

RESPONSE OF MAIZE (*ZEA MAYS L.*) CULTIVARS TO SINGLE WEEDING METHODS AT DIFFERENT CROP DEVELOPMENTAL STAGES.

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DECLARATION

I Nyambe Hastings Nyambe, hereby declare that all the work presented in this dissertation is my own and has never been submitted for a degree at this or any other University.

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APPROVAL

This dissertation of Nyambe Hastings Nyambe is approved as fulfilling part of the requirements for the award of the degree of Master of Science in Agronomy by the University of Zambia.

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DEDICATION

I wish to dedicate this work to my wife Mrs M. N. Nyambe and my children:

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ABSTRACT

It has been reported that 50 to 95% of small-scale maize (*Zea mays L.*) farmers weed their fields once during the growing season. The weeding is done at either 2-3 leaf or 7-8 leaf time of weeding. Farmers using hoes dig up the weeds, shake off the soil and either leave the weeds to dry in the field or heap them on the side. A field experiment to evaluate response of 3 maize cultivars weeded to single weeding methods at two different times of weeding was conducted at University of Zambia in 2000/2001. Two controls (no weeding and clean weeding) were used. The cultivars were MMV400 (open pollinated), SC 601 (single cross) and MM 604 (3-way cross). A split-split plot design with time of weeding as main plot, weeding method as sub-plot and cultivar as sub-sub plot was used. Standard agronomic practices were employed. Measurements were taken for growth and development parameters of both the crop and weeds. Parameters evaluated for the crop included Leaf Area Index (LAI), Leaf Area Ratio (LAR), and Leaf Weight Ratio (LWR), Stem Weight ratio (SWR), Specific Leaf Weight (SLW), Root Weight Ratio (RWR), cover and biomass. For weeds parameters included cover, density and biomass. Visual data was arcsine transformed while non-visual was log transformed.

The results indicated that there was no significant differences in the effect of the two single weeding methods on LAI, LAR, LWR SWR, grain yield and stalk barrenness. Observed differences were between clean weeding (CW) and no weeding (NW) with highest values in LAI (2.13) and lower SWR (0.43) while no weeding had lowest LAI (1.33) and highest SWR (0.46). Grain yield under CW was highest at had

3744 kg /ha while NW had the lowest 1548 kg /ha. Time of the weeding exerted significant effects. The weed cover of 2-3 leaf time of weeding was higher (63.1%) than 7-8 leaf time of weeding (50.7%). Among the cultivars SC 601 showed superior qualities in LAI (1.89), with lower LAR (0.24) and LWR (0.17) and higher SWR (0.46), which exerted negative effects on weed growth. The cultivar MM 604 had relatively similar attributes to SC 601. The highest grain yield was 2956 kg/ha for SC 601. This was followed by MM604 with 2585 kg/ha and MMV 400 with 1966 kg /ha. It can be concluded that among the cultivars evaluated SC 601 responded with the highest growth qualities that suppressed weed growth resulting into the highest grain yield and related components at single weeding methods at different times of weeding. MM 604 was closer to SC 601 in all attributes and ranked second. However, MMV 400 responded with the least growth qualities and as such resulted into the least grain and related yield components .

INTRODUCTION

Many seed companies dealing in maize (*Zea mays L*) such as ZAMSEED, PANNAR, SEEDCO offer production guides to farmers. A review of these guidelines shows emphasis on high yields under optimum conditions. These companies offer different hybrids whose end users vary in access and resources. Single cross and three way hybrids are generally uniform and need high levels of management making them suitable for large-scale farmers. On the other hand, double cross, top cross and cultivar hybrids are less uniform and are generally low-yielding, less costly and therefore more suitable for small-scale farmers (Pandey, 1998).

However, the adoption levels of these hybrids depend on economic, institutional and policy factors around the target farmers. Of interest is the fact that only 12 to 50 % of small-scale farmers are able to access and plant hybrid maize of different types (Njovu, 1987 and Andren et al, 1991). Due to differences in management levels among large and small-scale farmers yield levels tend to be much lower in the small-scale sector. Evidence of differences in the yields between large and small - scale farmers has been documented (Masi et al. 1989 and Anon, 1993). In the Southern Province commercial farmers obtained yields of about 5.4 tons /ha while small scale farmers had as low as 0.72-1.08 tons /ha (Masi et al. 1989). In Lusaka and Central Provinces the yield are 2.7 tons /ha for commercial and 0.9 tons /ha for small-scale (Anon, 1993).

Several field studies have been done to establish causes to the low yields (Rukandema and Hopkinson, 1984 and Njovu, 1987). These studies have shown that

inadequate fertilizers, draught power inadequacy and inadequate plant protection in terms of disease, pests and weeds management are prominent problems. Of interest in these studies is the extent to which the inadequate weeding practices affect the growth and yields of different cultivars grown by small-scale farmers.

The common recommendation of all seed providers, extension agents is to weed the maize crop 2 to 3 times during the growing season. To the contrary, field reports from different parts of the country have shown variations in the response of small-scale farmers to this recommendation. It was reported from Serenje in Central Province that about 95% of the small-scale farmers weed only once (Anon, 1986). Similarly, from Mkushi and Serenje districts in Central Province, it was reported that 50 % of the small-scale farmers weeded only once during the growing season (Anon, 1987). In the Southern Province it was reported that small-scale farmers weeded only once (Masi et al, 1989). Another report from Western Province, confirmed that small-scale farmers weeded their maize fields once, 30 days after emergence and rarely did they include a second weeding (Heemskerk, 1992). In the North -Western Province, it was reported that 63.4 % of the small-scale farmers weeded their maize only once (Rukandema, 1987). These findings generally indicated that about 50 % to 95 % of small-scale farmers in the country do not adhere to the 2 to 3 weeding recommendations.

The single weeding method involve hoe- scraping the weeds followed by shaking the soils from the weed roots, after which the weeds are either left to dry in the field or thrown out to dry out of the field (Kamau and Odiambo, 1987). This method is

administered at different time of weeding in maize in different geographical areas. In Southern Province, Masi et al (1989), reported two different time of weeding: either at 2 to 3 leaf time of weeding for mono-crop maize farmers or at 7 to 8 leaf time of weeding for farmers with higher crop diversification and larger hectarages. This approach allowed room to complete land preparation and planting of other crops in the growing season before weeding the maize crop. In Lusaka Province, it was mainly done at 2-3 time of weeding (2 to 3 leaf) and 7-8 time of weeding (7 to 8 leaf) of maize crop. The same situation was noticed in other parts of country.

The weeding at 2-3 or at 7-8 time of weeding fall within critical period during which if crop is kept weed free the grain yield will not be affected. This has been established to be within 40 days after planting (DAP) as reported by Vernon and Parker, (1983)

The reasons for failing to adhere to the recommended weeding had been associated with social, economic and cultural constraints. The loss of animals due to cattle diseases such as Corridor (*Theileriosis parva*) in the Southern Province, *Theilerelia parva* in Eastern Province have reduced the numbers of working oxen for use in weeding with cultivators (Rukandema and Hopkinson, 1984 and Njovu, 1987). Lack of financial support in form of loans for purchase of inputs (such as machinery and herbicides) is wide-spread. Scarce human- labour for weeding is also reported, as about 37 to 40 % of farm labour was required for weeding a hectarage of maize (Parker and Vernon, 1982). Depending on how labour is distributed to the various operations at peak periods it may

be impossible to completely adhere to the recommendations. Reports of small-scale farmers planting large hectares of maize for prestige, which they completely fail to weed within the prescribed period, have also been common. Under such situations weeding is delayed to the extent that it is only completed when part of the crop is already at tasselling time of weeding (Anon, 1993).

Several attempts have been made to study effects of single weeding but most of these studies were not conclusive (ARPT, 1983, ARPT, 1986). However, indirect studies by Vernon and Parker, (1983), showed losses of about 40% in experiments where a single weeding was done at 2 weeks after planting on maize c.v SR 52. The same authors reported losses of 19 to 20% in Magoye and 40 % in Msekera when a single weeding regime was adopted on local maize at 2 weeks after planting. A comprehensive treatise on the above is still lacking

The objective of the study was to evaluate the response of three (3) maize cultivars to single weeding methods at two different times of weeding.

LITERATURE REVIEW

1.0 Origin and importance.

The centre of origin of the maize plant is said to be the New world in Granada (FAO, 1980). Maize (*Zea mays L.*) belongs to the grass family *Gramineae*, the tribe *maydeae*, *Tripsaceae* that is distinguished from related tribes by separation of male and female flowers on the same plant. Among the different genera in maize are *Zea* (monotypic), *Euchlaena*, *Tripsacom*, *Coix*, *Polytoxa*, *Sclerachne*, *Cionachne* and *Trilobachne*. The main categories of maize are dent maize (*Zea mays indentata*), Flint maize (*Zea mays indurata*), Sweet maize (*Zea mays saccharata*), Floury maize (*Zea mays amylaceae*), Pop maize (*Zea mays tunicata*) and Waxy maize (*Zea mays ceretina*).

This plant is an annual, which terminates in a tassel with an ear produced laterally in a leaf axil. Ears can be potentially produced at every node, but modern cultivars only produce one or two per plant. The spikelets are arranged in pairs, one sessile and the other with a short stalk. Each spikelet is enclosed by two glumes. Two florets per spikelet each with a lemma and palea, three stamens, two lodicules and rudimentary pistil (Leonard and Martin, 1963).

Maize is open-pollinated and it is estimated that a single tassel may produce 25 million pollen grains or at least 25,000 pollen grains for each silk developed on the ear (Kiesselbach, 1949). The pistil is composed of the thick axis called the cob of the ear upon which pairs of spikelets are arranged in longitudinal rows. The spikelets often in pairs are sessile. Each spikelet has two flowers but normally only one is fertile. The second floret

of the spikelet develops into irregular rows. The husks completely cover the ear. When mature the silks become receptive throughout their length and ovule fertilisation is often completed in 12-28 hours of pollination. The kernel is a single seeded fruit enclosed in the pericarp. It is composed of the embryo, endosperm, aleurine and nucellus.

Maize is utilised in human diets, animal feed, forages, wet milling (for starch and sweetness), dry milling, fermentation and distilling and composite flours (Dowswell, et al, 1996).

2.0 Weed growth parameters

2.1 Weed Cover

This is defined as the relative area of the ground covered by vegetation or individual species. This is often estimated as percentage cover (or shading) of a certain area in total for an individual species. Methods used to determine weed cover include the line intercept method that records the cumulative distance of foliage and stems of the weeds in their vertical projection along a specified length of line stretched above the vegetation. The point quadrant and the step-point sampling methods are used often in rangelands (Walter, 1983). Weed cover effects are associated with competition for light as a high weed cover shades the crop thereby reducing crop interception of light. Tharker and Singh, (1954), observed that red portion of the spectrum is absorbed by leaves while the far red filters through. Red light promotes germination of weed seeds which inturn interferes with crop growth particularly if this occurs within the critical period of maize growth. With shade tolerant weeds red light has no significant effects on their growth.

2.2 Weed density

This is defined as the number of weeds in per given area (often per m^2 or per quadrant area) (Truelove, 1977). The counts are often from a sample area in the range of 0.1 to $1m^2$ of the experimental plot. The counting of individual perennial species reproducing from rhizomes or roots is normally impossible; instead the number of shoots is counted in weedy plants such as *Cynadon dactylon* (Walter, 1983). The density reflects both weed infestation and the degree of control. The density further plays a role in competition, increasing weed density decreases the yield. William, (1970) reported that one pigweed per 4 maize plants reduced yields 7 to 10 % and also for giant foxtail one per foot of row reduced yields about 7 to 10%. However, the weed density –crop yield relationship diverges from being linear at low weed densities and becomes curvilinear as weed density approaches infinity as defined by sigmoid equation reported by Roberts et al. (1975).

Factors such as soil fertility levels have been reported to affect densities in terms of competitiveness. Buchanan and Burns, (1971) indicated that some weed species competed more vigorously with cotton on sandy clay loam soil than on sandy loam. This was due to more favourable fertility and more moisture relationship in sandy clay loam soil than the latter.

2.3 Weed Height

This refers to the measured distance from the ground level to the lowest axis of the youngest leaves of any weed plant. Thomas et al, (1994) while working on winter wheat

showed that increasing weed height reduced the yield of short cultivars and that yield reduction caused by tall weeds diminished asymptotically as cultivar height increased. Johnson et al. (1998) while working with maize observed that weed height was not affected by row spacing. However, where weed height increases faster than the crop height, the yield is reduced due to competition with the weeds (Moolan et al, 1964).

2.4 Weed Biomass

This refers to the weight of the dry matter of the weeds. Increasing maize plant density from 4 to 10 plants/m² was reported to have reduced weed biomass by up to 50% (Tollenaar et al. 1994). Increasing crop LAI decreases Photosynthetic photon flux density (PPFD) transmittance to weeds and consequently weed biomass decreases (McLachlan et al, 1993). Cultivation was found to reduce weed biomass as it interfered with the partitioning of food reserves but increased maize biomass (Johnson et al, 1998).

3.0 Crop growth and development parameters

3.1 Leaf Area (LA)

The Leaf area (LA) is defined as the area of the leaf (Milthorpe, 1956). Total leaf area is a product of leaf number, size and net difference between addition of leaves and death of leaves at any given time (Bazzaz et al, 1977). Most of the methods of measuring LA point at regressing a measure of leaf size (length or width or both) or leaf dry mass against a measured area but requires applying a correction factor C to the product of the length and maximum leaf width. For maize, C is generally agreed to be 0.75 (Mc Kee, 1964). Other methods of determining leaf area include an optical method using leaf area

meter and direct determination (harvest and allometry). Hebert and Fownes, (1997), while working on broad-leaved hard wood forests observed a strong correlation between optical and direct method and found that direct estimates were higher than optical estimates by a factor of 2.44.

LA is affected by environmental factors such as soil fertility, soil moisture and light quality and quantity. In maize, lower leaves receive more light only when LA in the upper canopy is reduced providing more photosynthate for roots and harvestable organs. Zhang and Brandle (1997) while working on maize observed that the LA for sheltered and open plots was not significantly different. The LA reached a maximum of 7000 cm² at 50 DAP and remained at the maximum until 90 DAP. The LA then declined after 100 days at a rate of 420 cm² per day. When repeated, no difference was again observed between the sheltered and non-sheltered, however, LA reached a maximum of 9000 cm² at 70 DAP and declined at 60 cm² per day. At 135 DAP, LA was only 4000cm². Under weedy conditions the leaf area is reduced to various levels that affect leaf growth and expansion. From the LA the derivatives are the leaf area index and the leaf area ratio.

3.11 Leaf Area Index (LAI)

The leaf area index (LAI) is the ratio of the leaf area or other photosynthetic organs a plant possesses to the ground area they cover (Milthorpe, 1956). Changes in leaf morphology as the plant develops leads to increase in LAI. At low light radiation levels, growth can fall to zero at high LAI. Maximum growth and LAI increase with radiation. LAI is dependant on incident radiation (Zimahl, 1980). LAI increases from germination

and then reaches a maximum at flowering and later declines. The LAI for maize can vary depending on management. Tollenaar et al (1997) while working on maize observed that the LAI was reduced more by weedy treatment in the Cultivar Pioneer 3902 than in Pride 5. Also the LAI was 21% less in the low –Nitrogen treatment than in the high N-treatment. It was 18% less in the weed treatment compared to the weed-free control. Thus the more rapid early season maize leaf development is, the more the grain yield. Tollenaar et al (1994), observed that increasing maize density increased LAI but decreased transmittance of irradiance (red to infra red ratio) by maize canopy thereby reducing the ability of weeds to compete for light. This is with the exception of shade tolerant weeds. This in turn increases the interplant competition for light in the main crop. However, Thomas et al (1993) observed that an increase in plant density would lead to a decrease in plant size.

3.12 Leaf Area Ratio (LAR)

This is the ratio of the leaf area to the total plant weight (Milthorpe 1956).

Briggs, et al, (1920) pointed out that the LAR was important in explaining the relative growth rate (RGR). The RGR a plant is the product of (Net Assimilation Rate) NAR and LAR. NAR is the daily growth per square meter of leaf area. LAR is influenced by many physiological processes which control leaf expansion but not leaf weight gain (Evans, 1972). In this case light quality and quantity affected LAR as they affected total leaf area (Blackman, 1956). In maize LAR increased from 1.1 to 2.8 dm²/g as the temperature increased from 10° C to 25°C but in sunflower LAR increased from 1.8 to 28 dm²/g as the temperature increased to 34°C (Leopard, 1975) Other factors that affect LAR are

moisture content and soil fertility through their effects in reduction of leaf expansion and total leaf area respectively. Weeds limit physiological processes through competition with the maize for nutrients, light and moisture. This in turn affect leaf expansion and hence the LAR. Mac Lachlan, (1993). Lusk et al. (1977), while working on Chilean tree seedlings found that LAR values were higher in fertile-site species than in those tolerant to low fertility and associated the differences to (Specific leaf area) SLA rather than (Leaf weight ratio) LWR. SLA is the leaf area per gram dry weight. He found that very high LAR at high nutrient supply was characteristic of most angiosperms but not of shade tolerant conifers (gymnosperms). In beech seedlings, dry weight, leaf area and SLW increased as light increased the LAR decreased as light increased (Minotta and Pinzauti, 1996)

3.2 Leaf Weight Ratio (LWR)

This is defined as the ratio of the dry weight of leaves to the total plant weight (Milthorpe, 1956). LWR represents the productive investment into the plant. This is the ratio of the weight of the plant parts capable of photosynthesising to total plant weight. It is therefore influenced by several environmental factors, which includes competition from weeds. Such factors are those that affect the distribution of dry matter between leaves and the rest of the plant parts as reported by Evans, (1972).

As the leaves are removed, there is a decrease in the ratio of photosynthetic to non-photosynthetic tissue called the (LWR). This effect would decrease Photosynthetically Active Radiation interception, by altering the balance of photosynthesis and respiratory

loss independent of change in the rate of photosynthesis. Plant species, that are tolerant to shade, have higher LWR because their relative reduction in growth due to shading was slightly better than the non-shade tolerant (Homes and Cowling, 1993). In maize as leaf weight depends on the capacity to photosynthesise and store assimilates. Competition for light, nutrients and moisture reduce leaf photosynthetic capacity and affect the distribution of photo assimilates. This in turn reduces leaf weight ratio as observed by Maclachlan, (1993).

3.3 Specific Leaf Weight (SLW)

Specific Leaf Weight is defined as the ratio of dry weight of leaves to the respective leaf area (Milthorpe, 1956). However, this ratio reflects the relationship of the leaf area relative to leaf weight. In sunflower, it was observed that the SLW was higher in plants grown on compact soils (Andrade et al, 1993). In beech plants it was observed that the SLW increased as light increased (Minnota and Pizauti, 1996). SLW increases under water stress as the leaf tend to store more assimilates as sink for survival.

3.4 Stem Weight Ratio (SWR)

This is defined as ratio of the dry weight of stem to the total plant dry weight (Fisher, 1984). Information is scarce on studies regarding this parameter in maize.

3.5 Crop Cover

This is defined as the relative area of the ground covered by crop leaves. This is often estimated as percentage cover (or shading) of a certain area in total and for an

individual crop. High crop cover is assumed to suppress weed growth. This is particularly true in cover crops such as sunflower (Dyck et al, 1995).

3.6 Crop Height

For maize, this refers to the measured distance from the ground to the axis of the youngest leaves. Routine height measurement is used for assessing the rate of crop growth (Truelove, 1977). Plant height changes little after flowering while stem biomass normally increases to a maximum 2 to 4 weeks after silking and thereafter during the linear phase of grain filling. Crop height component is often determined to supplement final yield data. Selection for reduced plant height in maize has been accompanied by a reduction in stem volume and in stem non-structural carbohydrates reserves, which may result in increased instability of grain yield when plants are exposed to stress during grain filling (Edmeads and Lafitte, 1993). On the other hand, tall and leafy cultivars were found to yield small amounts of grain due to strong vegetative traits and low Harvesting Index (HI) (Donald and Hamblin, 1976). Maize height in cultivated plots was found not to be significant to weed free plots (Johnson et al, 1998). Moolani and Knake, (1964) observed that the yield reduced to 40% in maize when weeds were allowed to grow in a 6 inch band over the crop row during the entire season. The same weed and band reduced soyabean yield up to 65%. This yield loss difference was mainly due to shading effect of maize that was taller than the weed while soyabeans were only half as tall as the weed.

3.7-Crop Biomass

This refers to the weight of the dry matter of the crop after water has been removed. For maize, the rate of growth is slow for the first 5 weeks with only 15% of the total dry matter. The growth thereafter is described to be linear until grain is in the dough time of weeding. At silking it was reported that about 40% of the final dry matter would have been attained. Further increases in DM are mainly in form of cobs, husks and grain (FAO, 1980). The weed biomass of 3300 kg /ha was observed to have been reduced maize crop biomass by 20 % in maize (Ndon et al, 1976).

4.0 Yield parameters.

4.1 Yield (kg/ha).

In maize this refers to quantity of harvestable product (such as grain) per hectare. Mean yield per plant is in turn a function of population. The yield per hectare was observed to increase linearly with increase in plant population to a critical plateau level above which it is reduced (FAO, 1980). The plateau is influenced by many factors including the N-supply. The grain yield per plant and plant population are inversely related. An increase in population leads to strong inter and intra plant competition for light. In the latter case, upper pendent leaves tend to shade the lower leaves. Increasing plant population leads to a reduction in ear size and a marked increase in barrenness. Both plant height and ear height are increased while stalk diameter is reduced. Such effect result in more lodging and stem breaking under increased humidity (Rutger, 1971). Studies in Mexico conducted in maize hybrids showed losses in yield potential of

5000Kg / Ha reduced by 50% when weeds were left undisturbed for 40 days. This loss was 56 kgs / day sufficient to feed 200 people.

4.2 Harvesting index (H I)

This is defined as the ratio of the grain to the total weight of the plant. Initially, HI was used for assessing yield potential in small grain cereals and pulses in India. Western Europe and the USA and had been less useful for maize and tuber crops. The range for most intensively -cultivated plants falls within 0.4 to 0.6. Improvements in HI have been a consequence of increased grain population density coupled with stable individual grain weight. The high heritability of HI is explored by examining it's response to variations in environmental factors in the absence of severe stress. Maize differs from most small grain crops in that the HI was already high at the beginning of the century and increases in the yield potential have been largely the consequence of increased total biomass production. The HI for most pulses species and varieties tend to be low because selection for yield has not been done in all seasons (Hay, 1995).

4.3 100 Seed Weight

This refers to the weight of 100 seed of any crop. A lower 100 seed weight implies that there are more seeds in the cultivar than a higher value (Fischer and Palmer, 1984) This can result from the effect of weeds on the crop.

4.4 Percentage barrenness

This reflects the proportion of plants that are barren to the total plant population. It was estimated that normal post - flowering photoassimilation required 6 to 12 days to fill the stem of barren plants to capacity, at which labile carbohydrates account for 52% of total stem weight (Barnet and Pearce, 1983). Barrenness appears to be related to stress arising from high plant density. Lang et al 1956, observed that high weed competition arising from low plant density (4000 plants /ha) and high weed density increased stalk barren ness.

However, weed competition will tend to reduce all crop growth parameters depending of the degree of weed competition and the growth time of weeding of the crop more especially if this occurred within the critical period.

MATERIALS AND METHODS

The study was conducted at University of Zambia, School of Agricultural Sciences field station during the 2000/2001 season. The soil was Sandy Clay Loam (USDA). For Chemical properties see Appendix C. The field history indicated that most of the field was previously planted with maize and the remaining part was planted with rape (*Brassica napus L.*).

Plant materials

The three maize cultivars were: MMV 400, SC 601 and MM 604 seed.

The treatments were:

1. Cultivars were: - MMV 400 (an open pollinated cultivar, maturing at 100 days), SC601 (a single cross cultivar maturing at 125 days) and MM 604 (a 3-way cross hybrid, maturing at 145 days).
2. Time of weeding: at 2-3 and 7-8 leaf
3. Weeding methods: These were single weeding + removal, single weeding + no removal, clean weeding and no weeding.

Experimental design

A split- split plot design with 3 replications was used. The main plot treatment was time of weeding, the subplot was the weeding method and the sub-sub plot was maize cultivar. The main plots were 16m x 9m. The sub- plots were each 9m x 4m whilst the sub-sub plots were 4m x 3m. The main plots were separated by a 1m wide path while the sub-plots and sub-sub plots were separated by 0.5 m wide paths. These treatments were

randomly selected and assigned to the split-split plots. All the sub subplots were tagged on 5th January, 2001 as suggested by Dyke, (1974).

Land Preparation and Crop management:

Land preparation was done on 21st December, 2000 by discing with a tractor. Harrowing, was not done but, clod breaking and land levelling was done by hand hoes. Main plot, sub-plot and sub-subplot markings were done after levelling as suggested by Dyke. (1974).

The maize was planted manually on 22nd December, 2000. All the cultivars were planted at a seed rate of 20 kg ha⁻¹ at a spacing of 75cm x 25cm spacing and 5cm deep. Planting was done with the aid of hand hoe. Fertilizer was applied at 250 kg/ha for both X compound and Urea as basal and top-dressing respectively. A spot application method was employed. The basal fertiliser was applied at 15 DAP while top dressing was done at 40 DAP.

All the weedings were done using the hand hoe. The 2-3 leaf time of weeding was done at 18 DAP in respective plots. The 7-8 leaf time of weeding was done at 34 DAP in respective plots. The clean weeding plots were weeded further at 57 DAP, 76 DAP and 101 DAP.

Plot demarcation for sampling

For weed assessment two randomly selected sample areas were marked in the harvesting rows of each sub-sub plot. This was achieved by throwing a stone in the harvesting rows. Where the stone fell such an area was marked for weed assessment

For growth assessment, two (2) sampling areas were clearly marked within the harvesting rows of each sub- subplot. Each sampling area was 1.5 m long by 1.5 m wide bordered by 4m rows on either side. Each sampling area consisted of 12 plants. Twelve plants (12) were assigned for growth analysis data while the other twelve (12) was used for harvesting data collection (Wishart and Sanders, 1958).

Six (6) composite soil samples were taken before planting on 21st December, 2000 from a depth of 30 cm. These were then homogenised to determine the pH, soil texture and soil fertility status as suggested by Mutsaers et al, (1977).

Data collection

a) Weed assessment.

Four (4) routine visual estimates were conducted. At each assessment a square quadrat measuring 0.71m x 0.71m (0.50 m²) was placed in a marked sampling area within each sub-subplot. Weeds within each quadrat were identified by species (Vernon, 1983). Percentage weed cover was estimated visually where 100% represented full cover and 0% no cover. Weed density was done by counting the weed species in each quadrat. Weed height was taken by a 1m rule. During the final assessment weed biomass was also

taken. This was done by cutting the weeds at ground level, packing them into labelled paper bags and oven drying at 105°C for 24 hours. These samples were weighed three (3) times prior to attaining a constant weight. Dry weight of each sample was then taken. Weed assessment was carried out at 21 DAP, 37 DAP and 64 DAP and at 50% silking. The 50% silking assessment was done at the following times for each cultivar: 79 DAP for MM V400. 83 DAP for SC 601 and lastly 87 DAP for MM 604 .

b) Crop growth assessment.

Three samplings were conducted by taking 4 plants within each sub-sub plot per sampling time. The plants were cut at ground level. Each plant was placed in marked polyethylene bags to avoid losses due to evapotranspiration. These were then taken for measurements at the field station within 30 minutes. For each plant the height, leaf length, maximum leaf width was measured. The leaf area was determined by multiplying the leaf length by width and correcting with a factor, which was 0.75.

The first assessment was conducted at 26 DAP. During the first assessment the leaves from each sub- sub plot were stripped and unrolled. All external materials on the plant parts were brushed off. The area of all leaves from each of the 4 plants was measured with a metre rule following methods used Milthorpe, 1956. All the stems and leaves of each plant were packed in labelled paper bags and placed in draught oven at 105°C for 24 hours. The dry weights were then obtained by using the electronic balance. The second assessment was carried out at 47 DAP. The leaf area and plant height measurement was done in a similar way as for the first assessment. The collected samples

were placed in the oven for 24 hours at 105 °C. The weights of each sample were then taken separately.

The final analysis sampling was done on separate dates according to each cultivar's period of attaining 50% silking. For MMV 400 the assessment was done at 79 DAP. This time the roots and the tassels were also weighed in addition to the stem and the leaves. The samples were dried from 79 DAP to 80 DAP at 105 °C. For the cultivar SC601 the plants were apportioned as for MMV400 at 83 DAP. The samples were oven dried from 15.00 hours at 83 DAP through to 15.00 hours at 87 DAP at 105°C. This was because the tissues were mature and needed more time to dry to constant weight. On the other hand, MM604 samples were taken at 88 DAP and subjected to the same procedure. The samples were oven dried for 48 hours at 105°C due to their thickness, as they needed more time to attain constant weights.

Moisture content was also taken at 50% silking by taking the fresh weights of the sample placed in polyethylene bags immediately after sampling. All the external materials were removed prior to weighing the samples. From the fresh weights the dry weights were subtracted, the difference was divided by the total plant weights:

$$\text{Moisture \%} = (\text{Fresh weight} - \text{dry weight} / \text{total plant fresh weight}) * 100$$

From the above data, standard formulae were used to derive the Leaf Area Index, Leaf weight ratio, Leaf area ratio, Specific leaf weight, Stem weight ratio, Ear weight ratio and Root weight ratio (Evans, 1972, Milthorpe, 1956).

c) Yield data:

Population counts, number of ears, barren stalks and ears were recorded at 144 DAP. Sampling for yield was done on different dates according to cultivars ability to attain 95 % black layer formation. The sampling was done at 148 DAP for MMV400, 159 DAP for SC601 and 160 DAP MM604. For yield data, 12 plants were harvested from the marked area in each sub- sub plot. The stalks were removed. The ears for each plant were paper bagged and labelled. The stalks were tied and also labelled. Both the ears and stalks were then oven dried for 48 hours at 105 °C until constant weight was attained. Five (5) cobs from each sub-subplot were randomly selected, the weights determined and shelling percentage obtained by the formula

$$\text{Shelling \%} = W_g * 100 / W_e \text{ (ears)}$$

Where W_g is weight of grain from the 5 ears in sampling area.

W_e is the total weight of the 5 ears.

The Harvesting Index was also obtained by the Formula

$$HI = W_g / W_t \text{ harvesting}$$

Where W_g = Weight of grains.

W_t = Weight of whole plant.

The ears from each plant were shelled; 100-grain weight determined using the electronic scale. The remaining plants (trial border rows and remaining plants) were harvested on

4th June, 2001.

Data Analysis.

A Genstat 5. Release 3.22 package /Windows 95 was used for analysis. Prior to analysis the weed cover, crop cover, barren percentage of stalks and ears data was transformed using the arcsine square root transformation (Gomez and Gomez, 1976). This was because the data was based on counts expressed as percentages of the total sample and has binomial distribution rather than normal distribution. The weed density, weed biomass and crop biomass data was transformed using the log transformation. This was because the standard deviation of the samples are roughly proportional to the means and there is evidence of multiplicative rather than additive main effects. All data was statistically analysed using Genstat general Analysis of Variance for Least Significant Difference (LSD) and Coefficient of Variation (CV). Contrasts were also done for partitioning sums of squares where interactions existed. Mean separation was done using Duncan Multiple Range Test (DMRT) as proposed by Little and Hills, (1978). Treatments were considered significant at $P=0.05$.

RESULTS.

The results of the experiment are shown in Table 1-16. The analysis of variance (ANOVA) tables for weed and crop development parameters including contrasts are presented in Appendices A. 1 -21. In general, not many differences were observed between times of weeding (at 2-3 and 7-8 leaf stages) except at 50% silking where the weed cover for the former was higher than the latter. The results also indicated that there were no significant differences between the two single weeding methods for most parameters. However, differences observed between clean weeding and no weeding were due to the undisturbed weed growth and development in the latter. With cultivar effect, MMV 400 was significantly different from the other cultivars in most parameters with relatively lowest ratios. SC601 and MM 604 were not significantly from each other in most parameters taken.

Generally, the weed flora comprised a diversity of both broadleaved and narrow leaved plants. Based on weed density by species the prominent among the major broadleaved were: *Nicandra physalodes*, *Galinsonga parviflora*, *Portulaca oleraceae*, *Bidens pilosa*, *Oxalis ratiflora*, *Leucus martinensis* and *Targetis minuta*. Among the major narrow leaved were *Cynadon dactylon*, *Digitaria milanjiana*, *Eleusina indica* and *Setaria spss*. There were also sedges such as *Cyperus species*, which was prominent during early times in crop development.

Adequate rainfall totalling 1106.9mm was received during the season (Appendix B).

Effect of weeding method on weed growth (cover, density and height)

The results of the effect of weeding method on weed growth (cover, density and height) are shown in Table 1. The weed cover at 3 weeks after planting (WAP) and at 50% silking (11-12 WAP) was similar in the two single weeding methods but differences were observed when compared to control plots that were clean weeded.

No differences for weed density were observed at 3 WAP between the single weeding methods and the no weeding control. However, the clean weeding was significantly different from the other treatments. Similar results were observed at 9 WAP and 50 % silking. The weed heights in the two single weeding methods were not significantly different from each other. There were no weeds in the clean weeding treatment. The tallest weeds were obtained in no weeding treatment.

Table 1. Effect of weeding method on weed growth (cover, density and height)

Weeding method	Percentage weed cover		Weed density			Weed height (m)
	3 WAP	50% silking	3 WAP	9 WAP	50% silking	3WAP
Single weeding + removal	16.68	66.50	28.04	164.20	153.60	0.04
Single weeding + no removal	18.58	70.50	26.36	166.30	145.40	0.04
Clean weeding	0.00	0.00	0.00	0.00	0.00	0.00
No weeding	31.39	91.10	49.23	209.80	185.20	0.12
Mean	16.66	57.03	25.91	135.08	121.05	0.05
LSD	5.64	17.48	15.73	57.12	51.57	0.01
CV(%)	13.40	21.00	8.60	7.00	21.00	24.50

Effect of weeding method on crop growth parameters (LAI, SWR, cover, biomass, yield, HI and % barren stalks).

Table 2 shows the results of the effect of weeding method on crop growth parameters (LAI, SWR, cover, biomass, yield, HI and % barren stalks). The highest Leaf Area Index (LAI) was obtained from clean weeding (2.13) which was not different from the two single weeding treatments. However, the LAI for clean weeding was different from the no weeding treatment. The highest Stem Weight Ratio (SWR) of 0.46 was observed in the no weeding treatment which was not different from clean weeding and single weeding + no removal. However, the SWR for single weeding + removal was significantly lower than the no weeding treatment and single weeding + no removal. For the crop cover, there was no significant difference among the various weeding methods except for the clean weeding which had the highest crop cover at 50 % silking. The maize biomass of the two single weeding methods was not significant from each other. The lowest maize biomass was obtained from the no weeding treatment. The highest yield was obtained from clean weeding, followed by single weeding treatments and the lowest yield was from no weeding treatment. There was no significant difference between either leaving or removing the cut weeds from the field. The highest Harvesting Index (HI) was from clean weeding (0.70). There were no significant differences in HI between removing the cut weeds; no weeding treatment and not removing the weeds after weeding. The highest percentage of barren stalks was obtained from Single weeding + No removal. (20.6%). However, there were no differences in barrenness between the two (2) single weeding methods and no weeding. Percentage barrenness in clean weeding and removing weeds after weeding were not different.

Table 2. Effect of weeding method on crop growth parameters (LAI, SWR, cover, biomass, yield, HI and % barren stalks):

Weeding method	LAI	SWR	Crop cover	Crop biomass(g/m ²)	Yield (Kgs/ha)	Harvesting Index	% Barren stalks
Single weeding+removal	1.71	0.38	45.40	304.80	2393	0.53	13.40
Single weeding+noremoval	1.74	0.39	50.30	262.60	2324	0.56	20.60
Clean weeding	2.13	0.43	60.90	375.40	3744	0.70	4.60
No weeding	1.33	0.46	46.50	213.60	1548	0.42	19.90
Mean	1.73	0.42	50.78	289.10	2502.75	0.55	14.63
LSD	0.53	0.06	9.76	99.56	1183	0.22	11.75
% CV	24.40	11.00	10.10	6.50	37.70%	30.00%	47.20%

Response of three maize cultivars to weed cover and density.

The results of response of three maize cultivars to weed cover and density are shown in Table 3. The highest weed cover and density at 50% silking was obtained from MMV400. The weed covers of SC 601 and MM 604 were significantly different. At 50% silking the highest weed density was observed from MMV 400.

The weed density for SC 604 and MM 604 was comparable.

Table 3. Response of three maize cultivars to weed cover and density.

Cultivar	% weed cover	Weed density (No of plants/m ²)
MMV 400	60.70	314.20
SC 601	53.70	210.00
MM604	56.70	15.30
Mean	57.03	179.83
LSD	5.43	49.92
%CV	15.30	11.00

Effect of cultivar on maize LAI, LAR, LWR, SWR, cover, biomass, yield, 100 seed weight and HI

The results of effect of cultivar on maize LAI, LAR, LWR, SWR, cover, biomass, yield 100 seed weight and HI. are shown in Table 4. At 20 DAP the highest LAI of 0.20 was obtained in SC 601. The LAI for MMV 400 and MM604 were not significantly different from each other. The LAI for MMV 400 and SC 601 were significantly different from each other. At 50% silking, the highest LAI (1.92) was obtained from MM604, but this was not significantly different from that of SC 601. The lowest LAI was obtained from MMV 400. The results for Leaf area ratio (LAR) at 50% silking indicated that the

highest LAR (0.31) was observed in MMV 400 where as the LAR of SC 601 and MM604 were not significantly different from each other. The results for the Leaf weight ratio (LWR) at 50% silking show that the highest LWR (0.20) was obtained from MMV400. This LWR was significantly different from that of MM604. The LWR for SC 601 and MM604 was not differently different from each other. As for stem weight ratio (SWR) the highest (0.46) was obtained from SC 601. MMV 400 had significantly lower SWR from SC 601. MM604 was not different from the other two cultivars. The SWRs of SC 601 and MM 604 were comparable. As for the crop cover the results indicated that at 9 WAP, the highest crop cover (45.70%) was obtained from SC 601 followed by MM604 and the lowest was in MMV 400. At 50% silking, the highest crop cover (56.60%) was obtained from MM 604 followed by SC 601 although not significant. The lowest crop cover was from MMV 400.

At 50% silking the highest crop height (1.70m) was observed in the SC 601 followed by MM 604 whilst the lowest was for MMV 400. The heights of each of the cultivars were significantly different from each other at 50% silking. At 50% silking the highest crop biomass (240.80 g/m²) obtained from the SC 601 MM 604 was not significant from that of MM 604. The lowest crop biomass was obtained from MMV 400.

The highest grain yield (2956 kg /ha) of SC601 was not significantly different from MM604. However the grain yield of MMV400 was significantly lower than that of SC601 and MM604. The data on the effect of cultivar on 100 seed weight indicated that the highest and significant 100grain weight (0.03kg) was obtained from SC 601. There were no significant differences in 100 grain weight of MMV 400 and MM604. The HI was not significant among the three cultivars.

Table 4. Effect of cultivar on maize LAI, LAR, LWR, SWR, cover, biomass, yield 100 seed weight and HI.

Cultivar	LAI	LAR	LWR	SWR	% crop cover	Crop Height (m)	Crop Biomass (g/m ²)	Yield (kgs/ha)	100 seed weight (kgs)	Harvesting Index		
					<u>9WAP</u>	<u>50% silking</u>						
	<u>20 DAP</u>	<u>50% silking</u>										
MMV400	0.12	1.37	0.31	0.18	0.36	31.81	42.70	1.27	145.40	1966.00	0.02b	0.51a
SC 601	0.20	1.89	0.24	0.17	0.46	45.71	53.10	1.70	238.00	2956.00	0.03a	0.62a
MM604	0.16	1.92	0.24	0.15	0.42	41.57	56.60	1.56	240.80	2585.00	0.02b	0.60a
LSD	0.03	0.20	0.04	0.03	0.06	4.56	5.87	0.14	69.30	513.40	0.01	0.12
Mean	0.16	1.73	0.26	0.17	0.41	39.70	50.80	1.51	208.07	2502.33	0.02	0.58
%CV	32.60	19.70	27.70	26.20	24.80	77.90	12.90	16.00	8.20	34.90	18.40	36.00

Effect of time of weeding on weed cover and density.

Table 5a: below indicates the effect of time of weeding on weed cover and density. The weed cover in the 2-3 time of weeding (63.10%) was higher than that of the 7-8 time of weeding (50.96 %). The weed density between the 2-3 and 7-8 time of weeding were not significant different.

Table 5a. Effect of time of weeding on weed cover and density.

Time of weeding	% weed cover	Weed density (No of plants/m ²)
2-3 leaf	63.10	242.60
7-8 leaf	50.96	241.60
Mean	57.03	242.10
LSD	8.95	95.08
%CV	2.70	1.30

Effect of time of weeding on crop growth parameters.

The results of the effect of time of weeding on crop growth parameters are as shown in Table 5b. The various parameters showed no significant differences on the time of weedings.

Table 5b. Effect of time of weeding on crop growth parameters.

Time of weeding	LAI	LAR	LWR	SWR	%Crop cover	Crop Biomass (g/m ²)	Yield (Kg/ha)	HI	100 seed Wt
2-3 leaf	1.94	0.27	0.17	0.43	51.30	319.80	2799	0.58	0.22
7-8 leaf	1.51	0.25	0.17	0.40	50.20	258.40	2205	0.57	0.23
Mean	1.73	0.26	0.17	0.42	50.75	289.10	2502	0.58	0.23
LSD	0.83	0.10	0.07	0.16	16.49	304.29	1917	0.40	0.01
%CV	13.70	10.90	11.10	10.60	6.10	7.10	21.80	19.70	4.80

Effect of time of weeding and weeding method on leaf weight ratio (g/g) at 48 days after planting (DAP).

Table 6 shows the effect of time of weeding and weeding method on leaf weight ratio (LWR) at 48 hours after planting. Significant changes were observed between time of weeding and among the weeding methods. Significant interactions were also observed at $\alpha = 0.05$. Weeding at 2-3 leaf had a higher LWR (0.27) compared to 7-8 leaf (0.26). Among the methods significant changes were due to single weeding + removal which had lower LWR (0.24) compared to 0.27 for the other methods.

Within different times of weeding across the methods, at 2-3 leaf time of weeding, the LWR was highest (0.29) where the weeds were removed and dried out side the field but this was not significantly different from where weeds were left to dry in field and clean weeding treatments. The lowest LWR was observed in no weeding plot. At 7-8 leaf time of weeding LWR was significantly lower where the weeds were removed after weeding compared to the rest of the methods. There were no differences among where weeds were not removed after weeding, clean weeding and no weeding treatments.

However within methods across the time of weedings only the single weeding where weeds were removed had significantly lower LWR compared to the rest of the methods. Also for no weeding the 7-8 leaf time of weeding had a higher LWR compared to 2-3 leaf.

Table 6. Effect of time of weeding and weeding method on leaf weight ratio (LWR) at 48 days after planting (DAP).

Time of weeding	Method				Mean
	Single Weeding + removal	Single Weeding + no removal	Clean Weeding	No Weeding	
2-3leaf	0.29	0.26	0.26	0.24	0.27
7-8leaf	0.18	0.27	0.27	0.30	0.26
Mean	0.24	0.27	0.27	0.27	0.26

LSD (0.05) Time of weeding (A) = 0.04

CV (%) (A) = 4.80

LSD (0.05) Weeding method (B) = 0.03

CV (%) (B) = 8.40

LSD (0.05) (AxB) = 0.04

CV (%) (AxB) = 8.40

Effect of time of weeding and weeding method on % weed cover at 6 weeks after planting (WAP).

Table 7 shows the effect time of weeding and weeding method on % weed cover at 6 weeks after planting. Significant differences at $\alpha = 0.05$ were observed between the time of weeding and among the methods. Significant interactions were also observed. There were significant differences ($\alpha = 0.05$) between the time of weeding for % weed cover at 6 weeks after planting. Weeding at 2-3 leaf time of weeding had a higher % weed cover of 36.25% compared to 19.52% for weeding at 7-8 leaf. There were significant changes in methods for % cover at 6 weeks. These changes were mainly due to the % weed cover under no weeding which was 79.87% compared to 17.75% and 13.92% under for single weeding + no removal and single weeding + removal respectively.

Within time of weedings, across the methods, there were no significant differences in the weed cover between the two single weeding methods. There were differences between the clean weeding and no weeding treatments and the two single weeding methods with

highest cover (81.67%) in the no weeding treatment. In the 7-8 leaf time of weeding only the no weeding treatment was significantly higher than the other treatments.

Table 7. Effect of time of weeding and weeding method on % weed cover at 6 weeks after planting (WAP).

Time of weeding	Method				Mean
	Single Weeding + removal	Single Weeding + no removal	Clean Weeding	No Weeding	
2-3 leaf	27.83	35.50	0.00	81.67	36.25
7-8 leaf	0.00	0.00	0.00	78.06	19.52
Mean	13.92	17.75	0.00	79.87	27.69

LSD (0.05) Time of weeding (A) = 2.09

LSD (0.05) Weeding method (B) = 2.95

LSD (0.05) (AxB) = 3.72

CV (%) (A) = 2.40

CV (%) (B) = 9.60

CV (%) (AxB) = 9.60

Effect of time of weeding and weeding method on percentage weed cover at 9 weeks after planting (WAP).

Table 8 shows the effect of time of weeding and weeding method on % weed cover at 9 weeks after planting. Significant changes were observed between time of weeding and weeding methods. Significant interactions were also observed.

There were significant differences ($\alpha = 0.05$) between time of weeding for % cover at 9 weeks. Weeding at 2-3 leaf had a higher weed cover of 61.40% compared to 49.27% for weeding at 7-8 leaf. There were significant changes on methods for % weed cover at 9 weeks after planting. The changes were due to the % weed cover under No weeding which was 97.14% compared to 59.78% and 64.42% under single weeding + No removal and for single weeding + removal, respectively.

Within time of weedings across the methods no significant differences were found in the percentage covers between the two single weeding methods. There were differences between the clean weeding and no weeding treatments and the two single weeding methods with highest cover in the no weeding treatment. In the 7-8 leaf time of weeding only the no weeding treatment was significantly higher than the other treatments. Within methods and across the time of weedings, there were differences in the single weeding + no removal with 2-3 leaf being higher than 7-8 leaf. A similar pattern was observed when the means were compared across the weeding methods with highest percentage cover in no weeding treatment.

Table 8. Effect of time of weeding and weeding method on percentage weed cover at 9 weeks after planting (WAP).

Time of weeding	Method				Mean
	Single Weeding + removal	Single Weeding + No removal	Clean Weeding	No Weeding	
2-3 leaf	70.33	77.39	0.00	97.89	61.40
7-8 leaf	58.50	42.17	0.00	96.39	49.27
Mean	64.42	59.78	0.00	97.14	55.34

LSD (0.05) Time of weeding (A) = 10.11

CV (%) (A) = 6.10

LSD (0.05) Weeding method (B) = 6.04

CV (%) (B) = 10.20

LSD (0.05) (AxB) = 9.08

CV (%) (AxB) = 10.20

Effect of time of weeding and weeding method on weed density (No of plants /m²) at 6 weeks after planting (WAP).

Table 9 shows effect of time weeding and weeding method on weed density at 6 weeks after planting. Significant changes were observed between time of weeding and weeding

methods. There were also significant interactions observed at $\alpha = 0.05$. With respect to time of weeding, 2-3 leaf had a higher weed density of 170.84 plants/m² compared to 79.8 plants/m² for weeding at 7-8 leaf. With regard to weeding methods at $\alpha = 0.05$ changes were due to density under no weeding which was 310 plants/m² compared to 101.0 plants/m² and 89.8 plants/m² single weeding + No removal, single weeding + removal respectively. No difference was observed between the 2 single weeding methods.

Within time of weedings across the methods there were no significant differences in the weed density between the two single weeding methods. The no weeding treatment at 2-3 leaf time of weeding was significantly different from single weeding with weeds removed from the field. Clean weeding, however, was significantly different (0.00) from the rest of the weeding methods. In the 7-8 leaf time of weeding only the no weeding treatment had significantly higher weed density than the other treatments.

Within weeding methods and comparing across the time of weedings, there were differences between the two single weeding methods and not between the clean and no weeding treatments.

Table 9. Effect of time of weeding and weeding method on weed density (No of plants /m²) at 6 weeks after planting (WAP).

Time of weeding	Method				Mean
	Single Weeding + removal	Single Weeding + No removal	Clean Weeding	No Weeding	
2-3 leaf	179.60	202.00	0.00	301.80	170.84
7-8 leaf	0.00	0.00	0.00	319.20	79.80
Mean	89.80	101.00	0.00	310.50	125.32

LSD (0.05) Time of weeding (A) = 28.10

LSD (0.05) Weeding method (B) = 76.94

LSD (0.05) (AxB) = 94.86

CV (%) (A) = 6.40

CV (%) (B) = 33.60

CV (%) (AxB) = 33.60

Effect of time of weeding and weeding method on weed height (m) at 6 weeks after planting (WAP).

Table 10, also shows the effect of time of weeding and weeding method on weed height (m) at 6 weeks after planting. Significant differences were observed between time of weeding and weeding methods. There were also interactions observed between time of weeding and weeding methods at $\alpha = 0.05$. Weeding at 2-3 leaf time of weeding had a higher height of 0.20m compared to 0.13m for 7-8 leaf. Among the methods, significant changes were due to No weeding which was 0.39m higher compared to 0.10m and 0.11m for single weeding + removal, single weeding + removal respectively. There were no significant differences observed between the two single weeding methods. Across methods within time of weedings, the highest weed height (0.37 m) was in no weeding treatment at 2-3 leaf. There were no significant differences between the weed heights of two single weeding treatments. At 7-8 leaf time of weeding again the highest height (0.41m) was in the no weeding treatment. Within methods across time of weedings, there were notable significant differences between the two single weeding methods.

Table 10. Effect of time of weeding and weeding method on weed height (m) at 6 weeks after planting (WAP).

Time of weeding	Method				Mean
	Single Weeding + removal	Single Weeding + No removal	Clean Weeding	No Weeding	
2-3 leaf	0.22	0.20	0.00	0.37	0.21
7-8 leaf	0.00	0.00	0.00	0.41	0.13
Mean	0.11	0.10	0.00	0.39	0.17

LSD (0.05) Time of weeding (A) = 0.07
 LSD (0.05) Weeding method (B) = 0.05
 LSD (0.05) (AxB) = 0.07

CV (%) (A)=10.20
 CV (%) (B)=24.50
 CV (%) (AxB)= 24.50

Effect of time of weeding and weeding method on weed height (m) at 9 weeks after planting 9 (WAP).

Table 11 shows the effect of time of weeding and weeding method on weed height at 9 weeks after planting. Significant changes were observed between time of weeding and weeding methods at $\alpha = 0.05$. There were also significant interactions observed. With respect to time of weeding the 2-3 leaf had a higher weed height of 0.32m compared to 0.22m at 7-8 leaf. Among the methods, significant changes were due to No weeding which had higher weed height of 0.53m compared to 0.26 and 0.29m for single weeding + No removal, single weeding + removal. No differences were observed between the two single weeding methods. Within time of weeding, across the methods no significant differences were observed between the two single weeding methods at 2-3 leaf. However the weed height in the single weeding method with weeds not removed after weeding was significantly lower than the no weeding treatment.

At 7-8 leaf time of weeding, no significant differences were observed between the two single weeding methods. Notable significant differences were observed between the no weeding treatment with highest weed height (0.55 m) and the single weeding treatments (0.18m and 0.15 m respectively).

Table 11. Effect of time of weeding and weeding method on weed height (m) at 9 weeks after planting 9(WAP).

Time of weeding	Method				Mean
	Single Weeding + removal	Single Weeding + No removal	Clean Weeding	No Weeding	
2-3 leaf	0.40	0.37	0.00	0.50	0.32
7-8 leaf	0.18	0.15	0.00	0.55	0.22
Mean	0.29	0.26	0.00	0.53	0.27

LSD (0.05) Time of weeding (A)= 0.15

CV (%) (A)=16.40

LSD (0.05) Weeding method (B) =0.07

CV (%) (B)= 22.40

LSD (0.05) (AxB)= 0.12

CV (%) (AxB)=22.40

Effect of time of weeding and weeding method on weed height (m) at 50% silking.

Table 12 shows the effect of time of weeding and weeding method on weed height (m) at 50% silking. There were no significant differences in the weed height between the two times of weeding. There were observed differences in the weeding method and also significant interactions observed at $\alpha = 0.05$. Changes in methods are due to No weeding which was 10.58m higher compared to 0.33m and 0.38m for single, weeding + No removal, single weeding + removal. No differences were observed between the two single weeding methods. Within time of weeding, across the methods no significant differences were observed between the weed heights of single weeding + no removal and the no weeding treatment at 2-3 leaf. At 7-8 leaf time of weeding, the weed heights between the two single weeding methods were not significantly different. Notable significant differences were observed between the no weeding treatment with highest weed height (0.65m) and the single weeding treatments (0.31m and 0.24m respectively).

Table 12. Effect of time of weeding and weeding method on weed height (m) at 50% silking.

Time of weeding	Method				Mean
	Single Weeding + removal	Single Weeding + No removal	Clean Weeding	No Weeding	
2-3 leaf	0.45	0.42	0.00	0.51	0.35
7-8 leaf	0.31	0.24	0.00	0.65	0.30
Mean	0.38	0.33	0.00	0.58	0.32

LSD (0.05) Time of weeding (A) = 0.19

LSD (0.05) Weeding method (B) = 0.08

LSD (0.05) (AxB) = 0.15

CV (%) (A) = 16.60

CV (%) (B) = 19.80

CV (%) (AxB) = 19.80

Effect of time of weeding and weeding method on weed biomass (g/m^2) at 50% silking.

Table 13 shows the effect of weeding and weeding method on weed biomass (g/m^2) at 50% silking. There were no significant differences between the two times of weeding at $\alpha = 0.05$. There were observed differences on the weeding method resulting from clean weeding. The No weeding biomass (g/m^2) was 37.65g/m^2 higher compared to, 20.14g/m^2 and 28.22g/m^2 for single weeding + no removal, single weeding + removal. No differences were observed between the two single weeding methods.

Within the time of weedings, across the methods, there were no differences in the biomass of the single weeding treatments and the no weeding treatments in the 2-3 time of weeding. In the 7-8 leaf time of weeding the biomass in single weeding treatments with weeds removed was higher than where weeds were not removed. The highest biomass (33.32g/m^2) was obtained from the no weeding treatment. Within the methods, across time of weedings, there were significant differences between the two single

weeding methods with 2-3 leaf time of weeding on the higher side for single weeding + no removal.

Table 13. Effect of time of weeding and weeding method on weed biomass (g/m^2) at 50% silking.

Time of weeding	Method				Mean
	Single Weeding + removal	Single Weeding + No removal	Clean Weeding	No Weeding	
2-3 leaf	30.06	30.54	0.00	41.78	25.60
7-8 leaf	26.38	9.72	0.00	33.32	17.36
Mean	28.22	20.14	0.00	37.56	21.48

LSD (0.05) Time of weeding (A) = 17.84

CV (%) (A)= 8.80

LSD (0.05) Weeding method (B)= 6.5

CV (%) (B)= 10.30

LSD (0.05) (AxB)= 13.68

CV (%) (AxB)= 10.30

Effect of weeding method and maize cultivar on weed biomass (g/m^2) at 50% silking.

Table 14 shows the effect of weeding method and maize cultivar on weed biomass (g/m^2) at 50% silking. There were significant changes observed among the weeding methods and not among the maize cultivars. There were also significant interactions at $\alpha = 0.05$. These changes were due to No. weeding, which had 37.54g/m^2 higher weed biomass (g/m^2) compared to, 20.10g/m^2 and 28.22g/m^2 for single weeding + No removal, single weeding + removal. The highest biomass in no weeding (37.54g/m^2) was not significantly different from the two (2) single weeding treatments. The weed biomass in single weeding + removal (28.22g/m^2) significantly higher than that of single weeding + no removal. (20.10g/m^2).

Within the weeding method across the maize cultivars, for single weeding with weeds removed from the field, the weed biomass for MMV 400 and MM 604 were similar.

For single weeding with weeds not removed from the field, there were no differences between MMV 400 and SC 601. However, the weed biomass under SC 601 was significantly higher than that of MM604. MM 604 had the lowest weed biomass. Under clean weeding treatment no significant differences were observed among cultivars.

In the no weeding treatment, the weed biomass under MMV 400 was significantly lower than the other cultivars. There were no differences observed between SC 601 and MM 604. Across the methods, within the maize cultivars, for MM 400 the highest weed biomass was observed in single weeding with weeds removed after weeding. This was followed by no weeding treatment. The weed biomass in no weeding treatment was not significantly different from where the weeds were not removed from the field.

For SC 601 the highest weed biomass was observed from the no weeding treatment. The weed biomasses under the two single weeding treatments were comparable. For MM604, the highest weed biomass was obtained from no weeding followed by single weeding treatment where weeds were dried out of the field. The lowest weed biomass was obtained from where weeds were not removed after weeding.

Table 14. Effect of weeding method and maize cultivar on weed biomass (g / m²) at 50% silking.

Method	Cultivar			Mean
	MMV 400	SC 601	MM 604	
Single Weeding + removal	36.30	22.90	25.46	28.22
Single Weeding + No removal	23.64	21.64	15.00	20.10
Clean Weeding	0.00	0.00	0.00	0.00
No Weeding	21.44	48.46	42.74	37.54
Mean	20.34	23.26	20.80	21.46

LSD (0.05) Weeding method (B) = 6.82

LSD (0.05) Cultivar (C) = 13.68

LSD (0.05) (B x C) = 12.56

CV (%) (B) = 10.30

CV (%) (C) = 20.30

CV (%) (B x C) = 20.30

Effect of time of weeding and cultivar on crop height (m) at 6 weeks after planting (WAP).

The effect of time of weeding and maize cultivar on crop height (m) at 6 weeks after planting are shown on table 15. There were no significant differences between the two (2) times of weeding. Significant differences in maize cultivars and interactions were observed at $\alpha=0.05$. Among the cultivars significant changes were due to the lowest height of MMV 400 (0.35m), which was lower than SC601 (0.41m) and MM604 (0.38m). No differences were observed between the heights of SC601 and MM604.

Within time of weeding, across cultivars, the crop height at 2-3 leaf time of weeding was highest for SC 601. At 7-8 leaf time of weeding there were no significant differences between the heights of SC 601 and MM604. However, there were differences between the height of SC 601 and MMV 400 with SC 601 on higher side. Within cultivars across the time of weeding, no significant differences were observed in MMV 400. For SC 601,

the crop height at 2-3 leaf time of weeding was significantly higher than for 7-8 leaf time of weeding. There were no differences in crop heights for MM604.

Table 15. Effect of time of weeding and maize cultivar on crop height (m) at 6 weeks after planting (WAP).

Time of weeding	Cultivar			Mean
	MMV 400	SC 601	MM 604	
2-3 leaf	0.34	0.44	0.39	0.39
7-8 leaf	0.35	0.38	0.38	0.37
Mean	0.35	0.41	0.38	0.38

LSD (0.05) Weeding method (A) = 0.14

CV (%) (A) = 10.60

LSD (0.05) Cultivar (C) = 0.02

CV (%) (C) = 7.40

LSD (0.05) (A x C) = 0.13

CV (%) (A x C) = 7.40

Effect of weeding method and maize cultivar on crop height at 6 weeks after planting (WAP).

Table 16: shows the effect of weeding method and maize cultivar on crop height at 6 weeks after planting are shown on table 16. There were significant changes among the weeding methods and the maize cultivars. There were also interactions observed at $\alpha = 0.05$. The tallest plant height was due to clean weeding (0.42m) compared to 0.37m for single weeding methods and 0.36m for no weeding. No differences were observed among the other methods. Among the maize cultivars, changes are due to MM400, which was the shortest (0.35m) compared to 0.41m for SC601. No difference was observed between SC601 and MM604.

The effect of weeding methods and maize cultivar on crop height at 6 WAP is shown in Within the method across cultivars for the single weeding with weeds removed from the field, the tallest crop was observed in SC 601 followed by MM 604. The maize height for

MMV 400 and MM 604 were similar. For the single weeding with no weeds removed from the field, there were no significant differences among the cultivars. Similarly with the clean weeding there were no significant differences observed. In the no weeding treatment, the tallest crop was observed in SC 601 followed by MM 604 and the lowest was observed in MMV 400. Within cultivars and across the weeding methods, for MMV 400, the highest crop height was obtained from clean weeding but this was not significantly different from the two single weeding methods. The no weeding treatment resulted in the shortest plants. The single weeding where weeds were not removed from the field resulted in the shortest plants. For MM604 clean weeding provided the only highest and significant height.

Table 16. Effect of weeding method and maize cultivar on crop height (m) at 6 weeks after planting (WAP).

Method	Cultivar			Mean
	MMV 400	SC 601	MM 604	
Single weeding + removal	0.35	0.40	0.37	0.37
Single weeding + No removal	0.36	0.37	0.37	0.37
Clean Weeding	0.39	0.44	0.42	0.42
No weeding	0.30	0.41	0.36	0.36
Mean	0.35	0.41	0.38	0.38

LSD (0.05) Weeding method (B) = 0.05

LSD (0.05) Cultivar (C) = 0.02

LSD (0.05). (B xC) = 0.06

CV (%) (B) = 11.00

CV (%) (C) = 7.40

CV (%) (B xC) = 7.40

DISCUSSION

The weeding methods at 50% silking showed no significant effects in weed cover, density and height except for no weeding. In the no weeding treatment possibly because of competition between the weeds and the crop, the leaf area index (LAI) for the crop was reduced. The competition reduced leaf growth and expansion due to limited resources. There were no differences in weed and crop growth parameters between removal and no removal of weeds after weeding probably because both methods were done during the critical periods.

Effect of weeding method on weed, crop development and yield.

From Table 1 (a) and (b), the weed growth at 3, 9 WAP and 50% silking showed differences between clean weeding and no weeding. The number of weeds was constant per treatment. The weed height at 3 WAP was higher in no weeding. This arose from the fact that in this treatment weeds remained undisturbed throughout. The increase in values in weed cover, density and height emerged as the season progressed due to a gain in dry matter. Arising from the effects of weeds, as the developments continued were the following implications: The highest leaf growth and expansion in clean weeding suggests that the plant invested fairly in assimilate harvesting apparatus. In the absence of competition from the weeds, the maximum crop cover and crop biomass was eminent. This resulted into the highest grain yield and its components. In the single weeding treatments where the weeds were not removed a slightly lower LAI relative to clean weeding was observed and it implied lower leaf growth and expansion. Investment into the stem SWR (as a sink) was fair. Corresponding higher weeds cover, density and height (relative to single weeding + removal) led to a higher competition and lower crop biomass. This lower biomass resulted into lower grain yield relative to where

weeds were removed after weeding. Where weeds were removed after weeding, slightly lower leaf growth and expansion led to lower LAI relative to non-removal and slightly lowered investment into the stem (SWR). This effect reduced weed cover and increasing crop biomass. The increase in biomass led to increased investment into the reproductive organs and thus accounted for the increase in grain yield relative to the other single weeding method.

In the no weeding treatment competition for available resources was strongest. This competition reduced leaf growth and expansion leading to the lowest LAI attained. This effect increased investment into the stem at 50% silking to account for the highest stem weight ratio (SWR) in the no weeding treatment. The implication was that the plant could have been investing more carbohydrates in the stem relative to other sinks. This in turn could have been a mechanism aimed at maintaining itself in the presence of high competition with the weeds. The low leaf area increased photosynthetic photon flux density (PPFD) transmittance to the weeds, which in turn increased weed growth (McLachlan et al, 1993), hence the highest weed covers, density and height. Because weeds are reported to be more efficient resource users than the crop this effect reduced crop cover and biomass. The net effect of having the lowest crop biomass was the lowest investment into the reproductive organs, hence the lowest grain yield attained and the related components.

The effects the various weeding methods on crop growth were expressed into the grain yield and its components (Table 2). The highest grain yield obtained in clean weeding was expected because of the absence of competition between the crop and the weeds for available resources. Where different weed pressures were induced on maize as dictated by the efficacy of each

method, the grain yield varied accordingly. The decreases compared to clean weeding were about 36% for both single weeding methods and 58 % for no weeding. Similarly under clean weeding, the HI was highest (0.70) implying that the method resulted in more grain weights than the total plant weight. However, the decreases of HI from clean weeding were 31-35% for single weeding methods and 48% for no weeding. This decline could be associated with stress arising from competition for available resources between the maize and the weeds. The partitioning of photoassimilates to grains was reduced. Similar effects resulting from competition from weeds are observed in barrenness. The barrenness increased with increase in weed pressures as offered by the various methods. Plants in the weedy treatments appeared to have suffered from high competition due to high total plant density (weeds and crop). Rudger (1971) observed that as plant density increases competition increases up to a certain level. Further increase resulted in increased barrenness and lower grain yields. The increase in barrenness compared to clean weeding were 139 % for single weeding with weeds removed, 221% for weeding with weeds not removed and 210 % for no weeding.

Response of three maize cultivars to weed growth and crop development.

The response of three maize cultivars to weed growth and crop development, as observed from Table 3 and 4 were diverse. The cultivar MMV 400 was the shortest, with relatively small sized leaves. On the other hand, SC 601 and MM 604 were relatively tall plants with larger sized leaves. The effects and the implications for each cultivar can be discussed on their response to the weed growth. For MMV 400, the relatively small stature and expansion led to a low LAI development. Because of the low LAI, the LAR and LWR were highest since the plant seemed to have invested more in the leaf as a sink (in an effort to

increase growth and expansion). This in turn reduced investment of photo assimilates into the stem hence the lower SWR attained. Alternatively, since LAR and NAR are products of relative growth rate (RGR) it could imply that respiration from the roots and stem were relatively higher and therefore could account for this unusual performance of MMV400 (Van der Werf, 1996). Although respiration was not measured, it could account for reduced net assimilation in the plant thereby reducing plant dry weight. Because of the lower leaf size and expansion weed cover and density increased as light penetration to the ground increased this reduced the cultivar's competitive capacity (Tollenaar et al, 1994). The SWR was also linked to the plant structure and size. Since MMV 400 is a short cultivar it further implies that even the stem weight is lower relative to the tall cultivars. However, the LWR for MMV 400 was highest at 50% silking when SWR was at its lowest which tallies with the observation on round leaved leaf mallow (Blackshaw, 1996). A similar observation was conclusive for the leaf area ratio (LAR) to be reduced as light is increased in peach plants (Minnotta and Pinzauti, 1976).

As the crop cover was reduced, crop height and biomass was also reduced. SC 601 had the highest crop height (1.70m). The net effect of the weeds and the implications on crop development was the lower grain yield and related components as the cultivar suffered from weed competition.

For SC 601 and MM604 the high leaf growth and expansion led to high LAIs. The high LAI meant more efficient photosynthesis. This high leaf size and expansion in response to weed development suppressed weed growth as light penetration to the ground was reduced, hence weed cover and density was reduced. This in turn increases crop cover, crop height and biomass. However, SC 601 was on the higher side. Since 50% silking is a transition point

from vegetative to reproductive phase there should be adequate carbohydrate storage pools in the sinks to the reproductive parts to enhance the grain yield.

The net effect of the weeds and the implications on MMV 400 crop development was more direct on grain yield and related components (Table 4). These also could have been due to inherent genetic yield potential. The early maturing cultivar MMV 400 is reported to have lower yield potential than the single cross and three-way hybrids (Pandey, 1998).

Interaction effects of time of weeding, weeding method and cultivar

It appears that in the no weeding treatment at 2-3 leaf time of weeding the plants were investing more in all sinks except for the leaf hence the lower LWR value. This high investment seems to be associated with plant maintenance as the competition was high. Respiration could also have been higher. On the other hand, where weeding was done the investment was fairly distributed so that the leaf weight was relatively higher. Weeding improved light use efficiency and in turn reduced respiration (Homes and Cowlings, 1993). At 7-8 leaf time of weeding, the removal of weeds after weeding seem to have increased the evapotranspiration as the land was left bare initially with no residues. In this case, it can be speculated that this effect was followed by increased competition from newly emerged weeds. This in turn could have increased stem, root and leaf respiration as a result the plant could have invested more in the plant in general to maintain itself. Also after weeding, continuous heavy rainfall followed which could have washed away some nutrients thereby causing other negative effects. The overall effect therefore is possibly the reduction in the leaf weight relative to the plant.

At 6 WAP differences between the time of weedings arose from the fact that the assessment was done soon after the 7-8 leaf time of weeding. This explains the zero weeds in the two single weeding methods. At 9WAP (Table 7), the relatively lower weed cover between the 2-3-leaf time of weeding and 7-8 leaf time of weeding arose out of the differences in timing. This meant that at 2-3 leaf time of weeding weeds were much older than the in 7-8 leaf time of weeding. On the basis of the timing consequent differences in weed density and weed height emerged throughout until 50% silking.

The difference between the single weeding with weeds removed at 6 WAP and no weeding were arising because the weeds in the treatment were newly emerged. Those in the no weeding were not disturbed and maintained a higher weed density. In the other single weeding with weeds retained the weeds were a composite of old and newly emerged. (Table 9). Differences that arose between 2-3 and 7-8 leaf time of weedings were resulting from differences in timing with lower weed density in 7-8 leaf time of weeding for the two single weeding methods. With weed height again because of the differences in timing, the 2-3 leaf time of weeding maintained higher height than 7-8 leaf time of weeding as observed at 6, 9 WAP and 50% silking in Table 10,11 and 12. However at 50% silking differences in height was negligible, as all the weeds had reached maturity stage.

With weed biomass at 50% silking, (Table 13) again differences arose from timing with more weeds in the 2-3 leaf time of weeding. The weeds in the 2-3 leaf time of weeding had enough time to accumulate more dry matter than the 7-8 leaf time of weeding. However, since

there were no differences between the time of weeding at 50% silking this implies that the weeds had reached maturity, thus no further gains in dry matter was expected.

At 50% silking it appears each cultivar exerted different effects on weed biomass. (Table 14). The larger leaf size of SC 601 and MM 604 had more shading effect than the other cultivar. The LAI for MMV400 was lower and thus increased light transmittance to the weeds, which in turn increased the photosynthesis and weed biomass (McLachlan et al, 1993). Again weeds in the single weeding with weeds removed were much shorter because the weeds were much younger than in the single weeding with weeds not removed. For the younger weeds, the dry matter was much lower as the weeds had not accumulated adequate dry matter. The weed biomass in the no weeding treatment in MMV400 was lower possibly because it had reached maturity much earlier in life and much of it was dry and seed dispersal had occurred on large scale posing difficulties to sample at assessment time. In the other cultivars where most of the weeds were still green and able to photosynthesise, these weeds were able to accumulate relatively more dry matter.

The differences in the weeding method as observed explains that conditions in the clean weeding were devoid of competition effects from weeds hence the highest percentage weed covers. With crop height differences observed for SC 601 between the two times of weeding seem to suggest that the cultivar was reduced in height by weeding at 7-8 leaf time of weeding. (Table 15 and 16). Method x cultivar interaction differences appeared to have arisen on the basis of the capacity of each cultivar to perform under each of the weeding methods. While the clean weeding provided the best environment, SC 601 seem not to favour the single weeding

with weeds not removed after weeding as its height was reduced. The crop height for MMV 400 was drastically reduced when it was grown under no weeding environment. The difference between SC 601 and MMV 400 was due to differences in plant size.

CONCLUSION

In the evaluation, the response of the three maize cultivars varied according to the weeding methods and the time of weeding. In response to the single weeding methods at 50% silking, SC 601 and MM 604 exhibited relatively high LAI, low LAR and LWR, with high SWR. These attributes reduced weed cover and density thereby promoting high crop cover, height and biomass which in turn contributed to the relative higher grain yield, 100 seed weight and HI. However dual comparison between SC 601 and MM 604 showed that SC 601 was on the higher side. MMV 400 exhibited relatively low LAI, high LAR and LWR and low SWR. Because of low LAI and SWR, weed cover and density, were high hence the relatively lower crop cover, height and biomass exhibited. The effects of these attributes contributed to its lower grain yield.

With regard to cultivars the higher leaf size particularly the LAI gave advantage to the shading effects on the weeds suppressing weed growth and development by limiting light transmittance to the weeds. The single weeding with weeds removed exerted lower weed biomass due to the fact that the weeds were much younger. SC 601 was reduced in height by weeding at 7-8 leaf stage. There were also observed differences in the performance of each cultivar under different weeding methods. SC 601 was reduced in height in single weeding with weeds not removed. MMV 400 was reduced in height by growing under no weeding at 6 WAP. In weed cover the 2-3 leaf time of weeding had higher weed cover than the 7-8 leaf time of weeding.

In terms of cultivar response to different times of weeding, the 2-3 weeding favoured SC 601 in that the cultivar gained the highest height followed by MM 604 with the lowest being MMV 400. At 7-8 leaf time of weeding, only SC 601 was higher than MMV 400 and showed difference in height between the two stages at 6 WAP. Therefore it can be recommended that a crop such as SC 601 with high LAI from emergence to maturity can perform better under single weeding methods at different times of weeding.

REFERENCES

- Andrade, A. W. and D. W. Fereres. 1993.** Leaf expansion, photosynthesis and water relations of sunflower plants grown on compacted soil. *Plant and Soil Journal* 149: 175-184.
- Anon. 1993.** Knowledge, Attitude and Practice: A baseline survey on crop and livestock production in Kafue and Lusaka rural districts, Part 1, Department of Agriculture, Zambia in collaboration with Department of Monitoring & Evaluation unit .14.
- Anon. 1986.** Agricultural Commercialisation and allocation of labour time in Mpika, Northern Zambia. Occasional paper No: 6 .23.
- Anon. 1987.** A base study paper in Serenje, Mpika and Chinsali, Adaptive Research Planning Team. Occasional paper No: 10 -12.
- ARPT. 1983.** Annual reports, Mt Makulu Central. Research Station, Lusaka.
- ARPT. 1986.** Annual reports, Mt Makulu Central Research Station, Lusaka.
- Andren, U. A. Nkomesha, L. P. Singogo and A. Sutherland. 1991.** National seed availability study: seed problems, practices 8-9 and requirements among small-scale farmers in Zambia, ARPT, Lusaka.

Blackshaw, E. R. 1996. Temperature effect on vegetative growth of round-leaved mallow (*Malva pusilla*), Weed Science 44: 63-67. ✓

Barnett, K. H and R. B. Pearce.1983. Source-sink ratio alteration and its effect on physiological parameters in maize. Crop Science 23: 294-299. ✓

Bazzaz, F. A. and J. L. Harper. 1977. Demographic analysis of *Linum utitatisum*. New Phytologist 78: 193-208. ✓

Buchanan, G. A. and E .R. Burns. 1971. Weed Competition in Cotton 1 sicklepod and tall morning glory, Weed Science 19:576-579. ✓

Blackman, G. E. 1956. Influence of light and temperature on leaf growth. p p 151-177. In Milthorpe (eds).The growth of leaves. Proceedings of the 3rd Easter School of Agricultural Sciences. University of Nottingham. Butterworth Scientific publication London.

Burril, L. C. J. Cardenas and E. Locatellil. 1976. Field Manual For Weed Control Research, International Plant Protection Centre, Oregon State University, Oregon. .p. 8-15.

CIMMYT. 1981. World maize facts and trend. Analysis of changes in production, consumption, trade and prices over the last two decades p. 8-10.

Donald, C. M and D. Humblin. 1976. Biological yield and harvesting index of Cereals as agronomic and plant breeding criteria. *Advances in Agronomy* 28:361-405.

Dowswell, R. C, R. L Paliwal and R. P. Cartwell. 1996. Maize in the third world 1st Edition, Westview Press p.25-33.

Dyck, E M. Liebman and M. S. Erich. 1995. Crop-weed interference as influenced by a leguminous or synthetic fertilizer nitrogen source: Double cropping experiments with crimson clover, sweet maize, and lambsquarters, *Agriculture, Ecosystem and Environment* 56: 93-108.

Dyke, G. V. 1974. Comparative experiments with field crops. Butterworth and Co, South Africa 33-40.

Edmeads, G. O. and H. R. Lafite. 1993. Defoliation and plant density effects on maize selected for reduced plant height. *Agronomic Journal* 85: 850-855.

Evans, C. G. 1972. The quantitative analysis of plant growth. University of California Press . Black well scientific publication. Oxford. p p xxvi + 743.

FAO. 1980. Plant production and protection. Paper 24/2, Improvement and production of maize, sorghum and millet Vol 2: Breeding, Agronomy and Seed production, Prepared with support of SIDA.

FAO. 1986. Instructor's manual for weed management, International Plant Protection Centre, p.p.112-116.

Fischer, K .S. and A. F. E. Palmer. 1984. Tropical maize. In PR.Goldsworthy and N .M. Fischer (eds), The physiology of tropical field crops, New York. John Wiley & Sons pp .213-248.

Fog, G .E. 1963. The growth of plants, Penguin Books Ltd, Middlesex, p.p 176-179.

Fulton, E. F. 1952. Weed Control, Technical Officer, Department of Agriculture, Pietermaritzburg, Advisory leaflet No: 5. Farming Press . South Africa.

Gomez, O. K. and A. A. Gomez. 1984. Statistical procedures for agricultural research, 2nd Edition, John Wiley and sons, New York.

Hall, M. R .1992. The critical period for weed control in grain maize. Weed Science.40: 441-447.

Hance, R. J. 1990. Weed control handbook. Principles, 8th edition, Blackwell Scientific Publication, London, p.p .307-310. ✓

Hay, R. K. M. 1995. Harvest index: A review of its use in plant breeding and crop physiology, Annals of Applied biology 126: 197-216. ✓

Heemskerk, W. 1992. Lima recommendation for wetlands agricultural system First draft, Adaptive Research Planning Team Occasional paper 14.(Zambia). ✓

Hebert, D. A and J. H. Fownes. 1997. Effect of leaf aggregation in a broad-leaf canopy on estimates of leaf area index by gap-fraction method. Journal of Forestry Ecology and Management 97 : 277-282. ✓

Homes, P. M. and R. M Cowling. 1993. Effect of shade on seedling growth, morphology and leaf photosynthesis in six sub tropical thicket species from Eastern Cape, Journal of Forestry Ecology and Management 34: 199-220. ✓

Johnson, A. G, T. R. Hoverstad and R. E. Greenwald. 1998. Integrated weed management using narrow maize row spacing, herbicides and cultivation. Agronomy Journal 1: 40-45. ✓

Leopard, C. E. and P. E. Kriedelman. 1975. Plant growth and development .Mc Grand-Hill Book Company. New York. p.p.13-65. ✓

Little, M. T. and F. T Hills. 1978. Agricultural experimentation. Design and Analysis, John Wiley and Sons p.p.110-113. ✓

Lusk, C. H and O. J. Figueroa. 1997. Growth, biomass allocation and plant nitrogen concentration in Chilean temperate rain forest tree seedlings: Effect of nutrient availability, Ecological Journal 109: 49-58. ✓

Maclachlan, S. M. 1993. Effect of maize-induced shading on dry matter accumulation, distribution and architecture of pigweed (*Amaranthus retroflexus*) Weed Science, 41:568-573. ✓

Masi, C. A. Mumba. , A. Sutherland and N. Velardel. 1989. On farm diagnostic in formal survey of small- scale farmers in Choma and Monze Districts, Occasional paper, Mt Makulu Central. Research. Station. Lusaka. ✓

Meggitt, W. F. 1970. Weed control methods, losses and costs due to weeds and benefits of weed control in maize, FAO International Conference on Weed Control, Michigan State University, p .p. 88-100. ✓

- McKee, G. W. 1964.** A coefficient for computing leaf area in hybrid maize. Agronomic Journal, 56: 240-241.
- Milthorpe, F. L. 1956.** The growth of leaves. Proceedings of the Third Easter school in Agricultural Sciences, University of Nottingham. p .p .152-198.
- Minotta, G and S. Pinzauti. 1996.** Effects of light and soil fertility on growth, leaf chlorophyll content and nutrient use efficiency of beech (*Fagus sylvatica L*) seedlings. Journal of Forest Ecology and Management 86: 61-71.
- Moolani, M. K., E. L. Knake and F. W. Slife. 1964.** Competition of smooth pigweed with maize and soya beans. North Central Weed Control Conference Proceedings: 17: 26-27
- Mukanda, N. 1995.** Sustainable options for increased food production in Zambia, paper presented at workshop in Chilanga.(Zambia)
- Mutsaers, H. J. W. 1997.** A field guide for on farm experimentation, International Institute of Tropical Agriculture (IITA) 128-129.
- Ndon, B. A, R. G. Harvey and J. M. Scholl. 1976.** Weed control in double cropping maize, sorghum or soya beans: minimum tillage planted following peas, Agronomic Journal, 74: 266-269

Nieto, J. 1970. The struggle against weeds in maize and sorghum. In. FAO International Conference on Weed Control. Davis. California 79-86. ✓

Njovu, C. A. 1987. Problems and characteristics of small scale farming in Katete and Petauke districts in Zambia. Small Holder Farming Systems and Technology Adoption. Paper presented to Winrock international Network workshop, Nairobi, Kenya. ✓

Parker, C. and J. D. Foyer. 1975. Weed control problems causing major reductions in world food supplies, FAO, Plant Protection, Bulletin 23: 83-95. ✓

Parker, J. M. and R. Vernon 1982. Maize herbicides for small scale farmers in Zambia. Tropical pest management 28: 259-262. ✓

Pandey, S. 1988. Cultivar development in plant breeding. In M. L. Monis (ed). Maize seed industries in developing countries. Boulder, Colorado, Lynne Reinner Publishers. 61-72. ✓

Ramsel, K. J. 1989. Weed control in maize/legume intercrops-Proceedings of a workshop on research methods for cereals/legume intercrop on Eastern and Southern Africa, Lilongwe, Malawi. ✓

Roberts, H. A. and W. Bond. 1975. Combined treatment of propachlor and trifluran for weed control in cabbage. *Weed Research* 15: 195-198.

Renfro, B. L. 1985. Breeding for disease resistance in tropical maize. In breeding strategies for maize production improvement in the tropics (ed) .A. Brandohni and F.Salmin publication No 10, Firenze, Italy, FAO.

Rukandema, M. and D. Hopkins. 1984. Some farming systems in the North –Western province of Zambia: Their constraints and potential for development. Results of an informal Survey. Technical. reprint 2. Adaptive Research Planning Team 22. (Zambia).

Rukandema, M. 1987. Anatomy of subsistence agriculture: A Sorghum cultivation of N. W. Zambia. ADP, GRZ/IFAD/FAO Area Development project, Solwezi 7. (Zambia).

Rutger, J. H. 1971. Effect of plant density on yield of inbred lines and single crosses of maize (*Zea mays L.*). *Crop science*. 11:475-76.

Siddiqu, K. H .M and B. R. Whan. 1994. Ear: stem ratios in breeding population of wheat: significance for yield improvement. *Journal of Science*, 73: 241-254.

Slife, F . W . 1970 . FAO , International conference on weed control, June, 22 - 1st
July, Davis , USA , Weed Science Society of America. p.81

Staniforth, D. W. 1961. Responses of maize to yellow foxtail competition, Weeds 9:
132-136.

Thaker, C. and H. N. Singh. 1954. Nilkalamine (*Ipomea hederacea*) a manace to
sugar cane. Horticultural Abstract, 24: 530

Truelove, B. 1977. Research methods in weed science, Second Edition, Southern Weed
Science Society, p.p.18-19.

Thomas, B. J., G. B. Schaalje and M. N. Grant. 1994. Height , competition and yield
potential in winter wheat. Agronomic Journal, 74:9-17.

Tollenaar , M, A. A. Dibo , A. Aguilere , S. F. Weise and C. J. Swanton. 1994.
Effect of crop density on weed interference in maize. Agronomy Journal. 86:591-595.

Tollenaar , M. A. Aguilera and S. P. Nissanka. 1997. Grain yield is reduced more by
weed interference in an old than in a new maize hybrid, Agronomic Journal 89: 239-
244.

USDA. 1965. A survey of extent and cost of weed control and specific weed problems. Agricultural Research Services report No: 34-23-1 Washington DC 78. ✓

Van der, W. 1996. Growth analysis and photoassimilate partitioning. In (eds). Eli Zamsik and Arthur A Schaffer, Photoassimilate distribution in plants and crops –Sink –source relationships. Marcel Decker Inc. Wy , Bassel p . p . 1-20. ✓

Vernon, R, and Parker J. M. 1983. Maize weed competition experiments: Implications for tropical small-scale weed control research, Great Britain. 19: 341-347. ✓

Vernon, R .1983. Field guide to important arable weeds of Zambia, Baldig + Mansel Ltd, London, England. ✓

Walter, H. 1983. Weed management in the Philippines: Report of Seminars, Josef Margraf , oberwiesenstr. 32, 7000 75 FRG, 70-73. ✓

William, F. M. 1970. Weed control methods, losses and costs due to weeds and benefits of weed control in maize, FAO international Conference on Weed control, Weed Science Society of America. p. p . 88-100. ✓

White, J. W. and P. R. Grace. 1998. Directions in modelling wheat and maize for developing countries. Proceedings of a Workshop, CIMMYT, El Batan , Mexico/ Natural Resources Group Geographical Information Systems Series 01 – 02.

Wishart, J. and H. S. Sanders. 1958. Principles and practices of field experimentation, Technical Communication No. 18 Common wealth Agricultural Bureaux. 71-72.

Zhang, H and J. R Braddle. 1997. Leaf area development of maize as affected by wind break shelter, Agronomic Journal : 37: 1253-1257.

Zimdahl, R. L. 1980. Weed crop competition-A Review, First Edition. International Plant Protection Centre. p .p .29.

APPENDICES:

A Analysis of variance Tables

WEED ASSESSMENT

Appendix 1. Transformed weed cover at 6 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	8.30	4.15	0.97	
Rep.Time of weeding stratum					
Time of weeding	1	5499.91	5499.91	1289.48	<.001*
Residual	2	8.53	4.27	0.26	
Rep.Time of weeding.Method stratum					
Method	3	41422.34	13807.45	835.48	<.001*
Lin	1	14639.30	14639.30	885.81	<.001*
Quad	1	17160.02	17160.02	1038.34	<.001*
Cub	1	9623.02	9623.02	582.28	<.001*
Time of weeding.Method	3	4965.81	1655.27	100.16	<.001*
Time of weeding.Lin	1	3509.13	3509.13	212.33	<.001*
Time of weeding.Quad	1	11.15	11.15	0.67	0.427
Time of weeding.Cub	1	1445.53	1445.53	87.47	<.001*
Residual	12	198.32	16.53	0.85	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	56.89	28.44	1.47	0.245
Time of weeding.Cultivar	2	26.24	13.12	0.68	0.515
Method.Cultivar	6	139.09	23.18	1.20	0.333
Time of weeding.Method.Cultivar	6	83.99	14.00	0.72	0.634
Residual	32	619.56	19.36		
Total	71	53028.97			

%CV (A) = 2.4, %CV (B) = 9.6, %CV (C) = 17.9

Appendix 2. Transformed weed density at 6 WAP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.72704	0.36352	32.18	
Rep.Time of weeding stratum					
Time of weeding	1	91.49248	91.49248	8098.23	<.001*
Residual	2	0.02260	0.01130	0.06	
Rep.Time of weeding.Method stratum					
METHOD	3	223.68833	74.56278	406.33	<.001*
Time of weeding.Method	3	92.29448	30.76483	167.65	<.001*
Time of weeding.Lin	1	72.51827	72.51827	395.19	<.001*
Time of weeding.Quad	1	0.04133	0.04133	0.23	0.644
Time of weeding.Cub	1	19.73488	19.73488	107.54	<.001
Residual	12	2.20205	0.18350	4.29	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	0.04506	0.02253	0.53	0.596
Time of weeding.Cultivar	2	0.00946	0.00473	0.11	0.896
Method.Cultivar	6	0.27401	0.04567	1.07	0.402
Time of weeding.Method.Cultivar	6	0.41084	0.06847	1.60	0.179
Residual	32	1.36929	0.04279		
Total	71	412.53563			

%CV (A)= 1.3 %CV (B)= 10.4 % CV (C)= 8.7

Appendix 3. Weed height at 6WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	110.82	55.41	1.13	
Rep.Time of weeding stratum					
Time of weeding	1	1612.84	1612.84	32.76	0.029*
Residual	2	98.46	49.23	1.22	
Rep.Time of weeding.Method stratum					
Method	3	15165.90	5055.30	125.51	<.001*
Time of weeding.Method	3	2388.42	796.14	19.77	<.001*
Time of weeding.Lin	1	2141.98	2141.98	53.18	<.001*
Time of weeding.Quad	1	2.26	2.26	0.06	0.817
Time of weeding.Cub	1	244.18	244.18	6.06	0.030*
Residual	12	483.32	40.28	1.78	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	33.23	16.62	0.74	0.487
Time of weeding.Cultivar	2	89.55	44.78	1.98	0.154
Method.Cultivar	6	136.59	22.76	1.01	0.438
Time of weeding.Method.Cultivar	6	236.38	39.40	1.74	0.143
Residual	32	723.18	22.60		
Total	71	21078.69			

%CV (A)=13.5 %CV (B)= 24.5 % CV (C)= 31.8

Appendix 4. Transformed weed cover at 9WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	30.81	15.40	0.15	
Rep.Time of weeding stratum					
Time of weeding	1	877.94	877.94	8.83	0.097
Residual	2	198.89	99.44	1.44	
Rep.Time of weeding.Method stratum					
Method	3	65123.12	21707.71	313.93	<.001*
Time of weeding.Method	3	1499.51	499.84	7.23	0.005*
Time of weeding.Lin	1	429.29	429.29	6.21	0.028
Time of weeding.Quad	1	291.53	291.53	4.22	0.063
Deviations	1	778.69	778.69	11.26	0.006*
Residual	12	829.77	69.15	1.38	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	340.96	170.48	3.40	0.046*
Time of weeding.Cultivar	2	94.73	47.37	0.94	0.399
Method.Cultivar	6	368.76	61.46	1.23	0.319
Time of weeding.Method.Cultivar	6	419.40	69.90	1.39	0.247
Residual	32	1604.32	50.13		
Total	71	71388.20			

%CV (A) = 6.1, %CV (B) = 10.2, %CV (C) = 15.0

Appendix 5. Weed height at 9 WAP.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	178.79	89.40	0.39	
Rep.Time of weeding stratum					
Time of weeding	1	1778.37	1778.37	7.68	0.109
Residual	2	462.86	231.43	2.14	
Rep.Time of weeding.Method stratum					
Method	3	25247.37	8415.79	77.75	<.001*
Time of weeding.Method	3	2813.32	937.77	8.66	0.002*
Time of weeding.Lin	1	2460.61	2460.61	22.73	<.001*
Time of weeding.Quad	1	20.09	20.09	0.19	0.674
Time of weeding.Cub	1	332.62	332.62	3.07	0.105
Residual	12	1298.90	108.24	2.10	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	71.72	35.86	0.70	0.506
Time of weeding.Cultivar	2	151.26	75.63	1.47	0.246
Method.Cultivar	6	290.09	48.35	0.94	0.482
Time of weeding.Method.Cultivar	6	510.74	85.12	1.65	0.166
Residual	32	1651.05	51.60		
Total	71	34454.46			

%CV (A)=16.4 %CV (B)= 22.0 % CV (C)=26

Appendix 6: Weed height at 50% silking.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	178.790	89.400	0.390	
Rep.time of weeding stratum					
Time of weeding	1	1778.370	1778.37	7.680	0.109
Residual	2	462.860	231.430	2.140	
Rep.time of weeding.Method stratum					
Method	3	25247.370	8415.790	77.750	<.001*
Time of weeding.Method	3	2813.320	937.770	8.660	0.002*
Time of weeding.Lin	1	2460.610	2460.610	22.730	<.001*
Time of weeding.Quad	1	20.090	20.090	0.190	0.674
Time of weeding.cub	1	332.620	332.620	3.070	0.105
Residual	12	1298.108	242.10		
Rep.Time of weeding.method.Cultivar stratum					
Cultivar	2	71.720	35.860	0.700	0.506
Time of weeding.Cultivar	2	151.260	75.630	1.470	0.246
Method.Cultivar	6	290.090	48.350	0.940	0.482
Time of weeding.Method.Cultivar	6	510.740	85.120	1.650	0.166
Residual	32	1651.050	51.600		
Total	71	34454.460			

%CV (A) = 16.4 , %CV (B) = 22 , %CV (C) = 26.

Appendix 7. Transformed crop cover at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	1290.500	645.250	6.890	
Rep.Time of weeding stratum					
Time of weeding	1	5.920	5.920	0.060	0.825
Residual	2	187.370	93.690	1.480	
REP. TIME OF WEEDING.METHOD stratum					
Method	3	924.820	308.270	4.880	0.019*
Time of weeding.Method	3	248.920	82.970	1.310	0.316
Residual	12	758.520	63.210	1.820	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	877.730	438.870	12.670	<.001*
Time of weeding.Cultivar	2	95.390	47.700	1.380	0.267
Method.Cultivar	6	154.200	25.700	0.740	0.620
Time of weeding.Method.Cultivar	6	88.990	14.830	0.430	0.855
Residual	32	1108.630	34.640		
Total	71	5741.010			

%CV (A) = 6.1, %CV (B) = 10.1, %CV (C) = 12.9

Appendix 8. Transformed weed cover at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2211.760	1105.880	52.280	
Rep.Time of weeding stratum					
Time of weeding	1	1653.030	1653.030	78.150	0.013*
Residual	2	42.300	21.150	0.060	
REP.Time of weeding.Method stratum					
Method	3	62319.620	20773.210	63.800	<.001*
Time of weeding.Method	3	1466.990	489.000	1.500	0.264
Residual	12	3906.920	325.580	5.870	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	469.720	234.860	4.230	0.023*
Time of weeding.Cultivar	2	106.720	53.360	0.960	0.393
Method.Cultivar	6	258.040	43.010	0.780	0.595
Time of weeding.Method.Cultivar	6	567.430	94.570	1.700	0.152
Residual	32	1775.040	55.470		
Total	71	74777.560			

%CV (A) = 2.7, %CV (B) = 21, %CV (C) = 15.3

Appendix 9. Transformed weed density at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.353	0.17672	31.44	
Rep.Time of weeding stratum					
Time of weeding	1	0.00140	0.00140	0.25	0.667
Residual	2	0.01124	0.00562	0.10	
Rep.Time of weeding. Method stratum					
Method	3	62.69572	20.89857	383.51	<.001*
Time of weeding. Method	3	0.47058	0.15686	2.88	0.080
Residual	12	0.65391	0.05449	2.42	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	0.44417	0.22208	9.85	<.001*
Time of weeding.Cultivar	2	0.02233	0.01116	0.50	0.614
Method.Cultivar	6	0.22910	0.03818	1.69	0.155
Time of weeding.Method.Cultivar	6	0.13108	0.02185	0.97	0.462
Residual	32	0.72128	0.02254		
Total	71	65.73425			

%CV (A) = 1.3, %CV (B) = 8.3, %CV (C) = 9.3

Appendix 10. Transformed weed biomass at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.12889	0.06444	1.01	
Rep.Time of weeding stratum					
Time of weeding	1	0.43074	0.43074	6.76	0.122
Residual	2	0.12746	0.06373	2.87	
Rep.Time of weeding. Method stratum					
Method	3	17.44239	5.81413	261.40	<.001
Time of weeding. Method	3	0.56914	0.18971	8.53	0.003
Time of weeding.Lin	1	0.01985	0.01985	0.89	0.363
Time of weeding.Quad	1	0.09606	0.09606	4.32	0.060
Deviations	1	0.45324	0.45324	20.38	<.001
Residual	12	0.26691	0.02224	0.78	
Rep.Time of weeding. Method.Cultivar stratum					
Cultivar	2	0.04791	0.02395	0.84	0.443
Time of weeding. Cultivar	2	0.05964	0.02982	1.04	0.365
Method.Cultivar	6	0.62108	0.10351	3.61	0.008
Lin.Lin	1	0.29923	0.29923	10.43	0.003
Quad.Lin	1	0.09412	0.09412	3.28	0.079
Lin.Quad	1	0.15366	0.15366	5.36	0.027
Dev.Lin	1	0.00048	0.00048	0.02	0.898
Quad.Quad	1	0.00090	0.00090	0.03	0.861
Deviations	1	0.07271	0.07271	2.54	0.121
Time of weeding.Method.Cultivar	6	0.07522	0.01254	0.44	0.848
Residual	32	0.91763	0.02868		
Total	71	20.68702			

%CV (A) = 8.8, %CV (B) = 10.3, %CV (C) = 20.3

Appendix 11. Transformed crop biomass at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	1.71123	0.85561	4.55	
Rep.Time of weeding stratum					
Time of weeding	1	0.15769	0.15769	0.84	0.456
Residual	2	0.37592	0.18796	3.52	
Rep.Time of weeding.Method stratum					
Method	3	0.65838	0.21946	4.11	0.032*
Time of weeding.Method	3	0.23515	0.07838	1.47	0.273
Residual	12	0.64127	0.05344	1.86	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	1.17755	0.58878	20.54	<.001*
Time of weeding.Cultivar	2	0.17627	0.08813	3.07	0.060
Method.Cultivar	6	0.18302	0.03050	1.06	0.404
Time of weeding.Method.Cultivar	6	0.20567	0.03428	1.20	0.334
Residual	32	0.91733	0.02867		
Total	71	6.43947			

%CV (A) = 6.1, %CV (B) = 6.5, %CV (C) = 8.2

Appendix 12. Weed height at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	624.33	312.17	0.91	
Rep.Time of weeding stratum					
Time of weeding	1	368.47	368.47	1.07	0.410
Residual	2	688.43	344.21	2.81	
Rep.Time of weeding.Method stratum					
Method	3	31297.43	10432.48	85.02	<.001*
Time of weeding.Method	3	2680.89	893.63	7.28	0.005*
Time of weeding.Lin	1	2242.41	2242.41	18.27	0.001*
Time of weeding.Quad	1	305.21	305.21	2.49	0.141
Time of weeding.Cub	1	133.27	133.27	1.09	0.318
Residual	12	1472.48	122.71	1.23	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	165.69	82.84	0.83	0.445
Time of weeding.Cultivar	2	25.51	12.75	0.13	0.880
Method.Cultivar	6	462.23	77.04	0.77	0.597
Time of weeding.Method.Cultivar	6	394.16	65.69	0.66	0.683
Residual	32	3189.17	99.66		
Total	71	41368.78			

%CV (A) = 16.6, %CV (B) = 19.8, %CV (C) = 30.9

Appendix 13. Crop height at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	47633.1	23816.6	3.67	
Rep. Time of weeding stratum					
Time of weeding	1	6123.7	6123.7	0.94	0.434
Residual	2	12969.1	6484.5	3.94	
Rep. Time of weeding. Method stratum					
Method	3	14204.2	4734.7	2.87	0.080
Time of weeding. Method	3	2484.2	828.1	0.50	0.688
Residual	12	19767.0	1647.3	2.82	
Rep. Time of weeding. Method. Cultivar stratum					
Cultivar	2	23605.8	11802.9	20.22	<.001*
Time of weeding. Cultivar	2	3090.0	1545.0	2.65	0.086
Method. Cultivar	6	1855.5	309.3	0.53	0.781
Time of weeding. Method. Cultivar	6	6240.6	1040.1	1.78	0.134
Residual	32	18681.7	583.8		
Total	71	156654.9			

%CV (A) = 15.4, %CV (B) = 15, %CV (C) = 16.0

GROWTH ASSESSMENT

Appendix 14. Leaf area index 3 at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	14.4186	7.2093	10.69	
Rep. Time of weeding Stratum					
Time of weeding	1	3.3355	3.3355	6.19	0.016*
Residual	2	1.3489	0.6745	1.26	
Rep. Time of weeding .Method Stratum					
Method	3	5.7573	1.9191	3.56	0.021*
Time of weeding Method.	3	1.0952	0.3651	0.68	0.570
Residual	12	6.4059	0.5338	4.62	
Rep. Time of weeding. Method. Cultivar Stratum					
Cultivar	2	4.5138	2.2569	4.19	0.021*
Lin	1	3.5599	3.5599	6.61	0.013*
Quad	1	0.9539	0.9539	1.77	0.190
Time of weeding Cultivar.	2	2.7229	1.3614	2.53	0.091
Method. Cultivar	6	1.3157	0.2193	0.41	0.871
Time of weeding. Method. Cultivar	6	3.0435	0.5073	0.94	0.475
Residual	48	25.8691	0.5389		
Total	71	47.6530			

%CV(A) = 13.7, %CV (B) = 24.4, %CV(C) = 19.7

Appendix 15. Leaf area ratio (LWR) at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	390.29	195.15	1.99	
Rep.Time of weedings stratum					
Time of weedings	1	47.79	47.79	0.49	0.558
Residual	2	196.43	98.22	3.10	
Rep.Time of weedings.Method stratum					
Method	3	166.07	55.36	1.75	0.211
Time of weedings.Method	3	242.81	80.94	2.55	0.104
Residual	12	380.24	31.69	0.60	
Rep.Time of weedings.Method.Cultivar stratum					
Cultivar	2	748.58	374.29	7.08	0.003*
Time of weedings.Cultivar	2	28.13	14.07	0.27	0.768
Method.Cultivar	6	253.51	42.25	0.80	0.578
Time of weedings.Method.Cultivar	6	276.78	46.13	0.87	0.526
Residual	32	1692.41	52.89		
Total	71	4423.05			

%CV(A) = 10.9 , %CV (B) = 12.4, %CV (C) = 27.7

Appendix 16. Leaf weight ratio (lwr) at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	46.18	23.09	1.21	
Rep.Time of weedings stratum					
Time of weedings	1	9.80	9.80	0.51	0.548
Residual	2	38.24	19.12	1.32	
Rep.Time of weedings.Method stratum					
Method	3	147.50	49.17	3.39	0.054
Time of weedings.Method	3	692.51	230.8	415.9	<.001*
Residual	12	173.91	4.49	0.49	
Rep.Time of weedings.Method.Cultivar stratum					
Cultivar	2	271.21	135.61	4.55	0.018*
Time of weedings.Cultivar	2	102.12	51.06	1.71	0.196
Method.Cultivar	6	247.36	41.23	1.38	0.251
Time of weedings.Method.Cultivar	6	181.51	30.25	1.02	0.433
Residual	32	953.51	29.80		
Total	71	2863.88			

%CV(A) = 4.8 , %CV (B) = 8.4, %CV (C) = 20.9

Appendix 17. Stem weight ratio (SWR) at 50% silking

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.10768	0.05384	2.31	
Rep.Time of weedings stratum					
Time of weedings	1	0.01059	0.01059	0.45	0.570
Residual	2	0.04661	0.02330	3.77	
Rep.Time of weedings.Method stratum					
Method	3	0.08018	0.02673	4.32	0.028*
Time of weedings.Method	3	0.00600	0.00200	0.32	0.808
Residual	12	0.07421	0.00618	0.58	
Rep.Time of weedings.Method.Cultivar stratum					
Cultivar	2	0.14609	0.07305	6.89	0.003*
Time of weedings.Cultivar	2	0.03003	0.01502	1.42	0.257
Method.Cultivar	6	0.02010	0.00335	0.32	0.924
Time of weedings.Method.Cultivar	6	0.07531	0.01255	1.18	0.339
Residual	32	0.33903	0.01059		
Total	71	0.93584			

%CV (A) = 10.6, %CV (B) = 11.0 %CV (C) = 24.8

Appendix 18. Grain yield:

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	6.353E+07	3.176E+07	8.89	
Rep.Time of weeding stratum					
Time of weeding	1	6.350E+06	6.350E+06	1.78	0.314
Residual	2	7.144E+06	3.572E+06	1.35	
Rep.Time of weeding.Method stratum					
Method	3	4.491E+07	1.497E+07	5.65	0.012*
Time of weeding.Method	3	1.279E+06	4.263E+05	0.16	0.921
Residual	12	3.182E+07	2.652E+06	3.48	
Rep.Time of weeding.Method.Cultivar stratum					
Cultivar	2	1.200E+07	5.999E+06	7.87	0.002*
Time of weeding.Cultivar	2	2.382E+06	1.191E+06	1.56	0.225
Method.Cultivar	6	2.719E+06	4.532E+05	0.59	0.732
Time of weeding.Method.Cultivar	6	5.009E+06	8.349E+05	1.10	0.387
Residual	32	2.440E+07	7.624E+05		
Total	71	2.015E+08			

%CV(A) = 21.8, %CV (B) = 37.6, %CV.(C) = 34.9

Appendix 19. Harvesting index:

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.21589	0.10795	0.70	
Rep. Time of weeding stratum					
Time of weeding	1	0.00007	0.00007	0.00	0.985
Residual	2	0.30906	0.15453	1.73	
Rep. Time of weeding. Method stratum					
Method	3	1.45624	0.48541	5.44	0.014*
Time of weeding. Method	3	0.06800	0.02267	0.25	0.857
Residual	12	1.07128	0.08927	2.08	
Rep. Time of weeding. Method. Cultivar stratum					
Cultivar	2	0.17493	0.08747	2.04	0.147
Time of weeding. Cultivar	2	0.09072	0.04536	1.06	0.359
Method. Cultivar	6	0.21210	0.03535	0.82	0.560
Time of weeding. Method. Cultivar	6	0.08188	0.01365	0.32	0.923
Residual	32	1.37369	0.04293		
Total	71	5.05386			

%CV (A) = 19.7, %CV(B) = 30.0, %CV (C) = 36.

Appendix 20. 100 seed weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.00013336	0.00006668	4.81	
Rep. Time of weeding stratum					
Time of weeding	1	0.00001250	0.00001250	0.90	0.443
Residual	2	0.00002775	0.00001388	0.93	
Rep. Time of weeding. Method stratum					
Method	3	0.00008550	0.00002850	1.90	0.183
Time of weeding. Method	3	0.00000639	0.00000213	0.14	0.933
Residual	12	0.00017978	0.00001498	0.88	
Rep. Time of weeding. Method. Cultivar stratum					
Cultivar	2	0.00036586	0.00018293	10.78	<.001*
Time of weeding. Cultivar	2	0.00004225	0.00002113	1.24	0.302
Method. Cultivar	6	0.00007325	0.00001221	0.72	0.637
Time of weeding. Method. Cultivar	6	0.00002286	0.00000381	0.22	0.966
Residual	32	0.00054311	0.00001697		
Total	71	0.00149261			

%CV(A) = 4.8, %CV(B) = 10.0, %CV(C) = 18.4

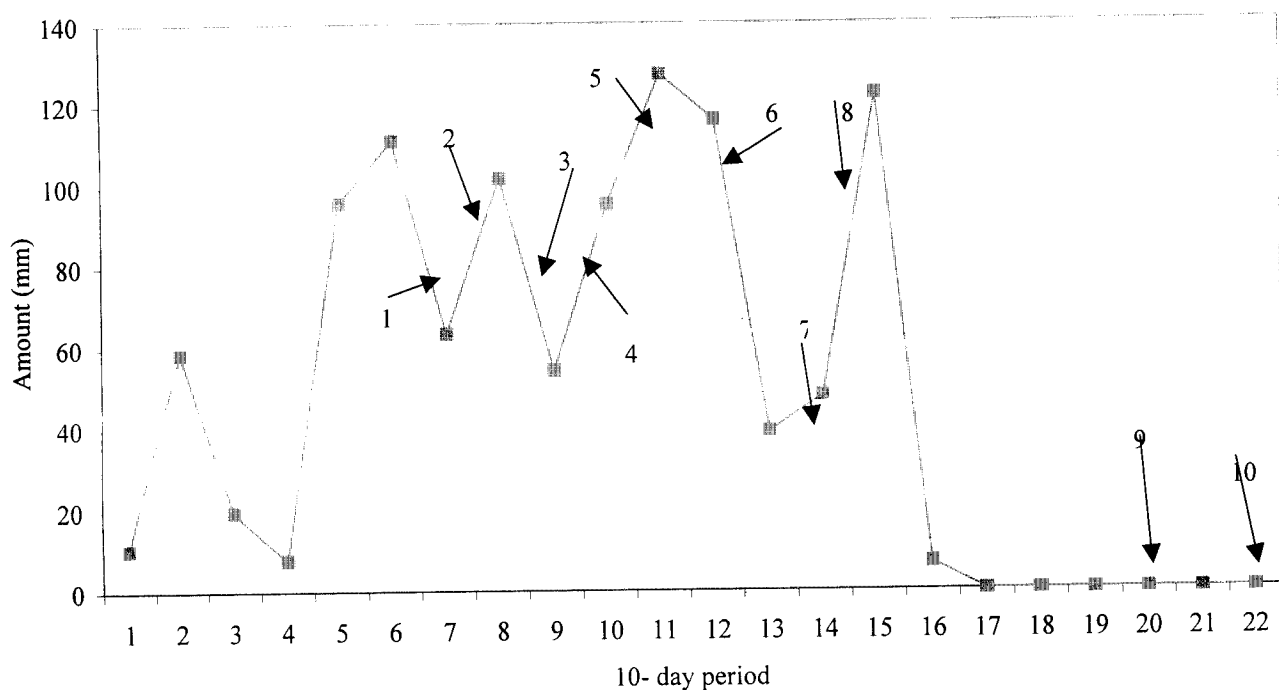
Appendix 21. Transformed barren stalks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	7125.42	3562.71	28.49	
Rep. Time of weeding stratum					
Time of weeding	1	669.35	669.35	5.35	0.147
Residual	2	250.09	125.05	0.63	
Rep. Time of weeding. Method stratum					
Method	3	2793.11	931.04	4.70	0.022*
Time of weeding. Method	3	50.52	16.84	0.09	0.967
Residual	12	2376.73	198.06	2.09	
Rep. Time of weeding. Method. Cultivar stratum					
Cultivar	2	414.99	207.50	2.19	0.128
Time of weeding. Cultivar	2	13.21	6.60	0.07	0.933
Method. Cultivar	6	728.49	121.41	1.28	0.292
Time of weeding. Method. cultivar	6	800.51	133.42	1.41	0.241
Residual	32	3025.53	94.55		
Total	71	18247.95			

%CV (A) = 18.7, %CV (B) = 47.2, %CV (C) = 56.4

Appendix B2002/2001 Ten day average rainfall showing agronomic practices and activity implementation schedules.

2000/2001 ten day average rainfall, agronomic practices and activity implementation schedule



Rainfall started from 1st Nov, 2000 to 31st May 2001. The grand total=1106.85mm

Key:

- 1 = planting
- 2= 2-3 Time of weeding weeding, 1st weed assessment, 1st growth assessment and basal application
- 3= 7-8 Time of weeding weeding.
- 4= Top dressing.
- 5= 2nd weed assessment.
- 6= 3rd weed assessment.
- 7= 50% silking weed assessment + final growth assessment for MMV 400 and SC 601.
- 8 = 50% silking weed + growth assessment for MM 604
- 9= Yield data sampling in MMV 400
- 10 = Yield data sampling in SC 601 + MM 604

Source: University of Zambia metiological station

Appendix C

Soil analysis results before planting.

Lab NO:	Sample type	pH Cacl2	%N	P mg/kg	K me/100g	Sand %	Clay %	Silt %	Textural class
10	Soil	7.72	0.05	37.38	0.14	64.8	20.8	14.4	SCL

Key:

SCL= Sandy Clay Loam

mg/kg= milligrams of element per kg of soil

me/100g= milli-equivalent of element per 100g of soil