THE EFFECT OF VARIETY, MULCHING AND PLANTING DATE ON THE GRAIN YIELD AND YIELD COMPONENTS OF BEAN (*PHASEOLUS VULGARIS* L.)

BY

WILFRED MARTIN ELIA, B.SC.(AGRIC)(DAR)

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DECLARATION

I, WILFRED MARTIN ELIA do hereby declare to the Senate of the Sokoine University of Agriculture that this thesis has not been submitted for a degree award in any other University.

Signature ....

Date ...27th September, 1984...

ABSTRACT

Kabanima (Kb), Canadian Wonder (CW) and Selian Wonder (SW) bean varieties were investigated on their growth and seed yield as influenced by variety, sowing date and mulching. Mulching promoted effective primary branches/plant, vegetative growth - plant height, leaf number, leaf area, leaf area index (LAI) but depressed plant uptake of Mg and K, shelling percentage, grain yield and water-use efficiency (WUE). Mulching appears undesirable under high soil moisture conditions, it should be encouraged only in arid conditions.

CW gave 154, SW 124% higher grain yield than Kb. CW outyielded SW by 124%. Kb was taller, thicker, had more leaves at maturity, greater leaf area, LAI and total plant dry weight but lower N, K and Mg at blooming, lower pod dry weight, shelling percentage, grain yield and WUE than CW and SW.

Mid-March planting gave the highest grain yield and WUE. Plant height at maturity increased with subsequent sowing date because of increased favourable moisture conditions. Mid-March planting appears the best date of planting beans under Morogoro conditions.

White Mould outbreak in mid-March planting depressed

leaf area and LAI but promoted grain yield. White Mould resistance was observed in two CW plants that exhibited the primitive trailing habit..

Bean leaf N, P, K decreased from seedling to flowering stage in respective values of 4.96 to 4.22%, 0.59 to 0.29% and 5.14 to 2.61%; Ca and Mg increased from 0.72 to 1.37% and 0.60 to 0.63% in the same growth stages, respectively. Nutrient uptake by bean plant is influenced by variety, growth stage and directly or indirectly by soil moisture in different dates and mulches.

Pod yield,shelling percentage, 100 grain weight and seed number/pod and pod length exerted positive influence on grain yield unlike plant height, LAI, leaf number and days to 50% flowering.

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1. INTRODUCTION

1.1 Background

Of the over 200 species of the genus Phaseolus, *Phaseolus vulgaris* is the most important and widespread of the cultivated species. It originated in the New World tropics and has been cultivated for centuries in that part of the world. The crop was introduced early to the rest of tropics and is now one of the most widely grown of the pulses (Cobley, 1956). The Portuguese were probably responsible for the spread of the bean crop to coastal areas of Africa (Greenway, 1945).

Africa produces nearly 1.4 million tons of beans per annum, 61% of this is raised in Eastern Africa - Uganda, Rwanda, Kenya, Burundi and Tanzania. The total bean production in Africa, however, is only 37% of that in Latin America (Londono *et al*. 1980).

Beans are produced in sixteen of Tanzania mainland's twenty regions. Arusha is the largest producer followed by Tanga, Kigoma, Mbeya, West Lake (Kagera), Rukwa, Mwanza, Ruvuma, Morogoro, Iringa, Tabora, Kilimanjaro, Dodoma, Shinyanga, Singida and Mara (Anonymous, 1979a).(Table 1).

Table 1: Trend of bean production in Tanzania between 1963 and 1978.(in metric tonnes).

1963/64	1968/69	1973/74	1976/77	1977/78
92,596	100,999	189,196	286,945	223,397

(Anonymous, 1979(a))

1.2 Importance of beans

Field beans (Phaseolus vulgaris L.) or common bean ranks first in importance among the grain legumes both as a staple food and as a foreign exchange earner in Tanzania (Karel et al.,1980).

As a staple food, field bean is consumed in all the regions of Tanzania and is popular both with the rural and urban populations; it is the most consumed legume in institutions such as colleges, schools and hospitals. The bean has higher nutritive value with a protein content of about 22% (Purseglove, 1974) and a relatively high content of methionine and lysine amino acids than most other pulses (Harvey, 1956; Smart, 1976). Therefore, beans are the cheapest source of proteins for the country's population. The protein content of beans supplements that of cereals, tubers (Bressani and Elias, 1978) and bananas (Karel *et al*., 1980). Beans are a cheap means of combating malnutrition which is rampant among Tanzanian children. The frequency of malnutrition in Maternal and Child Health Clinics between January and June, 1977 alone was 65,334 (TFNC, 1978).

Beans are produced primarily for local consumption, only a small portion is sold to the National Milling Corporation, the sole legal body empowered to purchase and market farmers' produce other than oilseeds and crops under respective crop authorities. Bean purchase by the Corporation has been increasing steadily sinee 1975/76 season except for a slight drop in the 1978/79 season and the large drop in the 1980/81 season. The purchases in metric tonnes increased from 7,784 in the 1975/76 season to 35,225 tonnes in the 1979/80 season and dropped to 16,021 in the 1980/81 season (Anon.1979(a); Anon.1982(a)).

As early as 1937 some farmers in the Northern Region started growing white haricot beans under contract with overseas seed companies for export and for canning (Kunzler, 1957). The bean seed industry ranks sixth in importance among agricultural exports of the country (Karel *et al*., 1980).

Bean seed production for the canning industry a and export has been 252; 2029; 2051; 2553; 172; 9080; 12,271; 4975; 3575 and 25,000 tons in the years 1949, 1950, 1951, 1952, 1957; 1963; 1964; 1965; 1966; and 1980 respectively (Kunzler, 1957; Annual Report - Northern Region 1966; Karel et al., 1980).

Because bean yields in Tanzania are usually very low between 200 to 670 Kg of dry beans per hectare (Jakobsen, 1976) beans are becoming a high value crop in the local markets. From the price trends of beans in the home markets the ever increasing prices show supply falls far short of demand. Prices vary in the villages and in urban areas. Current retail prices for a "Kibaba" (¾ Kg) are Shs.25/- in Mlali Village, Shs.30/- in Morogoro town and Shs.40/- in Dar es Salaam markets, that is, Shs.33.30, Shs.40/- and Shs.53.30 per kilogramme, respectively. The prices in Table 2 are official government prices.

Table 2: Local market prices of beans in Shs./kg 1972-1980.

Beans	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80
Gr. I	0.85	0.85	1.50	1.75	2.00	3.50	3.50	3.50
Gr. II	0.65	0.65	1.30	1.35	1.75	2.75	2.75	2.75

(TFNC, 1980)

1.3 Constraints to increased bean production

1.3.1 Climatological factors

The semi-arid tropics are characterised by seasonal rainfall of only a few months' duration, in some areas the distribution of rainfall is uneven, thus making the growing of beans limited. Over 60% of the arable land in Tanzania gets rainfall below 750 mm per annum (Griffiths, 1969; IBRD, 1974). Since rainfall in the arid or semi-arid areas is characterised by heavy downpours of short duration (Arnon, 1975) it is a common phenomenon for half the annual precipitation to occur in only 10 to 15 per cent of the rainy days (White, 1966). Thus, even though maximum bean production is said to occur when 300-400 mm of evenly distributed rainfall in the growing season (Macartney and Wilson, 1966), the high potential evapotranspiration (PET) of the crop in the tropics in excess of rainfall or other precipitation at any given time often brings severe water deficits in the crop plants, which eventually lowers the water use efficiency (WUE) of the crop due to decreased grain yield. WUE is defined as the yield of marketable crop produced per unit of water used in evapotranspiration and is given by the relationship $\frac{Y}{ET}$ where, Y = yield of marketable crop and

ET = evapotranspiration or "seasonal water use" (Arnon, 1975).

1.3.2 Biological factors

Beans grown in Tanzania are traditionally of a natural genetic mixture called "mixed beans" which have great diversity in seed colour and size; the majority are determinate with bush type growth habit, a few, however, are indeterminate non-climbing semi-bush types and indeterminate climbing (Acland, 1971). Only a few small scale farmers grow pure line varieties such as Canadian Wonder and Selian Wonder. The majority of bean cultivars grown by farmers are low yielders on account of pest and disease susceptibility (Karel, *et al.* 1980). The major bean pests of economic importance are known to cause substantial grain yield reductions. Misangu (1982) reported significant seed yield increments on sprayed treatments - the values were 3.2 and 2.5 quintals/hectare for the sprayed and non-sprayed treatments respectively. Bean grain yield reductions of 18.31% were recorded due to foliar damage by *Ootheca bennigseni* (Karel and Rweyemamu, 1983).

In Tanzania the major bean pests are the bean fly (*Melanagromyza phaseoli*), *Ootheca bennigseni*, the bean aphid (*Aphis fabae*) spotted borer (*Maruca testulalis*) flower thrips (Taeniothrips sjostedti) and American bollworm (Heliothis armigera).

Diseases are agreat drawback on the productivity of beans, perhaps more so than insect pests in most parts of Tanzania (Karel et al., 1980). In Tanzania the most serious diseases include Anthracnose (Collectotrichum lindemuthianum), Angular leaf spot (Isariopsis griseola Sacc), bean rust (Uromyces appendiculatus), Halo blight (Pseudomonas phaseolicola) and Bean common mosaic virus (Marmor phaseoli) (Acland, 1971; Karel et al.,1980).

It is therefore important that when breeding for high yield in beans genes conferring resistance to diseases and insects be identified and incorporated in the new varieties. Since most Tanzanian small scale farmers still intercrop beans with other crops like maize more research work on the breeding and agronomy of varieties adaptable to small farmers' field situations remains to be done.

1.3.3. Consumers' tastes and preferences

Due and Manday (1983) in their comparative analysis of bean varieties grown in Arusha region observed that palatability was a major factor limiting bean production; the most palatable variety irrespective of its yield performance is the most preferred and grown by farmers. Maasai Red variety in this case was the most palatable followed by Canadian Wonder. Thus, breeding for high bean yield should incorporate palatability and other consumers' tastes and preferences like seed coat colour. The black seeded variety P311-AL though a high yielder and resistant to rust, angular leaf spot and mosaic has no appeal to farmers (Anonymous 1979, Anon. 1982).

Due and Manday (1983) further found that the high storability of the seed grains of dry beans had a higher preference by farmers to low storability. The Maasai Red for instance, was far superior in storability of dry beans than Canadian Wonder and the other varieties, local and 'White'. Hence storability is among the factors limiting bean production in the tropics because of damage of seed by storage pests. Improvement in storage facilities and storability of the dry beans will inevitably lead to more acceptance by farmers of high yielding genotypes.

1.3.4. Infrastructural support

There is at present poor infrastructural support in the overall bean industry in Tanzania. There are, for instance, inadequate agricultural training institutions which has resulted in few research and extension staff being involved specifically in the bean industry (Anon. 1975). The situation is, however, improving on the part of researchers, with introduction of the National Grain Legume Improvement Project and establishment of the Bean Improvement Programme in 1979. Currently the training and research facilities in beans in Tanzania include Uyole Agricultural Centre, TARO Lyamungu, TARO Maruku, MATI Ukiriguru, TARO Ilonga and the Sokoine University of Agriculture at Morogoro.

There is no policy in the Ministry of Agriculture to date protecting farmers from the many risks involved in crop production. The bean crop is not insured and, thus, it remains purely an individual farmers' venture in shaping his production in relation to his needs and any market demand possibilities nearest to his production area. This has led to disorganized production and marketing pattern of the crops. Moreover, supply of inputs such as insecticides, fungicides, fertilizers and tools of production such as tractors which are necessary in increased bean production have not been readily available. Increased use of improved varieties and other inputs is inevitable if higher bean production is to be realised in Tanzania. Therefore, central planning in the direction of bean production and accompanying input supply and expertise in the country is vital to provide a strong base for the country to boost its bean production.

The transport network, both railway and road is still poor and often times transportation in Tanzania is hit by oil (energy) crisis and shortage of vehicles and wagons. This greatly discourages potential farmers who would like to venture in crop production. Improvement of the transport infrastructure would greatly stimulate potential farmers to enter into bean production.

Capital is another prime factor limiting increased bean production in Tanzania (Podedworny, 1973). When the farmer's purchasing power is exposed vis-a-vis current costs of fertilizers, insecticides, fungicides and other agro-inputs great economic constraints are felt by the farmer. The farmers' credit agencies in the country such as the Tanzania Rural Development Bank (TRDB) and the National Bank of Commerce (NBC) which are operated on strict commercial lines give loans at high interest rates of approximately 8% (Anonymous, 1980). The high interest rates demanded by the banks militate against the increased investment of such credits in bean production. There is need, thus, to deliberately provide soft loans to farmers in order to boost the country's bean output.

1.3.5 Agronomic practices

Increased use of agro-inputs is vital in bean farming. It is not, however, a panacea to increased bean yields, only when it is coupled with proper agronomic practices is maximum exploitation of the bean genotypes in respective agro-climatic regions achieved.

Lack of timeliness of sowing is a great constraint in bean yields. Timely planting (especially early planting) is crucial in the semi-arid and arid tropics for the crop plants to utilise the seasonal precipitation (White, 1966; Acland, 1971). In rain-fed agriculture soil moisture becomes limiting to crop yields with delay in planting. Mulching helps to conserve soil moisture (Swai, 1973, Lal, 1974, Masseri and Jana, 1977, Mashina and Jana, 1978). Other agronomic practices limiting increased bean production include lack of use, or, inadequate use, of pesticides such as insecticides, fungicides, herbicides and soil sterilants such as ethylene dibromide (EDB), too wide spacings resulting in low plant populations, improper and, or, untimely weeding, use of unimproved varieties. Increased use of pesticides at recommended doses, optimum spacings and plant populations per hectare, timely weedking and use of improved recommended varieties will greatly boost bean production in Tanzania.

This study was conducted with the objectives of:-

1. Investigating the yield and yield components of three commercial bean varieties as influenced by different sowing dates and two mulching treatments.

2. Determining the best time of planting beans under rain-fed conditions in Morogoro.

3. Assessing a practical remedial measure of mulching in countering moisture stress under rain-fed situation at critical plant developmental stages in order to increase bean grain yields.

2. LITERATURE REVIEW

2.1 Effect of sowing date on bean grain yield and its components

The time of planting in relation to the start and duration of the wet season and distribution of rainfall is of decisive influence on the grain yield of beans. Beans of determinate habit should be sown at a time which will allow them to mature in dry weather in order to avoid disease infestation and rotting. This is especially true for beans produced for seed industry and for canning.(Acland, 1971).

Experiments on the effect of sowing time on bean seed yield under rainfall conditions at Lambo and Arusha seed farm showed that early planting (early March) of bean varieties P311-AL and Canadian Wonder gave significantly higher grain yields than late planting (mid-May)(Anonymous, 1982). There was drastic reduction in the 100 seed weight, at Lambo of Canadian Wonder from 57 to 46g in the first and second planting, respectively. Work on the suitable time of planting beans at the Faculty of Agriculture, Morogoro for bean producing areas below 1000 metres above sea level, showed early planting gave higher seed yields. Drastic grain yield reductions of 50% were noted by Misangu (1982) while Karel (1982) observed over 50% seed yield reduction for the later planted crop. Observations at higher altitudes above 1000 metres above sea level also showed seed yield was markedly decreased by delay in sowing (Spurling, 1973, Mkuchu, 1982). In Kenya, Fisher (1980) noted that yield declined with delayed sowing; he found that the most important components determining planting date effects on yield were number of pods/plant and seeds/pod. Fattah, et al. (1974) observed a decline in weight of green pods/plant with late sowing.

Studies by Ishag and Ayoub (1974), however, showed that early planting resulted in very low seed yields, this was attributed to fewer plant survival; high ambient temperatures increased plant mortality. They noted that the number of plants/m^2 was primary in determination of grain yield and that the number of pods/plant was insufficient to compensate for plant loss.

2.2 Effect of soil moisture on seed yield and its components

In order to realise maximum grain yield of beans adequate soil moisture should be available from emergence to flowering. Severe moisture stress from emergence to flowering causes the shedding of the majority of flowers and small pods hence, severely lowering bean yields (Gabelman and Williams, 1960). Gabelman and Williams (1960) observed that maintaining available soil moisture at 50% level during flowering gave good grain yields; irrigation at flowering stage reduced flower and pod abscission and increased pods and seeds.

Robins and Domingo (1956) recorded 20% grain yield reductions of dry field beans due to soil moisture stress just perior to and during blooming; there was also reduction in number of pods and number of seeds per pod during flowering and a reduction in bean seed weight during maturing process. There was a retardation in plant development by stress before flowering and a hastening during blooming and maturing.

Ormrod (1979) noted apparent ammonium toxicity, in terms of visible injury and reduced bean plant height and weight, was generally accentuated by high water stress prior to ammonium application and to a lesser extent by cooler night temperature.

High or low moisture stresses can influence physiological processes, plant development and susceptibility to plant pathogens. A low soil moisture content can damage plants due to the unavailability of water for plant roots, the accumulation of toxic ions such as magnesium or boron, stomatal closure, restricted uptake of carbondioxide and temporary or permanent plant wilt (Anonymous, 1968).

High soil moisture and flooding may leach important nutrients for normal plant development, reduce oxygen content, induce general plant chlorosis and increase levels of toxic by-products from anaerobic metabolism, if combined with high temperatures, they may increase the rate of respiration (Anon.1968; Walker, 1969; Zaumeyer and Thomas, 1957).

A grain yield reduction of 20% was observed when bean plants were kept 14 days without irrigation. After 17 and 20 days without irrigation during the reproductive period, yield reduction of 38 and 52% respectively were observed (Magalhaes and Miller, 1978); after 20 days yield reductions remained constant until 29 days of water stress. By using the period of greatest response to water stress, Magalhaes and Millar (1979) observed that it is possible to obtain the relationship between relative grain yield and soil matrix potential, which is important in defining the operational level of for irrigation management.

Several other workers have noted the crop sensitivity to variations in soil moisture during the stages of flowering and pod filling, water stress resulting in highly significant lowering of yield (Hoffman *et al.* 1978; Giralt, 1979 and Diaz *et al.* 1981). Diaz and Castillo (1981) concluded that during blooming (28-30 days for the early naturing varieties) and pod filling (48-50 days) soil moisture tension should not be higher than 35 centibars.

Pod yield of Galegreen and Eagle snap bean cultivars irrigated when the soil moisture tension reached 0.25 bar averaged 11.9 t/ha, and irrigation at tensions of 0.5 and 0.75 bar reduced this yield by 41 and 48%, respectively; a 0.75 bar stress applied preblossom at flowering, or at pod development reduced pod yield by 25% in both cultivars (Stansell and Smittle, 1980).

2.3 Effect of soil moisture and temperature on nutrient uptake

Plant nutrient availability as influenced by soil moisture from the standpoint of root interception, mass flow and diffusion has been well discussed (Barber, 1962). Nutrients such as P and K, which move to roots by diffusion become limiting, when plants are under water stress, despite the fact that their supply in the soil is abundant. The concentrations of N, P and K in maize leaves was observed to decrease as plant moisture stress increased (Voss, 1970). Work by Cattini (1974) showed that bean height and water content had a direct correlation with the bean leaf K concentration. Charles *et al.*(1982) observed that N and P uptake by bean plants decreased as the osmotic potential increased.

Moisture supply and temperature alter the chemical solubility of nutrients for example P and K in soils and also the use that plants make of them. Large amounts of K are removed by most crop plants and soluble K measured in repeated analyses decreases as the season progresses (Cooke, 1975). Weber and Caldwell (1964) found low temperature lowered K availability for sorghum. Similar results were found by Nielsen *et al.*(1961) who studied the influence of temperature on nutrient concentrations of several crops. Simini and Leone (1982) found that Cl uptake by leaves of *Phaseolus vulgaris* was enhanced by low temperature ($10^{o}C$) and high relative humidity. Growth of *Phaseolus vulgaris* is favoured by moderate air temperature, warm soils, and adequate soil moisture but is restricted by cold or hot temperature, deficient or excessive water (especially the latter), and is not strongly modulated by irradiation (Wallace, 1978).

2.4 Effect of mulching on bean

Lal *et al.*(1975) have shown that mulching decreases soil temperatures, conserves moisture, prevents erosion and replenishes the soil by addition of nutrients. On erosion control on tropical soils mulching has been shown to have a distinct advantage in that it prevents the rain drop direct impact on the soil and also minimizes the runoff losses by increasing the soil infiltrability.

Miayasaka (1966) and Nazrala *et al.*(1976) observed that all legume green manures increased bean seed yields regarding the control in which green manure was not incorporated. In trials in the Zona da Mata region, Brazil, bean grain yields were 1.37 and 1.31t/ha in plots mulched with *Melinis minutiflora* or rice husks, respectively, compared with 0.87 for unmulched controls (Nogueira *et al*.1973). Mulching with aluminium foil and rice straw significantly increased bean seed yields and repelled the leafhopper (*Empoasca kraemeri*)(Hohmann *et al*.1979; Cardona *et al*. 1981). Cardona and his co-workers noted that aluminium foil and rice straw mulches significantly reduced adult leafhopper populations for at least 30 days after planting, they showed this regulatory effect as being directly related to the amount of light reflected by the mulch under study; the Al foil which reflected 20.3% of the light, effectively repelled adult leafhoppers, whereas the black plastic, with only 5.3% light reflection did not. Similar results were obtained by Cruz (1981) who found that the highest number of *Empoasca kraemeri* nymphs seen in plots treated with black plastic mulch and the highest bean yield was recorded in plots with silver plated plastic mulch.

Work by Galindo *et al*.(1983) on the effect of mulching on web blight (*Rhizoctonia solani*) showed that mulching was highly effective and superior to chemical treatments for the control of web blight. Mulching with rice husks (2.5cm thick) greatly reduced the splashing of inoculum and lowered disease severity, it significantly increased bean grain yields.

3. MATERIALS AND METHODS

3.1 Location

The experiment was conducted in the 1983 rainy season at the University Farm, Morogoro, near the Crop Museum area. The area is located at Latitude 6° 20'S Longitude 37° 39'E and altitude 525.8 metres above sea level near the foothills of the Uluguru Mountains. It is a typical rainshadow area as it is on the leeward side of the mountains. The University Farm receives very erratic rains of bimodal type, the short rains falling between end of October to late January, followed by a dry spell in February, and long rains between March and May. The average annual rainfall is 800mm. The Farm is, thus, a typical representative agro-climatic area of the semi-arid tropics.

High day temperatures above 31°C occur in October to December and February while low night temperatures of around 15°C occur in June, July and August; July figure is below 15°C.

The soil is an oxisol and texturally a kaolinitic sandy clay loam with a pH of 6.1. Ca, Mg and K are predominant cations with a cation exchange capacity of 19 m.e./100g of soil and an organic carbon of 1.6%.

3.2 Experimental Details

This study of the effect of variety, mulching and planting date on the grain yield and yield components of bean (*Phaseolus vulgaris* L.) was done with the aim of investigating three bean varieties on their grain yield and yield components as influenced by 4 planting dates 25/2/83, 15/3/83, 26/3/83 and 8/4/83 designated as D_1, D_2, D_3 and D_4, respectively and two mulches of 11kg dry grass (9,167 tonnes/ha) and 0kg/ha designated as M_1 and M_o, respectively. This was a 3 x 2 x 4 factorial experiment in a randomized complete block design (RCBD) of 4 replications in plot sizes of 4m x 3m = $12m^3$ and a harvest area of 3m x 1m = $3m^2$. The spacing was 50cm x 10cm, leaving one plant/hole thus maintaining a plant population of 200,000/ha. The treatments included three bean varieties of Kabanima, Canadian Wonder, Selian Wonder, two mulching treatments and four dates of planting. The total number of treatments was 24. The field layout was as shown in Appendix 8.

Field Operations

The land was disc ploughed and harrowed in early February, 1983. Composite soil samples were then collected randomly from the site for analysis before planting.

Sowing was done according to the specified dates above. Two seeds were sown per hill then thinned to one plant/hill, one week after emergence of each planting date. Thinning was done on 27/3/83, 7/4/83 and 21/4/83 for D_2, D_3 and D_4 respectively. Crop establishment was too low for D_1 to warrant thinning. To maintain good soil fertility, fertilizers were used at rates of 60kg N and 26.4kg P/ha applied as ammonium sulphate and triple superphosphate (TSP), respectively. TSP was applied at planting, Nitrogen was top dressed in two split applications of 30kg N/ha each that is at 10 days after emergence and at 28 days after planting (DAP). The application dates were 21/3/83, 31/3/83m 11/4/83 and 24/4/83 for D_1, D_2, D_3 and D_4 respectively for the first split and 25/3/83, 12/4/83, 25/4/83 and 6/5/83 for the second split. Weeding was done by hand one or two days before N application in each split.

Ootheca bennigseni prevalent in the experimental plots was controlled by spraying Endosulfan 35 at the rate of 750g.a.i./ha at 12-14 and 28 DAP in each date except D_1. Similarly, fungal disease control was done by spraying benomyl at the rate of 1g.a.i./ml of water at 28 and 38 DAP in each date.

Harvesting was done in 13/6/83 for D_1 and D_2; 30/6/83 and 13/7/83 for D_3 and D_4, respectively when the pods had completely dried. Only the middle 2 rows in each plot were harvested after counting the number of plants to be harvested. A 50 x 100cm guard row area in each plot was left unharvested.

The calculations of grain yield and yield components were based on the harvested area of $3m^2$.

3.3. Data collected. The following measurements and observations were made.

3.3.1 Date of 50% emergence. This was observed in all plots and in all four dates of planting. Date of 50% emergence here refers to the date in which 50% of the cotyledons of the seedlings were lifted above the ground surface.

3.3.2 Moisture tension at 10,20,30,40 and 50 days after emergence

Tensiometers were used after calibration. The porous portions of the tensiometers were installed 15cm below the soil surface. Gypsum blocks were also used, these were likewise installed at 15cm depth in the soil. The tensiometers registered direct soil suction in centibars whereas the gypsum blocks electrical resistance in milliohms and the per cent available soil moisture in connection to a soil moisture meter. All these installations were made between rows at the centre position of each plot where moisture in the soil was to be assessed. However, all calculations for WUE were not based on these readings - but on Blaney-Criddle method.

3.3.3 Plant height (cm) Three plants were randomly picked and measured at the seedling stage, flowering stage and at maturity stage from the ground level to apex of the main stem; the average gave the plant height for the respective treatment.

3.3.4 Days to 50% flowering

In every plot the date on which 50% of the bean plants flowered was recorded; the days from sowing to the date of 50% flowering were then calculated these gave the days to 50% flowering.

3.3.5 Leaf area (cm^2) at flowering or early pod formation. Leaf area/plant was determined from two plants randomly sampled from each plot at the flowering or early pod formation stage using the Electronic Leaf Planimeter. Dividing the leaf/plant by the ground area covered by one plant gives the Leaf Area Index for that respective plot.

3.3.6 Grain yield (tonnes ha^{-1})

Grain yield (g) per harvest area ($3m^2$) in a plot was taken and divided by the number of plants in the harvest area to give the grain yield (g)/plant in the respective plot: The mean grain yield was based on the actual number of plants established in the plots.

3.3.7 Pod yield (tonnes ha^{-1})

The procedure was as in 3.3.6 above.

3.3.8 100 grain weight (g)

One hundred grains were taken from each plot and weighed; this gave the 100 grain weight.

3.3.9 Shelling percentage

Grain yield over pod yield expressed as a percentage gave the shelling percentage. In statistical analysis, angular transformation was employed to the shelling percentage whereby Angle = $\sqrt{\text{Arcsin} \times \%}$

3.3.10 Number of primary branches per plant

Two plants from the harvest area were randomly taken and for each plant the number of branches originating from the main stem was counted. The average gave the number of primary branches per plant.

3.3.11 The number of effective primary branches per plant

A count was made on the number of primary branches bearing pods in each of the two plants. The average gave the number of effective primary branches per plant.

3.3.12 Number of seeds/pod

Five pods randomly picked from each of two plants had their seeds counted. The total number of seeds of 10 pods divided by 10 gave the number of seeds/pod.

3.3.13 Pods length (cm)

All pods from two randomly sampled plants were harvested then measured. The total length (cm) divided by the total number of pods measured gave the average pod length (cm).

3.3.14 Stem diameter (cm)

Measurement of the diameter of the stem was done at the first internode above the ground on the main stem.

3.3.15 Disease incidence

Observations and recording of the most prevalent diseases was done. A disease scoring scale of 0-4 was used to assess disease incidence in the plots; 0 - free from infection or nearly so, 1 - trace - 25% leaf area killed, 2 - 26-50% leaf area killed, 3 - 51-75% leaf area killed and 4 - 76-100% leaf area killed (Horsfall and Heuberger, 1942). Dates of scoring were 21/4/83 at 56 DAP, 24/4/83 at 30 DAP, 21/5/83 at 56 DAP and 25/5/83 at 47 DAP for D_1, D_2, D_3 and D_4 respectively.

3.3.16 Number of leaves/plant at maturity

A count of leaves in two randomly sampled plants in each plot at maturity stage and dividing the total by two gave the number of leaves/plant at maturity.

3.3.17 Total dry matter (TDM) of plant (oven-dry weight)

Two plants at harvest were oven-dried and their weights determined. The average gave the TDM of a plant.

3.3.18 Dry weights of leaves, branches, roots and pods/plant

These dry matters were calculated from the two plants; the average of the two plants gave the required dry matter for each individual plant parameter.

3.3.19 Plant analysis

Nutrient composition of bean plants was done at seedling stage for planting dates 3 (26.3.83) and 4 (8.4.83) and at the flowering stage for sowing dates 1, 2, 3 and 4, that is 25.2.83, 15.3.83, 26.3.83 and 8.4.83. Sampling plants for chemical analysis was done at around 11.00 a.m. when plants were actively photosynthesizing. At the seedling stage all the above ground portion of the plant was taken before plants were 10 days old after emergence, At full bloom, the plant part sampled was the third leaf from tip fully expanded, petioles were discarded. Three leaves were randomly picked in each of the 6 rows in a plot then two more from any row. A total of twenty leaves were picked per plot. These were oven-dried for three days at 80 ^{o}C then ground in a mortar by crushing with a pestle.

(i) Total Nitrogen

The micro-Kjeldahl Method as outlined by Juo, 1979 was followed.

(ii) Total P

Dry-ashing of the plant samples in a muffle furnace was done then P was determined colorimetrically using the Vanado-Molybdate Method.

(iii) Total K, Ca and Mg, Na (Benton Jones and Steyn, 1973)

Dry-ashing of plant samples in a muffle furnace and preparation of filtrates was done as outlined by Juo, 1979. The filtrates were read in the Atomic Absorption Spectrophotometer for the respective cation.

3.3.20 Soil analysis The methods employed are in brackets.

(i) pH-pH meter (Dewis and Freitas, 1970)

(ii) Organic carbon (Black and Walkley's method - Allison, 1965)

(iii) C.E.C. exchangeable bases Mg, Ca, K, Na (Atomic Absorption Method)

(iv) Total N (Macro-Kjeldahl Method - Bremner, 1965)

(v) Available P (Bray and Kurtz Method No.1 - 1945 as outlined by Uriyo and Singh, 1974).

4. RESULTS

4.1 Plant architecture and flowering

4.1.1 Emergence

The mean 50% emergence for all plots in dates of planting 2, 3 and 4 occurred after six days. There was erratic germination in the first date of planting due to scanty available soil moisture. At 7 days after sowing in D_1, the tensiometer installed in the experimental plots registered a soil suction of 21.3 eentibars for the mulched plots and 29.5 for the unmulched plots; the gypsum blocks showed 88.5% available soil moisture and 79.5% for the mulched and unmulched plots, respectively. Mean days to 50% germination for D_1 occurred after 14 days after planting (Fig.1).

4.1.2 Flowering

There were highly significant differences between the dates and varieties ($P \leqslant 0.05$) in the days to 50% flowering. The greatest variation was found between D_1 and other dates. 50% flowering occurred after 45 days for the first planting and this was significantly different from dates 2, 3 and 4 whose 50% flowering occurred after 32 for D_2 and D_3, and 31 days

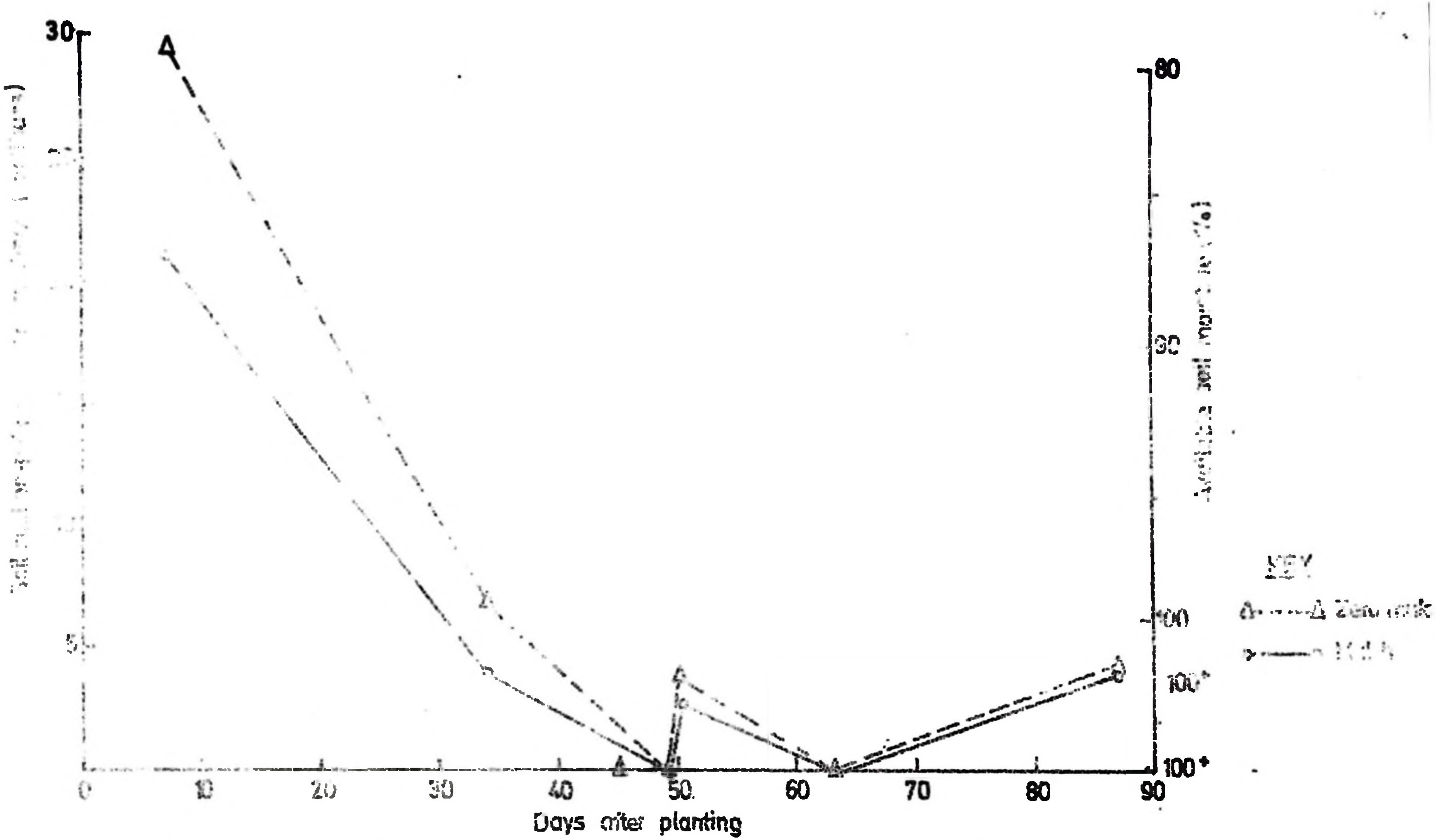

Fig.1. Effect of mulch on soil suction and available soil moisture in bean plots planted on 25-3-1983

for D_4. For D_1 the days to 50% blooming was 48 for Kabanima, and 43 for either Canadian Wonder or Selian Wonder. Delayed germination in D_1 resulted in delayed flowering. The D_4 planting, however, had the earliest days to 50% blooming and these were 34, 29 and 29 for Kabanima, Canadian Wonder and Selian Wonder, respectively. Overall Kabanima flowered 5 days later than Selian Wonder and Canadian Wonder (Table 3).

4.1.3 <u>First internode diameter</u>

There were significant differences ($P \leqslant 0.05$) in variety and mulching. Kabanima with 0.81cm stem diameter at first internode had significantly greater diameter than Selian Wonder with only 0.70cm. Mulched plants had significantly larger stem diameters at first internode than zero-mulch plants which measured 0.80 and 0.70cm, respectively. Significant interactions between mulching and dates of planting also existed (Table 4).

4.1.4 <u>Plant height</u>

There was a slow initial growth in plant height in the first week after emergence, then increasingly faster growth up to 14 days after emergence; followed by an exponential plant height increase up to flowering.

Table 3: Days to 50% flowering (days after planting)

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	48	43	43	45
	M_o	48	43	43	45
D_2	M_1	35	31	31	32
	M_o	35	31	30	32
D_3	M_1	36	30	30	32
	M_o	36	31	31	33
D_4	M_1	34	29	29	31
	M_o	34	29	29	31
Overall mean		38	33	33	35

$LSD_{0.05}$ Date = 1,92

Variety = 1.66

Table 4: Stem diameter(1st internode diameter) cm.

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.88	0.63	0.88	0.80
	M_o	0.83	0.75	0.50	0.69
D_2	M_1	0.83	0.98	0.63	0.81
	M_o	0.63	0.65	0.55	0.61
D_3	M_1	0.80	0.63	0.70	0.71
	M_o	0.83	0.73	0.85	0.80
D_4	M_1	0.83	0.90	0.88	0.87
	M_o	0.88	0.63	0.58	0.70
Overall mean		0.81	0.74	0.70	0.75

$LSD_{0.05}$ Variety = 0.08

Mulching = 0.07

Interaction D x M = 0.13

There was plant height increase at a decreasing rate from flowering to pod filling and maturity stage (Fig.2. Table 5).

Significant differences ($P \leq 0.05$) existed in the later stages of plant growth between the dates, varieties and the date x variety (D x V) interaction. Overall the mean plant height at maturity increased with subsequent date of sowing. D_4 differed significantly from D_3, D_2 and D_1 - their respective plant heights were 53.33, 47.62, 42.92 and 39.41cm. D_3 also had significantly taller plants than the first planting. Kabanima had significantly greater plant height than either Selian Wonder or Canadian Wonder; their stature were 49.94, 44.81 and 42.72cm, respectively. Though not significant mulched plots had taller plants, 47.44cm, than non-mulched ones, 44.21cm.

4.1.5 Primary branches plant^{-1}

Significant variations ($P \leq 0.05$) were noted in the date and mulching treatments. For mulched treatments D_4 and D_1 had significantly higher number of primary branches than unmulched ones; their values were 11.15 and 9.21, respectively. Overall mulched treatments had more effective primary branches than unmulched plots, 8.08 and 6.97 respectively (Table 6

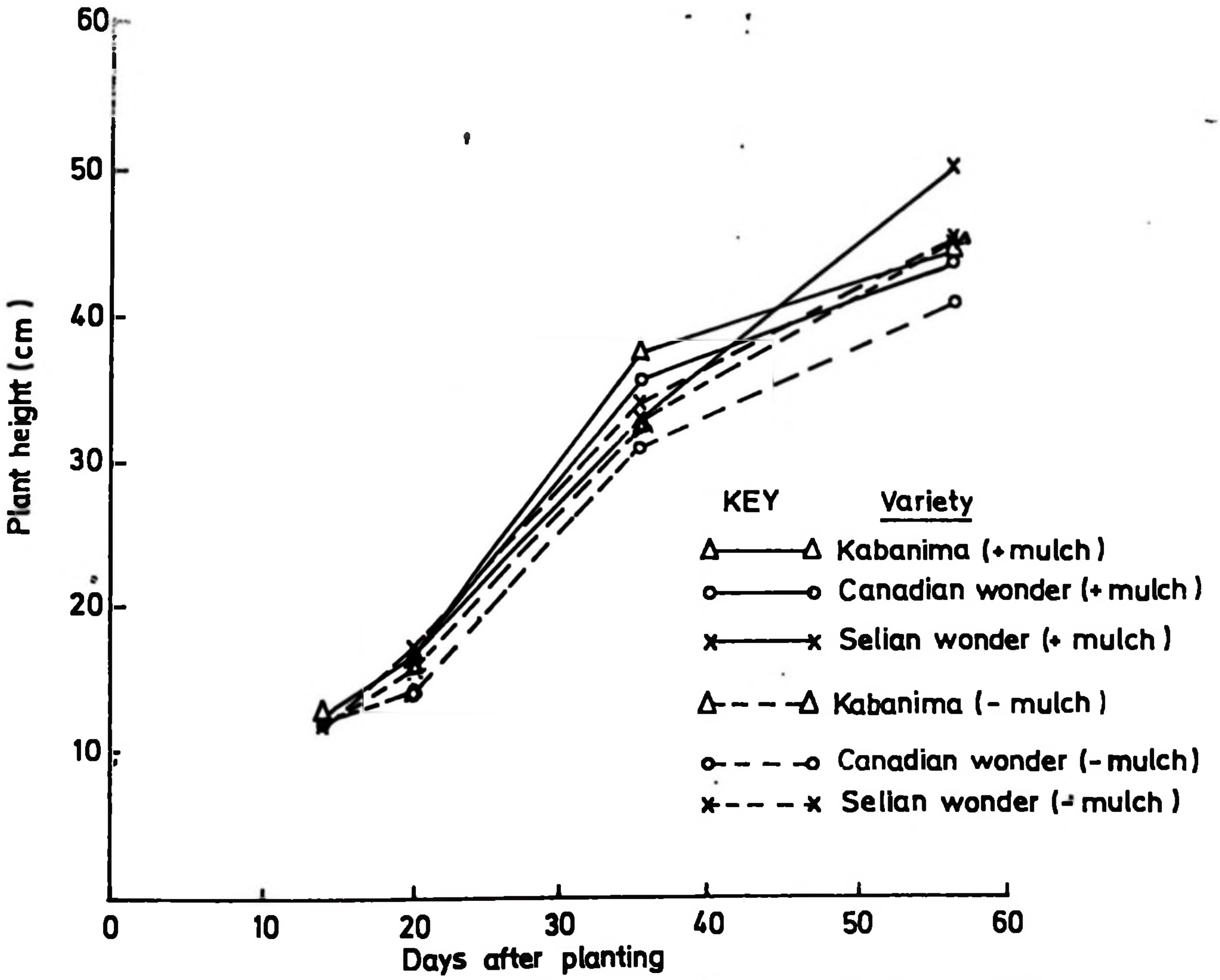

Fig.2. Bean plant development: Mulch & Unmulched plots for planting date 3

Table 5: Plant height at maturity (cm)

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	43.00	34.25	37.75	38.33
	M_0	42.50	43.00	36.00	40.50
D_2	M_1	53.50	41.75	40.25	45.17
	M_0	51.25	37.75	33.00	40.67
D_3	M_1	50.25	38.50	54.75	47.83
	M_0	53.25	42.00	47.00	47.42
D_4	M_1	54.75	58.50	62.00	58.42
	M_0	51.00	46.00	47.75	48.25
Overall mean		49.94	42.72	44.81	45.82

$LSD_{0.05}$

Dates = 5.25

Varieties = 4.55

Interaction, D x V = 9.09

and Table 7).

4.1.6 Number of leaves plant^{-1} at maturity

D_1 had the highest number of leaves (12.67) at maturity compared with D_4 which had 7.79 and D_2 with only 6.04. An outbreak of White Mould (*Sclerotinia sclerotiorum*) which was most severe in the second planting, a few days after flowering, significantly reduced the number of leaves at maturity in both Selian Wonder and Canadian Wonder. Kabanima variety highly out-performed both Canadian Wonder and Selian Wonder in retaining many leaves at maturity(Table 8).

4.1.7 Leaf Area Index at flowering

Kabanima had significantly higher ($P \leq 0.05$) leaf area than either Canadian Wonder or Selian Wonder. The fourth planting had the highest leaf area while D_2 the lowest. The LAI for Kabanima was 5.8, 3.37 for Canadian Wonder and 2.8 for Selian Wonder.

4.2 Dry matter production and distribution

4.2.1 Total dry matter plant^{-1} at maturity

Date variety and the interaction D x M were all significant ($P \leq 0.05$). The first planting had the highest total dry matter per plant (40.55g) and this

Table 6: Number of primary branches $plant^{-1}$

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	11.75	9.75	12.00	11.17
	M_0	14.25	9.75	8.00	10.67
D_2	M_1	13.00	13.25	8.25	11.50
	M_0	8.50	7.75	8.00	8.08
D_3	M_1	11.25	7.50	9.00	9.25
	M_0	8.25	8.25	9.75	8.75
D_4	M_1	13.00	12.50	12.50	12.67
	M_0	7.50	11.00	9.50	9.33
Overall mean		10.94	9.97	9.62	10.18

$LSD_{0.05}$ Dates = 1.62

Mulching = 1.15

Table 7: Number of effective primary branches plant^{-1}

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	7.25	9.00	11.50	9.25
	M_o	10.50	6.75	5.50	7.58
D_2	M_1	10.25	7.75	6.00	8.00
	M_o	6.50	6.50	6.00	6.30
D_3	M_1	9.00	5.00	7.25	7.08
	M_o	7.25	6.50	8.50	7.42
D_4	M_1	7.00	8.75	8.25	8.00
	M_o	6.25	6.00	7.50	6.58
Overall mean		8.00	7.03	7.56	7.53

$LSD_{0.05}$ Mulching = 0.88

Table 8: Number of leaves $plant^{-1}$ at maturity

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	30.75	4.50	7.25	14.17
	M_0	18.50	12.00	3.00	11.17
D_2	M_1	19.25	2.50	0.50	7.42
	M_0	9.25	2.25	2.50	4.67
D_3	M_1	17.50	6.25	3.50	9.08
	M_0	18.25	4.00	5.80	9.35
D_4	M_1	8.25	8.75	7.75	8.25
	M_0	10.25	5.75	6.00	7.33
Overall mean		16.50	5.75	4.50	8.92

$LSD_{0.05}$ Date = 3.86

Variety = 3.34

Table 9: Leaf Area Index

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	4.17	1.54	1.32	2.34
	M_0	5.06	2.37	2.16	3.20
D_2	M_1	6.25	2.26	1.96	3.49
	M_0	3.20	0.97	0.89	1.69
D_3	M_1	5.07	4.00	2.53	3.87
	M_0	6.46	2.88	3.06	4.13
D_4	M_1	8.49	7.14	5.24	6.96
	M_0	7.73	5.77	5.27	6.26
Overall mean		5.80	3.37	2.80	3.99

$LSD_{0.05}$

Date = 0.97

Variety = 0.84

Interaction D x M = 1.38

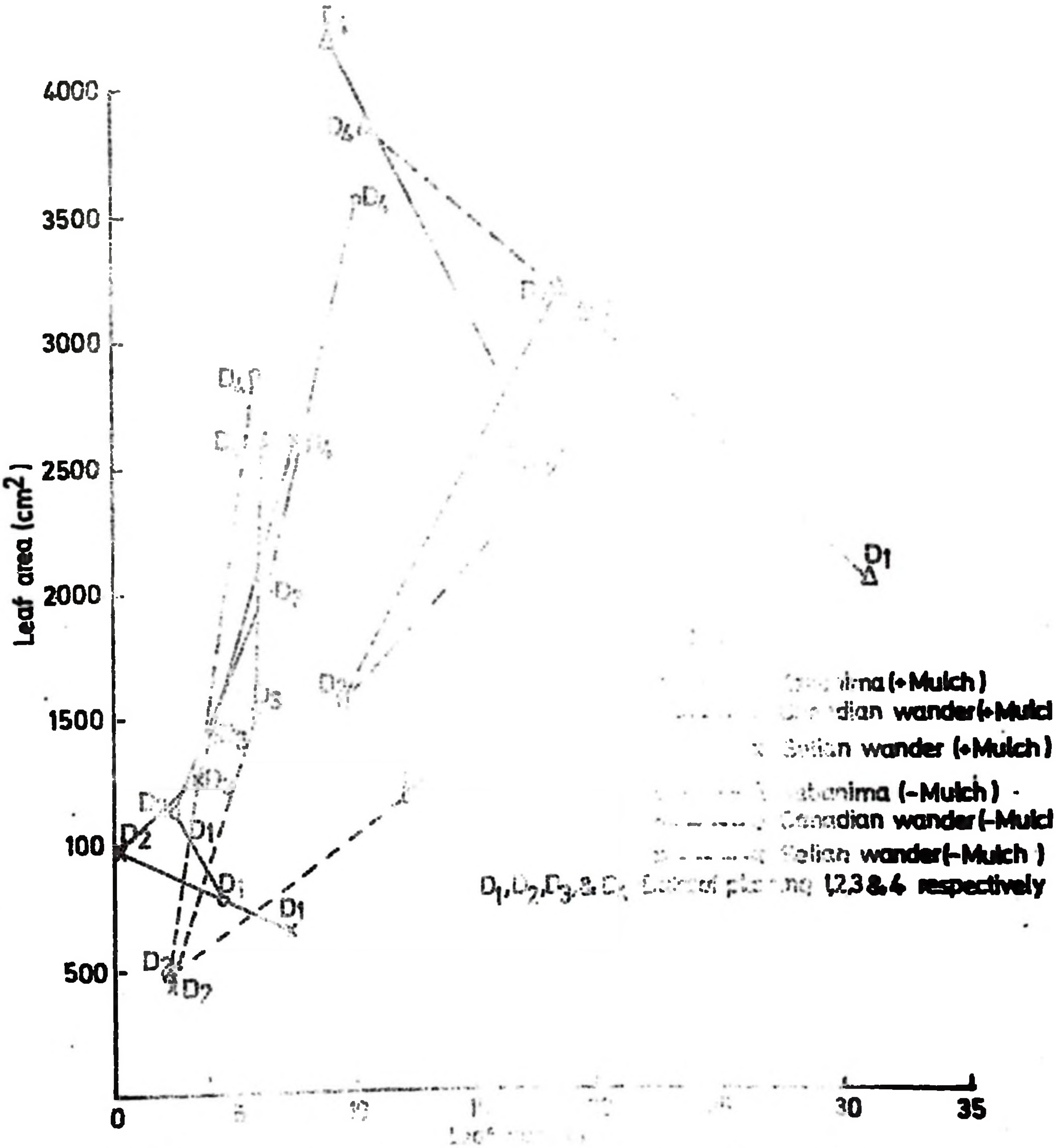

Fig.3. [illegible] leaves.

was significantly higher than the second, the third and fourth plantings which had 33.78, 18.62 and 30.20g. respectively. Kabanima had the highest total dry matter 34.33 in comparison with Canadian Wonder which had only 27.56g and Selian Wonder which had 30.49g. (Table 10).

4.2.2 Leaf dry weight per plant

Significant variations ($P \leq 0.05$) in date, mulching, variety and the D x M interaction were found. The fourth and first sowings differed significantly from the second and third ones, their respective values were 10.0, 8.3, 5.8 and 5.6g. Grass-mulched plots were superior to the un-mulched plots, their values were 8.2 and 6.6g.,respectively. Kabanima with 10.9g. had significantly higher leaf dry weight per plant than either Canadian Wonder (6.2g) or Selian Wonder (5.2g.) (Table 11).

4.2.3 Branch dry weight per plant

Plantings differed significantly ($P \leq 0.05$). The D_4 and D_1 sowings differed greatly from the D_2 and D_3 plantings; their values were 9.8, 9.7, 7.4 and 5.1g. respectively. The second sowing with 7.4g was

Table 10: Total dry weight per plant (g).

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	35.1	32.0	31.1	32.7
	M_0	47.0	40.4	57.7	48.4
D_2	M_1	52.8	33.1	35.4	40.4
	M_0	33.0	22.4	26.0	27.1
D_3	M_1	18.7	18.5	17.5	18.2
	M_0	19.6	18.3	19.1	19.1
D_4	M_1	39.8	32.0	34.1	35.3
	M_0	28.7	23.8	22.9	25.1
Overall mean		34.3	27.6	30.5	30.8

$LSD_{0.05}$ Date = 6.2

Variety = 5.4

Interaction D x M = 8.8

Table 11: Leaf dry weight per plant

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	11.3	5.7	5.2	7.4
	M_o	13.1	7.7	7.1	9.3
D_2	M_1	13.2	5.2	3.5	7.3
	M_o	7.4	2.4	2.9	4.2
D_3	M_1	6.9	4.8	3.5	5.0
	M_o	8.3	5.5	4.4	6.1
D_4	M_1	17.3	12.0	9.9	13.1
	M_o	9.4	6.2	5.2	6.9
Overall mean		10.9	6.2	5.2	7.4

$LSD_{0.05}$

Date = 1.8

Mulching = 1.3

Variety = 1.6

Interaction D x M = 2.6

significantly higher than the third planting. Mulched treatments were better (8.8g) than un-mulched ones (7.2g). Kabanima registered significantly more dry weight of branches (10.0g) than either Canadian Wonder (7.4g) or Selian Wonder (6.7g). The D x M interaction was also significant; D_4M_1 had the highest dry matter (12.0g) while D_3M_0 the lowest (5.0g)(Table 12).

4.2.4 <u>Root dry weight (g) per plant</u>

There were significant variations (P 0.05) between the sowings, mulching, variety and the D x M interaction. Dates 3 and 4 all had significantly lower values of root dry weight per plant than the first and second plantings; their respective values being 1.3, 1.6, 2.1 and 2.0g. Mulched plots were significantly higher than un-mulched plots; 2.0 against 1.6g. Kabanima roots weighed more (2.3g) than either Canadian Wonder (1.6g) or Selian Wonder (1.3g)(Table 13).

4.3 Nutrition Aspects

4.3.1 Nitrogen

Bean plants at the seedling stage had higher total N (4.96% N) than at blooming stage (4.22%N). Selian Wonder had a significantly higher % N (5.14) than Canadian Wonder (4.85) at the seedling stage; Kabanima

Table 12: Branch dry weight (g) per plant

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	9.1	8.6	6.7	8.1
	M_o	11.2	12.1	10.8	11.4
D_2	M_1	15.3	7.5	6.6	9.8
	M_o	7.7	3.7	3.9	5.1
D_3	M_1	6.9	4.4	4.6	5.3
	M_o	6.0	5.0	3.9	5.0
D_4	M_1	14.9	10.4	10.5	11.9
	M_o	9.3	7.1	6.4	7.6
Overall mean		10.0	7.4	6.7	8.0

$LSD_{0.05}$

Date = 1.9

Mulching = 1.3

Variety = 1.6

Interaction D x M = 2.7

Table 13: Root dry weight (g) per plant

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	2.5	2.4	1.3	2.1
	M_0	2.7	2.1	1.8	2.2
D_2	M_1	3.9	2.1	1.8	2.6
	M_0	1.7	1.3	1.4	1.5
D_3	M_1	1.7	1.3	1.2	1.4
	M_0	1.9	0.9	1.0	1.3
D_4	M_1	2.5	1.5	1.4	1.8
	M_0	1.8	1.3	0.9	1.3
Overall mean		2.3	1.6	1.4	1.8

$LSD_{0.05}$

Date = 0.4

Mulching = 0.3

Variety = 0.4

Interaction D x M = 0.6

had 4.90. When Kabanima variety was mulched the leaf % N was lower (4.72) than when not mulched (5.07%), at the seedling stage. Selian Wonder had 5.14 and 4.37% N at the seedling and flowering stages, respectively as opposed to 4.85 and 4.23% N for Canadian Wonder and 4.90 and 4.06% N for Kabanima at the same growth stages as Selian Wonder. At the flowering stage date 1 had the highest total N (4.79%) and this was significantly different from date 3, date 2 and date 4 which had respective % N of 4.27, 3.93 and 3.89. The third planting also was significantly different from the second and fourth dates. During the second date of planting, mulched plants had more N than the un-mulched ones (Tables 14 and 15).

4.3.2 Phosphorus

The concentration of phosphorus was higher in plants at the seedling stage than those at the flowering stage and the % P values were 0.39 and 0.29, respectively (Tables 6 and 7). The fourth planting gave significantly higher P content ($P \leq 0.05$), 0.42% than the third planting, 0.35%P, at the seedling stage. At the flowering stage highest % P in plants was recorded at the second planting (0.34) and this was significantly different

Table 14: Total N % N in leaves at bean seedling stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_3	M_1	4.55	4.62	5.39	4.85
	M_o	5.11	5.04	5.11	5.09
D_4	M_1	4.90	4.97	5.17	5.01
	M_o	5.03	4.76	4.90	4.90
Overall mean		4.90	4.85	5.14	4.96

$LSD_{0.05}$ Variety = 0.25

Interaction M x V = 0.36

Table 15: Total N-%N in leaves at bean blooming stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	4.47	4.78	4.90	4.72
	M_0	4.63	4.99	4.94	4.85
D_2	M_1	4.07	4.10	4.29	4.15
	M_0	3.41	3.78	3.94	3.71
D_3	M_1	4.17	4.06	4.41	4.21
	M_0	4.27	4.31	4.41	4.33
D_4	M_1	3.64	4.17	4.27	4.03
	M_0	3.78	3.64	3.82	3.75
Overall mean		4.06	4.23	4.37	4.22

$LSD_{0.05}$ Date = 0.21

Variety = 0.18

Interaction D x M = 0.30

($P \leq 0.05$) from all the other three plantings; D_1, D_3 and D_4 which had, respectively, 0.30, 0.27 and 0.28% P (Tables 16 and 17).

4.3.3 Potassium

The % K concentration in the seedling plants was almost double than in the flowering plants (Tables 18 and 19). Seedlings registered a % K of 5.14 while leaves at plant blooming stage only 2.61. At the seedling stage, date of planting, mulching, variety and the interaction D x M were significant ($P \leq 0.05$). The fourth planting had significantly higher K (5.54%) then the third planting 4.73% K. The overall no mulch plots had significantly higher K than mulched plots, 5.30 and 4.99% K, respectively. Both Canadian Wonder and Selian Wonder with 5.43 and 5.19% K, respectively, were significantly different from Kabanima with only 4.8%K. The D_3M_o interaction was significantly different from D_3M_1, 5.11 versus 4.36% K respectively. At flowering stage, date, variety and the D x M interaction were significant ($P \leq 0.05$). Date 1 with 2.78% K was significantly different from date 4 which only had 2.54% K. Date 2 and date 3, each with 2.66% K were also significantly different from date 4. Canadian Wonder had the highest

Table 16: % P in leaves at bean seedling stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_3	M_1	0.33	0.38	0.34	0.35
	M_0	0.36	0.35	0.35	0.35
D_4	M_1	0.46	0.42	0.42	0.43
	M_0	0.40	0.41	0.41	0.41
Overall mean		0.39	0.39	0.38	0.39

$LSD_{0.05}$ Dates = 0.03

Table 17: % P in leaves at bean blooming stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.32	0.31	0.29	0.31
	M_0	0.29	0.29	0.29	0.29
D_2	M_1	0.35	0.34	0.36	0.35
	M_0	0.34	0.32	0.34	0.33
D_3	M_1	0.29	0.29	0.29	0.29
	M_0	0.23	0.24	0.25	0.24
D_4	M_1	0.27	0.28	0.29	0.28
	M_0	0.26	0.28	0.28	0.27
Overall mean		0.29	0.29	0.30	0.29

$LSD_{0.05}$ Dates = 0.02

Table 18: % K in leaves at bean seedling stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_3	M_1	4.03	4.56	4.48	4.36
	M_0	4.72	5.32	5.29	5.11
D_4	M_1	5.33	6.18	5.33	5.61
	M_0	5.13	5.65	5.65	5.48
Overall mean		4.80	5.43	5.19	5.14

$LSD_{0.05}$

Date = 0.23

Mulching = 0.23

Variety = 0.29

Interaction D x M = 0.33

Table 19: % K in leaves at blooming stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	2.48	2.91	2.94	2.78
	M_0	2.48	3.21	2.65	2.78
D_2	M_1	2.22	3.06	2.54	2.61
	M_0	2.33	2.86	2.91	2.70
D_3	M_1	2.58	2.38	2.35	2.44
	M_0	2.79	2.99	2.82	2.87
D_4	M_1	2.28	2.65	2.48	2.47
	M_0	1.91	2.55	2.18	2.21
Overall mean		2.38	2.83	2.61	2.61

$LSD_{0.05}$ Date = 0.19

Variety = 0.16

Interaction D x M = 0.26

% K (2.83) and this differed significantly from both Selian Wonder and Kabanima which had % K contents of 2.61 and 2.38, respectively. Selian Wonder, similarly was significantly different from Kabanima. The D_3M_o interaction with 2.87 % K had significantly higher mean % K than D_3M_1 with only 2.44 % K. Similarly, D_4M_1 had significantly higher K value than D_4M_o, their respective % K values being 2.47 and 2.21.

4.3.4 Calcium

Seedlings had 0.72% Ca while plants at flowering had % Ca content of 1.37. Date, mulching and variety were all significant ($P \leq 0.05$) at the seedling stage. The fourth planting gave 0.78% Ca and this was significantly different from the date 3 planting which only had 0.66% Ca. Unmulched plants gave higher % Ca (0.8) than mulched ones (0.64). Variety Kabanima at the seedling stage, had higher mean % Ca than either Canadian Wonder or Selian Wonder and their respective values were 0.79, 0.69 and 0.68. No varietal differences existed between Canadian Wonder and Selian Wonder. At the flowering stage, only dates were significant. Date 3 with 1.75 % Ca was significantly different from date 4, date 2 and date 1 with respective % Ca values of 1.39, 1.34 and 0.99. The fourth planting was significantly different from the second and first planting; similarly, the second sowing from the first (Tables 20 and 21).

4.3.5 Magnesium

The concentration of Mg in seedlings was only slightly smaller than that in plants at blooming, 0.60 and 0.63, respectively. There were significant varietal differences ($P \leq 0.05$) in both the seedlings and plants at flowering stage. At the seedling stage Kabanima and Canadian Wonder varieties, each with 0.62% Mg were significantly different from Selian Wonder (0.57% Mg). At the blooming stage, however, Selian Wonder had the highest % Mg in leaves (0.66), this was higher than Canadian Wonder with 0.63 and Kabanima with 0.60. Mulching, date, and the interaction D x V were also significant at the flowering stage. Zero mulch plants had 0.64% Mg while mulched ones 0.62, D_3 with 0.68% Mg differed from the first planting, the second sowing and the fourth with concentrations of 0.60, 0.61 and 0.62% Mg, respectively in the leaves (Tables 22 and 23 and Fig.4).

4.3.6 Sodium

There was no difference in Na concentration in

Table 20: % Ca in leaves at seedling stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_3	M_1	0.70	0.55	0.51	0.59
	M_0	0.80	0.63	0.76	0.73
D_4	M_1	0.75	0.70	0.62	0.69
	M_0	0.92	0.87	0.83	0.87
Overall mean		0.79	0.69	0.68	0.72

$LSD_{0.05}$

Date = 0.08

Mulching = 0.08

Variety = 0.09

Table 21: % Ca in leaves at blooming stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.92	0.92	1.26	1.03
	M_0	0.69	1.06	1.09	0.95
D_2	M_1	1.30	0.97	0.94	1.07
	M_0	1.50	1.82	1.53	1.62
D_3	M_1	1.83	1.91	1.85	1.86
	M_0	1.60	1.62	1.68	1.63
D_4	M_1	1.10	1.57	1.26	1.31
	M_0	1.75	1.19	1.43	1.46
Overall mean		1.34	1.38	1.38	1.37

$LSD_{0.05}$ Date = 0.18

Table 22: % Mg in leaves at seedling stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.62	0.61	0.56	0.60
	M_0	0.66	0.65	0.62	0.64
D_2	M_1	0.63	0.59	0.53	0.58
	M_0	0.58	0.61	0.56	0.58
Overall mean		0.62	0.62	0.57	0.60

$LSD_{0.05}$ Variety = 0.04

Table 23: % Mg in leaves at blooming stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.50	0.56	0.66	0.57
	M_0	0.54	0.66	0.69	0.63
D_2	M_1	0.61	0.61	0.55	0.59
	M_0	0.66	0.63	0.64	0.64
D_3	M_1	0.66	0.64	0.75	0.68
	M_0	0.66	0.68	0.67	0.67
D_4	M_1	0.60	0.60	0.65	0.62
	M_0	0.57	0.64	0.66	0.62
Overall mean		0.60	0.60	0.66	0.63

$LSD_{0.05}$

Date = 0.04

Mulching = 0.02

Variety = 0.03

Interaction D x V = 0.06

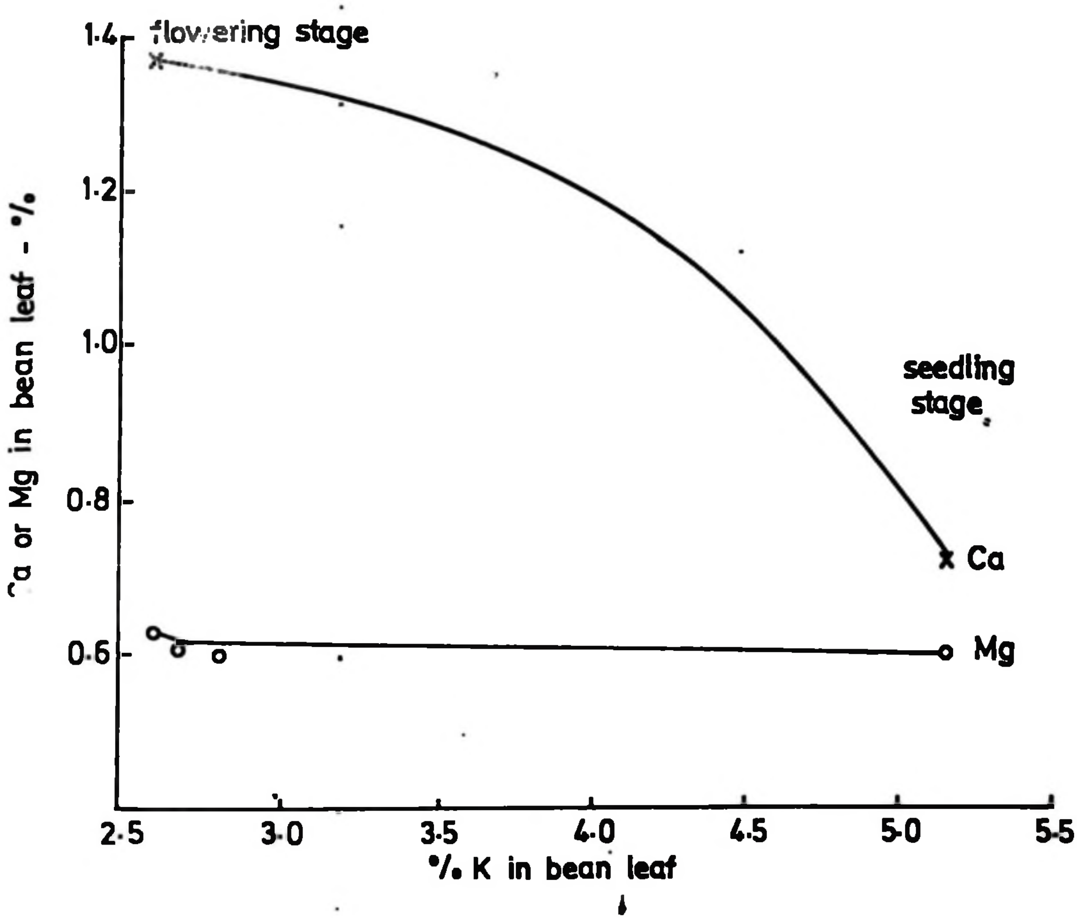

Fig.4. Concentrations of Ca and Mg in bean leaf as influenced by K

both seedlings and plants at blooming stage, in both growth stages the concentration was 0.09%. Mulching treatments were significant ($P \leq 0.05$) at both the seedling and flowering stages. At the former, mulched plots had 0.12% N which was significantly higher than the unmulched ones, 0.07% Na. At the flowering stage, % Na was 0.09 for the mulched plots, this was higher than the non-mulched plots which only had 0.08. Date 4 and date 2 with 0.12 and 0.11% Na, respectively, were each higher than either D_3 or D_1 which had 0.07 and 0.08% Na, respectively (Tables 24 and 25).

4.4 <u>Soil nutrients - at flowering stage of beans</u>

For all the nutrients analysed in the soil samples taken from plots at the flowering time of beans, highly significant differences ($P \leq 0.05$) were noted in the dates of planting (Tables 26 - 31). For nitrogen, D_4 had the highest total N (0.18%) whereas D_3 planting recorded 0.11% and the D_1 and D_2 plantings came in between with 0.14% N each. D_3 (30.56 ppm) had significantly higher P than D_4 (25.88 ppm) and D_1 (28.22 ppm). D_2 27.99 ppm) differed significantly from D_1. The earlier plantings D_1 and D_2 had significantly higher K values

Table 24: % Na in leaves at seedling stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.10	0.14	0.11	0.12
	M_0	0.08	0.06	0.06	0.07
D_2	M_1	0.11	0.13	0.13	0.12
	M_0	0.08	0.06	0.06	0.06
Overall mean		0.09	0.10	0.09	0.09

$LSD_{0.05}$ Mulching = 0.02

Table 25: % Na in leaves at blooming stage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.05	0.06	0.05	0.05
	M_0	0.07	0.05	0.05	0.06
D_2	M_1	0.13	0.13	0.13	0.13
	M_0	0.11	0.07	0.08	0.09
D_3	M_1	0.07	0.09	0.08	0.08
	M_0	0.06	0.05	0.05	0.05
D_4	M_1	0.11	0.13	0.10	0.11
	M_0	0.12	0.14	0.13	0.13
Overall mean		0.09	0.09	0.08	0.09

$LSD_{0.05}$

Date = 0.02

Mulching = 0.01

Interaction D x M = 0.02

than the later plantings D_3 and D_4, their values were 2.10, 2.48, 1.74 and 1.80 m.e.K/100g of soil, respectively. Grass mulched plots had higher K than zero-mulch plots, their values being 2.14 and 1.92 m.e. K per 100g.soil, respectively. The D_1 and D_2 sowings also had significantly higher soil Ca and Mg than the D_3 and D_4 plantings; their Ca values were 6.21, 6.24, 4.99 and 4.76 m.e./100g.soil, respectively and the Mg values 5.81, 5.43, 5.14 and 4.94 m.e./100g.soil, respectively. Kabanima planted plots had significantly more soil Ca than those with either Canadian Wonder or Selian Wonder.

The D_4 planting had significantly more soil Na than D_2 and D_3 at the bean blooming stage. The D_1 planting had more soil Na than the D_3 planting.

4.5 Disease incidence

Incidence of disease was very minimal in the first planting. Bean common mosaic virus (BCMV) was noted in all plantings and was most prevalent in Kabanima variety. Angular leaf spot (ALS)(*Isariopsis griseola* Sacc.) was common in Canadian Wonder and Selian Wonder. Powdery mildew (*Erysiphe polygoni* Dcex.Merat) was observed only the D_4 planting. White

Table 26: Soil total N(%) at flowering stage of beans

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.13	0.16	0.14	0.14
	M_o	0.14	0.15	0.13	0.14
D_2	M_1	0.15	0.13	0.13	0.14
	M_o	0.13	0.12	0.15	0.13
D_3	M_1	0.13	0.11	0.11	0.12
	M_o	0.12	0.11	0.11	0.11
D_4	M_1	0.18	0.18	0.18	0.18
	M_o	0.18	0.18	0.17	0.18
Overall mean		0.14	0.14	0.14	0.14

$LSD_{0.05}$ Date = 0.01

Table 27: Available soil P (ppm) at flowering stage of beans

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	26.78	24.35	24.79	25.31
	M_o	23.25	24.02	22.15	23.14
D_2	M_1	29.17	24.35	21.06	24.86
	M_o	31.36	26.87	35.09	31.11
D_3	M_1	30.70	31.14	32.02	31.29
	M_o	30.27	30.71	28.51	29.83
D_4	M_1	26.76	27.63	25.88	26.76
	M_o	24.12	26.32	24.57	25.00
Overall mean		27.80	26.92	26.76	27.16

$LSD_{0.05}$ Date = 3.57

Table 28: Soil K m.e./100g.soil at flowering stage of beans

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	1.78	2.50	1.98	2.09
	M_o	2.08	2.03	2.23	2.11
D_2	M_1	2.40	2.60	2.55	2.52
	M_o	2.35	2.48	2.45	2.43
D_3	M_1	2.08	2.23	1.85	2.05
	M_o	1.25	1.28	1.80	1.44
D_4	M_1	2.05	1.95	1.75	1.92
	M_o	1.83	1.60	1.65	1.69
Overall mean		1.98	2.08	2.03	2.03

$LSD_{0.05}$ Date = 0.25

Mulching = 0.18

Table 29: Soil Ca (m.e./100g. soil) at flowering stage of beans

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	6.50	6.40	6.10	6.33
	M_0	6.30	6.10	5.90	6.10
D_2	M_1	6.30	6.40	6.00	6.23
	M_0	6.40	6.40	6.00	6.26
D_3	M_1	5.50	5.50	5.00	5.33
	M_0	5.10	3.75	5.10	4.65
D_4	M_1	5.13	3.65	5.03	4.60
	M_0	5.20	4.25	5.30	4.92
Overall mean		5.80	5.31	5.55	5.55

$LSD_{0.05}$ Date = 0.45

Variety = 0.39

Table 30: Soil Mg (m.e./100g.soil) at flowering stage of beans

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	5.95	5.95	5.88	5.93
	M_0	5.63	5.88	5.55	5.69
D_2	M_1	5.35	5.38	5.18	5.30
	M_0	5.53	5.75	5.43	5.57
D_3	M_1	5.33	5.38	5.03	5.25
	M_0	5.10	4.78	5.23	5.04
D_4	M_1	4.85	4.20	4.78	4.61
	M_0	5.08	5.38	5.35	5.27
Overall mean		5.35	5.34	5.30	5.33

$LSD_{0.05}$ Date = 0.22

Interaction D x M = 0.31

Table 31: Soil Na (m.e./100g. soil) at flowering stage of beans

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.17	0.17	0.17	0.17
	M_0	0.17	0.16	0.16	0.16
D_2	M_1	0.16	0.15	0.18	0.16
	M_0	0.16	0.16	0.15	0.16
D_3	M_1	0.14	0.14	0.12	0.13
	M_0	0.15	0.14	0.17	0.15
D_4	M_1	0.18	0.16	0.16	0.17
	M_0	0.19	0.19	0.20	0.19
Overall mean		0.17	0.16	0.16	0.16

$LSD_{0.05}$ Date = 0.02

mould (*Sclerotinia sclerotiorum* (Lib) de Bary) came in the pod filling stage, it was spectacular in defoliating leaves in Selian Wonder and Canadian Wonder, especially in the D_2 planting. In Kabanima, White mould caused severe stem cankers often leading the falling of plants (D_2), sclerotia of the fungus *Sclerotinia sclerotiorum* were seen on the stems and pods of some infected plants. Date 2 which had the highest white mould infestation, ironically, gave the highest grain yield(Table 32).

Two plants in Canadian Wonder plots were observed to be resistant to White mould infestation; these two bean plants exhibited the primitive trailing habit (Plates 3 and 4).

4.6 Water use efficiency (WUE) in kg grain ha^{-1} cm^{-1} water

Highly sginficant differences were noted in the dates. The greatest WUE was established in the D_2 planting and this was 81.6 kg seed ha^{-1} cm^{-1} water. The D_2 WUE value was significantly higher than WUE values in other dates. The WUE for D_1 sowing was 65.3 and was 55.9 for the D_3 sowing and 56 kg grain ha^{-1} cm^{-1} water in the last sowing.

Table 32: Disease incidence in the various dates of planting at 50 days after emergence

Date	Variety	White mould	Angular leaf spot	Bean Common mosaic virus	Ascochyte	Powdery mildew
D 1	Kabanima	0	0	1	0	0
	Canadian Wonder	0	1	0	0	0
	Selian Wonder	0	1	0	0	0
D 2	Kabanima	1	0	1	0	0
	Canadian Wonder	4	2	0	2	0
	Selian Wonder	4	2	0	2	0
D 3	Kabanina	0	0	1	0	0
	Canadian Wonder	3	2	1	2	0
	Selian Wonder	3	3	1	2	0
D 4	Kabanima	1	0	1	0	1
	Canadian Wonder	2	2	0	1	3
	Selian Wonder	2	2	0	1	4

Plate 1: White mouldy growth of <u>Sclerotinia sclerotiorum</u> on pods. Black sclerotia are seen on the branch.

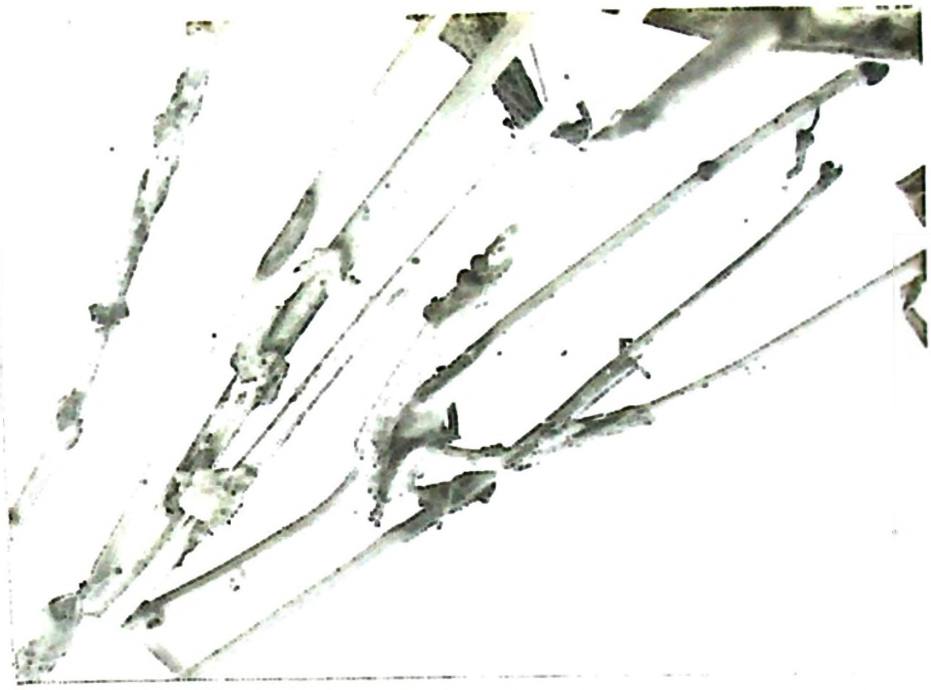

Plate 2: Stem cankers on bean branches caused by *Sclerotinia sclerotiorum*.

Plate 3: Canadian Wonder variety defoliated by White Mould. On the 1st row, left hand side, is a resistant plant.

Plate 4: Canadian Wonder variety defoliated by White Mould. Resistant Canadian Wonder plant exhibiting the primitive trailing character.

Plate 5: Kabanima plants showing varying degrees of Bean Common Mosaic Virus (BCMV).

Overall unmulched plots gave significantly higher WUE ($P \leq 0.05$) than mulched treatments; their respective values were 70.2 and 59.2 kg grain ha^{-1} cm^{-1} water.

Canadian Wonder had significantly higher (P 0.05) WUE than either Selian Wonder or Kabanima; their respective values were 85.8, 69.6 and 58.8 kg grain ha^{-1} cm^{-1} water. Kabanima was significantly less efficient in water utilization than Selian Wonder. The DxV interaction also had significant variations ($P \leq 0.05$). Canadian Wonder and Selian Wonder had significantly higher interactions with all the dates, except D_4 planting, than Kabanima (Table 33 and Fig.5). WUE increases linearly with grain yield increase at the same rate for Canadian Wonder and Selian Wonder, but at a slower rate for Kabanima.

4.7 Grain yield and yield components

4.7.1 Pod length (cm) per plant

Varieties were highly significant ($P \leq 0.05$). Selian Wonder had significantly longer pods than either Canadian Wonder or Kabanima; their respective pod lengths were 10.6, 9.5 and 8.4cm. The interaction of date and variety DxV was also significant ($P \leq 0.05$) (Table 54).

Table 33: Water use efficiency (WUE) in kg grain ha^{-1} cm^{-1} water

		Kabanima	Canadian Wonder	Selian Wonder	Mean
25.2.83	Mulch	25.3	110.5	63.2	66.3
	No mulch	49.2	90.3	53.7	64.4
15.3.83	Mulch	30.6	93.5	105.4	76.5
	No mulch	37.5	129.6	93.0	86.7
26.3.83	Mulch	25.1	53.0	49.2	42.4
	No mulch	50.7	86.9	70.2	69.3
8.4.83	Mulch	31.0	66.0	58.2	51.7
	No mulch	60.8	56.7	63.5	60.3
Mean		38.8	85.8	69.6	64.7

$LSD_{0.05}$

Date = 12.1
Mulching = 8.5
Variety = 10.4
Interaction D x V = 20.9

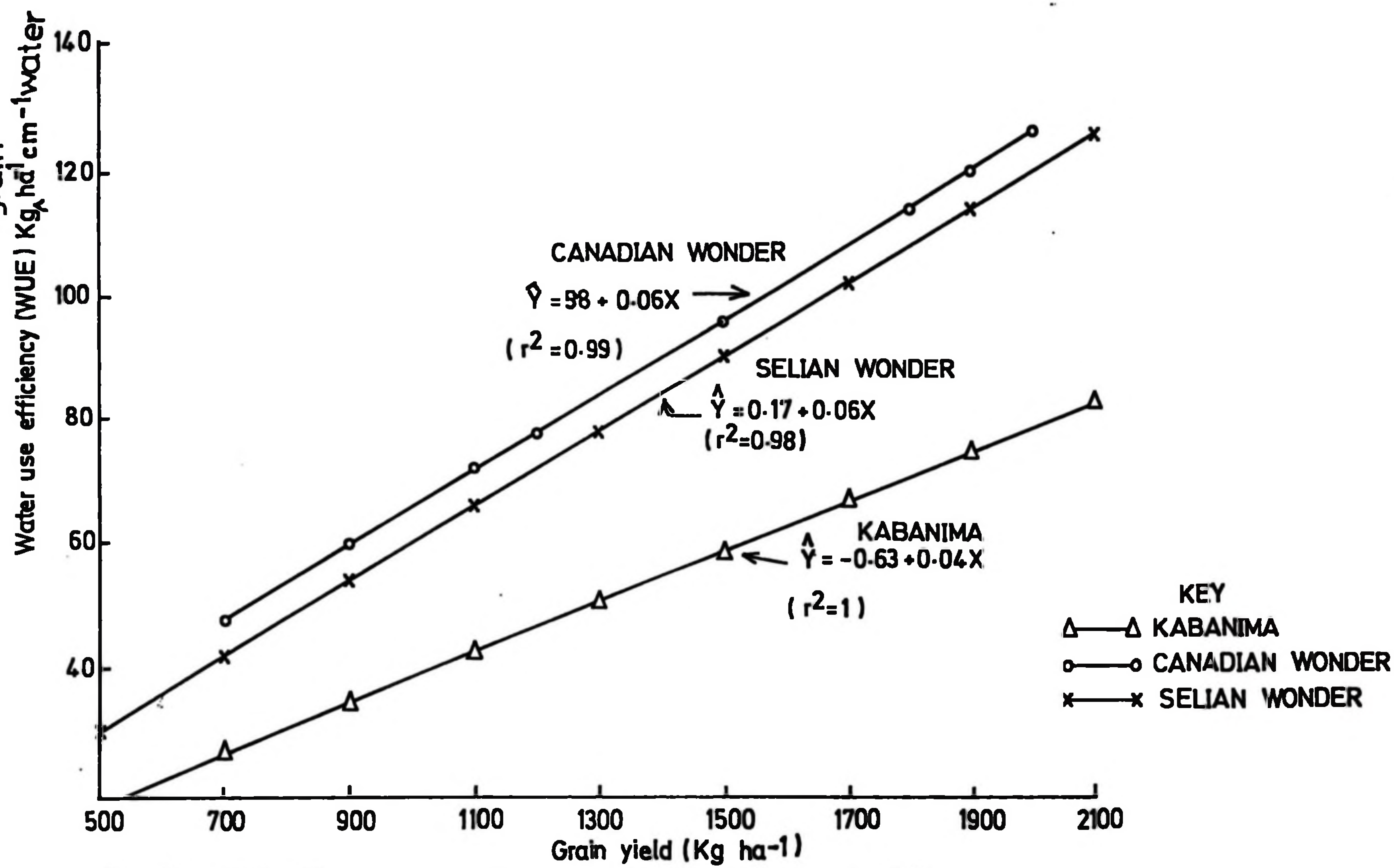

Fig.5. The relationship between water use efficiency and bean grain yield

Table 34: Pod length (cm) per plant

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	7.2	8.2	10.3	8.6
	M_0	8.6	8.8	10.5	9.3
D_2	M_1	9.1	9.5	12.2	10.3
	M_0	8.9	9.2	10.3	9.5
D_3	M_1	7.4	10.1	9.0	8.8
	M_0	9.1	10.8	9.7	9.9
D_4	M_1	7.8	9.5	10.5	9.3
	M_0	8.9	10.2	12.3	10.5
Overall mean		8.4	9.5	10.6	9.5

$LSD_{0.05}$ Variety = 0.7

Interaction D x V = 1.4

4.7.2 Number of seeds/pod

Highly significant variations ($P \leq 0.05$) were found in the varieties. Both the early maturing varieties Canadian Wonder and Selian Wonder had significantly more number of seeds per pod than the late maturing variety, Kabanima; the numbers were 3.9, 3.8 and 3 respectively (Table 35).

4.7.3 Number of pods per plant

Dates, mulching and variety were all significant ($P \leq 0.05$). The first, second and fourth plantings were all significantly higher than the third sowing. Mulched plots gave significantly more pods/plant than unmulched ones; their values were 20.58 and 15.85 respectively (Table 36).

4.7.4 100 grain weight(g)

There were significant differences in the dates and varieties. Date 3 gave relatively heavier seeds than date one, two and four. These had respective 100 grain weights of 53.2, 45.2, 43.3 and 44.7g. Selian Wonder had the heaviest grains (53.2g) compared to Canadian Wonder with 49.1 and Kabanima with only 37.5g (Table 37).

Table 35: Number of seeds per pod

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	2.7	3.5	3.8	3.3
	M_0	3.0	4.3	4.0	3.8
D_2	M_1	3.1	4.0	4.0	3.7
	M_0	3.4	4.0	3.7	3.7
D_3	M_1	3.0	3.5	4.1	3.5
	M_0	2.5	3.7	3.7	3.3
D_4	M_1	3.0	4.1	3.4	3.5
	M_0	3.3	4.3	3.7	3.8
Overall mean		3.0	3.9	3.8	3.6

$LSD_{0.05}$ Varieties = 0.3

Table 36: Number of pods per plant

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	21.0	17.3	26.0	21.4
	M_0	26.5	19.3	15.0	20.3
D_2	M_1	38.3	21.3	19.0	26.2
	M_0	19.3	15.0	11.3	15.2
D_3	M_1	17.8	7.3	11.0	12.0
	M_0	14.8	10.3	14.5	13.2
D_4	M_1	29.0	20.5	18.5	22.7
	M_0	21.5	12.3	10.3	14.7
Overall mean		23.5	15.4	15.7	18.2

$LSD_{0.05}$

Date = 5.2

Mulching = 3.7

Variety = 4.5

Table 37: 100 grain weight (g)

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	36.7	49.7	50.7	45.7
	M_0	37.1	46.3	50.6	44.7
D_2	M_1	34.6	44.8	52.2	43.9
	M_0	32.3	45.9	50.2	42.8
D_3	M_1	39.5	54.7	57.5	50.6
	M_0	45.1	59.9	62.4	55.8
D_4	M_1	36.5	50.4	51.6	46.2
	M_0	38.3	41.3	50.1	43.2
Overall mean		37.5	49.1	53.2	46.6

$LSD_{0.05}$ Date = 1.97

Variety = 1.70

Interaction D x V = 2.79

4.7.5 Shelling percentage

Dates, mulches and varieties had significant variations ($P \leq 0.05$). Date 1 had significantly higher shelling percentage than all the other dates, the second planting also was significantly higher than the third and fourth sowings; similarly, the fourth planting was better than the third sowing. The shelling percentage values were 54.8, 53.C, 50.7 and 47.9 for the first, second, fourth and third sowing, respectively (Table 38).

4.7.6 Pod dry weight per plant

Highly significant variations ($P \leq 0.05$) were found between the dates, varieties and the D x M interaction. Dates 1 and 2 with 20.5 and 18.5g were significantly greater than dates 4 and 3 with only 6.6 and 8.9g; Selian Wonder significantly accumulated more dry matter of pods/plant than either Canadian Wonder or Kabanima, their values were 16.8, 13.0 and 11.1g, respectively. Variations in the D x M interaction ranged from 24.2g in D_1M_o to 6.5g in D_3M_1 (Table 39).

Table 38: Shelling percentage

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	38.5	61.6	60.9	53.7
	M_0	46.6	61.8	59.2	55.9
D_2	M_1	41.2	54.9	55.4	50.5
	M_0	49.4	59.8	57.2	55.4
D_3	M_1	39.4	49.2	45.1	44.6
	M_0	46.5	53.9	53.2	51.2
D_4	M_1	39.5	55.2	54.6	49.8
	M_0	45.8	56.5	53.8	52.0
Overall mean		43.4	56.6	54.9	51.6

$LSD_{0.05}$

Dates = 1.6
Mulching = 1.1
Variety = 1.4
Interactions D x M = 1.1
D x V = 2.8
M x V = 2.0

Table 39: Pod dry weight (g) per plant

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	12.2	20.5	18.0	16.9
	M_0	20.0	18.6	34.1	24.2
D_2	M_1	20.3	18.3	23.6	20.7
	M_0	16.2	15.0	18.0	16.4
D_3	M_1	3.3	8.0	8.3	6.5
	M_0	3.4	6.9	9.7	6.7
D_4	M_1	5.1	8.1	12.4	8.5
	M_0	8.2	9.1	10.3	9.2
Overall mean		11.1	13.1	16.8	13.6

$LSD_{0.05}$

Date = 3.8

Variety = 3.3

Interaction D x M = 5.3

4.7.7 Pod yield

Significant variations ($P \leq 0.05$) existed between the dates and the interaction D x V. The second planting with the highest yield, differed significantly from all the other dates. Unmulched treatments though not significant had higher pod yield (1.928 tonnes/ha) than mulched treatments (1.728 tonnes/ha) (Table 40).

4.7.8 Seed yield

Dates of planting 1 and 2 significantly out yielded ($P \leq 0.05$) dates 3 and 4, the highest seed yield was recorded in the second sowing (1.39 tonnes/ha. Zero mulch was significantly superior to grass mulch, their respective grain yields were 1.244 and 1.022 tonnes/ha. Canadian Wonder significantly outyielded Selian Wonder and Kabanima; all the early maturing varieties Canadian Wonder and Selian Wonder gave significantly superior grain yields than the late maturing Kabanima. There were significant interactions (P 0.05) of Dates x Variety (D x V) and Mulching x Variety (M x V) (Table 41).

Table 40: <u>Pod yield</u> (tonnes/ha)

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	1.508	2.413	1.412	1.778
	M_0	2.044	1.968	1.243	1.752
D_2	M_1	1.670	2.215	2.490	2.125
	M_0	1.542	2.765	2.075	2.127
D_3	M_1	1.428	1.460	1.537	1.475
	M_0	2.245	2.086	1.725	2.019
D_4	M_1	1.734	1.517	1.549	1.533
	M_0	2.690	1.256	1.499	1.815
Overall mean		1.858	1.960	1.666	1.828

$LSD_{0.05}$ Dates = 0.29

Interaction D x V = 0.51

Table 41: Grain yield (tonnes ha^{-1})

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	0.585	1.883	1.077	1.182
	M_o	1.138	1.539	0.916	1.198
D_2	M_1	0.724	1.494	1.684	1.301
	M_o	0.886	2.071	1.486	1.481
D_3	M_1	0.584	0.833	0.772	0.730
	M_o	1.182	1.365	1.103	1.217
D_4	M_1	0.709	1.016	0.897	0.874
	M_o	1.390	0.873	0.978	1.080
Overall mean		0.900	1.384	1.114	1.133

$LSD_{0.05}$

Dates = 0.21
Mulching = 0.15
Variety = 0.18
Interactions D x V = 0.36
M x V = 0.26

4.8 Phenotypic associations between yield and yield components

The parameters pod yield, shelling percentage and 100 grain weight were strongly correlated with bean grain yield. The number of seeds per pod was also significantly and positively correlated with seed yield.

Plant height, leaf area index (LAI) at flowering or early pod formation and number of leaves per plant at maturity were negatively correlated with seed yield.

The mutual association of yield components from table 42 shows shelling percentage is also positively correlated to 100 grain weight, number of seeds/pod and pod length but is negatively correlated with plant height, LAI and number of leaves at maturity.

Plant height is significantly positively correlated with number of pods/plant, stem diameter, LAI, number of leaves per plant at maturity but is negatively correlated with days to 50% flowering.

The number of primary branches per plant is positively correlated with number of effective

Table 42. Simple correlation coefficients between pairs of bea

Parameter	2	3	4	5
1. Grain yield	0.8911***	0.5846***	0.2997***	-0.2897**
2. Pod yield		0.1783	0.1179	-0.1552
3. Shelling %			0.4678***	-0.3235***
4. 100 grain weight				-0.1466
5. Plant height(cm)				
6. No. of primary branches/plant				
7. Effective primary branches/plant				
8. No. of seeds/ pod/plant				
9. No. of pods/plant				
10. Pod length(cm)/plant				
11. Stem diameter				
12. L.A.I. at flowering/ early pod formation				
13. No. of leaves at maturity				
14. Days to 50% flowers				
15. Total dry matter of plant				

*,**, *** = P ≤ 0.05,0.01 and 0.001 respectively

branches/plant, number of pods/plant, stem diameter, LAI, number of leaves per plant at maturity and total dry weight of plant but is not directly associated with 100 seed weight (Table 42).

5. DISCUSSION

The aim of this study was to investigate three commercial bean varieties on their growth and seed yield as influenced by different sowing dates and two mulching treatments. In the course of this study, plant architecture and flowering were described, dry matter production and its partitioning was investigated, nutrition of the plants was established at seedling and flowering stages. Also examined were concentration of soil nutrients at the bean blooming stage and disease incidence. WUE was established for each variety from empirical formula applied on meteorological data, because all necessary data for its computation were available. Also, single season data are not reliable for WUE computations (Blaney and Criddle 1950).

5.1 Plant architecture and flowering

The delay in seedling emergence in the first date of planting was brought about by adverse soil water conditions and possibly the high ambient temperatures ($35^{o}C$) and evaporation rates. This was further reflected in the delay of days to 50% flowering. No significant varietal differences were noted in the early growth stages contrary to observations made by Ezedinma (1967), but differences existed in the later growth stages. Mulched plots had taller and thicker plants. This is attributed to the higher soil moisture conditions in the rhizosphere contrary to the non-mulched plots and also due possibly to reduction of surface run-off. Lal (1975), Masseri and Jana (1977) and Mashina and Jana (1978) have reported similar findings but these workers, however, reported a grain yield increase in the mulched plots, contrary to observations made in this study. The environmental conditions in this experiment favoured luxuriant vegetative growth. In D_2 planting where leaf area was severely reduced by White Mould, the highest grain yield and WUE were recorded, while in D_4 planting which had the highest leaf area its grain yield was the second lowest.Defoliation lowered LAI in D_2.

Kabanima, the late maturing variety, was taller, had a larger number of leaves, leaf area, leaf area index and total plant dry weight but lower dry weight of pods than the early maturing varieties Canadian Wonder and Selian Wonder.

Work in the Southern Highlands by Mayona (1982) shows that Kabanima is a high yielder. This leads to the suggestion that Kabanima is a variety specific to the high altitude areas. In Morogoro, University Farm, the low altitude coupled with high temperatures may have adversely influenced the hormonal mechanism of flowering and seed set of Kabanima in various ways. Haule (pers.comm.) reported a higher rate of flower abscision in Kabanima as compared with Selian Wonder under Morogoro conditions. In Mgeta area (high altitude) Quentin (pers.comm.) has reported high yields in Kabanima.

The flowering phase of reproductive growth is a relatively transitory one and is controlled primarily by hormonal mechanisms rather than by nutritive conditions within the plant (Meyer et al., 1960). Thus, any temperature stress during the flowering stage eventually leads to poor podding and lower grain yield. This proposition is in agreement with observations on several bean varieties in the hotter parts of northern Uganda (Leakey, 1970) and studies by Izhar and Wallace (1967) and Ormrod et al.(1967).

Kabanima was superior to either Canadian Wonder or Selian Wonder in producing more pods per plant. Poor pod filling in Kabanima may also be due to competition for assimilates with other parts of

the plant including roots and their nodules.
Kabanima registered highly significant root dry weight per plant (2.3g) than either Canadian Wonder (1.6g) or Selian Wonder (1.4g). Work by Magehema and Ndunguru (1983), however, showed that Kabanima is inferior to Selian Wonder in symbiotic nitrogen fixation. This may imply that the contribution of these nodules in supporting the reproduction structures was indeed small compared with Selian Wonder or Canadian Wonder.

5.2 Soil nutrients

The cations K, Ca, Mg and Na showed a general downward trend when earlier dates D_1 and D_2 were compared to later dates D_3 and D_4. This is attributed chiefly to leaching and crop removal (Salon, 1964; Hossner, 1965; Christensen, 1968; and Conyers and McLean, 1969). Variation in P in dates could be due to local variations in P availability within plots; also, high soil moisture content in D_2 and D_3 as compared to D_1 and D_4 (Mrema, person.comm.). Work by Fried *et al.* (1957) and work on nutrient movement and root uptake by Barber (1962), Olsen and Watanabe (1966) and Lewis and Quirk (1967) confirms this.

There was a higher removal of K from non-mulched plots than from grass mulched plots. The soil analysis showed 1.92% K and 2.15% K at flowering of beans for the unmulched and mulched plots, respectively. The bean plants recorded concentrations of 2.64% (unmulched) and 2.58% (mulched plots) at flowering. Since these differences were not significant it does imply that the mulch had little or no effect on the uptake of K.

5.3 Nutrition aspects

A comparative study of seedlings and plants at flowering stage revealed that N, P and K decreased from 4.96 to 4.22%, 0.39 to 0.29% and 5.14 to 2.61% in the seedlings and flowering plants, respectively, whereas Ca and Mg increased, respectively, from 0.72 to 1.37% and 0.60 to 0.63% at the same growth stages. There was no change in the Na concentration in the leaves at either the seedling or flowering stages; in both growth stages the concentration was 0.09% Na. Similar trends in nutrient concentrations were observed by Bartz(1959); Lorenz *et al.*(1944), Geraldson (1970); Charles *et al.* (1982).

The trend in nutrient concentrations at the seeding and flowering growth stages depicts to a certain extent the plant demand for the nutrients and also the function and use of the respective nutrients.

Nitrogen a key component of protoplasm is part of the protein molecule and its derivatives (Mitchell, 1970). Nitrogen is a constituent of the peptide bond, amino acids such as adenine and tryptophan. Adenine is one of the nitrogen bases in the De-oxyribo nucleic acid (DNA) the genetic code, and ribo-nucleic acid (RNA) which is concerned with protein synthesis. N is utilised in the production of indole acetic acid (IAA), adenosine triphosphate molecule (ATP), adenosine diphosphate molecule (ADP) adenosine monophosphate (AMP) molecule, NAD, mitochondria, enzymes, nucleoproteins and proteins which catalyse biochemical reactions and direct metabolism (Mitchell, 1970). In the vegetative stage of beans, the proteins are chiefly functional rather than structural in nature, hence, the higher N content in seedlings than in flowering plants.

Phosphorus has function in energy storage and release. It is also part of the phospholipids, fatty substances and plays role in the structure of cell membrane, RNA, DNA, NADP and phytic acid a source of phosphorus for the germinating seed and developing seedling (Mitchell, 1970). A seedling is still actively growing and differentiating and P furnishes energy in cells of high metabolic activity such as meristems; the excess P is stored in the leaves. In the flowering and pod filling stage, the flowers, pods and seeds become regions of great metabolic activity and high energy sinks which mobilise P accumulated in the leaves during vegetative growth into them. The lower leaf P content in the flowering plants compared to seedlings is indeed a reflection of these processes.

Potassium in association with micronutrients acts as an enzyme activator and is highly labile. This is why it is found in higher concentration in the meristematic tissue such as the leaves of seedlings than in older leaves of flowering plants.

On the contrary, calcium which has an essential role in maintaining and organisation of protoplasm and synthesizing membranes such as the tonoplast, plasmalemma and inner mitochondrial membrane, increases according to the dictates of the plant as it grows. The increase from 0.72 to 1.37% Ca in the seedlings and flowering plants, respectively, was in response to the plant's requirement with growth. More calcium pectate was synthesized to strengthen the middle lamella of cell walls as the bean plants developed from the seedling stage to the reproductive stage.

Magnesium is a component of the chlorophyll molecule. Its change is only slightly higher in the flowering plants compared to seedlings possibly because of the added plant demand for carbohydrates during flowering and pod filling. Magnesium activates many enzymes concerned with carbohydrate metabolism, and is conspicuous in the Krebs cycle and catalyses many phosphorylation reactions associated with nitrogen metabolism in plants.

There were significant varietal effects in nutrient concentrations at the seedling and flowering growth stages, Selian Wonder had significantly higher N than Kabanima, the values were 5.14 and 4.37%

N for Selian Wonder against 4.90 and 4.06% N for Kabanima at the respective growth stages. Kabanima also had lower % K 4.8 and 2.38 at the seedling and flowering stages, respectively, compared to Canadian Wonder (5.44 and 2.83) and Selian Wonder (5.19 and 2.61). Selian Wonder and Canadian Wonder had higher % Mg at flowering, 0.66 and 0.63% respectively, compared to Kabanima (0.60%). Kabanima had higher Ca (0.79%) than either Canadian Wonder (0.69%) or Selian Wonder (0.68%) at seedling stage, but lower Ca (1.34%) than these varieties which had 1.38% each at flowering.

Kabanima which appeared inefficient in partitioning of its assimilates from the vegetative organs to the reproductive parts, the pods, had significantly lower N, K and Mg than either Canadian Wonder or Selian Wonder at flowering. An examination of soil analysis at the bean blooming stage revealed that Kabanima planted plots had lower available K than those planted with either Canadian Wonder or Selian Wonder. Soluble K in the soil is markedly influenced by soil moisture and temperature (Cooke, 1975). Mg an element vital in the chlorophyll molecule is indirectly involved in carbon assimilation, but is not involved in the translocation of assimilates. Since K is involved in the translocation of carbohydrates, a lower level of leaf K (2%) means essentially that partitioning of the assimilates from the leaves to the pods is reduced and this possibly accounted for the poor pod filling of Kabanima; 2% leaf K lies in the deficiency range for beans at full bloom (Geraldson _et al._, 1973).

D_1 plants registered significantly higher N (4.79%) than D_2 (3.93%), D_3 (4.27%) and D_4 (3.89%) plants. The D_1 plants had the advantage of utilizing the flush of mineralized N from organic compounds in the soil early in the rainy season (Hardy, 1946; Birch, 1958, 1960; Semb and Robinson, 1969). D_1 had significantly higher K, 2.78% than D_4 plants 2.34% at flowering stage.

These results show that nutrient uptake by the beans plants is influenced by variety, plant growth stage and either directly or indirectly by soil moisture in the different dates and mulching treatments. Soil moisture coupled with temperature, changes the chemical solubility of nutrients like P and K (Nielsen et al, 1961. Caldwell, 1964 and Cooke, 1975) which correspondingly influence their uptake by plants.

5.4 Phenotypic associations between yield and yield components

Generally, the yield components which significantly correlated positively with grain yield tended to have positive mutual association which was significant while those that had strong and highly negative correlations with seed yield had positive and significant correlations among themselves.

Of the fifteen parameters examined, pod yield, shelling percentage, 100 grain weight and number of seeds per pod tended to exert marked positive influence on the seed yield. Pod length tended to be positively correlated, and nearly always highly significant, with yield components of greatest effect on grain yield. Similar observations were made by Rodrige et al.(1972). Selection for high grain yield, thus, should look for varieties with high pod yield, shelling percentage, 100 grain weight , high number of seeds per pod and longer pods. The number of seeds per pod was almost the same for Canadian Wonder and Selian Wonder but was smaller for Kabanima.

Seed yield appeared to be negatively correlated with plant height, LAI, number of leaves and days to 50% flowering. Further studies need to be initiated to establish the rationale of this finding, particularly on the geometry and architecture of plants of these bean varieties. Early maturity is a character of prime importance in efficient water utilisation, some consideration needs, therefore, to be directed on this character.

5.5 <u>Water use efficiency</u> (WUE)

D_2 planting gave the highest WUE 81.6Kg grain ha^{-1} cm^{-1} water compared to other sowings. This is because it had the smallest number of leaves, the smallest leaf area and leaf area index (LAI) and the second smallest plant height - characters which had strong negative correlations with grain yield.

Similar trends were noted for the unmulched plots which did not encourage luxuriant vegetative growth. Non-mulched plots registered WUE of 70.2kg grain ha^{-1} cm^{-1} water while the mulched plots only 59.2 kg grain ha^{-1} cm^{-1} water.

Kabanima gave the lowest WUE 38.8 kg grain ha^{-1} cm^{-1} water compared to Canadian Wonder (85.8) and Selian Wonder (69.6) possibly because of its greater height, LAI, number of leaves, leaf area, and poor pod filling. It appears that more assimilates were wasted in maintenance of its structure, as the partitioning of dry matter shows, than in accumulating enough photosynthate for grain filling. Both external and internal factors such as temperature and mineral nutrition or their interaction appear to have had influenced the translocation of assimilates to the pods consequently resulting in lower WUE of Kabanima compared to early maturing Canadian Wonder and Selian Wonder.

6. SUMMARY AND CONCLUSIONS

In this study it was observed that Canadian Wonder significantly outyielded Kabanima by 154% and Selian Wonder by 124% in grain. Selian Wonder similarly outyielded Kabanima by 124%. The relatively late maturing Kabanima was taller, thicker, had more leaves at maturity, greater leaf area, leaf area index (LAI), more total plants dry weight, leaf dry weight, branch dry weight, root dry weight and more pods per plant, but lower N, K and Mg at flowering stage, lower pod dry weight, shelling percentage, grain yield and water use efficiency (WUE) than either Canadian Wonder or Selian Wonder. The lower leaf K value ($\angle$2.5%) in Kabanima at blooming stage implies translocation of carbohydrates into the seed was impaired resulting in poor pod filling. Kabanima appears to be a variety specific to high altitude areas as other workers have observed its consistently high grain yield in these areas.

Mulching promoted effective primary branches per plant vegetative growth, plant height, leaf number, leaf area, LAI but depressed crop uptake of Mg and K, shelling percentage, grain yield and WUE.

Mulching appears undesirable under high soil moisture conditions; it should, thus, be encouraged only in arid conditions.

Mid-March planting, which had the lowest LAI, gave the highest grain yield and WUE. Subsequent later sowing promoted plant height because of increased favourable moisture conditions. Mid-March planting appears the best date of planting beans under Morogoro agro-climatic conditions.

Disease (White Mould) outbreak in mid-March planting date during pod filling stage depressed leaf area and LAI but apparently promoted grain yield. Resistance to White Mould was observed in two Canadian Wonder plants that had primitive trailing habit, thus suggesting that the gene or genes for disease resistance against White Mould (*Sclerotonia sclerotiorum* (Lib.) de Bary) is or are located in certain loci in the progenitors of Canadian Wonder. The two resistant bean plants were segregating plants since they exhibited the primitive character.

Bean leaf N, P and K decreased from seedling to flowering stage in the respective values of

4.96 to 4.22% , 0.39 to 0.29% and 5.14 to 2.61%, while Ca and Mg increased from 0.72 to 1.37% and 0.60 and 0.63% in the same growth stages respectively. The experiment revealed that nutrient uptake by bean plants is influenced by variety, plant growth stage and either directly or indirectly by soil moisture coupled possibly with soil temperature in the different dates and mulching treatments.

Pod yield, shelling percentage, 100 grain weight, and number of seeds per pod tended to exert strong positive influence on seed yield. Pod length tended to be positively correlated with yield components of greatest effect on grain yield. Selection for high grain yield, thus, needs to be directed on these characters.

Plant height, LAI, number of leaves and days to 50% flowering appeared to be negatively correlated with seed yield.

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Appendix 1 (b). **Plant leaf nutrient composition at seedling stage (%)**

Source of Variation	d.f.	Total N(%)	P	K	Ca	Mg	Na
Replication	3	0.202	0.000	0.238	0.039	0.004	0.000
Planting Date (D)	1	0.002	0.057***	7.889	0.185**	0.015	0.000
Mulching (M)	1	0.041	0.003	1.141	0.317***	0.006	0.037***
Variety (V)	2	0.400*	0.001	1.600	0.061*	0.015	0.000
DM	1	0.367	0.003	2.376	0.006	0.006	0.000
DV	2	0.130	0.001	0.141	0.015	0.000	0.000
MV	2	0.394*	0.000	0.215	0.013	0.003	0.002
DMV	2	0.106	0.002	0.161	0.004	0.002	0.000
Error	33	0.125	0.002	0.159	0.017	0.004	0.001
Total	47						

*, **, *** Significant at P = 0.05, 0.01 and 0.001 respectively.

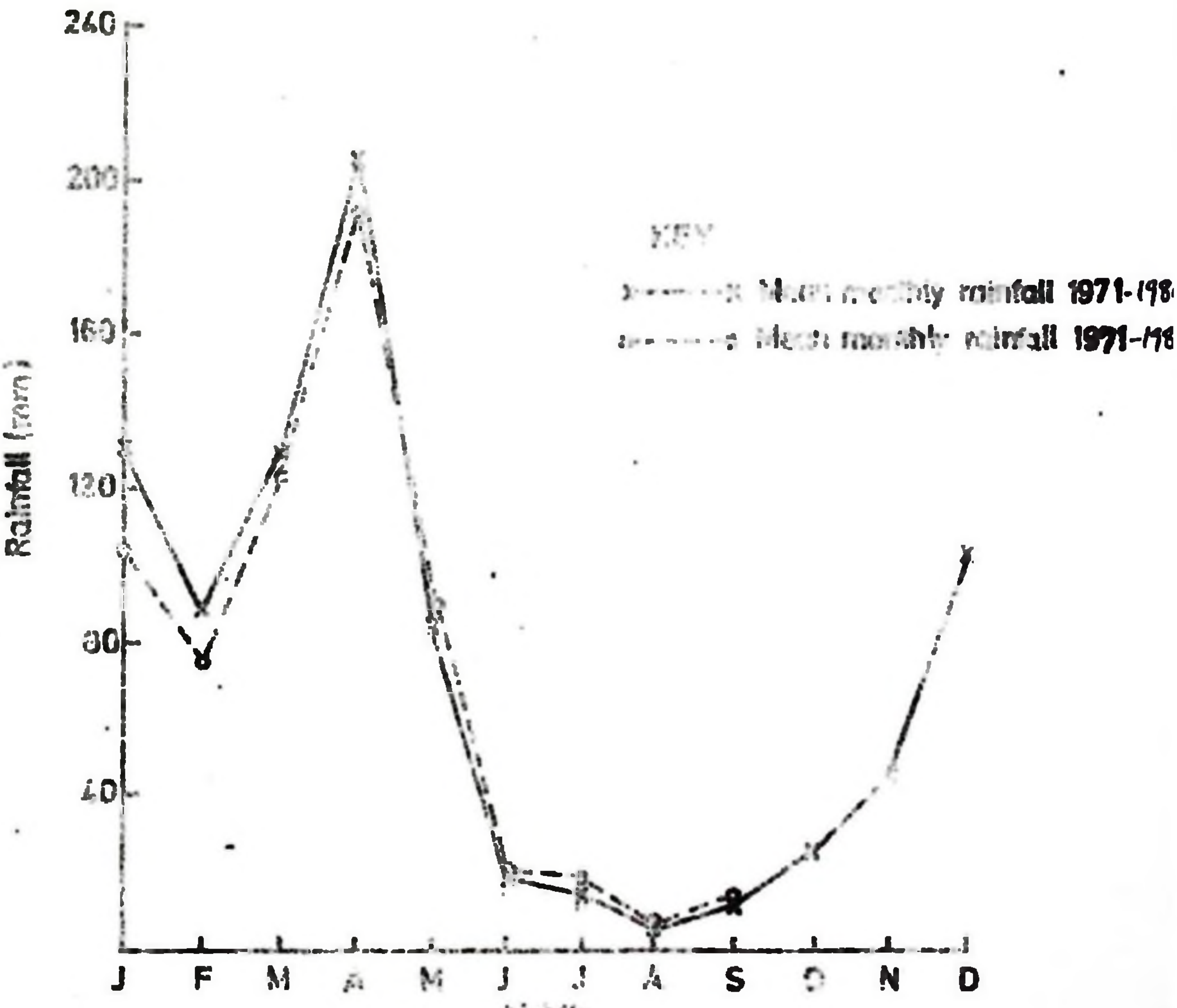
Appendix 1(c). Mean squares from the analyses of variance for dates(D), Mulching (M) and varieties (V) and their interactions for soil parameters.

Source of Variance	d.f.	Soil Nutrient Composition Total N(%)	P(ppm)	K(m.e./100g. soil)	Ca(m.e./100g.soil)	Mg(m.e./100g.soil)	Na(m.e./100g.soil)
Replications	3	0.001	12.790	0.176	0.769	0.212	1.000
Planting Date D	3	0.017***	179.538**	2.643***	14.983***	3.413***	0.006***
Mulching (M)	1	0.001	1.105	1.215*	0.482	0.338	0.001
Variety (V)	2	0.000	10.046	0.090	1.975*	0.021	0.001
DM	3	0.000	96.792	0.454	1.085	1.100***	0.002*
DV	6	0.001	15.546	0.122	1.195	0.131	0.000
MV	2	0.000	14.922	0.455	0.338	0.150	0.000
DMV	6	0.000	29.521	0.144	0.549	0.231	0.001
Error	69	0.000	30.468	0.193	0.604	0.142	0.001
Total	95						

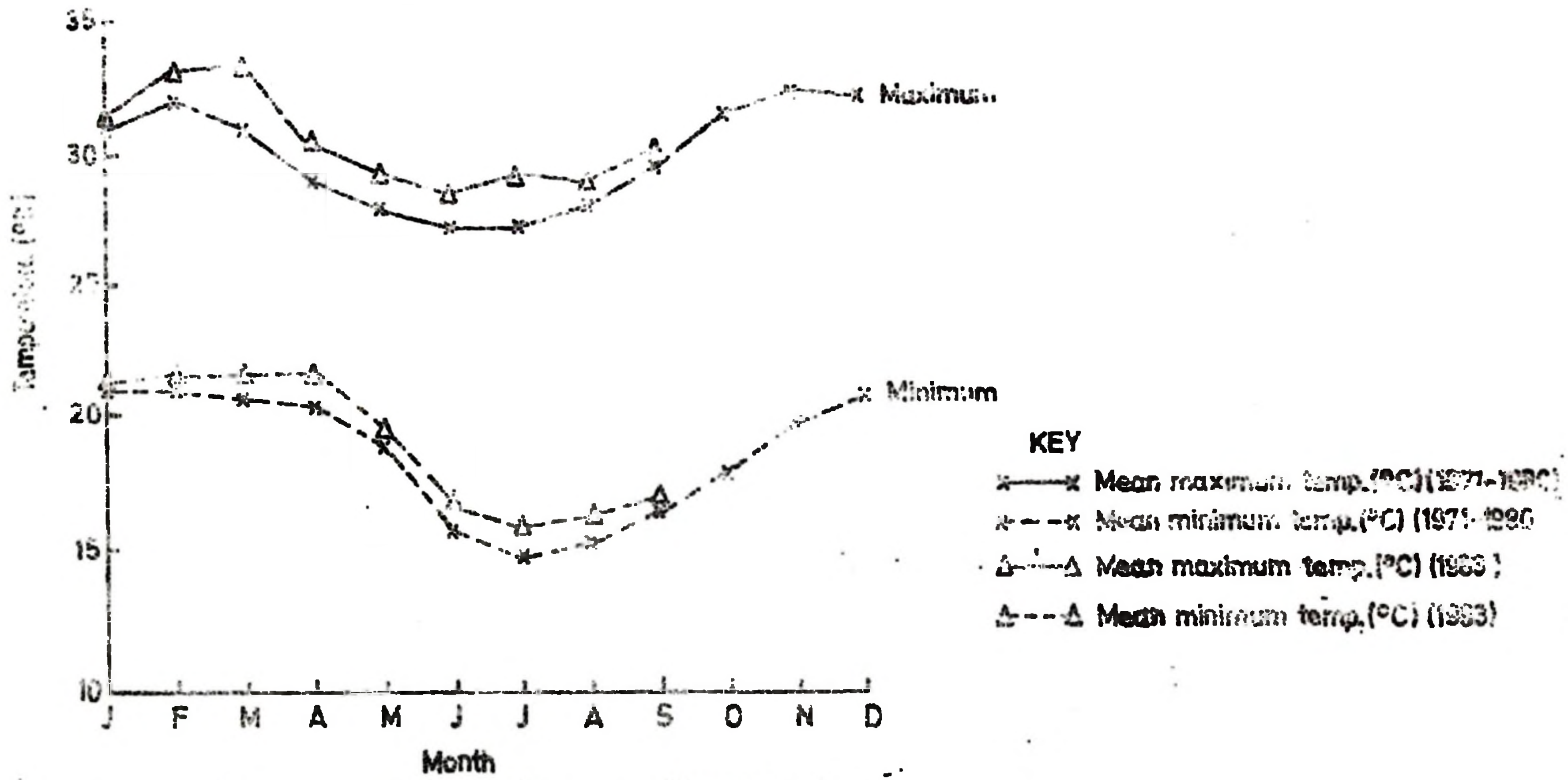
*, **, *** Significant at P = 0.05, 0.01 and 0.001 respectively.

Appendix 2: Climatological data at Morogoro, University Farm (Lat 6°20'S Long 37°39'E altitude 525.8 m.a.s.l. Monthly means 1971 - 1980.

Month	Temperature °C Max.	Temperature °C Min.	Relative Humidity Min %	Sunshine h/day	Wind(2m.height) Km/day	Rain mm/month
J	31.0	21.1	54.7	6.9	200.5	129.7
F	32.0	20.9	52.5	7.6	193.2	87.8
M	31.0	20.8	58.7	6.9	140.1	128.8
A	29.2	20.5	69.5	5.4	99.8	206.3
M	28.2	18.7	63.8	6.0	83.8	82.5
J	27.2	15.7	56.00	6.5	97.3	18.9
J	27.3	14.8	50.4	6.8	138.1	14.9
A	28.0	15.3	45.1	6.8	182.0	4.9
S	29.5	16.5	42.0	7.1	196.8	12.1
O	31.6	17.9	40.3	8.1	238.8	25.6
N	32.4	19.8	42.1	8.5	243.4	46.0
D	32.2	20.9	49.2	7.7	263.4	103.8



Appendix 3. Mean monthly rainfall at the Morogoro University Farm



Appendix.4. Mean monthly temperature at the Morogoro University Farm

Appendix 5: Rainfall distribution, Jan - September, 1983, Morogoro.

Date	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	47.5	0.0	1.2	TR	3.3	6.3	TR	2.5	0.0			
2	41.1	0.0	0.7	13.0	11.1	2.5	0.0	0.2	0.0			
3	0.3	0.0	0.3	6.8	9.6	1.6	TR	1.0	TR			
4	0.0	0.0	0.0	3.0	7.8	0.0	0.1	0.0	0.0			
5	0.0	0.0	0.0	0.0	2.5	2.6	0.0	0.0	0.0			
6	0.0	0.0	0.0	0.2	0.0	TR	0.0	0.0	0.0			
7	0.0	0.0	0.0	TR	0.0	0.0	0.0	0.0	0.0			
8	0.2	0.0	0.0	7.7	0.7	0.0	8.7	0.0	0.0			
9	0.9	0.0	0.0	4.4	1.0	0.0	0.0	0.0	0.0			
10	4.2	0.0	0.0	TR	0.2	0.0	0.0	0.0	0.0			
11	2.2	0.0	0.0	0.4	17.3	1.7	0.0	1.8	0.0			
12	0.0	0.0	0.7	1.0	12.6	6.6	0.0	TR	TR			
13	0.0	0.5	7.7	0.3	21.0	0.0	11.4	0.0	0.0			

Appendix 5: (Contd)

Date	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
14	0.0	0.3	0.3	18.7	5.5	0.0	0.0	0.0	0.0			
15	0.0	8.8	21.3	0.1	3.5	1.2	0.0	0.0	0.0			
16	TR	0.0	31.9	3.6	1.7	0.0	0.0	0.0	0.0			
17	0.3	18.7	2.3	2.5	0.1	TR	0.0	0.0	0.0			
18	2.0	1.0	3.0	TR	TR	0.0	0.0	0.0	0.0			
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
20	0.0	26.3	0.0	2.8	1.0	0.0	0.0	0.0	0.0			
21	0.0	0.0	0.0	4.9	0.0	TR	0.0	0.0	0.5			
22	0.0	0.0	0.0	0.0	0.0	TR	0.0	0.0	0.0			
23	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0			
24	0.0	0.0	22.1	0.0	6.1	0.0	0.0	0.0	0.0			
25	0.0	0.2	5.8	3.4	10.9	0.0	0.0	0.0	5.8			
26	0.2	0.0	0.0	1.9	4.3	0.0	0.0	0.2	0.0			

Appendix 5: (Contd)

Date	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
27	TR	0.0	2.5	0.7	3.2	0.0	0.0	0.0	0.0			
28	0.0	0.0	5.6	30.2	0.0	0.3	2.1	0.0	0.0			
29	0.0	-	0.7	3.7	TR	TR	0.0	0.0	0.0			
30	0.0	-	1.6	1.2	4.7	8.1	9.4	0.0	0.0			
31	0.0	-	0.0	-	TR	-	TR	0.0	0.0			
Total	14.4	53.8	106.5	113.8	132.5	24.6	34.2	3.2				
Total No.of days	4	5	10	17	19	7	5	2				

Appendix 6(a) : Rainfall pattern: weekly values, Jan - Sept., 1983, Morogoro.

Month / Week	1	2	3	4	Total	Mean
January	4.7	6.7	2.3	0.2	13.9	3.48
February	0.0	9.6	46.0	1.4	57.0	14.25
March	1.0	30.0	40.2	38.3	109 .5	27.38
April	30.7	24.9	13.8	44.4	113.8	28.45
May	31.7	61.1	2.8	36.7	132.3	33.08
June	6.7	9.5	0.0	8.4	24.6	6.15
July	8.8	11.4	0.0	14.0	34.2	8.55
August	1.2	1.8	0.0	0.2	3.2	0.8
September	0.0	0.0	0.6	6.8	7.3	1.83

Appendix 6(b): Temperature pattern: Weekly values Jan - Sept. 1983, Morogoro (^{o}C)

Month	Week	1	2	3	4	Total	Mean
Jan	Max	213.0	213.3	221.3	329.0	976.6	244.1
	Min	149.5	148.4	150.1	216.1	664.1	166.0
Feb	Max	234.0	236.3	230.7	234.0	935.0	233.8
	Min	148.1	152.3	152.5	155.0	607.9	152.0
Mar	Max	244.3	242.1	224.2	326.1	1036.1	259.2
	Min	152.7	153.7	149.0	215.2	670.6	167.7
Apr	Max	216.4	216.7	223.1	268.0	1024.2	256.0
	Min	144.9	143.7	147.2	188.2	618.0	154.5
May	Max	202.7	201.6	207.8	299.2	911.3	227.8
	Min	139.6	142.4	135.7	195.7	613.4	153.3
June	Max	199.6	201.5	198.7	261.3	861.1	215.3
	Min	129.9	117.0	114.4	144.9	506.2	126.6
July	Max	203.5	190.3	193.9	255.6	843.3	210.8
	Min	113.1	115.9	100.4	162.3	491.7	122.9
Aug	Max	198.5	196.5	187.1	257.1	839.2	209.8
	Min	121.4	108.2	107.7	149.0	486.3	121.6
Sept	Max	198.0	211.8	221.2	277.2	908.2	227.0
	Min	106.9	118.1	120.0	161.8	506.8	126.7

Appendix 6(c): Sunshine pattern(hours): Weekly values Jan - Sept. 1983, Morogoro.

Month	Week 1	2	3	4	Total	Mean
Jan	51.2	54.6	47.5	89.9	243.2	60.8
Feb	66.0	49.7	52.1	47.5	215.3	53.8
Mar	50.1	42.0	35.7	58.2	186.0	46.5
Apr	35.3	32.2	46.9	47.0	161.4	40.3
May	27.9	28.3	94.8	70.0	171.0	42.8
June	29.3	-	-	-		
July	54.5	41.8	50.0	61.9	208.2	52.0
Aug	36.7	39.7	25.7	60.9	163.0	40.8
Sept	50.4	54.2	61.8	76.2	242.6	60.7

Appendix 6(d): Wind Pattern (Km/week): weekly values Jan - Sept. 1983.

Month Week	1	2	3	4	Total	Mean
Jan	1457.5	1372.7	1207.5	1973.8	6011.5	1502.9
Feb	2076.6	1333.6	985.6	1170.4	5566.2	1391.6
Mar	961.3	804.7	798.3	961.4	3525.7	881.4
Apr	648.1	577.6	533.9	795.3	2554.9	638.7
May	504.4	649.1	519.3	804.1	2476.9	619.2
June	549.6	463.8	555.1	662.6	2231.1	557.8
July	897.3	668.1	758.4	2191.3	4515.1	1128.8
Aug	825.6	758.7	672.9	1633.8	3891.0	972.8
Sept	1285.2	1408.7	1409.8	1966.4	6070.1	1517.5

Appendix 6(e): Total Evaporation: Weekly values Jan - Sept. 1983, Morogoro (mm).

Month	Week 1	2	3	4	Total	Mean
Jan	27,6	23.3	33.3	56.7	140.9	35.2
Feb	51.5	37.6	33.0	40.2	162.3	40.6
Mar	38.0	44.5	27.2	47.8	157.5	39.4
Apr	26.9	14.0	30.5	32.9	104.3	26.1
May	19.7	11.7	14.8	36.1	82.3	20.6
June	16.7	22.0	21.0	23.9	83.6	20.9
July	28.8	24.4	21.0	38.5	112.7	28.2
Aug	15.0	21.0	19.5	42.0	97.5	24.4
Sept	34.5	38.5	46.5	54.3	173.8	43.4

Appendix 7 : Mean Number of Plants/m^2 at Maturity.

		Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	M_1	9.43	10.23	4.50	8.05
	M_o	6.10	6.93	5.68	6.24
D_2	M_1	10.08	14.33	12.25	12.22
	M_o	12.83	18.18	16.48	15.83
D_3	M_1	18.08	18.65	19.18	18.64
	M_o	16.9	19.55	21.43	19.23
D_4	M_1	17.1	16.18	17.4	16.89
	M_o	18.43	16.58	16.93	17.31
Overall mean		13.62	15.06	14.23	14.30

$L.S.D._{0.05}$

Dates		= 1.47
Varieties		= 1.28
Interactions	D x M	= 2.08
	D x V	= 2.55

Appendix : 8 Layout of Field.

D_1 (23.2.83)

Rep →

	I	II	III	IV
	V_2	V_3	V_1	V_3
M_1	V_1	V_2	V_3	V_1
	V_3	V_1	V_2	V_2
	V_1	V_1	V_2	V_1
M_0	V_3	V_2	V_3	V_2
	V_2	V_3	V_1	V_3

D_2 (15.3.83)

Rep → |←4m→|

↑ 3m

I	II	III	IV	
V_1	V_3	V_2	V_1	
V_2	V_2	V_3	V_2	M_0
V_3	V_1	V_1	V_3	
V_1	V_2	V_2	V_3	
V_3	V_1	V_3	V_2	M_1
V_2	V_3	V_1	V_1	

48m

↑ 2m ↓

	V_2	V_2	V_1	V_2
M_1	V_1	V_3	V_2	V_1
	V_3	V_1	V_3	V_3
	V_1	V_3	V_3	V_1
M_0	V_2	V_1	V_2	V_3
	V_3	V_2	V_1	V_2

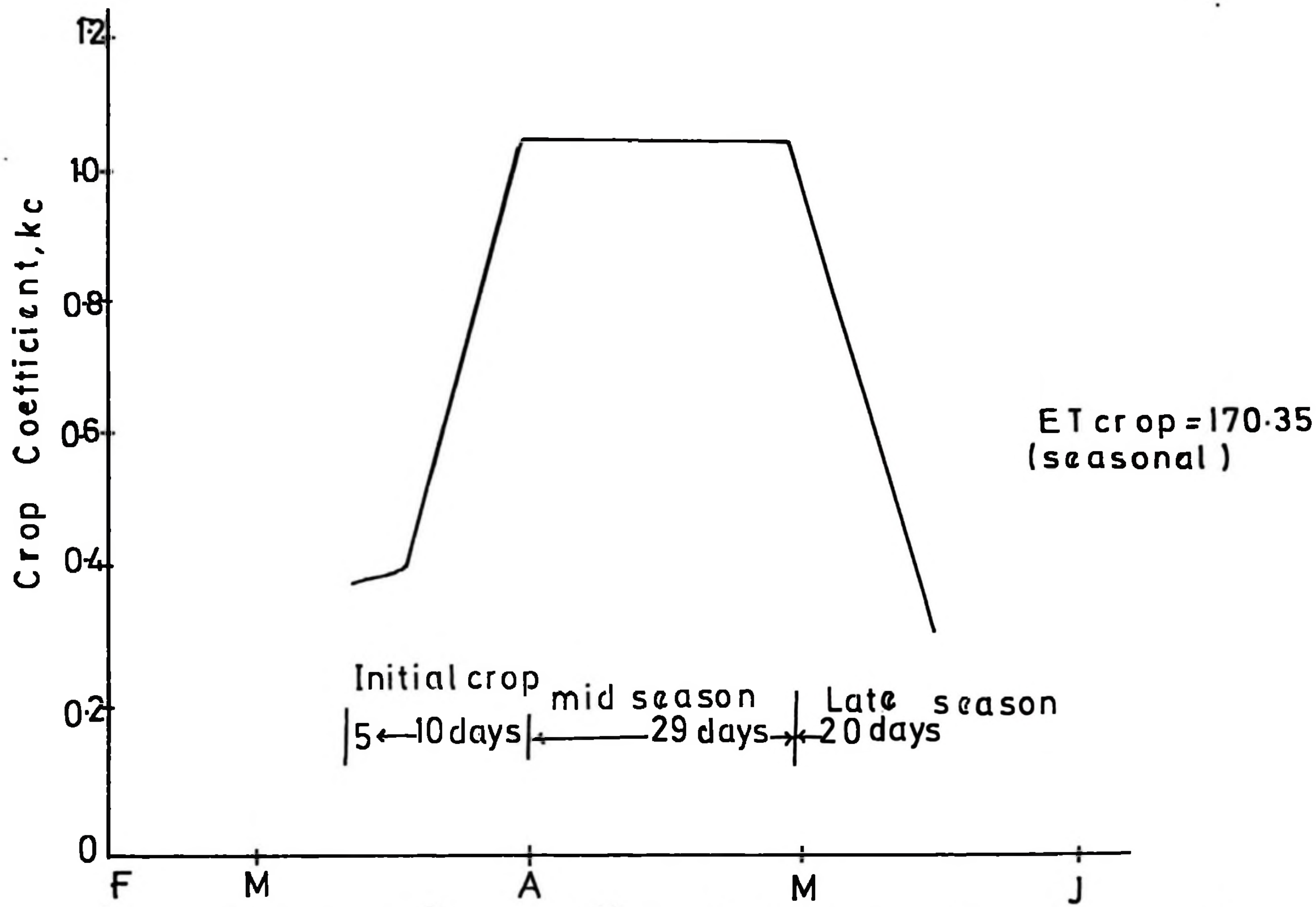
D_3 (26.3.83)

→2m←

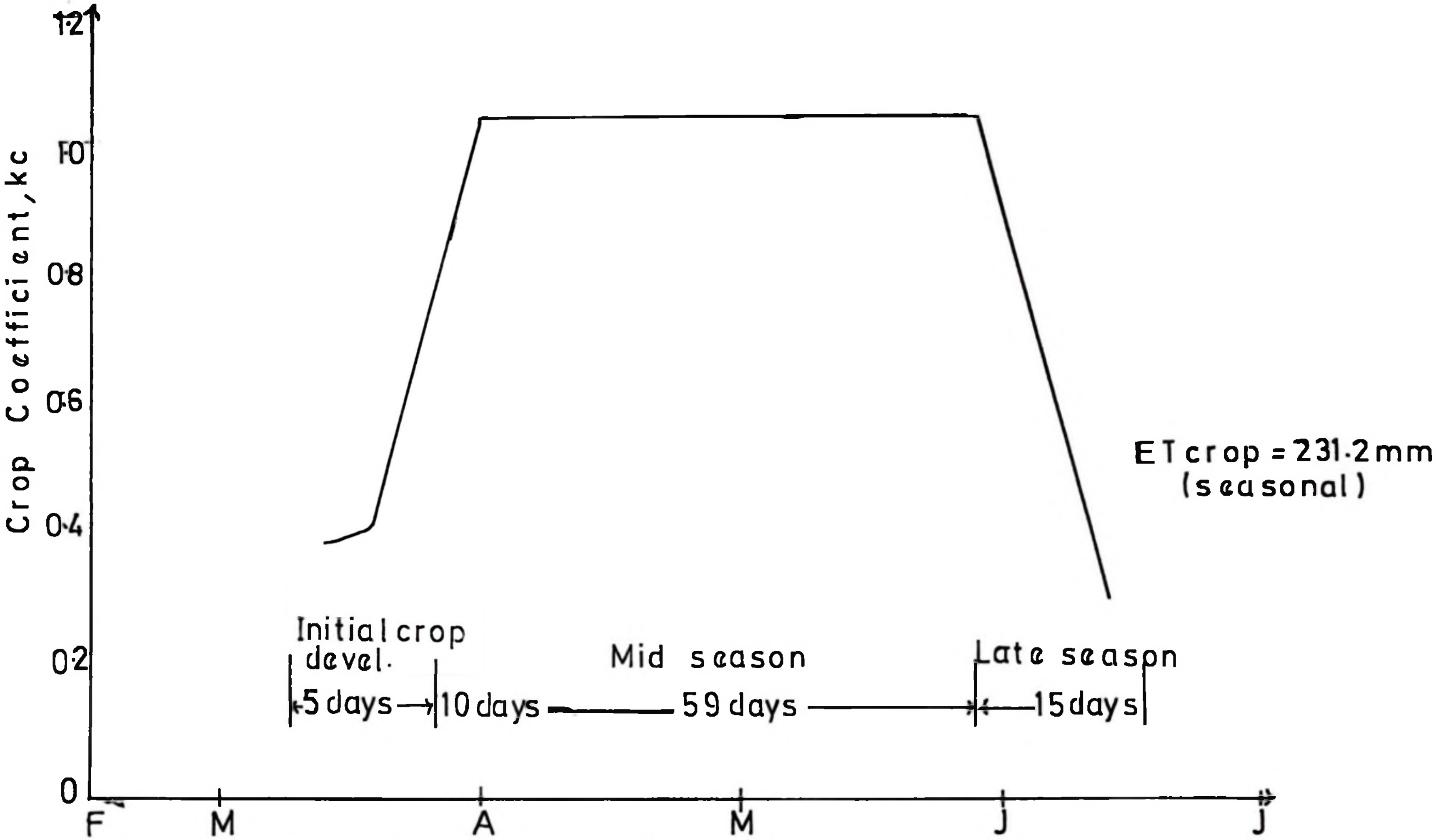
V_1	V_2	V_3	V_1	
V_3	V_1	V_2	V_2	M_0
V_2	V_3	V_1	V_3	
V_3	V_2	V_3	V_2	
V_1	V_3	V_1	V_3	M_1
V_2	V_1	V_2	V_1	

D_4 (8.4.83)

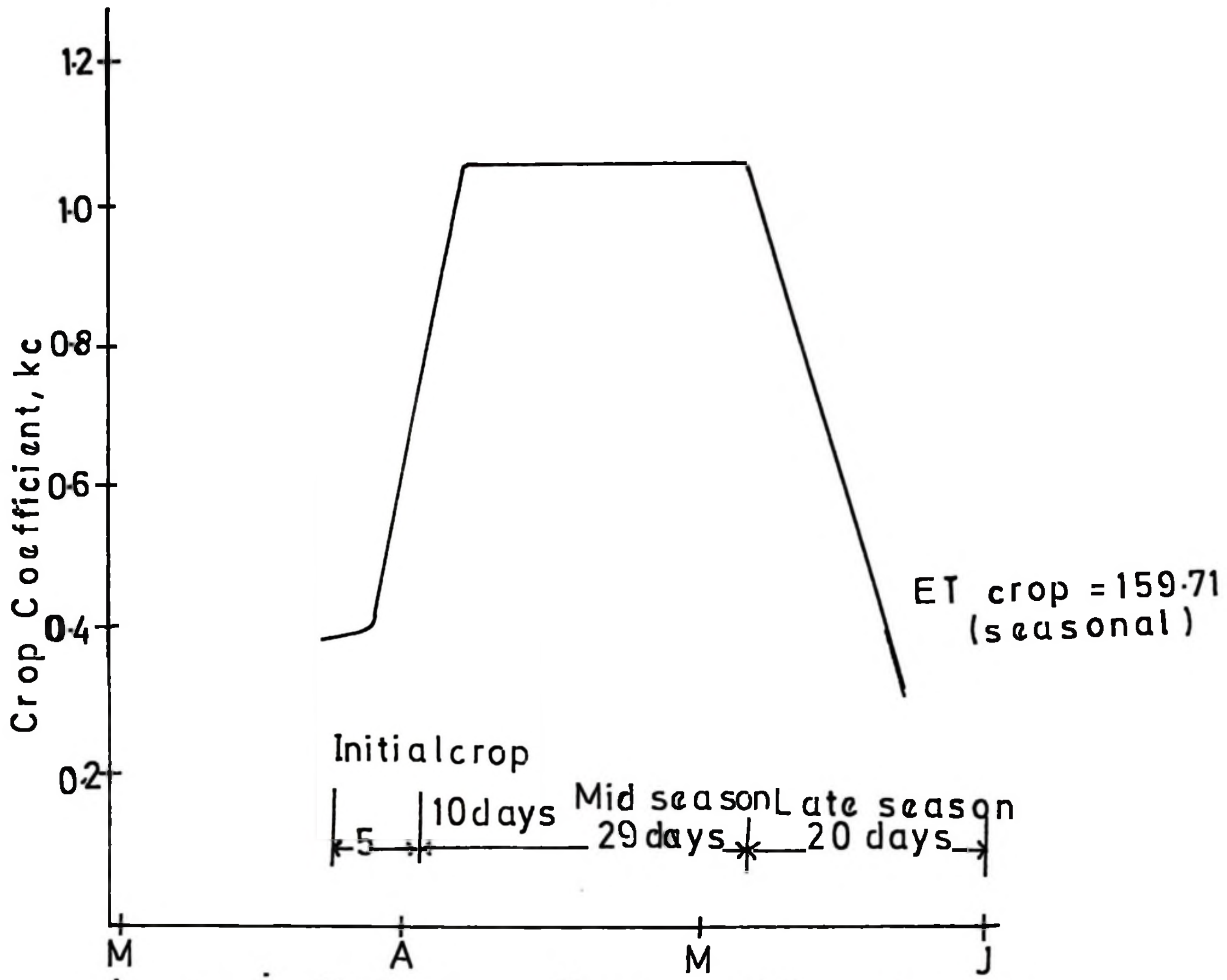
|←40m→|



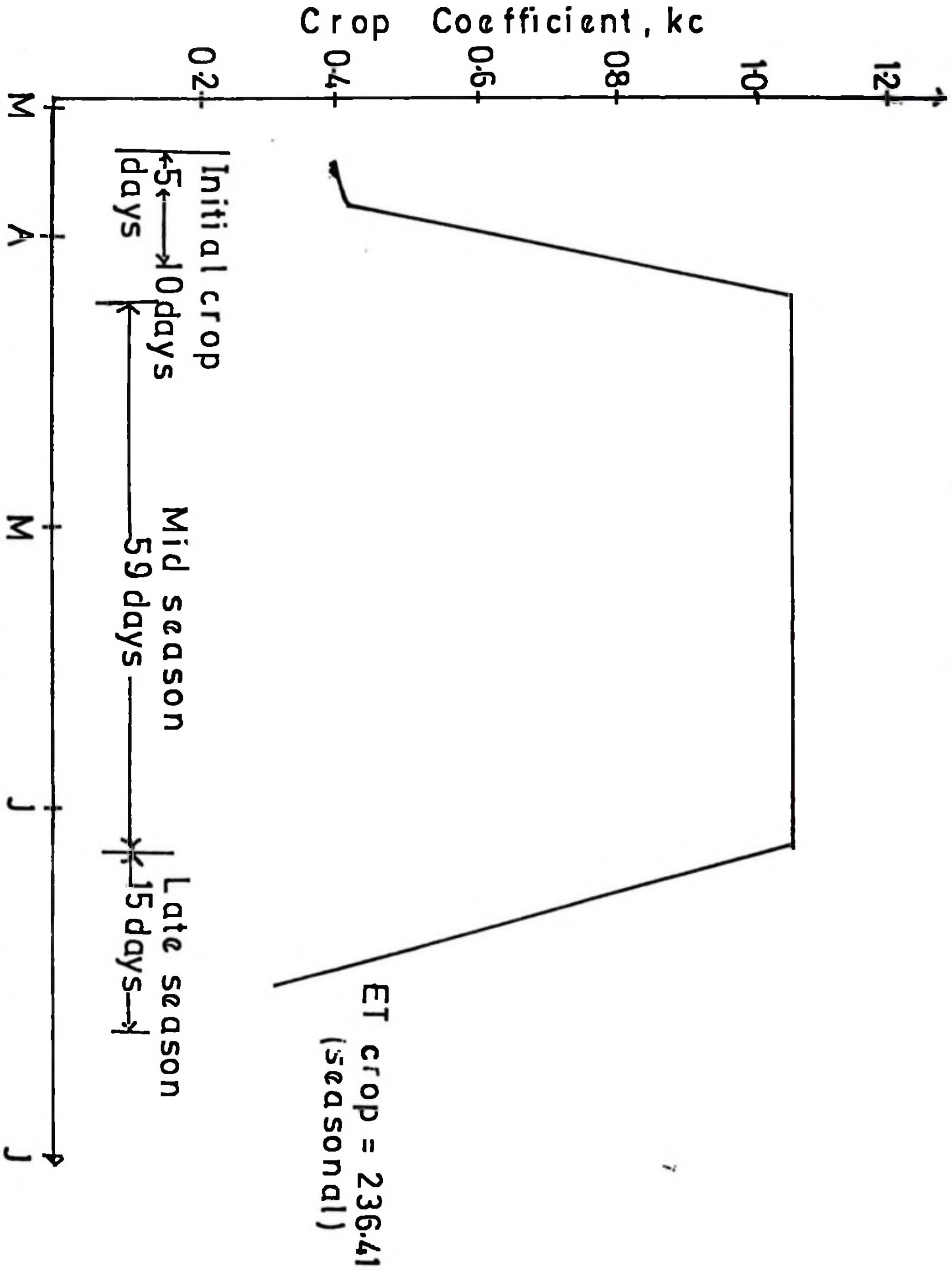
Appendix: 9 Bean Crop Coefficient curve for Cananian Wonder and Selian Wonder varieties sown on 25·2·93



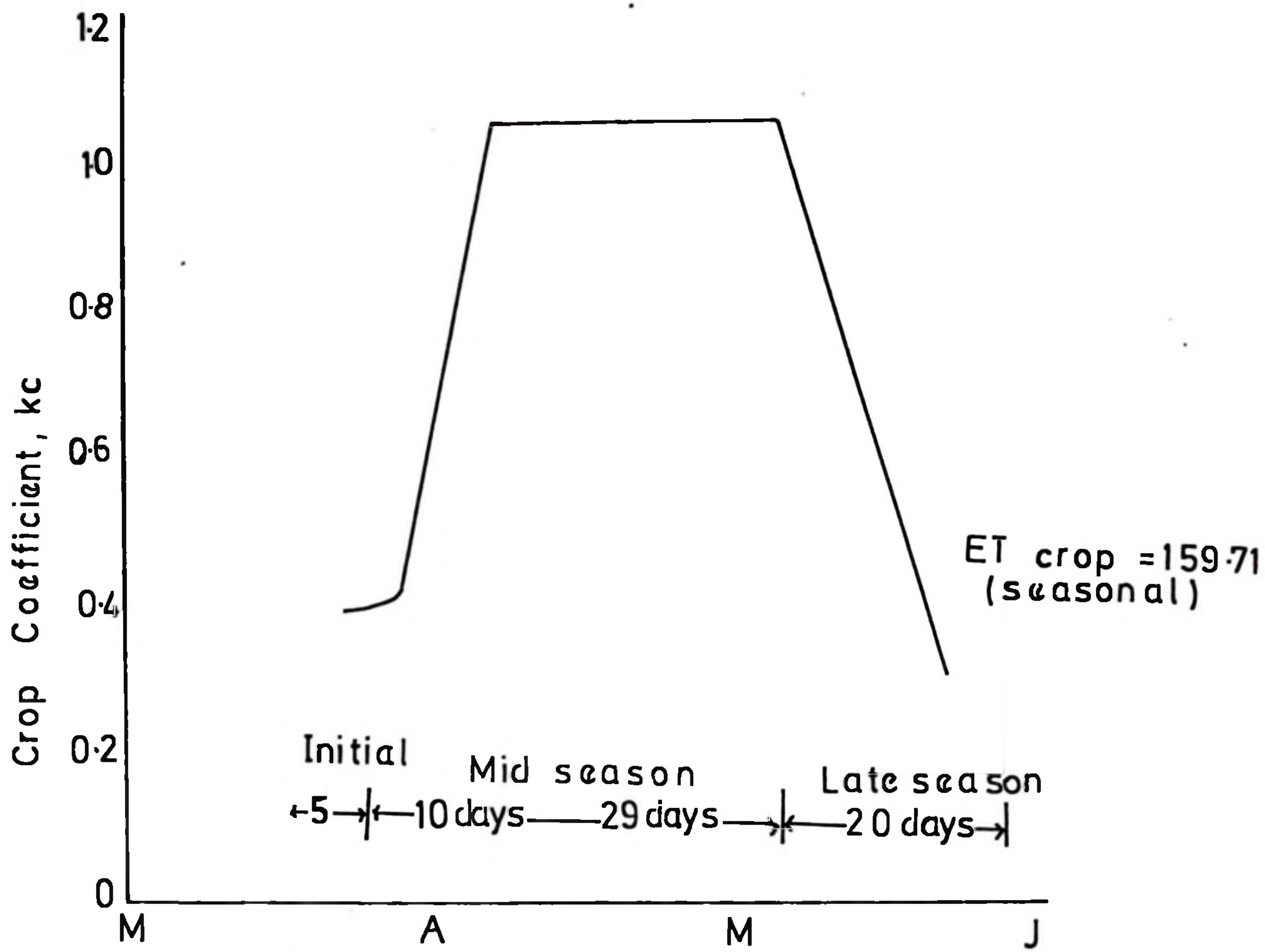
Appendix: 10 The Crop Coefficient for Kabanima Bean variety sown on 25·2·83



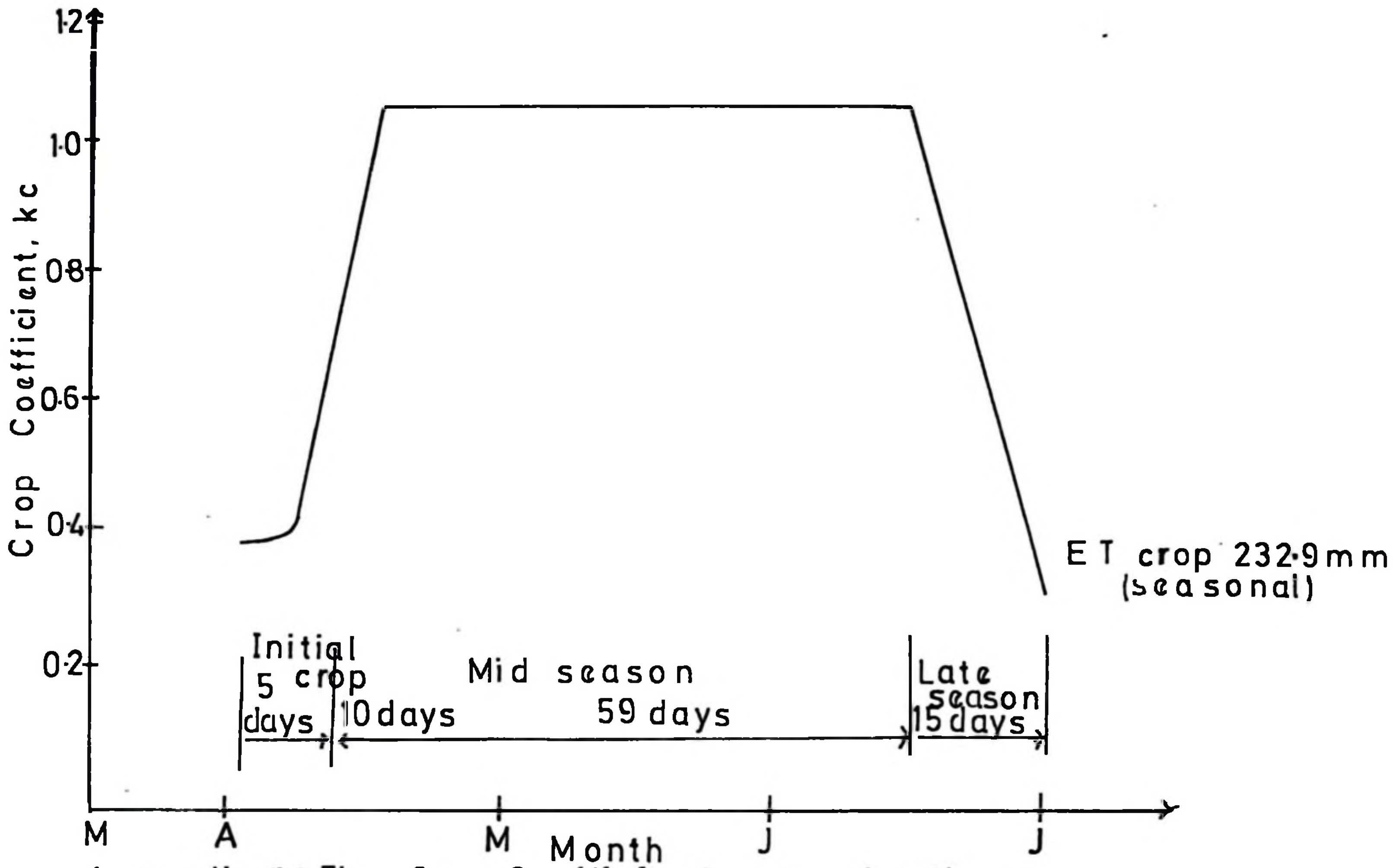
Appendix: 11 The Bean Crop Coefficient curve for Canadian Wonder and Selian wonder varieties sown at mid-March, 83



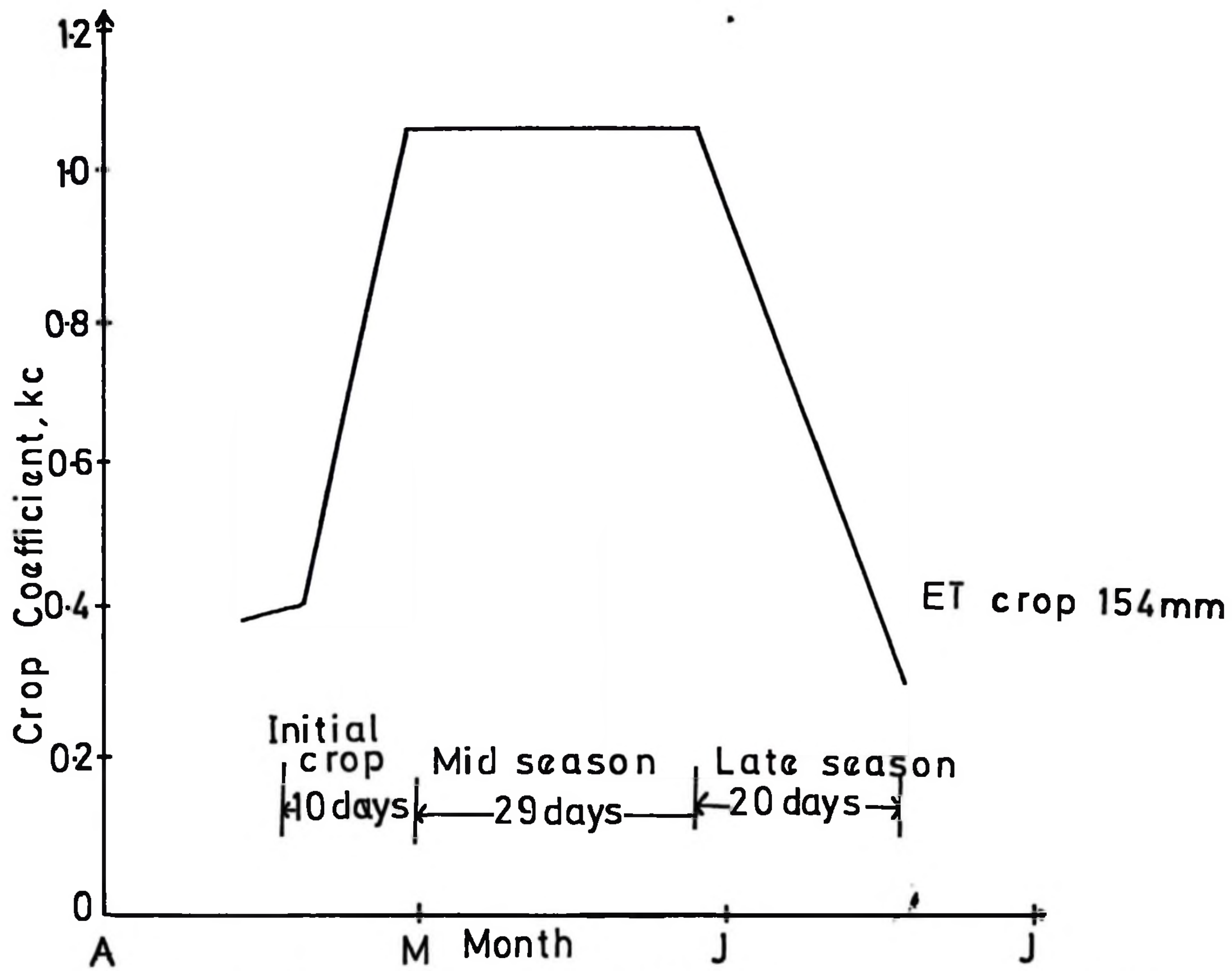
Appendix: 12 The Crop Coefficient curve for the Bean variety Kabanima sown at mid-March, 83



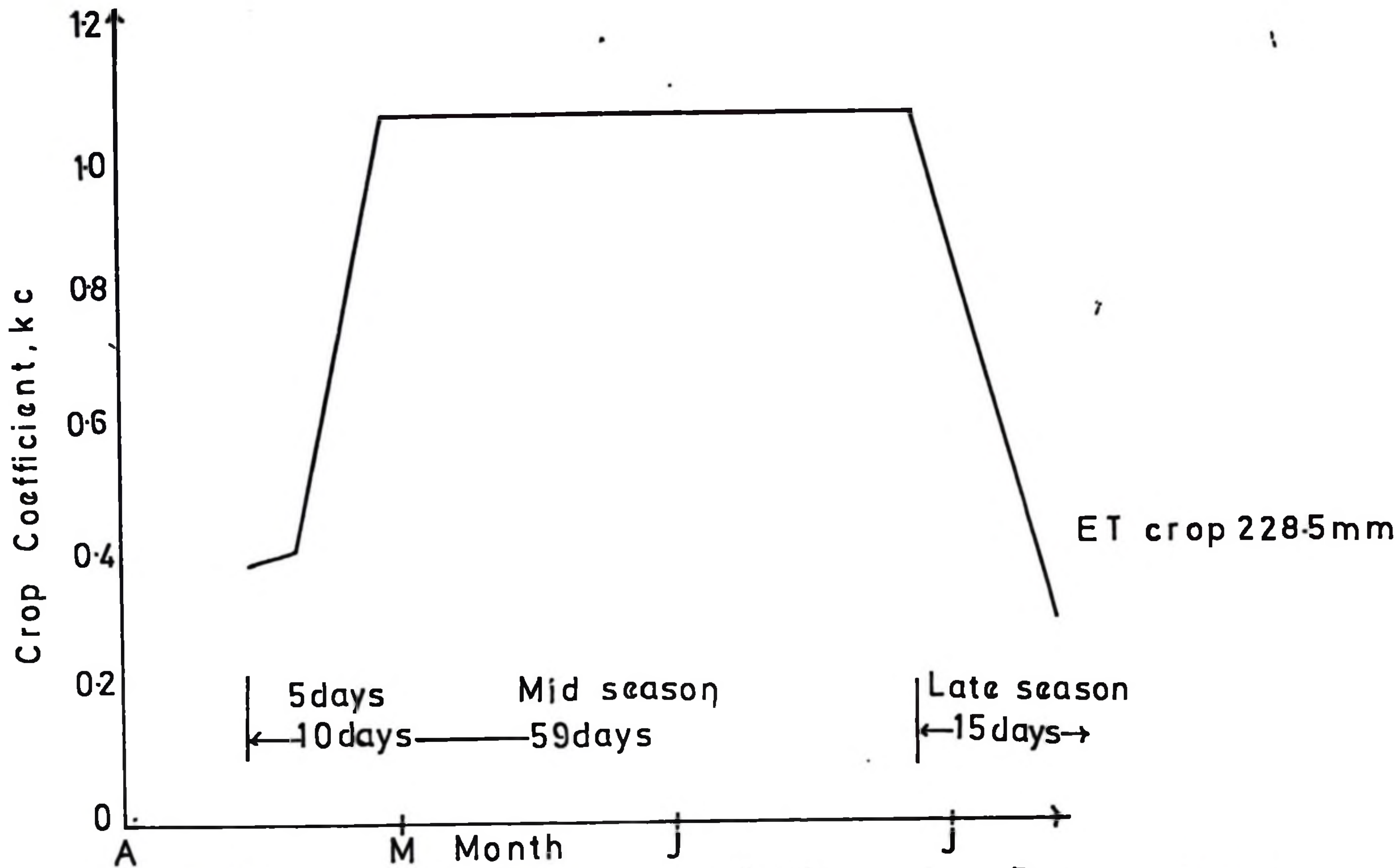
Appendix:13 Bean Crop Coefficient curve for Canadian Wonder and Selian Wonder varieties sown on 26·3·83



Appendix: 14 The Crop Coefficient curve for the Bean variety Kabanima sown on 26·3·83



Appendix: 15 Bean Crop Coefficient curve Canadian Wonder and Selian Wonder varieties sown on 8-4-83



Appendix:16 Crop Coefficient curve for Kabanima Bean variety sown on 8·4·83.

Appendix 17: M x V interaction for the total N - % N in leaves at bean seedling stage.

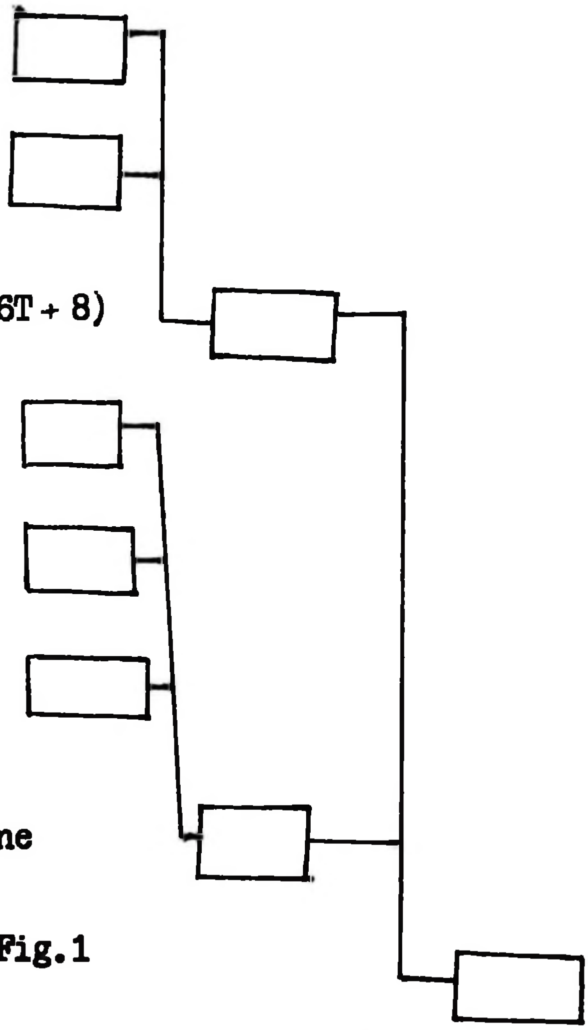
	Kabanima	Canadian Wonder	Selian Wonder	Mean
M_1	9.45	9.59	10.56	9.89
M_o	10.14	9.80	10.01	9.98
Over-all Mean	9.80	9.70	10.29	9.93

Appendix 18(a):

Format for the Blaney-Criddle Method

Data

T.mean	Temp.mean data	
Latitude Month	p Table 1	
	f = Calc $p(0.46T + 8)$	
R.H.min.%	Estimate	
n/N(Sunshine hrs)	Estimate	
U_2 daytime m/sec (Wind speed)	Estimate	
	Fig.1 Block/line	
	ET_o Fig.1	



Where, T.mean = Temperature mean $\frac{\text{maximum} + \text{minimum}}{2}$

p = Mean daily percentage of annual daytime hours for different latitudes.

f = Blaney-Criddle factor for different conditions of minimum relative humidity, sunshine duration and daytime wind.

R.H.min.% = Relative Humidity minimum (%)

Appendix 18(a)(contd.)

ET_o = The rate of evapotranspiration from an extensive surface of 8 to 15cm tall, green grass cover of uniform height, actively growing completely shading the ground and not short of water.

The crop water requirement was then established from the relationship

$ET_{crop} = ET_o \times kc$ where ET_{crop} = crop water requirement or "seasonal water use".

kc = crop constant (crop coefficient)

Crop coefficient curves were drawn for the bean varieties with known crop growth durations and (under disease free conditions) and from four crop development stages (critical, crop development, mid-season and late season) of known kc, it was thus possible to calculate the seasonal water use for each variety.

Initial stage refers to germination or early crop growth where ground cover is below 10%. Crop development stage refers from end of initial stage to attainment of effective groundcover, 70-80%. Mid season stage starts from effective full ground cover to time of start of maturing as indicated by discolouring of bean leaves. Late season stage starts from end of mid-season stage until full maturity or harvest (Appendix 9-16).

Appendix 18: (b)

Computed Blaney-Criddle Data for Morogoro University Farm Lat. 6^{o} 20'S Long. 37^{o} 39'E

Altitude 525.8m.

	T.mean	p	$f = p(0.46T + 8)$	R.H. min.%	n/N	U_2	Fig.1 Block/line	ET_0 Fig.1 mm/day
Feb	26.45	0.28	5.61	52.5 H	0.62	193.2 M	VI	4.7
Mar	25.9	0.28	5.58	58.7 H	0.57	140.1 L	IX	3.7
Apr	24.85	0.27	5.25	69.5 H	0.45	99.8 L	IX	3.0
May	23.45	0.27	5.07	63.8 H	0.50	83.8 L	IX	2.8
June	21.45	0.27	4.82	56.0 H	0.55	97.3 L	IX	2.7
July	21.05	0.27	4.77	50.4 H	0.58	138.1 L	IX	2.7

N.B.

H = High
M = Moderate
L = Light

Appendix 19: Seasonal water use, ET_{crop} (cm) for different varieties in different dates.

	Kabanima	Canadian Wonder	Selian Wonder	Mean
D_1	23.12	17.03	17.03	19.06
D_2	23.64	15.97	15.97	18.53
D_3	23.29	15.70	15.70	18.23
D_4	22.80	15.40	15.40	17.87
Overall Mean	23.21	16.02	16.02	18.42

Appendix 30: **COMPUTATIONS**

ANALYSIS OF VARIANCE (ANOVA)

Source	df	SS	MS	F
Replications	3			
Date, D	3			
Mulching, M	1			
Variety, V	2			
DM	3			
DV	6			
MV	2			
DMV	6			
Error	69			
Total	95			

1. Correction factor (C.F.) $= \dfrac{\left(\sum_{i=1}^{n=96} X\right)^2}{N}$ where N = 96

2. $SS_{Total} = \sum_{i=1}^{n=96} (X)^2 - C.F.$

3. $SS_{Treatments} = \dfrac{\sum_{i=1}^{n=24} (T_t)^2}{r} - C.F.$ where T_t = Treatment total

r = replications = 4

4. $SS_{Reps} = \dfrac{\sum_{i=1}^{n=4} (Rep)^2}{t} - C.F.$ where t = treatment = 24

Appendix 20:(contd.)

5. $SS_{Error} = SS_{Total} - (SS_{Tret.} + SS_{Rep.})$

DM interaction "Table A"

6. Entries are 3 levels of variety; $DM = V_1 + V_2 + V_3$

7. $$SS_{Total\ in\ A} = \frac{\sum_{i=1}^{n=8} (DM)^2}{vr} - C.F.$$ where, V = 3 varieties
   r = 4 replications

8. $$SS_{Date,D} = \frac{\sum_{i=1}^{n=4} (D)^2}{vrm} - C.F.$$ where D = date
   v = 3 varieties
   r = 4 replications
   m = 2 mulches

9. $$SS_{Mulching}\ M = \frac{\sum_{i=1}^{n=2} (M)^2}{dvr} - C.F.$$ where,
   M = Mulching
   d = 4 dates
   v = 3 varieties
   r = 4 replications

10. $SS_{DM} = SS_{A} - (SS_{Total} + SS_{Mulching})$

MV interaction "Table B"

11. Entries are 4 levels of dates, i.e.

   $MV = d_1 + d_2 + d_3 + d_4$

12. $$SS_{Total\ in\ B} = \frac{\sum_{i=1}^{n=6} (MV)^2}{dr} - C.F.$$ where,
   d = 4 dates
   r = 4 replications

13. $$SS_{Variety} = \frac{\sum_{i=1}^{n=6} (V)^2}{dmr} - C.F.$$ where, d = 4 dates
   m = 2 mulches
   r = 4 replications

Appendix 20:(contd.)

14. $SS_{MV} = SS_{B} - (SS_{Var} + SS_{Mulching})$

DV interaction "Table C"

15. Entries are sums of 2 levels of mulching,

$$DV = m_1 + m_0$$

16. $SS_{\text{Total in C}} = \dfrac{\sum_{i=1}^{n=12} (DV)^2}{mr} - C.F.$ where,
m = 2 mulches
r = 4 replications

17. $SS_{DV} = SS_{C} - (SS_{Var.} + SS_{date})$

18. $SS_{DMV} = SS_{Treat.} - (SS_{date} + SS_{mulching} + SS_{Var.} + SS_{DM} + SS_{MV} + SS_{DV})$

19. $MS = \dfrac{SS}{df}$

20. F value for variety = $\dfrac{M.S._{var.}}{\text{Error M.S.}}$

21. L.S.D. = $\sqrt{\dfrac{2\ \text{M.S. Error}}{r}} \times t_{0.05,\ 69\ d.f.}$

where, r = no. of varietes on which the means to be separated are based

$r = \dfrac{N}{n}$ N = Total number of treatment combinations (main effects)

n = Number of treatment on summary table.