depends on the previous years' population levels and weed control methods employed in the previous year. The results show that the no control treatment gave higher populations in the subsequent year than either the one-half recommended or the full herbicide treatments (Figure 3.1). In addition, in the no control treatment, the population in the following year was significantly higher than the previous years' population for each initial population level. This was not the case where weed control was instituted, where subsequent populations were similar to or less than the previous years' population. The rate of increase in *C. esculentus* as a function of previous year was, however, similar for the no control and the herbicide control treatments as shown by the parallel nature of the responses (Figure 3.1; Appendix 3.17). There were also no significant differences on recovery populations between the one-half recommended herbicide rate treatment and the full herbicide treatment.

The complete hand weeding weed control treatment was excluded from the analysis since weed counts in the initial year (three weeks after imposition of weed control treatments) were zero for all population levels, therefore no statistical analysis is needed to show that weed control method for complete hand weeding is significantly different from the other methods.

The interaction of weed control method and initial population level on regrowth of population levels can be observed where final populations in the subsequent year were lower where weed control was instigated than where there was no weed control (Figure 3.2). The results show that there were little differences between the *C. esculentus* population levels that regenerated from one season to the other where some weed control treatment had been

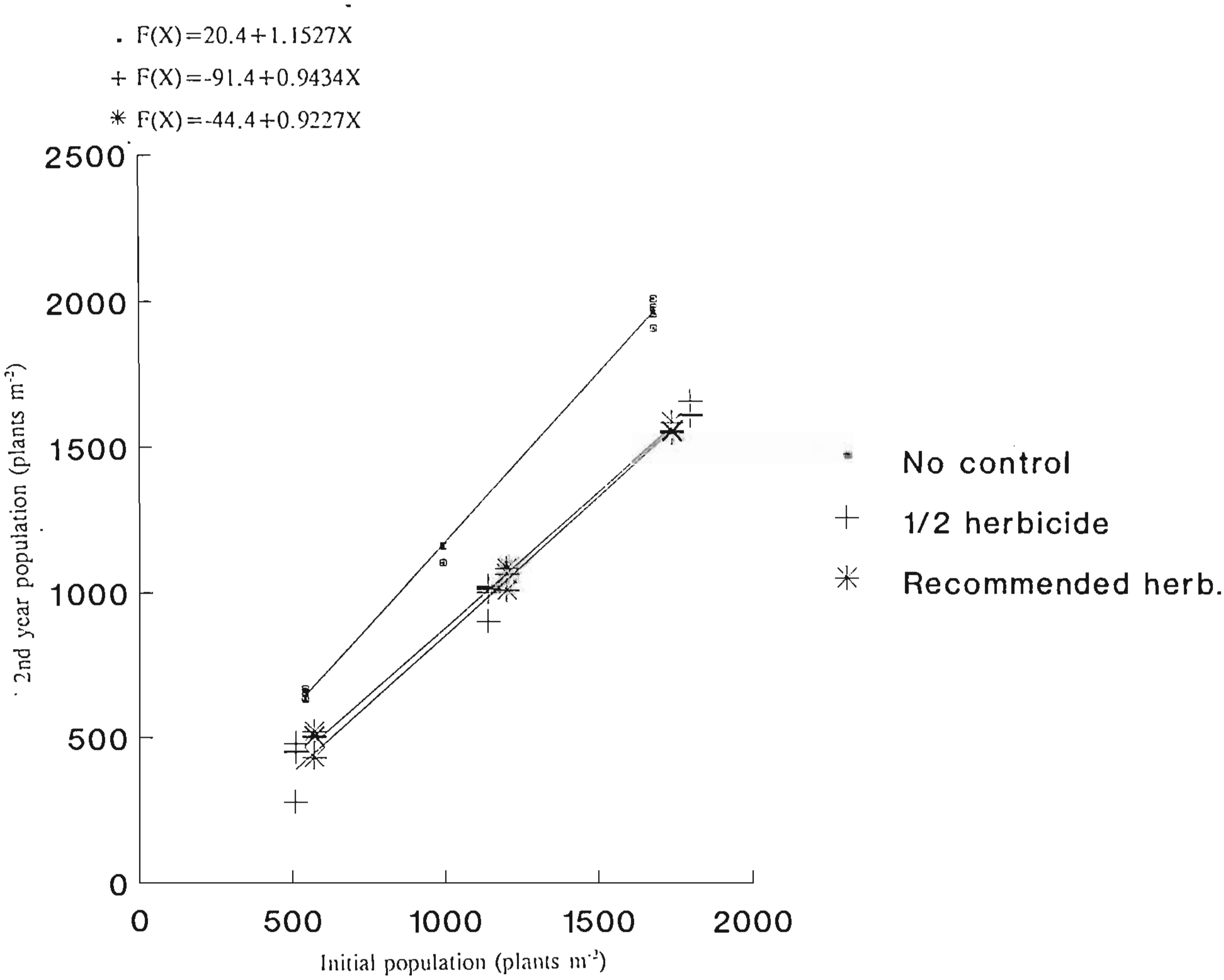


FIGURE 3.1 The relationship between previous years' *C. esculentus* population counts at the time of cane regrowth and year 2 population levels that regenerated after harvest for different weed control methods (Experiment I)

instituted. This trend was apparent even where the complete hand weeding treatment was executed. On the other hand, where no weed control was instituted, populations tended to increase from one year to the next. One might have expected weed control method to have had a greater influence on subsequent *C. esculentus* populations as there were major differences in weed populations three weeks after imposing weed control treatments (Figure 3.2). It is postulated that there may have been sufficient reserves in the stem bases of manually controlled plants to have allowed tuberisation to be completed. This is a likely possibility, as control treatments were imposed on plants that had reached the '5-leaf' stage

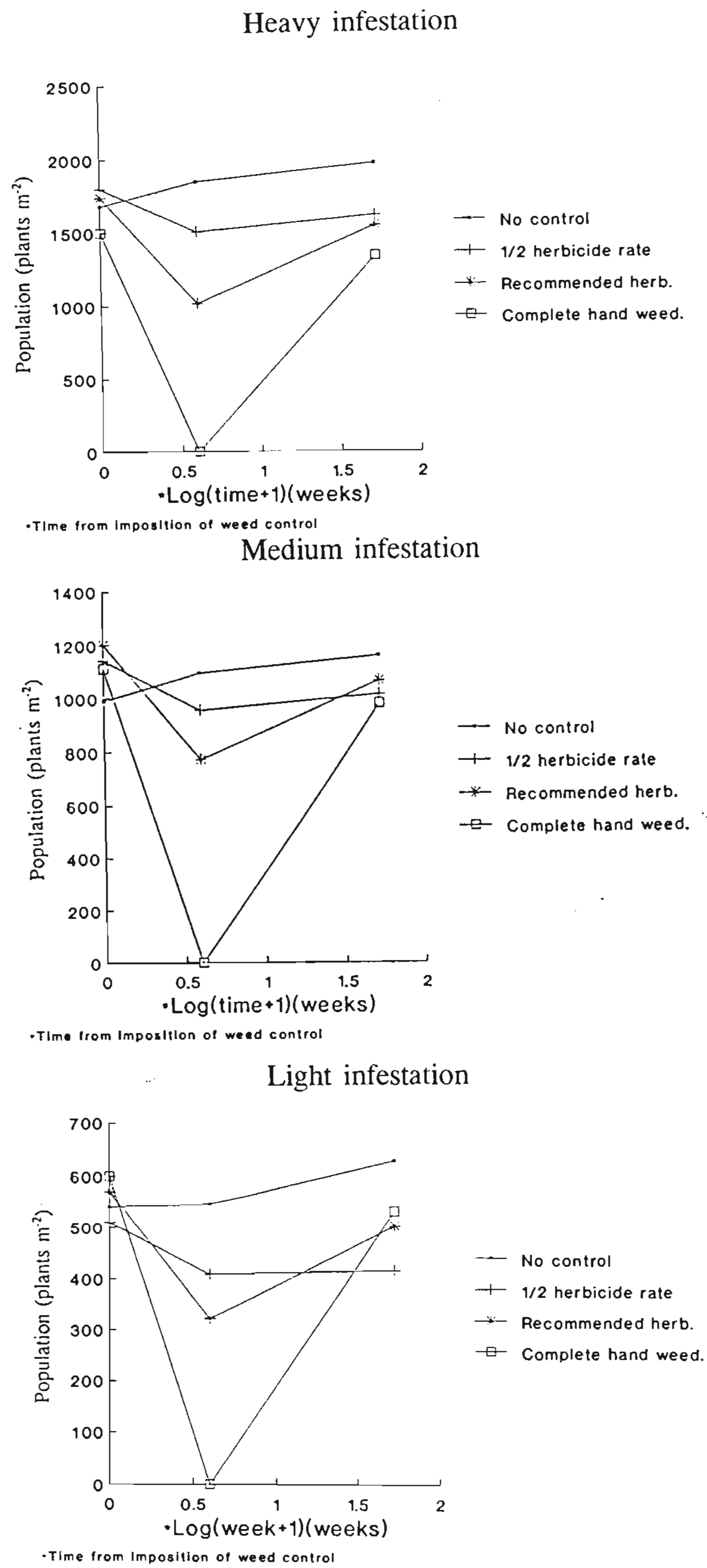


FIGURE 3.2 Comparison of *C.esculentus* population levels and weed control methods on weed populations at the time of imposition of trial, three weeks later and in the second year (Experiment I)

of growth which had already initiated rhizomes and tubers. However, this would be a subject for further research. Similarly in the case of herbicidally controlled treatments, populations regenerated at slightly lower levels than the complete hand weeding. It would appear that even in these treatments some tuberisation was taken to completion. Again it needs to be elucidated whether the herbicide inhibited tuberisation or killed all the tubers developing from the parent plant.

3.3.2 Growth analysis of sugarcane

3.3.2.1 Stalk population

Sugarcane stalk population followed the typical pattern, reaching a peak within the first four months of growth and declining thereafter due to stalk mortality caused by shading out of weaker tillers (Boyce, 1970; Durandt, 1978; Nixon, 1992). In both the 2nd and 3rd ratoon crops, separate curves describing weed population, weed control or interaction effects did not provide a significantly better fit than a single curve for all the data, indicating that there were no significant effects of either weed population levels or weed control methods on sugarcane stalk population (Appendices 3.5, 3.6, 3.7 and 3.8). Consequently the single curve was used to fit the data shown for weed population and weed control means (Figure 3.3).

3.3.2.2 Stalk height

The trends of stalk height in both 2nd and 3rd ratoon crops were similar. Growth was similar to other trials reported in the area (Nixon,1992). Analysis of treatment effects on sugarcane stalk height were undertaken using standard non-linear models, where various growth curves were fitted to the model. As in the case of stalk populations, it was observed that separate treatment curves did not provide a significantly better fit than a single curve through all the data points indicating that there was no evidence of significant effects of weed population levels or weed control methods on sugarcane stalk height (Appendices 3.9, 3.10, 3.11 and 3.12). Therefore, a single curve was used to fit all the data shown for weed population and weed control means (Figure 3.4).

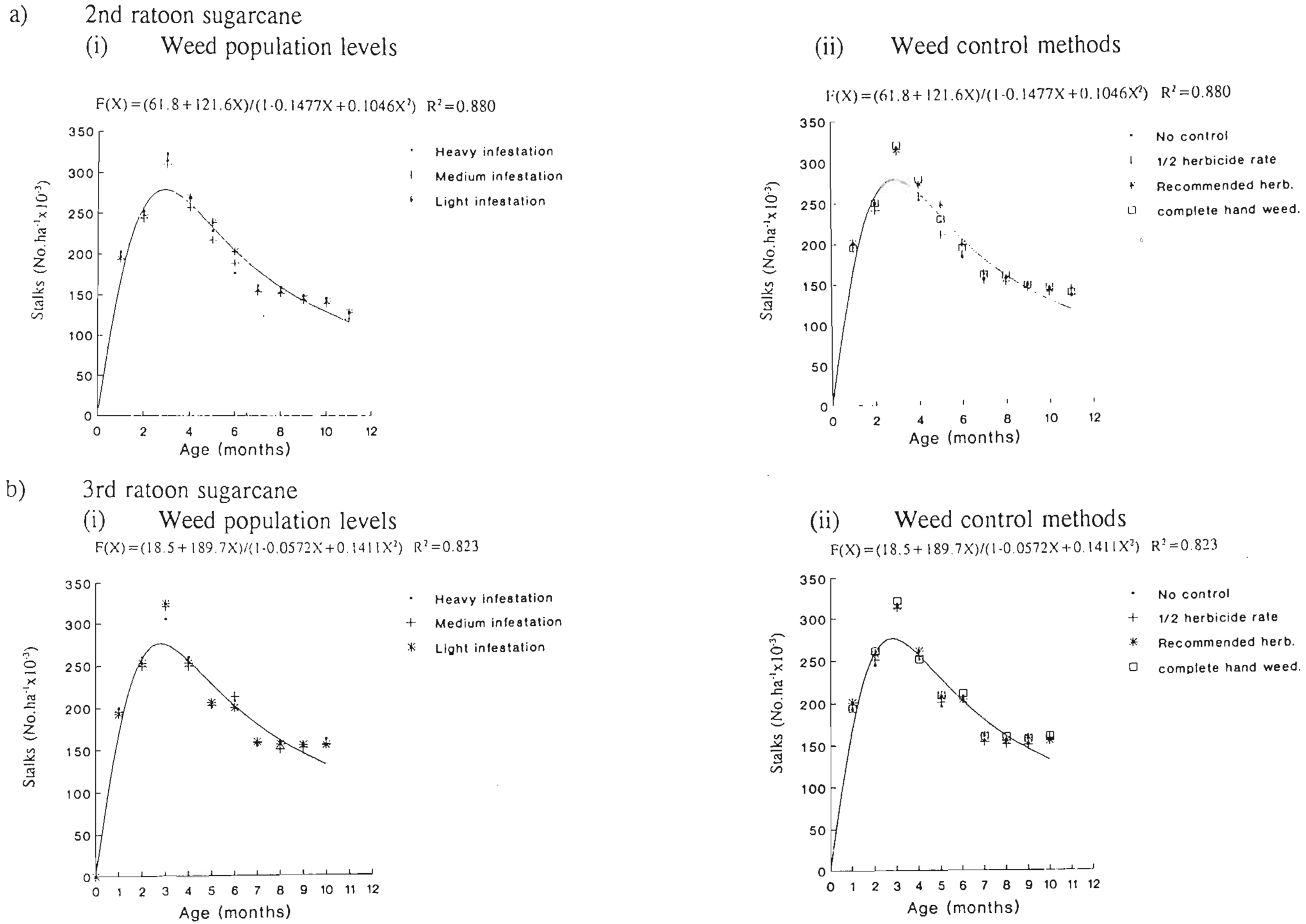
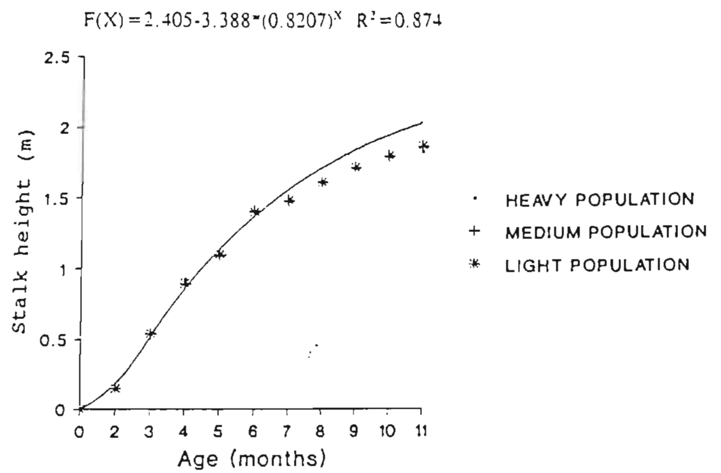


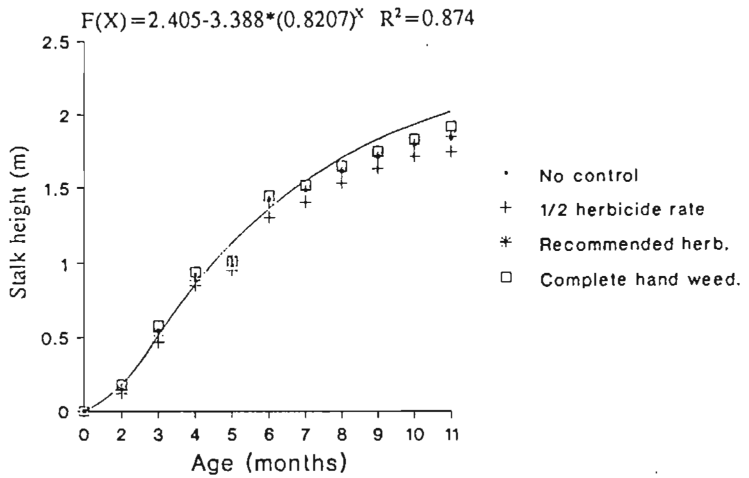
FIGURE 3.3 Effects of *C.esculentus* population levels and weed control methods on 2nd and 3rd ratoon sugarcane stalk population

a) 2nd ratoon sugarcane

(i) Weed population levels

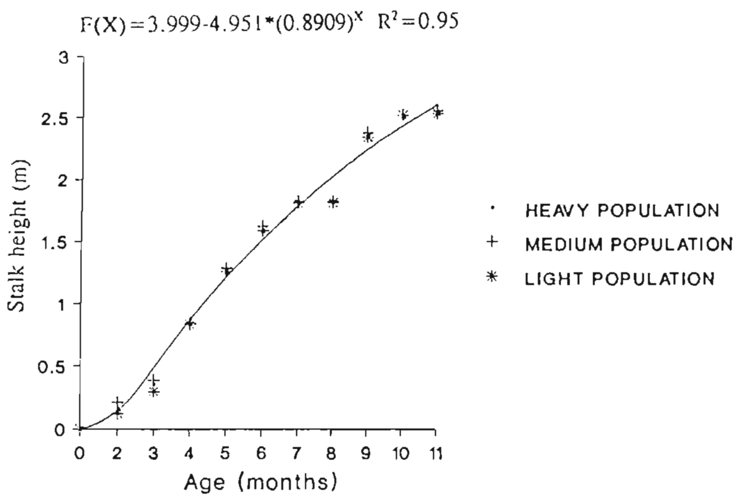


(ii) Weed control methods



b) 3rd ratoon sugarcane

(i) Weed population levels



(ii) Weed control methods

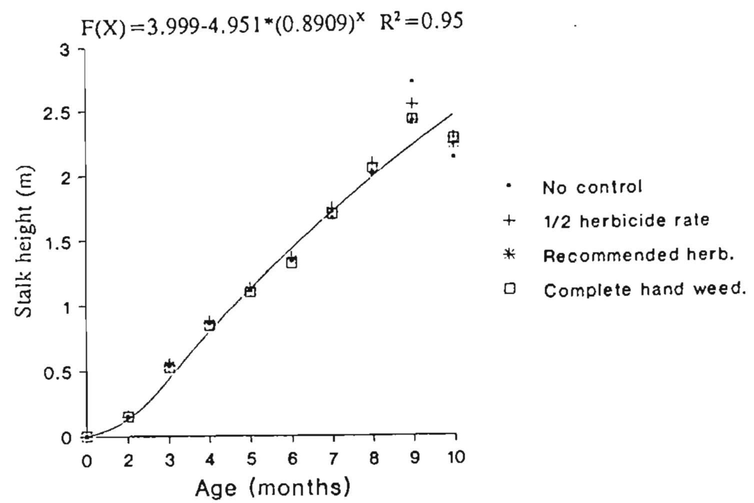


FIGURE 3.4 Influence of *C. esculentus* population levels and weed control methods on 2nd and 3rd ratoon sugarcane stalk height

3.3.2.3 Dry mass accumulation

The dry mass accumulation of sugarcane with time was observed to be sigmoidal. The parameters of growth curves (point of inflection, maximum growth rate and the asymptote) were analysed to see if there were any significant differences between treatments. For 2nd ratoon sugarcane, the asymptote (a measure of harvested yield) for the heavy infestation-no control treatment was significantly ($p=0.05$) less than those of the other treatments (Figure 3.5; Appendix 3.16; Table 3.2). Estimates of yield based on the asymptote use information prior to and including harvest. As the data from whole plots at harvest showed no differences between the treatments, either the result based on asymptote fitting was spurious as sample size was small, or there was a real lower yield in this treatment before harvest which was negated through compensatory growth by the time of harvest as determined from the trial plot data at harvest (Table 3.3). The differences between the maximum growth rates and the points of inflection for the various treatments were not statistically significant (Table 3.2).

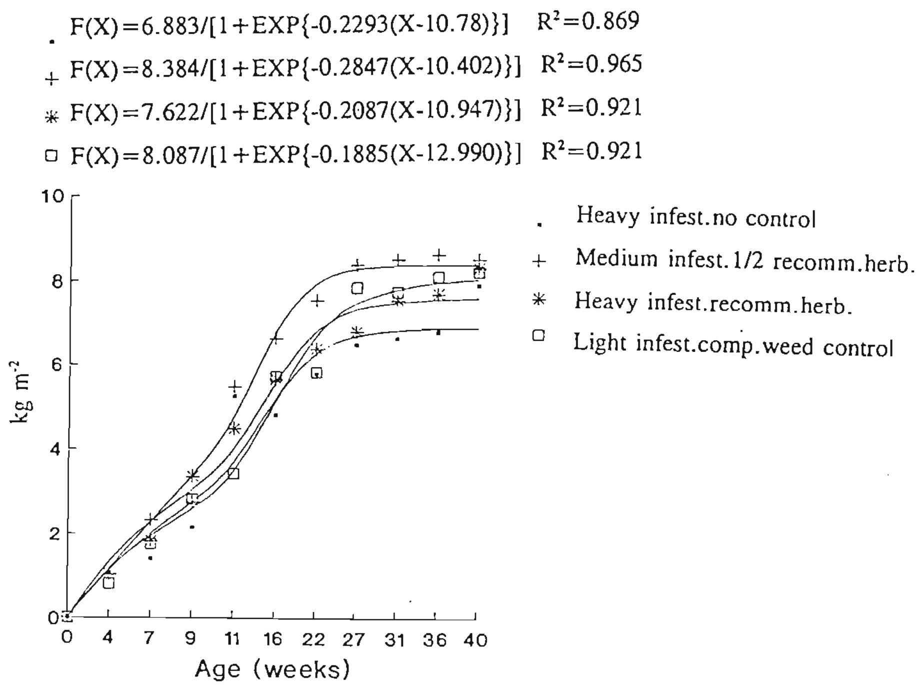


FIGURE 3.5 Influence of *C. esculentus* population levels and weed control methods on 2nd ratoon sugarcane dry mass accumulation with time

TABLE 3.2 Comparison of 2nd ratoon sugarcane growth parameters variate: sugarcane dry mass (kg m^{-2}) derived from data in Figure 3.5

Treatment	Growth parameters		
	Asymptote	Rate	Point of inflection
Heavy infestation, no control	6.88	1.58	10.78
Medium infestation, ½ herbicide rate	8.38	2.38	10.40
Heavy infestation, recommended herbicide	7.62	1.59	10.59
Light infestation, complete control	8.09	1.52	12.99
Grand mean	7.74	1.77	11.19
s.e.d.	±0.383	±0.787	±2.570

3.3.3 Sugarcane yield and quality

3.3.3.1 Second ratoon sugarcane

The effects of *C. esculentus* population levels and weed control methods on sugarcane yield (Mg ha^{-1}) were not statistically significant (Table 3.3 and Appendix 3.13). The weed population level by weed control method interaction was not significant at the 5% level. However, there was an indication of an interaction. At the heavy population level of *C. esculentus* there may be some benefit of implementing complete weed control. The results indicate that there may have been a reduction of the heavy *C. esculentus* competition by complete hand weeding to a level where there was some benefit to instituting complete hand weeding.

There was also no evidence of any significant differences in % sucrose and sucrose yield (Mg ha^{-1}) between the weed population levels or between the weed control methods (Tables 3.4 and 3.5; Appendix 3.13). The weed population levels by weed control method interaction was not significant for either % sucrose or sucrose yield (Mg ha^{-1}). Again, the weed population levels by weed control method interaction was almost significant for sucrose yields, showing a tendency for adequate weed control at high *C. esculentus* populations to increase sucrose yield but not % sucrose. The lack of response of 2nd ratoon sugarcane could be attributed to the adequate availability of growth resources during the growing period of the crop. Chapman (1966) suggested that the major cause for yield reductions by the weed was a competition for soil water at the tillering stage of the crop. This important growth limiting factor is negated to some extent in an irrigated environment as pertained in this study.

TABLE 3.3 Influence of *C. esculentus* population level and method of weed control on 2nd ratoon sugarcane yield (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	87.81	80.73	84.93	84.49
Herbicide at ½ recommended rate	70.92	95.31	85.79	84.01
Recommended herbicide rate*	92.71	81.36	86.36	86.81
Complete hand weeding	101.38	96.99	89.98	96.12
Weed population means	88.20	88.60	86.79	

	Standard error of difference (s.e.d)
Weed population levels	± 10.5
Weed control methods	± 11.9
Weed population levels x weed control methods	± 15.9

* Recommended rate - a mixture of 1.6 L MCPA (a.i.) ha^{-1} with 1.5 L ametryn (a.i.) ha^{-1}

TABLE 3.4 Influence of *C. esculentus* population level and method of weed control on percent sucrose of 2nd ratoon sugarcane

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	15.37	15.34	15.62	15.51
Herbicide at ½ recommended rate	15.52	15.64	15.59	15.29
Recommended herbicide rate	15.46	15.94	15.22	15.22
Complete hand weeding	15.61	15.60	15.51	15.51
Weed population means	15.49	15.38	15.51	

	Standard error of difference (s.e.d)
Weed population levels	± 0.67
Weed control methods	± 0.57
Weed population levels x weed control methods	± 0.79

TABLE 3.5 Influence of *C. esculentus* population level and method of weed control on sucrose yield of 2nd ratoon sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	13.68	12.31	13.39	13.13
Herbicide at ½ recommended rate	11.24	15.13	13.50	13.29
Recommended herbicide rate	14.40	11.72	14.49	13.54
Complete hand weeding	15.72	15.11	13.52	14.78
Weed population means	13.76	13.57	13.72	

	Standard error of difference (s.e.d)
Weed population levels	± 1.47
Weed control methods	± 1.67
Weed population x weed control methods	± 2.32

3.3.3.2 Third ratoon sugarcane

Sugarcane yield for the 3rd ratoon crop was notably affected by weed control methods (Table 3.6, Appendix 3.14) ($p=0.05$). The weed population level by weed control method interaction was also almost significant. The institution of one-half the recommended herbicide rate was insufficient to adequately control a heavy infestation of *C.esculentus* as this treatment had a similar yield to the no control treatment at the same weed population level. The complete hand weeding control gave an increase of 26% and 28% sugarcane and sucrose yield, respectively, compared to the no control treatment. In this trial the recommended herbicide rate was not significantly different from the complete hand weeding. The main effect response of weed population levels on sugarcane yield, % sucrose and sucrose yield was not significant (Tables 3.6, 3.7 and 3.8; Appendix 3.14). Weed population level by weed control method interaction was not significant for both % sucrose and sucrose yield.

TABLE 3.6 Effects of *C. esculentus* and weed control methods on yield of 3rd ratoon sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	69.55	72.66	77.11	73.11
Herbicide at ½ recommended rate	61.43	82.60	69.62	71.22
Recommended herbicide rate	87.19	77.52	70.86	78.52
Complete hand weeding	96.88	90.06	89.99	92.31
Weed population means	78.76	80.71	76.89	

	Standard error of difference (s.e.d)
Weed population levels	± 6.75
Weed control methods	± 7.67
Weed population levels x weed control methods	±10.70

TABLE 3.7 Influence of *C. esculentus* population level and method of weed control on percent of sucrose of 3rd ratoon sugarcane

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	15.91	16.51	16.14	16.19
Herbicide at ½ recommended rate	16.39	16.29	16.27	16.32
Recommended herbicide rate	15.96	16.42	16.30	16.23
Complete hand weeding	16.26	16.71	16.38	16.45
Weed population means	16.13	16.48	16.27	

	Standard error of difference (s.e.d)
Weed population levels	± 0.51
Weed control methods	± 0.58
Weed population levels x weed control methods	± 0.81

TABLE 3.8 Influence of *C. esculentus* population level and method of weed control on sucrose yield of 3rd ratoon sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	12.15	11.68	11.96	11.93
Herbicide at ½ recommended rate	10.15	13.68	11.44	11.76
Recommended herbicide rate	13.86	12.86	11.73	12.82
Complete hand weeding	15.75	15.12	14.79	15.22
Weed population means	12.98	13.33	12.48	

	Standard error of difference (s.e.d)
Weed population levels	± 1.16
Weed control methods	± 1.31
Weed population levels x weed control methods	± 1.83

The results indicate that the *C. esculentus* was probably more competitive during 3rd ratoon crop. This may be attributed to a commonly observed deterioration of soil conditions in older ratoons on this soil series, resulting in formation of a poor canopy (Nixon, 1992). From the weed data (Figure 3.2) it was observed that the amount of *C. esculentus* that regenerated from the no control treatments was clearly higher than the initial population. This may indicate that the growing conditions associated with slower canopy cover by the sugarcane were more favourable for the *C. esculentus* to be an effective competitor in the 3rd ratoon sugarcane crop. The initial rate of growth in the 3rd ratoon appears to be marginally lower than the 2nd ratoon in terms of sugarcane stalk height and population (Figures 3.3 and 3.4).

3.3.3.3 Second and third ratoon sugarcane combined

The results from the combined analysis were similar to those obtained from the individual years' data. There was evidence of significant differences between weed control methods for sugarcane and sucrose yields, with the complete hand weeding giving 19% and 20% more sugarcane and sucrose yield respectively compared to the no control treatment (Tables 3.9, 3.10 and 3.11 ; Appendix 3.15). It was however, surprising to note that the recommended herbicide rate gave yields that were not significantly different from both the no control treatment and one-half the recommended herbicide rate.

TABLE 3.9 Influence of *C. esculentus* population level and method of weed control on yield of 2nd and 3rd ratoon sugarcane combined (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	79.20	78.33	80.01	79.18
Herbicide at ½ recommended rate	67.45	88.94	75.66	77.35
Recommended herbicide rate	87.51	79.20	80.49	82.40
Complete hand weeding	97.65	94.51	90.92	94.36
Weed population means	82.95	85.24	81.77	

	Standard error of difference (s.e.d)
Weed population levels	± 2.69
Weed control methods	± 3.20
Weed population levels x weed control methods	± 5.42

TABLE 3.10 Influence of *C. esculentus* population level and method of weed control on percent sucrose of 2nd and 3rd ratoon sugarcane

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	15.60	15.84	15.93	15.79
Herbicide at ½ recommended rate	15.89	16.09	15.85	15.94
Recommended herbicide rate	15.67	15.66	15.81	15.71
Complete hand weeding	16.09	16.11	15.97	16.06
Weed population means	15.81	15.93	15.89	

	Standard error of difference (s.e.d.)
Weed population levels	± 0.15
Weed control methods	± 0.17
Weed population levels x weed control methods	± 0.30

TABLE 3.11 Influence of *C. esculentus* population level and method of weed control on sucrose yield of 2nd ratoon sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	12.96	12.30	12.63	12.63
Herbicide at ½ recommended rate	10.74	14.35	12.00	12.36
Recommended herbicide rate	13.71	12.35	13.37	13.14
Complete hand weeding	15.64	15.19	14.47	15.10
Weed population means	13.26	15.19	13.12	

	Standard error of difference (s.e.d)
Weed population levels	± 0.42
Weed control methods	± 0.51
Weed population levels x weed control methods	± 0.85

The weed population levels by weed control methods interaction was also significant (p=0.05) for both sugarcane and sucrose yields. Similarly to the 2nd ratoon crop the application of one-half the recommended herbicide rate on heavy infestation was not beneficial, indicating an inadequate effect of this method. Also, complete hand weeding gave consistently higher yields for all the weed population levels. The sugarcane sucrose yield for one-half the recommended herbicide rate was observed to be spuriously lower than the data for the other population levels. Consequently the mean one-half herbicide rate gave lower yields than the no control treatment. Again the highest yield and quality was associated with complete hand weeding.

3.3.4 Summary and conclusions

The results of this study have shown that *C. esculentus* population levels and weed control methods had no significant effect on 2nd ratoon sugarcane yield and quality. This was also evident from the growth and dry mass accumulation measurements because no significant differences between treatments were observed at any growth stage of the crop. This lack of response could be attributed to availability of adequate growth resources, especially water, making sugarcane an effective competitor against *C. esculentus* where water is not limiting, by virtue of the former crops' growth and height dominance. It was noted that complete hand weeding gave consistently higher yields at all the population levels, indicating that hand weeding was effective, although the differences were not statistically significant.

The results obtained in the 3rd crop ratoon had a similar trend to those obtained in the 2nd ratoon crop. Sugarcane and sucrose yields at 3rd ratoon were significantly affected by weed control methods (p=0.05). On average complete hand weeding of *C. esculentus* gave 26% and 28% more sugarcane and sucrose yield respectively compared to the no control treatment. It was also observed that weed population levels did not significantly affect sugarcane yield and quality of sugarcane. This response indicates that as a result of the institution of complete hand weeding, *C. esculentus* in the heavily infested plots may have been reduced to a level below the threshold resulting in some benefits of instituting complete hand weeding.

The combined analysis of the 2nd and 3rd ratoon crops showed that sugarcane and sucrose yields were significantly affected by weed control methods (p=0.05). Again, weed population levels did not significantly affect sugarcane yield and quality. Complete hand weeding was significantly different from the other weed control methods and it, on average, gave 19% and 20% more sugarcane and sucrose yield, respectively compared to the no control treatment.

It was surprising to note that in both 2nd and 3rd ratoon crops that *C. esculentus* population levels did not have any significant effects on sugarcane yield and quality. This could either be an indication that weed control level was important at any *C. esculentus* population level used in this study or the yield reduction may be due to allelopathic effects rather than competitive effects.

It can therefore be concluded that the control of *C. esculentus* is important regardless of the level of weed infestation particularly with older ratoons as the crop's competitive ability declines.

CHAPTER 4

EXPERIMENT II : INTERFERENCE OF *CYPERUS ESCULENTUS* WITH PLANT AND FIRST RATOON SUGARCANE ON A ZWIDE SOIL

4.1 INTRODUCTION

Responses of sugarcane and sucrose yields to *C. esculentus* population levels and imposition of weed control methods on a Westleigh soil in Experiment I on mature ratoons were either not statistically significant or small. It is generally perceived that plant sugarcane takes longer than a ratoon crop to establish a full canopy (Zimdahl, 1980), and plant sugarcane is therefore most likely to present weeds an opportunity for early competition. Hence it has been perceived as important that weed control practices should eliminate weed competition prior to the crop's establishment (Zimdahl, 1980). It was therefore decided to undertake a trial identical to Experiment I on plant sugarcane and 1st ratoon sugarcane crops on a slightly different soil under flood irrigation to investigate and describe the interference of *C. esculentus* with plant and 1st ratoon sugarcane in northern Swaziland.

4.2 MATERIALS AND METHODS

The last ratoon of the previous crop on site was harvested on 10 July 1989. Land preparation, planting, fertilization, irrigation and disease control were undertaken using methods described in Chapters 2.3.1, 2.3.2 and 2.3.3, respectively. Experiment II was planted on 15 September 1989 and was monitored through the plant and first ratoon cycles.

At the establishment of the trial, the weed control methods were instituted on the population levels which had been established by thinning (Chapter 2.4.1 and Table 4.1). Similarly to the 1st ratoon (Experiment I), the *C. esculentus* populations were left to regenerate from the previous plant crop treatments and were used as weed population treatments on the subsequent 1st ratoon crop. Weed control treatments used in the 1st ratoon crop were the same as those used in the plant crop.

TABLE 4.1 Population levels of *C. esculentus* established in plant sugarcane (Experiment II) - 1989/90

Population levels	Plant population (plant m^{-2})	
	Desired	Achieved
High	1833	1833
Medium	1228	1205
Light	605	582

The design, sampling procedures, harvesting and data processing were identical to those used in Experiment I. Similarly to Experiment I, the 1st year of study had separate growth analysis plots which had the same treatments as those used in growth analysis plots study in Experiment I (Table 2.5).

The trial area received uniform fertilization, irrigation and disease control practices (Chapters 2.3.1, 2.3.2 and 2.3.3).

4.3 RESULTS AND DISCUSSION

4.3.1 *Cyperus esculentus* population

The analysis of treatment effects on *C. esculentus* were undertaken using the same method described in Chapter 3.3.1. The results were similar to those observed in Experiment I. Separate lines were used to fit the different weed control methods used in this study (Figures 4.1 and 4.2), which indicated that the regrowth of *C. esculentus* depends on the previous years' populations and weed control methods instituted. The results showed that the no control treatment gave consistently higher populations in the subsequent year than the herbicidally controlled treatments. It is apparent, however that at the high initial population levels the differences between the herbicidally controlled treatments and the no control treatment was bigger than at the lower initial population levels (Figure 4.1). The recommended herbicide treatment gave slightly lower populations in the subsequent year than one-half the recommended rate at high initial population levels (Figure 4.1). It is postulated that the higher rates of herbicide may have killed or suppressed potential tuber production

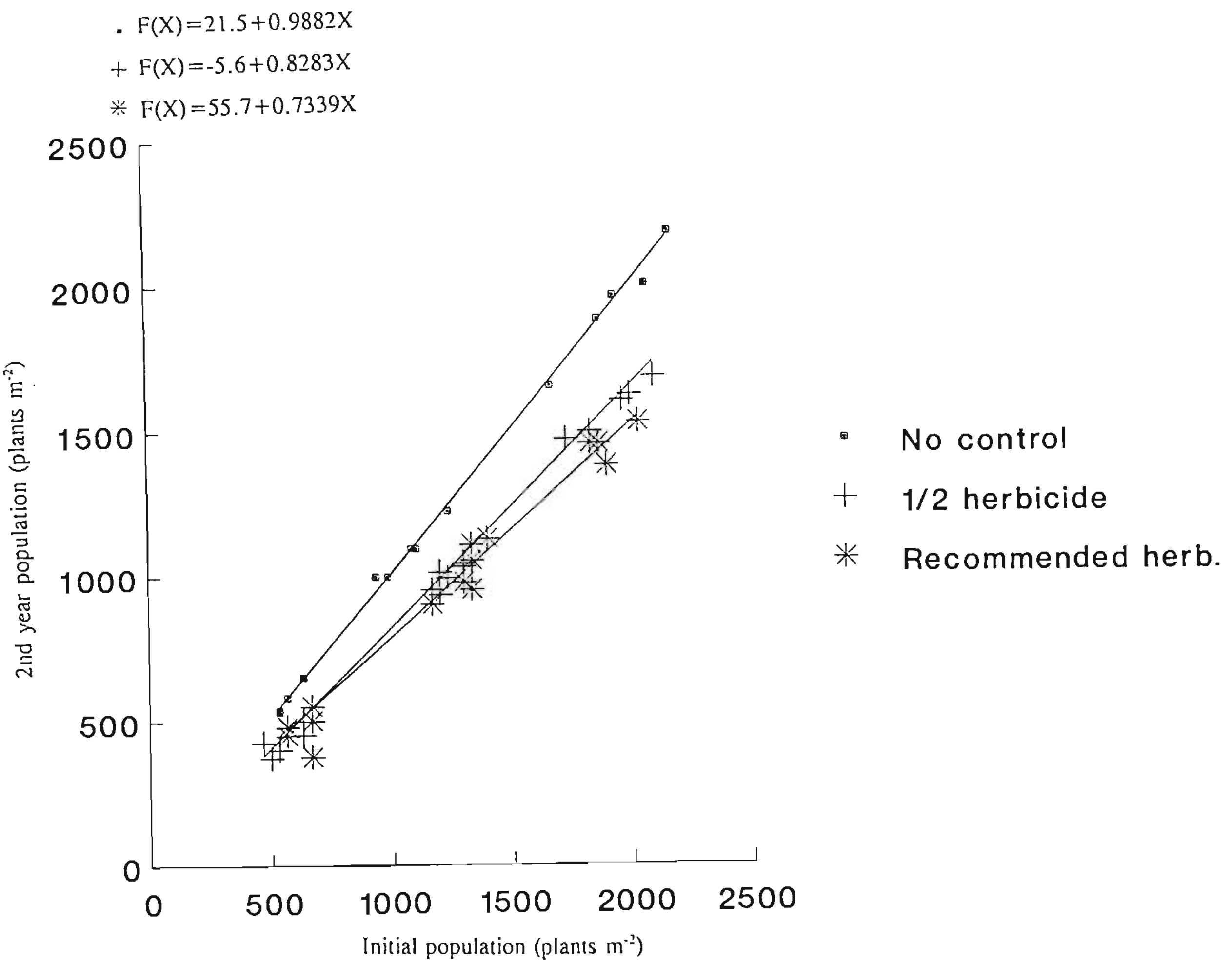


FIGURE 4.1 The relationship between previous years' *C. esculentus* population counts at the time of cane regrowth and year 2 population levels that regenerated after harvest for different weed control methods (Experiment II)

to a greater extent than the one-half recommended rate of herbicide application. Again this would be a subject for further research. The population levels that regenerated the following year from the no control treatment were similar to the initial populations. This is in contrast to the situation observed on the Westleigh soil site and could be a function of the soil type, the season, or ecotype of the different *C. esculentus* population.

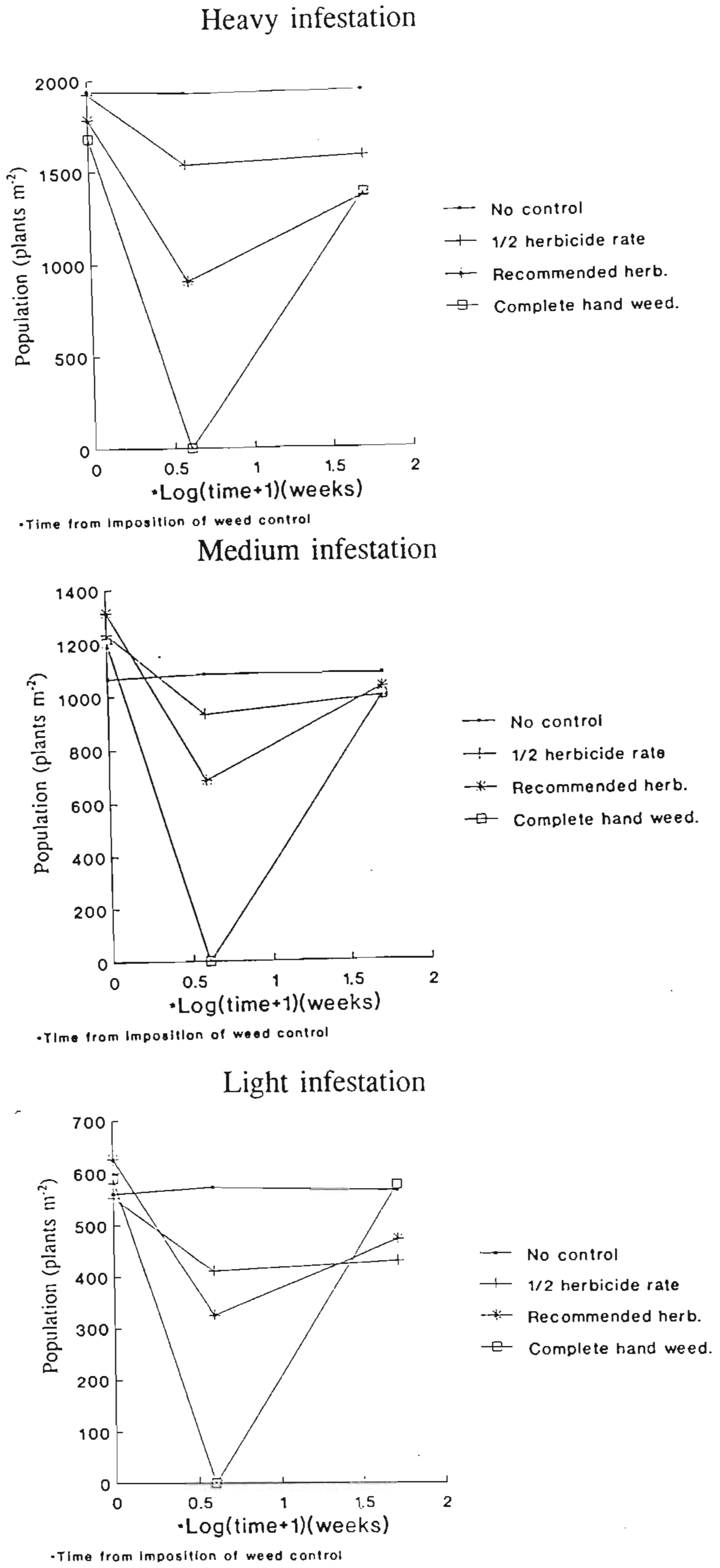


FIGURE 4.2: **Comparison of *C.esculentus* population levels and weed control methods on weed populations at the time of imposition of trial, three weeks later and in the second year (Experiment II)**

4.3.2 Growth analysis of sugarcane

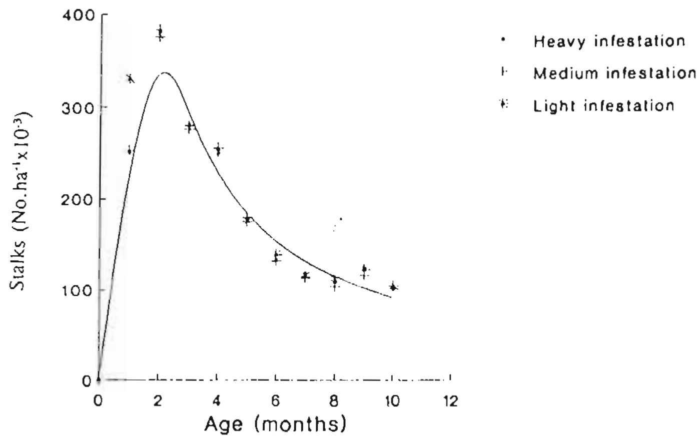
4.3.2.1 Stalk population

Sugarcane stalk population for both the plant and the 1st ratoon crops followed a similar trend to that observed in Experiment 1. Analysis of treatment effects on sugarcane stalk height were undertaken using standard non-linear models, where various growth curves were fitted to the model. The analysis was undertaken to test any significant effects of the various treatments on sugarcane stalk population. In both the plant and 1st ratoon crops, separate curves did not provide a significantly better fit than a single curve for weed population levels or weed control methods, indicating that there were no significant effects of either weed population levels or weed control methods on sugarcane stalk population (Appendices 4.3, 4.4, 4.5 and 4.6), consequently a single curve was used to fit all the data (Figure 4.3).

a) Plant sugarcane

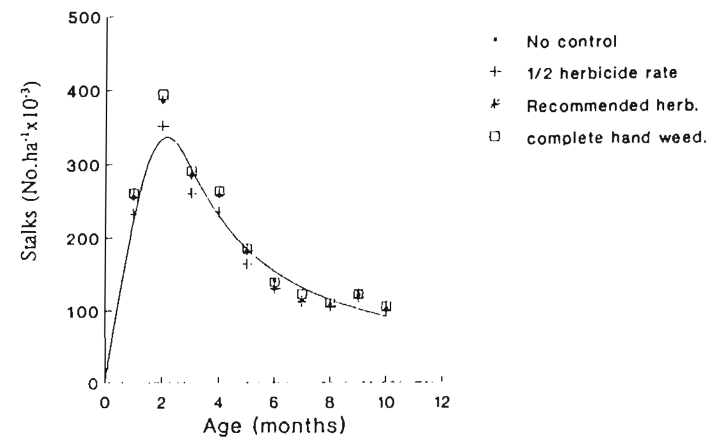
(i) Weed population levels

$F(X) = (-601 + 853X)/(1 - 0.944X + 0.951X^2)$ $R^2 = 0.962$



(ii) Weed control methods

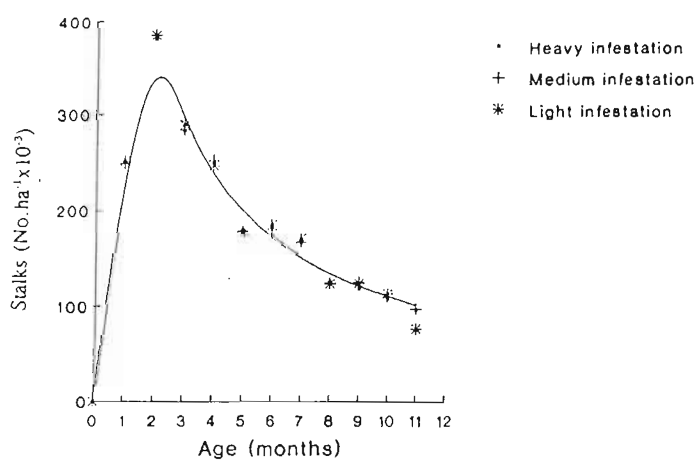
$F(X) = (-601 + 853X)/(1 - 0.944X + 0.951X^2)$ $R^2 = 0.962$



b) 1st ratoon sugarcane

(i) Weed population levels

$F(X) = (944 - 936X)/(1 - 0.2220X - 0.746X^2)$ $R^2 = 0.970$



(ii) Weed control methods

$F(X) = (944 - 936X)/(1 - 0.2220X - 0.746X^2)$ $R^2 = 0.970$

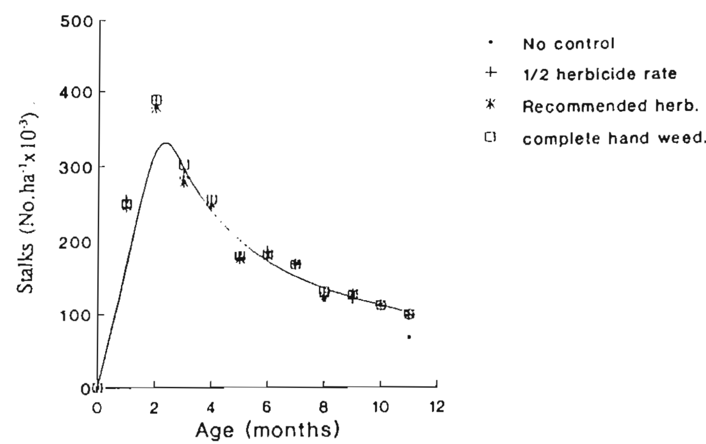


FIGURE 4.3 Effects of *C.esculentus* population levels and weed control methods on plant and 1st ratoon sugarcane stalk population

4.3.2.2 Stalk height

The trends of stalk height in both plant and 1st ratoon crops were similar. Analysis of treatment effects on sugarcane stalk height was undertaken using standard non-linear models, where various growth curves were fitted to the model. As for stalk population, it was observed that separate curves did not provide a significantly better fit than a single curve indicating that there was no evidence of significant effects of weed population levels or weed control methods on plant and 1st ratoon sugarcane stalk height (Appendices 4.7, 4.8, 4.9 and 4.10). Therefore, a single curve was used to fit all the data (Figure 4.4).

4.3.2.3 Dry mass accumulation

For the plant sugarcane crop, the differences between the asymptotes, maximum growth rates and the points of inflection for the different treatments used in the study were not statistically significant (Appendix 4.14; Table 4.2; Figure 4.5). Although final plant sugarcane yields from the plot trial were observed to be significantly different, the differences between the asymptotes were not statistically significant since the asymptotes depend not only on the final yield but on the yields over a number of months. The growth analysis data were inadequate to determine the influence of weed control methods because sample size was small (and errors large) compared to the estimate of final harvested yield.

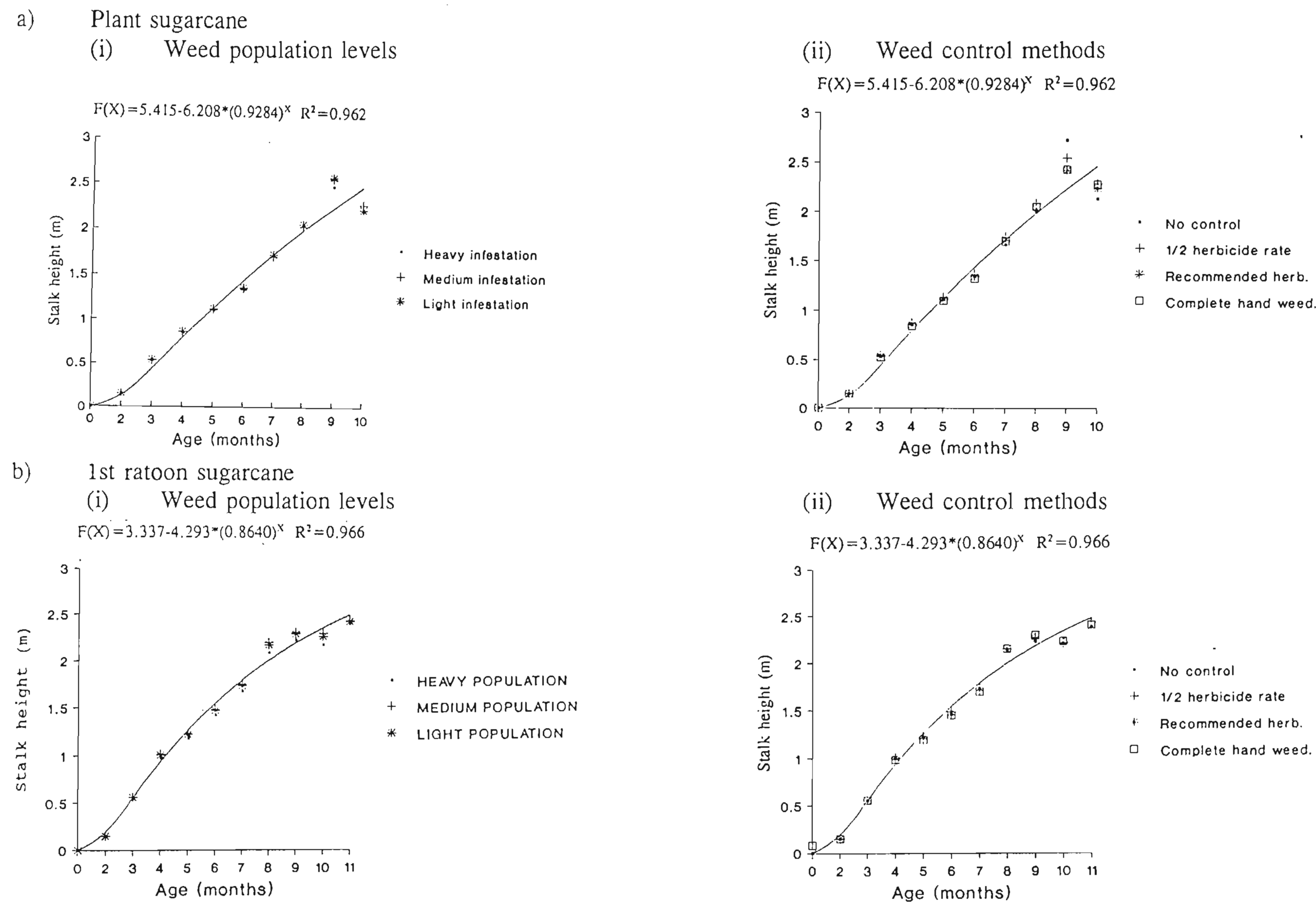


FIGURE 4.4: Influence of *C. esculentus* population levels and weed control methods on plant and 1st ratoon sugarcane stalk height

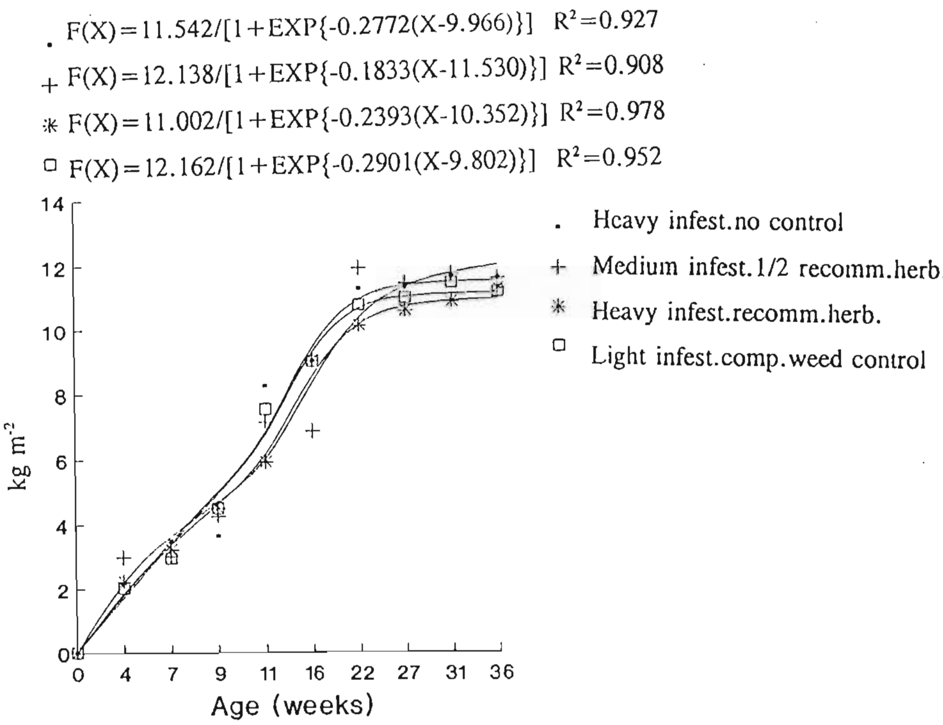


FIGURE 4.5 Influence of *C. esculentus* population levels and weed control methods on plant sugarcane dry mass accumulation with time

TABLE 4.2 Comparison of plant sugarcane growth parameters variate: sugarcane dry mass (kg m^{-2}) derived from data in Figure 4.5

Treatment	Growth parameters		
	Asymptote	Rate	Point of inflection
Heavy infestation, no control	11.57	3.79	10.04
Medium infestation, ½ herbicide rate	12.13	2.27	11.55
Heavy infestation, recommended herbicide	11.00	2.64	10.37
Light infestation, complete control	11.12	3.43	9.74
Grand mean	11.46	3.03	10.42
s.e.d	±0.462	±0.959	±0.758

4.3.3 Sugarcane yield and quality

4.3.3.1 Plant sugarcane

The effects of weed control methods on plant sugarcane (Table 4.3 and Appendix 4.11) were statistically significant (p=0.05), with the recommended herbicide rate and complete hand weeding giving sugarcane and sucrose yields higher than the other weed control treatments. The institution of the recommended herbicide rate and complete weeding gave yield increases of about 14% and 24%, respectively, compared to the no control treatment. The application of one-half the recommended rate of herbicide did not result in a significantly different yield to the no weed control treatment, indicating that this level of control was not effective in preventing sugarcane yield loss. Weed population levels did not have a significant effect on the plant sugarcane yield. Also, there was no evidence of a weed population level by weed control method interaction. The observation that sugarcane yields were not affected by population levels of *C. esculentus*, but were increased by controlling the weed, indicates that either the low population was above a competitive threshold, or that the suppression of sugarcane growth was influenced more by allelopathic effects rather than through competition. The latter explanation would appear to be more feasible, as if it were a competitive effect one would expect competition to increase with population (Aldrich, 1984).

TABLE 4.3 Influence of *C. esculentus* population level and method of weed control on yield of plant sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	70.07	68.78	71.52	70.12
Herbicide at ½ recommended rate	66.02	72.79	76.59	71.80
Recommended herbicide rate	82.01	75.77	82.89	80.22
Complete hand weeding	86.04	83.59	90.53	86.72
Weed population means	76.03	75.23	80.38	

	Standard error of difference (s.e.d.)
Weed population levels	± 9.94
Weed control methods	± 11.00
Weed population levels x weed control methods	± 15.90

Weed population levels and methods of controlling *C. esculentus* had no significant effects on % sucrose (Table 4.4 and Appendix 4.11). Sucrose yield was significantly affected by weed control methods, with the recommended herbicide and complete hand weeding giving 15% and 26% increases in yield, respectively, compared to the no control treatment. As was observed for the sugarcane yields, the effects of one-half the recommended herbicide rate on sucrose yield did not differ significantly from the no control treatments. There was also no evidence of interactions (Table 4.5 and Appendix 4.11). These results have shown that *C. esculentus* was competitive in plant sugarcane.

TABLE 4.4 Influence of *C. esculentus* population level and method of weed control on percent sucrose of plant sugarcane

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	16.65	16.28	16.38	16.44
Herbicide at ½ recommended rate	16.59	16.75	16.37	16.60
Recommended herbicide rate	16.47	16.47	16.37	16.44
Complete hand weeding	17.01	17.01	16.70	16.79
Weed population means	16.60	16.64	16.45	

	Standard error of difference (s.e.d.)
Weed population levels	± 0.26
Weed control methods	± 0.29
Weed population levels x weed control methods	± 0.42

The greater sensitivity of plant sugarcane to weeds may be due to plant sugarcane generally taking longer to establish canopy (Boyce, 1970). Hence the weeds may dominate before the crop canopies and utilise the available growth resources.

TABLE 4.5 Influence of *C. esculentus* population level and method of weed control on sucrose yield of plant sugarcane

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	11.65	11.27	11.65	11.53
Herbicide at ½ recommended rate	11.03	12.22	12.46	11.90
Recommended herbicide rate	13.52	12.53	13.67	13.24
Complete hand weeding	14.32	14.24	15.17	14.58
Weed population means	12.62	12.56	13.24	

	Standard error of difference (s.e.d.)
Weed population levels	± 1.72
Weed control methods	± 1.90
Weed population levels x weed control methods	± 2.74

4.3.3.2 First ratoon sugarcane

Unlike the observations from the plant crop, the effects of weed population levels and weed control methods on first ratoon sugarcane yield, % sucrose and sucrose yield were not statistically significant (Tables 4.6, 4.7 and 4.8; Appendix 4.12). Interactions of weed population level and by weed control methods were also non significant for all the measured components.

Generally, the first ratoon crop grows more vigorously than in the plant sugarcane and would achieve canopy earlier than in the plant crop. In this way a first ratoon crop would be more dominant over weeds and compete more effectively for growth resources.

TABLE 4.6 Influence of *C. esculentus* population level and method of weed control on yield of 1st ratoon sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	77.01	75.46	79.16	77.21
Herbicide at ½ recommended rate	67.67	80.04	82.33	76.68
Recommended herbicide rate	75.05	81.01	82.83	79.63
Complete hand weeding	79.16	80.68	74.42	78.09
Weed population means	74.72	79.30	79.69	

	Standard error of difference (s.e.d.)
Weed population levels	± 6.92
Weed control methods	± 7.66
Weed population levels x weed control methods	± 11.10

TABLE 4.7 Influence of *C. esculentus* population level and method of weed control on percent sucrose of 1st ratoon sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	17.00	17.31	16.94	17.08
Herbicide at ½ recommended rate	17.13	17.07	16.65	16.95
Recommended herbicide rate	16.54	16.81	17.00	16.81
Complete hand weeding	17.16	17.16	17.22	17.18
Weed population means	16.96	17.11	16.95	

	Standard error of difference (s.e.d.)
Weed population levels	± 0.21
Weed control methods	± 0.23
Weed population levels x weed control methods	± 0.34

TABLE 4.8 Influence of *C. esculentus* population level and method of weed control on sucrose yield of 1st ratoon sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	13.17	13.08	13.40	13.22
Herbicide at ½ recommended rate	11.62	13.66	13.69	12.99
Recommended herbicide rate	12.36	13.68	14.06	13.36
Complete hand weeding	13.56	13.85	12.83	13.42
Weed population means	12.68	13.57	13.49	

	Standard error of difference (s.e.d.)
Weed population levels	± 1.15
Weed control methods	± 1.27
Weed population levels x weed control methods	± 1.83

4.3.3.3 Plant and first ratoon sugarcane combined

The combined analysis of the plant and 1st ratoon sugarcane show that sugarcane yield, % sucrose and sucrose yields were significantly affected by weed control method (Tables 4.9, 4.10, 4.11; Appendix 4.13) ($p=0.05$). The weed population levels had no significant effect on sugarcane and sucrose yield and % sucrose. There were no significant differences between complete hand weeding and the application of herbicide rate. This indicates that the recommended herbicide rate was equally effective as the complete hand weeding in controlling the *C. esculentus*. Complete hand weeding and the recommended herbicide rate gave 12% and 8% more sugarcane yield, respectively, than the no control treatment.

The recommended herbicide rate and complete hand weeding gave 7% and 13% more sucrose and yield to the no control treatment. Percent sucrose from the completely hand weeded plots was significantly higher than in the other treatments. On average % sucrose was about 1% higher than the no control treatment.

TABLE 4.9 Influence of *C. esculentus* population level and method of weed control on yield of plant and 1st ratoon sugarcane combined (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	72.91	71.71	75.50	73.37
Herbicide at ½ recommended rate	69.60	75.58	80.99	75.39
Recommended herbicide rate	79.48	76.32	82.19	79.33
Complete hand weeding	82.15	81.67	82.63	82.15
Weed population means	76.03	76.32	80.33	

	Standard error of difference (s.e.d.)
Weed population levels	± 2.74
Weed control methods	± 3.33
Weed population levels x weed control methods	± 5.60

TABLE 4.10 Influence of *C. esculentus* population level and method of weed control on percent sucrose of plant and 1st ratoon sugarcane

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	16.86	16.75	16.68	16.76
Herbicide at ½ recommended rate	16.78	16.93	16.53	16.74
Recommended herbicide rate	16.53	16.76	16.72	16.67
Complete hand weeding	16.87	17.09	16.92	16.96
Weed population means	16.76	16.88	16.71	

	Standard error of difference (s.e.d.)
Weed population levels	± 0.08
Weed control methods	± 0.10
Weed population levels x weed control methods	± 0.16

TABLE 4.11 Influence of *C. esculentus* population level and method of weed control on sucrose yield of plant and 1st ratoon sugarcane (Mg ha^{-1})

Weed control method	Weed population levels			Weed control means
	Heavy	Medium	Light	
No control	12.34	12.07	12.58	12.33
Herbicide at ½ recommended rate	11.69	12.81	13.35	12.62
Recommended herbicide rate	13.12	12.82	13.77	13.24
Complete hand weeding	13.87	13.95	13.99	13.94
Weed population means	12.75	12.91	13.42	

	Standard error of difference (s.e.d.)
Weed population levels	± 0.45
Weed control methods	± 0.57
Weed population levels x weed control methods	± 0.96

There was no evidence of a weed population by weed control method and weed population levels interaction on sugarcane yield, sucrose yield and % sucrose. The combined analysis is likely to disguise the major differences in response between the two growth cycles. In this way the combined analysis may be misleading.

4.3.4 Summary and conclusions

The results of this study have shown that the recommended herbicide rate and complete hand weeding of plant sugarcane resulted in about 14% and 24% more sugarcane yield, respectively, compared to the no control treatment. The sugarcane yields from one-half the recommended herbicide rate did not result in any significant yield increase compared with the no control treatment. Sucrose yield was significantly affected by weed control methods, with the recommended herbicide and complete hand weeding giving 15% and 26% increases in yield, respectively, compared to the no control treatment. Similarly to the sugarcane yields, the effects of one-half the recommended herbicide rate on sucrose yield did not differ significantly from the no control treatments. This indicates that this method was not effective against the *C. esculentus*. The possible reason for the enhanced growth of plant sugarcane to weed control is that plant sugarcane takes longer to establish itself and hence it presents an opportunity for early competition by weeds. No evidence of significant effect of weed population levels on sugarcane yield and quality were observed.

In the 1st ratoon crop, sugarcane and sucrose yields were not significantly affected by either weed population levels or weed control methods. The possible reason for this is that it is generally perceived that 1st ratoon sugarcane initially grows more vigorously than the plant crop and would therefore achieve full canopy earlier than in the plant sugarcane crop, hence shading off the weeds earlier (Holm *et al.*, 1977; Keeley and Thullen, 1978; Patterson, 1982). *Cyperus esculentus* would only be competitive for a shorter period, allowing the affected sugarcane a longer period for compensatory growth. It was also clear from the results that on average the 1st ratoon sugarcane yields were slightly higher than those for plant sugarcane crop grown over the same period, confirming this hypothesis.

The combined analysis of the plant and 1st ratoon crop results showed evidence of significant differences between the weed control methods in sugarcane and sucrose yield ($p=0.05$). The combined analysis showed that there were no significant differences between complete hand weeding and the recommended herbicide control. On average, the recommended herbicide rate and complete hand weeding gave 8% and 12% more sugarcane yield, respectively. Again there were no apparent effects of weed population levels on sugarcane yield and quality over the two years. There were also no significant differences between sucrose percentages for all the treatments over the two years. The combined analysis however, disguises the major differences in response between the two growth cycles.

Similarly to observations made in Experiment I, the results of this study have clearly shown that previous years' populations had a long-term residual effect on the regrowth of *C. esculentus* populations in subsequent years. A greater reduction in weed infestation levels in the subsequent year was evident where weed control was practised. It was further observed that the recommended herbicide treatment was equally effective to the complete hand weeding on plant sugarcane.

It can therefore be concluded that the higher competitive ability of the 1st ratoon crop might allow the farmer to reduce his intensity of weed control practices by reducing control of the *C. esculentus* while the sugarcane crop is still highly competitive. This will not only be cost effective in suppressing future weed populations, but would also help in reducing potential herbicidal pollution of the environment. However, the data recorded in the study only represent a limited set of environmental conditions and time of harvest of sugarcane and more work will have to be undertaken before any recommendation of weed control could be made.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

The two sites used in the study are located in the same bioclimatic region. However soil types, irrigation methods and sugarcane cultivars used in the two study areas were different. Plant and ratoon sugarcane crops were monitored over different seasons to establish the effects of the weed on sugarcane yield and quality.

This study has been successful in characterizing the effect of weed control method on subsequent *C. esculentus* levels. The results showed an interaction of weed control method and initial weed population levels on regrowth population levels in the subsequent year. Final populations in the subsequent year were lower where weed control was instituted, than they were where there was no weed control. Poole and Gill (1987) emphasised the need and importance of assessing the value of weed control practices over time, highlighting the importance of weed tubers, which are produced in an infested land, and are carried forward to infest crops in later years. Marra and Carlson (1983) suggested that the future benefit from carryover effects of controlling in one year to later years may be so uncertain that it is best to ignore them. However, Auld and Tisdell (1986) argued that the increased uncertainty may be taken into account by applying larger discounts to the future costs and benefits thereby putting a reduced weight on these in decision making. In the study reported here there were, however, little differences between the *C. esculentus* that regenerated from one season to the other in both the herbicidally and manually controlled *C. esculentus*. One might have expected a more significant effect of weed control methods on subsequent *C. esculentus* populations as there were major differences in weed populations three weeks after imposing weed control treatments. It is postulated that there may have been sufficient reserves in the stem bases of the hand weeded plants to have allowed tuberisation to be completed. Similarly, the herbicidally controlled treatments' populations regenerated at slightly lower levels than the complete hand weeding. It is possible that even with these treatments tuberisation was taken to completion. It is likely that further research may shed some light on why *C. esculentus* populations from the other treatments regenerated at lower levels that the manually controlled treatments. However, from a commercial perspective this finding is important to the farmer in that the application of an appropriate weed control method would not only help in reducing competition in the current year, but will reduce populations in the following year.

Cyperus esculentus has been shown in this study to be strongly competitive in plant sugarcane. The results are in agreement with those obtained by Turner (1984) in South Africa where he observed that plant sugarcane may suffer severely from competition from *C. rotundus* under raingrown conditions. The *C. esculentus* germinated prior to the plant sugarcane crop and this may have given the weed a competitive advantage over the sugarcane crop. The 3rd ratoon crop was also observed to be significantly affected by weed control method. This could be attributed to the failure of the crop to form a good canopy in the 3rd ratoon cycle due to known deterioration of soil conditions (Nixon, 1992). It is postulated that this may have given the *C. esculentus* a competitive advantage over the sugarcane crop. Aldrich (1984) emphasized that a very slight advantage of the crop over weeds can result in a strong competitive advantage of the crop or *vice versa*. Trenbath (1976) cited the rapid expansion of a tall canopy as the most important factors influencing the competitive nature of plants. Although the differences between the recommended herbicide rate and complete hand weeding were marginal, it may be justified to institute pre-emergence herbicides or earlier weed control to suppress the weed before germination. However, the dynamics of tuberisation under weed control implemented earlier than the three to four weeks following planting or harvest needs to be undertaken to ascertain why one did not achieve a significant reduction in tuber numbers using weed control methods implemented in this study. The observations that weed control methods did not reduce future weed populations explains why *C. esculentus* populations have been increasing at Mhlume on commercial fields.

The results also showed that *C. esculentus* was non-competitive in 1st and 2nd ratoon sugarcane. This could be attributed to the more rapid and vigorous growth of the first two ratoons resulting in an earlier formation of canopy than in the plant sugarcane crop (Trenbath, 1976; Holm *et al.*, 1977). A lack of growth suppression from *C. esculentus* was also observed on young ratoons (Plate 5.1). It may become economic to control the weed in the 1st ratoon crop in order to attain partial control to suppress potential population regenerations in older ratoons. Suppression of growth by partial control was observed to be inadequate in reducing yield loss in plant sugarcane and older ratoons where the crop is less competitive. Partial control may be viable in the 1st and possibly 2nd ratoon crop where positive benefit may be realized in future crops. The use of partial herbicide control would not only contribute to financial savings for the farmer, but also help him to face the current challenge to produce economic crop yields while minimizing herbicide inputs and environmental degradation (Gordon and Wagner, 1994). However, the data recorded in the study only represent a limited set of environmental conditions and time of harvest of sugarcane and more work will have to be undertaken before any recommendation of weed control could be made.

Plate 5.1 A commercial sugarcane field infested with *C. esculentus*

Higher sugarcane yields have consistently been shown in this study to be associated with the complete hand weeding. When evaluating yield losses derived from crop-weed competition, it is often tempting to take the yield difference between the weed free and the weedy situation as the value which will accrue if a control measure is invoked. Poole and Gill (1987) argued that this would invariably be an overestimation of the likely gains from the complete control, particularly in the case of mechanical weeding and herbicide control as there may be some suppression or reduction in crop growth even with hand weeding due to physical damage. Complete hand weeding may be another weed control practice to consider in weed management strategies, but before this practice is ever adopted costs relative to benefits must be considered (Altieri and Liebman, 1986).

The sugarcane data did not show any significant response to population levels of *C. esculentus*. It was not as though the *C. esculentus* population levels used in the study were insufficient to significantly influence sugarcane yields and quality as the weed population in the heavy infestation treatment prior to thinning formed a thick carpet. One might particularly have expected weed population levels to have had an influence on sugarcane yield and quality as there were differences associated with control methods. It postulated that under the circumstances of this trial, differences may have been due to allelopathic rather than competitive effects. Sugarcane root systems in plant and older ratoons are shallow compared to the established shoot roots of first ratoon sugarcane in these soils due to compaction and other growth limiting soil conditions (Nixon, 1992). The observed differences in root distribution may explain why weed infestation affected plant and older ratoon sugarcane to a greater extent. This may render the crop less competitive during these stages of growth and more susceptible to allelopathic effects. The specific effects of allelopathy on sugarcane yields and quality are a subject for further study. Many researchers have admitted that allelopathy is a particularly difficult phenomenon to study (Drost and Doll, 1980; Aldrich, 1984). These researchers for instance found it difficult to separate the effects of allelopathy from those of competition because growth and yield may be influenced by each other.

The intensity of competition for soil factors has been reported to vary with the scarcity relative to the demand for the resource exerted by crop and the weed (Praffula and Ambasht, 1977; Tollenaar *et al.*, 1994). Chapman (1966) suggested that the cause for severe yield reduction may be as a result of competition for water at the time of tiller formation and as a result fewer sugarcane shoots were produced. The latter observations might explain why the yield loss from *C. rotundus* under rain-grown conditions (Turner, 1984) where water stress was prevalent was so much greater than that observed in this study.

The growth analysis was used to gain an insight into the reasons for responses (or lack of responses) to treatment effects. The growth analysis samples used in this study were inadequate to determine the observed difference in the main trial. This was because of insufficient sample size. This problem may have been overcome if the number of treatments was reduced with an increase in sample size,

This study was not able to determine a threshold population for *C. esculentus* which instituted loss in yield and quality loss in irrigated sugarcane. This could be attributed to the observation that *C. esculentus* population levels had no significant effect on sugarcane yields and quality, which appeared to be different from the response observed from weed control methods instituted in plant and older ratoon sugarcane. Thus if there is a threshold for economic control of *C. esculentus* under similar environmental conditions, it is likely to be below the lowest population used in this study. The response of plant sugarcane yield loss with weed interference was expected on plant sugarcane as it takes longer to establish itself and hence will present an opportunity for early competition by weeds.

The value of this study in the sugar industry in Swaziland is that:

1) It has shown clearly that for maximum benefit it is important that *C. esculentus* is intensively controlled during the growth cycle of sugarcane when the crop is less competitive (e.g. plant and older ratoons). Even though results under the environmental conditions and time of regeneration of young ratoons used in this study indicated little, if any, benefit of weed control, this aspect would need further study at other times of the year before no weed control on young, vigorously growing ratoons could generally be recommended.
2) The relationship that exists between the previous years' weed population and weed control method imposed on that population and the regrowth population levels in subsequent years is important in that it emphasises the importance of long term weed control programmes based on expected weed regrowth in future.

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INDEX OF APPENDICES

APPENDIX 2.1: Field plan of growth analysis plots used to determine the effects of *C. esculentus* population levels and weed control methods on 2nd ratoon sugarcane (Experiment I)

REP. 1		REP. 2	
*1 +00	2 11	3 02	4 11
5 23	6 02	7 00	8 23

Gross plot size: 13 rows @ 1.5m (19.5m) x 24m = 468m^2

Legend

	0	1	2	3
Weed population	Heavy	Medium	Light	
Weed control methods	No control	½ herbicide	Recommended herbicide level	Complete control

* Plot No. + Treatment designation

APPENDIX 2.2: Field plan of growth analysis plots used to determine the effects of *C. esculentus* population levels and weed control methods on 2nd ratoon sugarcane (Experiment II)

REP. 1		REP.2	
*1 +11	2 02	3 00	4 23
5 00	6 23	7 11	8 02

Gross plot size: 13 rows @ 1.5m (19.5m) x 24m = 468m^2

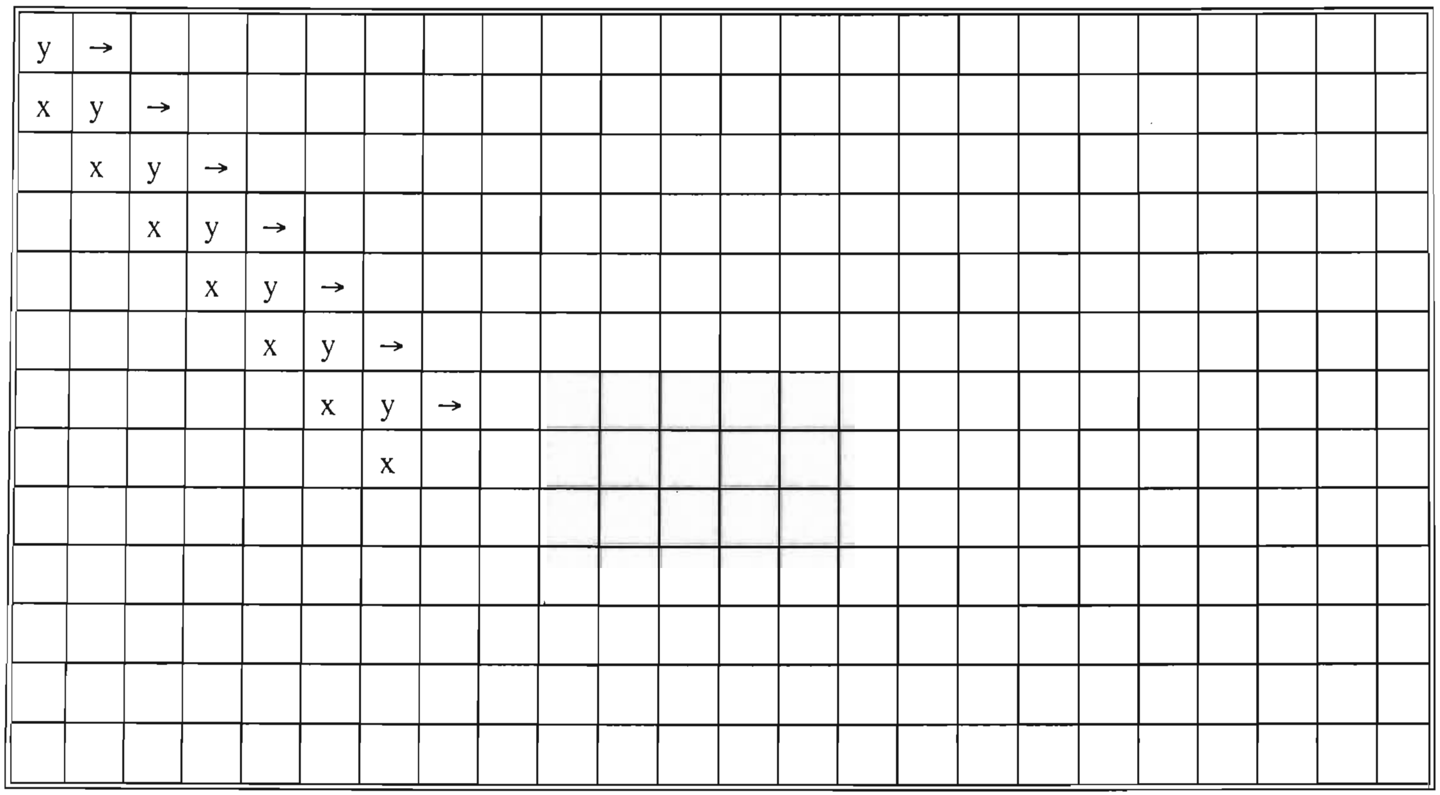
Legend

	0	1	2	3
Weed population	Heavy	Medium	Light	
Weed control methods	No control	½ herbicide	Recommended herbicide level	Complete control

* Plot No. + Treatment designation

APPENDIX 2.3: **Outline of growth analysis sampling areas used to determine the effects of *C. esculentus* population levels and weed control methods 2nd and plant sugarcane (Experiments I and II)**

1m



24m

x = sample units on 1st date of sampling
y = sample units on 2nd date of sampling, etc.

APPENDIX 2.4: Analysis of variance table: 3 x 4 rectangular lattice design in 3 replications analysed using the Mstat analysis package

SOURCE OF VARIATION	DF	SS	MS	VR
Replications	2	546.934	273.467	2.67
Treatments				
unadjusted	11	868.781	78.980	0.77
adjusted	11	873.673	79.425	0.77
Blocks within				
Replications (adjusted)	9	2061.529	229.059	2.23
Residuals				
Effective	13	1652.836	127.141	
RCB Design	22	3395.484	154.340	
Intrablock	13	1333.955	102.612	
TOTAL	**35**	**4811.199**	**137.463**	

GRAND MEAN 79.1675 CV 12.8%

APPENDIX 2.5: Analysis of variance table: 3 x 4 rectangular lattice design in 3 replications analysed as an incomplete block design

SOURCE OF VARIATION	DF	SS	MS	VR
Replications	2	546.8	273.4	2.66
Treatments				
unadjusted	11	868.9	79.0	0.77
adjusted	11	775.4	70.5	0.69
Blocks within Replications (adjusted)	9	2062.5	229.2	2.23
Residuals				
Intrablock	13	1334	102.6	
RCB Design	22	3396	154.4	
TOTAL	**35**	**4812.2**	**137.463**	

GRAND MEAN 79.1675 CV 12.79%

APPENDIX 3.1: Field plan and layout of 3 x 4 rectangular lattice design used to determine the competitive effects of *C. esculentus* population levels and weed control methods on 2nd and 3rd ratoon sugarcane (Experiment I)

REP.1				REP.2				REP.3				REP.4				REP.5			
1* 03†	2 20	3 13	4 22	13 20	14 12	15 21	16 22	25 12	26 20	27 11	28 02	37 00	38 02	39 10	40 11	49 03	50 21	51 12	52 01
5 12	6 10	7 01	8 23	17 00	18 02	19 13	20 23	29 10	30 23	31 21	32 22	41 12	42 21	43 01	44 03	53 11	54 20	55 22	56 10
9 02	10 00	11 21	12 11	21 10	22 03	23 01	24 11	33 13	34 03	35 00	36 01	45 22	46 20	47 23	48 13	57 13	58 02	59 23	60 00

Gross plot size: 6 rows @ 1.5m (9m) x 10m = $90m^2$

Net plot size: 4 rows @ 1.5m (6m) x 4m = $24m^2$

LEGEND:

	0	1	2	3
Weed population levels	Heavy	Medium	Light	
Weed control methods	No control	1/2 herbicide	Recommended herbicide	Complete control

* Plot No. † Treatment designation

APPENDIX 3.2: Mean monthly maximum and minimum temperatures (°C), rainfall (mm) and sunshine (h) at Mhlume in 1988

MONTH	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE	RAINFALL	SUNSHINE
JANUARY	32.8	20.9	41.9	7.4
FEBRUARY	32.1	21.3	95.7	8.1
MARCH	30.6	20.9	89.3	6.5
APRIL	28.6	17.6	31.1	6.7
MAY	27.0	12.3	8.5	8.4
JUNE	24.2	8.5	33.9	7.6
JULY	25.1	9.6	6.8	8.5
AUGUST	27.0	12.7	9.1	7.8
SEPTEMBER	27.2	14.8	46.3	6.7
OCTOBER	26.8	16.4	169.1	5.0
NOVEMBER	28.4	17.3	48.9	6.6
DECEMBER	28.3	18.9	112.2	4.5
TOTAL	**338.1**	**191.2**	**692.8**	**83.8**
MEAN	**28.2**	**15.9**	**57.7**	**7.0**

APPENDIX 3.3: Mean monthly maximum and minimum temperatures (°C), rainfall (mm) and sunshine (h) at Mhlume in 1989

MONTH	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE	RAINFALL	SUNSHINE
JANUARY	30.3	19.5	57.0	7.2
FEBRUARY	29.2	19.8	172.0	6.2
MARCH	30.5	19.3	52.1	9.1
APRIL	28.2	14.8	21.7	7.7
MAY	27.2	12.9	13.0	7.6
JUNE	24.0	10.5	120.9	7.0
JULY	24.9	9.9	3.5	8.0
AUGUST	27.4	13.8	7.7	8.4
SEPTEMBER	28.2	14.5	11.5	8.5
OCTOBER	28.7	16.4	52.9	6.7
NOVEMBER	28.4	18.3	142.4	5.0
DECEMBER	29.5	19.5	116.3	6.0
TOTAL	**336.5**	**189.2**	**771.0**	**87.4**
MEAN	**28.0**	**15.8**	**64.3**	**7.3**

APPENDIX 3.4: Mean monthly maximum and minimum temperatures (°C), rainfall (mm) and sunshine (h) at Mhlume in 1990

MONTH	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE	RAINFALL	SUNSHINE
JANUARY	30.8	20.2	115.4	6.8
FEBRUARY	29.1	19.9	62.1	5.5
MARCH	30.6	19.9	28.0	7.0
APRIL	28.2	17.6	70.1	7.4
MAY	26.3	13.1	1.6	7.9
JUNE	25.6	9.2	0.0	8.1
JULY	24.9	11.6	0.3	7.7
AUGUST	25.3	11.5	0.9	7.6
SEPTEMBER	27.7	13.9	2.2	7.6
OCTOBER	28.6	17.0	58.5	6.3
NOVEMBER	30.2	17.0	47.3	6.9
DECEMBER	29.8	19.8	81.5	5.0
TOTAL	**337.1**	**190.7**	**467.9**	**83.8**
MEAN	**28.1**	**15.9**	**39.0**	**7.0**

APPENDIX 3.5: Analysis of non-linear regression table: Experiment I; Effects of weed population levels on 2nd ratoon sugarcane

Variate: Sugarcane stalk population

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	4	5574981	1393745.20	3420.30**
Separate curves	8	1885	235.63	< 1ns
Residual	120	48899	407.49	
TOTAL	132	5625765		

Total number of observations 132

APPENDIX 3.6: Analysis of non-linear regression table: Experiment I; Influence of weed control methods on 2nd ratoon sugarcane

Variate: Sugarcane stalk population

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	4	5574981	1393745.2	3372.32**
Separate curves	12	2842	236.83	< 1ns
Residual	116	47942	413.29	
TOTAL	132	5625765		

Total number of observations 132

APPENDIX 3.7: Analysis of non-linear regression table: Experiment I; Influence of weed population levels on 3rd ratoon sugarcane

Variate: Sugarcane stalk population

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	4	5344402	1336100.5	2517.19**
Separate curves	8	579	72.38	< 1ns
Residual	108	57325	530.79	
TOTAL	120	5402306		

Total number of observations 120

APPENDIX 3.8: Analysis of non-linear regression table: Experiment I; Influence of weed control methods on 3rd ratoon sugarcane

Variate: Sugarcane stalk population

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	4	5344402	1336100.5	2439.83**
Separate curves	12	952	79.33	< 1ns
Residual	104	56952	547.62	
TOTAL	120	5402306		

Total number of observations 120

APPENDIX 3.9: Analysis of parallelism table: Experiment I; Influence of weed population levels on 2nd ratoon sugarcane

Variate: Sugarcane stalk height

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	2	43.518	21.759	393.5^{**}
Parallel curves(separate constants)	2	0.001	0.0005	$<1^{ns}$
Separate curves	2	0.001	0.0005	$<1^{ns}$
Separate non-linears (Rates)	2	0.002	0.0001	$<1^{ns}$
Residual	111	6.139	0.0553	
TOTAL	119	49.661		

Total number of observations 120

APPENDIX 3.10: Analysis of parallelism table: Experiment I; Influence of weed control methods on 2nd ratoon sugarcane

Variate: Sugarcane stalk height

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	2	43.518	21.759	397.06^{**}
Parallel curves (separate constants)	3	0.207	0.069	1.26^{ns}
Separate curves	3	0.012	0.004	$<1^{ns}$
Separate non-linears (Rates)	3	0.002	0.00067	$<1^{ns}$
Residual	108	5.922	0.0548	
TOTAL	119	49.661		

Total number of observations 120

APPENDIX 3.11: Analysis of parallelism table: Experiment I; Influence of weed control methods on 3rd ratoon sugarcane

Variate: Sugarcane stalk height

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	2	78.619	39.309	1091.92**
Parallel curves (separate constants)	2	0.028	0.014	< 1^{ns}
Separate curves	2	0.006	0.003	< 1^{ns}
Separate non-linears (Rates)	2	0.005	0.003	< 1^{ns}
Residual	111	3.999	0.036	
TOTAL	**119**	**82.657**		

Total number of observations 120

APPENDIX 3.12: Analysis of parallelism table: Experiment I; Influence of weed control methods on 3rd ratoon sugarcane

Variate: Sugarcane stalk height

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	2	78.619	39.309	1062.41**
Parallel curves (separate constants)	3	0.005	0.002	< 1^{ns}
Separate curves	3	0.013	0.004	< 1^{ns}
Separate non-linears (Rates)	3	0.01	0.003	< 1^{ns}
Residual	108	4.01	0.037	
TOTAL	119	82.657		

Total number of observations 120

APPENDIX 3.13: Analysis of variance table: Experiment I; Influence of Weed population levels and weed control methods on 2nd ratoon sugarcane

Variate: Sugarcane yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	6444.3	339.2	1.61^{ns}
Weed population levels (P)	2	20.2	10.1	$<1^{ns}$
Weed Control methods (C)	3	850.4	283.5	1.35^{ns}
P X C	6	1460.0	243.3	1.16^{ns}
Residuals	29	6103.5	210.5	
TOTAL	**59**	**14878.3**	**252.2**	

GRAND MEAN 87.9 CV 16.51%

Total number of observations 60

Variate: Percent sucrose

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	15.1325	0.7964	1.69^{ns}
Weed population levels (P)	2	0.1363	0.0682	$<1^{ns}$
Weed Control methods (C)	3	0.5774	0.1925	$<1^{ns}$
P X C	6	1.0300	0.1717	$<1^{ns}$
Residuals	29	13.6896	0.4721	
TOTAL	**59**	**30.5658**	**0.5181**	

GRAND MEAN 15.46 CV 4.44%

Total number of observations 60

APPENDIX 3.13 (continued)

Variate: Sucrose yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	180.225	9.486	2.31^{**}
Weed population levels (P)	2	1.601	0.800	$< 1^{ns}$
Weed Control methods (C)	3	13.018	4.339	$< 1^{ns}$
P X C	6	55.441	9,240	2.25^{ns}
Residuals	29	119.329	4.115	
TOTAL	**59**	**369.614**	**6.265**	

GRAND MEAN 13.68 CV 14.83%

Total number of observations 60

APPENDIX 3.14: Analysis of variance table: Experiment I; Influence of weed population levels and weed control methods on 3rd ratoon sugarcane

Variate: Sugarcane yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	3777.54	198.82	2.29^{**}
Weed population levels (P)	2	53.78	26.89	$<1^{ns}$
Weed Control methods (C)	3	2440.82	813.61	9.39^{**}
P X C	6	1217.49	202.91	2.34^{ns}
Residuals	29	2513.10	86.66	
TOTAL	**59**	**10002.72**	**169.54**	

GRAND MEAN 78.79 CV 11.82%

Total number of observations 60

Variate: Percent sucrose

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	5.4136	0.2849	$<1^{ns}$
Weed population levels (P)	2	0.8526	0.4263	$<1^{ns}$
Weed control methods (C)	3	0.3892	0.1297	$<1^{ns}$
P X C	6	0.5561	0.0927	$<1^{ns}$
Residuals	29	14.5232	0.5008	
TOTAL	**59**	**21.7346**	**0.3684**	

GRAND MEAN 16.29 CV 4.34%

Total number of observations 60

APPENDIX 3.14 (continued)

Variate: Sucrose yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	109.642	5.771	2.27**
Weed population levels (P)	2	3.132	1.566	$<1^{ns}$
Weed Control methods (C)	3	70.843	23.614	9.27**
P X C	6	24.402	4.067	1.60^{ns}
Residuals	29	73.862	2.547	
TOTAL	**59**	**281.881**	**4.778**	

GRAND MEAN 12.9 CV 12.37%

Total number of observations 60

APPENDIX 3.15: Combined analysis of variance table: Experiment I; influence of weed population levels and weed control methods on 2nd and 3rd ratoon sugarcane

Variate: Sugarcane yield

SOURCE OF VARIATION	DF	SS	MS	VR
Year (Y)	1	2467.2	2467.2	16.61**
Blocks within years	38	10221.8	268.9	1.8**
Weed population levels (P)	2	56.7	28.3	< 1ns
Weed control methods (C)	3	3080.5	1026.8	6.91**
P X C	6	2318.6	386.4	2.60**
Y X P	2	17.2	8.6	< 1ns
Y X C	3	210.7	70.2	< 1ns
Y X P X C	6	359.0	59.8	< 1ns
Residual	58	8616.6	148.6	
TOTAL	119	27348.3	229.8	

GRAND MEAN 83.32 CV 14.63%

Total number of observations 120

Variate: Percent sucrose

SOURCE OF VARIATION	DF	SS	MS	VR
Year (Y)	1	20.9418	20.9418	43.05**
Blocks within years	38	20.546	6.8490	14.08**
Weed population levels (P)	2	0.2448	0.1224	< 1ns
Weed control methods (C)	3	0.5888	0.1963	< 1ns
P X C	6	0.6914	0.1152	< 1ns
Y X P	2	0.7441	0.3721	< 1ns
Y X C	3	0.3778	0.1259	< 1ns
Y X P X C	6	0.8947	0.1491	< 1ns
Residual	58	28.2128	0.4864	
TOTAL	119	73.2423	229.8	

GRAND MEAN 15.88 CV 4.39%

Total number of observations 120

APPENDIX 3.15 (continued)

Variate: Sucrose yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Year (Y)	1	17.033	17.033	5.11**
Blocks within years	38	289.867	7.628	2.29**
Weed population levels (P)	2	1.605	0.803	$<1^{ns}$
Weed control methods (C)	3	72.128	24.043	7.22**
P X C	6	64.541	10.757	3.23**
Y X P	2	3.127	1.564	$<1^{ns}$
Y X C	3	11.733	3.911	1.17^{ns}
Y X P X C	6	15.302	2.550	$<1^{ns}$
Residual	58	193.191	3.331	
TOTAL	119	668.528		

GRAND MEAN 13.3 CV 13.72%

Total number of observations 120

APPENDIX 3.16: Analysis of variance for growth curve parameters for 2nd ratoon sugarcane

Variate: Asymptote

SOURCE OF VARIATION	DF	SS	MS	VR
Treat	3	3.2013	1.0671	7.29**
Residual	4	0.5854	0.1463	
TOTAL	7	3.7867		

Variate: Rate

Treat	3	0.7077	0.2359	< 1ns
Residual	4	2.4783	0.6196	
TOTAL	7	3.1860		

Variate: Time

Treat	3	16.996	5.665	< 1ns
Residual	4	26.417	6.604	
TOTAL	7	43.413		

APPENDIX 3.17: Analysis of deviance for parallelism table: Experiment I; Influence of initial *C. esculentus* population levels and weed control methods on regrowth population in year 2

Variate : *Cyperus esculentus* population

Source of variation	DF	Deviance
Block	19	5709.33***
Single line (initial population)	1	4285.91***
Parallel lines given single (weed control)	2	648.17***
Separate lines given parallel	2	56.79***
Residual	20	24.64
TOTAL	**44**	**10724.85**

Total number of observations 45

APPENDIX 4.1: **Field plan and layout of 3 x 4 rectangular lattice design used to determine the influence of *C. esculentus* population levels and weed control methods on plant and 1st ratoon sugarcane (Experiment II)**

REP.1				REP.2				REP.3				REP.4				REP.5			
1* †20	2 12	3 21	4 22	13 00	14 02	15 10	16 11	25 12	26 20	27 11	28 02	37 03	38 20	39 13	40 22	49 03	50 21	51 12	52 01
5 00	6 02	7 13	8 23	17 12	18 21	19 01	20 03	29 10	30 23	31 21	32 22	41 12	42 10	43 01	44 23	53 11	54 20	55 22	56 10
9 10	10 03	11 01	12 11	21 22	22 20	23 23	24 13	33 13	34 03	35 00	36 01	45 02	46 00	47 21	48 11	57 13	58 02	59 00	60 23

Gross plot size: 6 rows @ 1.5m (9m) x 10m = $90m^2$

Net plot size: 4 rows @ 1.5m (6m) x 4m = $24m^2$

LEGEND:

	0	1	2	3
Weed population levels	Heavy	Medium	Light	
Weed control methods	No control	1/2 herbicide	Recommended herbicide	Complete control

* Plot No. † Treatment Designation

APPENDIX 4.2: Mean monthly maximum and minimum temperatures (°C), rainfall (mm) and sunshine (h) at Mhlume in 1991

MONTH	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE	RAINFALL	SUNSHINE
JANUARY	31.8	20.4	283.6	7.6
FEBRUARY	30.6	19.6	144.5	7.7
MARCH	29.0	18.7	84.1	6.1
APRIL	29.1	14.3	4.0	9.1
MAY	26.8	12.4	17.0	7.9
JUNE	23.2	8.7	45.5	6.4
JULY	24.7	8.6	33.2	8.8
AUGUST	26.2	11.9	1.2	8.0
SEPTEMBER	28.4	16.0	16.3	5.7
OCTOBER	30.4	17.4	10.8	7.2
NOVEMBER	31.2	18.4	49.8	7.2
DECEMBER	30.4	19.1	90.5	7.3
TOTAL	**341.8**	**185.5**	**780.5**	**89.0**
MEAN	**28.5**	**15.5**	**65.0**	**7.4**

APPENDIX 4.3: **Analysis of non-linear regression table: Experiment II; Influence of weed population levels on plant sugarcane**

Variate: Sugarcane stalk population

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	4	5375704	1343926	4094.46**
Separate curves	8	548	68.5	<1ns
Residual	108	35449	328.23	
TOTAL	120	5411701		

Total number of observations 120

APPENDIX 4.4: **Analysis of non-linear regression table: Experiment II; Influence of weed control methods on plant sugarcane**

Variate: Sugarcane stalk population

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	4	5375704	1343926	4094.46**
Separate curves	8	548	68.5	<1ns
Residual	108	35449	328.23	
TOTAL	120	5411701		

Total number of observations 120

APPENDIX 4.5: Analysis of non-linear regression table: Experiment II; Influence of weed population levels on 1st ratoon sugarcane

Variate: Sugarcane stalk population

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	4	5984619	1496154.7	6467.34**
Separate curves	8	188	23.5	$<1^{ns}$
Residual	120	27761	231.34	
TOTAL	132	6012568		

Total number of observations 132

APPENDIX 4.6 Analysis of non-linear regression table: Experiment II; Influence of weed control methods on 1st ratoon sugarcane

Variate: Sugarcane stalk population

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	4	5984619	1496154.7	6651.65**
Separate curves	12	1857	154.75	$<1^{ns}$
Residual	116	26092	224.93	
TOTAL	132	6012568		

Total number of observations 132

APPENDIX 4.7: Analysis of parallelism table: Experiment II; Influence of weed population levels on plant sugarcane

Variate: Sugarcane stalk height

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	2	64.587	32.294	1291.8^{**}
Parallel curves	2	0.015	0.0075	$< 1^{ns}$
Separate curves (Rates)	2	0.007	0.035	$< 1^{ns}$
Separate non-linears	2	0.006	0.003	$< 1^{ns}$
Residuals	99	2.499	0.025	
TOTAL	**107**	**67.114**		

Total number of observations 108

APPENDIX 4.8: Analysis of parallelism table: Experiment II; Influence of weed control methods on plant sugarcane

Variate: Sugarcane stalk height

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	2	64.587	32.294	1242.1**
Parallel curves	3	0.025	0.0083	< 1ns
Separate curves (Rates)	3	0.011	0.004	< 1ns
Separate non-linears	3	0.002	0.00067	< 1ns
Residuals	96	2.489	0.026	
TOTAL	**107**	**67.114**		

Total number of observations 108

APPENDIX 4.9: Analysis of parallelism table: Experiment II; Influence of weed population levels on lst ratoon sugarcane

Variate: Sugarcane stalk height

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	2	66.840	33.42	1646.31**
Parallel curves	2	0.005	0.0025	< 1ns
Separate curves (Rates)	2	0.013	0.0065	< 1ns
Separate non-linears	2	0.01	0.005	< 1ns
Residuals	111	2.256	0.203	
TOTAL	**119**	**69.124**		

Total number of observations 120

APPENDIX 4.10: Analysis of parallelism table: Experiment II; Influence of weed control methods on 1st ratoon sugarcane

Variate: Sugarcane stalk height

SOURCE OF VARIATION	DF	SS	MS	VR
Single curve	2	66.840	33.420	1722.68**
Parallel curves	3	0.055	0.018	<1ns
Separate curves (Rates)	3	0.020	0.0067	<1ns
Separate non-linears	3	0.035	0.0012	<1ns
Residuals	108	2.174	0.0201	
TOTAL	**119**	**69.124**		

Total number of observations 120

APPENDIX 4.11: Analysis of variance table: Experiment II; Influence of weed population levels and weed control methods on plant sugarcane

Variate: Sugarcane yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	5359.3	282.1	1.53^{ns}
Weed population levels (P)	2	420.7	210.4	1.14^{ns}
Weed Control methods (C)	3	1807.0	602.3	3.26**
P X C	6	220.0	36.7	$<1^{ns}$
Residuals	29	5355.4	184.7	
TOTAL	**59**	**13162.4**	**223.1**	

GRAND MEAN 77.21 CV 17.60%

Total number of observations 60

Variate: Percent sucrose

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	8.5743	0.4513	3.54**
Weed population levels (P)	2	0.2387	0.1194	$<1^{ns}$
Weed Control methods (C)	3	0.7701	0.2567	2.01^{ns}
P X C	6	0.8436	0.1406	1.10^{ns}
Residuals	29	3.6988	0.1275	
TOTAL	**59**	**14.1255**	**0.2394**	

GRAND MEAN 16.56 CV 2.16%

Total number of observations 60

APPENDIX 4.11 (continued)

Variate: Sucrose yield (Mg ha-1)

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	171.889	9.047	1.64^{ns}
Weed population levels (P)	2	8.799	4.399	< 1^{ns}
Weed Control methods (C)	3	58.553	19.518	3.54**
P X C	6	5.826	0.971	< 1^{ns}
Residuals	29	159.979	5.517	
TOTAL	**59**	**405.046**	**6.865**	

GRAND MEAN 12.81 CV 18.34%

Total number of observations 60

APPENDIX 4.12: Analysis of variance table: Experiment II; Influence of weed population levels and weed control methods on 1st ratoon sugarcane

Variate: Sugarcane yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	5571.36	293.23	3.28**
Weed population levels (P)	2	311.10	155.55	1.74^{ns}
Weed Control methods (C)	3	22.83	7.61	$<1^{ns}$
P X C	6	374.48	62.41	$<1^{ns}$
Residuals	29	2594.95	89.48	
TOTAL	**59**	**8874.71**	**150.42**	

GRAND MEAN 77.9 CV 12.14%

Total number of observations 60

Variate: Percent sucrose

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	0.89262	0.04698	$<1^{ns}$
Weed population levels (P)	2	0.09989	0.04994	$<1^{ns}$
Weed control methods (C)	3	0.68711	0.22904	2.78**
P X C	6	0.80903	0.13484	1.64^{ns}
Residuals	29	2.38573	0.08227	
TOTAL	**59**	**4.87442**	**0.08262**	

GRAND MEAN 17.0 CV 1.69%

Total number of observations 60

APPENDIX 4.12 (continued)

Variate: Sucrose yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Block	19	159.723	8.410	3.41**
Weed population levels (P)	2	8.618	4.309	1.75ns
Weed Control methods (C)	3	0.881	0.294	<1ns
P X C	6	9.760	1.627	<1ns
Residuals	29	71.465	2.464	
TOTAL	**59**	**250.507**	**4.246**	

GRAND MEAN 13.25 CV 11.85%

Total number of observations 60

APPENDIX 4.13: Combined analysis of variance table: Experiment II; Effect of weed population levels and weed control methods on plant and 1st ratoon sugarcane

Variate: Sugarcane yield (Mg ha^{-1})

SOURCE OF VARIATION	DF	SS	MS	VR
Year (Y)	1	14.1	14.1	$< 1^{ns}$
Blocks within years	38	10930.3	287.6	2.09^{**}
Weed population levels (P)	2	547.7	273.9	2.00^{ns}
Weed control methods (C)	3	1054.6	351.5	2.56^{ns}
P X C	6	394.8	65.8	$< 1^{ns}$
Y X P	2	184.1	92.0	$< 1^{ns}$
Y X C	3	775.2	258.4	1.89^{ns}
Y X P X C	6	199.7	33.3	$< 1^{ns}$
Residual	58	7950.4	137.1	
TOTAL	119	22051.3	185.3	

GRAND MEAN 77.56 CV 15.1%

Total number of observations 120

Variate: Percent sucrose

SOURCE OF VARIATION	DF	SS	MS	VR
Year (Y)	1	5.8875	5.8875	56.12^{**}
Blocks within years	38	9.4670	0.2491	2.37
Weed population levels (P)	2	0.2743	0.1372	1.31^{ns}
Weed control methods (C)	3	1.2360	0.4120	3.93^{**}
P X C	6	0.6789	0.1131	1.08^{ns}
Y X P	2	0.0643	0.0321	$< 1^{ns}$
Y X C	3	0.2212	0.0737	$< 1^{ns}$
Y X P X C	6	0.9737	0.1623	1.55^{ns}
Residual	58	6.0845	0.1049	
TOTAL	119	24.8874	0.2091	

GRAND MEAN 16.78 CV 1.93%

Total number of observations 120

APPENDIX 4.13 (continued)

Variate: Sucrose yield (Mg ha-1)

Source of Variation	DF	SS	MS	VR
Year (Y)	1	5.685	5.685	1.42^{ns}
Blocks within years	38	331.672	8.728	2.19^{ns}
Weed population levels (P)	2	12.262	6.131	1.54^{ns}
Weed control methods (C)	3	35.127	11.709	2.93**
P X C	6	9.196	1.533	<1^{ns}
Y X P	2	5.155	2.5771	<1^{ns}
Y X C	3	24.307	8.102	2.03^{ns}
Y X P X C	6	6.3907	1.0653	<1^{ns}
Residual	58	231.444	3.990	
TOTAL	119	661.238	5.557	

GRAND MEAN 13.03 CV 15.33%

Total number of observations 120

APPENDIX 4.14: Analysis of variance for growth curve parameters for plant sugarcane

Variate: Asymptote

SOURCE OF VARIATION	DF	SS	MS	VR
Treat	3	1.5732	0.5244	2.46^{ns}
Residual	4	0.8525	0.2131	
TOTAL	7	**2.4257**		

Variate: Rate

Treat	3	2.9289	0.9763	1.06^{ns}
Residual	4	3.6791	0.9198	
TOTAL	7	**6.6081**		

Variate: Time

Treat	3	3.7764	1.2588	2.19^{ns}
Residual	4	2.2968	0.5742	
TOTAL	7	**6.0732**		

APPENDIX 4.15: Analysis of deviance for parallelism table: Experiment II; Influence of initial *C. esculentus* population levels and weed control methods on regrowth population in year 2

Variate : *C. esculentus* population

Source of variation	**DF**	**Deviance**
Block	19	1684.53***
Single line (initial population)	1	8553.33***
Parallel lines given single (weed control)	2	256.35***
Separate lines given parallel	2	93.83***
Residual	20	37.28
TOTAL	**44**	**10625.32**

Total number of observations 45