INTERFERENCE OF MEXICAN MARIGOLD (*Tagetes minuta* L) ON GROWTH AND YIELD OF MAIZE (Zea mays L)

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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Interference of Mexican Marigold (*Tagetes minuta L*) on growth and yield of maize (Zea mays L),

ABSTRACT

Damage caused by weeds and the cost of their control constitute one of the largest losses in production of feed, food and fiber. This study was conducted to determine whether application of recommeded fertilizer rate influence the critical period of competition between *Tagetes minuta* and maize . Inter and intraspecific competition between the weed and the crop was determined in potted green house, replacement series experiments.

The period when competition begins in the field was determined by allowing the weed to grow from crop emergence for varying lengths of time and then kept weed –free till harvesting. Length of required weed-free period for maximum yield was determined by keeping the crop weed-free for varying periods after emergence and then permiting weed growth the rest of the season. Both the weed and

crop parameters were measured. The experiment was conducted at the University of Nairobi, Kabete Campus Field Station, on reddish brown Humic Nitosol.

In greenhouse experiments increasing maize proportion in pots caused significant reduction in all growth and yield parameters. Plant relative yield (PRY) of maize was less than one under fertilization and no fertilization and decreased as the proportion of *T.minuta* increased in pots, indicating that maize was more affected by interspecific than intraspecific competition.

A mixture of maize and *T.minuta* significantly depressed plant height, irrespective of the proportion of the crop and the weed, below that of a single maize or *T.minuta* plant per pot at both fertilization levels(fertilizer and no fertilizer). Also other parameters such as total, root, stem, and leaf dry weight ratios followed the same trend. The differences in the amount of total dry matter production in experiments(1and2) were attributed to differences in leaf area, leave area duration of the canopy and the total amount of solar radiation intercepted. As planting proportion increased the LA was decreased due to competition. All other parameters such as specific leaf weight, leaf area ratio, crop growth rate, relative growth rate and net assimilation rate followed the same trend.

In field experiments maintaining maize free of *T. minuta* for the first 30 days of growth during 1996 resulted in significant increase in grain yield relative to full season interference (P=0.05) at both recommended and zero fertilization. In zero fertilizer application *T. minuta* interference for 50 days or more significantly reduced grain yields. Weed dry matter yields were generally higher in 1996 than 1997.

Linear regression predicted a significant maize yield increase of 160 Kg/ha and non-significant yield increase of 0.48 Kg/ha for each week of *T. minuta* weed - free maintenance in 1996 and 1997 respectively. Linear regression predicted significant maize yield reduction of 252.2 Kg/ha and non-significant yield reduction of 40 Kg/ha for each week of *T. minuta* interference in 1996 and 1997 respectively. The critical period for *T. minuta* interference in maize with zero fertilizer application was found to be within the 50 days after planting. Uncontrolled Mexican *marigold* population decreased maize grain yields by 59 and 38% during 1996 and 1997 respectively. On the other hand, under recommended fertilizer application *T. minuta* interference for 60 days or more significantly reduced grain yield. Also weed dry matter yields were generally higher in 1996 than in 1997. No significantly yield increases or reductions were obtained in weed-free or weed-interference treatments respectively.

Linear regression predicted a significant maize yield increase of 135 and 109.5 Kg/ha for each week of *T. minuta* weed -free maintenance in 1996 and 1997 respectively. Linear regression predicted a significant maize yield reduction of 152 Kg/ha and non-significant yield reduction of 51.1 Kg/ha for each week of *T. minuta* interference in 1996 and 1997 respectively. The critical period of *T. minuta* interference in maize with fertilizer application was found to be within the first 60 days after planting. Uncontrolled *T.minuta* populations decreased maize grain yield by 38 and 47% during 1996 and 1997 respectively.

Maize plants were found to be more competitive during early stages of growth than the weed. Also this studies indicated that application of recommended fertilizer rates reduces competition between *T.minuta* and maize.

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CHAPTER ONE

1.0. INTRODUCTION

1.1 Maize an important food and cash crop in East Africa

In most economies, at an early stage of development, starchy food-stuffs account for 70 to 90 percent of the calories produced and consumed in tropical Africa. Of the major starchy staple food crops, maize is the most widely grown. In fact it is present in every a sizable area where food crops can be raised, in most parts of Africa. Millets, sorghums and cassava are also of high calorific value in most parts of Africa.

Maize commonly became of major importance where foodstuffs had to be transported considerable distances to feed labourers and populations that were not self-sufficient. In a number of such regions maize has within the past three or four decades almost completely replaced traditional starchy food stuffs such as the millets and sorghums. It has also at one time or another been a major export of several tropical African countries. Thus its position in diets and commerce, and its potential role in increasing productivity in agriculture make maize of special interest in the study of tropical African economies.

The main reasons for the popularity of maize are as follows, it has a higher yielding potential than indigenous cereals with satisfactory rainfall and free draining soil; it is seldom seriously damaged by pests or diseases in the field seldom seriously damaged by pests or diseases in the field and is virtually untouched by birds, which can cause complete yield losses in indigenous cereals such as sorghum and millet.

Maize is the most important staple food crop in Eastern Africa.It was first introduced in the sixteenth or seventeenth century by Portuguese traders but the varieties came from the Caribbean and were only suited to the coastal strip (Acland, 1971). Different varieties of maize have been developed and grown in high, medium and low rainfall agricultural zones of Kenya and Somali, where production of indigenous cereals has declined. Maize production covers about 40% of the total area under crop production in Kenya.

Small scale farmers are the major producers in terms of the area cropped, production and labour input. Whereas small scale farmers grow maize for home consumption and only sell the surplus, large scale producers account for the major share of marketed maize.

Competition for capture of the essential resources for plant growth such as light, water and nutrients is one of the key determining factors of the performance of natural, semi-natural and agricultural ecosystems. Although farmers must have recognized competition effects in their systems as soon as they started to shape ecosystems to meet their needs, the first scientific reports on competition were published in the 14th century (Grace and Tilmon, 1990). Darwin (1859) identified the central role of competition in selection process of organisms in general. Since then, competition has been regarded as one of the major forces behind the appearance and life history of plants and the structure and dynamics of plant communities (Grace and Tilmon, 1990).

1.2 Economic importance of weeds in agricultural production

Crop competition with unwanted plants (weeds) account for a 10% loss of agricultural production on a world wide scale(Zimdahl,1980). Weeds compete with crops for water, nutrient, light, gases, and space. Without weed control, yield losses range from 10 - 100% depending on the competitive ability of the crop (Van Heemst, 1985).

Minimizing the effect of weeds by optimization of crop plant densities, sowing time in intercroped systems and on development of predictive tools for yield loss assessment to develop weed management systems with minimum herbicides inputs (Zimdahl, 1980; Radosevich and Holt, 1984; Altieri and Liebman, 1988).

In many agricultural systems, crops are grown at moderate to high resource levels to maximize yield. Competition in these systems could be defined as the process of capture and utilization of shared resources by the crop and its associated weeds. The more resources the weeds capture the more crop growth will be reduced resulting in yield loss.

Agriculture has been described as a controversy with weeds. This is because the energy for plant growth available on a given area of land is used by the crop, the weeds or it is lost or not used for crop production that growing season. Therefore, crop production is often reduced in direct porportion to the amount of weeds produced in a given field. Therefore, weed management is one of the key elements of most agricultural systems.

The development of weed management systems requires thorough quatitative knowledge in the behaviour and effects of weeds in different agroecosystems. This involves both insight in crop-weed interaction within the growing season as well as the dynamics of weed populations over growing seasons. The relationship between maize plant density and competitive ability of maize with weeds probably varies with intensity, duration and timing of the weed stress (Duncan, 1958 and Tollenaar, 1992).

Weed losses are numerous and varied. The losses caused by weeds and the cost of their control constitute one of the largest losses in production of feed, food, and fiber. The US Department of Agriculture (USDA) estimates the lossed, in various crops from weeds to be over 5 billion dollars annually in the USA (USDA, 1965). These losses are about equally divided between reductions in crop yields and costs of controlling weeds. About one-half of all tillage done on farms is done solely for weed control. Weeds reduce land values, lower the quality of crop and animal products, cause animal deaths and offer habitat and protection to insects and diseases. Weeds cause problems in water management by clogging ponds, recreational lakes, irrigation and drainage ditches and interferring with navigation. Some weeds may impair the health of man upon contact or by allergic reactions from pollen. Weeds also cause expenses in non-agricultural areas such as roads, rail roads, utilities, industrial sites, parks, lawns and forests.

Tagetes minuta, In this study was singled out because it is becoming the most dominant weed problem in most maize growing regions of Kenya and other parts in East Africa. Moreover, no research has been done to determine it's effects on maize yields.

Yield losses caused by *T.minuta i*n maize would show the magnitude by which the weed is restricting the goal of a achieving self-sufficiency in maize production. Also financial losses caused by lateness in weeding can be quantified. Knowing the weed-free and competition duration of the weed with maize would enable researchers to recommend to farmers when and for how long to control the weed to a achieve optimal yields in maize.

The objectives of this research were therefore:

(1) To quantify yield losses caused by *Tagetes minuta* when allowed to compete with maize.

(2) To determine the effect of fertilizer and time of weeding on growth of maize and T.minuta.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 CROP GROWTH AND NITROGEN USE EFFICIENCY

Crop development and growth comprise complex physiological and biochemical processes which are influenced by the crop'senvironment. The principal environmental variables include climate, soil and management (Gardner *et al.*, 1985; Fageria *et al.*, 1991b). High crop productivity can be expected only when conditions are optimal or favourable in the growth medium constituted by the interacting environmental variables. Optimal conditions for crop growth are rather difficult to define because they vary with plant species, soil type and agroclimatic factors (Fageria *et al.*, 1991a). Different cropping systems are practised under the same climatic regime in which different soil types occur. Similarly, the potential of a given soil type to produce crop is expressed differently under different climatic regimes (Silvakumar *et al.*, 1992). In the final analysis, therefore, the productivity of a crop will depend on the crop's capacity to integrate all the climatic and soil factors that influence crop development and growth. The capacity of the crop to efficiently exploit environmental resources is essentially determined by the genetic constitution of the crop plant, environmental variables and the cultural practises applied.

2.2 EFFECT OF GENOTYPE ON NUTRIENTS UPTAKE

Several authors (eg Kang and Gorman, 1989; Silvakumar *et al.*, 1992) have reported significant interaction between climatic factors and genotype on maize yield. Nutrient requirements and preferences by plant are known to vary between and within species (Gerloff and Gabelman, 1983). Genetic variation in root growth among the maize hybrids has also been reported (Wiesler and Horst, 1994a and b). Some authors (Tsai *et al.*, 1984; Mackay and Barber, 1986 and Ebelhar *et al.*, 1987) observed differences in uptake of N, P and K by maize genotypes. Rao *et al* (1983) comparing kinetic parameters of N uptake and translocation from NH_4 and No_3-N sources among legumes and cereals, reported significant differences in both uptake and translocation of the N sources between and within plant groups. Duncan and Baligar (1990) observed genotypic differences in nutrient utilization by maize. In the report by Clark (1990) it was noted that maize genotypes vary extensively in adaptation to soils and their productivity differed with fertilizer inputs. Thus, the plant genetic constitution determines the highest possible yield that can be realized from a plant under optimal growth conditions.

2.3: EFFECTS OF WEED INTERFERENCE ON MAIZE YIELD

A growing awareness of environmental issues has led to the development of integrated weed management systems that minimize the impact of crop production on the environment. An integrated weed management system must take all aspects of a cropping system into consideration, including effects of tillage, crop rotation, crop competitiveness and various methods of weed control (Swaton and Weise, 1991). In addition the same authors also noted that climatic and edaphic factors, such as soil moisture and soil fertility, must be taken into account. The impact of weed interference on crop production may vary during different phases of crop development and an effective weed management system should take into account the dynamic nature of crop weed interactions throughout the growing season.

The relative competitive ability of crop plants and weeds changes in the course of plant life cycles.Various studies have been reported on the influence of weed removal at various stages of crop development on maize yield. Hall *et al.* (1992) showed that maize yield was not influenced by weeds that had emerged after the 14 - leaf stage of maize. When weeds were allowed to interfere with maize from emergence, yield was not reduced if weeds were removed at maize stages of development ranging from the 3 to 14 leaf stage, depending on location and year (Hall *et al*, 1992).It is clear however, that maize suffers severe competition from early germinating weeds because of slow early development and wide row spacing.

2.4: EFFECT OF DELAYING WEED CONTROL ON CROP GROWTH

Weed competition leads to reduced crop yields (Allan, 1974). In Kenya, Somalia or elsewhere in the tropics rainfall is highly seasonal. Most crops have to be planted within a short period of time, early in the rainy season (Parker and Fryer, 1975). The otherwise abundant labour is fully stretched in land preparation, planting and weeding operation. According to Longeman (1978), in parts of Eastern Nigeria , 60 to 80% of the total field work is carried out during the first four to five months of the year corresponding to the early rains. He also showed that 90% of the labour hired by farmers for weeding and clearing was in the early period, making hoeing difficult and ineffective, if not impossible. Rarely are weeds removed at the optimum time, within the first 10 to 20 days and may be completed until 30 days or more (Parker and Fryer, 1975).

In many cases farmers have to hire labour, sometimes not in time, resulting in increased weed growth so that ultimately extra labour and therefore cash for weeding is needed. Druijff and Kerkhoven(1970),observed that weeding delayed by one week increased the initial weed growth six-fold in irrigated cotton and doubled the initial labour demand. A three week delaying in weeding increased the initial weed growth thirty - fold and quardruped the initial labour demand per hectare. Allan, (1974) working on maize in Kitale reported that unweeded plants in 1967 and 1970 gave 33 and 31 % less yields respectively than clean plants. He attributed this reduced effect of weed competition to an abundance of growth factors, mainly moisture and nutrients in the region. Nieto *et al;*(1968) found that when weeding was carried out one month after planting, yield reductions of 25% in maize resulted. Work at Kakamega, Kisii, Thika, Katumani and Embu in Kenya has shown that grain yields were influenced by the time of weeding , however , no critical periods have been conclusively determined. The general trend was in favour of early weeding for maximum yields. At Katumani, if weeds were not controlled at an early stage, the crops suffered to such an extent that even modest yields were not obtained(Anon, 1975). Time of weeding was therefore, the most significant aspect of weed control in terms of both yield and labour.

2.5: PROBLEM OF WEED CONTROL

Subsistence farmers of the tropics spend more time and energy on weed control than on any other single aspect of crop production(Terra,1959,Kasasian,1971;Shetty,1979).Handweeding, the most commonly used method for weed control is only economical where labour is abundant and is only effective where weeding frequency is minimal and the area to be weeded is small(Akobundu,1978). In some countries, such as Kenya and Nigeria,farm labour is ofen hard to find and too expensive for routine farm operation (Laycock, 1974; Akobundu, 1978). According to Young *et al*,(1978), Miller *et al*,(1978), and Fisher *et al*,(1978), manual weed control consumes 20 to 50% or higher of the total labour requirement for crop production within traditional agriculture system.

The favourable temperature and light regimes in the humid tropics not only provide a scope for multiple cropping but also favour rapid multiplication of weeds. Weeds depress yields by competing for growth resources, light, water, mineral nutrients and space (Ashby and Pfeiffer,1956; Donald, 1963). Nieto *et al* (1968) reported that season long weed infestation reduced maize yields from a potential of 4770 kg/ha to 382 kg/ha. Crops are able to compete with weeds better if they establish quickly and if weed control is effected on time. Whether weeds take over the crop or the crop smothers weeds, the interference of weeds depends upon the farmers managerial ability of the crop - weed balance (Rao and Shetty , 1977),

2.6 WEED CONTROL IN MAIZE

An effective weed control method is an integral part of a good crop management. Godfrey-Sam-Aggrey,(1978) working in Sierra Leone found highly significant differences between various weeding intervals and non-weeding. Guleria and Sigh(1980) repeated similar management in rainfed maize at Palampur, India. Control of weeds by either hand or chemical resulted in significantly higher yields compared to the non - weeded controls.

Reviewing weed control in Nigeria, Akobundu (1979) concluded that the hoe weeding is the most popular method of weed control. Hoe weeding however, relies on the abundance and availability of cheap labour. Due to rural - urban migration, labour for hand weeding is often scarce and when available it is too expensive for the average farmer.

Vernon and Parker (1983) working in Chilanga, Zambia estimated that 42% of the total cost of crop protection is due to weeds in tropical and perhaps the most expensive post - emergence operation.

2.7: CRITICAL PERIOD OF WEED COMPETITION.

One of the chief omissions of research workers in their studies of weed control is ignorance of the critical period for competition (Nieto *et al* , 1968). The practice, time and duration of maximum competition depends on many factors, such as the relative rate of growth of the crop and weeds, the density of planting, the variety grown, the time of moisture and nutrients stress among other factors (Kasasian, 1971).

The point is that there are periods when weeds must be removed and other periods when some may be allowed to grow because they do not cause significant harm to the crop (Nieto *et al*,1968; Gurnah,1974). Any large scale project to control weeds should begin with a thorough study in determining the most vulnerable stages in the life cycles of the weeds (Chandra Singh and Narayana Rao, 1973). Weeds are most competitive during the early stages of crop growth and they begin to interfere with crop growth within several weeks after planting and for as long as they are actively growing. Crop reductions from weeds are largely determined by the competitiveness of the crop and its associated production practices as opposed to the weed population species, duration and rate of growth. Most temperate zone cereal and grain crops require about a 30 day weed-free period in order to escape major yield loss from weeds. For example a Nebraska study with sorghum showed that weeds which did not emerge until 4 weeks after sorghum planting did not reduce sorghum yields (Burnside and Wicks, 1969). A longer weed-free period of 2 or more months is often required with some vegetable and slow growing crops. Weeds that emerge with or soon after the crop will provide the greatest interference. Therefore, early weed control becomes the key to successful and economical weed control program. Conversely, weeds that do not emerge until after a cultivated crop will cause little yield loss; so a farmer does not need season-long weed control for maximum crop yields. Late-emerging weeds, however, may have detrimental effects on furrow irrigation, subsequent weed seed supply, and harvesting efficiency.

Each crop has its own critical weed competition period. This is the period during the growth of the crop when the presence and competition of weeds is harmful to the crop". (Nieto, Brando and Gonzalez,1968; Gurnah, 1974), Nieto *et al,* (1968) observed that in some parts of the world, farmers spend a great deal of money on continuous weed control under the impression that the more cultural care is taken, the higher the production will be, but they forget that yield is a genetic factor which cannot be modified by further weeding. Further weed control only results into higher production costs. Thus weeding costs can be reduced by keeping the crop weed free only during the critical period.

2.8 FERTILIZATION AND THEIR EFFECTS ON WEEDS

A fertilizer program for a crop is generally designed to provide nutrients for the growth and economical yield of the crop. The most efficient use of nutrients by the crop requires excellent weed control. Without good control much of the growers investment for fertilizers will be wasted or it may even be detrimental to crop production.The use of nitrogen, for example, is important in weed control because it increases the growth rate and competitiveness of the crop (Staniforth, 1968) plant vigor and competitive ability has always been an important selection criterion in plant breeding and this characteristics of crops help in the control of weeds.Both crops and weeds are stimulated by supplying them with the necessary fertilizer nutrients. The goal is to stimulate the crop to the detriment of the weeds, or to have the fertilizer enhance herbicide selectivity and phytotoxicity. Herbicides have made it possible, in many cases, to apply the nutrients at the proper time for optimum crop utilization and production.An actively growing weed is more easily killed with herbicides than one stunted from a nutrient deficiency or for any other reason. This is because a herbicide generally moves into a plant through the vascular tissue. The more rapidly it accumulates at the site of action the less likely it is to be detoxified before destroying the plant (Scudder, 1967).

Many weeds will compete for fertilizer nutrients as well as or even better than the crop species therefore, starter fertilizer is generally placed in furrows adjacent and slightly beneath the planted seed in order to give the crop the maximum opportunity to assimilate it. Later application of fertilizer may be injected into soil when the crop root system and growth rate have developed sufficiently.

Broadcast application of fertilizer onto the soil surface have ofen benefited the weeds more than the crop, for this reason, the addition of herbicides with liquid fertilizer or suspension have actually made broadcasting application of fertilizer a more feasible procedure by eliminating the weeds (Doersch, 1969).

Fertilizer should also be supplied at the appropriate time to stimulate the particular crop in question. For example, a cool season grass shows the greatest growth in the spring and fall while a warm-season grass shows more growth during the summer. The growth patterns of the crop and problem weed species should be considered in timing fertilizer applications.

Incorporating fertilizers into the soil caused as much as a five-fold increase in germination of wild oat seed present in the soil (Sexsmith and Pittman,1963). This may offer another method of combating wild oats especially in fallow land. In crop land, fertilization might increase weed control problems. Fertilization of a dry seedbed before seeding stimulates the growth of barnyard grass and other weeds.

Nitrogen fertilization of soybeans in the absence of good weed control may stimulate the weeds to the detriment of production. In other cases, proper fertilization of established pastures has stimulated the desirable grass to the detriment of annual weeds. In a seedling study (Eckert and Evans, 1963) Dawny brome growth was increased more by low to intermediate levels of N than that of Crested wheat grass (Eckert and Evans, 1963). However, shoot growth of Crested wheat grass was increased more at high levels of N and at a more mature stage of growth than that of Downy brome. Such manipulations of crop - weed ecology are important in planning a fertilizer program, since all the vegetative shifts will not be beneficial to crop production.

Proper use of fertilizer has been helpful in weed control (Staniforth, 1961). Nitrogen encourages more rapid early vegetative growth and increased crop competitiveness and shading to associated weeds in some instances. Proper use of N Fertilizer decreased maize yield loss from weeds.

2.9: EFFECTS OF FERTILIZERS ON MAIZE

Fertilizer response is frequently attributed to the main fertilizing element in the compound. Other elements being disregarded, for instance, response to ammonium sulphate is usually attributed to nitrogen whereas it might be due partly or mainly to sulphur, which is often deficient in tropical soils. Similarly, superphosphate contains both calcium and sulphur in addition to phosphorous, and responses may therefore be due to any of these element. It is useful therefore to experiment with nitrogen, phosphorous and potash in form without confusion with other elements.

Application of fertilizers in amounts exceeding the absorptive capacity of the crop is wasteful. Increment of crop yield resulting from successive increases in the amount of fertilizing elements applied steadily declines until a point is reached when additions produce no increase in crop in accordance with the law of diminishing returns (Richardson, 1946).

The effect of manure may not be confined to the season during which they are applied for there may be residual effects which will benefit subsequent crops.

2.10: METHODS USED TO STUDY COMPETITION

The response of yield per unit area to competition in two species mixtures has been studied much more widely because of its relevant to agriculture.

In a replacement series, the species are grown in mixture of varying proportions and in monocultures, always keeping the total density the same (de Wit, 1960). The results are expressed using indices such as the relative yield total (the sum of the yields in mixture of the two species expressed as proportions of their yields in monoculture which describes how efficiently the two species use resources when grown together, and the relative crowding coefficient, which gives some indication as to the competitive ability of the two species (de Wit, 1960; de Wit and van den Bergh, 1965). The analysis reviewed by Hall (1974a), Harper (1977) and many others] is extremely popular not least because it is based on small experiments.

A series of papers (De Benedictis 1977; Inuye and Schaffer, 1981; Law and Watkinson, 1987) have strongly criticised this experiment in that the values of the standard indices vary according to the total density selected, a point stressed by Firbank and Watkinson (1985b). This means that the results from replacement series experiment cannot provide a reliable indicator of the outcome of competition over several generations (Law and Watkinson, 1987). Furthermore, the values of the indices are highly unstable, being highly dependent on the chosen experimental design (Connolly, 1986) and their statistical behaviour is difficult to comprehend (Thomas, 1970) and as a result tends to be ignored.

The replacement series is, however, extremely valuable for comparing the outcome of competition between two plant species under different conditions. Its use has to lead to important insights into the nature of niche differentiation (Trenbath, 1974) and differential resources use by plants.For example Berendse (1982) demonstrated niche differentiation between species with different rooting depth, and Hall (1974b) discovered that the depressing effect of Setaria on Desmodium could be a meliorated by the addition of potassium. Other experiments have shown that pathogens can alter the outcome of competition between species (Burdon, 1987), as can parasitic plants (Gibson, 1986) and herbivores (Whittaker, 1977). In a slightly different use of the replacement series, Cottam (1985) showed that herbivores may feed on plants according to their proportions in mixtures. Such experiments are highly informative, as they show the effects of single factors on the outcome of competition and suggest how plant interactions may be modified in the field.

2.11 REPLACEMENT SERIES EXPERIMENTS.

The replacement series technique developed by de Wit (1965) is a method used to evaluate early interference between plants. Using this system, the proportion of crop to weed plants in an area or pot varies, but total plant density remains constant. This allows evaluation of the relative competitiveness of the two species and their interactions. Various replacement series techniques have been used successfully to evaluate species interaction (Snaydon, 1971). Replacement series experiments also allow for evaluation of the relative importance of intra and interspecific interference in plants (Duke 1983; Radosevich 1987). The performance of the two species in monoculture and mixture is compared by calculating the plant relative yield (PRY). For example, the PRY of species A in competition with species B is the total dry weight per plant of A grown in mixture with B divided by its per plant dry weight when grown in monoculture. For a given comparison, PRY = 1.0 indicates that the effects of lntra and interspecific competition are similar. PRY < 1.0 indicates that interspecific competition is more than intraspecific competition, and PRY > 1.0 indicates that intraspecific competition is more severe.

2.12 ECOLOGY AND BIOLOGY OF *TAGETES MINUTA*

It is an annual herb, widespread in the region but most troublesome as a weed in upland crops above 1200m; notable for its strong aromatic smell when crushed. It grows in cultivated fields, and on many soil types. *T.minuta* has many ecological types, it has become adapted to most of the agricultural areas of the world. A complete life cycle may be 2 to 4 months in the tropics, depending on the length of the rainy season. Emergence may require 2 to 4 days, with a slow early growth and a rapid rate of vegetative growth at 15 days. At one month, when the plant has 10 or 12 leaves, flowering begins, the seeds of *T.minuta* are spread by wind, water and with the seeds of crops; it has a tap-root and the stem is errect, upto 2m tall, branched and furrowed. The leaves are opposite, upto 23cm long, divided into one terminal and several lateral leaflets. The flower heads are creamy yellow, upto 2mm wide and 12mm long. The fruit is achene, spindle shaped, flatened, 5-8mm long and 0.6mm wide. The friut is black, covered with short hairs, and clings readily to clothing. *T.minuta* is widespread in East Africa(Terry and Michieka , 1987).

2.13 PLANT GROWTH ANALYSIS

Beginning with the early works of Blackman (1919) and Kidd and West (1919),a discipline of study has developed that attempts to integrate the effects of environment, development and size on plant growth. These techniques, collectivelly called mathematical growth analysis, recognize total dry matter production and leaf area expansion as important processes in determining vegetative growth. The techniques require frequent destructive harvests of plant material at interval, throught a plant's life cycle. The basic information collected at each harvest includes dry matter production of roots, leaves, stems and reproductive organs and leaf area. From these basic data, it is possible to calculate rates of dry matter production per unit leaf area or net assimilation rates, relative growth rates, crop growth rates, leaf area duration and partition coefficients for plant biomass and leaf area. Thus the components of plant growth can be separated and compared under a range of environmental conditions and resource limitations. In table 1, patterson (1982) summarizes and defines the formulas commonly used for plant growth analysis.

Although the techniques of plant growth analysis are often performed on individual species and with uniform growing conditions, the comparative analysis of several species under similar environmental regimes is also possible. Such experiments provide valuable information for understanding the basis of differential success when plants are grown in mixed stands. By comparing the growth parameters of various crops and weeds it may be possible to better understand the competitive nature of weeds

Table 1 Growth Analysis Definitions and Formulas

T_2-T_1 = Length of harvest interval (days) $=\Delta T$

W_1, W_2 = dry weight at beginning and end of harvest interval

A_1, A_2 = leaf area at beginning and end of harvest interval

$\Delta W = W_2-W_1; \Delta A = A_2-A_1$

R_w = R = Relative growth rate (g/g.day) = $\ln w_2-\ln w_1)/\Delta T$

R_a = Relative leaf area growth rate (dm^2/dm^2.day) = $\ln A_2-\ln A_1)/\Delta T$

NAR = Net assimilation rate (g/dm^2.day) = $(\Delta W/\Delta A)$ X $(\ln A_2-\ln A_1)/\Delta T$

LAI = Leaf area index dimensionless ratio of leaf area to land area

CGR = Crop growth rate (g/dm^2 land surface. day) = NAR X LAI

LWR = Leaf weight ratio (g leaf wt/g total wt)

LAD = Leaf area duration (dm^2 days)= $[\Delta A/(\ln A_2-\ln A_1)]$ X (ΔT)

BMD = Biomass duration (g days) $=[\Delta W/(\ln W_2-\ln W_1)]$ X (ΔT)

SLW = Specific leaf weight (g/dm^2)

SLA = Specific leaf area dm^2/g), SLA = I/SLW

LAR = Leaf area ratio (dm^2/g total wt), LAR = LWR X SLA

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 GREEN HOUSE REPLACEMENT SERIES EXPERIMENTS

Green house replacement series experiments were done to compare intra and interspecific competition between *Tagetes minuta* and maize under recommended and zero fertilization regimes. Plants were grown in plastic pots 18 cm deep and 20 cm in diameter. The pots were filled with top soil and mixed either with no Diamonium phosphate (DAP) in some treatments or with DAP at the rate of 36 kgN and 92kgP_2O_5 per total pots then watered to field capacity once per day until the weed seeds germinated. The top soil was collected from a field previously infested by *Tagete-minuta*. Other weeds except *T. minuta* were uprooted by hand after germination. Maize hybrid 511 seed were planted, after *T. minuta* establishment, in each pot to achieve a population of *T. minuta* and maize mixture in the ratios of 0:100, 25:75, 50:50, 75:25 and 100:0, also one pure maize plant and one pure *Tagetes minuta* plant each grown alone, were included as controls to determine yield potential of each plant without competition.The plants are seperated into different components; namely stem,leaves and roots which were oven dried at 70°c to constant mass. Leaf area was determined prior to drying using scisors to cut out a pieces of leaf which were measured,while using a leaf area meter DT-Area Meter, MK2(Delta-T Device, Burwell, Cambridge, England). The plants in the pots were carefully washed to separate the

The plants in the pots were carefully washed to separate the soil from the roots. The roots were oven dried at 70°c and the dry mass determined.

The pots were arranged in a completely randomised design each treatment replicated six times. The experiments were carried out between May and September 1997. First and second experiments planted on May 10 and July 15 respectively. At four weeks after maize and *T. minuta* growth, crop and weed height were taken in three pots of each treatment and then destructively sampled and ovendried at 70°c to determine the following parameters, for both weed and maize:

root dry mass,leaf dry mass,stem dry mass,total dry mass,leaf weight ratio,stem weight ratio,root weight ratio,specific leaf weight,leaf area ratio,and leaf to stem ratio. After eight weeks of growth plant height of maize and *T. minuta* were recorded in the remaining three pots per treatment and then harvested and ovendried to determine the same parameters in above. In addition, the following parameters, which require data from two harvests over a time interval, were calculated.

Crop growth rate(CGR),relative growth rate(RGR),leaf area duration(LAD),net assimilation rate(NAR).

The data was subject to analysis of variance and intra and interspecific competition between maize and *T.minuta.*

3.2 FIELD EXPERIMENTS

3.2.1 EXPERIMENTAL SITE

Experiments were conducted at the University of Nairobi, Field Station Farm, Kabete during the short and long rains of 1996 and 1997, respectively. The farm is located on latitude of 1° 15′ south and longitude 36° 44′ East, at an altitude of 1800m above sea level. The soils are well drained, very deep, dark reddish brown to dark red, friable clay with acid humic top soil (Humic Nitosol), developed from Limuru Trachite (Nyandat and Michieka, 1970).

3.2.2 EXPERIMENTAL TREATMENTS AND DESIGN

Two separate weed interference studies were conducted involving different duration of *Tagetes minuta* interference in maize, during long rains in 1996 and short rains in 1997. The experimental design was Randomized Complete Block Design,

3.2.3 EXPERIMENTAL PROCEDURE

During the long rains of 1996, land was prepared and mature seeds of *Tagetes minuta*, harvested elsewhere, were broadcast over the entire experimental site. Two weeks after weed germination, other weeds were uprooted and T. *minuta* weed was allowed to seed naturally. One month prior to the onset of short rains of 1996, land was ploughed and harrowed. Soil samples were taken from the top 20cm and sent to the soil science laboratory of the University of Nairobi to determine fertility level(see appendix 2 and 3). Two weeks before the onset of rains, the experimental area was irrigated by overhead sprinklers to allow weeds to germinate. Other weeds except *T. minuta* were uprooted. Some *T. minuta* seedlings were uprooted in congested areas and transplanted in sparsely populated areas to achieve uniform distribution and population over the experimental site. Maize hybrid 511 was planted in the four leaf stage weed at a spacing of 75cm between rows and 25cm within rows, with or without application of DAP fertilizer. Each treatment replicated three times, each block consisted of 16 plots measuring 3 m x 4m,with treatments as indicated (Table 2). The meteorological data of the farm has been summarised (Oswaggo, 1980).

An overhead sprinkler system provided supplemented irrigation to each plot during 1997 only when the rainfall was not adequate. The net area harvested was 1.5 by 3.0 meters consisting of 2 middle rows of maize to determine weed and maize parameters. All data was subjected to analysis, and regression equations were developed to determine the relationship between duration of T. minuta interference and weed-free maintenance on maize grain yield. Regression analyses were based on mean measurements and data from maize grain yield were plotted against duration of weed-free maintenance or weed interference in field experiment.

Table 2: List of treatments to study effects of duration of weed-free maintenance and weed interference of Tagetes minuta on maize.

1.0-30 days weed-free after planting then weedy

2.0-50 days weed-free after planting then weedy

3.0-60 days weed-free after planting then weedy

4.0-75 days weed-free after planting then weedy

5.0-90 days weed-free after planting then weedy

6.0-120 days weed-free after planting then weedy

7.Weedy throughout the season.

8.0-30 days weedy then weed-free

9.0-50 days weedy then weed-free

10.0-60 days weedy then weed-free

11.0-75 days weedy then weed-free

12.0-90 days weedy then weed-free

13.0-120 days weedy then weed-free

14.Weed-free throughout the season

15.Weeded 30 and 45 days after emergence of maize

16.weeded 40 and 60 days after emergence of maize

CHAPTER FOUR

4.0 RESULTS

4.1 Green-house

4.1.0 Effects of intra and interspecific competition between maize and *T.minuta on growth and yield.*

4.1.1 (a) plant height

A mixture of maize and *T.minuta* significantly decreased maize and *T. minuta* height both fertilizer and no fertilizer treatment, irrespective of the proportion of the crop and the weed, compered to that of a single maize plant per pot. Crop-weed population ratio of 50:50% improved maize height whether if it is fertilizer or no fertilizer over that obtained from other crop-weed population mixtures due to the balanced demand of resources, at the two harvesting times in both experiments (Table 3). Increasing maize population from 1 to 12 plants per pot significantly decreased maize height both fertilizer and no fertilizer treatment at 30 and 60 DAE in both experiments 1 and 2. Therefore,fertilizer increased maize and *T.minuta* height by 34.9% and 56% respectively.

Table 3 Effect of population ratios and fertilizer on height of maize and *T. minuta* at 30 and 60 days after emergence (DAE)

Maize: T.M* Ratio	Plant height (cm)							
	30 DAE				60 DAE			
	Maize		*T. minuta*		Maize		*T. minuta*	
Experiment 1 (1997)	+N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	92.3a	69.3a	-	-	139.3a	116.0a
1:0	64.7a	54.3a	-	-	119.0a	92.7a	-	-
3:9	34.6c	20.7d	51.5c	35.1b	65.2c	43.7b	82.4b	60.4b
6:6	46.8b	31.1b	60.2b	36.7b	72.1b	50.3b	89.5b	60.0b
9:3	38.8bc	26.6c	37.3c	23.7c	64.0c	45.7b	64.6c	44.4c
12:0	42.1c	25.3c	-	-	56.2d	42.3b	-	-
0:12	-	-	40.0d	25.7c	-	-	65.8c	44.9c
C.V%:	**11.5**	**8.5**	**6.0**	**12.2**	**4.7**	**9.6**	**6.6**	**5.4**
S.E:	**5.3**	**2.5**	**3.4**	**4.7**	**3.5**	**5.3**	**5.8**	**3.5**
Experiment2								
0:1	-	-	78.0a	59.3a	-	-	125.0a	96.0a
1:0	61.7a	47.0a	-	-	109.0a	84.3a	-	-
3:9	32.9c	22.6c	43.6c	30.5b	50.8b	32.4c	65.6c	48.3b
6:6	40.0b	28.5b	35.9b	30.7b	58.8b	42.7b	81.1b	51.7b
9:3	38.5b	27.9b	32.6	21.9c	52.0	37.9c	46.9	36.9c
12:0	35.9bc	23.0c	-	-	55.4b	38.9c	-	-
0:12	-	-	33.9c	23.1c	-	-	57.7d	39.9c
C.V%:	**20.4**	**9.5**	**6.5**	**9.1**	**10.3**	**7.3**	**4.9**	**8.0**
S.E:	**8.2**	**2.8**	**3.0**	**3.0**	**6.8**	**3.5**	**3.7**	**4.4**

T.M+ *Tagetes minuta*
+N Fertilizer
-N No-fertilizer

4.1.2 (b) Plant dry mass

Interplanting maize and *Tagetes minuta* signficantly reduced root dry mass of both the crop and the weed in fertilizer and no fertilizer at 30 and 60 DAE in experiments 1 and 2 (Table 4) . Both fertilizer and no fertilizer treatment planting 12 pure maize or *Tagetes minuta* plants per pot signficantly reduced root dry mass of both crop and weed compared to single plants per pot.

Planting maize and *Tagetes minuta* together at all population ratios significantly reduced stem dry mass of both maize and the weed in fertilizer and no fertilizer at 30 and 60 DAE in both experiments (Table 5). Increasing the plants from 1 to 12 per pot in pure maize and Tagetes *minuta* stands decreased stem dry mass both fertilizer and no fertilizer over the growth periods and in the two experiments.

The presence of *Tagetes minuta* in the same pot with maize, irrespective of the total population also applying fertilizer and no fertilizer, significantly reduced the leaf dry mass of both the crop and the weed 30 and 60 DAE in experiments 1 and 2 (Table 6). Compared to single maize or *Tagetes minuta* per pot, at both sampling times and in the two experiments, increasing maize or *Tagetes minuta* plant population to 12 per pot significantly reduced leaf dry mass of the crop and the weed in fertilizer and no fertilizer. However, fertilizer were not affected much by root, stem and leaf dry mass, also the trend were the same at 30 and 60 DAE during both experiments.

(c) Total Dry mass

The presence of *Tagetes minuta* in the same pot with maize irrespective of the population significantly reduced the total dry mass of both the crop and the weed in fertilizer and no fertilizer at 30 and 60 DAE in the two experiments (Table 7). Increasing the population of maize or *Tagetes minuta* from 1 to 12 plants per pot resulted in reduction in total dry matter of the crop and the weed 30 and 60 DAE. Therefore, applying fertilizer was not affected much as compered to no fertilizer application.

Table 4 **Effect of population ratio and fertilizer on root dry mass of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M* Ratio	Root dry mass (g)							
	30 DAE				60 DAE			
	Maize		T.Minuta		Maize		T.minuta	
Experiment 1	N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	1.0a	0.5a	-	-	2.0a	1.0a
1:0	3.0a	2.3a	-	-	2.2a	3.6a	-	-
3:9	0.7^{b}	0.4^{c}	0.3^{b}	0.2^{b}	0.7^{c}	1.0^{c}	0.4^{c}	0.3^{b}
6:6	0.7^{b}	0.5^{b}	0.2^{b}	0.2^{b}	0.9^{bc}	2.4^{b}	0.3^{c}	0.3^{b}
9:3	0.5^{c}	0.7^{b}	0.3^{b}	0.2^{b}	1.0^{b}	2.1^{b}	0.5^{b}	0.4^{b}
12:0	0.4^{d}	0.4^{c}	-	-	1.1^{b}	1.6^{b}	-	-
0:12	-	-	0.3^{b}	0.3^{b}	-	-	0.4^{c}	0.3^{b}
CV%	22.3	26.6	14.2	34.5	11.4	13.1	6.5	12.4
S.E	0.3	0.2	0.1	0.1	0.4	0.3	0.1	0.1
Experiment2								
0:1	-	-	1.0a	0.4a	-	-	2.3a	0.6a
1:0	2.8a	2.0a	-	-	5.7a	1.2a	-	-
3:9	0.6^{b}	0.3^{b}	0.3^{b}	0.2^{b}	2.0^{d}	0.3^{c}	0.5^{b}	0.4^{b}
6:6	0.6^{c}	0.4^{b}	0.3^{c}	0.2^{b}	3.4^{b}	0.6^{b}	0.5^{b}	0.2^{b}
9:3	1.4^{b}	0.4^{b}	0.2^{c}	0.2^{b}	2.8^{c}	0.7^{b}	0.7^{b}	0.3^{b}
12:0	0.7^{c}	0.3^{b}	-	-	2.1^{d}	0.6^{b}	-	-
0:12	-	-	0.4^{b}	0.2^{b}	-	-	0.7^{b}	0.3^{b}
CV%	7.4	8.9	8.7	40.5	12.8	21.9	8.0	0.0
S.E	0.1	0.1	0.04	1.0	0.2	0.1	0.1	0.0

* T. Minuta

+N Fertilizer

-N No-fertilizer

Table 5 **Effect of population ratio and fertilizer on stem dry mass of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M* Ratio	Stem dry mass (g)							
	30 DAE				60 DAE			
	aize		*T.Minuta*		Maize		*T.minuta*	
Experiment 1	N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	4.7a	2.7a	-	-	13.1a	5.7b
1:0	15.3a	10.0a	-	-	26.1a	15.0a	-	-
3:9	2.3^{d}	1.4^{b}	1.4^{c}	0.8^{b}	5.1^{b}	2.6^{c}	3.0^{b}	2.1^{b}
6:6	3.6^{c}	1.8^{b}	1.6^{b}	0.9^{b}	4.3^{b}	3.4^{c}	3.1^{b}	1.7^{b}
9:3	4.6^{b}	2.2^{b}	1.6^{b}	1.0^{b}	4.7^{b}	4.0^{b}	2.2^{b}	1.6^{b}
12:0	2.2^{d}	2.0^{b}	-	-	5.5^{b}	3.3^{c}	-	-
0:12	-	-	0.7^{d}	0.4^{c}	-	-	3.8^{b}	1.1^{c}
CV%	**7.2**	**14.3**	**47.3**	**34.3**	**13.5**	**55.9**	**24.3**	**48.1**
S.E	**0.4**	**0.5**	**0.9**	**0.4**	**1.2**	**3.1**	**1.2**	**1.1**
Experiment2								
0:1	-	-	3.5a	2.0a	-	-	6.0a	3.5a
1:0	12.5^{a}	6.7^{a}	-	-	11.8^{a}	8.0^{a}	-	-
3:9	1.7^{c}	1.1^{b}	1.0^{b}	0.7^{b}	2.9^{b}	1.7^{b}	1.3^{b}	0.8^{b}
6:6	2.5^{b}	1.4^{b}	1.1^{b}	0.7^{b}	3.0^{b}	2.3^{b}	1.2^{b}	0.9^{b}
9:3	2.1^{c}	1.4^{b}	1.1^{b}	0.7^{b}	3.0^{b}	2.2^{b}	1.6^{b}	0.9^{b}
12:0	2.2^{c}	1.4^{b}	-	-	2.6^{d}	1.8^{b}	-	-
0:12	-	-	0.7^{b}	0.4^{b}	-	-	2.0^{b}	0.6^{b}
CV%	**6.9**	**29.9**	**41.1**	**26.8**	**8.4**	**16.4**	**21.5**	**21.1**
S.E	**0.3**	**0.7**	**0.6**	**0.2**	**0.4**	**0.5**	**1.2**	**0.3**

* *T. minuta*
+N Fertilizer
-N No-fertilizer

Table 6 Effect of population ratio and fertilizer on leaf dry mass of maize and *T. minuta* at 30 and 60 days after emergence (DAE)

Maize: T.M* Ratio	Leaf dry mass (g)							
	30 DAE				60 DAE			
	Maize		*T.Minuta*		Maize		*T.minuta*	
Experiment 1	+N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	2.5a	1.5a	-	-	5.3a	4.3^a
1:0	5.3^a	3.5^a	-	-	10.9^a	8.9^a	-	-
3:9	1.4^c	1.0^b	0.5^b	0.4^b	2.4^d	1.5^c	1.1^b	0.7^b
6:6	1.9^b	0.7^b	0.5^b	0.4^b	3.8^b	3.0^b	1.2^b	0.7^b
9:3	2.0^b	1.0^b	0.6^b	0.4^b	4.4^b	3.1^b	1.1^b	0.8^b
12:0	0.8^c	0.9^b	-	-	3.3^c	2.5^b	-	-
0:12	-	-	0.4^b	0.2^b	-	-	1.4^b	0.7^b
CV%	15.5	29.9	12.6	16.3	10.5	12.4	14.5	13.2
S.E	0.4	0.4	0.4	0.1	0.5	0.5	0.3	0.2
Experiment2								
0:1	-	-	2.2a	1.3a	-	-	3.7a	2.2a
1:0	5.0^a	3.6^a	-	-	8.0^a	5.5^a	-	-
3:9	1.2^b	0.8^b	0.5^b	0.4^b	1.5^d	0.9^c	0.6^b	0.4^c
6:6	1.2^b	0.6^b	0.5^b	0.3^b	1.9^b	1.6^b	0.9^b	0.3^c
9:3	1.1^b	0.5^b	0.5^b	0.3^b	1.9^b	1.7^b	0.9^b	0.6^b
12:0	0.7^b	0.8^b	-	-	1.7^b	1.2^c	-	-
0:12	-	-	0.3^c	0.2^b	-	-	1.2^b	0.4^c
CV%	6.5	23.5	13.7	15.1	15.3	13.2	19.0	12.1
S.E	0.1	0.2	0.3	0.3	0.5	0.4	0.3	0.4

+N Fertilizer
-N No-fertilizer

Table 7 Effect of population ratio and fertilizer on Total dry weight of maize and *T. minuta* at 30 and 60 days after emergence (DAE)

Maize: T.M Ratio	Total dry mass (g)							
	30 DAE				60 DAE			
	Maize		*T.Minuta*		Maize		*T.minuta*	
Experiment 1	N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	8.2a	4.7a	-	-	20.7^{a}	10.7^{a}
1:0	23.4^{a}	15.8^{a}	-	-	42.7^{a}	27.4^{a}	-	
3:9	4.3^{d}	2.7^{b}	2.2^{b}	1.5^{b}	9.5^{b}	5.1^{d}	4.6^{c}	3.1^{b}
6:6	6.1^{c}	3.0^{b}	2.4^{b}	1.5^{b}	11.5^{b}	8.8^{b}	4.8c	2.9b
9:3	8.0b	3.7b	2.4b	1.6b	11.9b	9.2b	4.0c	2.8b
12:0	3.2c	3.3b	-	-	10.7b	7.3c	-	-
0:12	-	-	1.5b	0.9c	-	-	5.9b	2.1c
CV%	**4.3**	**18.6**	**39.9**	**21.7**	**11.2**	**23.3**	**21.8**	**24.1**
S.E	**0.4**	**1.1**	**1.3**	**0.4**	**1.9**	**2.7**	**1.7**	**10.0**
Experiment2								
0:1	-	-	6.7a	3.7a	-	-	11.7a	6.3a
1:0	20.5a	12.3a	-	-	22.0a	14.7a	-	-
3:9	3.9c	2.2b	1.8b	1.3b	5.1c	9.9c	2.3c	1.6b
6:6	4.4b	2.4b	1.8b	1.2b	5.8bc	4.0b	2.4c	1.4c
9:3	3.7c	2.3b	1.9b	1.2b	6.0b	4.6b	3.0b	1.8b
12:0	3.3c	2.5b	-	-	5.3c	3.6bc	-	-
0:12	-	-	1.3c	0.8b	-	-	3.6b	1.3c
CV%	**5.4**	**22.2**	**35.1**	**27.0**	**10.7**	**18.8**	**16.0**	**13.2**
S.E	**0.4**	**1.0**	**0.9**	**0.4**	**0.9**	**1.2**	**0.7**	**0.3**

+N Fertilizer

-N No-fertilizer

4.1.3 (d) Plant Dry Mass Partitioning

Stem, leaf and root weight ratio for both maize and *Tagetes minuta* were not significantly affected by the population ratio of maize and *Tagetes minuta* with or without fertilizer application at 30 and 60 DAE in both experiments (Tables 8,9 and 10).

4.1.4 (e) Plant Canopy Characteristics

Interplanting maize and *Tagetes minuta* significantly decreased leaf area of both the crop and the weed in fertilizer and no fertilizer treatment at 30 and 60 DAE in experiments 1 and 2 (Table 11). Growing 12 pure maize or *Tagetes* minuta plants per pot significantly reduced leaf area of both the crop and the weed in fertilizer and no fertilizer treatment compered to single plants per pot at 30 and 60 DAE in both experiments. On the other hand, fertilizer were not significantly increased in leaf area in experiment 1 but it does increase significantly in experiment 2 (Table 11).

Interplanting maize and *Tagetes minuta* significantly decreased specific leaf weight of the crop, while that of the weed significantly increased both fertilizer and no fertilizer treatment at 30 and 60 DAE in experiments 1 and 2 (table 12) respectively. Growing 12 pure maize or *Tagetes minuta* per pot significantly reduced the specific leaf weight of both the crop and the weed in fertilizer and no fertilizer at 30 and 60 DAE in experiments 1 and 2 respectively.

In this parameter applying fertilizer were not affected much both experiments 1 and 2(Table 12).

Leaf area ratio of maize decreased with increasing proportion of maize in the mixture, while that one of *Tagetes minuta* decreased with decreasing proportion of the weed in the mixture both fertilizer and no fertilizer treatment at 30 and 60 DAE and in experiments 1 and 2 (table 13). Increasing maize or *Tagetes minuta* population from 1 to 12 had significant effect on leaf area ratio of the crop and the weed both fertilizer and no fertilizer treatment at both sampling times.

Interplanting maize and *Tagetes minuta* in the same pot both fertilizer and no fertilizer treatment did not affect leaf to stem ratio signficantly. The ratio of the population of each crop or weed had no effect on leaf to stem ratio, 30 and 60 DAE during both experiments 1 and 2 (Table 14). Planting 12 pure maize or *Tagetes minuta* in the same pot in fertilizer and no fertilizer treatment did not significantly affect leaf to stem ratio of the crop or the weed compared to single plant of each in a pot, except in maize at 30 DAE in experiment 1 and 60 DAE in maize and *T. minuta* in experiment 2.However,applyiny fertilizer were not affected significantly in this parameter.

Interplanting maize and *Tagetes minuta* at all ratios significantly reduced in leaf area duration both fertilizer and no fertilizer treatment compared to single maize and *Tagetes minuta* in both experiments, except that of maize in experiment 2 (Table 15). Therefore, fertilizer treatment was not increased significantly as compared to no fertilizer treatment.

Table 8 **Effect of population ratio and fertilizer on stem weight ratio of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M Ratio	Stem weight ratio							
	30 DAE				60 DAE			
	Maize		*T.Minuta*		Maize		*T.minuta*	
Experiment 1	N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	0.6a	0.6a	-	-	0.6a	0.5a
1:0	0.7a	0.6a	-	-	0.6a	0.6a	-	
3:9	0.5a	0.6a	0.7a	0.6a	0.5a	0.5a	0.6a	0.7a
6:6	0.6a	0.6a	0.6a	0.6a	0.4b	0.4b	0.6a	0.6a
9:3	0.6a	0.6a	0.7a	0.6a	0.4b	0.4b	0.6a	0.6a
12:0	0.7a	0.6a	-	-	0.5a	0.4b	-	-
0:12	-	-	0.4b	0.5a	-	-	0.7a	0.5a
CV%	**10.0**	**11.6**	**9.6**	**16.9**	**5.3**	**13.2**	**7.3**	**12.1**
S.E	**0.1**	**0.1**	**0.1**	**0.1**	**0.03**	**0.1**	**0.04**	**0.1**
Experiment2								
0:1	-	-	0.5a	0.6a	-	-	0.5a	0.5a
1:0	0.6a	0.5a	-	-	0.5a	0.5a	-	-
3:9	0.5a	0.5a	0.6a	0.6a	0.6a	0.6a	0.5a	0.6a
6:6	0.6a	0.6a	0.6a	0.6a	0.5a	0.5a	0.5a	0.6a
9:3	0.5a	0.5a	0.6a	0.6a	0.5a	0.5a	0.5a	0.5a
12:0	0.6a	0.6a	-	-	0.5a	0.5a	-	-
0:12	-	-	0.5a	0.5a	-	-	0.6a	0.5a
CV%	**6.4**	**8.2**	**9.2**	**8.0**	**7.0**	**5.1**	**0.0**	**6.8**
S.E	**0.04**	**0.04**	**0.1**	**0.04**	**0.04**	**0.03**	**0.0**	**0.04**

+N Fertilizer
-N No-fertilizer

Table 9 **Effect of population ratio and fertilizer on leaf weight ratio of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M Ratio	Leaf weight ratio							
	30 DAE				60 DAE			
	Maize		*T.Minuta*		Maize		*T.minuta*	
Experiment 1	N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	0.3a	0.6a	-	-	0.3a	0.5a
1:0	0.2a	0.6a	-	-	0.3a	0.6a	-	
3:9	0.3a	0.6a	0.2a	0.6a	0.3a	0.5a	0.2a	0.7a
6:6	0.3a	0.6a	0.3a	0.6a	0.3b	0.4b	0.3a	0.6a
9:3	0.3a	0.6a	0.2a	0.6a	0.4b	0.4b	0.3a	0.6a
12:0	0.2a	0.6a	-	-	0.3a	0.4b	-	-
0:12	-	-	0.3b	0.5a	-	-	0.3a	0.5a
CV%	**14.0**	**11.6**	**19.0**	**16.9**	**14.3**	**13.2**	**13.7**	**12.1**
S.E	**0.04**	**0.1**	**0.1**	**0.1**	**0.04**	**0.1**	**0.04**	**0.1**
Experiment2								
0:1	-	-	0.3a	0.6a	-	-	0.3a	0.5a
1:0	0.2a	0.5a	-	-	0.4a	0.5a	-	-
3:9	0.3a	0.5a	0.3a	0.6a	0.3a	0.6a	0.3a	0.6a
6:6	0.3a	0.6a	0.3a	0.6a	0.3a	0.5a	0.4a	0.6a
9:3	0.3a	0.5a	0.3a	0.6a	0.3a	0.5a	0.3a	0.5a
12:0	0.3a	0.6a	-	-	0.3a	0.5a	-	-
0:12	-	-	0.3a	0.5a	-	-	0.3a	0.5a
CV%	**15.6**	**8.2**	**20.6**	**8.0**	**7.9**	**5.1**	**8.2**	**6.8**
S.E	**0.04**	**0.04**	**0.1**	**0.04**	**0.04**	**0.03**	**0.03**	**0.04**

+N Fertilizer

-N No-fertilizer

Table 10 **Effect of population ratio and fertilizer on Root weight ratio of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M Ratio	Root weight ratio							
	30 DAE				60 DAE			
	Maize		*T.Minuta*		Maize		*T.minuta*	
Experiment 1	N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	0.1a	0.1a	-	-	0.1a	0.1a
1:0	0.1a	0.2a	-	-	0.1a	0.2a	-	
3:9	0.2a	0.2a	0.1a	0.1a	0.2a	0.2a	0.1a	0.1a
6:6	0.1a	0.2a	0.1a	0.1a	0.3b	0.3a	0.1a	0.1a
9:3	0.1a	0.2a	0.1a	0.1a	0.2a	0.2a	0.2a	0.1a
12:0	0.1a	0.1a	-	-	0.2a	0.2a	-	-
0:12	-	-	0.3a	0.3a	-	-	0.1a	0.2a
CV%	**26.1**	**25.2**	**31.5**	**28.9**	**17.1**	**12.6**	**0.0**	**43.3**
S.E	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.03**	**0.0**	**0.06**
Experiment2								
0:1	-	-	0.2a	0.1a	-	-	0.2a	0.2a
1:0	0.1a	0.2a	-	-	0.2a	0.1a	-	-
3:9	0.2a	0.2a	0.2a	0.2a	0.2a	0.1a	0.2a	0.2a
6:6	0.2a	0.2a	0.1a	0.2a	0.1a	0.1a	0.1a	0.2a
9:3	0.1a	0.1a	0.2a	0.1a	0.2a	0.2a	0.2a	0.2a
12:0	0.1a	0.1a	-	-	0.1a	0.2a	-	-
0:12	-	-	0.2a	0.2a	-	-	0.1a	0.1a
CV%	**30.6**	**35.2**	**38.0**	**26.8**	**0.0**	**26.1**	**15.5**	**25.8**
S.E	**0.04**	**0.05**	**0.1**	**0.04**	**0.0**	**0.04**	**0.3**	**0.04**

+N Fertilizer

-N No-fertilizer

Table 11 **Effect of population ratios and fertilizer on leaf area of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M* Ratio	Leaf area (g/dm^2.day)							
	30 DAE				60 DAE			
	Maize		*T. minuta*		Maize		*T. minuta*	
Experiment 1	+N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	42.6b	42.6a	-	-	165.9a	128.1a
1:0	40.9a	40.9a	-	-	67.8a	66.7a	-	-
3:9	29.9b	29.6b	75.1a	36.2b	55.7c	54.2a	94.5b	65.6b
6:6	30.6b	30.6b	25.4c	70.8b	61.0b	51.0a	75.4c	19.2c
9:3	27.0b	27.0b	5.3d	4.1b	45.5b	69.9a	24.5d	8.4b
12:0	29.9b	11.0c	-	-	41.3c	55.2a	-	-
0:12	-	-	35.5d	10.4b	-	-	91.6b	20.8c
C.V%:	**15.4**	**15.3**	**24.4**	**13.1**	**6.7**	**9.1**	**9.4**	**6.7**
S.E:	**4.9**	**2.8**	**9.0**	**2.5**	**11.6**	**5.9**	**8.5**	**3.2**
Experiment2								
0:1	-	-	54.8a	45.5a	-	-	182.4a	115.8a
1:0	27.6a	15.1a	-	-	155.1a	47.6a	-	-
3:9	5.5d	1.8c	36.5b	8.0b	48.5d	26.7c	172.9b	32.8b
6:6	10.5c	2.2c	12.5c	3.7c	79.9b	25.4c	36.4d	9.4c
9:3	15.6bc	9.3b	3.2d	1.6c	69.4bc	33.7bc	12.4c	3.9d
12:0	21.2b	5.6d	-	-	58.1cd	37.3b	-	-
0:12	-	-	11.4c	2.9c	-	-	45.6c	10.1c
C.V%:	**22.2**	**34.9**	**11.2**	**17.9**	**9.3**	**14.1**	**4.8**	**6.5**
S.E:	**3.6**	**2.4**	**2.6**	**2.2**	**7.7**	**4.8**	**4.4**	**2.2**

T.M+ Tagetes minuta
+N Fertilizer
-N No-fertilizer

Table 12 **Effect of population ratio and fertilizer on Specific leaf weight of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M Ratio	Specific leaf weight (g/dm^2)							
	30 DAE				60 DAE			
	Maize		*T.Minuta*		Maize		*T.minuta*	
Experiment 1	N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	5.9a	6.5a	-	-	3.2a	2.4a
1:0	1.3a	1.5a	-	-	3.5a	6.3a	-	
3:9	1.2a	1.4ab	0.2c	0.5c	0.8b	1.0b	0.1c	0.3c
6:6	1.0a	0.8b	0.3c	0.6c	0.8b	1.0b	0.2c	0.6b
9:3	0.8a	0.6b	0.7b	2.0b	0.3c	0.5b	0.5b	1.0b
12:0	0.3b	0.6b	-	-	0.2c	0.4c	-	-
0:12	-	-	0.2c	0.2d	-	-	0.2c	0.2c
CV%	**28.3**	**25.6**	**37.7**	**58.0**	**12.8**	**43.8**	**16.8**	**28.3**
S.E	**1.3**	**1.2**	**1.0**	**2.6**	**0.3**	**0.3**	**2.1**	**0.9**
Experiment2								
0:1	-	-	2.8[a]	4.3[a]	-	-	4.5a	1.3a
1:0	1.9a	2.4a	-	-	5.2a	3.7a	-	-
3:9	1.4b	1.5b	0.6c	0.5c	1.2b	1.1b	0.2c	0.5b
6:6	0.6b	0.8c	0.9c	0.2d	0.4c	1.0b	0.3c	0.6b
9:3	0.9b	0.6c	1.6b	2.0b	0.3c	0.5b	0.9b	1.2b
12:0	0.4c	0.3d	-	-	0.3c	0.3c	-	-
0:12	-	-	0.3d	0.4d	-	-	0.3c	0.3c
CV%	**47.5**	**73.8**	**42.3**	**78.0**	**18.5**	**46.1**	**24.0**	**22.8**
S.E	**2.2**	**3.2**	**1.8**	**3.3**	**0.6**	**2.0**	**0.7**	**0.9**

+N Fertilizer

-N No-fertilizer

Table 13 Effect of population ratios and fertilizer on leaf area ratio of maize and *T. minuta* at 30 and 60 days after emergence (DAE)

Maize: T.M* Ratio	Leaf area ratio (dm^2/g)							
	30 DAE				60 DAE			
	Maize		*T. minuta*		Maize		*T. minuta*	
Experiment 1	+N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	32.2a	23.8a	-	-	29.7a	23.1a
1:0	6.8a	7.8a	-	-	14.1a	10.9a	-	-
3:9	5.1b	5.1b	16.4b	7.3b	11.3b	5.9b	19.9b	6.8b
6:6	3.4c	4.7b	5.6c	7.8b	12.2b	7.6b	18.0b	9.3b
9:3	6.4a	4.2c	10.8b	4.8b	13.3b	7.7b	19.1b	6.9b
12:0	1.7d	1.0d	-	-	7.5c	3.6c	-	-
0:12	-	-	3.7c	4.4c	-	-	4.2c	4.5c
C.V%:	**16.5**	**20.4**	**40.5**	**23.5**	**10.3**	**18.9**	**12.7**	**20.2**
S.E:	**0.8**	**1.5**	**5.6**	**2.3**	**1.2**	**1.3**	**1.8**	**2.2**
Experiment2								
0:1	-	-	21.3a	12.6a	-	-	30.6a	21.4a
1:0	6.4a	4.0a	-	-	13.7a	10.3a	-	-
3:9	1.6c	0.9b	6.3b	2.4c	9.4b	5.2b	19.9b	6.5c
6:6	4.2b	1.0b	8.7b	6.8b	11.6b	7.3b	15.8b	18.4b
9:3	2.4c	2.3b	6.6b	3.2c	11.0b	9.4b	12.1c	5.3c
12:0	1.4c	1.2b	-	-	7.0c	3.3c	-	-
0:12	-	-	2.6c	2.0c	-	-	3.6d	3.1d
C.V%:	**24.2**	**25.1**	**32.9**	**20.2**	**14.8**	**21.9**	**16.8**	**18.2**
S.E:	**0.8**	**0.9**	**3.0**	**3.3**	**1.6**	**1.6**	**2.8**	**2.0**

T.M+ Tagetes minuta
+N Fertilizer
-N No-fertilizer

Table 14 **Effect of population ratio and fertilizer on Leaf to stem ratio of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M Ratio	Leaf to stem ratio							
	30 DAE				60 DAE			
	Maize		*T.Minuta*		Maize		*T.minuta*	
Experiment 1	N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	0.6a	0.6a	-	-	0.6a	0.8a
1:0	0.4c	0.4b	-	-	0.7a	0.7a	-	
3:9	0.7b	0.7b	0.6a	0.5a	0.5a	0.6a	0.5a	0.4b
6:6	2.2a	0.4b	0.4c	0.4b	0.6a	0.9a	0.7a	0.5a
9:3	0.6b	0.5a	0.5a	0.5a	0.6a	0.8a	0.6a	0.5a
12:0	0.5b	0.5a	-	-	0.7a	0.8a	-	-
0:12	-	-	0.5a	0.6a	-	-	0.6a	0.6a
CV%	**20.5**	**22.8**	**23.1**	**37.4**	**5.5**	**17.5**	**8.7**	**28.7**
S.E	**0.1**	**0.1**	**0.1**	**0.2**	**0.04**	**0.1**	**0.04**	**0.2**
Experiment2								
0:1	-	-	0.6a	0.7a	-	-	0.4b	0.6a
1:0	0.3b	0.6a	-	-	0.4b	0.7a	-	-
3:9	0.6a	0.7a	0.4b	0.5a	0.5a	0.6a	0.4b	0.6a
6:6	0.5a	0.5a	0.4b	0.5a	0.9a	0.7a	0.4b	0.4b
9:3	0.5a	0.7a	0.3b	0.5a	0.9a	0.7a	0.6a	0.7a
12:0	0.3b	0.6a	-	-	0.6a	0.7a	-	-
0:12	-	-	0.7a	0.6a	-	-	0.4b	0.8a
CV%	**15.4**	**13.8**	**17.0**	**20.1**	**7.1**	**17.6**	**8.4**	**16.3**
S.E	**0.1**	**0.1**	**0.1**	**0.1**	**0.04**	**0.1**	**0.1**	**0.1**

+N Fertilizer

-N No-fertilizer

Table 15 **Effect of population ratios and fertilizer on Leaf area duration of maize and *T. minuta* mean at 30 60 days after emergence (DAE)**

Maize: T.M Ratio	Leaf area duration (dm^2.day)			
	Mean of 30 and 60 DAE			
	Maize		T. minuta	
Experiment 1	+N	-N	+N	-N
0:1	_	_	4.0a	3.1a
1:0	9.2a	2.4a	-	-
3:9	2.5c	1.2c	0.6c	1.0b
6:6	4.3b	1.1c	1.7b	0.4c
9.3	4.0b	1.8b	0.7c	0.1c
12:0	3.7b	1.4c	-	-
0:12	-	-	1.9b	0.3c
C.V%:	**9.6**	**15.3**	**13.6**	**18.6**
S.E:	**0.5**	**0.2**	**0.03**	**0.2**
Experiment2				
0:1	_	_	4.3a	2.3a
1:0	4.3a	1.1a	-	-
3:9	1.4cd	0.8a	1.2b	0.8b
6:6	2.3b	0.8a	0.8c	0.2c
9.3	1.8c	0.8a	0.3d	0.1c
12:0	1.2d	1.1a	-	-
0:12	-	-	1.1b	0.2c
C.V%:	**10.2**	**17.6**	**7.5**	**14.8**
S.E:	**0.2**	**0.2**	**0.1**	**0.1**

+N fertilizer
-N No fertilizer

4.1.5 (f) Plant growth parameters

A mixture of maize and *T.minuta* at all ratios significantly increased plant relative yield both fertilizer and no fertilizer at 30 and 60 DAE in both experiments 1 and 2 (Table 16). On the other hand, pure maize or *T.minuta* had no significant effect on plant relative yield when the population of each was increased from 1 to 12 plant per pot, also fertilizer treatment were not affected significantly.

A mixture of maize and *Tagetes minuta* significantly decreased crop and weed growth rates both fertilizer and no fertilizer treatment. The trends in crop growth rate reduction in fertilizer and no fertilizer was similar after a growth period of 30 and 60 days during experiments 1 and 2 (Table 17). Growing 12 maize or *Tagetes minuta* plants per pot significantly decreased crop and weed growth rates in fertilizer and no fertilizer treatment compared to a single plant per pot, during the two sampling dates and in both experiments. On the other hand, fertilizer treatment was not increased significantly in this parameter.

Interplanting maize and *Tagetes mi*nuta did not significantly increase relative growth rate both fertilizer and no fertilizer treatment in experiments 1 and 2 (Table 18). Crop-weed population ratio of 50:50% improved relative growth rate in maize over that obtained from a single maize plant per pot both fertilizer and no fertilizer treatment, at two sampling times in both experiments (table 18). Planting 12 maize plants per pot significantly increased relative growth rate of maize in experiment 2 compared to a single maize per pot both fertilizer and no fertilizer treatment but in *Tagetes minuta* was not significantly affected in experiments 1 alone.

Planting maize and *Tagetes minuta* together at all ratios signficantly decreased net assimilation rate of both the crop and the weed in fertilizer and no fertilizer treatment in both experiments (Table 19). Increasing maize and *Tagetes minuta* population from 1 to 12 plants per pot significantly decreased net assimilation rate during both experiments,whether if it is fertilizer or no fertilizer treatment.Therefore,fertilizer treatment was increased significantly as compared to no fertilizer treatment.

Table 16 **Effect of population ratios and fertilizer on plant relative yield of maize and *T. minuta* at 30 and 60 days after emergence (DAE)**

Maize: T.M* Ratio	Plant relative yield							
	30 DAE				60 DAE			
	Maize		*T. minuta*		Maize		*T. minuta*	
Experiment 1	+N	-N	+N	-N	+N	-N	+N	-N
0:1	-	-	-	-	-	-	-	-
1:0	-	-	-	-	-	-	-	-
3:9	0.18c	0.17c	0.27a	0.32a	0.22b	0.19b	0.22a	0.29a
6:6	0.26b	0.19b	0.29a	0.32a	0.27a	0.32a	0.23a	0.27a
9:3	0.30a	0.23a	0.29a	0.34a	0.28a	0.34a	0.19a	0.26a
12:0	-	-	-	-	-	-	-	-
0:12	-	-	-	-	-	-	-	-
Experiment2								
0:1	-	-	-	-	-	-	-	-
1:0	-	-	-	-	-	-	-	-
3:9	0.18c	0.17c	0.27a	0.32a	0.22b	0.19b	0.22a	0.29a
6:6	0.26b	0.19b	0.29a	0.32a	0.27a	0.32a	0.23a	0.27a
9:3	0.30a	0.23a	0.29a	0.34a	0.28a	0.34a	0.19a	0.26a
12:0	-	-	-	-	-	-	-	-
0:12	-	-	-	-	-	-	-	-

+N Fertilizer
-N No fertilizer

Table 17 **Effect of population ratios and fertilizer on Crop growth of maize and *T. minuta* mean at 30 and 60 days after emergence (DAE)**

Maize: T.M Ratio	Crop growth rate (g/dm^2.day)			
	Mean of 30 and 60 DAE			
	Maize		*T. minuta*	
Experiment 1	+N	-N	+N	-N
0:1	_	_	0.43a	0.21a
1:0	0.9a	0.4a	-	-
3:9	0.2b	0.1b	0.08b	0.04b
6:6	0.2b	0.2b	0.05b	0.04b
9.3	0.1b	0.2b	0.14b	0.08b
12:0	0.2b	0.1b	-	-
0:12	-	-	0.08b	0.06b
C.V%:	**22.0**	**45.7**	**44.1**	**54.1**
S.E:	**0.1**	**0.1**	**0.1**	**0.1**
Experiment2				
0:1	_	_	0.17a	0.09a
1:0	0.1a	0.1a	-	-
3:9	0.1a	0.02b	0.02c	0.005b
6:6	0.1a	0.1a	0.03bc	0.02b
9.3	0.1a	0.1a	0.08b	0.02b
12:0	0.1a	0.04b	-	-
0:12	-	-	0.02c	0.009b
C.V%:	**33.7**	**41.9**	**42.8**	**54.0**
S.E:	**0.02**	**0.03**	**0.03**	**0.02**

+N Fertilizer
-N No fertilizer

Table 18 **Effect of population ratios and fertilizer on Relatative growth rate of maize and T. minuta mean at30 and 60 days after emergence (DAE)**

Maize: T.M Ratio	Relative growth rate (g/g.day)			
	Mean of 30 and 60 DAE			
	Maize		*T. minuta*	
Experiment 1	+N	-N	+N	-N
0:1	–	–	0.0156ab	0.12a
1:0	0.015a	0.011ab	-	-
3:9	0.011bc	0.003b	0.009c	0.008a
6:6	0.009c	0.016a	0.007c	0.008a
9.3	0.006d	0.013ab	0.02a	0.012a
12:0	0.012b	0.012ab	-	-
0:12	-	-	0.01bc	0.011a
C.V%:	**25.5**	**26.3**	**19.2**	**21.0**
S.E:	**0.003**	**0.003**	**0.002**	**0.01**
Experiment2				
0:1	–	–	0.08a	0.008a
1:0	0.001d	0.004b	-	-
3:9	0.005bc	0.004b	0.018a	0.002a
6:6	0.004c	0.008ab	0.006a	0.006a
9.3	0.007a	0.01a	0.017a	0.009a
12:0	0.007ab	0.006ab	-	-
0:12	-	-	0.0.003	0.004a
C.V%:	**20.1**	**17.3**	**26.9**	**21.0**
S.E:	**0.001**	**0.02**	**0.01**	**0.01**

+N Fertilizer

-N No fertilizer

Table 19 **effect of population ratios and fertilizer on net assimilation rate of maize and *T. minuta* mean at 30 and 60 days after emergence (DAE)**

Maize: T.M Ratio	Net assimilation rate ($g/dm^2.day$)			
	Mean of 30 and 60 DAE			
	Maize		T. minuta	
Experiment 1	+N	-N	+N	-N
0:1	_	_	27.2a	8.7a
1:0	54.7a	41.2a	-	-
3:9	21.4b	5.5b	9.8b	1.6c
6:6	29.0b	13.4b	10.8b	4.5b
9.3	18.9b	13.9b	5.0c	1.0c
12:0	29.5b	8.1b	-	-
0:12	-	-	3.8c	0.4d
C.V%:	**29.6**	**62.4**	**52.9**	**46.0**
S.E:	**20.0**	**14.8**	**13.8**	**15.6**
Experiment2				
0:1	_	_	15.2a	2.2a
1:0	39.6a	7.0a	-	-
3:9	1.9c	4.3b	0.7b	0.1b
6:6	4.3b	1.3b	2.9b	0.2b
9.3	5.6b	2.9b	1.6b	0.2b
12:0	4.9b	1.3b	-	-
0:12	-	-	1.0b	0.1b
C.V%:	**21.6**	**20.1**	**21.3**	**22.3**
S.E:	**19.8**	**13.2**	**17.1**	**19.5**

+N Fertilizer

-N Nofertilizer

4.2 Field experiments

4.2.1. Interference of *Tagetes minuta* on growth and yield of maize

4.2.1.1 Effects of treatments on *Tagetes minuta*

(a) Weed counts

Hand weeding 30 and 45 or 40 and 60 DAE was as effective, in reducing weed counts both fertilizer and no fertilizer treatment, as all weed-free treatments including weed-free throughout 1996 season (Table 20). Weed-interference throughout the season significantly increased weed counts compared to all weed-free treatments with or without fertilizer application.

During 1997 season (Table 20) weed-free throughout the season significantly reduced weed counts compared to the rest of the weed-free treatments, all the weed-interference treatments and two weedings 30 and 45 or 40 and 60 DAE in fertilizer and no fertilizer treatment.

In 1997,two weedings 40 and 60 DAE had similar weed counts and were as effective as allowing *Tagetes minuta* to compete with maize for the first 30 days in fertilizer treatment and then weed-free throughout the remainder of the season. However , weeding at 30 and 45 DAE signifcicantly reduced weed count compared to keeping maize weed free for the first 30 days in fertilizer and no fertilizer treatment. Also, there was more weeds in weed-interference treatments during 1997 compared to 1996 across treatments both fertilizer and no fertilizer treatment.

Table 20 **Effect of fertilizer and duration of weed-free and interference maintenance on weed count in maize field (1996 and 1997)**

Duration of weed-free or interference (DAE)	Number of weeds/m^2 1996 +N	1996 -N	1997 +N	1997 -N
0-30	36.9cde	52.0efg	44.1c	43.3d
0-50	45.8cde	32.6fg	52.2bc	36.3def
0-60	54.1cd	51.7efg	56.3bc	36.1def
0-75	43.2cde	23.8g	48.6bc	30.5f
0-90	51.6cd	39.2fg	55.2bc	33.0ef
0-120	50.9cd	29.4fg	39.6c	36.0def
0-180	0.0e	0.0g	0.0d	0.0g
Weed-interference				
0-30	28.1de	138.8cd	43.1c	37.9def
0-50	64.6bcd	98.1de	122.4a	155.3c
0-60	36.9cde	84.6ef	174.6a	160.2bc
0-75	84.5abc	175.9bc	174.8a	166.4ab
0-90	68.6bcd	156.8bc	178.8a	169.6a
0-120	108.9ab	192.0ab	183.9a	166.7ab
0-180	124.8a	322.0a	188.9a	166.7ab
Weed 30-45	31.1de	29.8fg	40.0c	33.3ef
Weed 40-60	50.3cd	36.9fg	72.9b	41.6de
C.V%	1.3	0.5	0.1	0.1
S.E:	13.0	7.2	2.4	1.2

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

(b) Weed-height

Keeping maize free of *Tagetes minuta* during the first 90 and 120 days or less significantly increased weed height compared to leaving the weed-free treatment throughout 1996 and 1997 season both fertilizer and no fertilizer treatment respectively(Table 21). Weed-interference throughout the season significantly increased weed height compared to the rest of the treatments in fertilizer and no fertilizer treatment both 1996 and 1997. Two weedings at 30 and 45 or 40 and 60 DAE reduced height of the weed both fertilizer and no fertilizer treatment comparable to keeping maize free of the weed for 60 days during 1996 and 1997 respectively (Table 21).

In 1997, interference of *T.minuta* in maize for 120 days or more significantly increased weed height compared to all other treatments in fertilizer and no fertilizer treatment (Table 21). Maintaining maize weed-free for only the first 50 days or less significantly increased weed height both fertilizer and no fertilizer treatment compared to two weedings stagerred at 30 and 45 DAE or 40 and 60 DAE respectively. Weeds were taller in 1997 than in 1996 season across treatments.

Table 21 Effect of fertilizer and duration of weed-free and interference maintenance on weed height in maize field (1996 and 1997)

Weed-free period (DAE)	Weed height (cm) 1996		1997	
	+N	-N	+N	-N
0-30	16.7	13.7d	29.7f	32.1f
0-50	16.1e	11.9de	30.0f	26.7fg
0-60	12.8ef	9.5def	25.9f	19.5gh
0-75	11.7efg	8.8def	22.6f	20.6gh
0-90	11.3efg	7.8def	20.6f	17.0h
0-120	8.9fg	5.8efg	19.3f	14.2h
0-180	0.0	0.0	0.0g	0.0i
Weed-interference				
0-30	32.7d	28.2c	75.6cd	51.7de
0-50	38.2c	32.7c	58.0e	47.6e
0-60	53.2b	45.5b	76.2cd	67.4bc
0-75	54.9b	44.3b	80.7bc	59.1cd
0-90	54.2b	44.0b	69.9d	62.8bc
0-120	55.4b	43.4b	87.1ab	70.8ab
0-180	90.8a	60.3a	96.4a	76.7a
Weed 30-45	7.4fg	4.3fg	40.8f	13.2h
Weed 40-60	6.4g	4.1fg	21.3f	16.1h
C.V%	3.0	1.0	1.0	0.8
S.E:	3.5	0.9	1.9	1.2

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

(c) Fresh weed biomass

In 1996 the highest weed fresh weight was obtained when maize was kept weed-free for the first 30 and 50 DAE both fertilizer and no fertilizer treatment (Table 22). As the number of weed-free days increased the fresh weed weight decreased significantly (P=0.05) in fertilizer and no fertilizer treatment compared to the full-season weed control. The lowest fresh weed weight was achieved when maize was kept *Tagetes* free for 60 and 75 days in 1996 and 75 and 90 days in 1997 both fertilizer and no fertilizer respectively. As the number of days of weed-interference increased the fresh weed weight increased signficantly compared to full-season interference in fertilizer and no fertilizer treatment.

Tagetes minuta interference for 50 or more DAE signficantly increased weed fresh weight compared to other treatments. The trend in fresh weed weight during 1997 season both fertilizer and no fertilizer treatment (table 22) across treatments was similar to that described for fresh weed weight in 1996. Maintaining maize free of Tagetes *minuta* during the first 50 DAE, then left weeds, significantly increased weed fresh weight compared to full-season control. Weed fresh weight in full-season interference during 1996 season was generally higher than fresh weed weight under the same treatment in 1997 season both fertilizer and no fertilizer treatment.

Table 22 Effect of fertilizer and duration of weed-free and interference maintenance on fresh weed yield in maize field (1996 and 1997)

Weed-free period (DAE)	Fresh weed yield (kg/ha) 1996		1997	
	+N	-N	+N	-N
0-30	5318de	4524d	4365ef	3611de
0-50	4921def	3889de	4921ef	4643cd
0-60	3214efg	2540e	3929ef	2381e
0-75	2937fg	2608e	4286ef	1865ef
0-90	1706gh	3810de	2381fg	1984ef
0-120	3175efg	3556de	2857ef	2500e
0-180	0.0h	0.0f	0.0g	0.0f
Weed-interference				
0-30	5556d	5394cd	3810ef	3016de
0-50	14921b	9365bc	13738ab	7659ab
0-60	14921b	8095bc	9373d	7937ab
0-75	13651bc	9842bc	11111c	7857ab
0-90	12461c	9365bc	11588bc	6191bc
0-120	15080b	12143b	9762cd	8095ab
0-180	17699a	14921a	14524a	8334a
Weed 30-45	3889defg	3254de	5635e	3651de
Weed 40-60	4762def	3033de	5238e	3492de
C.V%	15	45.0	22	24.8
S.E:	30	57	36	28

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

(d) Dry weed biomass

Data indicates that dry weed biomass significantly decreased with increase in the period of weed-free maintenance in fertilizer and no fertilizer treatment (Table 23).Controlling *Tagetes minuta* for more than 50 days of maize growth significantly decreased dry weed biomass during 1996 as well as 1997 both fertilizer and no fertilizer treatment (Table 23). Weeding twice 30 and 45 DAE was as effective in reducing dry weed biomass as weed-free throughout the 1996 season but not in 1997.

Weed-interference throughout 1996 season significantly increased yield of dry weeds compared to all other treatments in 1996 and 1997 both fertilizer and no fertilizer treatment, except weed-interference during the first 50 days of maize growth in 1997

Dry weed biomass across treatments were similar in 1996 and 1997. However weed interference treatments in 1996 produced twice as much dry weed biomass as that produced in similar treatments in 1997 both fertilizer and no fertilizer treatment.

Table 23 **Effect of fertilizer and duration of weed-free and interference maintenance on dry weed yield in maize field (1996 and 1997)**

Weed-free period (DAE)	Dry weed yield (kg/ha) 1996		1997	
	+N	-N	+N	-N
0-30	3810c	2699de	1667efg	1349de
0-50	2857cd	2143def	1905def	1587de
0-60	1508de	1270ef	1111fg	724ef
0-75	1905cde	1429ef	1587fg	635ef
0-90	476e	2064def	1191fg	595ef
0-120	476e	1493ef	1111fg	873def
0-180	0.0f	0.0f	0.0g	0.0f
Weed-interference				
0-30	3175cd	3810cd	1984def	1984d
0-50	11905b	5476bc	7619a	3175c
0-60	11111b	5397bc	4445bc	4127bc
0-75	11191b	6984b	4206bc	3572c
0-90	10159b	6826b	5556b	4921ab
0-120	11429b	9842a	3651cd	3651c
0-180	15080a	9842a	8413a	5953a
Weed 30-45	1587de	1825def	3492cde	1191def
Weed 40-60	3413cd	1984def	2699cdef	1508de
C.V%	**20.4**	**30.8**	**31.2**	**29.6**
S.E:	**28**	**29**	**47.0**	**65.8**

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

4.2.1.2 Effects of treatments on maize

(a) Maize Height

Table 24 shows that *Tagetes minuta* interference, for the whole season significantly reduced height of maize in both fertilizer and no fertilizer treatment in 1996 and 1997. Maize height was lower in 1997 than in 1996. in 1997, weed-free days for only the first 50 days in fertilizer and no fertilizer treatment significantly reduced maize height compared to full-season control. The rest of the treatments were not significantly different. Two weedings at 40 and 60 DAE significantly reduced maize height in both seasons compared to weed-free treatment throughout the season with or without fertilizer application.

Table 24 **Effect of fertilizer and duration of weed-free and interference maintenance on crop height in maize field (1996 and 1997)**

Weed-free period (DAE)	Maize height (cm) 1996		1997	
	+N	-N	+N	-N
0-30	322abc	253ab	92de	92b
0-50	318bc	244ab	89ef	84bc
0-60	321bc	245ab	107c	89b
0-75	327abc	273a	103c	85bc
0-90	332ab	251ab	120b	96b
0-120	326abc	237abc	127b	113a
0-180	339a	252ab	148a	121a
Weed-interference				
0-30	315bc	248ab	109c	93b
0-50	314bc	269a	100cd	73cde
0-60	322bc	253ab	82efg	70de
0-75	316bc	184c	78g	62e
0-90	310c	247ab	80fg	75cde
0-120	317bc	195bc	74h	67de
0-180	281d	214abc	80fg	75cd
Weed 30-45	324abc	223abc	102cd	71de
Weed 40-60	310c	237abc	84efg	71cde
C.V%	**0.01**	**0.8**	**0.01**	**0.5**
S.E:	**0.1**	**7.8**	**0.02**	**1.8**

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

(b) Fresh maize stover yield

Data (table 25) show that fresh maize stover was significantly high during 60 and 50 days of weed-free maintenance in fertilizer and no fertilizer treatment respectively as compared to full-season, but in 1997 while as number of weed-free period increased fresh maize stover yield increased both fertilizer and no fertilizer treatment. The fresh maize stover in second-season (1997) was higher than in the first-season (1996). Weed-interference for any number of days significantly reduced fresh maize stover yield. Weed-interference did not significantly reduce fresh stover in 1996 but it had significant effect on fresh stover yield in 1997. Weed-interference throughout the season and two weedings 30 and 45 DAE significantly decreased fresh maize stover yield of maize compared to weed-free throughout the season both fertilizer and no fertilizer treatment (Table 25).

Table 25 **Effect of fertilizer and duration of weed-free and interference maintenance on fresh maize stover yield (1996 and 1997)**

Weed-free period (DAE)	Fresh maize stover yield (kg/ha) 1996		1997	
	+N	-N	+N	-N
0-30	6508ab	3453abc	9921abcd	9921abcde
0-50	6826ab	4683a	13096ab	10318abcd
0-60	8413a	3929abc	13096ab	12302a
0-75	7381ab	4286ab	10080ab	8333abcde
0-90	7738ab	4127ab	11588abcd	11905ab
0-120	8651a	4365ab	10715abcd	9524abcde
0-180	8215a	3968abc	14127a	11111abc
Weed-interference				
0-30	7461ab	4206ab	12429abc	6746cde
0-50	6865ab	4484ab	10318abcd	7619bcde
0-60	7262ab	5119a	7937cd	7540bcde
0-75	7222ab	2579bc	7540d	5952de
0-90	4921b	4167ab	7540d	6746cde
0-120	2143ab	2262c	9921abcd	8730abcde
0-180	5635ab	3651bc	7143d	5556e
Weed 30-45	5794ab	3769abc	9127bcd	5952de
Weed 40-60	6270ab	4365ab	12302abc	7937abcde
C.V%	**22.4**	**24.7**	**23.0**	**27.2**
S.E:	**39**	**44.3**	**60.2**	**57.6**

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

(c) Dry maize stover yield

Results (Table 26) indicate that increasing weed-free or weed-interference period from maize emergence to harvest had no significant improvement or reduction in dry maize stover yield during 1996 both fertilizer and no fertilizer treatment. Two weedings 30 and 45 DAE or 40 and 60 DAE produced similar amount of maize stover to the rest of the treatments. Dry maize stover yield was higher in 1997 than in 1996 (Table 26). However in 1997, controlling *T.minuta* throughout the season and two weedings 40 and 60 DAE significantly increased the yield of dry maize stover, compared to full-season *T.minuta* interference both fertilizer and no fertilizer treatment.

Table 26 **Effect of fertilizer and duration of weed-free and interference maintenance on dry maize stover yield (1996 and 1997)**

Weed-free period (DAE)	Dry maize stover yield (kg/ha) 1996		1997	
	+N	-N	+N	-N
0-30	4048a	2341ab	5794abc	5714abc
0-50	3810a	3690a	8413a	5635abc
0-60	5357a	2619ab	8095a	7381a
0-75	4921a	3254a	6111abc	4603abc
0-90	5000a	3016a	7778ab	7381a
0-120	5357a	2579ab	5953abc	5953ab
0-180	5040a	2778ab	8413a	6191ab
Weed-interference				
0-30	3810a	3056a	6905abc	3651bc
0-50	4881a	3373a	5794abc	4445bc
0-60	4365a	3175a	6111abc	3651bc
0-75	4524a	1699b	3810bc	4286bc
0-90	3849a	3056a	3889bc	3651bc
0-120	4207a	1349b	6032abc	4206bc
0-180	4167a	2460ab	3016c	2857c
Weed 30-45	4246a	2381ab	4921abc	3373bc
Weed 40-60	3730a	2659ab	7619ab	4365bc
C.V%	**21.5**	**29.2**	**34.5**	**30.3**
S.E:	**39.0**	**40.1**	**53.7**	**36.7**

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

(d) **Unshelled maize yield**

Data in (table 27) show that weed-free for 30 days had the lowest grain yield of unshelled maize while maintaining the crop weed-free for 50 days or more had no significant yield increase compared to weed-free throughout the season both fertilizer and no fertilizer treatment. Weed-free and weed-interference days had no significant effect as unshelled maize yield remained constant with increase of weed-free or weed-interference duration both 1996 and 1997 in fertilizer and no fertilizer treatment.

Maintaining maize weed-free for 50 days or more was adequate as it significantly increased yield of unshelled maize in 1996 both fertilizer and no fertilizer treatment but it does not increase in 1997 comparable to weed-free maintenance respectively. *Tagetes minuta* interference for 75 days or more significantly reduced unshelled maize yield in no fertilizer both 1996 and 1997 relative to weed-free maintenance throughout the season (Table 27). Weeding twice at 30 and 45 or 40 and 60 DAE was effective as weed-free maintenance. Unshelled maize yield in 1996 was generally higher than that of 1997. Weeds reduced unshelled maize yield by 56% and 37.8% during 1996 and 1997 respectively.

Table 27 Effect of fertilizer and duration of weed-free and interference maintenance on unshelled maize yield (1996 and 1997)

Weed-free period (DAE)	Unshelled maize yield (kg/ha) 1996		1997	
	+N	-N	+N	-N
0-30	4445bcd	2937bcd	3731ab	3278a
0-50	5714abc	3810abc	3532ab	3572a
0-60	5595abc	3572abc	3572ab	2937a
0-75	4921abcd	3968ab	4048ab	2818a
0-90	5675abc	4008ab	3810ab	3095a
0-120	5159abc	3492abc	3095ab	3294a
0-180	5040a	2778ab	8413a	6191ab
Weed-interference				
0-30	5080abcd	3730abc	3532ab	3072a
0-50	4326cd	4326a	3095ab	2307a
0-60	4873abcd	3333abc	3135ab	2937a
0-75	4841abcd	2460cde	3532ab	2341a
0-90	4286cd	2738a	3532ab	2619a
0-120	4286cd	1984dc	2794a	2619a
0-180	3651d	1587e	2341b	2222a
Weed 30-45	4841abcd	3095cd	3095ab	2854a
Weed 40-60	5080abcd	3373abc	3611ab	3095a
C.V%	**14.8**	**21.4**	**27.4**	**30.2**
S.E:	**18.4**	**27.8**	**29.5**	**28.4**

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

(e) Shelled Grain yield

Results (Table 28) show that compared to *T.minuta* full-season control, grain yield was significantly lowered when *T.minuta* was controlled in maize for only the first 30 days both fertilizer and no fertilizer treatment, and there after left to compare with maize in 1996 (see figure 1 a and b).

No significant yield increase or decrease in maize was obtained when maize was maintained weed-free or left to compete with *T.minuta* for more than 30 days in both seasons in fertilizer and no fertilizer treatment. Two weedings 40 and 60 DAE was as good as weed-free, interms of maize yield, during both fertilizer and no fertilizer treatment in 1996 and 1997 seasons.

Maize grain yield was comparatively higher in 1996 than in 1997. Although there was a significant decrease in grain yield when *T.minuta* competed with maize throughout the season compared to weed-free treatments, the rest of the treatments were not significantly different in 1997 both fertilizer and no fertilizer treatment (Table 28)(see figure 2 and 3 a and b).

Compared to weed-free throughout the season, uncontrolled *T.-minuta* significantly decreased grain yields by 38% and 59.1% and 47%and 37.5% during 1996 and 1997 respectively. There was no significant differences in maize stand at harvest within treatments during both 1996 and 1997 seasons.

Table 28 **Effect of fertilizer and duration of weed-free and interference maintenance on shelled maize grain yield (1996 and 1997)**

Weed-free period (DAE)	Shelled maize grain yield (kg/ha) 1996		1997	
	+N	-N	+N	-N
0-30	3056ab	2937bcd	2500ab	2103abcd
0-50	4087a	3810abc	2778ab	2738ab
0-60	3968a	3572abc	2500ab	2460abcd
0-75	3413ab	3968ab	2738ab	2976a
0-90	3849a	4008ab	2580ab	3056a
0-120	3651ab	3492abc	2818ab	2262abcd
0-180	4167a	3611abc	3095a	2619abc
Weed-interference				
0-30	3651ab	3730abc	2500ab	2738ab
0-50	3056ab	4326a	2064ab	1627cde
0-60	2613b	3333abc	1825ab	2262abcd
0-75	3135ab	2460cde	2223ab	3016a
0-90	3056ab	2738bcde	2103ab	1786bcde
0-120	3016ab	1984de	1945ab	1468de
0-180	2579b	1587e	1627b	1072e
Weed 30-45	3413ab	3095cd	2341ab	2142abcd
Weed 40-60	3730ab	3373abc	2278ab	2302abcd
C.V%	**17.6**	**21.4**	**20.4**	**23.6**
S.E:	**24.6**	**27.4**	**27.5**	**35.3**

+N Fertilizer
-N No-fertilizer

Means followed by the same letter are not significantly different by DMRT(α=0.05)

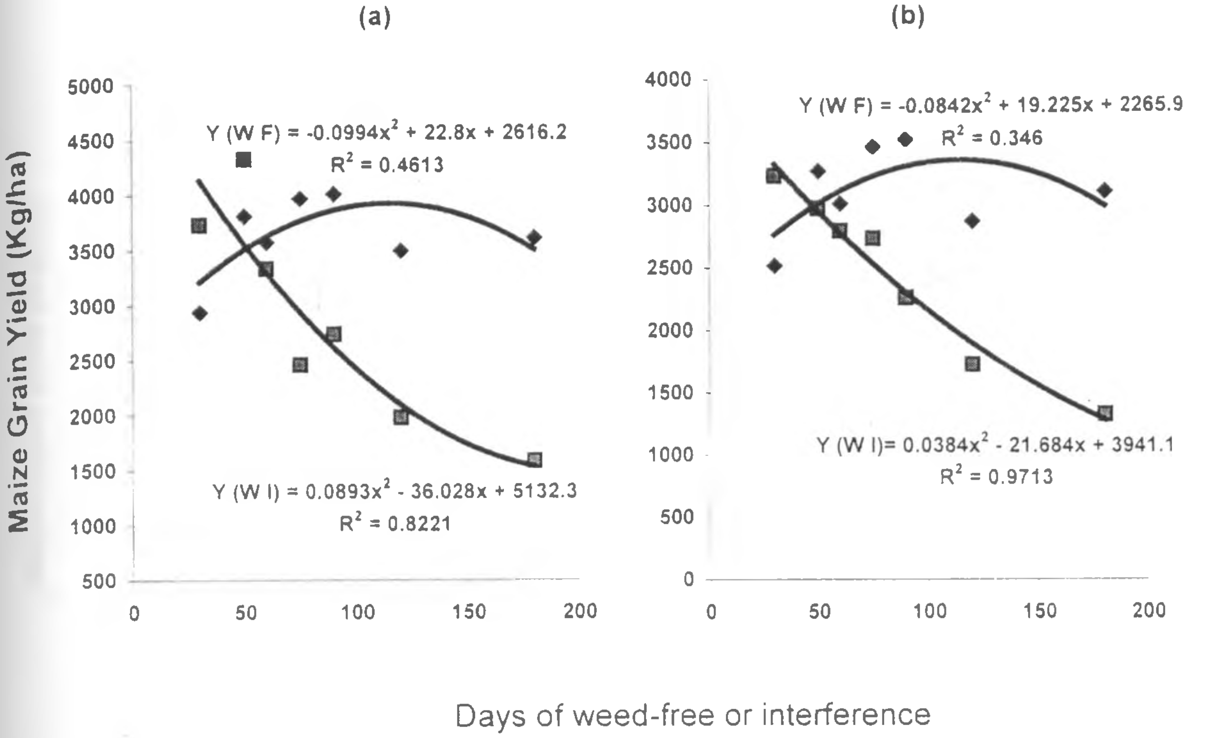

Figure 1: Effects of weed-free maintenance and weed intereference of *Tagetes minuta* on maize grain yield under fertilization (a) and no fertilization (b) in 1996

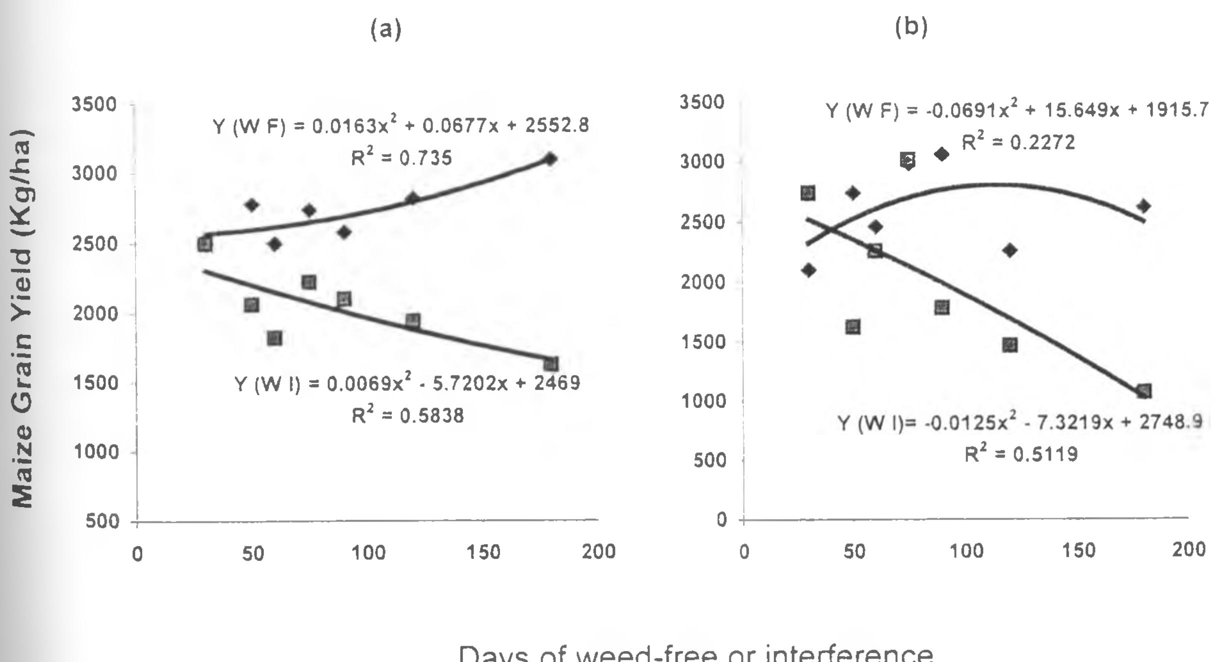

Figure 2: Effects of weed-free maintenance and weed intereference of *Tagetes minuta* on maize grain yield under fertilization (a) and no fertilization (b) in 1997

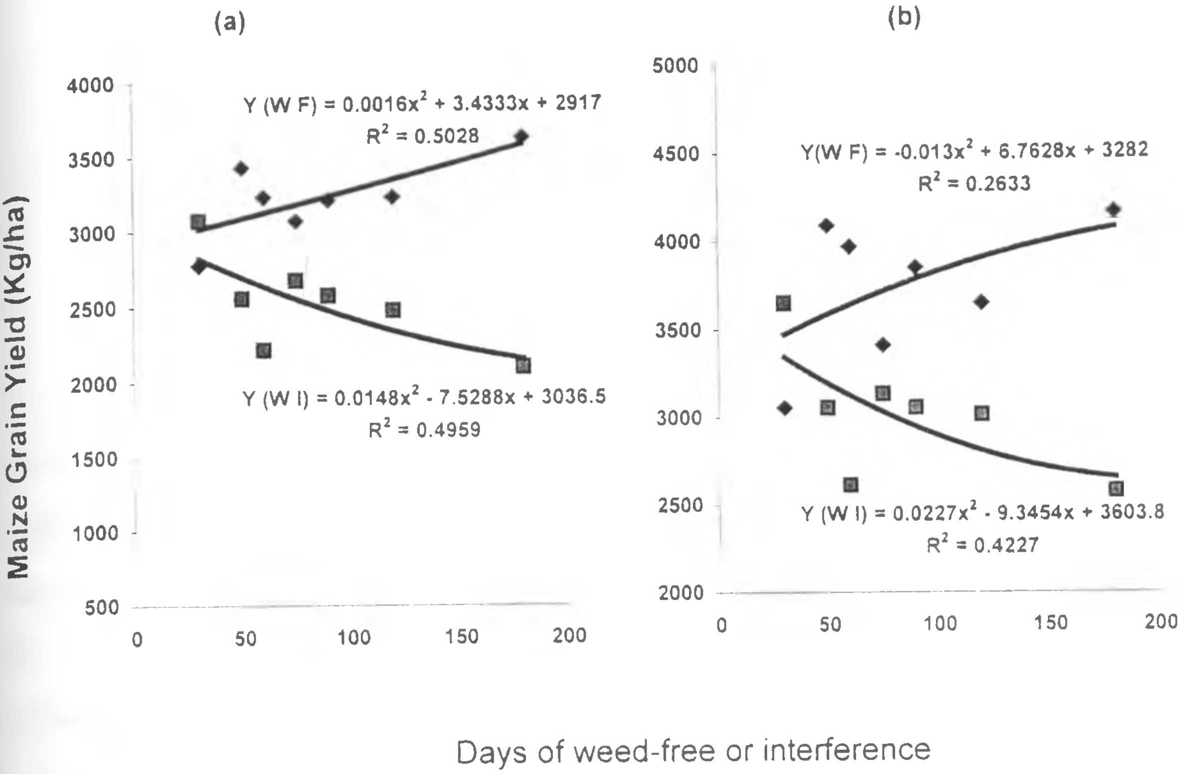

Figure 3: Effects of weed-free maintenance and weed intereference of *Tagetes minuta* on maize grain yield under fertilization (a) and no fertilization (b) averaged over 1996 (a) and 1997 (b) respectively

CHAPTER FIVE

5.0 DISCUSSION

5.1 Greenhouse experiments

5.1.1 Effects of intra and interspecific competition between maize and *Tagetes minuta* on growth and yield

Interspecific competition between maize and *T.minuta* was high and this contributed to a reduction in height of both maize and the weed at all plant population ratios. However, at 50 percent maize and 50 percent *T.minuta* ratios, interspecific competition seems to have eased, probably because of a more balanced demand on soil nutrient, moisture and sunlight. The main reason for plants to grow tall is competition for light, which makes it advantageous to divert resources from leaf surfaces to erect stems. In a purely competitive situation, the plant height represents a balance between two factors. On one hand it is always advantageous to be slightly taller than the neighbors and on the other hand, the taller the plant, the greater fraction of available resource must be allocated to support structures. This balance summarized above has been analysed by Givnish (1982) in an ingenious way. The model of Givnish (1982) is based on the tacit assumption that tissue losses either do not occur or they are independent of short height. This implies that competition for light may have contributed to increase in height of maize and *T.minuta* when both were grown in mixture. Donald (1961) in his comprehensive review states that competition for light occurs almost in all cropping situations. Intraspecific competition in maize and *T.minuta* significantly reduced the height of maize and *T.minuta* when their population were increased from 1 to 12 plants per pot. Intraspecific competiton within maize and within *T.minuta* resulted in a reduction in crop and weed height by 38 and 51 percent and 55 and 54 percent in fertilizer and 51 and 54 percent and 62 and 60 percent in no fertilizer application after 30 and 60 days of crop growth, averaged over two experiments respectively. Therefore *T.minuta* or maize grown together in the same pot were making the same nutrient demand from the soil in the pot. Since no fertilizer was applied, nutrient became limiting and this resulted in stunted growth as shown by significantly shorter plants in 12 compared to 1 crop or weed. In green house experimets, Gray *et al* (1955) found that bentgrass (Agrostis palustris) maintained a higher level of potassium uptake relative to that of ladino clover when the two species were grown seperately or together. The authors suggested that in certain weed/crop associations, the weeds may consume nutrients luxuriously relative to the crop.

Interspecific competition between maize and *T.minuta* was high because of decrease in root, stem and leaf dry mass of both maize and *T.minuta* irrespective of crop-weed ratio at

30 and 60 DAE in both experiments. The behavior of mixtures of plants can be explained, at least in principle by the behavior of the component individual plants. Maize and *T.minuta* are competing for the same resources, light, water and nutrients, and so the performance of each plant depended on its ability to obtain and utilize those resources. Just as it does in monocultures. In extremely crowded conditions, this behavior should lead to self-thining. Also, as the total yield of the mixture depends on the amounts of resources available one should expect mixtures to obey competiton density effects (Kira *et al*, 1953). Nevertheless, competition within mixture is more complex than that in monocultures as the different species may have different resource requirements, different patterns of growth, respond differently to environmental conditions and modify the environment for each other. Few studies have investigated the effects of competition on individual plants in mixtures. In a comparison of size hierarchy development in monocultures and two-species mixtures of wild oats (Avena fatua), leafless pea (pisum satirum cv.fibe), and conventional pea (pisum satium cv. Birke), Butcher (1983) found that the degree of inequality among all individuals in the mixtures appeared to be related to the ability of one species to out compete the other, where the two species seemed evenly matched, the degree of size inequality was similar to that observed in the monoculures. Considering the

inequality within the component species of the mixturesm, Weiner (1985) found that Lolium perenne, the dominates species when grewn with *trifolium incarnatum,* showed less size inequality in mixture than in monoculture, where trifolium plants, the suppressed species, usually developed greater degree of inequality. But on the other hand intraspecific competition within maize and within *T.minuta* was high due to the number of plants which were involved in each parameter measured. As the number of plants in purestand increased from 1 to 12 plants per pot there were significant reduction in each parameter due to the increased resource demand. Increase in root volume of maize or *T.minuta* per pot in pure stands with higher population could have lead to fast depletion of nutrients. The reduction in root, stem and leaf dry mass of maize and T.minuta points to a reduction in photosynthesis and therefore in yield of the crop and the weed as a result of competition. Leaf development and expansion are important factors in determining competitive outcome when simulating crop- Weed interference (Kropff, 1988). Various experiments and surveys have evaluated crop loss due to weeds (spitters *et al* 1982). Similar experiments are also utilized to correlate weed populations during early crop growth with subsequent losses (Dawson *et al* 1971).

Maize planted at high population at 12 per pot even in the absence of *T.minuta* compete among themselves and this leads to reduction in yield, especially under this situation where fertilizer was not applied. Similarly if weeding is not done in a maize field infested with *T.minuta* then the weed, apart from competing with maize, also compete among themselves for available growth resources Patterson (1979) found that shading markedly reduced dry matter production and relative growth rate of itch grass (Rottbolellia exaltata). Patterson (1979, 1982) further suggests that this characteristics of itchgrass to maintain the potential for high photosythentic activity even in light-limited conditions can help explain this species ability to compete effectively with tall and dense crops, such as corn or sugar cane. The trend in reduction of a total dry mass was similar to that of reduction in root, stem and leaf dry mass. This therefore could have contributed to the sum total reduction in the total dry matter production of both the crop and the weed. However, like other parameters the total dry matter production suffered as a result of inter and intraspecific competition between and among maize and T.minuta respectively. The effect was made worse as a result of a reduction in soil fertility because no fertilizer was applied.

On the other hand intraspecific competition between maize and *T.minuta* had no effect on stem, leaf and root weight ratio. This was reflected in results which showed that different population mixtures had stem, leaf and root weight ratios which were not significantly different from that obtained from single plants of maize or *T.minuta* per pot. Similarly intraspecific competition had no significant effect on stem, leaf and root weight ratios of maize or *T.minuta,* irrespective of time of sampling. This implies that intra and interspecific competition reduced root, stem and leaf dry mass by margins, that could have contributed to a non significant decrease in root, stem and leaf weight ratios in the crop and the weed irrespective of the time harvest and the ratios of the mixtures.

On the other hand, both inter and intraspecific competition between and among maize and *T.minuta* was low as shown by the specific leaf weight, also the trend was the same in both experiments. Intraspecific competition within the crop and the weed was highly significant and increased as the ratio of the weed was increased from 1 to 12 plants per pot. Increase in leaf area ratio was due to the interspecific competition between maize and *T.minuta* when planted in the same pot irrespective of the crop-weed ratio but the intraspecific competition within maize and within *T.minuta* was significantly high as the number of ratio increased from 1 to 12 plants per pot. Therefore the LAR of all treatments when fertilizer was applied was higher than LAR at no fertilizer application. The LAR itself is the product of the leaf weight ratio and specific leaf area. The increasing in LAR represent an adaptation of itchgrass to shading at the whole plant level. Patterson (1979, 1982) further suggests that this characteristic of itchgrass to maintain the potential for high photosynthetic activity even in light limited conditions can help explain this species ability to compete effectively with tall and dense crops, such as corn or sugarcane.

Blackman and Black (1959) made such an observation during their ecological studies on the plant environment. In their experience, the higher temperatures of tropics and subtropics led to greater LAR and therefore enhanced relative growth rate. Inter and intraspecific competition had no effect on leaf to stem ratio between and within maize and *T.minuta*. The trend was the same 30 and 60 DAE and this was confirmed in the two experiments. Both maize and *T.minuta* were equally affected.

Plant relative yield of maize and *T.minuta* was less than one under recommended and zero fertilizer and increased or decreased as the proportion of both maize and *T.minuta* increased in pots indicating that maize and the weed were more affected by interspecific than intraspecific competition.

Since relative yield total (RYT) was less than 1 it indicated that a mixture of the crop and the weed was antagonistic. However, the increase in plant relative yield (PRY) of maize as proportion of maize increased where as that of *T.minuta* decreased shows that intraspecific competition among maize was less severe than interspecific competition between maize and *T.minuta*. The fact that relative yield of *T.minuta* increased as the proportion of the weed decreased but with increasing population of maize indicate that *T.minuta* is more sensitive to intraspecific competition among them than interspecific competition btween *T.minuta* and maize .Interspecific competition between maize and *T.minuta* was not high due to the small variation of population ratios. However, at 75 percent maize and 25 percent *T.minuta* ratio seems to have been affected probably because of more demand resources in maize than in *T.minuta* in experiment one but in experiment two competition was more severe at 50 percent maize and 50 percent *T.minuta* due to the balanced demand of resources of both maize and *T.minuta*. Interspecific competition between maize and *T.minuta* had no effect on crop growth rate. This could be explained by the fact that there was no significant different in crop growth rate irrespective of the ratio of the crop to the weed. The trend was the same 30 and 60 DAE and this was confirmed with two experiments. Intraspecific competition within maize and within *T.minuta* was significantly high as indicated in the reduction of crop growth rate of both the crop and the weed when their population were increased from 1 to 12 plants per pot.

Interspecific competition between maize and *T.minuta* had no effect on relative growth rate (RGR). There was signficant increase in the intraspecific competition as the plants/pot were increased.

Intra and interspecific competition between maize and *T.minuta* had no effect on leaf area duration on the crop and the weed. This was reflected in the results which showed that similar or different population mixtures had leaf area duration which were not significantly different from that obtained in single plants of maize or *T.minuta* per pot.

Interspecific competition between maize and *T.minuta* was high and this was responsible for the decrease in net assimilation rate in treatments where maize and *T.minuta* were planted in the same pot without regard of the crop-weed ratios. The trend was the same 30 and 60 DAE in the two experiments. Also intraspecifc competition was high. This was indicated by the significant reduction in net assimilation rate of maize and *T.minuta* when population of each of them was increased from 1 to 12 plants per pot

The poor response of cotton in relation to the weeds appeared to be associated with the long-term effects of cold treatment on leaf area since leaf area duration was reduced more than NAR (Patterson and Flint, 1979). In this case, LAR declined, not withstanding increase in both NAR and RGR, presumably growth rate would have been further enhanced if LAR had not diminished. Ford and Thorne (1967) demonstrated a similar effect on barley, sugarbeet, kale and corn.

Rodin and Boyer (1982) working with sunflower under controlled environment showed that decrease in leaf nitrogen resulted in reduced leaf expansion. Daytime leaf expansion was reduced due to inability of the plants to maintain adequate turgor. Crop growth rate (CGR) has been expressed as a product of LAI and the efficiency of dry matter production per unit leaf area.

Plant species from contrasting habitats differ in their relative growth rate (RGR) under growing conditions. Distributed and productive habitats are dominated by inherently fast growing plant species, where as slow growing species are often associated with more stable and less productive sites (Grime and Hunt, 1975). Plant species also differ in the relative importance of their leaf area ratio (LAR), net assimilation rate (NAR) and relative growth rate (RGR) Corre 1983; Waring *et al*, 1985; Lambers and Dijkstra, 1987). In short terms growth experiments, however, species from infertile sites tend to grow more slowly than those from more fertile environments, even at very low nutrient availablity (Chapin, 1980). The effect of a low or no nitrogen supply on dry matter distribution has been documented (Bradshaw *et al*, 1964; Chapin, 1980) as having an caused increase in the root: shoot ratio and a reduction in the leaf area ratio (LAR) (Waring *et al*, 1985). Differences in RGR between maize and *T.minuta* at no fertilizer level corresponded to differences in the nitrogen availability in their natural habitat. As expected, in the RGR of maize and *T.minuta* would be lower when the availability of nitrogen was lower but the results showed that there was no significant difference in RGR under inter and intraspecific competition. This is in agreement with the findings of Clarkson (1967), Rorison (1968) and Grime and Hunt (1975).

The results suggest that maize and *T.minuta* are characterised by a low leaf weight ratio and a high specific leaf area. In this set of experiments species differences in LAR are mainly the result of differences in the SLA, where as differences in LAR within species grown at no fertilizer supply is the result of a change in LWR. Maize and *T.minuta* showed a strong reduction in their net assimilation rate when there was no fertilizer applied. There were no significant differences in net assimilation ratios under interspecific competition but there were significant differences under intraspecific competition. This is in agreement with Hirose (1988) who showed that the NAR is constant over a wide range of nitrogen concentration in the leaves but is reduced when nitrogen concentration in the leaves become less than one percent. In this experiment Relative yield (Ry) was used because this would be more appropriate in this event. After calculating the Ry for both maize and *T.minuta* the sum of the two gives the relative yield total (RYT). This is a particularly valuable calculation because it predicts whether the two species are making demands upon the same resources. The RYT is less than 1.0. This implies that there is mutual antagonism between maize and *T.minuta* neither maize nor weeds contributed its expected share to the total yield. Harper (1977) indicated a situation would arise where each species damages the environment of the other more than its own.

5.2 Field experiments

5.2.1. Interference of mexican marigold (*Tagetes minuta) on growth* and yield of maize(zea maysl)

5.2.1.1 Effect of treatments on *Tagetes minuta*

Weed counts were generally higher in 1996 than in 1997 and this could be attributed to differences in raining seasons, because short rains depressed the growth of weed counts more than the long rains.

Results show that fertilizer influences maize growth and that intertreatment differences were significant only during the long rains because of availability of moisture during that season. Weed-free treatments had consistantly higher percent emergence compared to the other treatments during both seasons. Higher percent emergence was recorded during the short rains, than the long rains. This could have been due to lack of adequate soil moisture at germination during the long rains, when rainfall was 91.1 mm at the time of planting in mid April compared to 209.7 mm at the time of planting in November during the short rains (see Appendix 1). Generally, there were more weed/m^2 and taller during the long rains compared to the short rains. This is explained by the lush growth of weeds encouraged by the heavy rains during the long rains as opposed to the short rains which lasted for a shorter period. Extended availability of moisture during long rains was conducive to both maize and weed growth. However, weeds are known to be better in utilisation of growth resources. Also the faster maize growth during the short rains due to availability of fertilizer applied in the planting holes meant that the weeds were out competed at an earlier stage and thereby smothered by shading effect of maize. Weed density increased with time reaching peak at six and eight weeks after maize emergence during the long rains and short rains respectively. It was evident that weed suppressions by maize was higher during the short rains than during long rains, although fertilizer was applied discriminatly to maize against *Tagetes minuta*.

Weeds offer substantial competition for light moisture and nutrients. Earlier work in Australia (Smith and Levick, 1974) indicated that wheat height decreased with increasing rye grass (Lollum rigidum Garld) density when both species competed for nitrogen. The long period of association between the weed and maize after 30 and 50 days of weed-free harvest resulted in prolonged competition for light. The weed therefore, grew taller compared to the treatment where the weed and the crop only competed for a short time to harvesting after being kept weed-free for the first 120 days. Maize was harvested 180 days after emergence, this means that *Tagetes minuta* competed with maize only 60 days and 120 weed-free maintenance while the weed and the crop competed for 150 and 130 days for weed-free maintenance at 30 and 50 days respectively. Therefore, the importance of early weeding in cassava is illustrated by Doll (1978) who estimates that weed competition in the first month could reduce the crop by quarter, and in the first two months by a half.

Weed height was measured prior to harvest when the crop was physiologically mature, this means than in the two weeding treatments of 30 than 45 and 40 than 60 days. *Tagetes minuta* only competed with maize after weed-free periods of 45 and 60 days respectively. This therefore, produced weed-height similar to weed-free maintenance of 60 days or more. Blanco et al (1973) working in Sao paulo, found that weed competition reduced maize height by 36 percent at final harvest. Although Tagetes minuta seeds germinated later and the plants failed to catch-up with early maturing maize plants, they were all enough to shade many of the leaves of maize. This prevented the maize plants from manufacturing enough photosynthates. This agree with the findings of Thomas (1974) who grew maize with the weed R.exaltata l. at different densities in pot experiments and found that although R. exaltata were shorter than maize, they were able to shade most of the lower maize leaves. In subsequent growth period, this was reversed, maize height decreased with increasing Tagetes minuta density and the latter gained superiority in height. This could suggest that the relatively growth rate of plants in dense stands fall below that of sparse stands at an early growth stage and progressively declined thereafter. Donald (1951) similarly observed that as density increased, the growth stage at which competition became operative was relatively earlier.

The height of the corn plants increased with increasing plant population to a maximum and then the average height decreased again this observation is in agreement with a more general statement by Yoda, kira and Hozumi (1957) who observed that when plants are experimentally exposed to shade, there is usually found a certain light intensity at which the plant attains it's maximum height, thus the taller plants must have elongated at a more rapid rate than the shorter ones. This tendency of shaded plants to elongate more rapidly than unshaded ones was first reported by Hozumi, Kayoma, and Kira (1955) as a result of their observations with corn. They noted that in closely spaced plants, the shorter plants had a higher elongation rate than the taller one that were shading them.

As with plant height discussed earlier decreased dry matter production in short rains could have been due to competition for light and water. The interaction of competition for environmental resources enables the successful species to acquire a continuously increasing share of each factor to increase its dry matter yield. When *Tagetes minuta* competed with maize, it probably had it's prime effect through reducing the concentration of light, nutrients and water to the weaker competitor. Alternatively, absorption ability and efficiency of utilization of resources available for the two species might differ even if mineral nutrient and water content of the soil were adequate. This suggests that different crop species can resist the effects of a weed species to different extents.

In fresh and dry weed biomass the results show that interference of *Tagetes minuta* is a very important factor in maize production. This points out that weeds interference in crop plants is more severe when there is inadequate moisture. This findings agrees with that of Williams (1973) who found bean to be more susceptible to weed competition during dry season. Other researchers have also observed a direct relationship between the severity of weed interference and available moisture (corble *et al*, 1981, Eaton *et al*, 1973, Harison et al 1985) Staniforth (1958) also reported similar results, that crop vigour may be affected by drought, hence lower yields. Hart quoted by Moody and Shetty (1979) reported that there were no statistically significant differences in the total dry matter production from all systems that he studied. He, however found that weeds constituted 20 and 80 percent of the total biomass in maize and bean sole crops and 16 percent when these crops were intercropped.

The results presented in fresh and weed biomass also show that the number of weeding is not as important as the timing of the weeding. It was observed that plots weeded during the critical weed competition period gave higher yields than those weeded only upto four weeks after emergence or those weeded after eight weeks. This was because during the early periods the weeds had not started having a depressing effect on the crop, in which case weeding was not necessary. On the other hand, weeding after eight weeks was not useful because by this time the weeds had already damaged the crop so that recovery when weeding was done at this stage was not possible. It has been reported that the average crop yields in the tropics are generally low mainly because the first weeding is usually done too late when the weeds have begun to exert a depressive effect on yields (Nieto *et al* 1968).

5.2.1.2 Effect of *Tagets. Minuta* on maize

Observation on maize height showed that during 1996 season maize plants were taller than in 1997 season. The tall crop in 1996 could have been as a result of more rainfall in 1996 compared to 1997 as indicated by rainfall data in appendix 1. Increased rainfall could also lead to efficient uptake and use of available soil nutrients. Even though fertilizer was not applied the soil contained moderate nutrients as indicated by soil analysis done prior to planting (see appendix 2). There was no significant differences in maize height under weed-free maintenance treatments. Lack of significant variation under other treatments indicate that only weed-interference for the first 50 DAE signficantly decreased maize height compared to full season control during the same season in 1996. Kimani (1985) reported that crop plant at Kiboko grew taller than at Thika and Kabete and attributed this variation of height to temperature differences while in this study temperatures were high in short rains (1997) as compared to long rains (1996) as indicated in climatic data (appendix 1). This was not corresponding the height as the height was high in 1996 than in 1997. It was observed that fresh and dry maize stover were not significantly different within treatments in 1996 and 1997 respectively. However, 1997 maize stover was higher as compared to 1996. Lack of significance in fresh stover yield of maize within treatments indicated that treatments had no influence on moisture content of maize stover at harvesting periods. Treatments did not hasten or delay maturing of maize, with resultant uniform moisture content at the stover at harvest.

Although short rains could explain the high maize stover yield during the season, it could also mean that maize stover contained more moisture at the time of harvest in 1997 compared to 1996. Both crops were harvested at 180 DAE during both seasons. The decrease in fresh maize stover yield when *Tagetes minuta* was allowed to interfere with maize for the first 30 DAE indicate that maize is vulnerable to the weed competition during this period.

Maize was harvested at 180 DAE, this means that in 30 days *Tagetes minuta* free maintenance treatment, the weed competed with maize from 30 days to harvesting, which is 150 days the long period of competition contributed to the significant yield reduction in unshelled maize. This indicates that at 30 days of maize growth, the crop is sensitive to competition from *Tagetes minuta* even under recommeded fertilization. *Tagetes* minuta control for the first 30 days of maize growth was adequate to obtain optimum yield. This shows that the critical period of competition between *Tagetes minuta* and maize, under fertilizer and no fertilizer application during 1996 and 1997 season was the first 50 and 60 days of growth respectively. Nieto *et all* (1968) reported that maize should be kept weed-free during the first 60 days following germination to obtain optimum yield. Lack of significance in yield increase or decrease with increase in weed-free maintenance or interference respectively during 1997 can be explained by low *Tagetes minuta* dry matter yield during this period. Although unshelled maize yield was higher during 1996 than in 1997, dry matter yield of weeds was higher in 1996 than in 1997.

This can be explained by favourable amount of rainfall and duration during 1996 compared to 1997. High rainfall with fertilizer in 1996 favoured the growth of maize and *Tagetes minuta* respectively. Fertilizer was applied to maize only in the planting hole. This could have provided the crop with competitive advantage over *Tagetes minuta*, which did not benefit from the fertilizer.

Reduction in fresh and dry maize stover yields was due to competition perhaps for nutrients in 1996 when moisture was adequate and nutrient and moisture in 1997 when moisture was limiting. No fertilizer was applied during both periods. Previous reports suggests that competition for nutrients is an important component in the interference between wheat and annual weeds, Henson and Jordan (1980).

Unshelled maize yield is an important parameter for comparing treatments in this experiments since farmers harvest and keep their maize unshelled. Duration of *Tagetes minuta* free maintenance or interference had no effect on final maize stand at harvest. During 1996 and 1997 respectively did not induce maize mortality. This disagrees with what a number of scientists (Mock and Erbach, 1977; Aina, 1978 and Michieka, 1985) who reported that final plant density was lower in their maize plots left weedy throughout the season. This could be explained by the fact that the scientists worked with a mixture of weed population which could have a higher of proportion of more aggressive weeds than *Tagetes minuta* used into my study.

Results on the unshelled maize and grain yields point out the importance of weed control at the correct time in maize production. Differences between treatments were highly significant during the short rains. This corresponded with water stress during low rainfall figures recorded in December, January and February, 2.6, 4.7 and 0.00 mm respectively. Considering the grain weights, the grains were heavier during the long rains than during the short rains, this could be due to sufficient availability of soil moisture (or rainfal) during the grain filling period of the long rains (as indicated in data, appendix 1). Isfan (1984,b) in an experiment on soil water nitrogen yield relationship noted that at low soil moisture content, the applied N had no or even a negative effect on water use efficiency and yield while at high moisture content, the water use efficiency was greatly increased by the applied N. In another experiment, Isfan (1984,a) found that maximum yields were closely correlated with water stored in soil at the beginning and during the growing season, and that soil water may be a good index for forecasting yields as early as three months prior to harvest, except for years with weather accidents.

The weedy check had a lightest grains during both seasons, an observation explained by weed competition for available nutrients and water. Weeds tend to aggravate water shortage, afact reflected in the very low of weed weight (Weedy check) during the short rains.

Hence,weeds that germinate with the crop and persist throughout the season considerably reduce the grain weights. Other results are indirect contrast to those obtained with maize, where fertilizer increased maize yield markedly and greatly minimised the losses due to weed competition (nieto and Staniforth, 1961, Staniforth, 1957).

The increase in maize yield by fertilizer in the absence of hand weeding did not compensate the decrease in yield caused by the *Tagetes minuta* competition. This suggests that with fertilizer applications weed control is absolutely essential if maximum yield increases due to fertilizer are to be ensured therefore, maize has be reported else where to respond faster to DAP additions in the early stages of growth (Tisdale and Rucker, 1964, Okalobo, 1973; Allen, 1976).

Results showed that 30 days of weed-free was not adequate to increase yield of unshelled maize but after 30 days yields were increased. Hil and Santelman (1969) found that 4 to 8 weeks of competition from large crabgrass and smooth pigwood were necessary to reduce yield of maize. During 1997 both weed-free and weed-interference treatments were not signficantly difference in terms of unshelled maize yields. It appears from the results that the losses in yields due to *T.minuta* in maize grain are appreciable and where no weeding was done the yield of the crop was substantially reduced both 1996 and 1997 season. The percentage losses in yield due to unchecked *T.minuta* growth reduced maize yield by more than 50 percent in 1996 season. This finding agrees with that of Mani et al (1968) who found that in same crops such as rice, maize, onion and cotton the yield reduced by more than 50 percent due to weed competition. Ample moisture in rainy months helped the weeds to flourish and unless they were controlled well in time, the crop may be smothered out of existence by the aggressive weed growth. These results point out the critical nature of availability of rainfall about flowering time as found by many workers (Glover 1948, Saltar and Goode, 1967 and Simango, 1976). They are also in agreement with the results found by smith (1914) that rainfall availability from flowering to ripeness and the grain filling period is the most important in determining yield. Although it is not usual to leave weeds uncontrolled throughout the growing periods of a crop, small growers who sometimes plant more land than they can weed, could face this situation due to shortage of family labour, lack of money to engage casual labour, heavy and continuos rains that make the soil unworkable and other factors. Without weeding yields are extremely lower, even when they have used improved cultivars and fertilizers. Such reduction in yield of maize grains shows clearly that good husbandry is not complete without weed control, several reports (nieto *et al*, 1968; Anon, 1975, DeGroot, 1979) have shown that early weed competition is critical on crop yield. On the other hand, keeping the crop weed-free throughout the growing period is rather expensive and might not be all that useful.

Surprisingly there was a big drop in yield in the plots that suffered weed-infestation for the first 60 days both in 1996 and 1997. Experiments in other places showed that weed competition did not affect the yields of maize during the first four weeks. Zimdahl (1980) and Nieto (1960) found that, inorder to obtain maximum yields with tropical maize, the crop must be kept free from weeds during the first 30 days. Weeds growing after that period having no depressing effect on yield, and that under dry climatic conditions, even three months of weed-infestation did not reduce the yield (Azzi and Fernandes 1971).

Maize plants were able to tolerate upto six weeks of *T. minuta* interference without experiencing significant yield loss. These results point out that critical duration of *T. minuta* interference was 60 days after emergence of maize. These results give a definite indication that maize yield may markedly be decreased by weed infestations during the early stages of crop growth. Thus the presence of weeds during the first 60 days depressed production by about 50 percent while weed competition starting 60 days after planting was less detrimental to the yield of maize. There was no advantage in controlling *T. minuta* after 90 or 120 days or only for the first 30 days. These plots gave same yields as the unweeded control or just slightly more. The presence of *T.minuta* for the first 60 days gave 2262 and 1627 kg/ha in 1996 and 1997, respectively of maize which was less than yield of maize of 2738 and 2302 kg/ha when *T. minuta* was present for only 30 days after emergence in 1996 and 1997 respectively.

Further more controlling *T.minuta* after the first 60 days did not improve yields very much. This again emphasizes the importance of controlling weeds in the early growth periods of the maize. It is obvious from the results that *T.minuta* competition between 50 and 90 days reduced the yield significantly both 1996 and 1997. Experimental evidence from Trinidad (Lamuse, 1965) showed that weed-free conditions were necessary between the third and twelfth week in maize. In South Africa, it was found that with wet weather, the first hand weeding was necessary not latter than 28 days after planting, while when conditions were dry, the first weeding could be delayed till 42 days without detrimental effects on the maize yield (Gordon, 1960).

Regression equations derived to show relationship between duration of weed-free and weed-interference treatment on maize yield were derived. The independent variable, maize grain yielld (y) was regressed against the dependent variable, days of weed-free maintenance or days of weed-interference (X), to produce the following equations;

Under fertilizer and no fertilizer respectively.

Duration of weed-free maintenance

(1996) $Y = -0.0994x^2+22.8x+2616.2$ ($r^2 = 0.46$) **F(Fertilizer)(a)**

(1996) $y -0.0842x^2+19.225x+2265.9$ ($r^2=0.35$) **NF(Nofertilizer)(b)**

Duration of weed-inferference

(1996) $Y = 0.0893x^2-36.028x+5132.3$ ($r^2=0.82$) **F (a)**

(1996) $y = 0.0384x^2-21.684x+3941.1$ ($r^2=0.97$) **NF (b)**

Linear regression accounted for 46 and 35 percent of variation in maize grain yield and predicted a significant yield increase by 160 and 135kg/ha for each of weed-free maintenance in 1996. During the same year, linear regression accounted for 82 and 97 percent of the variation in grain yield and predicted a significant yield decrease of 252.2 and 152kg/ha for each week of weed interference(as indicated figure 1 a and b).

Also, in 1997 produced the following equations:

Duration of weed-free maintenance

(1997) $y = 0.0163x^2+0.0677x+2552.8$ ($r^2=0.74$)**F (a)**

(1997) $y = {}^-0.0691x^2+15.649x+1915.7$ ($r^2=0.23$)**NF (b)**

Duration of weed-interference

(1997) $Y = 0.0069x^2-5.7202x+2469$ ($r^2=0.58$)**F (a)**

(1997) $y = -0.0125x^2-7.3219x+2748.9$ ($r^2=0.51$)**NF (b)**

Linear regression accounted for 74 and 0.23 percent of the variation in maize grain yield and predicted a non-significant and significant grain yield increase by 0.48 and 109.5kg/ha for each week of weed-free maintenance. Likewise, linear regression accounted for 58 and 51 percent of the variation in maize grain yield and predicted a non-significant yield decrease of 40 and 51.1kg/ha for each week of *T.minuta* interference(as indicated in figure 2 a and b). Uncontrolled *T.minuta* weed population decreased maize grain yield by 38 and 56% and 47 and 59% during 1996 and 1997 fertilizer and no fertilizer respectively.

Although not entirely consistent these findings suggest that with early season control, established *Tagetes minuta* plants do not compete strongly with maize under no fertilizer conditions especially if available soil nutrients are not limiting. None the less maize kept weed-free for 6 to 8 weeks produced higher yields than maize kept weed-free for less time, and weed-free maintenance for 4 or more weeks after crop emergence significantly increased maize yield. Hauser *et al,* 1975, reported that at least 10 weeks of interference from Florida begar weed and sicklepod were required to cause a significant yield reduction. Weed timing is therefore more necessary than the number of weedings to achieve optimum yield. It is therefore, reasonable to conclude that inorder to obtain maize yields with maize hybrid 511 under conditions similar to Kabete region, *Tagetes minuta* must be controlled during the first 50 and 60 days after maize emergence under fertilizer and no fertilizer respectively. It is possible that *Tagetes minuta* interference with uniform maturation of maize drying and harvesting may be more serious problems than reduction in maize yield under low weed population. These results confirm those reported elsewhere (Zimdahl, 1980) that the critical period for weed competition is within the first six weeks of maize growth. Similar observations on influence of weeds on crop yield (Young et Al, 1984; Rothmann and Miller, 1981), quality (Buchanan, and Burns, 1971; Crowlet and Buchanan, 1978) harvesting efficiency (Mcwharter and Hartwing, 1972; Nave and Wax, 1971), and subsequent weed populations

(Appelby *et al*, 1976; Vaseckg *et al*, 1973) have been reported. In this experiment, *Tagetes minuta* had significant effect on maize yield during 1996 when rainfall was plenty and not in 1997 when moisture was limiting. Although the experiment in 1997 was cited on the same land as the 1996 one, subsequent weed dry matter was reduced. Others have found weeds to rapidly reinfest crops after relatively long periods of weed control indicating that weed seeds in soil may remain insufficient numbers for many years to be harmful to the production of crops (Schweizer and Zimdahl, 1984). Other researchers such as Norris, 1992, stated that there is a dilemma if the farmer is a protector of the environment, then there may have to be a compromise between the most cost effective and the most environmentally sound method which may or may not be the same.

5.2.2 Effects of fertilization on crop weed competition

The growth, development and yield of cereal crops can be adversely affected by a deficient, or excessive supply of any one of a series of essential macro-nutrients as well as other toxic substances (Russell, 1973; and Hay 1981b. Nitrogen plays a central role in plant biochemistry, consequently, a deficiency in the supply of nitrogen has a profound influence upon crop growth and can lead to a total loss of grain yield in extreme cases. As far as crop physiology is concerned, nitrogen fertilizer influences cereal crops in the following ways:

1 Increased nitrogen supply, through it effect upon leaf size and longevity and upon tiller formation and survival, results in increases in the size duration of the crop canopy.

2 The amount and timing of nitrogen fertilizer treatments can also influence the development of the individual plants of the stand, with important implications for the components of grain yield.

3 The quality as well as the quantity of harvested grain is determined by fertilizer practice.

4 The larger leaves and taller stems of heavily fertilized crops are mechanically much weaker, leading to potential yield loses by lodging and various types of pathogenic attack.

However, fertilizers are used to supply nutrients that are not present in the soil in amounts necessary to meet the needs of the growing crops. The nofertilizers are generally stunted and yellow in appearance in the treatments as compared to fertilizer treatments. This yellow usually appears first on the lower leaves, the upper leaves remain green. This is because fertilizer in the lower, older leaves is translocated to the new growing areas of the plant when no fertilizer supplies are being provided through roots. In this experiment where competition between *T.minuta* with maize was studied under no fertilization, such deficiency symptoms were not seen. This is because of adequate nutrient availability in the soil prior to planting. Such symptoms could have been seen if several season growing of maize without fertilization is undertaken to rid of nutrients through roots. In grasses such as corn, sorghum, sugar cane and forage grasses the no fertilizer symptoms may appear as yellowing in the left tip that develops down the center midrib of the leaf. Eventually under very sever deficiencies the entire leaf becomes yellow and eventually died. Therefore, plants that have received no fertilizer are quite yellow and much smaller than plants that have received adequate amounts of fertilizer in several cases, fertilizer response has been expressed both in terms of higher yield and improved crop quality. Fertilizer yield responses in corn and sorghum have frequently been dramatic. Yield and water utilization efficiency of many crops including corn, sorghum and wheat can be increased significantly through application of adequate amounts of fertilizer. Fertilized crops extract more water from the soil profile than do unfertilized crops because of better root growth. This is perhaps what happed in 1996 when moisture was adequate than in 1997 even though no fertilizer was applied in both cases. From these data in the field, showed us it is apparent that crop yields are improved from fertilizer usage, even under conditions where soil moisture seriously limits the growth of the crop. It appears probable that if there is sufficient moisture in the soil to warrant seeding a crop, appropriate fertilizer should be used on soil believed to be deficient in available nutrients. The well-fertilized crops use water more efficiently than no fertilized crops because such fertilized crop has a larger root system and a greater root area.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Greenhouse experiments

Comparative studies between maize and *T.minuta* that use growth analysis techniques are valuable because the changes in growth response to the availability of a resource fertilizer indicate when in the development of maize or *T.minuta* competition may be most detrimental to maize yields. Such analysis also indicate how the limitation of one resource influences the availability of others as the crop developmentally and physiologically proceeds through the growing season. By determining the growth characteristics of *T.minuta* when exposed to varying levels of fertilizers or conditions, the potential range and degree of competitiveness can be determined. When *T.minuta* or maize are grown together, the behavior of the crop or the weed in the mixture is often different from when the species are grown separately. This observation results from mutual interference for both above and below ground resources among the crop and the weed that are growing together. Thus experiments in which mixtures of *T.minuta* and maize are grown under differing levels of resources (zero and recommeded fertilizer rates) are especially instructive about the effects of competition of the various aspects of the weed and crop development. Interms of weed control, it is important to know the environmental factors for which the species are competing.

6.2 Field experiments

Maize has periods during which weeds do not cause loses. Accordingly if crops are kept free of *Tagetes minuta* during the first sixty days maximum yields may be obtained. Alternatively the applications of fertilizer may be recommeded. Maize is clearly better able to compete with *Tagetes minuta* and that is why most farmers plant maize because it does not require early weeding, and early weeding is costly and difficult to carry out because of peak labour demand from other enterprises during this season. The practice of cleaning a crop thirty days after weeds have appeared is not recommended, because the productive potential of maize cannot operate to the full after that time.

The field experiment results clearly show that critical duration of Tagetes minuta interference in maize under recommeded fertilizer is shown to be 60 days after emergence thus leaving this weed in maize fields beyond 60 days after emergence would cause significant maize yield loss.

In Kenya and particularly around Kabete area, it is common to find the *Tagetes minuta* in pure stands at density close to those established in these experiments. An attempt should therefore be made by farmers to control this weed before the maize reaches flowering stage to ensure maximum maize yields. The results of this interference studies show that *Tagetes minuta* are very important weed in maize production, when not controlled this weed reduced maize yields severely after critical duration periods. These studies confirmed that *Tagetes minuta* reduced maize yield mainly by affecting the number of cobs formed and overall growth of maize.

6.3 Further Recomendation

The future research involving crop-weed interference with *T.minuta* should attempt to address the following

1. Competitive mechanisms, that is the mode of competition between weed species and crop plant should be determined. Intereference of *T.minuta* in maize may be due to competetion for growth factors, allelopathy or both. The relative importance of these effects and the effects of above and below ground intereference of *T.minuta* on maize should be determined
2. Economic thresholds, that is the density of *T.minuta* in field and greenhouse that warrant control measures should be determined in different crops including maize.
3. The effect of late emerging populations of *T.minuta* and other crops should be determined.
4. Since it is common to observe almost pure strands of *T.minuta* in maize fields, effective intergrated control methods should be determined to control the spread of the weed.
5. Studies should also be conducted to determine the contributioon of *T.minuta* in the control of root-knot nematodes in various crops including maize

Appendix 2. Soil analysis result for long rainy seasoon of 1996

		%	%		Me/100g				ppm		
pH in water	pH in 0.01m $CaCl_2$	C	N	K	Na	Ca	CEC	AL	H	P	Mn
5.70	5.70	2.52	0.34	4.30	0.50	9.50	17.4	Trace	0.20	5.70	520.0

Appendix 3. Soil analysis result for short rainy season of 1997

		%	%		Me/100g				ppm		
pH in water	pH in 0.01m $CaCl_2$	C	N	K	Na	Ca	CEC	AL	H	P	Mn
6.40	6.10	2.80	0.29	5.0	0.80	9.10	17.0	Trace	0.20	7.50	566.0

Appendix 4. **Analysis of variance table for yield of shelled maize under fertilization in the field in 1996 and 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	15	9052638.7	603509.3	1.6*
Block	2	769611.7	384805.9	0.9ns
Error	30	12347831.3	411594.4	
Total	47			

Appendix 5. **Analysis of variance table for yield of shelled maize under no fertilization in the field in 1996 and 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	15	9768223.1	651214.9	1.5*
Block	2	2085275.8	1042637.9	2.5*
Error	30	12655072.5	421835.8	
Total	47			

Appendix 6. **Analysis of variance table for yield of weed dry weight under fertilization in the field in 1996 and 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	15	726297771.4	48419851.4	42.2***
Block	2	849092.4	424546.2	0.4 ns
Error	30	34411365.6	1147045.5	
Total	47			

* = Significant at 10%   *** = Significant at 1%
** = Significant at 5%   ns = Not significant

Appendix 7. Analysis of variance table for yield of weed dry weight under no fertilization in the field in 1996 and 1997

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	15	926005490.5	61733699.4	66.8***
Block	2	1391011.4	695505.7	0.8ns
Error	30	27734303.8	924476.8	
Total	47			

Appendix 8. Analysis of variance table for crop growth rate of maize under fertilization during first and second planting in greenhouse in 1997

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	0.707	0.177	61.9***
Error	10	0.0286	0.00286	
Total	14			

Appendix 9. Analysis of variance table for crop growth rate of maize under no fertilization during first and second planting in greenhouse in 1997

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	0.0924	0.023	5.2*
Error	10	0.0444	0.00444	
Total	14			

Appendix 10. **Analysis of variance table for crop growth rate of *T.minuta* under fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	0.172	0.0431	15.4**
Error	10	0.028	0.0028	
Total	14			

Appendix 11. **Analysis of variance table for crop growth rate of *T.minuta* under no fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	0.03872	0.00968	8.2*
Error	10	0.01186	0.001186	
Total	14			

Appendix 12. **Analysis of variance table for leaf area duration of maize under fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	49.42	12.36	95.5***
Error	10	1.294	0.1294	
Total	14			

Appendix 13. **Analysis of variance table for leaf area duration of maize under no fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	1.7834	0.446	10.8*
Error	10	0.412	0.0412	
Total	14			

Appendix 14. Analysis of variance table for leaf area duration of *T.minuta* under fertilization during first and second planting in greenhouse in 1997

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	26.18	6.545	97.4***
Error	10	0.672	0.0672	
Total	14			

Appendix 15. **Analysis of variance table for leaf area duration of *T.minuta* under no fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	14.1	3.53	168.1***
Error	10	0.21	0.021	
Total	14			

Appendix 16. **Analysis of variance table for relative growth rate of maize under fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	3.84	0.96	1.7ns
Error	10	5.5	0.55	
Total	14			

Appendix 17. **Analysis of variance table for relative growth rate of maize under no fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	8.415	2.104	2.8ns
Error	10	7.6	0.76	
Total	14			

Appendix 18. **Analysis of variance table for relative growth rate of *T.minuta* under fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	4.06	1.015	15.1*
Error	10	0.671	0.0671	
Total	14			

Appendix 19. Analysis of variance table for relative growth rate of *T.minuta* under no fertilization during first and second planting in greenhouse in 1997

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	2.532	0.633	2.8ns
Error	10	2.245	0.225	
Total	14			

Appendix 20. Analysis of variance table for net assimilation rate of maize under fertilization during first and second planting in greenhouse in 1997

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	761.96	190.5	54.5**
Error	10	35.05	3.505	
Total	14			

Appendix 21. Analysis of variance table for net assimilation rate of maize under no fertilization during first and second planting in greenhouse in 1997

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	164.46	41.12	7.3*
Error	10	56.36	5.636	
Total	14			

Appendix 22. **Analysis of variance table for net assimilation rate of *T.minuta* under fertilization during first and second planting in greenhouse in 1997**

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	284	71	21.7*
Error	10	32.73	3.273	
Total	14			

Appendix 23. Analysis of variance table for net assimilation rate of *T.minuta* under no fertilization during first and second planting in greenhouse in 1997

Source of Variation	Degree of freedom	Sum of squares	Mean square	F value
Treatment	4	121.1	30.26	12.7*
Error	10	23.8	2.38	
Total	14			

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