THE EFFECT OF WEEDS ON GROWTH AND YIELD OF BEANS

(*Phaseolus vulgaris*)

BY

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DECLARATION

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

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This thesis has been submitted for examination with my approval as the University supervisor.

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Dr. D.R. Basiime

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ABSTRACT

Field studies were conducted in 1979 and 1980 at the Field Station, University of Nairobi, to evaluate dry bean (*Phaseolus vulgaris*, L.) varieties Canadian Wonder, Mwezi Moja and Rose Coco growth and yield as influenced by competition from annual mixed weeds and different weeding treatments. In one set of experiments, the beans were left to grow in weeds the first four and eight weeks respectively after planting or left to grow with weeds the entire season. In another set the beans were freed of weeds the first four and eight weeks respectively after planting and thereafter kept weed free or were weeded the entire season. The leaf areas, dry weights of whole plants, shoots, roots, stems, leaves as well as plant height and number of branches per plant were determined at intervals during the phase of the vegetative growth. At the end of the growth period, grain yield and yield components were determined.

Season-long weed competition reduced bean grain yields by 49.5, 55.5 and 58.0% with ample moisture in 1980 and by 53.0, 58.0 and 67.0% when

moisture was limiting in 1979 for Canadian Wonder, Mwezi Moja and Rose Coco respectively.

In all instances, the pod number per plant was the most severely affected component of yield and showed similar trend of weed effects to those observed in grain yields. Seeds per pod and weight per seed were not affected by weeds except in cultivar Rose Coco when moisture was limiting in 1979, when in addition, the number of seeds per pod was significantly reduced by weed competition.

Plant growth as measured by the total plant dry weight and the dry weights of other plant parts named above were significantly reduced by weed competition lasting eight weeks and beyond after planting except stems in Mwezi Moja. Similarly LAI and number of branches per plant were significantly reduced by weed competition beyond the reproductive phase (six to eight weeks after planting).

There was no need to keep the cultivar free from weeds beyond the fourth week after planting. However, upto and beyond eight weeks in weeds the bean growth and yield were significantly reduced.

CHAPTER 1

INTRODUCTION

Leguminous grains have been recognized as important protein sources in the diet of populations of many tropical areas of the world (Ricardo, 1973). The bulk of the protein intake in these areas comes from the vegetable origins of which grain legumes are by far the most important after cereals (Mian, 1976). In use and importance the legumes are second to the grasses in the entire kingdom of plants. They provide food, fuel, fibre, shade, shelter, medicine, and other useful products for man, feed, shade, and shelter for animal, and fertilizer (nitrogen and organic matter) for soil (Mian, 1979). Among the most important grain legumes in Eastern Africa are the dry beans (Phaseolus vulgaris), cowpeas (Vigna unguiculata), pigeon peas (Cajanus cajan), field peas (Pisum sativun L.); chick peas (Cicer arietinum L.) and grams - black (Vigna mungo (L.) (Hepper)), green (<u>Vigna</u> <u>radiata</u> (L.) (Wilcz)) and yellow

Dry beans are by far the most important pulse crop in Eastern Africa. They are an ancient crop known to have originated from Central and South America (Vavilov, 1951) and are believed to have been cultivated in East Africa for about 300 years even though there are no written records available before the nineteenth century (Mukunya and Keya, 1975). They form an important part of the diet of the people in East Africa where they are an important source of protein to a large number of people in the low income group. Their value as protein source have been found to be very satisfactory (Harvey, 1956), being in the range of 20-30% with relatively high amounts of lysine and methionine as compared with other pulses (FAO Production Year Book, 1969 and 1970; Mukunya and Keya, 1975). Other staple foods like the cereal grains, root crops and plantains consumed regularly by East Africans have comparatively little protein with very small amounts of lysine and methionine (see Appendix table 1). These beans provide a good supplement for the essential amino acids especially where animal proteins are too expensive.

Dry beans are extensively grown in Kenya where they are often intercropped with maize and/or sorghum. The production area comprised approximately 322,600 hectares by 1973 (Statistical Abstracts - Kenya, 1973). Except in the coastal areas of Kenya, dry beans are grown in all agricultural areas, with the greatest production in Eastern and Central Provinces (Acland, 1971). Many local cultivars are available to the Kenyan farmer, the outstanding high yielding ones include, Canadian Wonder, Rose Coco, Mwezi Moja and Mexico 142. Canadian Wonder is grown as a later maturing cultivar which is common in Central Province; Rose Coco which is a medium maturing cultivar is common in Western, Central and Eastern Provinces; Mwezi Moja, grown as an early maturing cultivar is mainly grown in the lower altitude areas such as Machakos and Kitui Districts of Kenya; and finally Mexico 142, grown purely for canning (Van Eijnatten *et al*., 1974). Many other cultivars of less importance are recognized, but differ in seed shape and growth habits depending on locality.

During the current investigation, three outstanding cultivars (Canadian Wonder, Mwezi Moja and Rose Coco) were used. Canadian Wonder, originally introduced as a pure line is semi-determinate with large purple seeds. Rose Coco has small pink-mottled oval seeds; it is a land race with determinate bush-type of growth. Mwezi Moja has liver coloured - light purple seeds with determinate bush type of growth. Other characteristics of the three cultivars are given on page 5.

Average yields of beans obtained by Kenyan farmers is low and averages between 220-670 kg/ha (Macartney and Watson, 1966; Acland, 1971). With improved varieties, good husbandry and good pest and disease control up to 2500 kg/ha should be expected (see page 5) for yield potentials of the outstanding cultivars). Canadian Wonder and Mexico 142 cultivars are capable of higher

Some characteristics of the three cultivars used in the experiment

CULTIVAR	ORIGIN	SEED CHARACTERISTICS	GROWTH CHARACTERISTICS	HEIGHT (cm)
Canadian-Wonder (C)	Originally introduced into Kenya through Grain Legume Project and Nairobi University but many local types now exist	Purplish brown, medium sized (about 0.35g per seed), oblong. Yield potential 2500 kg/ha.	Semi-determinate in growth habit, upright with large biomass and light foliage colour. Pods medium in length. Adapted to medium rainfall areas represented by Embu and Kabete with desease pressure not too severe. Season length about 95 days.	40-60
Mwezi Moja	Local (Katumani) through Grain Legume Project.	Many fine purple spots on cream. Medium to large sized (about 0.45g per seed), oblong. Yield potential 1500kg/ha.	Determinate in growth, habit, upright with long pods kept well of the ground. Early flowering with season length of about 80 days. Adpted to drier areas represented by Machakos (Katumani) where desease problems are of restricted importance.	20-60
Rose Coco	Uganda through Grain Legume Project and Nairobi University	Variegated with large red flecks on cream, large sized (about 0.55g per seed), oblong.	Determinate in growth habit, strong and upright of the architectural type. Pods are long, but kept reasonably well of the ground. Season length about 85 days. Wide adaptability but specially suited to high rainfall areas represented by Kisii and Kakamega	20-60

Source: Kenya Seed Company, 1978.

yields than those figures and on experimental basis have given yields equivalents of 3000 kg/ha (Ministry of Agriculture - Kenya, 1974). While world mean yield of dry beans stood at 510 kg/ha in 1971 (Pinchinat, 1973), the maximum commercial yield in U.S.A. was 4,035 kg/ha under irrigation in Colorado (U.S. Department of Agriculture, 1970) and farmers in the Dominican Republic had commercial dry bean yields of 4000-5000 kg/ha (Pinchinat, 1973). The need to increase research on dry beans becomes therefore inevitable especially in these areas.

Potentially all the bean plant can be put on use by the farmers. Fresh leaves from young plants with the protein content of as high as 20-25% may be used as vegetable, thus serving as a cheap plant protein (Mukunya and Keya, 1975). The whole plant while fresh may also be ploughed in at flowering as green manure. Occassionally, bean haulms obtained after harvesting are used as cattle-bed or as fuel or fed to animals in dry areas. But, most commonly the average farmer grows beans mainly for seeds. Bean seeds are vital in the diet of most people. It is due to its protein contribution that much of the harvested and marketed crop is consumed locally by various institutions and very little is exported (Jameson, 1970). In Kenya therefore, dry beans could become an important export crop.

Weed management is a major constraint in dry bean production. It is an established fact that weeds, due to their competition for water, light and nutrients reduce crop yields, but little is known about the physiological interaction between crop plants and weeds that brings about the yield reduction (Aspinall and Milthorpe, 1959). The heaviest loss caused by weeds probably results from their competition with crop plants for water, nutrients and light. Within certain limits the three are used in definite proportions, consequently when one becomes lessened, the others cannot be used effectively even when present in abundance (Crafts and Robbins, 1962; Buchanan and Burns, 1969). In addition, weeds impair the quality of farm products by contamination, hence reduces their quality and market value. A large number of weeds in grain may retard drying and promote growth of molds; the presence of weed fragments and broken seed pods of such plants like wild radish (Raphanus raphanistrum) may cause spoilage in threshed grain in storage or in transit. Weeds also reduce the quantity and quality of livestock products by imparting certain undesirable flavour to the milk e.g. wild garlic (Allium vineale), bitterweed (Medicago lupulina) and ragweed (Ambrosia spp.) from cows that graze upon them and by becoming entangled in the hair of animals hence reduce the values of wool or hide. Many weeds will harbour insect and fungus pests as well as bacterial and viral disease organisms that attack crop plants. The bacterial organism causing bean blight lives on some of the wild legumes; prickly lettuce (Lactuca scariola) and common sowthistle (Sonchus spp.) will harbour bean thrips (Crafts and Robbins, 1962). Keith Moody (1973) in his report on weed control in tropical grain legumes quoted results obtained by Afolami and Caveness that of 39 weed species sampled at the International Institute of Tropical Agriculture (IITA-Nigeria) only two i.e. Euphorbia heterophylla and Trianthema portulacustrum were found to habour no endoparasitic nematodes. Moody also quoted results contained in IITA letter No. 3 that when cowpeas and soybeans were not weeded insect damage to the developing seed increased by 15.8 and 13.0% respectively compared with results obtained with seeds from weed free plots. Higher proportion of mouldy black gram (Vigna mungo) seeds were also reported in unweeded plots in Fiji (Patel and Rhodes, 1969).

The amount of competition on a crop has also been found to be influenced by the particular nature or species of weed, crop species and varieties, cultural weed control practices and climatic and edaphic conditions (Staniforth 1958, 1961,1962 and 1965; Wax and Pendleton, 1968; Wiese et al.,1964).

Dry beans (P. vulgaris) have been shown to be weak competitors with weeds especially in the early stages of growth (Nieto et al., 1968; Freytag, 1973; Blanco et al 1969; Kasasian and Seeyave, 1969; Vengris et al., 1972;

Barreto, 1970; William 1973; Williams, 1973; and Williams *et al.*, 1971). The objective of this study was to investigate the influence of weed competition on:

(i) Dry matter accumulation and distribution at different stages of bean growth.

(ii) Yield and yield components of three bean cultivars under Kabete conditions.

CHAPTER 2

LITERATURE REVIEW

2.1. WEED COMPETITION AND CROP YIELD LOSSES

Plant competition in both natural and artificial communities is one of the most important influences on the growth of individual plants. Aspinall (1960) defined competition as restriction that arises from association with other plants, and must result from a change in one or more factors of the local environment of a plant. Bell and Koeppe (1972) defined competition as the mechanism by which one plant depletes some essential element for plant growth to a level that is limiting to the growth of a second plant sharing that habitat.

Weed species and crop plants growing in association compete for light, nutrients and water as a result of which yields are greatly reduced. Crop yield losses from weeds usually are proportional to the amount of light, nutrients and water used by the weeds at the expense of the crop (Blackman and Templeman, 1938; Burnside and Wicks, 1965; Hurst and Feltner, 1966; Pavlychenko, 1949; Nieto and Staniforth, 1961 and Wiese *et al.*, 1964).

2.1.1. Competition for light

Those weeds that grow taller than the crop and those with large coarse leaves if not controlled early enough will reduce crop yields through shading. Starck (1974) when studying the effect of shading on the metabolic activity of roots in young beans (*P. vulgaris*) and sunflower (*Helianthus annuus*) seedlings compared to those seedlings put for a few days in shade (50% of natural light) with those grown in natural light conditions and found that with extended period of shading, not only growth of roots, but also the rate of root respiration, sugar content, transport of ^{14}C assimilates and ^{32}P absorption decreased. Aspinall (1960) had similar findings when working with barley in competition with white persicaria (*Polygonum lapathifolium*), that reduction in incident radiation reduces the rate of growth of the root system and thereby accentuating the deficiency in nutrient supply. Light therefore is an important factor in crop-weed interaction as it influences the rate of root extension through supply of assimilate to the root and in turn effects the rate of nutrient uptake. The above results conform with Crafts and Robbins (1962)assertion that light, nutrients and water are used in definite proportions and lack of one affects use of the others.

Smith (1967) working with rice in competition with hemp sesbania (Sesbania exaltata), nothern jointvetch (Aeschynomene virginica), duck salad (Heteranthera limosa) and barnyard grass (Echinochloa crusgalli) found hemp sesbania and nothern jointvetch to decrease yields of rice during the late season growth; he concluded that this was due to differences in height and hence competition for light since the species involved were taller than rice in ten to twelve weeks. Staniforth and Weber (1956) on their study on the effects of weed growth upon soybean yields found that weeds that-topped and hence shaded the soybeans reduced more than other weeds which did not shade the beans and that the latter reduced yields by half those that topped them. Nieto et al.,

(1968) working with dry beans and maize found beans to be less able to compete with weeds. He suggested height of the plant to be one of the reasons since taller weeds smothered the beans and competed strongly for light.

2.1.2. <u>Competition for nutrients</u>

Weeds are generally vigorous plants and their competition for mineral nutrients are therefore great. Blackman and Templeman (1938) suggested that competition between crops and weeds was for some limiting factor; when water is adequate either from rainfall or irrigation and one plant is not growing in the dense shade of the other, the limiting factor is probably nitrogen. Pavlychenko and Hurrington (1934) studied the root development of weeds and cereals under dry farming conditions and found that when plants grew very closely there is a competition between overlapping root-systems long before the tops begin to shade one another. Root competition (competition for nutrients) therefore appears to set in earlier than competition for light. Vengris *et al* (1955) working with pigweed (Amaranthus spp.), lambsquarters (Chemopodium album), crabgrass (Digitaria spp.) and barnyard grass (Echinochloa crusgalli) compared corn grown alone, corn grown with common certain weeds and weeds grown alone. They found that corn with low phosphorus grew much better and gave better yields than corn with high phosphorus in competition with weeds. They found in addition that even at high rates of fertilization with N, P and K weeds competed strongly for essential elements and suppressed the growth of corn and resulted in decreased corn yields.

Some weeds have been found to be able to accumulate certain elements in their tissues at the expense of cultivated plants, thereby reducing yields, especially when these elements are in short supply. Vengris et al. (1953) with an objective to determine chemical composition of field collected weed species and their companion cultural crops found weeds to be important competitors with cultivated plants for N and K which are often limiting factors in crop production; they found weeds to be able to accumulate considerable amounts of these elements.

Nutrients under study in this latter experiment were N, P, K. Ca and Mg. The authors concluded that high P accumulation in weeds indicate that they are competing with cultivated plants for this element especially when quantities of available P are inadequate. On the other hand, high P levels in weeds even with low levels of available P in the soil indicate an ability on the part of many weeds to utilize forms of soil-P which are relatively unavailable to cultivated plants. The authors also found that generally weeds and especially dicots have a high content of minerals and protein and that weeds are able to accumulate as much calcium and magnesium as grasses. Lucas et al. (1942) presented analytical data indicating that potassium uptake by weeds was greater than that for red clover (*Trifolium pratense*). Bear and Wallace (1950) found that where the available soil potassium was low, crabgrass (*Digitaria* spp.) and other weeds contained much larger percentage of potassium than alfalfa (*Medicago sativa*) that was growing on the same plots. Klapp (1938) found in general that grassland weeds accumulate more phosphorus, potassium, calcium and magnesium than associated grasses or legumes. Woo (1919) found in his study of the chemical constituents of rough pig weed that a large amount of nitrate is stored chiefly in stems and branches, and that the rate of nitrate absorption increases with the aging of a plant. Woo suggested that the greater capacity of pig weed to absorb and store nitrate is an important factor in making the plant a successful competitor with crop plants. Crafts and Robbins (1962) reported that one plant of common yellow mustard (*Brassica spp.*) needs twice as much nitrogen, twice as much phosphorus, and four times as much potassium as well developed oat plant.

2.1.3. Competition for water

In the event that light and nutrients are not limiting, water may be a critical factor for crop-weed competition. The vigour of a crop is greatly influenced by soil-water relations. Crafts and Robbins (1962) reported that one plant of common yellow mustard needs four times as much water as well developed oat plant. Bakke (1939) found that corn infested with field bindweed (Convolvulus arvensis) wilted sooner than non-infested corn. Stahler (1948) reported that field bind weed used much water than soybeans (Glycine max) or sorghum and removed it from the soil earlier in the growing season.

Competitive effects of weeds on crops tend to be minimized by adequate soil moisture throughout the growing season (Staniforth, 1958). It is natural that any plant would grow vigorously with ample rainfall and weeds have been found to be mostly competitive during periods of ample rainfall when growth is vigorous. Staniforth and Weber (1956) working with soybeans found competition with weeds to be most serious during periods of ample rainfall when weed growth was most vigorous. They also found that competition from lower growing weeds was principally for water and mineral nutrients. Pavlychenko and Hurrington (1938) when studying the competitive efficiency of weeds and cereals found that with ample moisture the seeds of pig weeds, cockless (Agrostemma githago) and representatives of mustard family germinated as readily as the cereals, giving them a better chance of competition with cereals.

In contrast to the above findings, Staniforth (1958) found when studying the role of competition from foxtail (Setaria spp.) in soybean yield under varying soil moisture conditions to have reduced yields severely when soil moisture was limiting during the late season growth.

Although the major factors of competition in crop-weed interaction are light, nutrients and water, it has been shown by a number of workers that the amount of competition exerted on a crop is influenced by the particular nature or species of weed, crop species and varieties, cultural weed control practices and climatic and edaphic conditions (Staniforth, 1958, 1961, 1962 and 1965; Zimdahl and Stanford, 1967; Burnside and Wicks, 1965; Nieto and Stanforth, 1961; Wax and Pendleton, 1968 and Wiese et al., 1964).

2.2. The Nature of Weeds and Crop Yield Reductions

Weed plants and crop species growing in association definitely influence the proximity of each other. Weed scientists have long recognized some major weed characters that make them influence crop yields; viz. the nature or species of weed, the density and the relative time of crop and weed emergence. Staniforth (1958 and 1965) and Zimdahl and Stanford (1967) provided evidence that the amount of competition exerted on a crop is influenced by the particular nature or species of weed, and that weeds' competitive ability depends upon its growth habit and extent and nature of top and root growth. Blackman and Tempelman (1938) studied the nature of competition between cereal crops and annual weeds and found that the intensity of competition varies with species, for example, *Brassica arvensis* in competition with spring barley there was chiefly a reduction in the number of tillers and fertile shoots of barley; when *Raphanus raphanistrum* (wild raddish) was in competition with the same crop, size of spike was reduced in addition to the above two; when the latter was in competition with spring oats, both shoot number and panicle size were decreased and that with equal density *R. raphanistrum* brings about greater crop yield loss than *B. arvensis*. Pavlychenko and Hurrington (1935) when comparing root systems in the development of cereals and weeds under dry farming conditions showed the yield of wheat to be 40% lower in plots containing wild mustard (*Brassica kaber*) than in those where the weed was lacking. In the same experiment, barley competed more successfully with wild oat (*Avena fatua*) and wild mustard than wheat. The writers related the findings to the fact that wild oat root system is much more extensive than that of wheat, whereas that of wild mustard is less extensive than that of wheat. Smith (1967) and Staniforth and Weber (1956) had similar findings that weeds shorter than the crop usually compete most severely during the early growing season while those taller than the crop generally reduce yields by competing late in the season.

The reduction in crop yields in crop-weed interaction has also been shown to be influenced by the density of the weed associate. Smith (1967) working with rice found that damage to rice increased as the population of barnyard grass, hemp sesbania and nothern jointvetch increased. Knake and Slife (1962), Staniforth and Weber (1956) and Swan and Furstich (1962) had similar findings that as weed populations increase, crop yields are reduced proportionately.

Weeds that emerge with the crop have been found to be more competitive. Knake and Slife (1966) working with giant foxtail seeded at various times in corn and soybeans found that weeds that emerge with the crop are generally most competitive. This is particularly true since most crops have been found to be less competitive or more susceptible to weed invasion during the early stages of growth when growth is slow. According to Crafts and Robbins (1962) the characteristics that enable a species to be a successful competitor are high germination of seeds under adverse conditions, rapid development of foliage in the seedling stage, rapid development of an extensive root system having both surface and deep roots; all being characteristics found with the majority of weeds.

2.3. Crop Species and Varieties and Weed Competition

The amount of weed competition exerted on a crop is influenced by the species and varieties of a crop grown. The spreading type of crop species, due to their initial fast rate of leaf area index increase, intercept more light than do the compact types, thus possessing more weed suppressing ability (Rao and Shetty, 1977). Crops also differ in their relative growth rates, spreading habit, canopy structure and duration, and accordingly vary in their weed-smothering ability (Shetty and Rao, 1977). The writers (Shetty and Rao) reported findings on weed studies in pigeon pea based intercropping that quick growing, fast covering cowpea and tall and fast developing maize smothered weeds effectively than did other crops; pearl millet, by its growth and tillering ability smothered weeds equally as did sorghum.

The authors compared low growing and tall crops in their weed smothering ability and found groundnuts (Arachis hypogea) and mung beans (P. aureus) to be susceptible to tall and hardy weeds like Celosia argentes, Digitaria sanguinalis and Acanthospermum hispidum which overtook them at later stages. Lawson and Wiseman (1976) working with raspberries found that once the young canes have emerged and made some growth, the raspberry plant becomes less vulnerable to weeds since the canes can grow relatively quickly above the weed canopy with their roots developing rapidly and the balance of competition swings in favour of the crop. It appears therefore that a major factor involed in the crop-weed competition is the ability of a smothering weed cover during the early stages of growth.

Thullen and Keeley (1980) working with Japanese millet (Echinochloa crusgalli) var. frumentacea) competed strongly with nutsedge (Cyperus esculentus) reducing its dry weight and the number of plants and tubers without any loss in dry weight to the millet, suggesting that some plants are better able to compete with others at their own advantage. Knake and Slife (1962) reported that total yield of dry matter remained constant whether corn (Zea mays) or soybean (Glycine max) was grown alone or with giant foxtail (Setaria faberii) as the proportion of dry matter produced by the giant foxtail increased, the yield of dry matter produced by corn or soybean decreased. Williams (1973) reported an ability of wheat (Triticum aestivum) to compete with quackgrass (Agropyron repens) and red top (Agrotis gigantes) without appreciable loss in yield to the wheat; weed competition resulted in 7% loss in wheat shoot weight and 13% loss of grain, whereas the weight loss to the grasses was 80%. Similar findings were reported by Evetts and Burnside (1975) with common milk weed (Asclepias syriaca) in competition with sorghum (Sorghum bicolor); the milk weed shoot weight was reduced by competition with sorghum but the weight of the sorghum was not reduced by competition with the milk weed. Pavlychenko and Hurrington (1934) when comparing competition among several weed species and several varieties of wheat, one variety of spring rye, four barley varieties and one of flax found barley to be the best competitor although all weeds suffered crop plant competition.

In any fast growing crop species, genotypes which close canopy rapidly are more successful in competing against weeds (Shetty and Rao, 1977). These workers reported some work in weed management in pigeon peas based intercropping that weed growth in the compact genotype of pigeon pea (Hy 3A) was 37% higher than in the spreading variety (ST I). Remison (1978) working with several cowpea varieties found the yield of the climber variety Dinner to have been least affected by weed competition while the sem-erect variety, Ife brown was the most affected. Barreto (1970) working with five dry bean cultivars in competition with weeds found climbing varieties to have been the most resistant to competition from weeds.

2.4. Critical Periods of Weed Competition and Crop Yields

Determination of when weeds cause the most competition is important in deciding upon a weed control programme. Crop growth is extremely slow immediately after germination and this permits weed plants to become established (Burnside and Wicks, 1967; Shetty and Rao, 1977).

A number of workers have reported vulnerability of many crop plants to weeds during this early period of slow growth, and that many crops have their yields depressed by this early weed competition more than any other time (Dawson, 1964; Swan and Furstich, 1962; Wilson and Cole, 1966). Cereals and legumes alike have been reported to be weak competitors during the early growing period. Burnside and Wicks (1968) working with sorghum reported that weeds that did not emerge until four weeks after planting did not reduce sorghum yields, and that two weeks of weed control only was not enough as the weeds that emerged later reduced sorghum yields by 20%. Hurst and Feltner (1966) and Wiese (1964) reported the same findings with sorghum that competition begins early from weeds that emerge with the crop and often persists through a major portion of the growing season, and that weeds that emerge after the crop is established cause less competition. Knake and Slife (1966) working with corn reported that if weeds in corn were destroyed the first three weeks after planting, little yield loss resulted from subsequently emerging weeds. Swan et al. (1975) working with Cyperus defformis and rice showed that this particular weed reduced rice yields if not removed by the pre-tillering or during the tillering stage - weed removal prior to tillering led in all cases to rice yields significantly higher than those obtained when weeds were removed after tillering.

Legumes and particularly dry beans have been reported to be more susceptible to weed competition during the early growing period. Burnside (1980) reported that early season weed removal aided soybean stand establishment and that soybeans weeded at two weeks through four weeks after planting did not show significantly reduced soybean yields from later emerging weeds - thus weed control during the first month after planting is the most critical in obtaining high soybean yields. Similar findings have been reported by Knake and Slife (1966) working with corn and soybeans. Staniforth and Weber (1956) studying the effects of weed growth upon soybean yields reported the findings with both planted and natural weed infestations that in contrast with cereals competition was most serious during periods of ample rainfall when weed growth was vigorous and most marked was competition from the stage when pods developed until maturity. The same author in (1957) reported that soybean yield reductions were most serious when weeds grew throughout the season.

Dry beans have been reported to have their critical weed competition period during the early growth period. Blanco _et al_. (1969) reported that uncontrolled infestation reduced bean yield by 23%, but weeding the first ten days reduced the loss by 6% while weeding the first 20 days eliminated the loss entirely. Kasasian and Seeyave (1969) reported the first 25-30% of the crop growth cycle to be critical with regard to weed competition for crops which eventually give good ground cover such as dwarf beans (Phaseolus vulgaris, tomato (Lycopersicum esculentum), sweet potato (Ipomea batatus) pigeon pea (Cajanus cajan) and sugar cane (Saccharum officinarum) and for beans it was the first four weeks (one month). William (1973) working with beans in competition with Cyperus rotundus found that maximum seed yields of P. vulgaris was obtained when C. rotundus was mechanically controlled about four weeks after sowing. The presence of Cyperus spp. reduced P. vulgaris seed yields by 50% in the wet season and by 80% in the dry season. Williams (1973) working with corn and snap beans and onions found that removal of weeds for three weeks in P. vulgaris was required to eliminate losses due to weed competition. Williams et al. (1971) working with the same crops (snap beans, onions and corn) to determine at what time weed control becomes important and to determine if time at which competition begins could be determined found the yield of P. vulgaris was significantly reduced by weed competition throughout the growing season; weed competition for five to six weeks after crop emergence were not different from full season weed competition in terms of yield. The authors found that three weeks of cultivation was required after emergence to reduce losses due to weed competition. Barreto (1970), working with five *P. vulgaris* cultivars allowed to compete with weeds for varying periods of growth concluded that weed infestation markedly reduced seed yields, and that the damage began 20 days after crop emergence and intensified upto maturity; each *P. vulgaris* cultivar was found to be most competitive during the middle stages of growth.

2.5. Weed Competition and Parts of the Crop Affected

Crop scientists have observed generally that in crop plants that produce tillers the reduction in yield may be brought about by a reduction in the number of tillers formed, the number of ear-bearing tillers and the size of individual ears; those crops that prodce axillary branches, the reduction may be brought about by reduction in the number of side branches and the number of reproductive organs produced on each branch. Blackman and Templeman (1938) found barley and oat yields to have been reduced by weed competition mainly by reducing the number of tillers and fertile shoots as well as panicle and spike sizes. Enyi (1973), working with sorghum (Sorghum vulgare), cowpeas, and green gram (Vigna aureus) found that weed competition decreased grain yields of all the three crops by reducing leaf area index, dry weight of stems and number of mature pods at harvest in green grams and cowpeas, while in sorghum the reduction in leaf area index, length of ears, and grain weight per unit length of ear was observed. Remison (1978) working with cowpeas in competition with Euphorbia heterophyla found in glasshouse experiment that plant height, number of nodes, green leaves, peduncles, weight of pods and seeds of cowpea were decreased by weed competition. The same author with a field experiment found competition from natural weeds to have affected the number of days to 50% flowering and yield components of the four cowpea varieties studied. Grupce (1969/70) in trials with maize and _Sorghum halepense_ found heavy infestations of sorghum halepense to have reduced the rate of growth and differentiation of leaves, nodes and internodes, reduced leaf area, retarded flowering, reduced inflorescence size and increased the number of sterile flowers; the plants produced small cobs and grain of typical shape. Eaton _et al_. (1973) working with soybeans found weed competition to have reduced plant height, and number of pods per plant while number of seeds per pod and 100 seed weight were not affected.

Similar trend of observations have been reported by a number of workers with dry beans. Aguilar (1977) when studying the effects of plant density and thinning on high yielding dry beans in Mexico found pods per plant sensitive to interplant competition between 36-78 days after seeding, but seeds per pod and especially seed weight were not sensitive. He suggested the close positive relation between yield and leaf area duration derives from the influence of the photosynthetic supply upon pod number. Stang (1976) working on responses of bush bean cultivars (*P. vulgaris*) to plant population densities found that high pod yields were mainly a function of an early, concentrated development and growth of reproductive organs and a concurrent reduction in vegetative growth. Stang found plots with high leaf area during the reproductive phase to have lower pod yields because those high leaf areas had developed as a compensatory reaction to poor initial reproductive development. Westermann and Crothers (1977) when studying plant population effects on the seed yield components of beans found that pods per plant increased linearly as area per plant increased for all varieties they used and had the largest effect on seed yield per plant; seeds per pod and grain weight per seed also increased as area per plant increased for indeterminate varieties but remained relatively constant for the determinate ones. The authors concluded that determinate varieties are subject to less competitive stress than the indeterminate ones at higher plant populations.

CHAPTER 3

MATERIALS AND METHODS

Dry bean cultivars, Canadian Wonder, Mwezi Moja and Rose Coco were grown at the University of Nairobi Field Station at Kabete during the second rains of 1979 and the first rains of 1980.

3.1. Experimental Site

The University of Nairobi Field Station is at an altitude of 1800m above sea level, and at latitude 1^{o} 15S longitude 36^{o} 44E receives an average annual rainfall of just above 1000mm per year with a mean monthly maximum temperature of 23^{o}C and minimum of 12^{o}C. The area lies in a deep friable clay type of soil, a continuation of the Kikuyu Red or friable loam of Kenya formed in situ from the Tertiary Trachytic larva very resistant to erosion. The top soil extends upto 15cm depth with dark-reddish brown colour and well drained. The soil has humus content of 4%, base saturation of 16-70%, pH of 4.5 - 7.0 and CEC of about 16 me/100g.

3. 2. Experimental Treatments

Treatments involved having the three cultivars, Canadian Wonder, Mwezi Moja and Rose Coco beans to compete with naturally occuring weeds for a definite period of time during the growing season. In one set of two treatments, natural weed flora were allowed to grow with the crop for differeing periods and were then removed, the plots being kept clean thereafter. In a second set, initial weeding took place at the same times but further weed growth was allowed to develop. These latter weeds were not removed throughout the growing season. Other plots were kept weedfree throughout the growing season. The treatments included:

a) no weeding all season (W_1)

b) kept weedfree throughout the season (W_2)

c) kept weedfree the first four weeks after planting and thereafter no weeding (W_3)

d) kept weedfree the first eight weeks after planting and thereafter no weeding (W_4)

e) Not weeded the first four weeks after planting and thereafter kept weedfree for the remaining part of the season (W_5)

f) not weeded the first eight weeks after planting and thereafter kept weedfree for the remaining part of the season(W_6)

3.3. Experimental Procedure and Design

Bean seeds originally dressed with Aldrin 40% at the rate of 1g/200g seed (for bean fly control) were planted in land originally disc ploughed and harrowed to produce a fine seedbed. Prior to planting, 5.1 x 6.9 m experimental plots were marked out in which shallow six centimetre deep furrows were dug at 30 cm spacing for fertilizer application. Fertilizer diamonium phosphate (DAP) was then applied into the furrows to produce a uniform application rate of 130 Kg DAP/ha. The fertilizer was incorporated in the soil. Beans were planted at a spacing of 30 x 30 cm to give a plant population of about 11 plants per m^2 or 110,000 plants per hectare.

The experimental design was a complete randomised block (CRBD) replicated three times in 1979 and four times in 1980. Each replication consisted of 18 plots measuring 5.1 x 6.9m. The number of replications was increased in 1980 to provide more data and to eliminate the variability in soil as the land was rather sloppy.

3.4. Experimental Measurements

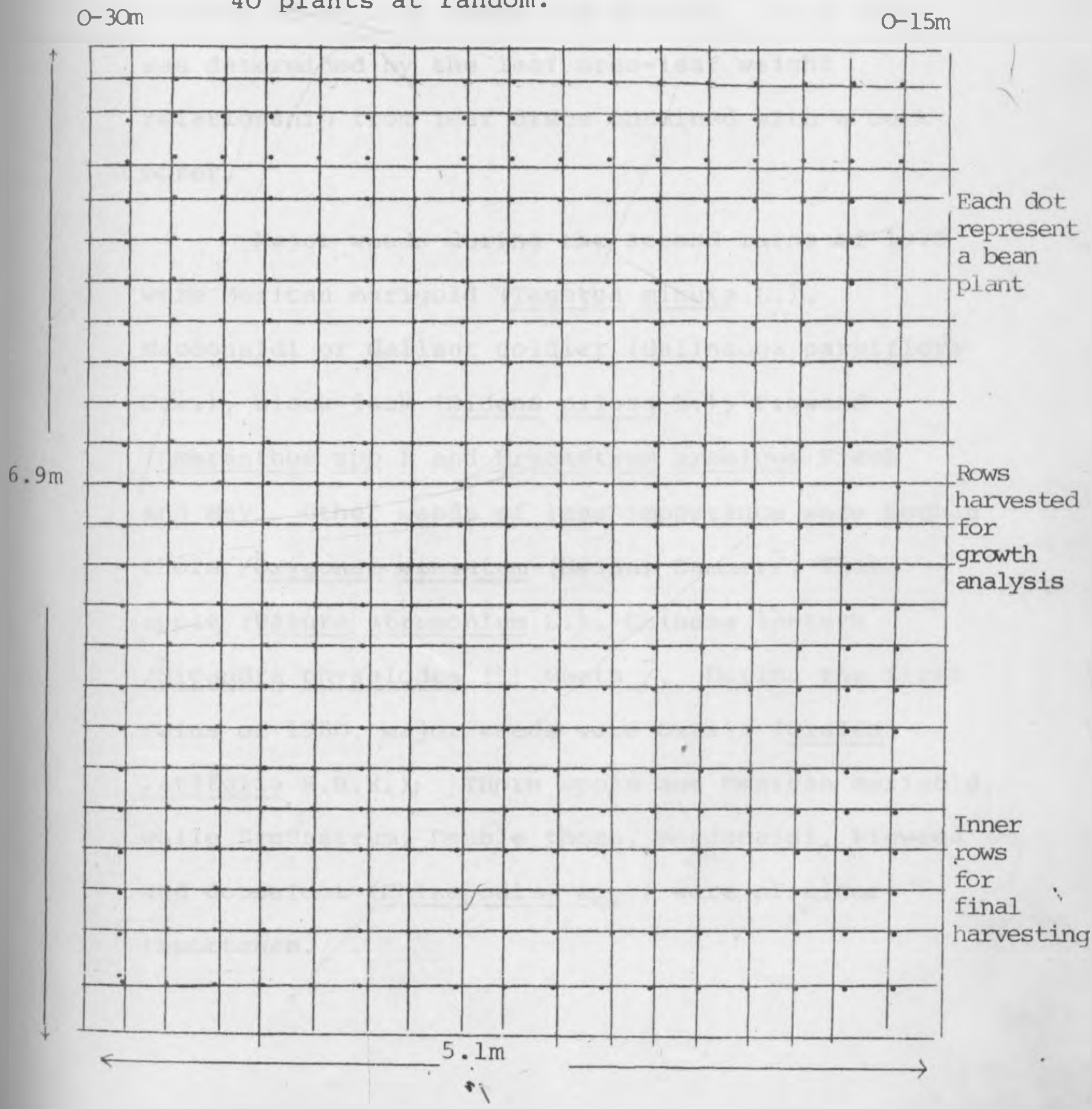
3.4.1. Sampling Procedure

The growth of the bean plants as affected by weed competition was observed by determining dry matter accumulation and distribution in both above and underground bean plant parts, the degree of branching and increament in height of the bean plants during the growth period.

Sampling for growth analysis was carried out at fortnightly intervals; each time ten plants were harvested at random from each plot by careful uprooting. The manner in which the ten plants were picked from each plot is demonstrated on page 39 and shown by dots (---) but not necessarily in the same order.

Bean plants were separated into components - roots and shoots in 1979 and roots, stems, leaves and the reproductive parts in 1980. The need to seperate the shoot into components arose simply because it was observed during the 1979 experiment

Sketch:- Layout of each experiment plot showing the sampling technique. Area subtended by rectangle aa' - aa' on either side were used for destructive sampling. Area a'a'-a'a' was used for final harvesting, by picking 40 plants at random.



that the results of competition from weeds were better expressed in shoots. It was therefore necessary to look into which part of the shoot is stressed more by competition from weeds. The separated plant parts were then dried to constant weights at 90°C in ovens and weighed. Leaf area was determined by the leaf area-leaf weight relationship from leaf discs obtained with a cork borer.

Major weeds during the second rains of 1979 were Mexican marigold (*Tagetes minuta* L.), Macdonaldi or Gallant soldier (*Galinsoga parviflora* Cav.), Black jack (*Bidens pilosa* L.), Pigweed (*Amaranthus spp*.) and *Erucastrum arabicum* Fisch and Mey. Other weeds of less importance were Double thorn /*Oxygonum sinuatum* (Meisn) Dammer/, Thorn apple (*Datura stramonium* L.), Chinese lantern /*Nicandra physalodes* (L) Gaetn/. During the first rains of 1980, major weeds were Oxalis (*Oxalis latifolia* H.B.K.); Thorn apple and Mexican marigold, while Erucastrum, Double thorn, Macdonaldi, Pigweed and Goosefoot (*Chinepodium spp*.) were of minor importance.

Weed data was obtained from those plots to be weedy all season (W_1) and those to be weedy the first eight weeks from planting (W_6) by harvesting a metre square ($1m^2$) using a quadrat. Those weeds in the area whose beans were to be sampled were each time clipped at the ground level before the beans were pulled out. The weeds were then dried to constant weight at 90°C for 48 hours then finally weighed for dry matter determination.

During the final harvest, 40 bean plants were harvested from the centre five rows, pods removed and counted and the average number of pods found by dividing the total number of pods by the total number of plants (40 in this case). The total number of seeds from the 40 plants per plot was divided by the total number of pods from the same to give the average number of seeds per pod. Weight per seed was calculated from the total weight of seeds per plot and the number of seeds per plot. Grain yield per unit area was calculated from plot yield.

CHAPTER 4

RESULTS

4.1. Cultivar Canadian Wonder

4.1.1. Grain yield

The grain yield of Canadian Wonder as affected by weed competition and the applied weeding treatments are presented in table 1. During the second rains of 1979, Canadian Wonder gave an average yield of 1499.10 kg/ha under weedfree conditions and 711.23 kg/ha where weeds were allowed to grow with the crop throughout the season (W_2 and W_1 respectively in table 1). This represented a reduction in yield of 53%. When grown during the first rains of 1980, the cultivar doubled its yield and under full season weedfree conditions, a yield of 2960.83kg/ha was realized. When cultivar Canadian Wonder was left to compete with weeds all season, a yield of 1604.17kg/ha resulted and this represented a yield reduction of 46% during the latter season.

However during the two seasons, keeping the cultivar under weedfree conditons for the first four and eight weeks after planting (W_3 and W_4) significant yield differences were not realized as compared to those weeded all season (W_2). Four weeks of weed competition (W_5), though reduced bean grain yields, the differences from those weeded all season were not significant. But, bean grain yields were significantly reduced when weeds were not removed upto eight weeks from planting (compare W_6 and W_1 with W_2 in table 1).

4.1.2. Yield Components

4.1.2.1. Pods per plant

The results (table 1) show that Canadian Wonder was able to form more pods per plant during the first rains of 1980 as compared to those of observed during the second rains of 1979. Pod yield results show a similar trend to those of grain yields; while weeding, if done early increased the number of pods per plant, weed competition upto and beyond eight weeks after planting reduced pod number per plant significantly. However, keeping the cultivar free from weeds the firs four and eight weeks after planting and leaving it in weeds the first four weeks after planting did not reduce yield.

Table 1. The effect of weeds and the weeding treatments on yield and yield components. Cultivar Canadian Wonder.

Weeding Treatment	Weight/ seed(g)	Seeds/ pod	Pods per plant	Yield/ha (kg)
W_1	0.29	3.36	4.58 b	711.23 c
W_2	0.33	4.28	9.67 a	1499.10 a
W_3	0.32	4.23	9.99 a	1470.94 a
W_4	0.32	3.91	10.22 a	1398.41 a
W_5	0.33	3.09	9.44 a	1040.25 ab
W_6	0.30	3.66	5.53 b	749.29 bc
F Weeding	0.052	1.322	3.950*	6.899*
Mean	0.32	3.76	8.24	1144.87
S.E. Mean	0.01	0.32	0.97	106.46
C.V.	6.0%	19.0%	26.0%	21.0%

a) Second rains of 1979

Weeding Treatment	Weight/ seed(g)	Seeds/ pod	Pods per plant	Yield/ha (kg)
W_1	0.42	3.53	10.20 b	1604.17 b
W_2	0.41	3.85	16.99 a	2960.83 a
W_3	0.44	4.05	19.69 a	3804.17 a
W_4	0.42	4.02	18.44 a	3336.68 a
W_5	0.43	4.04	18.65 a	3529.17 a
W_6	0.43	3.51	9.41 b	1576.67 b
F Weeding	0.400	2.335	17.270*	13.710*
Mean	0.42	3.83	15.56	2801.95
S.E. Mean	0.01	0.15	0.98	236.20
C.V.	2.4%	8.6%	14.1%	18.9%

b) The first rains of 1980

Figures in same column followed by same letter (s) are not significantly different by DNMRT.

Key to abbreviations

W_1 = no weeding all season

W_2 = kept weedfree all season

W_3 = kept weedfree the first four weeks from planting and thereafter not weeded.

W_4 = kept weedfree the first eight weeks from planting and thereafter not weeded.

W_5 = left with weeds the first four weeks from planting and thereafter kept weedfree.

W_6 = left with weeds the first eight weeks from planting and thereafter kept weedfree.

* = significant at 5% level.

significantly as compared to full season weedfree conditions.

4.1.2.2. Seeds per pod

The results (table 1) show that weed competition and the different weeding treatments did not have significant effect on the number of seeds per pod during the two seasons in cultivar Canadian Wonder. However, when left with weeds upto four weeks and beyond during the second rains of 1979 and upto eight weeks and beyond during the first rains of 1980, the number of seeds per pod showed slight reductions but these were non-significant.

4.1.2.3. Weight per seed

Weight per seed was similarly not affected by weed competition (table 1) and the other weeding treatments during both seasons. But it is worth mentioning that during the first rains of 1980, the beans produced bigger seeds as compared to those produced during the second rains of 1979 season.

4.1.3. Accumulation and distribution of plant dry matter

4.1.3.1. Total dry matter per plant

During the second rains of 1979, sampling for dry matter extended over a period of only ten weeks while with ample soil moisture and cool weather conditions experienced during the first rains of 1980, the plants experienced a slow growth allowing more samples to be taken. Hence, during the latter season, sampling did spread over a period of 14 weeks from planting. Likewise, during the first rains of 1980, the bean plants produced more dry matter as compared to that observed during the second rains of 1979 (see table 2 and figure 1).

The results show that during the second rains of 1979, weed competition lasting at least four weeks from planting reduced the plants potential to accumulate dry matter. This is well illustrated in figure 1(a). But the beans were able to recover once the weeds were removed from the fifth week onwards and produced dry matter equal to those kept weedfree all season. During the first rains of 1980, the most adversely

Table 2. The effect of weeds and the weeding treatments on total plant dm (gm/plant). Cultivar Canadian Wonder.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	1.35	5.88	9.68	10.60 c
W_2	1.51	7.80	20.49	29.72 a
W_3	1.69	7.18	18.88	22.82 ab
W_4	1.49	7.59	18.24	19.75 abc
W_5	1.34	5.32	13.01	21.33 abc
W_6	1.37	5.65	13.79	13.68 bc
F Weeding	1.208	1.532	3.044	4.140*
Mean	1.46	6.57	15.68	19.65
S.E. Mean	0.10	0.67	1.85	2.59
C.V.	14.7%	23.0%	26.4%	29.5%

a) The second rains of 1979 experiment

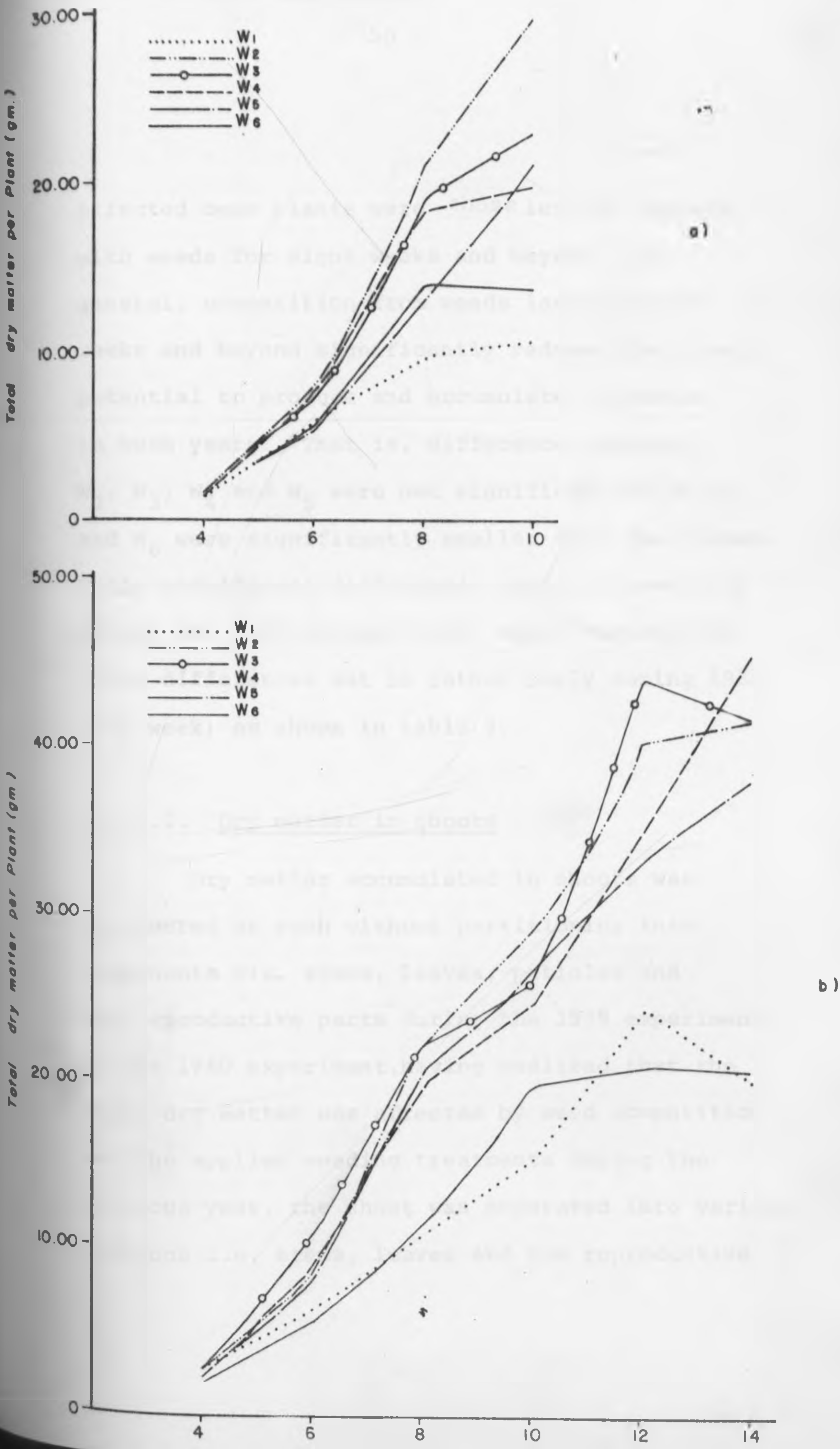
Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12	14
W_1	2.60	6.28 bc	10.70 b	15.12	24.05cd	20.10
W_2	2.69	8.26 abc	21.86 a	28.84	39.84ab	41.43
W_3	2.70	10.50 a	22.07 a	25.55	43.68 a	41.37
W_4	2.22	8.77 ab	19.57 a	24.51	34.70ab	45.42
W_5	2.85	8.01abc	20.12 a	26.39	33.00bc	37.75
W_6	2.12	5.51 c	11.41 b	19.54	20.68 d	20.21
F weeding	1.443	4.176*	6.088*	2.613	7.833*	11.015*
Mean	2.53	7.89	17.62	23.32	32.66	34.38
S.E. Mean	0.22	0.78	1.88	2.80	2.84	3.04
C.V.	19.3%	22.2%	23.8%	26.8%	19.5%	19.8%

b) The first rains of 1980 experiment
Figures in same column followed by same letter (s) are not significantly different by DNMRT.

Figure 1: CULTIVAR CANADIAN WONDER TOTAL DRY MATTER (gm./plant) AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS

a) The Second Rains of 1979 Experiment

b) The First Rains of 1980 Experiment



affected bean plants were those left to compete with weeds for eight weeks and beyond. In general, competition from weeds lasting eight weeks and beyond significantly reduced the plants potential to produce and accumulate dry mater in both years. That is, differences between W_2, W_3, W_4 and W_5 were not significant while W_1 and W_6 were significantly smaller than the former. While significant differences were realised only during the last harvest (10th week) during 1979, these differences set in rather early during 1980 (6th week) as shown in table 2.

4.1.3.2. Dry matter in shoots

Dry matter accumulated in shoots was considered as such without partitioning into components viz. stems, leaves, petioles and the reproductive parts during the 1979 experiment. In the 1980 experiment,having realized that the shoot dry matter was affected by weed competition and the applied weeding treatments during the previous year, the shoot was separated into various portions i.e. stems, leaves and the reproductive parts and dry matter determined individually to asses which part is more vulnerable to weed competition.

4.1.3.2.1. Total shoot dry matter

The accumulation of total plant dry matter of above ground parts is shown in table 3 and figure 2. Association of the cultivar with weeds lasting eight weeks and beyond significnatly reduced dry matter distribution into the above-ground parts. Significant differences were not realized when the cultivar was given an early weeding (W_2, W_3 and W_4), and the cultivar was able to recover from competition from weeds lasting four weeks from planting (W_5) and accumulate dry matter equal to those given early weeding. The data suggest that for maximum dry matter accumulation in the above-ground parts, weedfreedom during the vegetative phase (at least upto four weeks from planting) is just enough as further weeding will not be economical. Significant differences between the early weeded (W_2, W_3 and W_4) together with those left to compete with weeds

Table 3. The effect of weed competition and the weeding treatments on total shoot dry matter (gm/plant). Cultivar Canadian Wonder.1980 First Rains.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	1.20	5.45	9.54 b	10.87
W_2	1.35	7.28	19.85 a	29.04
W_3	1.54	6.74	18.19 a	22.17
W_4	1.33	7.13	17.56 a	19.18
W_5	1.19	4.92	12.41 ab	20.71
W_6	1.04	4.89	8.78 b	13.15
F Weeding	2.608	1.676	4.348*	2.572
Mean	1.28	6.07	14.39	19.19
S.E. Mean	0.08	0.66	1.77	2.73
C.V.	14.5%	24.4%	27.5%	31.8%

Figures in same column followed by same letter (s) are not significantly different by DNMRT.

for one month after planting and those weeded after the eighth week and the non-weeded were realized only during the eighth week from planting.

4.1.3.2.2. Leaf dry matter

In table 4 and figure 3 are presented leaf dry weights per plant as observed during the 1980 experiment. In all treatments dry matter accumulated in leaves progressed rapidly at first, attaining peak dry matter during the eighth week after planting. There was a slow decline upto the twelfth week and a rapid one between the twelfth and the fourteenth week mainly due to leaf senescence.

Weeds reduced the dry matter in leaves and significant differences occurred from week six through week 14 from planting. For optimum dry matter accumulation in leaves, the cultivar needed only four weeks of weedfree conditions (compare treatments W_3, W_4 and W_2 in table 4), and that weeds persisting through the reproductive stage upto eight weeks from planting significantly reduced dry matter in leaves (see treatment W_6 and W_1 in table 4 and figure 3). While the beans

Table 4. The effect of weed competition and the weeding treatments on leaf dry matter (gm/plant). Cultivar Canadian Wonder. 1980 First Rains.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12	14
W_1	1.82	4.42b	7.00b	5.77c	5.50bc	0.40c
W_2	1.93	5.72abc	14.03a	10.33ab	7.89ab	1.08bc
W_3	1.96	7.39a	13.56a	9.99ab	10.24a	2.48a
W_4	1.58	6.16abc	12.11a	9.18abc	7.62abc	1.87ab
W_5	2.08	5.35bc	12.35a	11.37a	7.05abc	1.34bc
W_6	1.47	3.92c	7.45b	6.76bc	4.37c	0.89bc
F Weeding	1.575	4.281*	6.044*	2.905*	3.729*	4.405*
Mean	1.81	5.49	11.08	8.90	7.11	1.34
S.E. Mean	0.17	0.54	1.12	1.14	0.94	0.31
C.V.	20.7%	21.9%	22.6%	28.7%	29.7%	52.6%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 2: CULTIVAR CANADIAN WONDER. TOTAL DRY MATTER IN SHOOT (gm./plant) AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS DURING THE 1979 EXPERIMENT

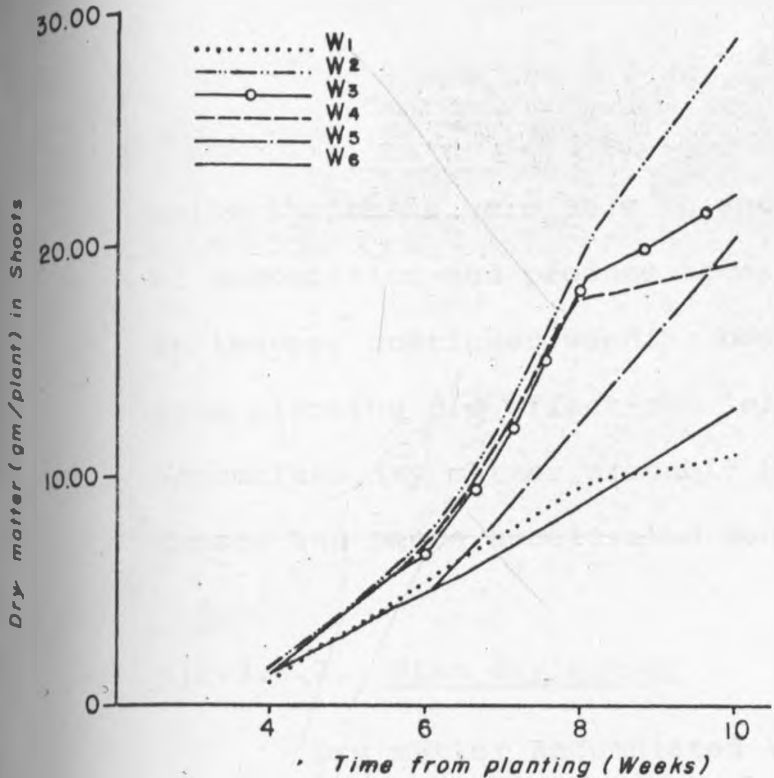
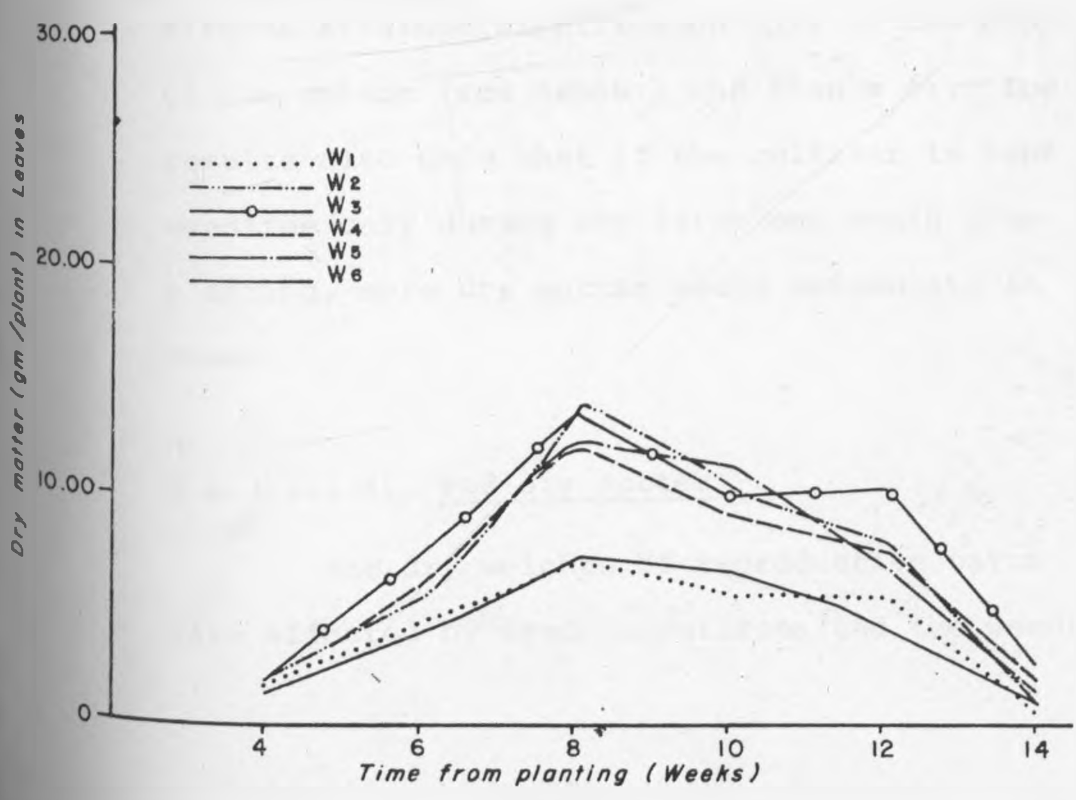


Figure 3: CULTIVAR CANADIAN WONDER. DRY MATTER IN LEAVES (gm./plant) AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS IN THE 1980 EXPERIMENT



While the beans were able to endure four weeks of competition and produce acceptable dry matter in leaves, continued weeding beyond four weeks from planting did affect the leaves ability to accumulate dry matter probably due to leaf damage and hence accelerated senescence and fall.

4.1.3.2.2. Stem dry matter

Dry matter accumulated and distributed into stems was reduced by weed competition and the weeding treatments especially when weeds were allowed to grow with the crop for eight weeks and beyond from planting. But these effects attained significance only at the end of the season (see table 5 and figure 4). The results also show that if the cultivar is kept weedfree only during the first one month from planting, more dry matter would accumulate in stems.

4.1.3.2.2.4. Pod dry matter

The dry weights of reproductive parts were affected by weed competition and the weeding

Table 5. The effect of weed competition and the weeding treatments on stem dry matter (gm/plant). Cultivar Canadian Wonder. 1980 First Rains.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12	14
W_1	0.49	1.42b	2.85	4.10	4.52	3.24d
W_2	0.47	1.97ab	6.14	7.77	6.25	6.52ab
W_3	0.47	2.46a	7.19	7.81	7.12	6.60a
W_4	0.40	2.00ab	5.74	6.08	5.44	6.10abc
W_5	0.51	2.06ab	6.09	8.42	4.87	4.73acd
W_6	0.41	1.29b	3.16	5.97	3.98	3.82d
F Weeding	1.036	2.942*	1.729	1.861	2.803	6.633*
Mean	0.46	1.87	5.20	6.69	5.36	5.17
S.E. Mean	0.04	0.23	1.20	1.06	0.62	0.50
C.V.	18.4%	27.2%	51.6%	35.3%	25.9%	21.7%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Table 6. The effect of weed competition and the weeding treatments on pod dry matter (gm/plant). Cultivar Canadian Wonder. 1980 First Rains.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12	14
W_1	-	0.07	0.42bc	4.75	13.50b	17.98b
W_2	-	0.09	0.76ab	9.54	24.58a	32.87a
W_3	-	0.11	0.51abc	6.88	25.14	31.37a
W_4	-	0.12	0.82a	8.29	20.63a	36.46a
W_5	-	0.18	0.84a	5.66	20.32a	30.78a
W_6	-	0.05	0.38c	6.18	11.71b	14.97b
F Weeding		2.000	3.530*	2.317	11.351*	9.752*
Mean		0.10	0.62	6.88	19.31	27.41
S.E. Mean		0.03	0.10	1.04	1.48	2.51
C.V.		64.0%	36.2%	33.7%	17.2%	20.4%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT

Figure 4 : CULTIVAR CANADIAN WONDER. DRY MATTER YIELDS OF STEMS (gm./plant) AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS (1980 EXPERIMENT)

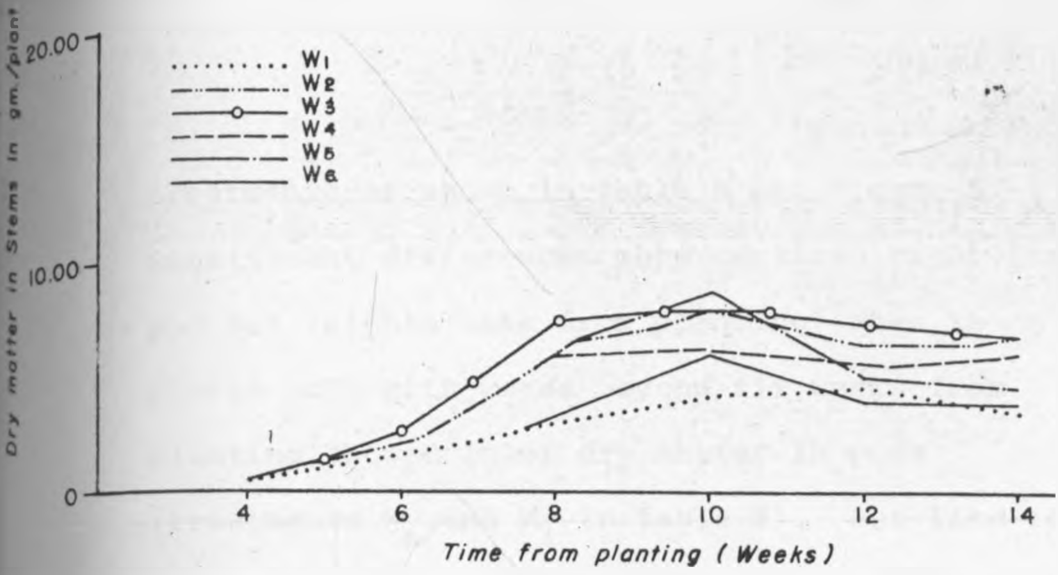
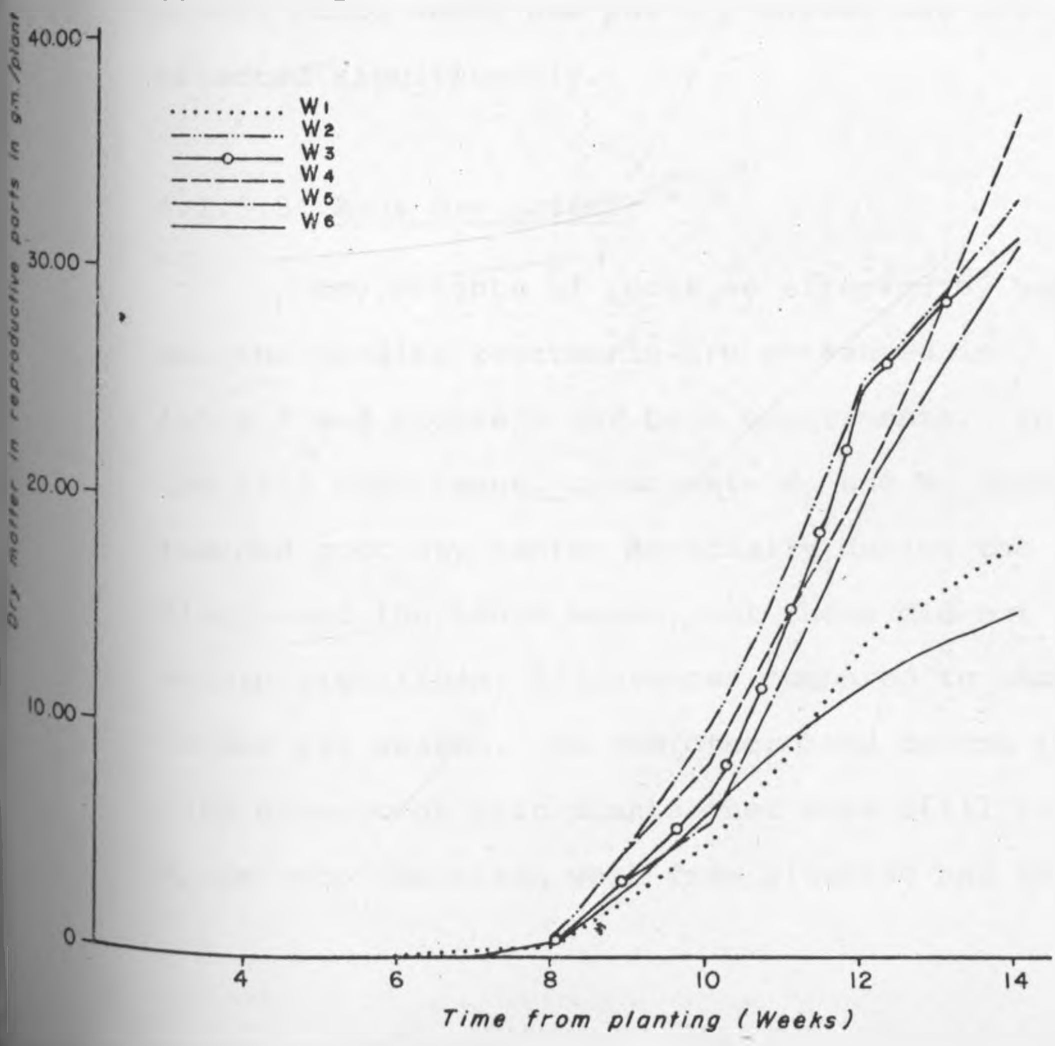


Figure 5: CULTIVA CANADIAN WONDER. DRY MATTER IN REPRODUCTIVE PARTS AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS (1980 EXPERIMENT)



treatments as shown in table 6 and figure 5. Significant differences were realized right from pod set (eighth week from planting) when those plants left with weeds beyond six weeks from planting showed lower dry matter in pods (treatments W_6 and W_1 in table 6). But like the total dry matter accumulation, these differences were not realized during the tenth week, reappearing again in weeks 12 and 14. The cultivar was able to endure four weeks of competition from annual mixed weeds and pod dry matter was not affected significantly.

4.1.3.3. Root dry matter

Dry weights of roots as affected by weeds and the weeding treatments are presented in table 7 and figure 6 for both experiments. In the 1979 experiment, treatments W_6 and W_1 showed reduced root dry matter especially during the eighth and the tenth weeks, but these did not attain significant differences compared to those weeded all season. On the other hand during the 1980 experiment bean plants that were still in weeds upto the sixth week from planting had their

Table 7. The effect of weed competition and the weeding treatments on root dry matter (gm/plant).

Cultivar Canadian Wonder.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	0.15	0.43	0.45	0.40
W_2	0.16	0.52	0.65	0.68
W_3	0.16	0.44	0.69	0.66
W_4	0.16	0.46	0.68	0.57
W_5	0.15	0.40	0.59	0.63
W_6	0.15	0.46	0.47	0.52
F Weeding	0.300	0.574	2.414	1.699
Mean	0.16	0.45	0.59	0.58
S.E. Mean	0.01	0.04	0.05	0.06
C.V.	12.5%	20.4%	20.3%	24.0%

a) Second rains of 1979

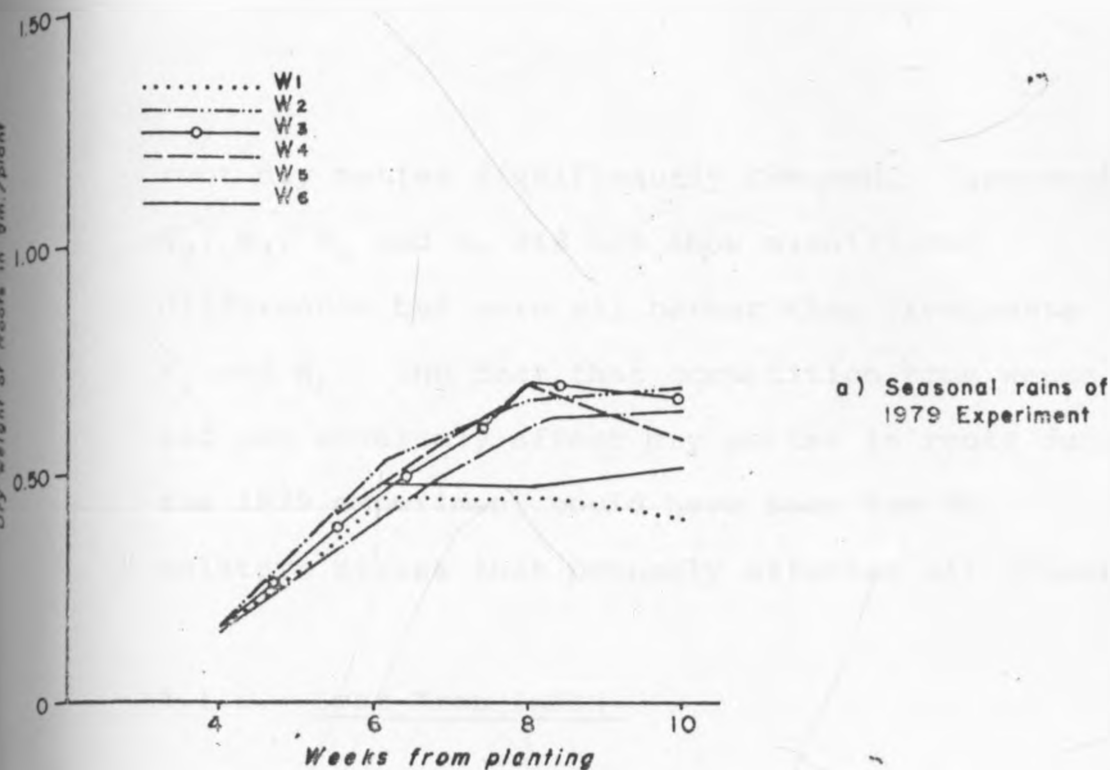
Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12	14
W_1	0.29	0.38	0.45b	0.50d	0.54c	0.46b
W_2	0.30	0.49	0.95a	1.23a	1.13a	0.99a
W_3	0.28	0.54	0.83a	0.85abcd	1.19a	0.94a
W_4	0.25	0.50	0.88a	0.97ab	1.00ab	0.99a
W_5	0.27	0.43	0.84a	0.95abc	0.77bc	0.83a
W_6	0.24	0.26	0.43b	0.63bcd	0.62c	0.53b
F Weeding	1.056	1.855	9.431*	4.767*	7.388*	16.893*
Mean	0.27	0.43	0.73	0.86	0.88	0.79
S.E. Mean	0.02	0.07	0.07	0.11	0.09	0.05
C.V.	15.7%	35.0%	20.4%	27.2%	22.8%	14.7%

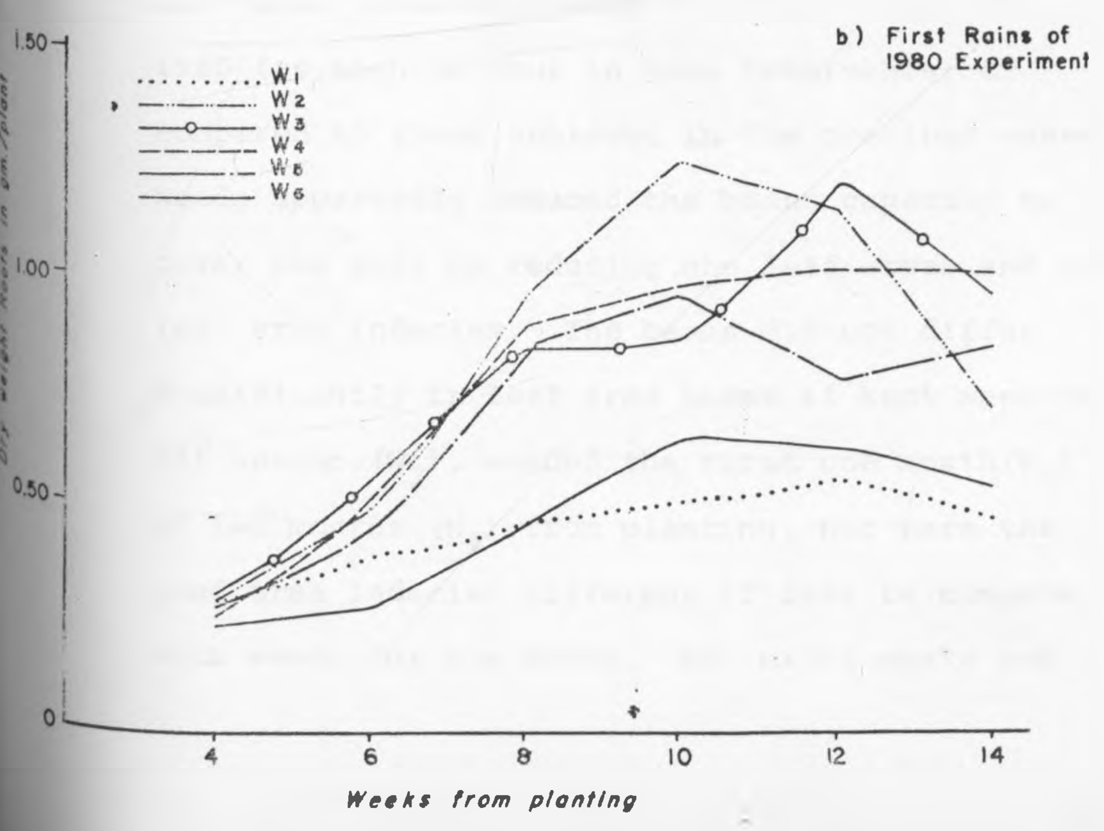
b) First rains of 1980

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 6: CULTIVAR CANADIAN WONDER. DRY MATTER IN ROOTS AS AFFECTED BY WEED COMPETITION AND WEEDING TREATMENTS DURING THE TWO EXPERIMENTS

a) 1979 EXPERIMENT
b) 1980 EXPERIMENT





root dry matter significantly reduced. Treatments W_2, W_3, W_4 and W_5 did not show significant differences but were all better than treatments W_1 and W_6. The fact that competition from weeds did not adversely affect dry matter in roots during the 1979 experiment could have been due to moisture stress that probably affected all plants.

4.1.4. Leaf Area Index

In table 8 and figure 7 are presented leaf area indecies of Canadian Wonder as affected by the weeding treatments during both experiments. It is realised that the beans achieved higher leaf area indecies during the first rains of 1980 (as high as four in some treatments) as compared to those achieved in the previous season. Weeds apparently reduced the beans capacity to cover the soil by reducing the leaf areas and hence leaf area indecies. The beans did not differ significantly in leaf area index if kept weedfree all season (W_2), weeded the first one month(W_3) or two months (W_4) from planting, nor were the leaf area indecies different if left to compete with weeds for one month. But eight weeks and

Table 8. The effect of weed competition and the weeding treatments on leaf area index. Cultivar Canadian Wonder.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	0.08	0.41	0.45	0.21c
W_2	0.09	0.60	1.00	0.93a
W_3	0.12	0.63	1.02	0.69ab
W_4	0.09	0.60	0.95	0.59ab
W_5	0.09	0.39	0.55	0.62ab
W_6	0.09	0.40	0.61	0.37bc
F Weeding	5.000*	1.048	2.918	4.842*
Mean	0.09	0.51	0.76	0.57
S.E. Mean	0.00	0.08	0.11	0.09
C.V.	9.3%	36.9%	33.7%	34.8%

a) 1979 second rains

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12	14
W_1	0.48	1.22	1.66	1.46	1.29bc	0.04c
W_2	0.41	1.72	3.28	3.09	2.10ab	0.16bc
W_3	0.45	2.00	4.13	2.71	2.71a	0.35a
W_4	0.34	1.54	3.31	2.70	1.89ab	0.32a
W_5	0.51	1.52	3.78	2.93	1.73bc	0.27ab
W_6	0.36	1.03	1.70	2.09	1.02c	0.10c
F Weeding	2.311	2.583	3.644*	1.709	4.878*	6.451*
Mean	0.43	1.51	2.98	2.50	1.82	0.21
S.E.Mean	0.04	0.19	0.49	0.42	0.24	0.04
C.V.	20.7%	28.7%	37.1%	37.4%	29.7%	47.1%

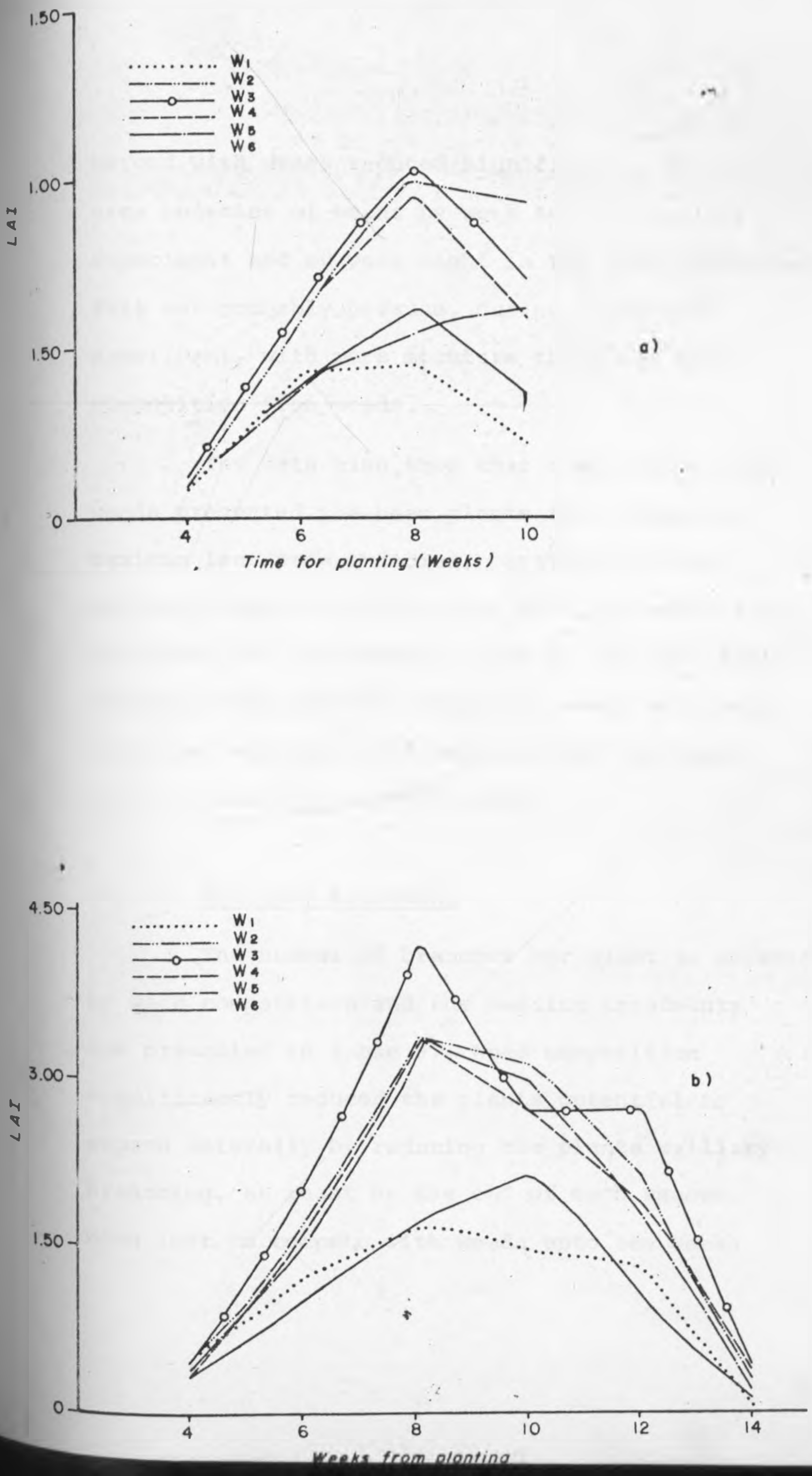
b) 1980 first rains

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 7: CULTIVAR CANADIAN WONDER. LEAF AREA INDECIES AS AFFECTED BY WEED COMPETITION AND THE WEEDING TRETMENTS

a) The 1979 Second Rains Experiment

b) The 1980 First Rains Experiment



beyond with weeds reduced significantly the leaf area indecies of beans by week ten in the 1979 experiment and by week eight in the 1980 experiment. This was probably because, during the latter experiment, with more moisture there was more competition from weeds.

The data also show that competition from weeds prevented the bean plants from attaining maximum leaf area indecies, particularly when left to compete with the crop upto six weeks from planting [see treatments W_1 and W_6 in table 8(b)]. In experiment of 1979, even four weeks with weeds prevented attainment of maximum leaf area index [see treatment W_5 in table 8(a)].

4.1.5. Axillary Branching

The number of branches per plant as affected by weed competition and the weeding treatments are presented in table 9. Weed competition significantly reduced the plants potential to expand laterally by reducing the plants axillary branching, at least by the end of each season. When left to compete with weeds upto ten weeks

Table 9. The effect of weed competition and the weeding treatments on number of branches per plant. Cultivar Canadian Wonder.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	1.2	4.2	4.0	4.3b
W_2	1.3	5.3	4.9	5.2a
W_3	1.9	5.0	5.1	4.8a
W_4	1.7	5.1	5.1	4.7a
W_5	1.4	4.0	4.7	4.6a
W_6	1.3	4.6	5.3	4.9a
F Weeding	2.608	2.402	1.933	3.646*
Mean	1.5	4.7	4.9	4.8
S.E. Mean	0.12	0.21	0.36	0.20
C.V.	18.1%	10.3%	16.3%	9.5%

a) 1979 Second rains experiment

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	10	12
W_1	2.6	4.5	4.3	4.3b
W_2	2.6	5.1	6.4	7.3a
W_3	3.4	4.5	7.0	7.3a
W_4	2.7	4.8	5.7	7.4a
W_5	2.8	5.1	6.0	7.1a
W_6	2.6	5.0	3.8	4.0b
F Weeding	0.777	1.563	5.896*	10.021*
Mean	2.8	4.8	5.5	6.2
S.E. Mean	0.32	0.20	0.45	0.46
C.V.	25.6%	9.5%	18.4%	16.6%

b) 1980 First rains experiment

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Table 10. The effect of weed competition and the weeding treatments on mean plant height (cm). Cultivar Canadian wonder.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	10.50	25.22	34.81c	37.83
W_2	10.62	29.64	46.09ab	54.59
W_3	11.49	27.54	51.97a	50.89
W_4	10.66	29.20	50.45a	53.83
W_5	10.19	23.59	35.57bc	39.94
W_6	10.51	26.71	43.06abc	40.08
F Weeding	0.454	2.349	5.580*	2.604
Mean	10.66	26.98	43.66	46.19
S.E. Mean	0.45	0.95	1.54	1.14
C.V.	9.4%	7.9%	7.9%	5.5%

a) 1979 Second rains experiment

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	19.90	57.40b	53.03	51.35	50.20
W_2	22.45	69.25a	58.40	44.75	63.10
W_3	22.98	68.33a	64.20	49.80	59.80
W_4	20.40	58.10b	56.85	47.35	64.05
W_5	22.70	66.05a	56.85	49.30	56.30
W_6	19.90	56.28b	51.90	50.25	50.30
F Weeding	0.892	5.908*	1.731	0.328	1.207
Mean	21.39	62.57	56.87	48.80	57.29
S.E. Mean	1.43	2.18	2.94	3.72	4.96
C.V.	15.0%	7.8%	11.6%	17.1%	19.4%

b) 1980 First rains experiment

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

in 1979 and upto eight weeks in 1980, the number of branches were reduced significantly. Other treatments did not affect branching as compared to whole season weed removal.

4.1.6. Plant Height

In both seasons, competition from weeds reduced plant height by nearly 20% (table 10). Significant differences in height were realized in week eighth in 1979 and week six in 1980 after planting. The data suggest that, weeding, if effected during the first five weeks after planting would improve Canadian Wonder's height.

4.2. Cultivar Mwezi Moja

4.2.1. Grain Yield

In table 11 are presented the data for bean grain yield and the yield components as affected by weed competition and weeding treatments in 1979 and 1980 experiments. When left to compete with the crop the whole season, weeds reduced bean grain yield by an average of 56% for the two seasons when compared to whole season weed control. While the 1980 bean grain yield almost doubled the 1979 crop, weed removal treatments did not show significant differences if the cultivar was kept weedfree the first one month (W_3), the first two months (W_4), the whole season (W_2) or were left in weeds for the first one month (W_5) from planting and thereafter kept weedfree. Weed competition for eight weeks and beyond significantly reduced bean grain yield as compared to whole season weedfree conditions.

4.2.2. Yield Components

4.2.2.1. Pods per plant

The cultivar formed more pods during the 1980 experiment than in 1979. As with Canadian Wonder, pod yield data showed a similar trend as those observed with grain yield, and seemed to have had the greatest influence on grain yield (see table 11). The data show that the cultivar needed only be kept free the first four weeks after planting and the pod number per plant was not significantly different from those given whole

Table 11. The effect of weed competition and the weeding treatments on yield and yield components. Cultivar Mwezi Moja.

Weeding Treatment	Weight/ seed(g)	Seeds/ pod	Pods per plant	Yield/ha (kg)
W_1	0.40	2.73	5.36b	553.91d
W_2	0.43	3.71	8.43a	1329.78ab
W_3	0.35	3.92	7.41ab	1593.58a
W_4	0.36	4.08	7.90a	1434.25ab
W_5	0.35	3.84	6.80ab	1120.30bc
W_6	0.36	3.49	5.00b	826.04cd
F Weeding	0.842	2.884	3.415*	10.484*
Mean	0.38	3.63	6.82	1142.98
S.E. Mean	0.03	0.22	0.58	93.92
C.V.	16.2%	13.6%	19.0%	18.4%

a) The second rains of 1979

Weeding Treatment	Weight/ seed(g)	Seeds/ pod	Pods per plant	Yield/ha (kg)
W_1	0.64	2.97	5.98b	1228.34b
W_2	0.62	3.38	11.50a	2630.83a
W_3	0.64	3.27	11.19a	2580.00a
W_4	0.69	3.08	8.62ab	1970.83ab
W_5	0.62	3.40	11.01a	2575.83a
W_6	0.59	3.14	6.63b	1347.50b
F Weeding	0.565	0.893	5.513*	5.873*
Mean	0.63	3.21	9.16	2056.39
S.E. Mean	0.04	0.16	0.93	237.75
C.V.	13.2%	11.2%	22.7%	25.9%

b) The first rains of 1980

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

season weedfree conditions. In addition, four weeks with weeds did not seem to reduce pod number but upto eight weeks with weeds after planting significantly reduced the number of pods per plant in both years.

4.2.2.2. Seeds per pod

The data in table 11 show that the number of seeds per pod was not affected by competition from weeds and the different weeding treatments in both years. The differences that existed failed to attain significance.

4.2.2.3. Weight per seed

As with seeds per pod,weight per seed was similarly not affected by competition from weeds and the different weeding treatments during both years. But it was realized that the cultivar produced comparatively heavier, bigger seeds in 1980 than in 1979 probably due to favourable weather conditions.

4.2.3. Accumulation and distribution of plant dry matter

4.2.3.1. Total dry matter per plant

Table 12 and figure 8 show total plant dry weights per plant for both experiments as sampled during the 10 and 12 weeks of growth in 1979 and 1980 respectively. The data show that in 1979, those plots which had weeds upto four weeks from planting and beyond had less total dry matter as compared to those which were clean during the first four weeks from planting. These differences attained significance as early as the sixth week after planting. Even when weeded after the fourth week, these plants [treatments W_5 and W_6 in table 12(a)] were not able to recover and hence had significantly lower dry weight at the end of the season as compared to treatments W_2, W_3 and W_4. Therefore, in 1979, although the cultivar needed only four weeks of weedfree conditions, the first weeks of competition reduced plant dry matter significantly at the end of the sampling period.

In 1980, however, significant differences

Table 12. The effect of weed competition and the weeding treatments on total plant dry matter (gm/plant). Cultivar Mwezi Moja.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	1.74	6.84bc	13.95	12.02c
W_2	1.99	8.13ab	24.36	26.97a
W_3	1.87	8.86a	21.97	26.60ab
W_4	1.84	7.07bc	20.23	25.40ab
W_5	1.80	6.20c	17.49	17.43c
W_6	1.97	7.62abc	17.05	12.29c
F Weeding	0.779	3.846*	2.706	8.177*
Mean	1.56	7.45	19.18	20.12
S.E. Mean	0.09	0.38	1.77	1.92
C.V.	12.6%	11.3%	20.6%	21.3%

a) 1979 First rains

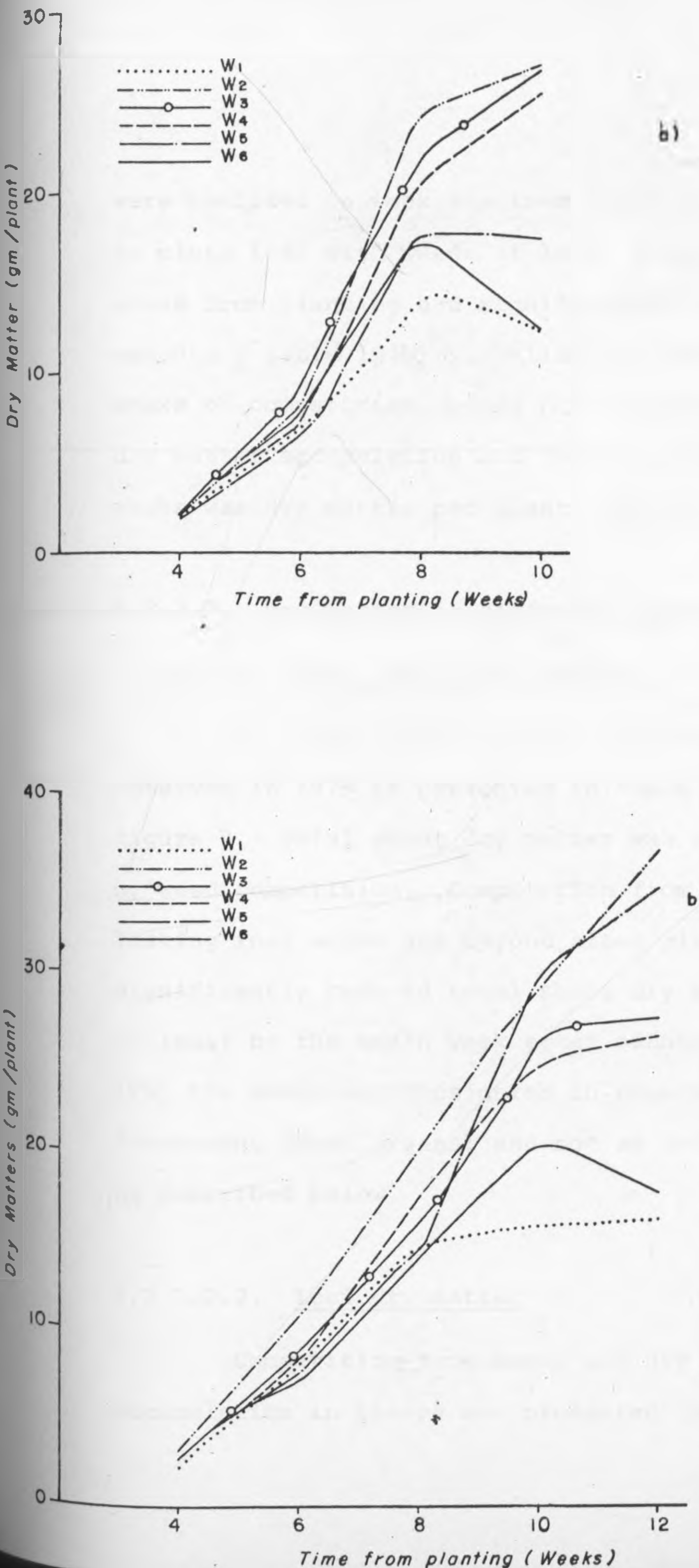
Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	2.14	7.20	14.43	15.46b	15.90b
W_2	3.10	10.36	20.02	18.82a	36.46a
W_3	2.54	8.38	15.61	26.05a	26.90a
W_4	2.48	7.96	17.14	24.59a	26.12a
W_5	2.38	7.42	14.48	29.12a	34.29a
W_6	2.47	7.07	13.95	20.06ab	17.49b
F Weeding	1.805	1.997	1.307	3.294*	3.924*
Mean	2.52	8.07	15.94	24.02	26.19
S.E. Mean	0.21	0.78	1.80	2.48	3.80
C.V.	18.8%	21.5%	25.3%	23.1%	32.4%

b) 1980 Second rains

Figures in the same column followed by letter(s) are are not significantly different by DNMRT.

BY COMPETITION FROM WEEDS AND THE WEEDING TREATMENTS

a) 1979 EXPERIMENT
b) 1980 EXPERIMENT



were realized in week ten from planting when plants in plots left with weeds at least after four weeks from planting had significantly lower dry weights /̄ table 12(b)/̄. Unlike in 1979, four weeks of competition seemed not to have affected dry matter accumulation and that only upto eight weeks was dry matter per plant affected.

4.2.3.2. Dry matter in different plant organs

4.2.3.2.1. Total shoot dry matter

The data for total shoot dry matter as observed in 1979 is presented in table 13 and figure 9. Total shoot dry matter was reduced by weed competition. Competition from weeds lasting four weeks and beyond after planting significantly reduced total shoot dry matter, at least by the tenth week after planting. In 1980 the sboot was considered in components (component shoot organs) and not as total shoot as described below.

4.2.3.2.2. Leaf dry matter

Competition from weeds and dry matter accumulation in leaves are presented in table 14

Table 13. The effect of weed competition and the weeding treatments on total shoot dry matter (gm/plant). Cultivar Mwezi Moja. 1979 Second Rains. rains.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	1.54	6.43bc	13.52	11.60b
W_2	1.78	7.62ab	23.76	26.27a
W_3	1.68	8.27a	21.44	25.98a
W_4	1.64	6.63c	19.69	24.86a
W_5	1.60	5.82c	16.99	16.91b
W_6	1.75	7.13abc	16.55	11.73b
F Weeding	0.703	3.421*	2.636	8.272*
Mean	1.67	6.98	18.66	19.56
S.E. Mean	0.08	0.37	1.77	1.89
C.V.	11.2%	11.8%	21.2%	21.6%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Table 14. The effect of weed competition and the weeding treatments on leaf dry matter (gm/plant). Cultivar Mwezi Moja. 1980 First Rains.

Weeding	DURATION FROM PLANTING (WEEKS)				
Treatment	4	6	8	10	12
W_1	1.29	4.29	5.59	2.88c	1.02
W_2	2.01	6.09	8.20	5.88a	3.00
W_3	1.67	5.18	6.20	6.14a	2.13
W_4	1.67	4.98	7.30	5.39ab	1.61
W_5	1.51	4.33	5.56	6.28a	3.06
W_6	1.56	4.00	5.27	3.77bc	1.28
F Weeding	1.268	2.218	1.643	6.575*	1.793
Mean	1.62	4.81	6.35	5.06	2.02
S.E. Mean	0.19	0.46	0.81	0.49	0.58
C.V.	26.0%	21.5%	28.5%	21.6%	64.1%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 9 : CULTIVAR MWEZI MOJA. TOTAL SHORT DRY MATTER AS AFFECTED BY WEED COMPETITION AND THE DIFFERENT WEEDING-TREATMENTS DURING THE 1979 EXPERIMENT

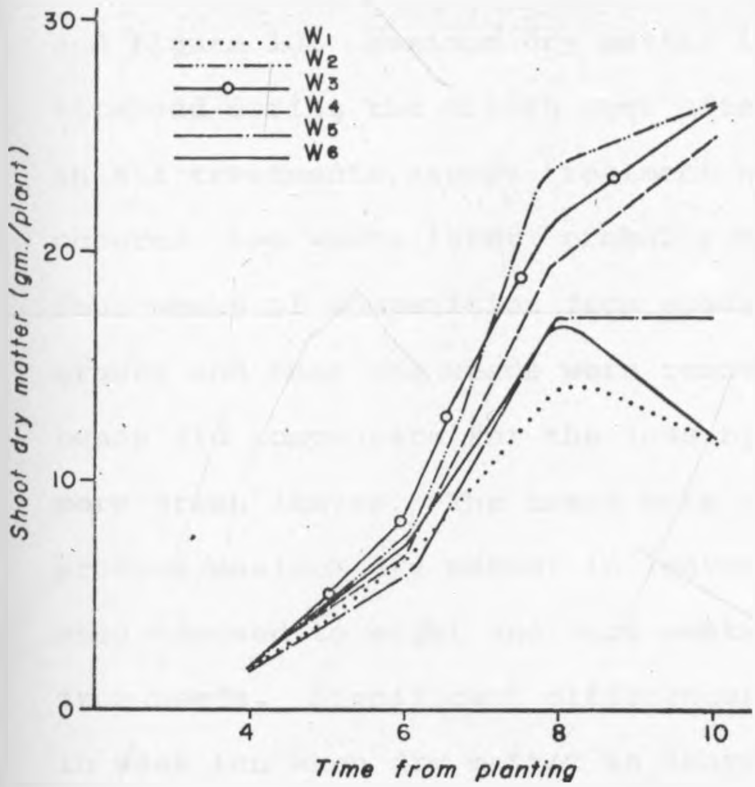
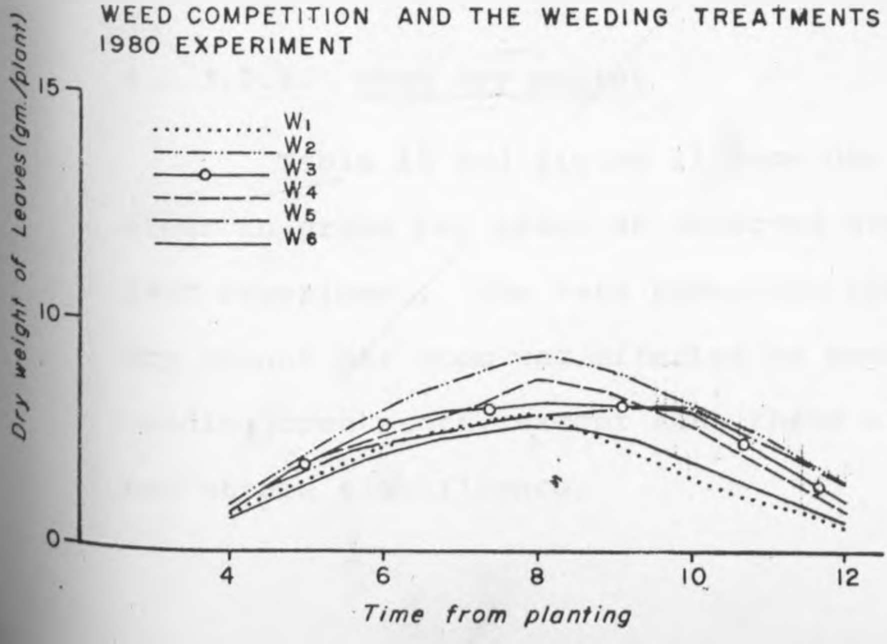


Figure 10 : CULTIVAR MWEZI MOJA. DRY MATTER IN LEAVES AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS DURING THE 1980 EXPERIMENT



and figure 10. Maximum dry matter in leaves was attained during the eighth week after planting in all treatments except treatment W_5 where it occured two weeks later probably because the four weeks of competition from weeds delayed growth and once the weeds were removed the beans did compensate for the loss by producing more green leaves. The beans were unable to produce maximum dry matter in leaves at least when exposed to eight and more weeks of competition from weeds. Significant differences were realized in week ten when dry matter in leaves had started declining and where weeds competed with the crop for eight weeks and beyond, leaf senescence and fall was hastened and could probably explain the significant differences in dry matter.

4.2.3.2.3. Stem dry matter

Table 15 and figure 11 show dry matter in stems in grams per plant as observed during the 1980 experiment. The data show that the average dry weight per stem was affected by weeds and the weeding treatments, except that these effects did not attain significance.

Table 15. The effect of weed competition and the weeding treatments of stem dry matter (gm/plant). Cultivar Mwezi Moja. 1980 First Rains.

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	0.51b	2.14	3.84	4.34	2.79
W_2	0.73a	3.20	5.04	5.33	4.66
W_3	0.58b	2.35	3.88	5.31	2.98
W_4	0.52b	2.13	4.74	4.06	3.14
W_5	0.56b	2.24	3.64	4.74	3.73
W_6	0.61a	2.24	4.47	4.64	2.43
F Weeding	2.965*	2.351	0.639	0.610	2.042
Mean	0.59	2.38	4.27	4.74	3.29
S.E. Mean	0.04	0.24	0.64	0.58	0.50
C.V.	15.6%	22.8%	33.3%	27.6%	33.9%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

4.2.3.2.4. Pod dry matter

In table 16 and figure 12 are presented dry matter accumulated in reproductive parts. The data show that, at the end of the season, the beans growing with weeds at least upto eight weeks from planting accumulated significantly less dry matter in the pods than those which were kept weedfree at least during the first four weeks after planting. Keeping the cultivar weedfree during the first one month after planting was just enough to enable the cultivar to accumulate reasonable dry matter in pods; the cultivar was in addition able to compete with weeds during the first four weeks and still put enough plant material in the pods. This was probably because the pods are produced later than four weeks from planting and once the weeds were removed during week five and beyond these parts were not affected.

4.2.3.3. Root dry matter

The plant material distributed to the roots are presented in table 17 and figure 13.

Table 16. The effect of weed competition and the weeding treatments on pod dry matter (gm/plant). Cultivar Mwezi Moja. 1980 First Rains.

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	-	0.41	4.45	8.73c	11.70b
W_2	-	0.53	6.14	16.77ab	27.96a
W_3	-	0.44	4.89	14.02abc	21.09ab
W_4	-	0.39	4.33	14.35abc	20.69ab
W_5	-	0.39	4.70	17.22a	26.65a
W_6	-	0.34	3.72	10.96bc	13.35b
F Weeding		1.219	1.903	3.178*	4.368*
Mean		0.42	4.71	13.78	18.57
S.E. Mean		0.05	0.52	1.66	2.84
C.V.		28.0%	24.9%	26.9%	34.2%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 11 : CULTIVAR MWEZI MOJA. DRY MATTER IN STEMS (gm./plant) AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS (1980 EXPERIMENT)

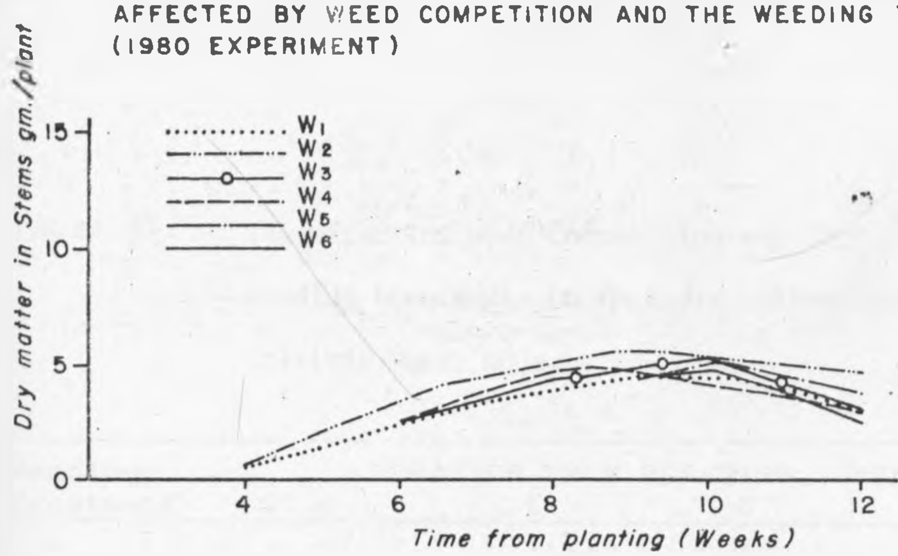


Figure 12 : CULTIVAR MWEZI MOJA. DRY MATTER IN REPRODUCTIVE PARTS (gm./plant) AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS (1980 EXPERIMENT)

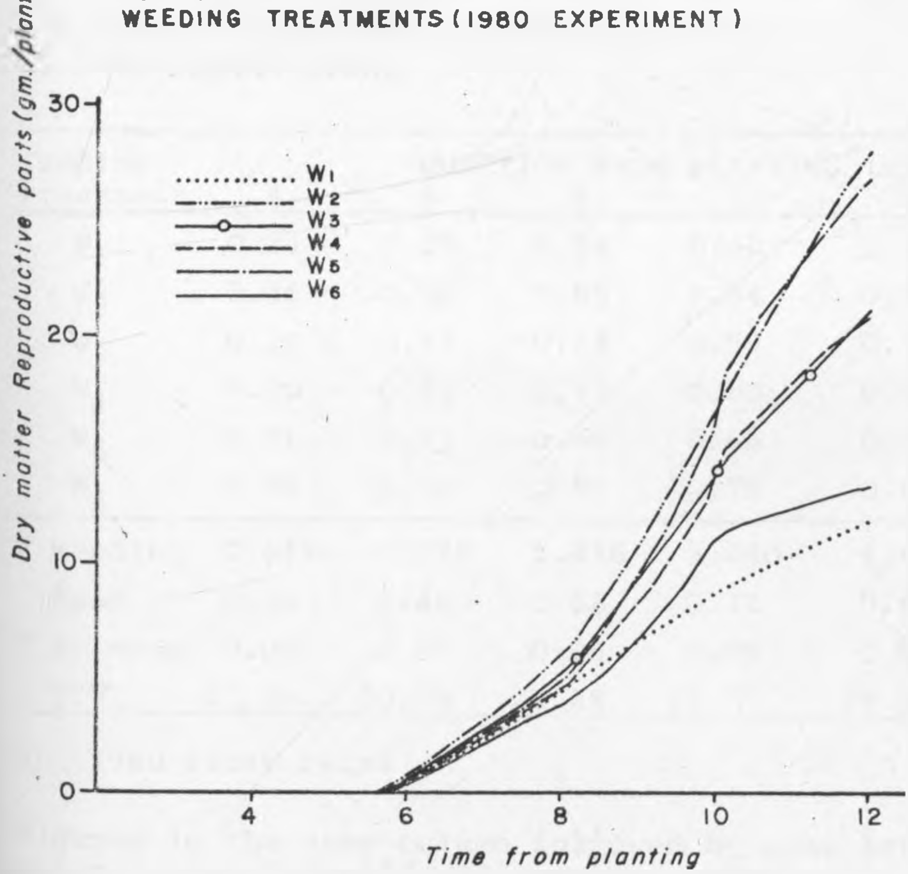


Table 17. The effect of weed competition and the weeding treatments on root dry matter (gm/plant). Cultivar Mwezi Moja.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	0.19	0.41bc	0.43	0.43
W_2	0.21	0.51ab	0.61	0.69
W_3	0.19	0.59a	0.53	0.62
W_4	0.21	0.43c	0.53	0.54
W_5	0.20	0.39c	0.50	0.52
W_6	0.22	0.50abc	0.50	0.56
F Weeding	0.800	5.594*	1.486	0.933
Mean	0.20	0.47	0.52	0.56
S.E. Mean	0.01	0.03	0.04	0.07
C.V.	11.2%	12.0%	16.3%	28.5%

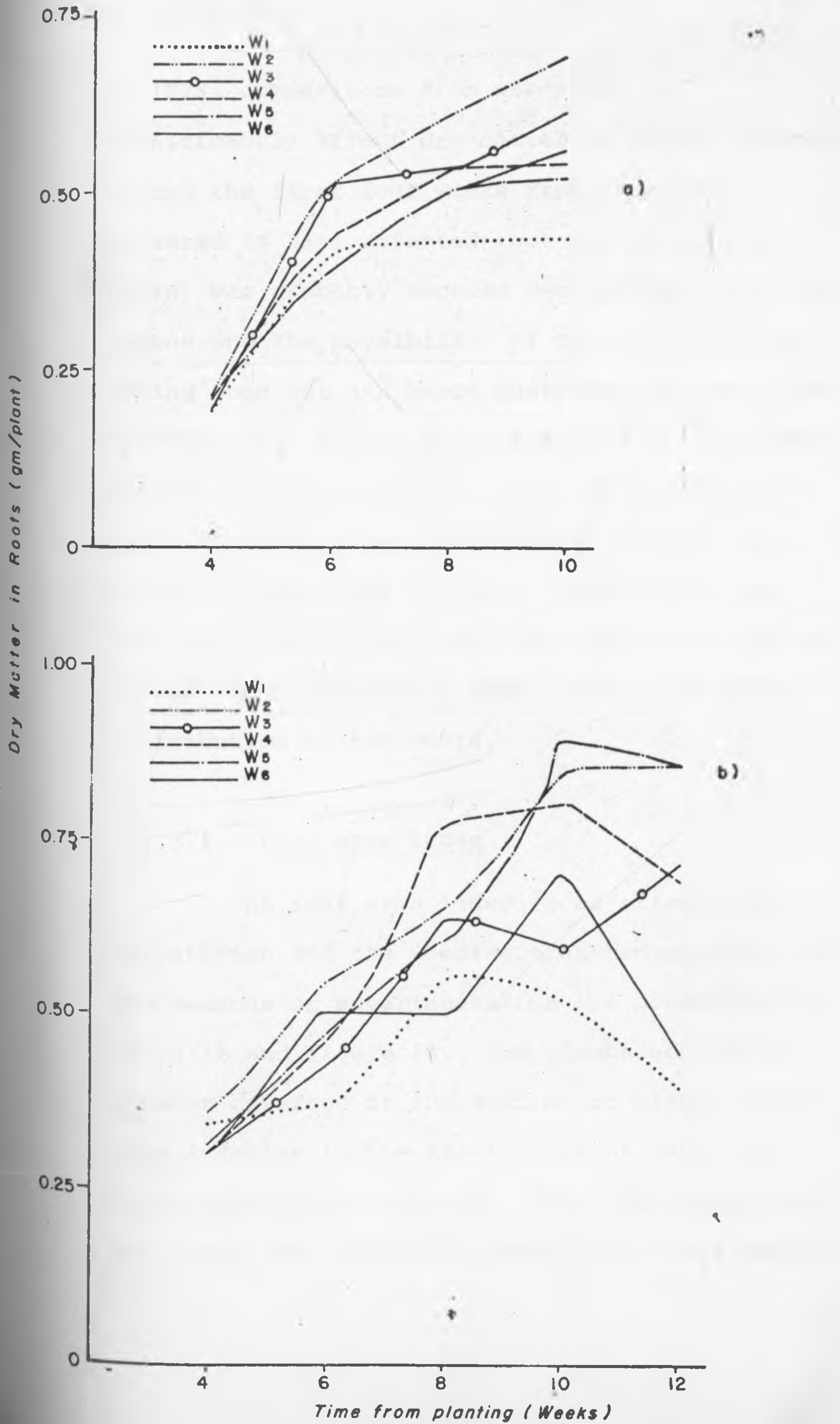
a) 1979 Second rains

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	0.34	0.37	0.55	0.52	0.39c
W_2	0.36	0.54	0.65	0.84	0.85a
W_3	0.30	0.42	0.63	0.59	0.71ab
W_4	0.30	0.46	0.77	0.80	0.68abc
W_5	0.31	0.47	0.60	0.88	0.85a
W_6	0.30	0.50	0.50	0.70	0.44bc
F Weeding	0.549	0.776	1.816	2.240	4.429*
Mean	0.32	0.46	0.62	0.72	0.65
S.E. Mean	0.03	0.06	0.06	0.09	0.08
C.V.	23.2%	30.7%	22.2%	26.7%	29.0%

b) 1980 first rains

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 13: CULTIVAR MWEZI MOJA. DRY MATTER IN ROOTS AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS (In Gm./Plant)
a) 1979 EXPERIMENT
b) 1980 EXPERIMENT



In 1979, competition from weeds did not significantly affect dry matter in roots. Weeding beyond the first four weeks from planting appeared to have affected root dry matter. The latter was probably because weeding was done with jembes and the possibility of some of the roots having been cut and hence destroyed are many (see treatment W_2, W_4 and W_5 in table 17a.). In 1980, however, weed competition upto and beyond eight weeks from planting significantly reduced dry matter accumulation in roots (table 17b), and that four weeks under weedfree conditions appeared to have been enough for near maximum dry matter distribution to the roots.

4.2.3.4. Leaf area index

The leaf area indecies as affected by weed competition and the weeding treatments during the two seasons of experimentation are presented in table 18 and figure 14. The plants achieved a greater coverage of the soil hence bigger leaf area indecies in the first rains of 1980 than during the second rains of 1979. The plants on the other hand achieved maximum leaf area indecies

Table 18. The effect of weed competition and the weeding treatments on leaf area index. Cultivar Mwezi Moja.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	0.09b	0.35	0.31	0.05b
W_2	0.12a	0.42	0.62	0.24a
W_3	0.11a	0.51	0.59	0.26a
W_4	0.11a	0.42	0.48	0.32a
W_5	0.11a	0.34	0.41	0.21a
W_6	0.11a	0.43	0.39	0.06b
F Weeding	18.000*	2.267	2.861	6.873*
Mean	0.11	0.41	0.47	0.19
S.E. Mean	0.00	0.03	0.05	0.03
C.V.	2.9%	17.6%	25.8%	38.0%

a) 1979 Second rains

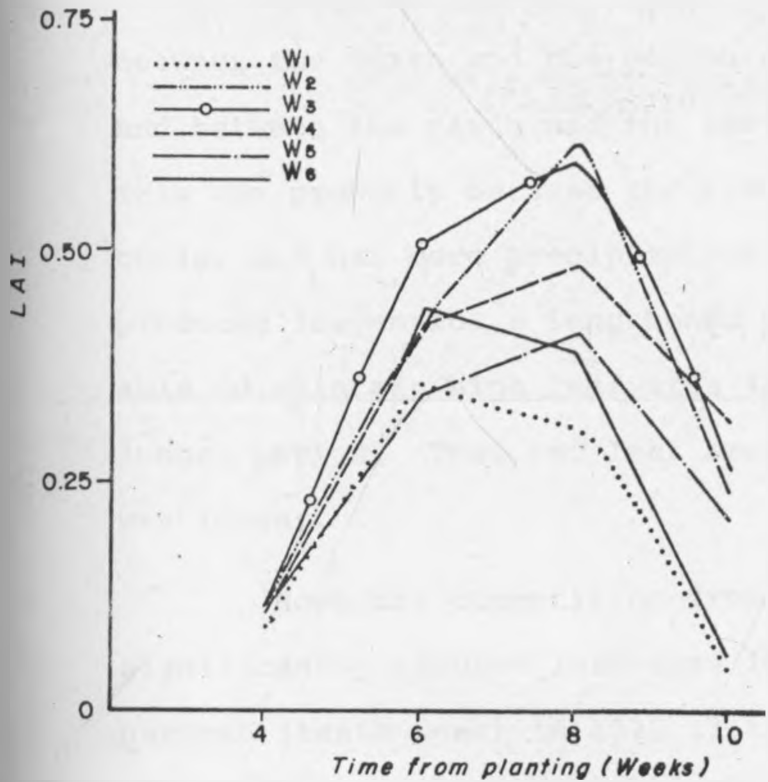
Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	0.37	0.99	1.06	0.76	0.21
W_2	0.47	1.37	1.46	1.47	0.58
W_3	0.41	1.35	1.10	1.30	0.36
W_4	0.25	1.11	1.36	1.22	0.30
W_5	0.35	1.02	1.11	1.37	0.32
W_6	0.33	0.99	1.18	1.12	0.23
F Weeding	2.393	2.194	0.788	2.756	1.244
Mean	0.36	1.14	1.21	1.21	0.33
S.E. Mean	0.04	0.11	0.16	0.13	0.11
C.V.	26.4%	21.1%	29.4%	24.8%	73.4%

b) 1980 First rains

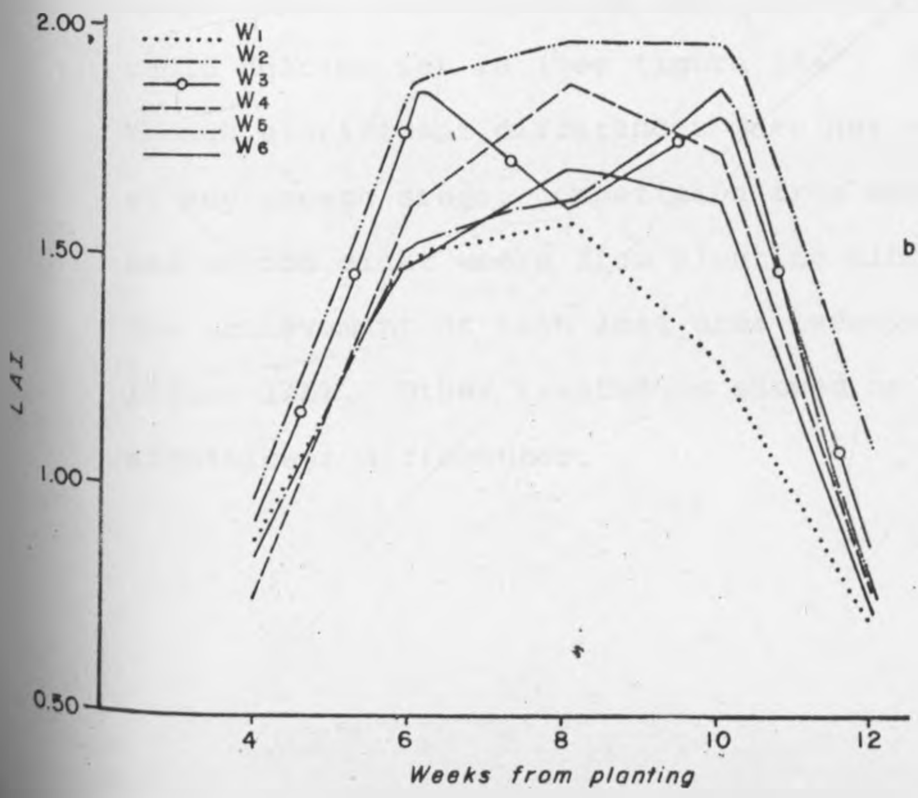
Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 14 : CULTIVAR MWEZI MOJA. LAI AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS

a) 1979 EXPERIMENT
b) 1980 EXPERIMENT



a)



b)

between the sixth and the eighth weeks in 1979 and between the sixth and the tenth weeks in 1980. This was probably because the 1980 season was cooler and had more precipitation hence the plants produced leaves for a lengthened period and were able to maintain high leaf area indecies for a longer period. That is, leaf area duration was longer.

However, competition from weeds significantly reduced leaf area index at final harvest (tenth week) in 1979 if the plants were not weeded upto and beyond eight weeks from planting. During the same season plots not weeded upto the eighth week had their leaf area index maximum in the sixth week after which a rapid delcine set in (see figure 14a). In 1980, though significant differences were not observed at any growth stage, competition from weeds upto and beyond eight weeks from planting hindered the achievement of high leaf area indecies (see figure 14b). Other treatments showed no significant differences.

4.2.3.5. Axillary branching

Table 19 shows the number of branches per plant as affected by weed competition and the applied weeding treatments during the two seasons. As with other parameters the bean plants had more axillary branches in 1980 than in 1979 experiments.

During the second rains of 1979, there were no significant differences among treatment means, though plots which experienced some competition from weeds had relatively fewer branches. In 1980, however, plots which had beans growing with weeds upto and beyond eight weeks from planting had fewer branches at the final harvest. The reduction in the number of branches showed significant differences between those plants weeded during the first one month and those not weeded during the same period as early as the sixth week from planting. But the beans were able to compensate and produce more branches once the weeds were removed from the fifth week on (see treatment W_5). Results from other treatments were not significantly different and the beans did not need weedfree conditions beyond four weeks after planting.

Table 19. The effect of weed commetition and the weeding treatments on mumber of branches per plant. Cultivar Mwezi Moja.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	2.3	4.7	4.6	3.9
W_2	2.4	5.2	5.7	4.5
W_3	2.3	5.2	5.1	4.5
W_4	2.0	4.7	5.2	4.4
W_5	1.9	4.5	4.7	3.9
W_6	2.6	4.8	4.3	3.9
F Weeding	3.001	1.130	1.214	1.520
Mean	2.3	4.9	4.9	4.2
S.E. Mean	0.12	0.22	0.36	0.20
C.V.	11.8%	9.9%	16.3%	10.8%

a) 1979 Second rains

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	10	12
W_1	2.1	3.4c	4.9	5.5
W_2	3.0	6.1a	6.4	7.7
W_3	2.6	5.8a	6.5	7.3
W_4	2.9	5.9a	6.5	6.0
W_5	2.7	4.7b	6.3	7.5
W_6	3.1	4.6b	5.3	5.7
F Weeding	1.873	13.159*	2.173	4.153*
Mean	2.7	5.1	6.0	6.6
S.E. Mean	0.23	0.26	0.41	0.44
C.V.	18.9%	11.2%	15.4%	14.8%

b) 1980 First rains

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Table 20. The effect of weed competition and the weeding treatments on mean plant height (cm). Cultivar Mwezi Moja.

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10
W_1	14.80	31.17	35.84	34.62
W_2	15.81	33.06	35.83	39.20
W_3	15.10	32.92	35.61	37.69
W_4	15.05	28.32	31.60	36.65
W_5	14.62	31.68	33.75	35.10
W_6	15.60	31.27	32.99	34.97
F Weeding	0.622	1.966	0.800	1.522
Mean	15.16	31.40	34.27	36.37
S.E. Mean	0.45	0.95	1.54	1.14
C.V.	6.6%	6.7%	10.0%	7.0%

a) 1979 Second rains

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	24.11	35.14c	40.50	42.65	41.75
W_2	26.35	39.95ab	40.60	36.35	38.45
W_3	24.00	35.20c	38.55	35.85	39.40
W_4	24.55	35.85bc	36.95	34.40	32.65
W_5	25.12	37.88abc	40.30	35.80	36.85
W_6	25.75	41.36a	42.95	40.55	40.75
F Weeding	0.893	3.879*	1.112	1.952	1.594
Mean	24.98	37.56	39.98	37.60	38.31
S.E. Mean	0.89	1.20	1.73	2.07	2.31
C.V.	7.9%	7.1%	9.7%	12.3%	13.5%

b) 1980 First rains

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

4.2.3.6. Plant height

Mean plant height of Mwezi Moja was not affected by competition from weeds and the different weeding treatments in both years (table 20).

4.3. Cultivar Rose Coco

4.3.1. Grain Yield

In table 21 are presented bean grain yields and the yield components as affected by weed competition and the weeding treatments. It is realized again that the average yield of the cultivar under weedfree conditions all season was higher in 1980 first rains than in 1979 second rains. When not weeded the entire season, the cultivar experienced yield reductions of 49% in 1980 and 67% in 1979. When weeds were removed the first four weeks and the first eight weeks from planting, there were no significant differences in grain yield as compared to weeding all season. Leaving the cultivar with weeds for upto four weeks from planting did not significantly reduce grain yield and eight weeks of competition from weeds was not different from whole season competition (grain yield reduction was to the extent of 57% in 1979 and 48% in 1980).

4.3.2. Yield Components

4.3.2.1. Pods per plant

The cultivar formed more pods per plant with ample moisture in 1980 as compared to 1979 when moisture stress was experienced. However, the results show that pods per plant had similar trend as grain yield and seemed to be the most sensitive component of yield to weed competition. When weeded early, at least before the eighth week from planting, the cultivar formed more pods than when not weeded. But with moisture stress as did occur during the 1979 experiment, the number of pods was slightly reduced when weeds competed with the crop for four weeks (see treatment W_5 table 21). Eight weeks of competition from weeds and whole season competition did not significantly differ in the number of pods per plant. The cultivar did not require more than four weeks of weedfree conditions to give maximum yield of pods.

Table 21. The effect of weed competition and the weeding treatments on yield and yield components. Cultivar Rose Coco.

Weeding Treatment	Weight/ seed (g)	Seeds/ pod	Pods per plant	Yield (kg/ha)
W_1	0.39	1.41d	4.26e	398.40c
W_2	0.31	5.30a	7.25ac	1212.36ab
W_3	0.34	4.00bc	7.88ab	1179.00b
W_4	0.34	4.46ab	8.49a	1527.01a
W_5	0.30	4.37ab	5.98ade	887.15b
W_6	0.28	3.02c	5.05bcde	518.43c
F Weeding	1.778	16.554*	3.897*	17.410*
Mean	0.33	3.76	6.49	957.73
S.E. Mean	0.02	0.26	0.65	80.86
C.V.	15.8%	15.5%	22.4%	18.9%

a) 1979 Second rains

Weeding Treatment	Weight/ seed (g)	Seeds/ pod	Pods per plant	Yield (kg/ha)
W_1	0.47	3.75	6.70b	1283.33b
W_2	0.46	3.60	13.92a	2511.67a
W_3	0.49	3.53	13.07a	2530.00a
W_4	0.49	3.36	12.19a	2200.00a
W_5	0.46	3.85	11.63a	2282.50a
W_6	0.48	3.55	7.37b	1310.83b
F Weeding	0.186	0.561	6.370*	4.794*
Mean	0.48	3.61	10.81	2019.72
S.E. Mean	0.03	0.21	1.08	234.58
C.V.	14.6%	12.7%	22.3%	26.0%

b) 1980 First Rains.

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

4.3.2.2. Seeds per pod

The number of seeds per pod was sensitive to competition from weeds and to the different weeding treatments in 1979. During this season, the number of seeds per pod was significantly reduced if the cultivar was not weeded upto and beyond eight weeks from planting. On the other hand keeping the cultivar weedfree the first four weeks from planting alone was not enough as compared to whole season weedfree conditions. But if left in weeds the first four weeks from planting and thereafter weeded upto maturity, seeds per pod were not affected. This suggests that the reproductive phase is very important as regards seeds per pod and weed competition. In 1980, however, there were no significant differences among treatments.

4.3.2.3. Weight per seed

Seed weight was not significantly affected by competition from annual mixed weeds in both seasons, although in 1980 season, the cultivar had heavier seeds than in the previous year (table 21).

4.3.3. Accumulation and distribution of plant dry matter

4.3.3.1. Total dry matter per plant

In table 22 and figure 15 are presented the data for total dry matter per plant as observed during the two seasons. While sampling for dry matter analysis extended over a ten weeks period in 1979, it spread over a period of 12 weeks in 1980. As with the foregoing two cultivars, dry matter accumulated was greater during the first rains of 1980 as compared to the 1979 second rains experiment. In both years competition from weeds lasting eight weeks and beyond significantly reduced plant dry matter at the final harvest. The data also show that if weeding is done early (particularly during the first one month from planting) then discontinued, the cultivar was able to accumulate more dry matter (see treatment W_3). The cultivar did not need to be kept weedfree beyond one month from planting in order to accumulate maximum plant material. But when left in weeds for the first one month from

Table 22. The effect of weed competition and the weeding treatments on total plant dry matter (gm/plant). Cultivar Rose Coco.

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10
W_1	1.23	4.72	9.19c	6.58e
W_2	1.31	5.43	15.90ab	19.95ab
W_3	1.45	5.67	16.15ab	20.51a
W_4	1.48	6.98	20.56a	18.75abc
W_5	1.21	4.52	10.96bc	15.20abcd
W_6	1.37	5.10	9.95c	10.85de
F Weeding	1.981	2.585	7.923*	11.076*
Mean	1.34	5.40	13.79	15.31
S.E. Mean	0.06	0.47	1.23	1.30
C.V.	10.3%	19.3%	19.9%	19.0%

a) 1979 Second rains

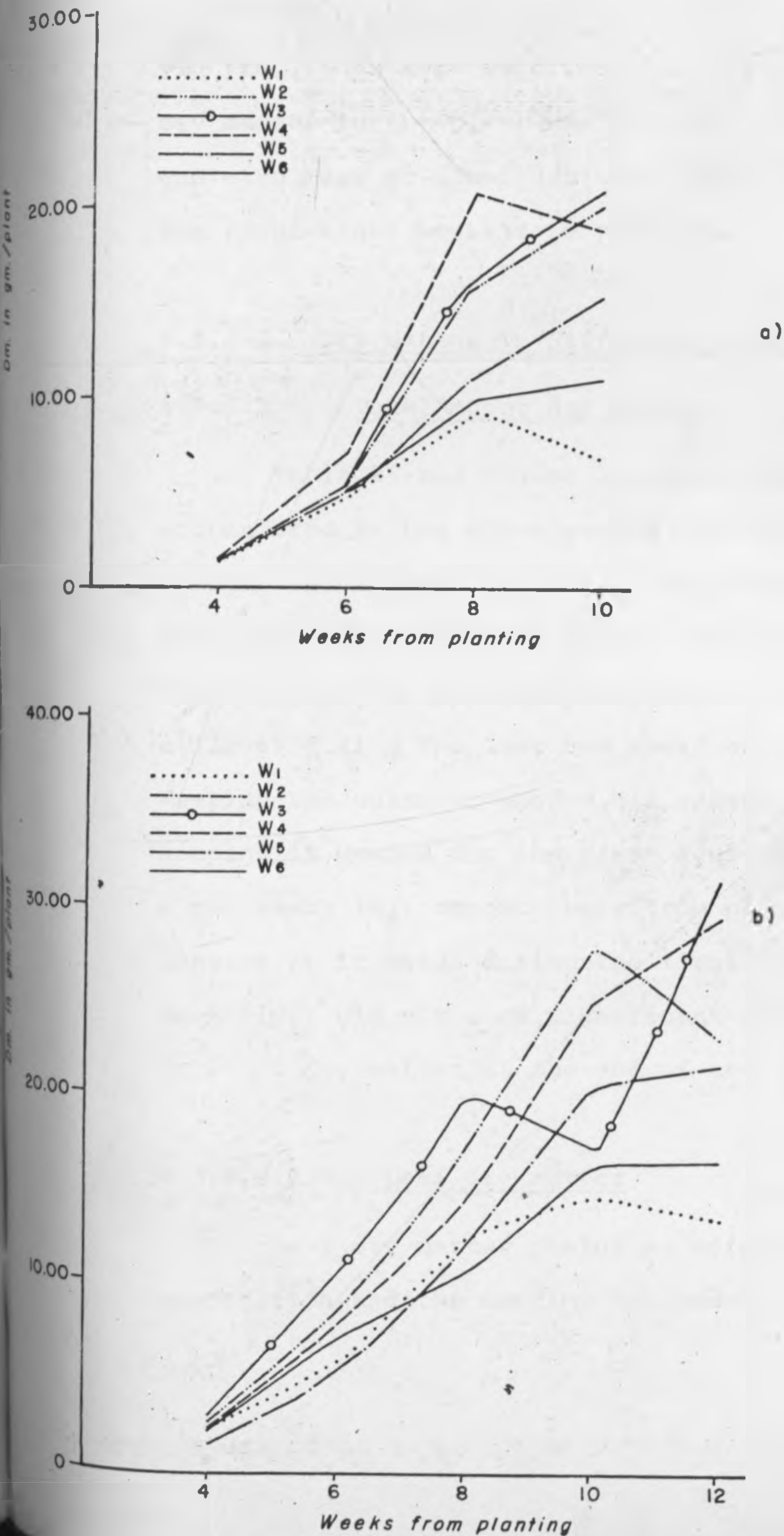
Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	2.38abc	5.80bc	12.15bc	14.40	13.32b
W_2	2.62ab	8.32ab	17.01ab	27.50	22.65ab
W_3	3.10a	10.22a	19.51a	17.12	30.87a
W_4	2.29bc	7.72abc	14.38abc	25.04	29.32a
W_5	1.65c	5.27c	12.47bc	20.13	21.77ab
W_6	2.34bc	7.07bc	10.69c	15.98	16.31b
F Weeding	3.951*	4.542*	3.303*	2.351	3.203*
Mean	2.40	7.40	14.37	20.03	22.37
S.E. Mean	0.21	0.75	1.64	3.06	3.46
C.V.	19.8%	22.8%	25.5%	34.2%	34.6%

b) 1980 First rains.

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 15: CULTIVAR ROSE COCO. TOTAL DRY MATTER AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS

a) 1979 EXPERIMENT
b) 1980 EXPERIMENT



planting, then kept weedfree thereafter (W_5), dry matter in the plant was slightly reduced and even more so when left with weeds during the first eight weeks from planting.

4.3.3.2. Dry matter in different plant organs

4.3.3.2.1. Total shoot dry matter

Table 23 and figure 16 show plant material accumulated in the above ground parts of the plants, as observed in 1979. If not weeded for upto eight weeks and beyond after planting, shoot dry matter was significantly reduced at least during the last two weeks of growth. Keeping the cultivar weeded all season (W_2), keeping it weeded for the first four (W_3) and eight weeks (W_4) respectively from planting or leaving it in weeds during the first four weeks (W_5) did not show significant differences in shoot dry matter at the end of the season.

4.3.3.2.2.2. Leaf dry matter

Leaf dry matter yields as affected by weed competition and the weeding treatments in 1980

Table 23. The effect of weed competition and the weeding treatments on total shoot dry matter (gm/plant). Cultivar Rose Coco. 1979 Second Rains.

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10
W_1	1.08	3.95	8.86c	6.26c
W_2	1.16	5.02	15.56ab	19.48a
W_3	1.30	5.26	15.74ab	19.99a
W_4	1.32	6.41	19.95a	18.26a
W_5	1.06	4.15	10.58bc	14.74ab
W_6	1.21	4.74	9.61c	10.50bc
F Weeding	2.357	2.456	7.672*	10.640*
Mean	1.19	4.92	13.38	14.87
S.E. Mean	0.06	0.44	0.74	1.31
C.V.	10.4%	19.9%	20.5%	19.7%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Table 24. The effect of weed commetition and the weeding treatments on leaf dry matter (gm/plant). Cultivar Rose Coco. 1980 First Rains.

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10	11
W_1	1.61a	3.53cd	4.75bc	3.13	1.70
W_2	1.74a	5.31ab	6.90ab	5.32	1.35
W_3	2.09a	6.37a	8.01a	3.81	2.29
W_4	1.56a	4.80abc	6.01abc	4.75	1.33
W_5	1.02b	3.15d	4.33bc	3.98	0.87
W_6	1.58a	4.30bcd	4.02c	4.02	1.14
F Weeding	3.860*	4.987*	3.853	0.814	0.457
Mean	1.60	4.58	5.67	4.17	1.45
S.E. Mean	0.16	0.47	0.72	0.76	0.65
C.V.	22.0%	23.1%	28.4%	40.8%	100.9%

Figures in the same column followd by same letter(s) are not significantly different by DNMRT.

Figure 16 : CULTIVAR ROSE COCO. TOTAL SHOOT DRY MATTER (gm/plant) AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS DURING THE SECOND RAINS OF 1979 EXPERIMENT

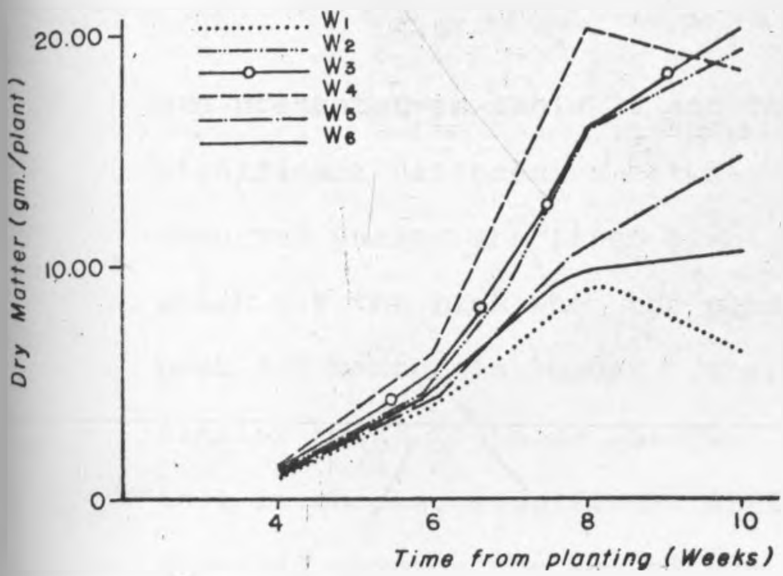
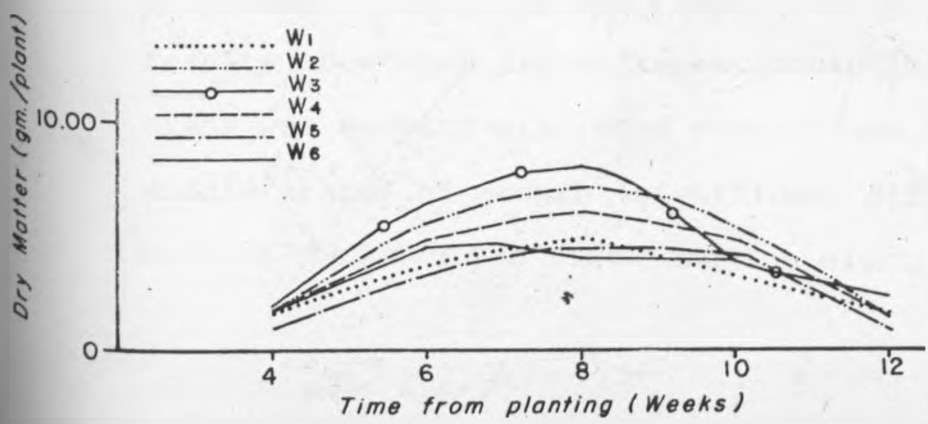


Figure 17 : CULTIVAR ROSE COCO. LEAF DRY MATTER YIELD AS AFFECTED BY WEED COMPETITION AND THE WEEDINGS DURING THE FIRST RAINS OF 1980 EXPERIMENT



are presented in table 24 and figure 17. Significant differences between treatments were observed during the first eight weeks of growth which was the time when the plants achieved peak dry matter in leaves. The results show a similar trend to those observed in shoots except that in shoots, significant differences were observed towards the end of the growing season. When weedfree at least during the first four weeks after planting, dry matter accumulation in leaves was not affected. But competition from weeds lasting as little as four weeks from planting significantly reduced dry matter in leaves.

4.3.3.2.3. Stem dry matter

The data for dry matter yield of stems as affected by weed competition and the weeding treatments during the first rains of 1980 are presented in table 25 and figure 18. The results show that dry matter accumulation in stems was sensitive to weed competition in the middle stages of growth (significant differences occured between the sixth and the eighth weeks

Table 25. The effect of weed competition and the weeding treatments on stem dry matter (gm/plant). Cultivar Rose Coco. 1980 First Rains.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	0.50	1.57bc	2.77b	2.45	2.08
W_2	0.54	2.09abc	3.91ab	3.65	2.03
W_3	0.63	2.81a	4.60a	2.24	3.34
W_4	0.49	2.21ab	3.23ab	4.33	3.09
W_5	0.38	1.36c	2.44b	2.78	1.86
W_6	0.49	1.85bc	2.36b	3.03	2.18
F Weeding	2.665	4.912*	3.223*	2.243	2.037
Mean	0.51	1.98	3.22	3.08	2.43
S.E. Mean	0.05	0.21	0.44	0.47	0.39
C.V.	20.0%	23.1%	30.7%	34.1%	35.9%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

after planting). The cultivar suffered significant dry matter reduction in stems with as little as four weeks in weeds and by the sixth week those plots which had suffered weed competition (W_1, W_5 and W_6) had significantly less dry matter in stems than other treatments (viz. W_2, W_3 and W_4). For maximum dry matter accumulation in stems, the cultivar did not need more than four weeks of weedfree conditions. However, towards the end of the growing season, there appeared to be no significant differences among treatments, probably because of the shift of dry matter to the developing seeds.

4.3.3.2.4. Pod dry matter

In table 26 and figure 19 are presented ~~are~~ dry matter yields of pods as observed during the 1980 experiment. At the end of the growing season, those plots which were weeded all season, those weeded the first four and eight weeks respectively after planting and those left in weeds the first four weeks after planting and thereafter kept clean upto maturity did not differ

Table 26. The effect of weed competition and the weeding treatments on pod dry matter (gm/plant). Cultivar Rose Coco. 1980 First Rains.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	-	0.36	4.13	8.31	10.10b
W_2	-	0.38	5.47	17.86	18.66ab
W_3	-	0.44	6.11	10.30	24.52a
W_4	-	0.40	4.48	15.25	22.81a
W_5	-	0.33	5.16	12.82	18.48ab
W_6	-	0.34	3.52	9.17	12.55b
F Weeding		1.200	2.752	2.863	3.619*
Mean		0.38	4.81	12.29	17.85
S.E. Mean		0.03	0.51	1.97	2.65
C.V.		20.2%	23.8%	35.9%	33.1%

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 18: CULTIVAR ROSE COCO. DRY MATTER (gm./plant) IN THE STEMS AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS DURING THE FIRST RAINS OF 1980 EXPERIMENT

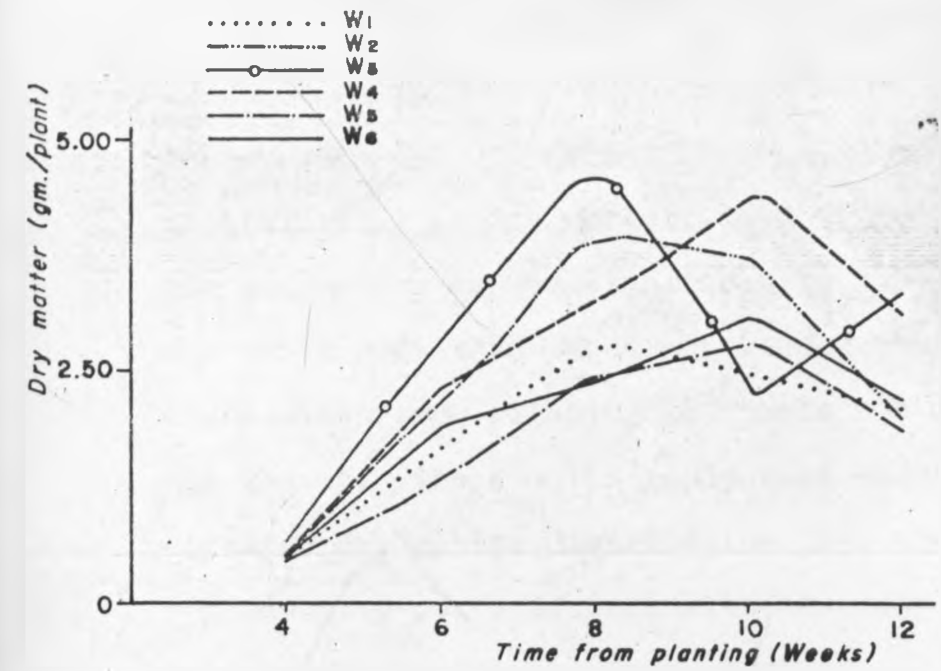
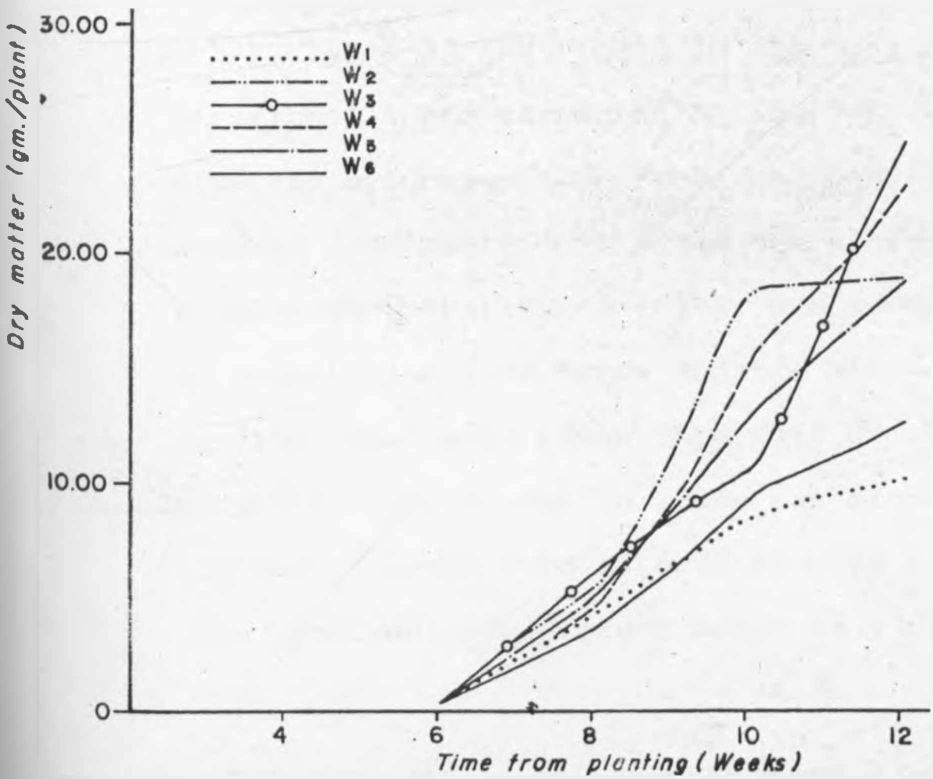


Figure 19: CULTIVAR ROSE COCO. DRY MATTER (gm./plant) IN THE REPRODUCTIVE PARTS AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS DURING THE FIRST RAINS OF 1980 EXPERIMENT



significantly in dry matter yield of pods. However, the said plots showed significantly larger dry matter in pods than those not weeded the first eight weeks from planting and those not weeded all season. The results imply that weeds affected dry matter distribution into the reproductive parts if left with the crop for upto and beyond eight weeks from planting. Although the crop suffered dry matter reduction when left with weeds for four weeks, it was able to recover and make up for the loss once the weeds were removed.

4.3.3.3. Root dry matter

Table 27 and figure 20 show dry matter distribution and accumulation in roots as affected by competition from weeds and the applied weeding treatments during the two seasons. The results show that the cultivar was susceptible to competition from weeds and the kind of weeding treatments given. Like most of the parameters, dry matter in roots was significantly reduced if weeds were allowed to grow with the crop upto and beyond eight weeks from planting,

Table 27. The effect of weed competition and the weeding treatments on root dry matter (gm/plant). Cultivar Rose Coco.

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10
W_1	0.14	0.32b	0.33b	0.32c
W_2	0.15	0.41b	0.38b	0.47ab
W_3	0.15	0.41b	0.41b	0.52a
W_4	0.16	0.56a	0.61a	0.48ab
W_5	0.15	0.37b	0.38b	0.46ab
W_6	0.15	0.36b	0.34b	0.36c
F Weeding	0.600	3.804*	6.774*	3.776*
Mean	0.15	0.41	0.41	0.44
S.E. Mean	0.01	0.03	0.03	0.03
C.V.	11.6%	18.4%	16.5%	15.9%

a) 1979 Second rains

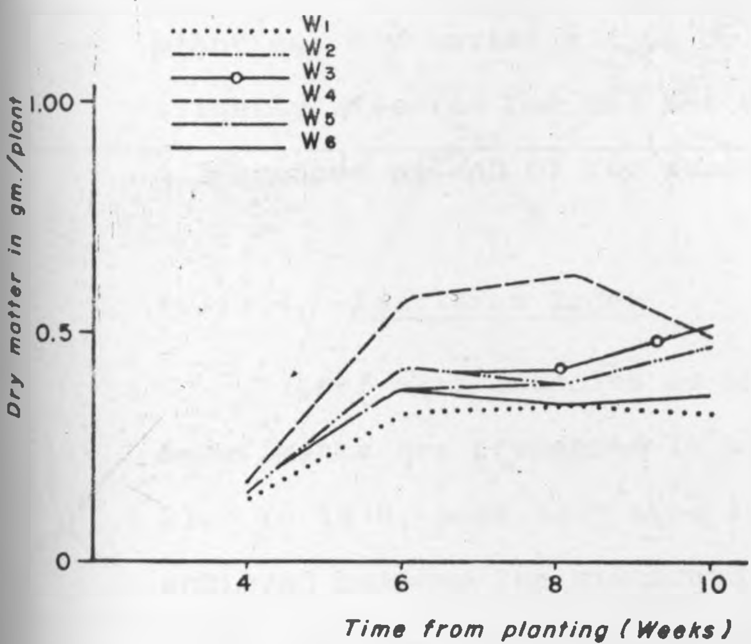
Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	0.28bc	0.35c	0.51cd	0.52	0.46b
W_2	0.35ab	0.55ab	0.73ab	0.67	0.62ab
W_3	0.39a	0.61a	0.79a	0.77	0.72a
W_4	0.26c	0.41bc	0.67abc	0.71	0.70a
W_5	0.26c	0.42bc	0.55bcd	0.56	0.56ab
W_6	0.29bc	0.39bc	0.41d	0.57	0.44b
F Weeding	4.740*	3.641*	5.522*	0.958	2.906*
Mean	0.31	0.46	0.61	0.63	0.58
S.E. Mean	0.02	0.05	0.06	0.09	0.06
C.V.	15.5%	23.1%	20.2%	31.9%	24.0%

b) 1980 First rains.

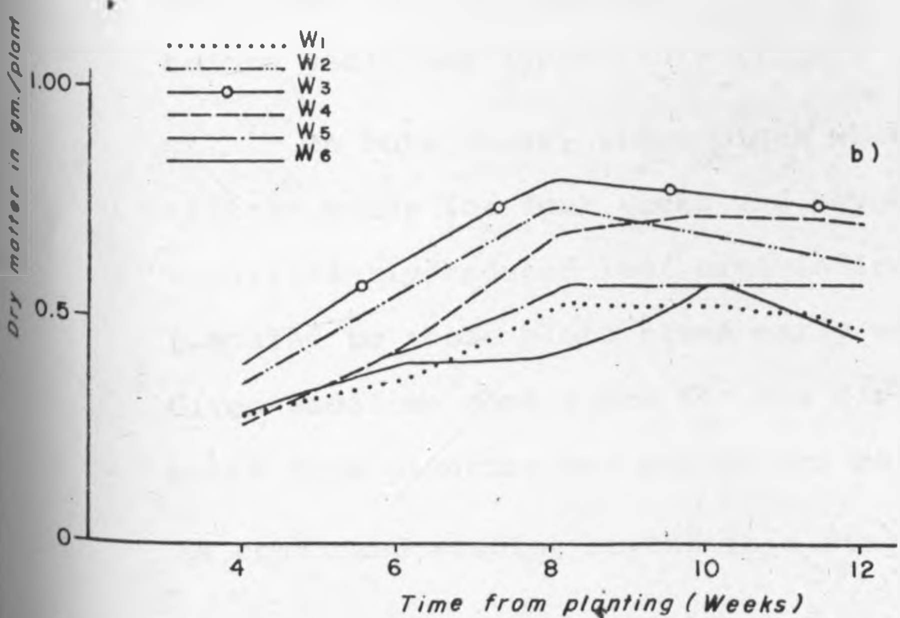
Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 20 : CULTIVAR ROSE COCO. DRY MATTER YIELDS OF ROOTS (gm./plant) AS AFFECTED BY WEED COMPETITION AND THE WEEDING TREATMENTS

a) Second Rains of 1979 EXPERIMENT
b) First Rains of 1980 EXPERIMENT



a)



b)

at least at the end of the growing season (treatments W_1, and W_6 in table 27). In addition, if the crop was weeded beyond four weeks after planting, dry matter yields of roots were slightly affected but did not bring about significant differences at end of the season.

4.3.3.4. Leaf Area Index

Leaf area indecies as observed in both experiments are presented in table 28 and figure 21. In 1979, peak leaf area indecies were achieved between the sixth and the eighth weeks after planting. In 1980, however, the plants were able to retain leaves longer, hence maximum leaf area indecies persisted upto the tenth week before declining appreciably (figure 21).

In both years, those plots which were left in weeds for four weeks and beyond showed significantly reduced leaf area indicies as compared to those plots given early weeding. Given weedfree conditions for the first four weeks from planting was enough for maximum LAI as continued weeding beyond this stage seemed to

Table 28. The effect of weed competition and the weedings treatments on leaf area index. Cultivar Rose Coco.

Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10
W_1	0.07	0.19	0.20c	0.04c
W_2	0.07	0.26	0.26bc	0.12ab
W_3	0.08	0.32	0.38ab	0.18a
W_4	0.07	0.31	0.52a	0.18a
W_5	0.06	0.20	0.22c	0.09bc
W_6	0.08	0.26	0.26bc	0.04c
F Weeding	1.600	2.014	6.945*	8.985*
Mean	0.07	0.26	0.31	0.11
S.E. Mean	0.01	0.03	0.04	0.02
C.V.	14.3%	24.9%	26.0%	32.8%

a) 1979 Second rains

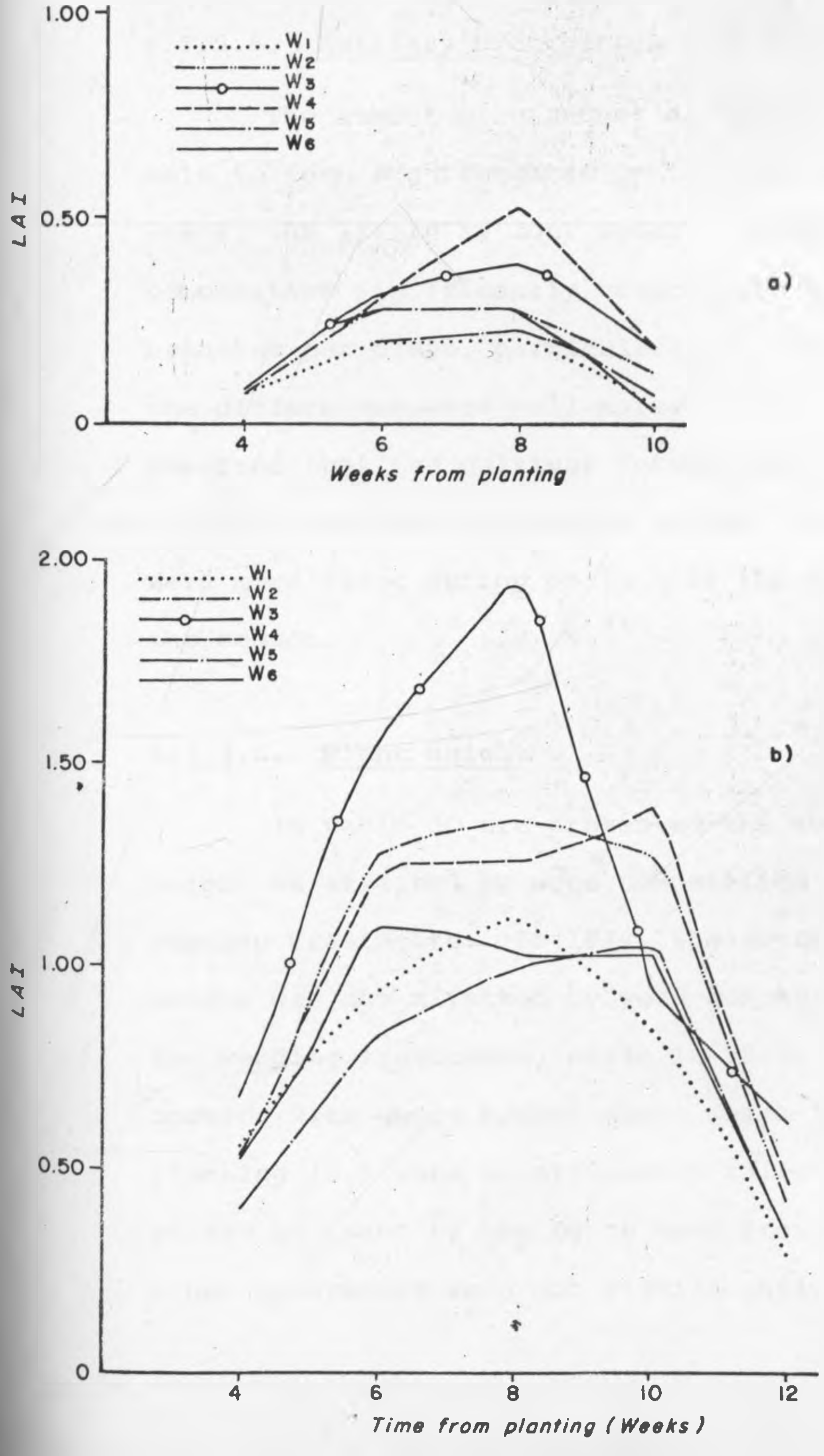
Weeding Treatment	PERIOD FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	0.38	0.77	0.93b	0.66	0.10
W_2	0.37	1.10	1.18 ab	1.10	0.27
W_3	0.50	1.38	1.76a	0.76	0.44
W_4	0.36	1.05	1.08b	1.21	0.28
W_5	0.22	0.65	0.81b	0.86	0.16
W_6	0.35	0.91	0.85b	0.85	0.16
F Weeding	5.084*	2.437	3.305*	1.016	1.253
Mean	0.36	0.98	1.10	0.91	0.24
S.E. Mean	0.04	0.15	0.17	0.18	0.10
C.V.	22.2%	34.0%	35.3%	45.3%	92.3%

b) 1980 First Rains

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Figure 21: CULTIVAR ROSE COCO. LAI AS AFFECTED BY WEEDS AND THE WEEDING TREATMENTS

a) Second Rains of 1979 Experiment
b) First Rains of 1980 Experiment



have affected LAI.

4.3.3.5. Axillary branching

The number of branches each plant was able to form are tabulated in table 29 for both years. As little as four weeks of weed competition significantly reduced the number of branches per plant, particularly in 1980 when the differences were well marked. It is also observed that the cultivar formed more branches in 1980, but the differences between treatments were more clear during or towards the end of the season.

4.3.3.6. Plant height

In table 30 are presented the average plant height as affected by weed competition and the weeding treatments. In 1979, the average plant height was not affected by weed competition and the weeding treatments, while in 1980, plants growing with weeds beyond eight weeks from planting (W_1) were significantly taller than others at least by the tenth week from planting. Other treatments were not significantly different.

Table 29. The effect of weed competition and the weeding treatments on number of branches per plant. Cultivar Rose Coco.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	1.0c	3.1	3.5	3.1b
W_2	1.3b	4.1	3.6	3.4ab
W_3	1.3b	3.4	4.0	4.2a
W_4	1.5a	4.2	4.9	4.1a
W_5	1.1c	3.5	2.8	3.5ab
W_6	1.5a	3.6	3.5	3.6ab
F Weeding	14.458*	1.781	2.952	3.703*
Mean	1.3	3.6	3.7	3.6
S.E. Mean	0.04	0.25	0.32	0.17
C.V.	6.8%	15.9%	19.3%	10.7%

a) 1979 Second rains

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	10	12
W_1	1.5	3.3b	3.6c	4.7b
W_2	2.4	4.6ab	5.6ab	6.2a
W_3	2.7	5.5a	5.7ab	6.2a
W_4	1.9	4.1b	6.0a	6.6a
W_5	1.7	3.5b	4.3abc	4.8b
W_6	1.9	3.9b	4.1bc	4.4b
F Weeding	1.360	3.514*	3.496*	5.962*
Mean	2.0	4.1	4.9	5.5
S.E. Mean	0.35	0.38	0.48	0.35
C.V.	39.3%	20.9%	21.7%	14.2%

b) 1980 First rains.

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

Table 30. The effect of weed competition and the weeding treatments on plant heights (cm). Cultivar Rose Coco.

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10
W_1	11.94	25.70	28.73	27.80
W_2	12.32	26.10	27.04	29.13
W_3	12.21	24.29	28.50	31.93
W_4	12.72	28.86	33.25	31.13
W_5	11.68	26.49	28.23	29.61
W_6	12.41	27.66	30.03	30.89
F Weeding	0.502	1.669	1.738	1.438
Mean	12.21	26.52	29.30	30.08
S.E. Mean	0.40	0.95	1.27	1.09
C.V.	7.3%	8.0%	9.7%	8.1%

a) 1979 Second rains

Weeding Treatment	DURATION FROM PLANTING (WEEKS) 4	6	8	10	12
W_1	20.10	34.80	43.50	44.50	39.20
W_2	22.00	29.60	37.20	37.50	34.20
W_3	23.80	33.30	39.00	36.20	35.30
W_4	20.40	30.80	39.20	35.80	34.30
W_5	22.10	30.40	36.40	33.60	32.40
W_6	22.30	37.00	39.50	35.60	34.90
F Weeding	2.308	2.072	1.938	4.034*	2.311
Mean	21.78	32.65	39.13	37.20	35.05
S.E. Mean	0.80	1.81	1.57	1.68	1.30
C.V.	8.2%	12.4%	9.0%	10.1%	8.3%

b) 1980 First rains.

Figures in the same column followed by same letter(s) are not significantly different by DNMRT.

4.4. Weed Yields

Weed dry matter yields as observed during the two seasons in those plots which were left weedy all season are presented in table 31. The results show that weed growth was more in 1980 as compared to the previous season (weed dry matter doubled that of 1979). In addition, weed growth was more where the determinate varieties were associated, and that the semi-determinate Canadian Wonder suppressed weed growth more.

Maximum weed dry matter increase was attained in the eighth week in 1979 and the tenth week in 1980. In other words, weeds grew very fast for the first eight weeks in 1979 and ten weeks in 1980 then declined.

Table 31. The effect of the three varieties on weed dry matter accumulation. The differences were not statistically tested.

Time from planting (weeks)	Weed dry matter in grammes per M^2 of land					
	Canadian Wonder		Mwezi Moja		Rose Coco	
	1979	1980	1979	1980	1979	1980
4	8.26	72.08	10.88	105.58	6.79	67.24
6	59.10	127.10	72.15	158.97	64.92	146.56
8	154.17	136.53	175.43	191.83	141.17	145.76
10	196.11	214.14	195.92	304.88	272.61	292.36
12	-	257.67	-	333.64	-	417.08
14	-	172.15	-	-	-	-
Average	104.41	163.28	113.47	218.98	121.37	213.80

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1. DISCUSSION

The grain yield, dry matter content in the plant organs, the number of branches, leaf area indecies and the average plant height was higher during the first rains of 1980 as compared to those observed during the 1979 second rains. The rainfall data (appendix figure 1) show that the plants experienced moisture stress during the latter season, particularly during the reproductive phase when only about 82mm of rainfall was available compared to, 150mm during the same stage of development in the first rains of 1980. It is a common observation that physiological processes such as photosynthesis, respiration, nutrient uptake, synthesis of cellular constituents and hydrolysis of macromolecules respond to moisture stress, and the usual effect is that the rates of these processes are inhibited or slowed down by moisture stress. These results therefore could be explained by this fact. These results agree with those of Magalhaes and Millar (1978) and those of Elnadi (1969) who found beans to be sensitive to drought, particularly during the reproductive phase. The results suggest that where water is non-limiting, dry matter production increase at a higher rate until near maturity hence result in high production of plant material. Clarke and Simpson (1978) when working with Brassica napus under high seeding rates and no-irrigation conditions found similar results. Elnadi (1969) when working on the effect of water stress on growth and flowering of beans found in addition to the sensitivity of beans to water stress during the flowering phase that plant height and node number decreased with dry treatments. Brandes (1971) showed that leaf area index values were highest with more moisture. This is particularly true since with more moisture, among other things, leaf area values are higher.

The determinate cultivars, Mwezi Moja and Rose Coco showed almost equal yield-potential, while the semi-determinate Canadian Wonder showed greater yield-potential. Under weedfree conditions, the determinate bush cultivars gave average yields of 1980.31 and 1862.02 kg/ha for Mwezi Moja and

Rose Coco respectively over the two seasons, while the semi-determinate Canadian Wonder yielded an average of 2229.97 kg/ha. The average pod number per plant and the number of branches per plant were higher in Canadian Wonder as compared to the other cultivars, and this might have contributed to the higher seed yield. According to available information, Canadian Wonder is capable of giving more yield than the determinate local cultivars and under experimental conditions had given a yield equivalent of 3000 kg/ha (Ministry of Agriculture - Kenya, 1974). This value was actually achieved during the first rains of 1980 (see table 1). Mwezi Moja and Rose Coco achieved a yield of about 2500kg/ha, which according to Acland (1971) and Macartney and Watson (1966) is the potential yield of most of the East African varieties if improved and exposed to good husbandry and protected from pests and diseases. Allen and Morgan (1975) when working on quantitative comparison of the growth, development and yield of different varieties of oil seed rape found the highest yielding variety to have more pods per plant.

5.1.1. Yield and yield components and weed competition

The data presented in tables 1, 11 and 21 show that weed competition is a major factor in bean production. When not removed the whole season, weeds reduced bean grain yields by 49.5, 55.5 and 58.0% during the first rains of 1980 and by 53.0, 58.0 and 67.0% during the second rains of 1979 for Canadian Wonder, Mwezi Moja and Rose Coco respectively. This points out that, although competition from weeds reduced bean grain yields in both years, the reduction was more when moisture was limiting during the second rains of 1979. This resulted into a greater competition among the crop plants and between the crop and the weeds. This would definitely go along to affect crop vigour and the resultant crop yield. Williams (1973) when working with a *P. vulgaris* cultivar found beans to be more susceptible to weed competition during dry season. Similar results reported by Staniforth (1958), that crop vigour may be affected by drought hence lower yields.

These results point out that bean grain yields would be reduced considerably by the weeds that germinate with the crop and persist throughout the growing season. Weeds that germinate later in the season after the crop has become established offer substantially less competition. If left to compete with weeds upto eight weeks from planting, the grain yields and yield components of the three cultivars were not different from those left in weeds the whole season. Two cultivars, Canadian Wonder and Mwezi Moja were able to tolerate four weeks of weed competition without suffering severe yield reductions. Rose Coco on the other hand tolerated the same with more moisture (first rains of 1980 experiment) but suffered severe grain yield and the number of seeds per pod reductions when left in weeds for four weeks after planting. These results therefore show that when not exposed to adverse weather conditions, beans will tolerate four weeks of competition from weeds without suffering severe yield reductions. Staniforth and Weber (1956) when studying the effects of weed growth upon soybean yields found that the most marked competition was from when pods developed upto maturity. The same author in 1957 found that soybean yield reductions were most serious when weeds grew throughout the season. These results support those of Williams *et al.* (1973) who, when working with beans found the yield to have been reduced by weed competition lasting at least five weeks from emergence; Dawson (1964) when working with irrigated beans (*P. vulgaris*) and weed competition, found that beans needed five to seven weeks of competition from weeds after planting in order to have significant yield reductions. Williams *et al.* (1973), Barreto (1970), Dawson (1964) and Kasasian and Seeyave (1969) had similar results. These results suggest therefore that weed control measures can be carried out any time within the first four weeks after planting (given right weather conditions) without the beans suffering significant reductions in yield. However, if left upto the fourth week, the weeds will be too big to allow control with post-emergence herbicides or mannually without harming the bean plants.

The most important period therefore lies between five and seven weeks after planting. The three cultivars flower and form pods within this period and apparently the most sensitive period to competition is the reproductive phase. It is no wonder that pods per plant suffered most and probably contributed most to the loss in yield. Other yield components (weight per seed and seeds per pod) were not affected by competition in both seasons except in Rose Coco when moisture was limiting during the second rains of 1979, when in addition to pods per plant, seeds per pod were significantly reduced with at least four weeks of competition (table 21). When given four weeks of weedfree conditions from planting the cultivars did not differ in yield to those weeded all season, and in some cases gave better yields than those weeded beyond four weeks.

In practically all instances the pod number per plant was the most severely affected component of yield and showed distinctly the differences between weeding treatments (tables 1, 11 and 21 for Canadian Wonder, Mwezi Moja and Rose Coco respectively). This is to be expected since the fruit is the last item produced by the plant (the bean being an annual) and all the ills experienced by the plant earlier would be expressed in the fruit. Other yield components were not affected probably due to the widely held view of yield component compensation. A reduction in the metabolic input to the inflorescence, therefore, should be accompanied by appropriate adjustments in the yield component system. Thurling (1974) working with Brassica compestris and B. napus found that a sharp reduction in the total dry weight was accompanied by a decrease in the number of pods per plant without any changes in the seed weight per plant. Aquilar (1977) when working with dry beans found pods per plant to be sensitive to interplant competition between 5-11 weeks after planting, but seeds per pod and seed weight were not sensitive. Westermann and Crothers (1977) found the number of pods per plant to have the largest effect on bean yield.

5.1.2. Weed competition and bean growth

Plant growth as measured by the total plant dry weight was significantly reduced by competition from weeds lasting eight weeks and beyond after planting. Significant reductions were realized from the sixth week after planting in most cases, a fact which supports the above idea that the reproductive phase is the most critical as regards competition from weeds. Partition of the total plant dry matter show that all the plant parts, except roots in Canadian Wonder (1979 experiment) and stems in Mwezi Moja were affected by weeds if left with the crop for eight weeks and beyond. These effects started as early as the fourth week from planting but did not attain significance in most cases upto the sixth week from planting.

Growth as measured by the lateral spread and leaf area index was similarly reduced by weed competition beyond the reproductive phase (six to eight weeks after planting). Plant height on the other hand did not show any trend and hence no conclusion can be drawn out of it.

These results therefore show that the

plants left in weeds failed to have a concentrated early vegetative growth which had consequences on the reproductive phase. These plants were not able to build enough plant material before flowering and in most cases did not attain high dry matter values, hence the young fruits did not have enough to draw from. Stang (1976) when working on responses of bush bean cultivars to plant population densities found high pod yields to be a function of early concentrated growth and development of reproductive parts and a concurrent reduction in vegetative growth.

5.2. CONCLUSION

The results show clearly that weeds and particularly those that germinate with the crop and persist through the major portion of the growing period reduce bean grain yields. The yield reduction which starts as early as within the first four weeks after planting in the crop growth cycle affect nearly all parts of the plant and particularly the number and weight of pods per plant. Weed control programme therefore should start early in order to give a bean crop a good beginning. If effected within the first four weeks after planting, significant yield reductions would not be realized.

Most of the East African dry bean cultivars flower and form pods from the fifth week from planting. Grain yield and dry matter reducing competition did attain significance in most cases when the beans were left in weeds during and beyond this stage. A farmer therefore should keep his beans free of weeds during the first four weeks after planting and should not bother with the weeds germinating later than this period.

LITERATURE CITED

Acland, J.D. 1971. East African crops; an introduction to the production of field and plantation crops in Kenya, Tanzania and Uganda. London. Longman by arrangement with F.A.O. 252p.

Afolani, S.O and F.E. Caveness. 1973. A nematode survey in IITA. International institute of Tropical Agriculture. Ibadan-Nigeria. 22p.

Aguilar, M.I.; Fischer, R.A. and J. Kohashis. 1977. Effect of plant density and thinning on high yielding dry beans (*P. vulgaris*) in Mexico. Experimental Agric. 13(4): 325-335.

Allen, E.J. and D.G. Morgan. 1975. A quantitative comparison of the growth, development and yield of different varieties of oil seed rape. J. Agric. Sci. 85: 159-174.

Aspinall, D. and F.L. Milthorpe. 1959. An analysis of competition between barley and white persicaria. I. The effect on growth. Ann. appl. Biol. 47(1): 156-172.

Aspinall, D. 1960. An analysis of competition between barley and white persicaria. II.Factors determining the course of competition. Ann. appl. Biol. 48(3): 637-654.

Bakke, A.L. 1939. The soil moisture relationship of European bindweed growing in corn. Agron. J. 31: 352-357.

Barreto, A. 1970. Competition between weeds and beans. Agricultura en Mexico 2(12): 519-526.

Bear, F.E. and A. Wallace. 1950. Alfalfa. Its requirements and chemical competition. N.J. Agric. Sta. Bul. 748:32.

Bell, D.T. and O.E. Koeppe. 1972. Non-competitive effects of giant foxtail on growth of corn. Agron. J. 64. 231 -235

Black, C.C., T.M. Chen and R.H. Brown. 1969. Biochemical basis for plant competition. Weed Sci. 17: 338-344.

Blackmann, C.C. and W.G. Templeman. 1938. The nature of competition between cereal crops and annual weeds J. Agric. Sci. 28: 247-271.

Blanco, H.G. *et al*. 1969. Weed competition with a bean crop (*P. vulgaris*). Biologico 35: 304-308.

Brandes, D. 1971. Analysis of growth in beans; effect of planting density and date. Tese Mag. Sc. Vicosa, Brazil, Universidade de Vicosa Federal de Vicosa. 109p.

Brar, G. and W. Theis. 1977. Contribution of leaves, stem, siliques and seeds to dry matter accumulation in ripening seeds of rape seed, *Brassica napus* L.Z. Pflanzen physiol 38: 1-13.

Buchanan, G.A. and E.R. Burns. 1969. Influence of weed competition on cotton. Weeds 18: 149-154.

Burnside, O.C. and G.A. Wicks. 1967. The effect of weed removal treatments on sorghum growth. Weeds 15: 204-207.

______________ and _______________. 1968. Influence of weed competition on sorghum growth. Weed Sci. 17: 332-334.

Burnside, O.C. 1980. Soybean (Glycine max) growth as affected by weed removal, cultivar and spacing. J. Weed Sci. Soc. of America 27(5): 562-565.

Clarke, J.M. and G.M. Simpson. 1978. Growth analysis of Brassica napus cv. Tower. Can. J. Plant Sci. 58: 587-595.

Crafts, A.S. and W.W. Robbins. 1962. Weed control. Text and manual 3rd Ed. Tata McGraw-Hill. New Delhi. 660p.

Donald, C.M. 1951. Competition among pasture plants. I. Intra-specific competition among annual pasture plants. Aust. J. Agric. Res. 2: 355.

Dawson, J.H. 1964. Competition between irrigated field beans and annual weeds. Weeds 12: 206-208.

Eaton, B.J.; Feltner, K.C. and D.G. Russ. 1973. Venice mallow competition in soybeans. Weed Sci. 21(2): 89-94.

El Nadi, A.H. 1969. Water relations of beans. I. The effect of water stress on growth and flowering. Exp. Agric. 5: 195-207.

Enyi, B.A.C. 1973. An analysis of the effect of weed competition on growth and yield attributes in sorghum (Sorghum vulgare), cowpeas (V. unguiculata) and green gram (Vigna aureus) J. Agric. Sci. 81(3): 449-453.

Evetts, L.L. and O.C. Burnside. 1973. Competition of common milkweed (Asclepias syriaca) with sorghum.

F.A.O. Production Year Books (Volumes 23 and 24). 1969 and 1970. Amino acid content of foods and biological data on protein.

Freytag, G.H. 1973. Potential of field beans and other food legumes in Latin America. Seminar in the agronomic practices for food production in Latin America. Duncan Wall-Tacoma Park; Maryland, U.S.A.

Grupce, R. 1969/1970. Effect of _Sorghum halepense_ weed infestation on the morphology of _Zea mays_. Zemjodelska 23: 169-173.

Harvey, D. 1956. Tables of the amino acids in food and feeding staffs. Commonwealth Bureau. Animal Nutr. Tech. Comm., No. 19.

Hurst, H.R. and K.C. Feltner. 1966. Grain sorghum weed competition. Influence of weed density and time of removal on crop. Grain sorghum weed competition. Influence of weed density and time of removal on crop yield. W.S.A. Abstracts p. 57.

Jameson, J.D. 1970. Agriculture in Uganda. 2nd Ed. Oxford Univ. Press P 241 - 243

Kasasian, L. and J. Seeyave. 1969. Critical periods for weed competition. PANS 15: 208-212.

Keith Moody. 1973. Weed control in tropical grain legumes. In the proceedings of the first IITA Grain Legume Improvement Workshop. 29th Oct - 2nd Nov. 1973.

Klapp, E. 1938. Wiese and Weiden. Berlin, Germany.

Knake, F.L. and F.W. Slife. 1962. Competition of Setaria faberii with corn and soybeans. Weeds 10: 26-29.

Knake, F.L. and F.W. Slife. 1966. Control those weeds early. Illinois Res. 8(2): 8-9.

Lawson, H.M. and J.S. Wiseman. 1976. Weed competition in spring planted raspberries. Weed Research Vol.16 155 - 162

Lucas, R.W.; Scarsath , G.D and D.H. Sieling. 1942. Soil fertility level as it influences plant nutrient composition. Ind. Agric. Exp. Sta. Bul. 468.

Macartney, J.C. and D.R.W. Watson. 1966. Beans. Tengeru Report No. 89. Ministry of Agriculture, Forests and Wildlife Bulletin No. 20. Published by Ministry of Agriculture, Tanzania 28.

Mian, A.L. 1979. World Pulses. Paper presented at the symposium on Grain Legume Improvement in Eastern Africa. Faculty of Agriculture, Univeristy of Nairobi - Kenya. 20-24 August 1979.

____________________ 1976. Grow more pulses to keep your pulse well. An invited paper presented at the First National Workshop on oil seeds and pulses in Bangladesh, 11-13 October 1976.

Ministry of Agriculture, Kenya. 1974. Bean Research Project. Long Rains 1974. Hort. Res. Sta. Thika.

Mukunya, D.M. and S.O. Keya. 1975. Phaseolus Bean Production in East Africa. Faculty of Agriculture, University of Nairobi. Report on bean production study.

Nieto, J.H.; Brondo, M.A. and Gonzales, J.T. 1968. Critical periods of the crop growth cycle for competition from weeds. PANS(c) 14: 159-166.

Nieto, J.H. and D.W. Staniforth. 1961. Corn-foxtail competition under various production conditions. Agron. J. 53: 1-5.

Patel, N.P. and P.L. Rhodes. 1969. Problems and progress in weed science in Fiji. Fiji Dept. Agric. Bull. 53. 22p.

Pavlychenko, T.K. and J.B. Hurrington. 1935. Root development of weeds and crops in competition under dry farming. Sci. Agric. 16: 151-160.

Pavlychenko, T.K. and Hurrington. 1934. Competition efficiency of weeds and cereal crops. Can. J. Res. 10: 77-94.

Pavlychenko, T.K. 1949. Plant competition and weed control. Agric. Int. Rev. 4(2): 142-145.

Pinchinat, A.M. 1973. Relative agronomic merits of various food legumes for the lowland tropics. In the papers presented in Seminar on potentials of field beans and other legumes in Latin America. Series seminar No. 2E. Cali, Colombia, Feb 26th - March 1st, 1973. CIAT.

Remison, U.S. 1978. Performance of cowpea (Vigna unguiculata) as affected by weed competition. J. Agric. Sci. 90(3): 523-530.

Shetty, R.V.S. and M.R. Rao. 1977. Weed management studies in pigeon pea based intercropping. Paper presented at the 6th Asian Pacific

Weed Science Society Conference, Jakarta, Indonesia.

Stahler, L.M. 1948. Shade and moisture factors in competition between selected crops and field bindweed (Convolvulus arvensis). Agron. J. 40: 490-502.

Smith, R.J. 1967. Weed competition in rice. Weed Sci. 16: 252-255.

Staniforth, D.W. 1958. Soybean-foxtail competition under varying soil moisture conditions. Agron. J. 50: 13-15.

____________________1965. Competition effects of three foxtail species on soybeans weeds 13: 191-193.

____________________1961. Responses of corn hybrids to yellow foxtail competition. Agron. J. 9: 132-136.

__________________1962. Responses of soybean varieties to weed competition. Agron. J. 54: 11-13.

Staniforth, D.N. and C.R. Weber. 1956. Effect of annual weeds on the growth and yield of soybeans. Agron. J. 48: 467-471.

Stang, J.R. 1976. Responses of bush snap beans (*P. vulgaris* L.) to plant population densities. Ph.D. Thesis Corvallis, Oregon State University 141p.

Starck, Z. 1974. The effect of shading on the metabolic activity of roots. In the structure and function of primary root tissues. Proceedings of a symposium, Tatranska Lomnica, Sept. 7-10, 1971. Czechoslovakia, Brastislava, Czechoslovakia; Veda 277 - 283.

Statistical Abstracts. 1973. Kenya. Ministry of Finance and Economic Planning.

Swan, D.G. and W.R. Furstich. 1962. Competition of fiddleneck with wheat. Weeds 10: 121-123.

Swan, D.J. *et al*. 1975. Competition between *Cyperus difformis* and rice. Weed Research, Vol. 15: 149-152.

Thullen, R.J. and P.E. Keeley. 1980. Competition between yellow nutsedge (*Cyperus esculentus*) and Japanese millet (*Echinochloa crusgalli* var. frumentacea). J. Weed Sci. Soc. of America. 28:24-26.

Wax, L.M. and J.W. Pendleton. 1968. Effect of row spacings on weed control in soybean. Weed Sci. 16: 462-465.

Westermann, D.T. and S.E. Crothers. 1977. Plant population effects on the seed yield components of beans. Crop Sci. 17: 493-496.

Wiese, A.F.; J.W. Collier; L.E. Clark and U.D. Havelka. 1964. Effect of weeds and cultural practices on sorghum yields. Weeds 12: 209-211.

Williams, C.F. 1971. Interaction of crop plant population with weed competition in corn (Zea mays L.), bush snap beans (P. vulgaris L.) and onion (Allium cepa L.) at differing stages of development. Dissertation Abstracts International, B(1971) 32 (4) 1944-1945.

William, R.D. 1973. Competition between Cyperus rotundus L. and Phaseolus vulgaris L. Revista Ceres (1973) 20 (112) 424-432.

Williams, E.D. 1973. A comparison of the growth and competition behaviour of seedlings and plants from rhizomes of Agropyron

Thurling, N. 1974. Morphological determinations of yield in Rapeseed (Brassica compestrins and B. napus). I & II Yield Components. Aust. J. of Agric. Res. 25: 697-721.

U.S. Department of Agriculture. 1970. Agronomic potentials of U.S. food crops for production of calories and protein. U.S.D.A./FEDS staff paper 2. 19 (Mimeographed).

Van Eijnatten, C.L.M.; Muna, S. and D. Hasselmark. 1974. Grain Legume Development. Report on the mission evaluating the Dry Bean Project. Cyclostyled. 60 p.

Vavilov, N.I. 1951. The origin, variation, immunity and breeding of cultivated plants. Translated from Russia. Cronica Botanica. (Phaseolus vulgaris extraction).

Vengris et al. 1965. Plant nutrient competition between weeds and corn. Agron. J. 47: 213-216.

Vengris, J; Drake, M.; Colby, G. and J. Bart. 1953. Chemical composition of weeds and accompanying crop plants. Agron. J. 45: 213-215.

repens L. Beaur. and *Agrotis gigantea* Roth. Weed Res. 13: 422-429.

Williams, C.F. *et al*. 1973. Effect of spacing on weed competition in sweet corn, snap beans and onions. J. of American Soc. of Hort. Sci. 98 (6): 526-529.

Wilson, H.P. and Cole, R.H. 1966. Morningglory competition in soybeans. Weeds 14: 49-51.

Woo, M.L. 1919. Chemical constituent of *Amaranthus retroflexus* Bot. Gaz. 68: 313-334.

Zimdahl, R.L. and N.F. Staniford. 1967. Influence of weed competition on sugar beets. Weeds 15: 336-339.

Appendix 1. Comparison of amino acid content per 100 grammes food.

FOOD	Protein (g)	Lysine (mg)	Sulphur containing amino acids			Tryptophan	Total essential Amino-acids	Total Amino acids
			Methionine (mg)	Cystine (mg)	Total			
<u>Cereal Grains</u>								
Maize	9.5	254	182	147	329	67	3,820	9,262
Rice-brown	7.5	299	183	84	264	98	3,033	7,973
-polished	6.7	255	150	108	259	95	2,695	6,785
Wheat	12.2	374	196	332	528	142	4,280	12,607
<u>Roots and Tubers</u>								
Potato	2.0	96	26	12	38	33	667	1,572
Cassava	1.6	67	22	23	45	19	405	1,184
<u>Legumes (Pulses)</u>								
Beans (*P. vulgaris*)	22.1	1593	234	188	422	223	8,457	20,043
Cowpeas (Vigna)	20.1	1376	209	238	447	174	7,802	19,290
Peanut	25.6	1036	338	366	704	305	9,502	27,610
Pigeon pea	20.9	1607	107	204	311	117	7,505	18,460

<u>Source</u>: 1969 Production Year Book (FAO. Vol. 23) and 1970 Amino acid content of Foods and Biological data on protein (FAO. Vo. 24).

Appendix 2. Yield and the yield components (Analysis of variance) as affected by the weeding treatments during the second rains of 1979. (a) Canadian Wonder (b) Mwezi Moja (c) Rose Coco.

	Source of variation	df	Mean square for:			
			Weight/seed	Seeds/pod	Pods/plant	Yield/ha
a)	Weedings	5	0.0008	0.6776	18.76*	390931.36*
	Error	10	0.0004	0.5127	4.75	56664.01

	Source of variaction	df	Mean square for:			
			Weight/seed	Seeds/pod	Pods/plant	Yield/ha
b)	Weedings	5	0.0032	0.7043	5.73*	462443.80*
	Error	10	0.0038	0.2442	1.6800	44108.07

	Source of variation	df	Mean square for:			
			Weight/seed	Seeds/pod	Pods/plant	Yield/ha
c)	Weedings	5	0.0048	5.6185*	8.27*	569161.32*
	Error	10	0.0027	0.3394	2.12	32691.83

*= Significant at 5% level of significance.

Appendix 3. Analysis of variance for the yield and yield components as affected by the weeding treatments (1980 first rains experiment).

Source of variation	df	Mean square for:			
		Weight/seed	Seeds/pod	Pods/plant	Yield/ha
a) Weedings	5	0.0004	0.2541	82.8340*	3824356.60*
Error	15	0.0001	0.1088	4.7964	278942.93

Source of variation	df	Mean square for:			
		Weight/seed	Seeds/pod	Pods/plant	Yield/ha
b) Weedings	5	0.0039	0.1144	23.8597*	1659802.80*
Error	10	0.0069	0.1280	4.3282	282616.80

Source of variation	df	Mean square for:			
		Weight/seed	Seeds/pod	Pods/plant	Yield/ha
Weedings	5	0.0009	0.1184	36.8313*	1318994.30*
Error	10	0.0049	0.2109	5.7824	275132.49

(a) Cultivar Canadian Wonder
(b) " Mwezi Moja
(c) " Rose Coco.

* significant at 5% level

Appendix 4. Cultivar Canadian Wonder. Analysis of variance for different characters as affected by the weeding treatments during the whole season of growth (second rains of 1979 Experiment).

Source of variation	df	Weeks from plan-ting	Mean square for:					
			Dry matter total	Dry matter in shoots	Dry matter in roots	LAI	No. of branches	Mean height
		4	0.0558	0.0897	0.0001	0.0005*	0.2222	0.5789
		6	3.4899	3.6842	0.0048	0.0371	0.7619	16.1906
Weedings	5	8	52.0043	67.8990*	0.0345	0.1914	0.6796	159.1888*
		10	139.1729*	86.0731	0.0328	0.1903*	0.2880*	178.4041
		4	0.0462	0.0344	0.0004	0.00007	0.0852	1.2783
		6	2.2787	2.1987	0.0084	0.0354	0.3172	6.8937
	10	8	17.0848	15.6181	0.0143	0.0656	0.3516	28.5310
		10	33.6164	37.3513	0.0193	0.0393	0.0790	68.5247

*Significant at 5% level of significance.

Appendix 5. Cultivar Canadian Wonder. Analysis of variance for different characters as affected by the weeding treatments during the growth period (First rains of 1980 Experiment).

Source of variation	df	Weeks from plan-ting	Mean square for:							
			Total dry matter/ plant	Dry matter in leaves	Dry matter in stems	Dry matter in reprod. parts	Dry matter in roots	LAI	No. of branches/ plant	Mean height
		4	0.3431	0.2216	0.0075		0.0019	0.0183	0.3987	9.1844
		6	12.7982*	6.2153*	0.7606*	0.0084	0.0419	0.4840	0.3257	140.70042*
		8	107.4838*	37.8993*	12.4715	0.1775*	0.2094*	4.4507*	-	74.9558
Weedings	5	10	102.2772	19.0069*	10.4002	12.4429	0.2617*	1.4910	6.04166*	22.6880
		12	316.1506*	16.5996*	5.3980	124.8590*	0.2970*	1.4277*	10.5766*	148.6897
		14	509.3630*	2.1915*	8.3689*	305.9630*	0.2264*	0.0632*	-	-
		4	0.2377	0.1407	0.0072		0.0018	0.0079	0.5133	10.2862
		6	3.0646	1.4517	0.2585	0.0041	0.0226	0.1874	0.2083	23.8173
Error		8	17.6559	6.2704	7.2151	0.0503	0.0222	1.2214	-	43.3011
	15	10	39.1496	6.5433	5.5897	5.3706	0.0549	0.8724	1.0248	69.2436
		12	40.3619	4.4514	1.9257	10.9980	0.0402	0.2927	1.0555	123.1555
		14	46.2413	0.4975	1.2618	31.3743	0.0134	0.0098	-	-

* significant at 5% level

Appendix 6. Cultivar Mwezi Moja. Analysis of variance for different characters as affected by weeding treatments during the season of growth (Second rains of 1979 Experiment).

Source of variation	df	Weeks from planting	Mean square for: Total plant dry matter	Shoot dry matter	Root dry matter	LAI	No. of branches/ plant	Mean plant height
Weedings	5	4	0.0301	0.0244	0.0004	0.0002	0.2209	0.6296
		6	2.7378*	2.3282*	0.0197*	0.0118	0.2653	8.8205
		8	42.3207	41.0872	0.0107	0.0421	0.7766	9.4430
		10	150.3840*	147.6242*	0.0238	0.0357*	0.3140	9.8880
Error	10	4	0.0387	0.0347	0.0005	0.00001	0.0736	1.0124
		6	0.7119	0.6805	0.0032	0.0052	0.2350	4.4859
		8	15.6414	15.5896	0.0072	0.0147	0.6399	11.8049
		10	18.3909	17.8473	0.0255	0.0052	0.2060	6.4970

* significant at 5% level

Appendix 7. Cultivar Mwezi Moja. Analysis of variance for different characters as affected by weeding treatments during the growth period (1980 first rains Experiment).

Source of variation	df	Weeks from planting	Mean square for:							
			Total dry matter/ plant	Dry matter in leaves	Dry matter in stems	Dry matter in reprod. parts	Dry matter in roots	LAI	No. of branches/ plant	Mean plant height
Treatment		4	0.4065	0.2252	0.0252*	-	0.0030	0.0215	0.4880	3.5133
(Weedings)		6	6.0091	2.3650	0.6641	0.0168	0.0154	0.1268	4.3044*	27.6836*
	5	8	21.2707	5.3731	1.2879	2.6083	0.0343	0.0998	-	16.6430
		10	100.9433*	7.8706*	1.0418	43.6668*	0.0827	0.2472	1.8457	41.8480
		12	282.5741*	3.0075	2.5424	176.0003*	0.1577*	0.0729	3.9657*	42.3617
		4	0.2252	0.1776	0.0085	-	0.0055	0.0090	0.2605	3.9356
		6	3.0087	1.0662	0.2825	0.0138	0.0199	0.0578	0.3271	7.1405
Error	15	8	16.2755	3.2709	2.0156	1.3703	0.0189	0.1267	-	14.9675
		10	30.6471	1.1970	1.7085	13.7398	0.0369	0.0897	0.8492	21.4436
		12	72.0147	1.6775	1.2450	40.2951	0.0356	0.0586	0.9550	26.5759

* significant at 5% level

Appendix 8. Cultivar Rose Coco. Analysis of variance for different characters as affected by the weeding treatments during growth (Second rains of 1979 Experiment).

Source of variation		Weeks from planting	Mean square for: Total plant dry matter	Shoot dry matter	Root dry matter	LAI	No. of branches/ plant	Mean plant height
		4	0.0374	0.0358	0.0002	0.0002	0.1142*	0.4015
		6	2.7999	2.3450	0.0217*	0.0085	0.5809	7.5710
Weedings	5	8	59.8937*	57.5864*	0.0312*	0.0451*	1.5062	14.0239
		10	93.9360*	91.3451*	0.0185*	0.0117*	0.5480*	8.6248
		4	0.0189	0.0152	0.0003	0.0001	0.0079	0.8006
		6	1.0830	0.9550	0.0057	0.0042	0.3262	4.5364
Error	10	8	7.5594	7.5058	0.0046	0.0065	0.5102	8.0701
		10	8.4811	8.5849	0.0049	0.0013	0.1480	5.9992

* significant at 5% level

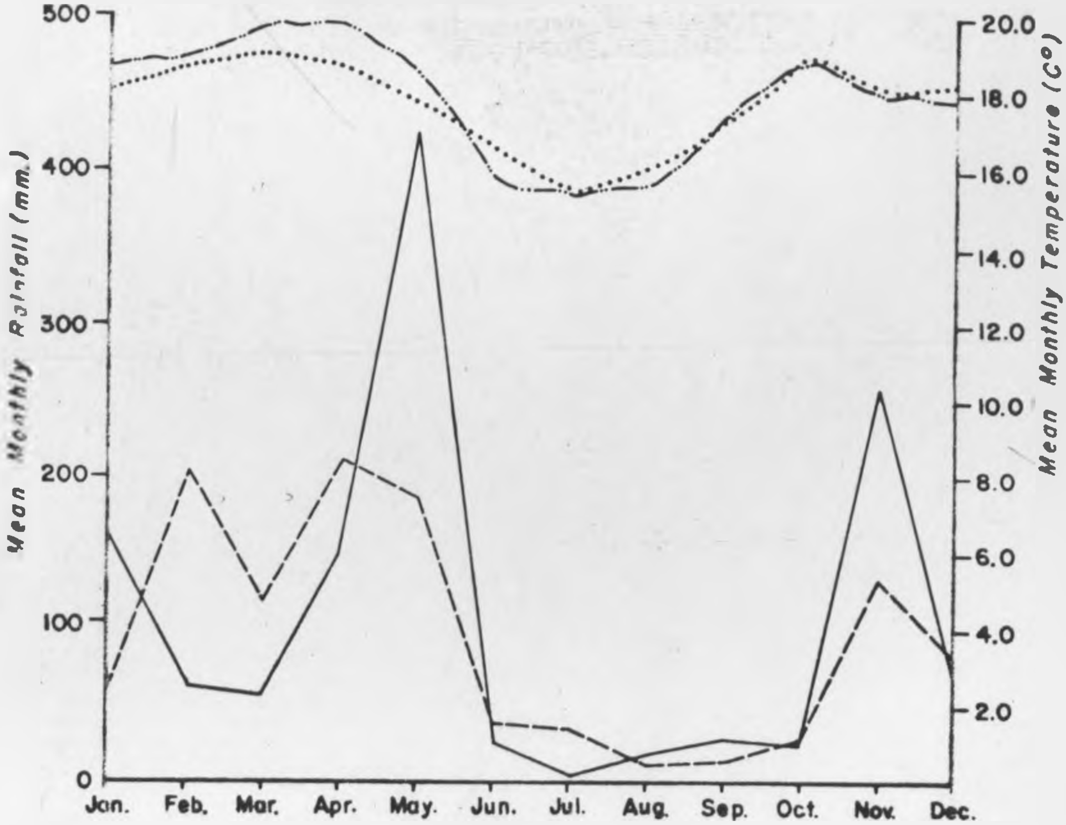
Appendix 9. Cultivar Rose Coco. Analysis of variance for different characters as affected by weeding treatments during the growing period (1980 first rains experiment).

Source of variation	df	Weeks from plan-ting	Mean squares for:							
			Total dry matter/ plant	Dry matter in leaves	Dry matter in stems	Dry matter in reprod. parts	dry matter in roots	LAI	No. of branches/ plant	Mean height
		4	0.8898*	0.4771	0.0277	-	0.0109*	0.0325*	0.8390	7.4317
		6	12.8888*	5.5843*	1.0267*	0.0071	0.0411*	0.2708	2.5880*	33.8188
Weedings	5	8	44.3420*	9.9973*	3.1497*	3.6038	0.0839*	0.4981*	-	24.0107
		10	110.0172	2.3527	2.4794	55.7015	0.0388	0.1726	3.9590*	57.0187*
		12	191.6572*	0.9781	1.5507	126.5553*	0.0564	0.0615	3.6537*	19.4147
		4	0.2252	0.1236	0.0104	-	0.0023	0.0064	0.6168	3.2201
		6	2.8375	1.1199	0.2090	0.0059	0.0113	0.1111	0.7365	16.3199
Error	15	8	13.4253	2.5948	0.9774	1.3095	0.0152	0.1507	-	12.3867
		10	46.7971	2.8913	1.1053	19.4570	0.0405	0.1699	1.1323	14.1333
		12	59.8351	2.1420	0.7614	34.9663	0.0194	0.0491	0.6128	8.4005

* significant at 5% level

Appendix Fig. I: MEAN MONTHLY TEMPERATURE AND RAINFALL FOR 1979 AND 1980

Source: Meteological Station — Field Station (KABETE) University of Nairobi



Mean Monthly Rainfall (1979) Season
Mean Monthly Rainfall (1980) Season
Mean Monthly Temperature (1979) Season
Mean Monthly Temperature (1980) Season