EFFECTS OF NITROGEN FERTILIZER, SUGARCANE TRASH MULCH, COWPEA INTERCROP AND HERBICIDES ON ITCHGRASS CONTROL, YIELD AND QUALITY OF SUGARCANE

BY

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE AT THE SOKOINE UNIVERSITY OF AGRICULTURE

NOVEMBER, 1994

ABSTRACT

A field experiment was conducted (under rainfed conditions with supplimentary irrigation) to evaluate the effects of nitrogen fertilizer, post emergence herbicides and other weed control treatments on itchgrass (*Rottboellia cochinchinensis* (Lour) Clayton) control, yield and quality of sugarcane (*Saccharum officinarum* L.).

The experiment was laid out as split-plot in a randomized complete block design replicated four times. Nitrogen fertilizer rates (0, 50 and 100 kg N/ha) were main plots while herbicides and other weed control treatments were subplots. The herbicides included gramuron (3.2 kg a.i/ha), basta (2.0 kg a.i/ha) and asulam (3.7 kg a.i/ha). Other weed control treatments were cane trash mulch, cane trash mulch plus hand weeding, cowpea intercrop, cowpea intercrop plus hand weeding, gesapax combi (4 kg a.i/ha) plus two hand weedings plus mechanical cultivation, weed free and unweeded checks.

Nitrogen fertilization was ineffective in controlling itchgrss. Mulching or intercropping supplemented with hand weeding as well as gesapax combi (4 kg a.i/ha) plus two hand weedings plus mechanical cultivation completely eliminated itchgrass. Asulam (3.7 kg a.i/ha) controlled the weed by an average of 88%. Gramuron (3.2 kg a.i/ha) basta

(2.0 kg a.i/ha) and mulching had between 70 and 75% control of the weed. Intercropping was ineffective in itchgrass control.

Increasing the rate of nitrogen from 0 to 100 kg N/ha significantly ($P \leq 0.05$) increased cane yield by 14%. Plots which were mulched and then hand weeded, treated with asulam (3.7 kg a.i/ha) or gesapax combi (4 kg a.i/ha) plus two hand weedings plus mechanical cultivation provided better control of itchgrass and higher cane yields averaging between 85 and 88 tons/ha.

Sugarcane yields positively correlated with number of sugarcane tillers (r=0.766), stalk population (r=0.734) and stalk length (r=0.433). Among sugarcane growth parameters, tiller counts, number of harvestable stalks and stalk length negatively correlated (r=0.749, 0.850, 0.886 respectively) with itchgrass count. Analysis of coefficient of determination (r^2) indicated that cane yield was more influenced (r^2=0.60) by tiller counts than by the other parameters.

Application of 100 kg N/ha significantly ($P \leq 0.05$) reduced sucrose content which is the main parameter of sugarcane quality compared to unfertilized cane.

Economic analysis showed that mulching plus hand weeding applied with 100 kg N/ha had the highest marginal rate of return of 192%.

DECLARATION

I, ANTHONY HERMAN NJALAYAO, do hereby declare to the senate of the Sokoine University of Agriculture that this thesis has not been submitted for a degree award in any other University.

Signature: ....

Date: ....13/11/1994....................

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ACKNOWLEDGEMENTS

I am greatly indepted to Prof. K.P. Sibuga under whose supervision and guidance I managed to write this thesis.

I would also like to thank the management of Mtibwa Sugar Estates for sponsorship and granting me a study leave.

Finally I would also like to thank Miss Grace Msimbe for her careful typing of this thesis.

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1.0 INTRODUCTION

The sugar industry is one of the largest food manufacturing sector in Tanzania (Sterkenburg, 1992). It contributes substantially to the economy of the country. Sugar production not only earns the nation some revenue but also saves the national expenditure on importing it. It also provides raw materials for chemical and food processing industries. The importance of sugar in Tanzania has led the government to give emphasis on high domestic sugar production (Tanzania: Ministry of Agriculture, 1983).

The sugar industry in Tanzania consists of four estates which have a total production capacity of 236,000 tons of sugar per annum with average annual sugar output of 100,000 tons. Capacity utilization amounts to less than 50% (Sterkenburg, 1992). This suboptimal use of sugar processing capacity has been attributed mainly to low cane output at the estates. It has been reported that low cane yield is caused by several factors including insect pests, diseases and weeds (Sterkenburg, 1992). Weed infestation particularly in the early stages of sugarcane growth is a major factor determining yield of cane. Humbert (1968) observed instances in Hawaii where yield of cane had more than doubled after weeds had been brought under control.

Obien and Baltazar (1979) reported 106 weed species belonging to 32 families associated with sugarcane. Of these, itchgrass (*Rottboellia cochinchinensis* (Lour) Clayton) is reported to pose serious problems in Tanzania (Haki, Unpublished). Millhollon (1992) found that losses of sugarcane due to itchgrass infestation were as high as 70% when weeds were not controlled promptly.

Several methods are currently being used to control itchgrass. In Tanzania, hand weeding is the most common method (Acland, 1971) but very expensive in terms of labour and time. Disking and interrow cultivation methods are also practised. However, the methods do not solve the problem fully as they do not remove itchgrass within the crop rows (Acland, 1971; Arnon, 1982). On the other hand, application of herbicides controls many weeds but most herbicides currently available in Tanzania are not very effective against itchgrass (Fute, 1987).

Agronomic practices such as nitrogen fertilization, mulching and intercropping increase the competitive ability of crops and as such can improve the efficiency of weed control. Their effectiveness in controlling weeds is evident in the literature. Mathur (1960) observed that cane trash cover suppressed growth of weeds in sugarcane fields. On the other hand, Rau (1976) observed that mulching followed by the application of post emergence herbicides considerably reduced the frequency of hand weeding. Bose and Ashraf (1972) reported that intercropping was effective in suppressing growth of weeds in sugarcane as well.

The above suggest that effective control of itchgrass in cane fields can be achieved through application of suitable herbicides supplemented with other practices such as nitrogen fertilization, mulching and intercropping. However, there is little information on effective herbicides and supplementary control practices combinations that can be used effectively under Tanzania conditions. This study was therefore undertaken to fulfil the following objectives;

i) To determine the effects of nitrogen fertilizer, cane trash mulch, cowpea intercrop and selected post emergence herbicides on control of itchgrass, yield and quality of sugarcane.

ii) To conduct an economic analysis on agronomically acceptable methods in order to determine the most profitable one for purpose of adoption.

2.0 LITERATURE REVIEW

2.1 The Itchgrass

2.2.1 General

Itchgrass (*Rottboellia cochinchinensis* (Lour) (Clayton) is an erect strongly tufted annual grass weed. It is a weed in many important crops such as maize (*Zea mays* L.) soybean (*Glycine max* (L.) merr), upland rice (*Oryza sativa* L.) sorghum (*Sorghum bicolor* L.), groundnuts (*Arachis hypogea* L.) and sugarcane (Holm *et al.*, 1977; Fisher *et al.*, 1985; Bridgemohan and Brathwaite, 1989). The identifying characteristics of itchgrass are the prop roots that descend from the lower nodes of the plant and needle like hairs on leaf sheaths which cause itching sensation when touched (Holm *et al.*, 1977; Millhollon, 1980; Lencse and Griffin, 1991).

2.1.2 Ecology

Itchgrass is native to tropical Asia but has become naturalized in many other tropical and subtropical areas of the world. It is at present a major weed in sugarcane in East Africa, the Philippines, West indies, Trinidad and Louisiana U.S.A. (Millhollon, 1980; Holm *et al.*, 1977). Sugarcane infestation by itchgrass has also been reported in Australia (Freshwater *et al.*, 1986), Venezuela, Columbia and Puerto Rico (Patterson, 1979; Millhollon, 1980).

Although itchgrass grows best in areas with high rainfall, good drainage, warm temperatures and at an altitude in the range of 800 to 1300 metres above sea level, its habitat within its traditional range of adaptation vary widely across the world (Holm *et al.*, 1977; Millhollon, 1980). In Zimbabwe, it is found at an altitude of up to 1600 m, in Kenya and Tanzania at 1900 m and in Madras India up to above 2,300 m. In South Africa, it is frequently found in wet places while in the Madras area of India it even grows in shallow water (Holm *et al.*, 1977). During his comprehensive survey of weeds in Zimbabwe, Thomas (1970) recorded itchgrass only in heavier soils (Clay and Clay loams).

2.1.3 Biology

Holm *et al.*, (1977) classified itchgrass as one of the major weeds of crops in the world. The importance of itchgrass as a serious weed depends on several characteristics which enable it to interfere with crop growth. These include; rapid growth in height which can reach 1.8 m in non crop environments or as much as 3 metres in cane fields (Millhollon, 1965), early profuse tillering (Fernandez, 1974; Mercado, 1978), prolific seed production of up to 16,000 seeds per plant (Fernandez, 1974) and seed dormancy that allows seed to persist for one to four years in the soil (Millhollon, 1965; Mercado, 1978; Thomas and Allison, 1975). In addition, the control of itchgrass by application of different selective herbicides available for use in sugarcane, maize, sorghum and other crops has generally not yielded satisfactory results (Millhollon, 1965; Mercado, 1978; Pamplona and Imlan, 1977).

2.1.4 Weed competition in sugarcane

Weeds like crop plants require nutrients, light and water for their growth and reproduction. When the essential resources are inadequate for the needs of any plant community, competition for resources between plants occurs to the adverse effects of each plant in the community (Peng, 1984).

The effects of weed competition on sugarcane have been reported by various workers. In South Africa, Gosnell (1965) demonstrated with series of experiments that non weeded plots yielded 13-14 tons less cane per hectare compared to weeded plots. In India, Perihar and Murkerji (1969) found that in three consecutive crops, cane in unweeded plots was reduced by 31% compared to hand weeded plots. In the Philippines, Obien and Baltazar (1979) estimated that losses due to weed infestation ranged from 25 to 75%. Working in Kilombero Tanzania, Fute (1990) found that natural weed community reduced sugar yield by 83% and 84.3% compared to weed free cane for the rainfed and irrigated crops, respectively. Ibrahim (1984) reported that, in the Sudan, weeds reduced sugar yield by 40%. He attributed the reduction of sugar to depression of population of millable stalks, stalk length, stalk girth and number of nodes per stalks. These parameters were lowered by 32%, 24%, 15% and 14%, respectively. Similarly, Blanco *et al.*, (1981) found that weeds in a spring season crop in Brazil reduced stalk population by 45% and stalk length by 84%.

Various workers have reported effects of itchgrass competition on sugarcane. In experiments spanning over a period of ten years in Louisiana USA, Millhollon (1992) found that uncontrolled itchgrass growth reduced sugar yield by 70% as compared to weed free control. The reduced sugar yield was mainly attributed to reduction in tillering and stalk population by 20% and 25% respectively. However, it was also observed that the sucrose content of unweeded cane increased by 4% compared with weed free cane. The increase in sucrose content was attributed to slowing of sugarcane growth and tendency of stalks to store sugar rather than using it for growth.

In Burdeking district of Australia, Freshwater *et al.*, (1986) recorded reduction of cane yield from the original 113 tons per hectare in 1974 when itchgrass was not present to an average of 76 tons per hectare in 1981 when fields were infested with itchgrass. Lencse and Griffin (1991) found that in a sugarcane field where itchgrass was not controlled growth of sugarcane was reduced especially in stalk population as well as cane and sugar yields by an average of 34%, 42% and 43%, respectively. In the Philippines, Dalisay and Mercado (1985) found that four weeks of itchgrass infestation after cane planting reduced sugar yield by 14%. In Cuba, on the other hand, La *et al.*, (1985) reported that heavy infestation of itchgrass caused losses of 51 to 70% of cane and sugar yield.

Causes of the adverse effects of itchgrass infestation in sugarcane are not well documented but studies in maize showed that the weed competes strongly for light, which consequently reduces photosynthesis in crop plants (Thomas and Allison, 1975).

2.1.5 Critical period of weed competition in sugarcane

Lamusse (1965) conducted studies to establish the critical period of weed competition in sugarcane. He found that the cane crop was very sensitive to weed competition from the emergence of primary shoots at the third week to the appearance of first tillers at the sixth week after planting. Peng (1984), Ibrahim (1984), Singh and Verma (1969), Peng and Sze (1969 and Millhollon (1971) recorded a reduction of 30% in cane yield when they left cane under competition with weeds between the fourth and eighth week after planting. This period coincided with establishment of primary shoots and tillering phase. Blanco *et al.*, (1979) established that, in Brazil, the critical period of weed competition in sugarcane was between 2.5 and 9 weeks after planting. In Taiwan, Peng (1984) found that the period from the third to sixth week after planting was the critical period of spring planted cane. On the other hand, Azzi and Fernandez (1968) found that in Brazil such critical period for spring planted cane was the third week after planting.

In the Philippines, Dalisay and Mercado (1985) conducted experiments in a field heavily infested with itchgrass to determine the critical period of competition of sugarcane with the weed. They found that for optimum yield sugarcane needed a weed free condition between second and tenth weeks after planting. Weeding period of 12 weeks gave maximum yield and competition for 20 weeks reduced sugar yield by 100%. Punzalan and Dela Cruz (1981) found that itchgrass weeding in sugarcane needed to be started one month after planting and that weeding once every 3 weeks for the first 12 weeks after planting was required for the proper weed control and for maximum yield. In a study by Millhollon (1992) in which itchgrass was allowed to reseed and develop naturally in sugarcane crop while the weed was removed in some plots after 30, 60 and 180 days of competition it was found that after 30 days of competition, itchgrass biomass ranged from 200 to 2700 kg/ha and sugar yield was reduced by 7%. After 60 days of competition itchgrass biomass ranged from 1,400 kg/ha to 2,900 kg/ha and sugar yield was reduced by 17%. Itchgrass removed after 180 days of competition reduced sugar yield by 19%. It was thus concluded that to prevent rapid increase in itchgrass biomass and loss in sugar yield, itchgrass must be removed from sugarcane before 30 days of competition. This is in contrast to the results of Zimdhal (1980) and La *et al.*, (1985) who found that the critical period of itchgrass competition in sugarcane was between 30 and 60 days after cane emergence at populations of 20 to 40 weed plants per metre square.

2.1.6 Effect of nitrogen fertilizer on weed control, yield and quality of cane

Rao (1982) and Akobundu (1987) reported a positive effect of nitrogen on weed control in crops. The general observation was that increased growth of crops following nitrogen application enables full canopy to develop faster and this suppresses weeds quicker. In the Philippines, Fisher *et al*; (1985) found that nitrogen fertilization without itchgrass control increased maize yield from 1.65 to 2.67 tons per hectare. Working in sugarcane in the Philippines, Dalisay and Mercado (1985) found that compared to weed free cane, cane yield at 6 weeks of itchgrass competition decreased by 49% at 100 kg N/ha and 29% at 300 kgN/ha. However, when itchgrass control was delayed for 8 or more weeks after planting cane yield decreased more with higher fertilizer rate than with lower fertilizer rate.

This suggests that during early crop-weed association, cane grown at a higher fertilizer rate is more competitive than cane at a lower amount of fertilizer. However, when competition occurs for eight weeks or more, cane with lower fertilizer rate is more competitive than cane with higher fertilizer rate.

Studies have shown that economic yield of cane depends on the quality and quantity of cane during harvesting and that nitrogen supply to the crop during growth highly affects both of these parameters (Wood, 1968; McAleese *et al.*, 1970; Ojha *et al.*, 1974; Singh, 1974; Rao *et al.*, 1975; Patil *et al.*, 1970). Generally, an abundant supply of nitrogen to sugarcane results in high tillering and fast growth, while with inadequate supply of the nutrient the life cycle of the crop is usually shortened and early senescence occurs. Humbert (1968) summarized the role of nitrogen on sugarcane growth with a general conclusion that the nutrient plays a great role in cane growth and development as well as in tillering. Husz (1972) pointed out that nitrogen enables bullshoots to mature earlier without affecting older stalks. Takashashi (1967) and Salunkhe *et al.*, (1981) found that nitrogen application had a positive effect on stalk population, while Singh (1974) and Thomas and Oerther (1975) reported an increase in cane growth when nitrogen was applied.

On the other hand, it has also been reported that nitrogen supply to sugarcane has some effect on the quality of cane juice extracted at mill. Humbert (1968), Ojha *et al.*, (1974) and Wang (1976) generally noted that a high supply of nitrogen to sugarcane had negative effects on the juice quality of the harvest as measured by the pol (apparent percentage of sucrose in the juice) as well as the brix (percentage of soluble solids in the juice) both of which determine the sugar yield of the crop. In Queensland Australia, McAleese *et al.*, (1970) surveyed eight different cane growing areas and found that excessive use of nitrogen fertilizer in some areas decreased sugar content. Ojha *et al.*, (1974) found a decrease in pol and purity of juice over the control as nitrogen rates were increased from 50 to 100 kgN/ha although there was a significant increase in cane yield due to the increase in fertilizer treatment. Negative effects of nitrogen on pol and brix in the juice have also been reported by Gervet *et al.*, (1978).

2.1.7 Effects of mulching on weed control, yield and quality of cane crop

Mulching has smothering effects on weed control by excluding light from photosynthetic portion of a plant thus inhibiting growth (Rao, 1982; Muzik, 1970; Klingman, 1961). Mulching is generally very effective against annual weeds (Rao, 1982). In Mauritius and Hawaii mulching forms an important component of weed management in sugarcane (Peng, 1984). Mulching in sugarcane is commonly done with dry sugarcane leaves stripped from harvested cane stalks (Peng, 1984). It is reported that to be effective, at least 10 cm thick mulch is required to prevent light transmission and eliminate photosynthesis (Rao, 1982).

Several studies have shown that mulching increases cane yield (Humbert, 1968; Peng, 1984). In South Africa Millard (1974) found that mulching sugarcane crop increased stalk population, stalk height, and cane yield without affecting sucrose content. In Taiwan, Fu *et al.*, (1969) found that mulching markedly speeded up cane germination, tillering and eventually resulted in 15 to 30% increase of cane yield at harvest. In India, Mathur and Saksena (1965) found that mulching cane interrows with 15 cm thick layer of cane trash gave higher yield of cane than in unmulched cane. Lall (1977) reported that a trash mulch of dried sugarcane leaves increased cane yield but also increased termite and rodent infestation.

Rao (1982) reported that mulching increased crop yield through its ability to regulate soil temperature, conserve soil moisture and encourage proliferation of surface feeder roots which enhance uptake of plant nutrients. Literature on the effect of mulching on quality of sugarcane is not well documented.

2.1.8 Effects of intercropping on control of weeds, yield and quality of cane crop

Wide interrow spaces between cane rows provide areas for weeds to beseige cane plants and rob water and nutrients from the soil for their rapid growth. Sowing growing crops in the interrow may help to suppress weeds render the cane a better position and bring in extra weeds quite apart return from harvesting the intercrops.

Lall (1977) reported that intercropping cane with chick peas (*Cicer arientinum* L.) suppressed weed growth. Forty days after planting, 4 ton/ha of weeds were harvested from the sole crop plots whereas only 0.5 ton/ha of weeds were harvested from intercropped plots. Bose and Ashraf (1972) reported that potato (*Solanum tuberosum* L.) gave good weed control when intercropped with sugarcane. Gervetz (1963), Webster and Wilson (1966), Walters (1971) and Enyi (1973) attributed the reduced weed growth following intercropping to more complete ground cover provided by the intercrop which smoothed weed growth.

Working with maize in the Philippines, Fisher *et al.*, (1985) found that mungbean (*Phaseolus mungo* L.) grown as a companion crop was a promising practical control measure of itchgrass provided that conditions allowed vigorous crop growth. However, in Trinidad, Bridgemohan and Brathwaite, (1989) reported that although mungbean intercrop suppressed itchgrass in maize it had a low weed control efficacy.

In India, Venkturaman *et al.*, (1978) found that intercropping mungbean (*Phaseolus mungo* L.) in sugarcane reduced cane tillering, cane girth and stalk population density but increased stalk length and did not influence cane yield and quality. The main quality considered was sucrose content which was 15.6% in both intercropped and sugarcane grown alone. Rage and Patwardhan (1952) observed that maize intercropped with sugarcane at 30 cm spacing adversely affected the cane crop. They, however, showed that this could be made profitable by applying an additional dose of 65 kgN/ha for the cane crop and by increasing spacing between maize plants with the row from 30 cm to 80 cm.

Bose and Ashiraf (1972) intercropped cane with wheat (*Triticum aestivum* L.), cowpeas (*Vigna unguiculata* L.) potato (*Solanum tuberosum* L.) and mustard (*Brassica juncea* L.). They found that potato gave significantly higher cane yield over that of cane grown alone. Wheat depressed the yield of cane by 50%, mustard by 47% and maize by 24.6%. All intercrops did not affect brix, pol and purity of cane juice. Rathi and Singh (1979) reported that intercropping cane with potato (*Solanum tuberosum* L.) followed by onion (*Allium cepa* L.) gave 20% more cane than cane grown alone.

2.1.9 Chemical control of weeds in sugarcane

Among the sugarcane producing regions, Hawaii was the earliest to develop modern techniques of chemical weed control in sugarcane. Reviews by Hanson (1959; 1962) and Hilton (1967) revealed that chemical weed control in Hawaii began in 1913 when sodium arsenate was applied for weed control in sugarcane. Present herbicides used for weed control include 2,4-D(2,4-dichlorophenoxy acetic acid), sodium salt of TCA (Trichloro acetic acid) dalapon (2,2 dichloro proprionic acid), monuron [3(P-chlorophenyl)-1-1 dimethyl urea], diuron
[3,3,4(dichlorophenyl)-1-dimethyl urea) and simazine (2 chloro-4,6 bis (ethylamino)-5-triazine] (Peng 1984). In Florida, a herbicide mixture consisting of CDAA (N-N-diallyl-2-chloroacet- anilide) and fenac (2,2,3,6 trichlorophenoxy acetic acid) has been reported to provide good control of grass and broadleaf weeds. In Puerto Rico, diuron has been reported to be used mainly in heavier soils while simazine has been recommended for lighter soils. In Mauritius, diuron and atrazine [2-chloro-4-(ethylamine)-6-(isopropylamino)-5-triazine] have been recommended for higher rainfall areas while monuron and simazine have been used in dry areas (Peng, 1984). In South Africa, a mixture of diuron (2.5 kg a.i/ha) and 2,4-D(1 kg a.i/ha) has often been used for early post emergence application. Paraquat (1,1 dimethyl-4,4-bipyridinium dichloride) at 1 kg a.i/ha has often been added to the mixture. Diuron (2.5 kg a.i/ha)

mixed with paraquat (1.0 kg a.i/ha) or 2,4-D(1 kg a.i/ha) plus paraquat (1 kg a.i/ha) have been used for post emergence application (Peng, 1984).

Several studies have been reported on chemical control of itchgrass in sugarcane. Millhollon (1980) reported good itchgrass control using soil incorporation treatment of trifluralin (a,a,atrifluoro-6-dinitro-n-dipropyl-p-toloidine) at 2.0 kg a.i/ha. Successful control of germinating itchgrass seedlings by using 2,4-D at 2.5 kg a.i/ha in sugarcane has similarly been reported by Ivens (1971).

Working in Louisiana, Millhollon (1984) demonstrated the efficacy of diuron at 5 kg a.i/ha, fenac at 5 kg a.i/ha, bromocil (5-bromo-5-butyl-6-methyl uracil) at 3 kg a.i/ha, metribuzin [4-amino-6-tertbutyl-3-methyl thio-s-triazine 5(4H) one] at 2.0 kg a.i/ha and terbacil (3 tertbutyl-5-chloro-6-methyl uracil) at 1.8 kg a.i/ha as pre emergence application. He also recommended the use of asulam (methyl sulfanyl carbamate) at 3.7 kg a.i/ha mixed with dalapon (2,2 dichloro proprionate) at 6 kg a.i/ha in controlling young seedlings of itchgrass at about 5-10 cm in height.

In Australia, a mixture of hexazinone [3-cyclone-xyl-6-(dimethylamino)-1-methyl-1,1,3,5-triazine 2,4(1H,3H)-

dione] and diuron at 3 kg a.i/ha applied as pre-emergence treatment proved very successful in controlling itchgrass in sugarcane (Freshwater *et al.*, 1986). The addition of paraquat at 3 kg a.i/ha was reported to increase efficacy of hexazinone and diuron in controlling itchgrass particularly when applied as early post emergence treatment (Freshwater *et al.*, 1986).

2.1.10 Economics of weed control in sugarcane

Workers have reported economics of different weed control methods in sugarcane. In India, Mathur and Saksena (1965) packed cane trash mulch 10-15 cm thick between cane rows. They found that the cost of weed control was reduced by 90% compared to the cost of weed control by normal weed control practice. Similar results were obtained by Lall (1977). In maize Bridgemohan and Bratuwaite (1989) found that mulching interrow spaces of maize crop with rice straw completely eliminated itchgrass but increased the cost of weed control by 70%.

Webster and Wilson (1966) studied labour requirements for weed control in intercropped combinations. They found that intercropped combinations required less amount of labour in weeding. In India, Lall (1977) reported less expenditure on weed control when sugarcane was intercropped with chick pea than when grown alone. On the other hand, Surtytna (1976) reported that significantly more time was required to weed maize-cassava (*Mahihot esculenta* L.) intercrop than cassava sole crop. In Nigeria, Baker and Norman (1975) reported that weeding intercrops required 29% more labour than sole crops.

Singh and Singh (1956) recorded slightly lower income from the combined crops of cane and blackgram than that of non intercropped cane. Bhoj and Tandon (1959) found that intercropping cane with cowpeas and blackgram gave about 20% and 7% more profit, respectively, than sole cane and recorded no advantage with mustard. However, Singh and Gupta (1961; 1962) intercropped cane with blackgram and cowpeas and Narayaran (1969) with groundnuts, and reported that intercropping was less remunerative than growing the cane alone.

In some instances, the control of weeds in sugarcane using herbicides has been reported to be cheaper than hand weeding and mechanical cultivation. In work carried out in South Africa, Pearson and Thomson (1962) found that the cost of chemical weed control was the same as the cost of weed control by hand weeding. Using 2,4-D and MSMA (Monosodium methyl Arsenate), Mustaffe and Ray (1976) demonstrated that chemical control of weeds was cheaper than hand weeding. Brandaver (1977) reported higher net benefit from chemical weed control than hand weeding.

3.0 MATERIALS AND METHODS

3.1 Location of the Experiment

The experiment was conducted at Mtibwa Sugar Estates which lies between latitudes $6^0$10' and $6^0$50' South and longitudes $37^0$31' and $38^0$03' East about 100 km North West of Morogoro town Tanzania.

The area has a bimodal rainfall pattern. The short rains start in November and end in January while the long rains begin in March and continue up to May. Generally the rains are irregular and unreliable. Unpredictable drought and floods are quite common. The mean rainfall data for the estates for the last 10 years and the rainfall received during the 1993 cropping season during which this field experiment was conducted is given in appendix A5.

Mtibwa Sugar Estates has an area of about 4500 ha under cane. About half of the area is rainfed while the other half is sprinkler irrigated.

3.2 Field Experiment

A field experiment was laid out in a field which had been infested with itchgrass for the last five years.

The land was ploughed and harrowed followed by furrowing. The furrows were 150 cm apart. The field operations were done using a tractor drawn plough, a harrow and a ridger respectively. Soil samples were collected and analyzed for their physical and chemical characteristics (Table 1).

3.3 Experimental Layout

The experiment was laid out in a split plot design with nitrogen fertilizer rates as main plots and ten weed control treatments as subplots. The treatments were replicated four times. Each subplot was 18 m^2 comprising 3 cane rows of 4 m long spaced at 1.5 m apart. Adjacent plots were separated by 1 m buffer of weed free path while replications were separated by 2 m of weed free path. Details of the treatments are given in Table 2.

3.4 Nitrogen Fertilizer Application

Calcium ammonium nitrate (CAN 26% N) was used as a source of nitrogen. The fertilizer was applied in planting furrows and then covered with about 3 cm of soil before seed cane was placed in the furrows.

Table 1. Physical and chemical characteristics of the soil at experimental site.

Total N (%)	Organic carbon (%)	Organic matter (%)	C:N ratio	Texture (%)			Textural class	pH (H_2O)
				Sand	Silt	Clay		
0.08	0.68	1.0	8.5	69.7	11.2	19.1	Sandy loam	6.8

Table 2. Details of weed control treatments.

Treatment	Description	Dose	Application time
Main Plots			
N_0	No nitrogen fertilizer	0 kg N/ha	-
N_1	Nitrogen fertilizer	50 kg N/ha	At planting
N_2	Nitrogen fertilizer	100 kg N/ha	At planting
Sub-Plots			
T_1	Gramuron	3.2 kg a.i/ha	4 weeks after planting
T_2	Basta	2.0 kg a.i/ha	4 weeks after planting
T_3	Asulam	3.7 kg a.i/ha	4 weeks after planting
T_4	Canetrash mulch	3.5 tons/ha	3 weeks after planting
T_5	Canetrash mulch plus hand weeding	3.5 tons/ha	3 weeks after planting 7 weeks after planting
T_6	Cowpea intercrop		3 weeks after planting
T_7	Cowpea intercrop plus hand weeding		3 weeks after planting 7 weeks after planting
T_8	(Recommended practice) Gesapax combi	4 kg a.i/ha	4 weeks after planting
	+ Two hand weedings	-	7 and 10 weeks after planting
	+ Mechanical cultivation	-	12 weeks after planting
T_9	Weed free check	-	Hand weeding after every two weeks
T_{10}	Unweeded check		Unweeded from planting to harvesting

3.5 Cane Planting and Post Planting Operations

Cane planting was done on 30th October, 1992 soon after the fertilizer was applied. Whole stalks of cane variety NCO 376 with leaf tops removed above the apical meristems were planted in pairs with the bottom ends of successive stalks overlapping the top ends by 10% and then covered with about 6 cm of soil layer.

After cane planting, itchgrass seeds were broadcasted in all plots at about 100 gm of seeds per plot except the weed free treatment plots. The seeds were then incorporated into the soil and spread on the plots by gentle raking. This was done in order to increase itchgrass infestation and ensure that plots were uniformly infested with itchgrass.

Irrigation water was applied to supplement rainfall in dry periods. Irrigation setting was 3 hours for the first month and 5 hours for the rest of the experimental period. Irrigation discharge rate was 5.6 mm per hour.

Sugarcane smut (*Ustilago scitaminea* sydow) which is the most important disease of sugarcane at Mtibwa was controlled by rouging infected stools once per month.

3.6 Cowpea Planting

Cowpea was planted manually in the interrow spaces of test rows of cane crop three weeks after cane planting. Three cane test rows and twelve cowpea rows were planted per plot alternating three cowpea rows for each cane test row. Spacing was 150 cm between adjacent cane rows and 50 cm between adjacent cowpea rows. Within cowpea rows plants were spaced 25 cm apart with one plant per hill to make a population of 72,000 cowpea plants per hectare.

3.7 Cane Trash Mulch Application

Cane trash mulch was collected from cane field harvested one week prior to application. The mulch was spread manually in the interrows and up to the cane rows at a rate of 3.5 ton/ha three weeks after cane planting.

3.8 Herbicide Spraying

Herbicides were sprayed using a CP15 knapsack sprayer. The sprayer output was determined by calibrating the sprayer prior to spraying and according to procedure described by Fisher and Sabio (1984). The sprayer was fitted with a floodjet nozzle and was operated at a pressure of 1 kg/cm^2.

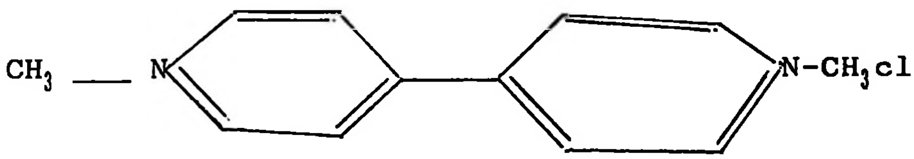
The herbicides were applied as post emergence sprays four weeks after planting at a spray volume of 200 l/ha. A brief description of the herbicides evaluated is given below.

3.8.1 Gramuron

The formulation contains 200 g/l paraquat and 250 g/l diuron. It is recommended for a broad spectrum control of broadleaf weeds and grasses in sugarcane, tea, rubber, coffee and banana. The characteristics of individual herbicides are as follows:

Paraquat: Chemical name is 1, 1'dimethly 1-4-4'biprydinium chloride.

Chemical structure:

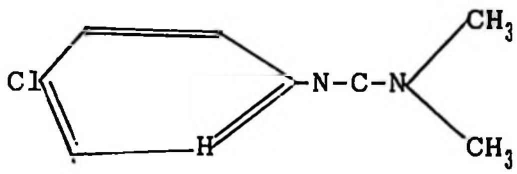


Paraquat was developed by Imperial Chemical Industries of England in 1955. It is formulated as aqueous solution. The herbicide is a general contact herbicide recommended for non selective control of annual weeds in coffee, sugarcane and banana. The herbicide kills plants by producing hydrogen peroxide (H_2O_2) which is a powerful plant toxicant (Klingman, 1961).

Diuron: Chemical name is

3-(3,4 Dichlorophenyl) Diethylurea.

Chemical structure:



Pure diuron is a white, odourless, non volatile, non flammable crystalline solid which melts at 159^{0}C. It is soluble in water at 25^{0}C to concentration of 42 ppm. Diuron was developed by Pont de Nemour and Company of France and is formulated as wettable powder. It is absorbed by roots and translocated apoplastically to the leaves. The herbicide kills the plant by inhibiting the hill reaction of photosynthesis. Diuron is recommended for pre or post-emergence control of annual grasses and broadleaf weeds in cotton, pineapple and sugarcane (Rao, 1982).

3.8.2 Basta

Basta is a non selective contact herbicide discovered and developed by Hoechst AG of Germany. The formulation contains 200 g Ammonium - DL- homoalanin 4DY-L(methyl) phosphinate per litre. Pure chemical is slightly pungent, white to yellow crystalline powder. The compound is readily soluble in water.

Chemical name; Ammonium-DL-homoalanin 4DY L(methyl)phosphinate

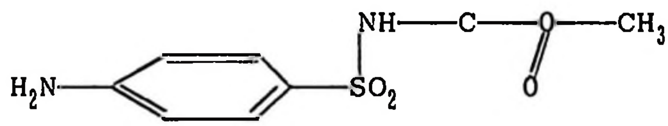
Molecular formula: $C_5H_{15}N_2O_4P$

Basta kills the weed plants by producing ammonia (NH_3) which is a strong phytotoxin in plant cells. The herbicide is recommended for post emergence control of annual broadleaf weeds and grasses in palms, rubber, tea, citrus and sugarcane (Hoechst undated).

3.8.3 Asulam

Chemical name: Methyl sulfanyl carbamate

Chemical structure:



Asulam is a white crystalline solid with water solubility of 5000 ppm. It is formulated as an aqueous solution of the sodium salt. Asulam is a post emergence herbicide discovered by May and Baker. Following application, the herbicide is absorbed by foliage and translocated symplastically to the roots. Asulam inhibits bud growth, ribonucleic acid synthesis and reduces photosynthesis. The herbicide is recommended for control of grass weeds in sugarcane (Rao, 1982).

3.9 Data Collection

3.9.1 Weed counts

Weed plants were counted at 3 weeks after cane planting before weed control treatments were applied and repeated 11 weeks later(14weeks after planting). Weeds were counted from three fixed quadrats in each plot. The quadrats were established by randomly throwing a 50 x 50 cm quadrat and the areas marked by fixing pegs at the corners. At each counting all weeds from within these quadrats were counted and recorded as number of weeds/m^2. However in the fourteenth week after planting, itchgrass was counted and recorded separately from other weeds. This was done in order to study more on the influence of different treatments on itchgrass population.

3.9.2 Weed dry weight

Total dry weight of weeds was taken at 14 weeks after cane planting. All weeds in the fixed quadrants (section 3.9.1) were cut at ground level, itchgrass was separated from other weeds, and weeds from each lot was oven dried at 80^0C for 24 hours then weighed. The weed dry weight was expressed in g/m^2.

3.9.3 Cane germination

Percent cane germination was assessed at four weeks after cane planting. Cane shoots were counted from three test rows in each plot and percent germination was calculated against count of 300 shoots per plot as equivalent to 100%.

3.9.4 Cane tillering

Cane tillering was assessed by counting the number of cane shoots from three test rows in each plot at 10 weeks after planting. It was expressed in number of shoots/m^2.

3.9.5 Length of harvestable cane stalks

This was assessed one day before harvesting. Five cane stalks from each plot were used for measurement of length of harvestable cane. The stalks were randomly selected and length was measured from ground level to the top visible dewlap. The length was expressed in metres.

3.9.6 Numbers of harvestable cane stalks

This was assessed by counting all cane stalks in three test rows in each plot just before harvesting. It was expressed in number of stalks/m^2.

3.9.7 Cane yield

This was assessed by recording cane yield after harvesting. The cane crop was harvested on 30th June, 1993 at the age of 8 months. All stalks of sugarcane from the three test rows in each plot were cut at ground level, the trash removed, chopped at the top visible dewlap, bundled and then weighed using a balance (Salter scale) fixed to a tractor mounted crane. Cane yields were expressed as tons of cane per hectare (TCH).

3.9.8 Cane quality

This was assessed by determining the brix, pol, purity and sucrose content of cane. After harvesting, 15 stalks were randomly selected from the harvestable cane rows in each plot and crushed in three roller mills to obtain juice for cane quality analysis. The samples were analyzed at the estates laboratory according to SATA method (1971) to determine brix, pol, purity and sucrose content as follows:

3.9.8.1 Brix

This is the percent soluble substances (sucrose and impurities) in the cane. The brix in the extract (b) was determined by refractometer and brix content in the cane (B) was calculated as follows:

$$B = b(4 - 0.0125F)$$

where F is percent fibres in the cane and 4 and 0.0125 are constants.

3.9.8.2 Pol

This is the apparent sucrose content in the cane. Pol in the extract (p) was measured by a saccharimeter and the pol content in the cane (P) was calculated as follows:

$$P = p(4 - 0.0125F)$$

where 4 and 0.125 are constants and F is percent fibres in the cane.

3.9.8.3 Purity

This is the percentage of apparent sucrose content in the cane juice. It was calculated from the following relationship:

$$\text{Purity} = \frac{P \times 100}{B}$$

where P is pol and B is brix content of cane.

3.9.8.4 Sucrose content

Sucrose content in the cane stalks (R) was calculated by using the following formula:

$$R = p\left(\frac{170 - 2.1F}{100 - F}\right) - 0.78$$

where 170, 2.1 and 0.7 are constants and F is fibres content of cane

3.9.9 Sugar yield

Sugar yield was expressed as tones of sugar per hectare (TSH) and was estimated from the following relationship:

$$TSH = \frac{R \times TCH}{100}$$ R = Sucrose content of cane stalk

3.9.10 Cowpea yield

This was assessed by recording yield of dry cowpea seeds after harvesting. The cowpea crop was harvested on 3rd February 1993 seventy five days after cowpea had been planted. All cowpea pods from the twelve cowpea test rows in each plot were picked, threshed, the seeds were sun dried for two days and then weighed using an electronic balance. Yield of cowpea seeds were expressed as kilograms of seeds per hectare.

3.10 Data Analysis

3.10.1 Statistical analysis

A statistical test appropriate for a split plot design Gomez and Gomes (1984) was used to analyze the data. Analysis was done using MSTAT Computer Programme (Michigan State University, 1983). Weed counts and weed dry weights were square root transformed ($y = \sqrt{x+1}$) before being subjected to statistical analysis. Mean separation was performed using Tukey's Honestly Significant Difference Test (Steel and Torrie, 1980) to detect the difference between treatment means.

3.10.2 Economic analysis

An economic analysis using partial budget (Perrin *et al*; 1976) was carried out to identify the most profitable weed control method. Only treatments which gave statistically ($P \leq 0.05$) equal or higher than cane yield from the recommended practice were subjected to economic analysis.

3.10.3 Partial budget

All variable costs involved in the experiment were identified and determined as follows:

3.10.3.1 Cost of Nitrogen Fertilizer Application

This was calculated as follows:

i) Cost of nitrogen fertilizer (shs/ha) = field price of nitrogen fertilizer (shs/ha) x quantity of fertilizer (kg/ha).

Field price of nitrogen fertilizer was shs 1450 per 50 kg bag and was obtained from stores department of Mtibwa sugar estates.

ii) Cost of fertilizer transportation from the store to the field (shs/ha) = quantity of fertilizer transported (kg/ha) x cost per unit quantity of fertilizer transported (shs/kg).

Cost of transportation within the estate was shs 1000/= per ton and was fixed by Accounts Department of Mtibwa Sugar Estates.

iii) Cost of fertilizer placement in the field = Mandays for fertilizer placement per hectare x labour cost per manday (shs/manday).

Casual labourers with an average age of

30 years were randomly allocated to subplots and the time taken to apply the fertilizer to the plot was recorded. From this a manday which is equivalent to 8 working hours was calculated.

The rate paid to casual labourers for all manual field operations was the same and was fixed by the Accounts Department of the Company based on the following:

Wage	Shs	135/manday
Labour inducement allowance	"	40/manday
Task completion bonus	"	30/manday
Breakfast	"	40/manday
Total	"	245/manday

The costs of items (i), (ii) and (iii) listed above were added up to give the total variable costs for nitrogen fertilizer application.

3.10.3.2 Cost of mulch application

This was calculated as follows:

i) Cost of cane trash transportation = quantity of cane trash transported (kg/ha) x price per unit quantity of mulch transported (shs/kg).

Cane trash was transported in a trailer pulled by a tractor. The amount of trash required was calculated from the recommended application rate of 3.5 tons/ha. Trash was piled up in 18 lots each being enough to mulch one plot, weighed using a balance (Salter scale) suspended on a tractor mounted crane, tied with sisal twine and then put in a trailer and transported to the experimental site.

The mulch was transported at shs 1000/= per ton.

ii) Cost of mulch application = mandays per hectare required to apply the mulch x labour cost per manday (shs/manday).

Mandays for mulch application included mandays for collecting, tying, weighing, untying and spreading the mulch. Mandays for collecting tying and weighing the mulch were determined by randomly assigning casual labourers to the field were mulch was taken and recording the time taken by them to collect tie and weigh the mulch. Mandays for untying and spreading the mulch were obtained by randomly assigning casual labourers to subplots and recording their time taken in untying and spreading the mulch in the plots. From the time recorded mandays for collecting, tying, weigh untying and spreading the mulch were computed and then added together to get mandays for mulch application.

The labour requirement for mulch application was 8 mandays/ha. The cost for one manday was shs 245/=. The costs of items (i) and (ii) above were added up to give the total variable cost for mulch application.

3.10.3.3 Cost of planting cowpea intercrop

This was calculated as follows:

i) Cost of cowpea seeds = price per unit quantity of cowpea seed (shs/kg) x quantity of cowpea seeds (kg/ha).

Cowpea seed was bought at shs 200/kg from the horticultural unit of Mtibwa Sugar Estates. Seed rate was 20 kg/ha.

ii) Cost of planting cowpea = mandays required to plant cowpea seeds in one hectare x labour cost per mandays (shs/manday).

Time taken by labourers to plant cowpea in each plot was recorded and from the time recorded mandays for planting cowpea were computed.

An average of 10 mandays were required to plant the cowpea intercrop per hectare.

Cost per manday was shs 245/= as given in subsection 3.10.3.1.

iii) Cost of harvesting cowpea = mandays required to harvest cowpea seeds in one hectare x labour cost per manday (shs/manday).

The time taken by labourers to harvest cowpea in each plot was recorded and from the time recorded mandays for harvesting cowpea were computed.

An average of 4 mandays were required to harvest cowpeas per hectare.

Cost per mandy was shs. 245/= as given in subsection 3.10.3.1.

iv) Cost of cleaning cowpea seeds = mandays required to thresh cowpea pods and clean the seeds from one hectare.

The time taken by labourers to thresh the pods and clean the seeds in each plot was recorded and from the time recorded mandays for cleaning cowpea seeds were calculated.

An average of mandays were required to clean cowpea seeds from one hectare.

Cost per manday was shs. 245/= as given in subsection 3.10.3.1.

The cost of items (i), (ii), (iii) and (iv) above were added up to give the total variable costs for intercropping cowpea.

3.10.3.4 Cost of herbicide application

This was calculated as follows:

i) Cost of herbicide = price of herbicides (shs/ha) x quantity of herbicides (L/ha).

Market prices of the herbicides were obtained from the agent of The Tanganyika Farmers Association (TFA) at Mtibwa. The market prices for the herbicides for 1992/93 were as follows:

Asulam	Shs	2 500 per litre
Gramuron	"	3 000 per litre
Basta	"	7 000 per litre
Gesapax combi	"	2 500 per litre

ii) Cost of spraying herbicide = manday required to spray one hectare x labour cost per manday (shs/manday).

The time taken to spray herbicides in different plots was recorded carefully in order to calculate the mandays required to spray one hectare. One manday was required to spray one hectare.

As outlined in subsection 3.10.3.1 the labour cost per manday for spraying was shs 245/=.

The costs in the items (i) and (ii) given above were added up to give the total variable cost of herbicide application.

3.10.3.5 Cost of hand weeding

This was determined by multiplying mandays required to handweed one hectare x labour cost per manday.

i) In each hand weeding operation, casual labourers were assigned randomly to appropriate plots and the time taken to weed the plots was recorded. Mandays required to hand weed one hectare in the appropriate treatments were calculated from the time recorded. Each of the two hand weedings in plots pre treated with gesapax combi (4 kga.i/ha) required an equivalent of 5 mandays per hectare. To hand weed mulched and intercropped plots needed an equivalent of 4 and 12 mandays per hectare respectively.

ii) As shown in subsection 3.10.3.1 labour cost per manday was shs 245/=.

3.10.3.6 Cost of mechanical cultivation

This was determined by multiplying tractor hours required to carry out interrow cultivation per hectare x cost per tractor hour.

i) A tractor was assigned to carry out interrow cultivation in four rows of cane each 100 metres long in a section meant for commercial cane production in a field where the experiment was established at 12 weeks after planting. From the time taken to undertake mechanical cultivation in the 4 rows, tractor hours required to carry mechanical cultivation per hectare was calculated; 0.5 hour were required to carry out mechanical cultivation per hectare.

ii) The cost per tractor hour was shs 15 000/= and was obtained from the field department of Mtibwa Sugar Estates.

3.10.3.7 Cane yield

In carrying out economic analysis average cane yields were used. Economic analysis was carried out only for treatments which yielded ($P \leq 0.05$) higher than or equal to the present recommended weed control practice.

3.10.3.8 Sugarcane price

Both market and field prices of sugarcane used in the economic analysis were set by the management of Mtibwa Sugar Estate. For 1992/93 the market price of sugarcane was shs 4 500 per ton and the field price was obtained by subtracting harvesting (shs 500/ton) and transport costs (1 000 shs/ton) of the crop from the market price.

3.10.3.9 Gross benefits

This was determined by multiplying cane yield and field price of sugarcane. In intercropping and intercropping plus hand weeding plots gross benefit also included benefit from cowpea intercrop which was determined by multiplying yields of cowpea seeds and price of cowpea. Price of cowpea was shs 200/kg.

3.10.3.10 Net benefit

This was obtained by subtracting total variable costs from gross income.

3.10.3.11 Dominance analysis

Dominance analysis separated dominated and undominated treatments before calculation of marginal rates of return. An undominated treatment is one for which there is no alternative treatment with higher net benefit but has lower variable cost. In contrast, a dominated treatment has a lower net benefit and higher variable costs than some other treatments. Dominated treatments were not subjected to marginal analysis since they are economically non viable.

3.10.3.12 Marginal rate of return

Marginal rate of return was calculated by dividing change in net benefit between two treatments by the change in total variable costs.

$$MRR_{A-B} = \frac{\text{net benefit}_{A-B}}{\text{total variable costs}_{A-B}} \times 100$$

Where MRR_{A-B} = Marginal rate of return when moving from treatment A to B

net benefit A-B = Change in net benefit when moving from treatment A to B

total variable costs A-B = Change in total variable costs when moving from treatments A to B.

Marginal rates of return were used as the basis to draw recommendations. The rate of return of cash of 40% was used as a reference profit margin in determining the profitability of the treatments. The choice of 40% was made on the basis of 30% interest charged on loans by banks plus 10% as risk premium.

4.0 RESULTS

4.1 Weed Abundance

Weed counting carried out in the third week after planting just before weed control treatments were applied showed no significant ($P \leq 0.05$) variations in weed distribution (Table 3). Itchgrass was the dominant weed, representing 66% of the total weed population. Other frequent weed species (Tables 4, 5 and 6) included lovegrass (*Setaria verticillata* (L.) beauv.), wild finger-millet (*Eleusine indica* (L.) Gaertn) and goat weed (*Ageratum conyzoides* L.).

4.2 Weed Control

The effect of nitrogen fertilization and different weed control methods on itchgrass population is summarized on table 7. Application of different levels of nitrogen did not cause any significant ($P \leq 0.05$) effect on itchgrass population. Both mulching and intercropping followed by a single handweeding as well as recommended practice reduced numbers of itchgrass to the same level as in the weed free check plots. The above treatments eliminated itchgrass. Basta (2.0 kg a.i/ha), gramuron (3.7 kg a.i/ha) asulam (3.7 kg a.i/ha) and mulching reduced itchgrass population by average of 72% to 88%.

Although intercropping reduced itchgrass population the least, the mean itchgrass count for the treatment was significantly lower ($P \leq 0.05$) than that found in the unweeded treatment (Table 7).

Table 3. Mean weed counts (plants/m^2) at 3 weeks after planting.

Weed control treatment	Rate (kg a.i/ha)	Nitrogen (kg N/ha)			Mean
		0	50	100	
Gramuron	3.2	63	61.4	56.8	60.4
Basta	2.0	66.2	56.8	63.0	62.0
Asulam	3.7	64.6	63.0	66.2	64.6
Mulching		63.0	58.3	69.6	63.6
Mulching+handweeding		74.7	64.6	58.3	65.9
Intercropping		69.6	61.4	68.2	66.4
Intercropping + handweeding		66.2	71.3	72.3	69.9
Recommended practice	4.0	73.0	61.4	66.0	66.9
Weedfree check		66.0	64.7	66.0	65.6
Unweeded check		80.0	74.7	83.6	79.4
Mean		68.6	63.8	66.9	

S.E: Sub-plots (S) = Weed control treatments = 2.8

S.E: Main-plots (M) = Nitrogen levels = 4.0

S.E. M x S = 0.25

C.V: = 10.61%

Table 4. Mean weed counts (Plants/m^2) of main weed species at 0 kg N/ha and different weed control treatments 3 weeks after planting.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (0 kg N/ha)			
		RT	SV	EI	AG
Gramuron	3.2	40.0	10.0	13.0	-
Basta	2.0	44.0	5.0	10.0	7.4
Asulam	3.7	42.6	8.0	-	14.0
Mulching		40.0	-	13.0	10.0
Mulching + handweeding		50.0	16.0	8.7	-
Intercropping		46.1	10.0	5.0	8.5
Intercropping + handweeding		40.0	6.0	6.0	14.2
Recommended practice	4.0	50.2	11.0	11.0	0.8
Weed free check		38.0	4.5	8.0	15.5
Unweeded check		55.0	13.0	6.5	5.5

RT = *Rottboellia cochinchinensis*

SV = *Setaria verticillata*

EI = *Eleusine indica*

AC = *Ageratum conyzoides*

Table 5. Mean weed counts (Plants/m^2) of main weed species at 50 kg N/ha and different weed control treatments 3 weeks after planting.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (50 kg N/ha)			
		RT	SV	EI	AC
Gramuron	3.2	40.5	11.0	5.6	4.3
Basta	2.0	30.0	20.0	6.8	-
Asulam	3.7	50.0	6.0	5.8	1.2
Mulching		38.3	10.0	10.0	-
Mulching + handweeding		42.6	5.0	6.0	11.0
Intercropping		41.0	3.6	7.5	9.3
Intercropping + handweeding		47.0	13.0	4.7	6.6
Recommended practice	4.0	40.5	1.7	10.7	8.5
Weed free check		42.7	1.9	10.0	10.0
Unweeded check		49.3	5.5	8.1	11.8

RT = *Rottboellia cochinchinensis*

SV = *Setaria verticillata*

EI = *Eleusine indica*

AC = *Ageratum conyzoides*

Table 6. Mean weed counts (Plant/m^2) of main weed species at 100 kg N/ha and different weed control treatments 3 weeks after planting.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (100 kg N/ha)			
		RT	SV	EI	AC
Gramuron	3.2	37.0	5.0	8.0	6.8
Basta	2.0	41.6	7.0	7.0	7.4
Asulam	3.7	43.7	10.0	3.0	9.3
Mulching		45.9	23.7	-	-
Mulching + handweeding		38.5	-	19.8	-
Intercropping		40.0	9.4	9.4	9.4
Intercropping + handweeding		47.0	15.0	6.0	3.3
Recommended practice	4.0	46.0	5.0	8.0	7.2
Weed free check		45.6	3.0	-	17.4
Unweeded check		50.0	10.0	7.5	16.1

RT = *Rottboellia cochinchinensis*

SV = *Setaria verticillata*

EI = *Eleusine indica*

AC = *Ageratum conyzoides*

Table 7. Mean itchgrass counts at different levels of nitrogen and weed control treatments 14 weeks after planting.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha)			Mean
		0	50	100	
Gramuron	3.2	18.3 b-e[1]	10.8 b-g[1]	13.5 b-f[1]	14.2 c[1]
Basta	2.0	13.8 b-f	14.3 b-f	17.3 b-e	15.1 c
Asulam	3.7	7.0 fg	9.3 c-g	7.8 c-g	8.0 d
Mulching		5.8 efg	8.0 c-g	5.0 fg	6.3 d
Mulching+handweeding		0.0 g	0.0 g	0.0 g	0.0 e
Intercropping		22.3 b	18.8 bcd	20.3 bc	20.5 b
Intercropping + handweeding		0.0 g	0.0 g	0.0 g	0.0 e
Recommended practice	4.0	0.0 g	0.0 g	0.0 g	0.0 e
Weedfree check		0.0 g	0.0 g	0.0 g	0.0 e
Unweeded check		53.8 a	53.3 a	56.3 a	54.5 a
Mean		12.1 a[2]	11.5 a	11.9 a	

S.E: Sub-plots (S) = Weed control treatment = 0.16

S.E: Main-plots (M) = Nitrogen levels = 0.25

S.E. M x S = 0.15

C.V: = 15.21%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukery's Honestly significant difference test.

Similarly, nitrogen fertilization did not cause any significant (P≤0.05) change in the number of other weed species. The mean weed count was lowest in weed free treatment which was achieved by handweeding after every two weeks. Basta (2.0 kg a.i/ha), asulam (3.7 kg a.i/ha) and gramuron (3.7 kg a.i/ha) controlled other weeds poorly. Nevertheless, these treatments significantly (P≤0.05) reduced weed population below that of unweeded plots (Table 8). The mean number of itchgrass and other weeds which were counted three weeks after planting (before application of weed control treatments) and 14 weeks after planting (11 weeks after weed control treatments were applied) are further compared on Tables 9 and 10.

The trends of dry weights of itchgrass (Table 11) and other weeds (Table 12) were similar to that of their respective counts for the different combinations of nitrogen and weed control treatments.

4.3 Cane Growth

4.3.1 Germination

Germination of cane was not significantly (P≤0.05) affected by either nitrogen fertilization or weed control treatments alone or their interaction (Table 13). The overall mean germination was 66.9%.

Table 8. Mean counts of weeds other than itchgrass at different levels of nitrogen and weed control treatment 14 weeks after planting.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha) 0	50	100	Mean
Gramuron	3.2	11.5 c-f[1]	11.0 c-f[1]	10.0 c-g[1]	10.8 bc[1]
Basta	2.0	11.8 c-f	12.5 cde	14.3 bcd	12.9 cb
Asulam	3.7	13.3 b-e	12.5 cde	15.0 bc	13.6 b
Mulching		8.3 c-g	7.5 c-g	11.5 c-f	9.1 cde
Mulching+handweeding		9.0 c-g	7.8 c-g	5.3 efg	7.4 d
Intercropping		9.0 c-g	9.5 d-g	11.3 c-f	9.9 bc
Intercropping + handweeding		4.0 fg	3.5 fg	7.0 c-g	4.8 d
Recommended practice	4.0	5.8 efg	6.5 d-g	4.5 fg	5.5 d
Weedfree check		0.0 1	0.0 1	0.0 1	0.0 e
Unweeded check		25.0 ab	21.0 abc	24.5 ab	23.5 a
Mean		9.8 a[2]	9.2 a	10.3 a	

S.E: Sub-plots (S) = Weed control treatments = 0.08

S.E: Main-plots (M) = Nitrogen levels = 0.13

S.E. M x S = 0.13

C.V: = 14.39%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukery's Honestly significant difference test.

Table 9. Comparison of itchgrass counts (plant/m^2) at 3 weeks and 14 weeks after planting.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen rate (kg N/ha)					
		0	50	100	0	50	100
		weed numbers at 3 weeks			weed numbers at 14 weeks		
Gramuron	3.2	40	40.5	37.0	18.3	10.8	13.5
Basta	2.0	44	30.0	41.6	13.8	14.3	17.3
Asulam	3.7	42.6	50.0	43.7	7.0	9.3	7.3
Mulching		40	38.3	45.9	5.8	8.0	5.0
Mulching + handweeding		50	42.6	38.5	0.0	0.0	0.0
Intercropping		46.1	41.0	40.0	22.3	18.8	20.3
Intercropping + handweeding		40.0	47.0	47.0	0.0	0.0	0.0
Recommended practice	4.0	50.2	40.5	46.6	0.0	0.0	0.0
Weed free check		38	42.7	45.6	0.0	0.0	0.0
Unweeded check		55	49.3	50.0	53.8	53.3	56.3

Table 10. Comparison of counts of weeds other than itchgrass at 3 weeks and 14 weeks after planting.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen rate (kg N/ha)					
		0	50	100	0	50	100
		weed numbers at 3 weeks			weed numbers at 14 weeks		
Gramuron	3.2	23.0	20.9	19.8	15.1	11.0	10.0
Basta	2.0	22.4	26.8	15.1	11.8	12.4	14.3
Asulam	3.7	22.0	13.0	22.3	13.3	17.5	15.0
Mulching		23.0	20.0	23.7	8.3	7.5	15.5
Mulching + handweeding		24.7	22.0	19.8	9.0	7.8	5.3
Intercropping		23.5	20.4	28.2	9.0	9.5	11.3
Intercropping + handweeding		26.2	24.3	24.3	4.0	3.5	7.0
Recommended practice	4.0	22.8	20.9	20.2	5.8	6.5	4.5
Weed free check		28.0	21.9	20.4	0.0	0.0	0.0
Unweeded check		25.0	25.4	33.6	25.0	21.0	24.5

Table 11. Mean dry weights of itchgrass top growth at different levels of nitrogen and weed control treatments 14 weeks after planting.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha)			Mean
		0	50	100	
Gramuron	3.2	19.8 bcd[1]	20.2 bcd[1]	15.7 bcd[1]	18.6 c[1]
Basta	2.0	22.9 bc	23.8 bc	23.8 bc	23.5 bc
Asulam	3.7	15.3 cd	18.3 bcd	17.5 bcd	17.0 cd
Mulching		18.3 bcd	14.4 d	17.5 bcd	16.7 c
Mulching+handweeding		0.0 e	0.0 e	0.0 e	0.0 d
Intercropping		18.3 bcd	17.3 bcd	19.2 bcd	18.3 c
Intercropping + handweeding		0.0 e	0.0 e	0.0 e	0.0 d
Recommended practice	4.0	0.0 e	0.0 e	0.0 e	0.0 d
Weedfree check		0.0 e	0.0 e	0.0 e	0.0 d
Unweeded check		52.5 a	41.1 a	46.5 a	46.7 a
Mean		14.7 a[2]	13.5a	14.0 a	

S.E: Sub-plots (S) = Weed control treatments = 0.05

S.E: Main-plots (M) = Nitrogen levels = 0.10

S.E. M x S = 0.09

C.V: = 10.11%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukery's Honestly significant difference test.

Table 12. Mean dry weights of top growth of weeds other than itchgrass at different levels of nitrogen and weed control treatments.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha) 0	50	100	Mean
Gramuron	3.2	20.0 b[1]	16.8 bc[1]	19.5 b[1]	18.8 b[1]
Basta	2.0	15.3 bc	18.8 b	19.0 b	17.7 b
Asulam	3.7	18.5 b	17.5 b	15.3 bcd	17.1 b
Mulching		5.7 ef	7.2 def	8.8 c-f	7.2 c
Mulching+handweeding		4.4 ef	2.3 ef	1.3 ef	2.7 d
Intercropping		8.8 c-f	8.9 cde	8.9 cde	8.9 c
Intercropping + handweeding		8.8 c-f	8.3 c-f	5.8 ef	7.6 c
Recommended practice	4.0	2.1 ef	2.5 ef	1.3 ef	2.0 d
Weedfree check		0.0 k	0.0 k	0.0 k	0.0 d
Unweeded check		33.5 a	33.5 a	34.1 a	33.7 a
Mean		11.7 a[2]	11.6 a	11.4 a	

S.E: Sub-plots (S) = Weed control treatments = 0.05

S.E: Main-plots (M) = Nitrogen levels = 0.14

S.E. M x S = 0.12

C.V: = 24.35

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukery's Honestly significant difference test.

Table 13. Mean percentage cane germination at different levels of nitrogen and weed control treatments.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg a.i/ha)			Mean
		0	50	100	
Gramuron	3.2	67.8	66.8	63.8	66.1
Basta	2.0	66.0	65.3	64.0	65.1
Asulam	3.7	65.3	67.3	66.0	66.2
Mulching		66.5	64.3	64.5	64.1
Mulching+handweeding		64.3	68.3	69.0	67.2
Intercropping		65.5	66.5	66.0	66.0
Intercropping + handweeding		69.8	64.8	67.0	67.2
Recommended practice	4.0	69.5	71.5	69.8	70.3
Weedfree check		71.0	69.3	65.3	68.5
Unweeded check		67.3	68.3	68.8	68.1
Mean		67.3	67.2	66.4	

S.E: Sub-plots (S) = Weed control treatments = 0.56

S.E: Main-plots (M) = Nitrogen levels = 1.4

S.E. M x S = 1.35

C.V: = 7.08%

4.3.2 Tillering

The sugarcane tiller counts are given in Table 14. The weed free check plots had the highest tiller counts averaging 13.0 tillers per m^2. Similar ($P \leq 0.05$) levels of tiller counts were recorded for mulching plus hand weeding and recommended practice. Plots which were mulched or intercropped but not hand weeded as well as plots treated with asulam (3.7 kga.i/ha) gramuron (3.2 kga.i/ha) and basta (2.0 kga.i/ha) gave lower numbers of tillers although these were also significantly ($P \leq 0.05$) higher than the tiller counts in the unweeded check plots which averaged 2.3 tillers per m^2.

The population density of tillers was not significantly ($P \leq 0.05$) affected by levels of nitrogen fertilization.

4.3.3 Harvestable stalk counts

There was a tendency of harvestable stalk counts to increase with increasing level of nitrogen fertilization. The weed free check plots and mulching plus hand weeding treatment had the highest stalk counts. Stalk population in each of the two treatments averaged 9.8 per m^2. At each level of nitrogen fertilization stalk population was lowest in the unweeded plots (Table 15).

Table 14. Mean tiller count per m^2 at different levels of nitrogen and weed control treatments.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha) 0	50	100	Mean
Gramuron	3.2	9.7 bcd[1]	8.1 cd[1]	10.2 bcd[1]	9.3 b[1]
Basta	2.0	8.7 bcd	9.6 bcd	9.7 bcd	9.3 b
Asulam	3.7	9.4 bcd	10.1 bcd	10.3 a-d	9.9 b
Mulching		8.2 cd	8.6 bcd	8.7 bcd	8.5 b
Mulching+handweeding		12.7 a-d	13.0 abc	13.5 ab	13.1 a
Intercropping		9.7 bcd	7.7 d	8.0 cd	8.5 b
Intercropping + handweeding		7.7 d	8.3 cd	10.8 a-d	8.9 b
Recommendedpractice	4.0	12.3 abc	12.8 a-d	12.7 a-d	12.6 a
Weedfree check		12.7 a-d	13.4 a	13.0 abc	13.0 a
Unweeded check		2.0 e	2.3 e	2.6 e	2.3 c
Mean		9.3 a[2]	9.4 a	10.0 a	

S.E: Sub-plots (S) = Weed control treatments = 5.8

S.E: Main-plots (M) = Nitrogen levels = 10.4

S.E. M x S = 10.3

C.V: = 18.3%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

Table 15. Mean millable stalk counts per m^2 at different levels of nitrogen and weed control treatments.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha) 0	50	100	Mean
Gramuron	3.2	7.5 def[1]	7.5 def[1]	8.3 a-f[1]	7.8 cd[1]
Basta	2.0	7.5 def	7.9 c-f	8.1 b-f	7.8 cd
Asulam	3.7	8.1 b-f	8.4 a-f	8.5 a-f	8.3 bc
Mulching		7.3 ef	7.6 def	7.2 f	7.4 d
Mulching+handweeding		9.2 a-e	10.0 ab	10.4 a	9.9 a
Intercropping		8.3 a-f	8.4 a-f	8.8 a-f	8.5 bc
Intercropping + handweeding		7.6 def	8.5 a-f	8.5 a-f	8.2 bc
Recommended practice	4.0	8.2 b-f	8.4 a-f	9.4 a-d	8.7 b
Weedfree check		9.7 abc	10.0 ab	10.0 ab	9.9 a
Unweeded check		1.2 g	1.1 g	1.1 g	1.1 e
Mean		7.5 a[2]	7.7 a	8.0 ab	

S.E: Sub-plots (S) = Weed control treatments = 0.2

S.E: Main-plots (M) = Nitrogen levels = 0.2

S.E. M x S = 0.2

C.V: = 8.82%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

4.3.4 Stalk length

The longest harvestable stalks averaging 2.2 m were recorded in plots where 100 kgN/ha was applied and weed control was achieved by mulching plus hand weeding. Millable stalk length for other combinations of nitrogen and weed control treatments was generally shorter but was significantly ($P \leq 0.05$) reduced to the lowest value of 1.6 m without nitrogen application in the unweeded plots (Table 16).

4.4 Cane Quality and Yield

4.4.1 Brix content

Neither nitrogen fertilization nor weed control treatments or their interaction had significant ($P \leq 0.05$) effects on brix content. Generally, the brix values accross the weed control treatments followed no defined trend but ranged between 14.4% and 16.6% (Table 17).

4.4.2 Pol content

There were significant ($P \leq 0.05$) interactions between nitrogen fertilization and weed control treatments on pol content. Table 18 shows that in plots treated with asulam (3.7 kg a.i/ha) or intercropped, increasing nitrogen from zero to 50 kg N/ha decreased pol values significantly ($P \leq 0.05$). Further increase in nitrogen, however, caused slight increases in pol values even though the increases were not significant ($P \leq 0.05$). Similar trends of decreases in pol values with increases in nitrogen levels were observed at various weed control

Table 16. Mean length (m) of harvestable stalks at different levels of nitrogen and weed control treatments.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha)			Mean
		0	50	100	
Gramuron	3.2	1.8 bc[1]	1.7 bcd[1]	1.8 bc[1]	1.8 b[1]
Basta	2.0	1.9 bc	1.8 bc	1.8 bc	1.8 b
Asulam	3.7	1.7 bcd	1.7 bcd	1.8 bc	1.7 bc
Mulching		1.9 bc	1.8 bc	2.0 b	1.8 b
Mulching+handweeding		1.8 bc	2.0 b	2.2 ab	2.0 b
Intercropping		1.8 bc	1.7 bcd	1.7 bcd	1.7 bc
Intercropping + handweeding		1.8 bc	1.8 bc	1.8 bc	1.8 b
Recommended practice	4.0	1.8 bc	1.9 bc	1.8 bc	1.8 b
Weedfree check		1.8 bc	1.9 bc	1.9 bc	1.9 b
Unweeded check		1.5 d	1.6 cd	1.6 cd	1.6 c
Mean		1.8 a[2]	1.8 a	1.8 a	

S.E: Sub-plots (S) =	Weed control treatments	=	0.04
S.E: Main-plots (M) =	Nitrogen levels	=	0.03
S.E. M x S =	0.02		
C.V: =	6.39%		

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

Table 17. Mean brix content (%) at different levels of nitrogen and weed control treatments.

Weed control treatment	Rate (kg a.i/ha)	Nitrogen (kg N/ha)			Mean
		0	50	100	
Gramuron	3.2	16.6	15.4	14.4	15.5
Basta	2.0	14.2	14.6	14.7	14.5
Asulam	3.7	14.7	16.0	15.2	15.3
Mulching		15.5	15.1	15.7	15.4
Mulching+handweeding		15.7	15.5	15.1	15.4
Intercropping		14.1	15.4	14.7	15.7
Intercropping + handweeding		15.5	15.0	14.4	15.0
Recommended practice	4.0	15.3	15.5	15.5	15.4
Weedfree check		15.3	15.1	15.0	15.1
Unweeded check		16.1	15.9	15.3	15.8
Mean		15.3	15.4	15.0	

S.E: Sub-plots (S) = Weed control treatments = 0.21

S.E: Main-plots (M) = Nitrogen levels = 0.25

S.E. M x S = 0.23

C.V: = 5.7%

Table 18. Mean pol content (%) at different levels of nitrogen and weed control treatment.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha) 0	50	100	Mean
Gramuron	3.2	12.9 abc[1]	11.6 abc[1]	12.0 abc[1]	12.2 b[1]
Basta	2.0	11.6 abc	12.9 abc	12.6 abc	12.4 b
Asulam	3.7	13.8 ab	11.2 c	11.7 abc	12.2 b
Mulching		13.5 abc	12.4 abc	13.0 abc	13.0 ab
Mulching+handweeding		13.6 abc	12.5 abc	12.9 abc	13.0 ab
Intercropping		13.8 ab	11.2 c	11.6 abc	12.2 b
Intercropping + handweeding		13.5 abc	11.7 abc	11.5 abc	12.2 b
Recommended practice	4.0	12.5 abc	13.2 abc	11.6 abc	12.4 b
Weedfree check		12.6 abc	12.2 abc	12.5 abc	12.4 b
Unweeded check		14.0 ab	13.8 ab	13.8 ab	13.9 a
Mean		13.2 ab[2]	12.3 b	12.3 b	

S.E: Sub-plots (S) = Weed control treatments = 0.16

S.E: Main-plots (M) = Nitrogen levels = 0.26

S.E. M x S = 0.25

C.V: = 7.2%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

treatments although the changes were not significant ($P \leq 0.05$).

4.4.3 Purity of cane juice

Nitrogen fertilization and weed control treatments interacted significantly ($P \leq 0.05$) for purity of cane juice (Table 19). In plots which were intercropped then hand weeded as well as in plots treated with recommended practice, purity of cane juice at 0 kgN/ha was significantly higher than at 50 kgN/ha. At 100 kg N/ha purity of cane juice in asulam (3.7 kg a.i/ha) as well as intercropping plots was significantly lower than mulching treatment. Purity of cane juice in the remaining combinations of nitrogen and weed control treatments did not differ significantly ($P \leq 0.05$) from each other.

4.4.4 Sucrose content

On the average, the application of 100 kg N/ha significantly ($P \leq 0.05$) reduced sucrose content compared to unfertilized plots (Table 20).

There were significant ($P \leq 0.05$) interactions between nitrogen fertilization and weed control treatments for sucrose content. At 100 kgN/ha, sucrose content in unweeded plots was significantly ($P \leq 0.05$) higher (6.7%) compared to 4.8% recorded for asulam (3.7 kg a.i/ha), intercropping and recommended practice at similar nitrogen level. The remaining combinations of nitrogen levels and weed control treatments did not show any significant variations in sucrose content (Table 20).

Table 19. Mean purity (%) of cane juice at different levels of nitrogen and weed control treatment.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha)			Mean
		0	50	100	
Gramuron	3.2	82.6 abc[1]	80.0 abc[1]	82.8 abc[1]	81.8 ab[1]
Basta	2.0	82.0 abc	88.9 ab	85.8 abc	85.6 a
Asulam	3.7	80.0 abc	80.8 abc	74.4 c	78.4 b
Mulching		87.0 abc	82.0 abc	89.2 a	86.1 a
Mulching+handweeding		86.4 abc	80.7 abc	86.9 abc	84.7 a
Intercropping		85.7 abc	81.4 abc	76.1 bc	81.0 ab
Intercropping + handweeding		89.4 a	76.4 bc	79.0 abc	81.6 ab
Recommended practice	4.0	89.0 a	74.8 c	80.0 abc	81.2 a
Weedfree check		83.1 abc	80.0 abc	83.3 abc	82.1 ab
Unweeded check		81.0 abc	86.9 abc	86.9 abc	84.9 a
Mean		84.6 a[2]	81.2 ab	82.4 ab	

S.E: Sub-plots (S) = Weed control treatments = 0.42

S.E: Main-plots (M) = Nitrogen levels = 0.46

S.E. M x S = 1.3

C.V: = 5.54%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

Table 20. Mean sucrose content (%) at different levels of nitrogen and weed control treatments.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha)			Mean
		0	50	100	
Gramuron	3.2	5.8 a-d[1]	4.8 bcd[1]	5.4 a-d[1]	5.3 b[1]
Basta	2.0	5.2 a-d	6.0 abc	5.7 a-d	5.6 ab
Asulam	3.7	5.1 a-d	6.0 abc	4.8 bcd	5.3 b
Mulching		6.0 abc	5.5 a-d	6.0 abc	5.8 ab
Mulching+handweeding		6.3 ab	5.5 a-d	5.8 a-d	5.9 ab
Intercropping		5.5 a-d	6.3 abc	4.8 bcd	5.5 b
Intercropping + handweeding		6.2 abc	5.1 a-d	5.0 bcd	5.4 b
Recommended practice	4.0	5.5 a-d	6.0 abc	4.8 bcd	5.4 ab
Weedfree check		5.6 a-d	5.3 a-d	5.6 a-d	5.5 ab
Unweeded check		5.8 a-d	6.3 ab	6.7 a	6.3 a
Mean		5.7 a[2]	5.7 ab	5.4 b	

S.E: Sub-plots (S) = Weed control treatments = 0.07

S.E: Main-plots (M) = Nitrogen levels = 0.10

S.E. M x S = 0.16

C.V: = 10.02%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

4.4.5 Cane yields

The effect of nitrogen fertilization on cane yield was significant ($P \leq 0.05$). Application of 50 kgN/ha increased cane yield by 14% over that of unfertilized plots (Table 21).

The weed free check, mulching plus hand weeding, asulam (3.7 kga.i/ha) and recommended practice treatments resulted in the highest yields. The lowest cane yields were recorded in the unweeded plots.

4.4.6 Sugar yields

Application of 100 kgN/ha significantly ($P \leq 0.05$) increased sugar yields compared to unfertilized plots (Table 22).

Nitrogen fertilization and weed control treatments interacted significantly for sugar yield. At 0 kg N/ha sugar yield was significantly ($P \leq 0.05$) lower in unweeded and intercropping plots compared to other weed control treatments. At 50 kg N/ha, sugar yield at mulching plus hand weeding was significantly ($P \leq 0.05$) higher than in gramuron (3.2 kg a.i/ha), mulching, intercropping, intercropping plus hand weeding and unweeded plots. At 100 kg N/ha sugar yield in mulching plus handweeding was significantly ($P \leq 0.05$) higher than in intercropping, intercropping plus handweeding and unweeded plots.

Table 21. Mean cane yield (tons/ha) at different levels of nitrogen and weed control treatments.

Weed control treatment	Rate (kg a.i/ha)	Nitrogen (kg N/ha) 0	50	100	Mean
Gramuron	3.2	64.4 e-h[1]	68.9 d-g[1]	72.0 b-e[1]	68.4 c[1]
Basta	2.0	70.1 c-f	79.0 a-d	86.4 a	78.5 b
Asulam	3.7	83.1 abc	85.0 ab	89.9 a	86.0 a
Mulching		52.5 hi	52.3 hi	60.6 e-h	55.1 d
Mulching+handweeding		82.0 a-d	84.3 ab	90.0 a	85.4 a
Intercropping		30.6 j	31.8 j	33.8 j	32.1 e
Intercropping + handweeding		42.4 ij	55.6 ghi	58.8 fgh	52.3 d
Recommended practice	4.0	82.5 a-d	84.3 ab	89.9 a	85.6 a
Weedfree check		84.3 ab	87.5 a	92.5 a	88.1 a
Unweeded check		11.7 k	11.4 k	11.4 k	11.5 f
Mean		60.4b[2]	64.0ab	68.5 a	

S.E: Sub-plots (S) = Weed control treatments = 0.44

S.E: Main-plots (M) = Nitrogen levels = 0.74

S.E. M x S = 1.34

C.V: = 7.46%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

Table 22. Mean sugar yields (tons/ha) at different levels of nitrogen and weed control treatments.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha) 0	50	100	Mean
Granuron	3.2	3.4 c-i[1]	3.3 d-i[1]	3.8 a-i[1]	3.5 b[1]
Basta	2.0	3.6 b-i	4.8 a-d	4.9 abc	4.4 a
Asulam	3.7	4.3 a-h	4.9 abc	4.1 a-g	4.4 a
Mulching		3.3 d-i	2.9 g-k	4.0 a-g	3.4 b
Mulching+handweeding		4.6 a-f	5.1 ab	5.2 ab	5.0 a
Intercropping		1.6 jkl	1.7 jkl	1.8 jkl	1.7 c
Intercropping + handweeding		2.6 ijk	2.8 hij	3.2 f-i	2.9 b
Recommended practice	4.0	4.5 a-f	4.5 a-f	5.1 ab	4.7 a
Weedfree check		4.7 a-e	4.7 a-e	5.1 ab	4.8 a
Unweeded check		0.6 l	0.7 l	0.7 l	0.7 d
Mean		3.3 b[2]	3.5 ab	3.8 a	

S.E: Sub-plots (S) = Weed control treatments = 0.05

S.E: Main-plots (M) = Nitrogen levels = 0.15

S.E. M x S = 0.15

C.V: = 14.15%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

4.4.7 Cowpea yield

There was a tendency of yields of cowpea to increase with increasing nitrogen fertilization. Intercropping plus hand weeding generally yielded higher amount of cowpeas than intercropping alone (Table 23).

Table 23. Mean yields (kg/ha) of cowpea seeds at different levels of nitrogen and intercropped treatments.

Weed control treatment	Nitrogen rate (kg N/ha)			
	0	50	100	Mean
Intercropping	38.8	44.8	45.8	42.6
Intercropping + hand weeding	74.3	78.0	85.5	77.3
Mean	56.3	61.4	65.6	

4.4.8 Correlations between yield parameters of sugarcane and weeds

Sugarcane yields were positively correlated with number of sugarcane tillers (r = 0.776) number of harvestable stalks (r = 0.734) and harvestable stalk length (r = 0.433) as shown on Table 24.

Among the cane growth parameters tiller counts, harvestable stalk number and stalk length were negatively correlated with itchgrass counts as well as population density of other weeds (Table 24). Sucrose content positively correlated with itchgrass and other weed count (Table 24).

Table 24. Correlation coefficients between pairs of different parameters of sugarcane and weeds.

Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Germination													
2. Tillering	0.081												
3. Stalk count	-0.039	0.759*											
4. Itchgrass count	-0.025	-0.749*	-0.850*										
5. Other weed counts	-0.109	-0.662*	-0.774*	0.792*									
6. Harvestable stalk length	-0.052	0.399*	-0.473*	-0.886*	-0.847*								
7. Brix content	0.220*	-0.118*	-0.174*	-0.453*	-0.024	0.056							
8. Pol content	0.140*	-0.113	-0.307*	-0.089	-0.121*	0.047	0.081						
9. Purity	-0.028	0.029	0.208*	-0.201*	-0.123*	0.068	0.093	0.145*					
10. Cane yield	0.047	0.776*	0.734*	-0.657*	-0.516*	0.433*	-0.048	-0.159*	-0.130*				
11. Sucrose content	0.081	-0.116	-0.305*	0.507*	0.502*	0.036	0.429*	0.961*	0.836*	0.181*			
12. Sugar yield	0.074	0.762*	0.681*	-0.725*	-0.509*	0.438*	0.057	0.117	0.125*	0.945*	0.111		
13. Net proft	0.037	0.771*	0.742*	-0.751*	-0.531*	0.457*	-0.065	-0.131	-0.077	0.945*	-0.139*	0.907*	1.000

* Denote significant difference at $P \leq 0.05$ level of significance.

4.4.9 Coefficient of determination between parameters of sugarcane and weeds on cane yield

Results of coefficient of determination (r^2) analysis are given in Table 25. Important factors which contributed to cane yield are tillering and harvestable stalk counts with coefficient of determination values of 0.60 and 0.53, respectively. On the other hand itchgrass and other weeds reduced cane yield with coefficient of determination of 0.43 and 0.26%, respectively.

Table 25. Coefficient of determination of some sugarcane parameters and weeds on cane yield.

Parameter	Coefficient of determination (r2)
Tiller count	0.60
harvestable stalk count	0.53
harvestable stalk length	0.19
Itchgrass count	0.43
Other weed count	0.26

4.5 Economic analysis

Statistical analyses of net benefit showed significant differences between weed control treatments. Net benefit from sugarcane and cowpeas in intercropped treatments were lower than that from the recommended practice. However, no differences due to nitrogen level or interaction between nitrogen and weed control treatments were detected (Table 26).

A partial budget for weed control treatments which gave yields equal or higher ($P \leq 0.05$) than the recommended practice applied with 50 kg N/ha is presented in Table 27.

The maximum net profit of shs. 251 777.00/ha was obtained in plots which were supplied with 100 kg N/ha, then mulched and supplemented with hand weeding. When nitrogen was not applied, mulching plus hand weeding had the lowest total variable costs while asulam (3.7 kg a.i/ha) used in combination with 100 kg N/ha resulted in the highest total variable costs.

Dominance analysis showed that mulching plus hand weeding at 100 kg N/ha, 50 kg N/ha and 0 kg N/ha were undominated treatments (Table 28). Marginal analysis showed the highest marginal rate of return of 192% when changing from mulching plus hand weeding at 50 kg N/ha to mulching plus hand weeding at 100 kgN/ha (Table 29).

Table 26. Net benefit (shs/ha) at different levels of nitrogen and weed control treatments.

Weed control treatments	Rate (kg a.i/ha)	Nitrogen (kg N/ha) 0	50	100	Mean
Gramuron	3.2	177 880.0 gh[1]	185 239.0 efg[1]	190 533.3 d-g[1]	184 550.8 c[1]
Basta	2.0	188 130.0 d-g	219 413.0 abc	226 106.8 a-d	211 216.6 b
Asulam	3.7	225 130.0 bcd	231 619.8 abc	231 619.8 abc	229 456.7 b
Mulching		152 040.0 ghi	145 311.6 hij	167 132.0 ghi	154 827.9 d
Mulching+handweeding		242 780.0 ab	240 894.8 ab	251 777.0 ab	245 150.6 a
Intercropping		111 000.0 jk	90 811.5 k	92 392.0 k	98 067.8 e
Intercropping + handweeding		132 985.0 ij	163 281.5 ghi	165 702.0 ghi	153 989.5 d
Recommended practice	4.0	229 795.0 abc	228 616.8 abc	220 627.0 b-e	226 346.3 b
Weedfree check		249 080.0 ab	252 653.0 ab	264 422.0 a	255 385.0 a
Unweeded check		39 375.0 l	28 483.2 l	22 529.5 l	30 129.2 f
Mean		174 819.5 ab[2]	178 632.4 ab	183 284.1 a	

S.E: Sub-plots (S) = Weed control treatment = 2 500.0

S.E: Main-plots (M) = Nitrogen levels = 3 326.4

S.E. M x S = 7 437.2

C.V: = 14.53%

[1,2] Values in the same column and rows respectively, followed by the same letters do not vary significantly ($P \leq 0.05$) by Tukey's Honestly significance difference test.

Table 27. Partial budget of weed control.

Weed control treatments	Herbicide kg a.i/ha	Nitrogen kg N/ha	Cane yield ton/ha	Gross income Shs/ha	Fertilizer costs Shs/ha	Fertilizer application costs Shs/ha	Herbicide costs Shs/ha	Herbicide application costs Shs/ha	Mulch transport costs Shs/ha	Mulch application costs Shs/ha	Hand weeding costs Shs/ha	Mechanical cultivation costs Shs/ha	Total variable costs Shs/ha	Net benefit Shs/ha
Basta	2.0	50.0	79.0	237 000.00	5 576.76	351.60	21 000.00	245.00	-	-	-	-	27 173.30	209 826.80
Basta	2.0	100.0	86.4	259 200.00	11 153.40	629.60	21 000.00	245.00	-	-	-	-	33 028.00	226 172.00
Asulam	3.7	0.0	84.1	252 300.00	-	-	25 000.00	245.00	-	-	-	-	25 245.00	224 130.00
Asulam	3.7	100.0	89.9	269 700.00	11 153.4	629.60	25 000.00	245.00	-	-	-	-	37 028.00	232 672.00
Mulching + handweeding	-	0.0	82.0	246 000.00	-	-	-	-	3 500.00	1 960.00	980.00	-	6 440.00	239 560.00
Mulching + handweeding	-	50.0	84.3	252 900.00	5 576.70	351.60	-	-	3 500.00	1 960.00	980.00	-	12 368.30	240 531.30
Mulching + handweeding	-	100.0	90.0	270 000.00	11 153.40	629.60	-	-	3 500.00	1 960.00	980.00	-	18 223.00	251 777.00
Recommended practice	4.0	0.0	82.5	247 500.00	-	-	8 000.00	245.00	-	-	1 960.00	7 500.00	17 705.00	229 795.00
Recommended practice	4.0	50.0	84.3	252 900.00	5 576.70	351.6	8 000.00	245.00	-	-	1 960.00	7 500.00	23 633.30	229 266.70
Recommended practice	4.0	100.0	89.9	269 700.00	11 153.40	629.60	8 000.00	245.00	-	-	1 960.00	7 500.00	29 468.00	220 287.00

Table 28. Dominance analysis of weed control responses.

Net profit Shs/ha	Weed control treatment	Rate (kg a.i/ha)	Nitrogen (kg N/ha)	Total variable costs Shs/ha
251 777.0	Mulching + handweeding	-	100	18 223.0*
240 531.8	Mulching + handweeding	-	50	12 368.3*
239 560.0	Mulching + handweeding	-	0	6 440.0*
232 672.0	Asulam	3.7	100	37 028.0
229 795.0	Recommended practice	4.0	0	17 705.0
229 266.7	Recommended practice	4.0	50	23 633.3
226 172.0	Basta	2.0	100	33 028.0
224 130.0	Asulam	3.7	0	25 245.0
223 826.8	Asulam	3.7	50	31 173.0
220 287.0	Recommended practice	4.0	100	29 488.0
209 826.8	Basta	2.0	50	27 173.3

* Undominated treatments

Table 29. Marginal analysis of undominated treatments for cash.

Treatment	Net benefit	Total variable costs	Marginal increase in net benefit	Marginal increase in variable costs	Marginal rate of return
	Shs/ha				
Mulching plus hand weeding at 100 kgN/ha	251 777.00	18 223.00	11 246.00	5 854.75	192%
Mulching plus hand weeding at 50 kgN/ha	240 531.75	12 368.25	971.75	5 924.25	16%
Mulching plus hand weeding at 0 kg N/ha	239 560.00	6 440.00	-	-	-

5.0 DISCUSSION

5.1 Weed Control

The cropping season (1992/93) during which the experiment was conducted received higher rainfall than that of the previous ten year average. November and April were the wettest months and they received 275 mm and 300 mm of rainfall respectively. During the period, itchgrass was the dominant weed species followed by lovegrass, wild finger millet and goat weed. Growth of weeds in the unweeded plots was generally good implying that the rains favoured weed growth.

Gramuron (3.2 kg a.i/ha), basta (2.0 kg a.i/ha) and asulam (3.7 kg a.i/ha) were significantly effective in controlling itchgrass. Asulam (3.7 kg a.i/ha) reduced itchgrass population by average of 88% while control levels achieved after application of basta (2.0 kg a.i/ha) and gramuron (3.2 kg a.i/ha) averaged 72% and 77%, respectively. Effective control of itchgrass using the same herbicides has been observed by other workers. From a study carried out in the USA, Millhollon (1984) reported good control of itchgrass 10-20 cm in height using asulam (3.7 kg a.i/ha). On the other hand, Hoechest (undated) reported efficacy of basta (2.0 kg a.i/ha) in controlling itchgrass plants 5-20 cm in height. The Imperial Chemical Industries (undated) reported good control of itchgrass plants using gramuron at a rate of 3.2 kg a.i/ha. In this study, asulam (3.7 kg a.i/ha), basta (2.0 kg a.i/ha) and gramuron (3.2 kg a.i/ha) were however, less effective against weeds other than itchgrass which included lovegrass, goat weed and wild finger millet. The cause for the low herbicidal effects on weeds other than itchgrass could not be well established. However, most of the weeds which were not affected by the herbicides were observed to emerge two weeks after the herbicides had been applied as post-emergence sprays indicating that the weeds had no contact with herbicides and consequently not affected. This suggests that an additional herbicide application or supplementary control operation was needed in order to control weeds which emerged after the herbicides application.

Intercropping proved unsatisfactory for control of itchgrass and other weed species as well. The growth of itchgrass and other weeds was considerably reduced during the active growth period of cowpeas (between 15-30 days after planting). However, when cowpeas approached maturity (50 days after planting), weeds in turn exhibited vigorous growth. This was ascribed to the fact that senescence of cowpea plants opened up cowpea canopy which exposed weeds thus allowing greater light interception and consequently increasing photosynthesis rate which resulted into rapid growth. In studies conducted earlier by Patterson (1979), itchgrass was described as a shade intolerant species but capable of rapid growth when exposed to intense solar radiation.

In this study cane trash mulch reduced itchgrass count by an average of 85% indicating that the method was significantly effective in controlling itchgrass. The results are in agreement with earlier findings by Mathur and Saksena (1965) who reported effective control of weeds in a sugarcane crop when sugarcane trash mulch was used. Control levels of itchgrass and other weeds which resulted from mulching plus hand weeding or intercropping plus hand weeding and recommended practice were higher than those given by mulching, intercropping, gramuron (3.2 kg a.i/ha) and basta (2.0 kg a.i/ha) as sole treatments. The results are comparable with those earlier reported by Humbert (1968) and Millhollon (1984) who found that successful control of itchgrass and other weeds in general, in sugarcane, was dependent on integration of cultural, chemical and mechanical weed control methods.

5.2 Cane Growth, Yield and Quality

Nitrogen fertilization significantly ($P \leq 0.05$) increased cane yield. Similar trends of cane yield increases due to nitrogen fertilizer application have been reported elsewhere (Wood, 1968; Patil *et al*., 1970; Ojha *et al*., 1974) implying that absence of nitrogen limits cane production.

Generally plots which were mulched and then hand weeded as well as those hand weeded after every two weeks or in which weeds were controlled using the recommended practice provided better control of itchgrass and other weeds resulting in producing higher cane yields. Increase in cane yield due to effective control of weeds has also been reported by other workers. Humbert (1968) found that cane yield was more than double after weeds were brought under control. On the other hand Millhollon (1992) reported 70% increase in cane yield as a result of control of itchgrass. Increase in cane yield is attributed to good cane growth resulting from reduced competition from itchgrass and other weeds (Gosnell, 1965; Humbert, 1968).

Although intercropping plus hand weeding was as effective as mulching plus hand weeding, or recommended practice in weed control, the cane yield realized under intercropping conditions was reduced by an average of 40% compared to yields from other weed control treatments. This could be attributed to competition between sugarcane and cowpea plants. Since cane plants were taller than cowpeas and soil moisture was not limiting as the experiment was supplemented with irrigation in dry periods, cane plants were not competing for light and moisture. Competition was therefore, mainly for nutrients. The cowpeas grown in the interrow spaces of sugarcane crop in this experiment possibly reduced nutrients which could be available to cane crop and which could help to increase cane growth. The possibility of reduced nutrients available to sugarcane could possbly account for reduction in cane yield observed in the intercropping plus hand weeding treatment. Reduction of cane yield due to intercropping has been reported by Bose and Ashraf (1972) who found 24.6% reduction in cane yield when sugarcane was intercropped with cowpeas.

There were significant positive correlations between cane yield and tiller count (r=0.766), stalk population (r=0.734) and stalk length (r=0.433). These results agree with those reported by Fute (1990). The fact that cane yield was positively associated with these yield components indicates that cane yield can appreciably be increased by increasing tillering, stalk population and stalk length. On the basis of corresponding coefficients of determination (r^2) for tiller counts (r^2=0.60), stalk population (r^2=0.53) and stalk length (r^2=0.19) tiller count was the most important factor which contributed to cane yield. Treatments where these parameters were higher were weed free check, mulching plus hand weeding and recommended practice. Itchgrass (Millhollon, 1992) and weeds in general (Ibrahim, 1984) have been reported to reduce tillering, stalk population and stalk length of sugarcane. In this study tillering, stalk population and stalk length were lowest in unweeded plots providing further evidence that these parameters were affected by itchgrass and other weeds resulting in reduced cane yields.

Sucrose content which is the main parameter of sugarcane quality was generally low. The overall mean sucrose content for the crop under study was 5.3%. This is markedly below the average sucrose content of 8.5% (Kiyumbi, Personal Communication) for the estate in the last five years. The low sucrose content could be attributed to the prevailing environmental conditions at the time of harvesting. The crop was harvested at the end of June, 1993 when soils were still moist owing to rains which continued until 20 days before harvesting. According to Alexander (1973) excess soil moisture is detrimental to cane ripening because it encourages vegetative growth rather than accumulation of sucrose in stalks.

Application of 100 kg N/ha significantly ($P \leq 0.05$) reduced sucrose content. This relationship has also been reported by other workers (McAleese *et al.*, 1970 Singh 1974; Patil *et al.*, 1979). Wang (1979) attributed such effects to high uptake and assimilation of applied N by cane plants which consequently impaired sucrose accumulation in stalks.

Sucrose content was positively correlated with population density of itchgrass (r=0.507) or other weeds (r=0.502) implying that weed infestation increased sucrose content. This was attributed to reduced cane growth caused by weed competition. Millhollon (1992) found that in a sugarcane field where itchgrass was not controlled growth of sugarcane was reduced especially tillering, stalk population and stalk length and the cane tended to store more sugar rather than using it as energy source for growth processes.

Nitrogen fertilization and weed control treatment interacted significantly for sucrose content. At 100 kg N/ha, for example, sucrose content in the unweeded plots was higher (6.7%) than the level (4.8%) recorded from plot treated with asulam (3.7 kg a.i/ha), intercropped or where recommended practice was used. On the other hand, sucrose content in other combinations of nitrogen and weed control treatments was intermediate and comparable. These results indicate that sucrose content was not appreciably changed at levels of 0 and 50 kg N/ha regardless of weed control treatments.

The brix values varied between 14.1% and 16.1%. These values are below the 20% minimum brix figure (Acland, 1971) required for harvestable cane. According to Acland (1971) about 80% of soluble solids in cane juice is sucrose. This suggests that excess soil moisture which causes low sucrose content in cane (Alexander, 1973) may also account for the low brix values observed.

The consequence of high cane yields where 100 kg N/ha was applied was to increase sugar yields. In plots where weed control was achieved by basta (2.0 kg a.i/ha), asulam (3.7 kg a.i/ha), hand weeding after every two weeks, mulching plus hand weeding and recommended practice, sugar yields were higher than in other weed control treatments. However, since sucrose content was generally low and sugar yield is a product of cane yield and sucrose content, the higher yields of sugar are attributed to higher cane yield recorded in the treatments rather than the sucrose content.

Nitrogen application did not cause significant change in pol and juice purity values. These results are in contrast with those reported by Valdivia *et al.*, (1978) who found decreases in pol and purity values with increases in nitrogen when using variety HC 32-8560. Since different varieties may differ in their ability to utilize nitrogen (Clements, 1962) the difference in the results reported here could be a manifestation of varietal differences. Effects of itchgrass control on pol content or purity of cane juice is not well documented but the positive correlations between itchgrass counts and pol values (r=0.961) or juice purity (r=0.836) indicate that these parameters were positively influenced by itchgrass infestation.

5.3 Economic Analysis

Adoption of any agricultural practice to a large extent is governed by its economics. To ensure that agronomically acceptable treatments were also economical, treatments which yielded equal or higher amount of cane than the estate weed control practice were subjected to economic analysis. Dominance analysis showed that the weed control practice currently being practised at Mtibwa Sugar Estates was one of the dominated treatments and therefore uneconomical. Dominated treatments were not considered for marginal analysis because there were alternative treatments with higher net profit and lower total variable costs (Perrin *et al.*, 1977). Mulching plus hand weeding at 0, 50 and 100 kg N/ha were undominated treatments. Mulching plus hand weeding at 100 kg N/ha had the highest marginal rate of return of 192%. This implies that for every shilling invested in mulching plus hand weeding and 100 kg N/ha would give a return of shillings 1.92. On the other hand investing on mulching plus hand weeding and 50 kg N/ha would give a return of shilling 0.16 (marginal rate of return 16%). The marginal rate of return obtained from mulching plus hand weeding at 100 kg N/ha exceeded the target rate of return of 40% indicating that the treatment would generate profit in addition to paying for the cost of capital management of the new weed control practice.

On the basis of marginal rate of returns mulching plus hand weeding applied together with 100 kg N/ha would be the most economical treatment for itchgrass control in sugarcane particularly when labour is not limiting. A farmer choosing to adopt this treatment, would spend shillings 18,223.0 to get a net benefit of shillings 251,777.0 per hectare. However, when labour (for mulch application) is limiting as it is the case at Mtibwa Sugar Estate (Stekernburg, 1992), asulam (3.7 kg a.i /ha) would be a better choice. In this case extra shillings 19,205.0 would be spent and the net benefit of shillings 232,672.0 per hectare would be obtained.

6.0 CONCLUSION AND RECOMMENDATIONS

The following conclusions were drawn on the basis of this study:-

1. Infestation of itchgrass and other weeds reduced sugarcane yield by an average of 86.8% when compared to weed free cane.

2. Mulching plus hand weeding, intercropping plus hand weeding and recommended practice eliminated itchgrass and considerably reduced weeds other than itchgrass.

3. Nitrogen fertilization had no effect on control of itchgrass and other weeds.

4. Nitrogen at 100 kgN/ha increased cane yield by 14% when compared to unfertilized plots. Asulam (3.7 kga.i/ha), mulching plus hand weeding and recommended practice showed higher cane yield than the weed free check treatment.

5. Economic analysis of treatments which yielded equal or greater amounts of cane than the currently recommended practice showed that the estate weed control practice was undominated and therefore uneconomical. The highest marginal rate of return (MRR) was 192% obtained after mulching plus hand weeding in plots

applied with 100 kgN/ha. This MRR was above the targeted rate of 40%.

6. Because of the high marginal rate of return of 192% mulching plus hand weeding at 100 kg N/ha is recommended for itchgrass control in sugarcane particularly when labour is not limiting. However, when labour is limiting herbicide asulam (3.7 kg a.i/ha) at 100 kg N/ha is a better alternative.

7. Further studies are recommended to cover the nature of the competition between sugarcane and itchgrass and on the factors influencing the degree to which sugarcane yields are affected. These will be useful in assessing the extent to which control of the weed is necessary and in devising control measures.

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Appendix A1: Statistical significance of analysed variables.

PARAMETER	NITROGEN (N)	WEED CONTROL (W)	NxW
Weed count, 3 weeks	ns	ns	ns
Itchgrass count, 14 weeks	ns	*	ns
Other wed count, 14 weeks	ns	*	ns
Itchgrass dry matter, 14 weeks	ns	*	ns
Other weed dry matter, 14 weeks	ns	*	ns
Germination	ns	ns	ns
Tillering	ns	*	ns
Harvestable stalks/m^2	ns	*	ns
Harvestable stalk length	ns	*	ns
Brix content	ns	ns	ns
Pol content	ns	*	*
Purity of cane juice	ns	*	*
Sucrose content	*	*	*
Cane yield	*	*	ns
Sugar yield	*	*	*
Net profit	ns	*	ns

ns = non significance
* Significance at $P \leq 0.05$

Appendix A2: Summary of analysis of variance for nitrogen levels (Main Plots)

PARAMETER	TREATMENT MEAN SQUARE	ERROR MEAN SQUARE	$F_{(2,6)*}$
Weed count, 3 weeks	1.244	1.010	4.76
Itchgrass count, 14 weeks	0.099	0.305	0.324
Other weed count, 14 weeks	0.225	0.243	0.930
Itchgrass dry matter, 14 weeks	0.056	0.085	0.660
Other weed dry matter, 14 weeks	0.131	0.018	1.620
Germination	7.408	12.764	0.580
Tillering	4.8x104	3.7×10^4	1.290
Harvestable stalk/m^2	4.0×10^4	1.1×10^4	3.60
Harvestable stalk length	0.075	0.065	1.150
Brix content	1.206	1.728	0.70
Pol content	1.627	1.050	1.550
Purity of cane juice	35.60	7.222	4.930
Sucrose content	1.785	0.268	6.660
Cane yield	678.234	35.62	19.040
Sugar yield	1.972	0.207	9.527
Net profit	1.1×10^9	1.9×10^9	0.579

*Tabulated value for $P \leq 0.05$ = 5.14.

Appendix A3: Summary of analysis variance for weed control treatments (Sub Plots)

PARAMETER	TREATMENT MEAN SQUARE	ERROR MEAN SQUARE	$F_{(9,81)}$*
Weed count, 3 weeks	1.156	0.752	1.54
Itchgrass count, 14 weeks	52.826	0.246	214.7
Other weed count, 14 weeks	13.326	0.201	66.30
Itchgrass dry matter, 14 weeks	54.150	0.112	483.48
Other weed dry matter, 14 weeks	27.369	0.234	117.19
Germination	35.742	22.458	1.59
Tillering	$1.4x10^5$	$3.6x10^3$	38.55
Harvestable stalk/m^2	$7.7x10^5$	$5.2x10^3$	15.53
Harvestable stalk length	0.162	0.013	12.33
Brix content	4.728	0.751	6.3
Pol content	4.493	0.811	5.54
Purity of cane juice	120.927	20.856	4.02
Sucrose content	2.518	0.312	8.012
Cane yield	$8.2x10^3$	22.998	356.552
Sugar yield	24.878	0.265	93.76
Net profit	$6.4x10^5$	$1.9x10^5$	89.9

*Tabulated value for $P \leq 0.05$ = 1.96

Appendix A4: Summary of analysis of variance (Nitrogen x Weed Control).

PARAMETER	TREATMENT MEAN SQUARE	ERROR MEAN SQUARE	$F_{(9,81)}$*
Weed count, 3 weeks	0.238	0.752	0.32
Itchgrass count, 14 weeks	0.246	0.203	1.21
Other weed count, 14 weeks	0.262	0.201	1.31
Itchgrass dry matter, 14 weeks	1.182	0.112	1.63
Other weed dry matter, 14 weeks	0.272	0.231	1.16
Germination	12.464	22.458	0.55
Tillering	$3,5x10^4$	$3.6x10^4$	0.99
Harvestable stalk/m^2	$3.3x10^3$	$5.2x10^3$	0.64
Harvestable stalk length	0.033	0.023	1.43
Brix content	0.732	0.751	0.98
Pol content	2.094	0.811	2.58
Purity of cane juice	68.719	20.856	3.29
Sucrose content	1.017	0.312	3.25
Cane yield	33.575	22.998	1.46
Sugar yield	1.017	0.312	3.25
Net profit	$3.2x10^6$	$2.0x10^6$	1.61

a* Tabulate value for $P \leq 0.05$ = 1.662

Appendix A5: Monthly rainfall during crop period (Nov. 1992 - Jun. 1993) and 10 year (1983 - 1992) monthly means at Mtibwa Sugar Estates.