CHEMICAL WEED CONTROL IN IRISH POTATOES
(*Solanum tuberosum* L.)

by

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A thesis submitted in part fulfilment for the degree of Master of Science in Agriculture (Agronomy) in University of Nairobi.

1981

DECLARATION BY THE CANDIDATE

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

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ABSTRACT

Studies on weed control in potatoes by use of herbicides at pre-emergence stage were conducted between 1979 and 1981 at National Potato Research Station - Tigoni. Sencor (metribuzin), afalon (linuron) and galex (mixture of metobromuron and metolachlor) applied at three rates (low, medium and high rates) were effective in controlling weeds in that order. Sencor was particularly very effective irrespective of the rates used (350g a.i., 875g a.i. and 1400g a.i. ha^{-1}). *Oxalis* sp., *Tagetes minuta* L., *Galium spurium* L. and *Pennisetum clandestinum* Chiov. were not effectively controlled by all the herbicides under field conditions. However, under glasshouse conditions, *Tagetes minuta* L. was well controlled by all the herbicidal sprays especially if applied at near emergence to two leaf stage of the weed; sencor suppressed the *Oxalis* sp. effectively, particularly the higher rates above 1400g a.i. ha^{-1} under glasshouse conditions. Sencor application particularly at the higher rate (1400g a.i. ha^{-1}) suppressed *Tagetes minuta* L. and was more effective in

causing leaf chlorosis of <u>Oxalis</u> sp. in the field. The chlorosis recovered later in the seasons. Potato total tuber yield and the large sized tubers were reduced by weeds. In general, herbicide treatments gave higher yield of tubers than hand weeding. Herbicides had no consistent effect on potato leaf, stem and tuber mineral nutrient contents (N, P, K, Ca and Mg), plant height, stems per plant and tubers per plant. The non-weeded treatment, however, was observed to cause reduction of the number of stems per plant and hence lower tubers per plant. High weed infestation caused reduction of percent residual moisture content of soil, especially under drought conditions. The tuber dry matter content and processing quality (as determined by crisp colour) were not affected by the herbicides, but seasonal variation was noticed. A positive correlation between percent tuber dry matter content and crisp colours was also noticeable. The herbicides seemed to have no residual effect on the following crop of maize after 5 months of herbicide application. Also, a similar weed flora emerged after 3-5 months after the herbicide applications.

Nevertheless, sencor and afalon appeared to scorch maize and beans planted soon after herbicide applications (about one month after herbicide application). The net benefits indicated that hand weeding is comparatively more expensive than other weed control methods studied. This is with respect to the recommendation domain which may be encompassed by this study situation.

CHAPTER 1

1.1. INTRODUCTION

1.1.1. Importance of Potatoes in Kenya

The cultivated potato (*Solanum tuberosum* L.) often referred to as Irish potato has become an important food and cash crop in Kenya over the last twenty years, particularly in urban centres where it is consumed mainly as chips. Its ability to grow in the high altitude areas (>2000m) where maize (major food crop in Kenya) does not do well and its high nutritive value makes it an important food crop. The balance between proteins and calories is excellent. There are no limiting amino acid constituents such as exists with the cereals and the legume crops. Potentially, more food value (calories and proteins) can be produced per unit of time, per unit of land and per unit of water with the potato than with any other major food crop (Sawyer, 1978). As a starchy, energy-rich food, potato is ranked fourth after wheat, rice and corn in the world (Ngugi, 1979a; Sawyer, 1978). In terms of calories production per unit of land, it is second only to sugar cane. Similarly, it is second only to soyabean in vegetable protein production per unit area. Furthermore, its use as a complement to maize is progressive and has a bright future. This means that expansion of potato production to meet the ever-mounting local food demand and for export is inevitable. Provision of clean seed in adequate quantities and at the right time has never been satisfactory and this factor has contributed to poor crops being grown every year (Waithaka, 1976). Hence, the Kenya Government is doing as much as it can to stream-line all that goes into production of this important crop as portrayed in the 1979-83 Development Plan (Republic of Kenya, 1979) by allocating more funds to the potato improvement programmes.

A survey conducted in Kenya (Durr and Lorenzl, 1980) indicates that about one-third of all farmers in Kenya grow potatoes. They grow about 75,000-100,000 hectares per year in two seasons. Total production is estimated at 400,000-500,000 tonnes per year. The survey also shows that 35-40% of Kenya's population consume potatoes regularly. The sessional paper No. 4 of 1981 on

National food policy (Anon. 1981), indicates a target of 628,000 tonnes by 1989 - in order to feed the fast growing population. This means an extra 378,000 tonnes on top of current production and this calls for increasing yields per unit of land.

1.1.2. Potato crop and its uses

In Kenya, potatoes are mainly consumed either boiled, fried or mashed. However, in the urban centres, the utilization of potato as chips is quite promising while some crisps are increasingly being sold as snacks. This means that potato processing in Kenya is not fully exploited as yet and has some potential.

An average annual rainfall of 500-750 mm well distributed is required. At lower altitudes in Kenya, potato yields are very low due to moisture stress and high temperatures. This is confirmed by work done at Thika (1548m) (Holler, 1974), where under rainfall plus irrigation the variety Anett yielded 42.8 tonnes ha^{-1} while under no irrigation supplementation, yield was 19.7 tonnes ha^{-1}. Studies by Holler (1974) in Kenya indicate that in addition to the need for application of phosphorus and nitrogen, the amount of rainfall is the second major factor limiting potato yields (apart from diseases). He indicated that optimal rainfall distribution for such an early variety as Anett is a monthly rainfall of 150mm (varying according to the rate of evaporation). The minimum monthly rainfall necessary for a variety like Anett (early maturing) in areas above 1500m can be stated as 80mm. For varieties which have no drought resistance (or drought escaping capacity), a higher minimum monthly rainfall is required.

High potential areas are located between 1800-3000m above sea level. However, small holdings are found between 1500-1800m.

The potato requires a cool growing season. An average daily temperature of 15-18°C is ideal (Smith, 1977; Ngugi, 1979b; Janick, Schery, Woods and Ruttan, 1969). Ambient temperatures above 21°C have adverse effects on yields and when soil temperatures are above 21°C, tuber formation is retarded (Janick, *et al.*, 1969; Holler, 1974). At soil temperatures above 29°C, very few tubers are formed and those formed remain very small in size. Results of experiments at Mtwapa in Kenya (Holler, 1974) showed that at high soil temperatures, some potato varieties never emerged due to heat stress. In this study, the growth of the plants which survived after emergence was characterised by single stems, slow foliage growth, small leaves, formation of tubers close to the stem (no stolons), small and misshapen tubers, while the varieties having coloured tubers ended with colourless tubers.

Potatoes grow well in sandy loam or deep, well drained loam and slightly acid soils (Smith, 1977; Janick, *et al*., 1969; Acland, 1975). Heavy soils restrict tuber expansion and make harvesting difficult. Water-logging which accompanies such soils is detrimental to potato growth.

Soil pH of 5.5-6.0 is preferred (Holler, 1974; Ngugi, 1979b). At soil pH above 6, outbreak of potato scab (*Streptomyces scabies*) may occur.

1.1.3. Weed problems in potato production

Weeds can simply be defined as plants which the farmers do not want to have in their crops.

The definition encompasses volunteers of previous crops.

Weeds compete with potatoes for nutrients, moisture, light and space especially at critical period of crop growth. This may cause considerable yield losses to a magnitude of 16-76 percent (Neild and Proctor, 1962) [as quoted by Makepeace and Holroyd (1978)]. Work done in Colombia indicates yield losses due to weeds as high as 50 percent (Furtick, 1970).

Different opinions exist as to when the weeds are detrimental to potatoes. Pereira (1941) working in Rothamsted indicated that even small weeds at the time of potato emergence cause reduction in potato yields while Zimdahl (1980) reviewing work by Everaarts and Satsyati (1977) emphasized that potatoes kept weed-free for the first four weeks after planting did not experience yield reduction. However, work by Saghir and Markoullis (1974) disagree slightly to this by indicating that a weed-free 3 weeks period after planting was insufficient to avoid yield loss. This study showed that full yield was obtained when plots were weeded for the entire 6-9 weeks after planting leading to the conclusion that, weed presence early in the season was not detrimental to yields unless permitted to remain past the 6-9 weeks point after planting.

However, for effective control of weeds, correct timing of weed control is of paramount importance and can be achieved through use of herbicides particularly the pre-emergence types. Cultivation stimulates germination of weed seeds and hence, much of the effectiveness of the pre-emergence application of herbicides is dependent upon this principle.

Very limited work on herbicides for use in potatoes has been reported in Kenya. Their use immediately before or soon after emergence of potatoes should be related to specific local conditions. Variation in climate, soils and weed species can influence rate of application (Smith, 1977) and type of herbicide to use. The need to obtain high yields and to ease the drudgery that is usually experienced in crop production by most farmers in the tropics as compared to their counterparts in the developed countries, calls for taking risks in the use of herbicides. There is need to develop locally adapted recommendations on the use of herbicides which are suited to the local weed and climatic conditions.

The objectives of this study were therefore to evaluate three promising herbicides: Afalon (Linuron) which is a substituted urea; Sencor W.P. 70 (Metribuzin) and Galex (Mixture of Metobromuron (patoran) and Metolachlor (dual) as well as to assess the effects of weeds on potato growth and tuber yield.

CHAPTER 2

2.1. LITERATURE REVIEW

2.1.2. Potato origin and its production in Kenya

Several authorities (Smith, 1977; Salaman, 1970; Janick *et al*., 1969; Howard, 1969; Correll, 1962; Hawkes, 1978) agree that the origin of the potato was in the South American continent. The potato was cultivated by the Incas in the Andes mountains of South America as early as 500 B.C. This is confirmed by archaeological findings of potato designs on early Andean pottery and by data from early Spanish post conquest chronicles (Salaman, 1970; Hawkes, 1978). The most striking archaeological evidence for the antiquity of potato cultivation is afforded by ceramics from the northern coast of Peru belonging to the Mochica, Chimu and Inca cultures which are made in form of potatoes. Historical and linguistic evidence clearly corroborates the archaeological evidence as to the origin of the cultivated potato in the Western parts of South America (Hawkes, 1978). Salaman (1970) reveals that, the South American immigrants found a large variety of wild potatoes and cultivated them at about 2000 years before the Spanish conquest.

During the pre-Columbian times, the potato was not cultivated outside South America. Europeans saw the potato in 1537 when the Spaniards landed in one of the valleys of the Andes (now Colombia) from where the crop was taken to Europe in 1570. By 1600, it was grown throughout the continent and in 1663 it was introduced to Ireland (Smith, 1977).

Introduction to North America was in 1621 and by 1700, it was extensively cultivated. The association of the potato between Ireland and the Irish people is as early as 1693 since it became the staple food in the greater part of that country (Smith, 1977).

It can be concluded that, potato is undoubtedly of ancient origin, although our knowledge of its early stages of domestication is not so precise as that of some other crops such as wheat and barley and the exact area where it was first grown, the details of its introduction into Europe and other parts of the world from South America are still matters of debate (Hawkes, 1978).

At present, the potato is grown chiefly in Europe (230 million tonnes per year) followed by North America (15 million tonnes per year). Latin America falls third (7 million tonnes per year) (Janick, et al., 1969).

The potato plant is an introduced plant in Kenya. However, there are no clear records of the date of its introduction in Kenya, but it is definite that it was introduced during the late 19th century by the English travellers and more particularly by the British East Africa Trading Company which had been given powers by the British Government to look after the protectorate (Waithaka, 1976). Early settlers mainly of South African origin, started growing potatoes in the "White Highlands" as soon as they settled there in the late 1800s.

Although potatoes have been grown for well over 70 years on a commercial basis, the crop has never been cleared of its wide range of major problems. Pest control has continued to be a major drawback. Similarly, the provision of clean seed in adequate quantities at the right time has never been satisfactory and this factor has contributed to poor crops being grown every year.

The yield per hectare varies considerably from one area to another (Table 2.1). National average yield is about 5-7.5 t/ha (Acland, 1975; Durr and Lorenzl, 1980). This is far below the average yields in other potato growing countries (Table 2.2). The national average figures may be doubled if good husbandry is effected. The yield achieved for commercial potato production in Kenya is 40 t/ha (Acland, 1975). Maximum potential in the tropics can be 65 t/ha if management of water, pests, fertilizers, etc. are well looked after (Burton, 1979).

Potatoes have become an important food and cash crop in Kenya over the last 20 years or so and intense efforts are being made to overcome the above age-old problems. The approach is through local breeding for resistance to late blight (Phytophthora infestans) and bacterial wilt (Pseudomonas solanacearum), provision of locally produced certified seed and streamlining of the marketing and distribution system.

Importance of the potato in the diet of the population is depicted in the regional hectarage and production figures given in Table 2.3.

Table 2.1. Average Yields of Potatoes in Different Areas of Kenya.

Area	Average Yield (Tonnes per hectare)
Nyeri/Murang'a	5.0
Molo	4.5
Kiambu	4.8
Ol Kalou	5.2
South Kinangop	5.2
Kibirichia	9.4
Average	5.8

Source: Georg Durr, 1976/77 "Studies on the potato sector in Kenya", Interim Reports Nos. 1-6.

Table 2.2. Average Yields of Potatoes by Countries

Country	Average Yield (Tonnes per hectare)
The Netherlands	35.5
U.K.	24.5
U.S.A.	24.0
Colombia	10.7
Ceylon (Sri Lanka)	8.5
India	8.0
Venezuela	8.0
Peru	6.25
Uganda	5.0

Source: D.E. Kay, 1973, "TPI Crop and Product Digest, No. 2", Root Crops, P. 109.

Table 2.3. Regional hectarage and production figures for potatoes

	Area Harvested (x1000 ha)				Yield (kg/ha)				Production (1000 tonnes)			
	1969-71	1977	1978	1979	1969-71	1977	1978	1979	1969-71	1977	1978	1979
WORLD	20071	18551	18406	18350	13745	14319	14999	15503	275891	265635	276072	284471
AFRICA	355	509	517	528	8215	8611	8574	8770	2915	4384	4433	4629
ALGERIA	43	75	73	73F	5906	6304	6483	6534	253	472	473	477F
ANGOLA	5	6F	6F	6F	6296	7273	6364	7273	34	40F	35F	40F
BURUNDI	14	25F	25F	26F	5435	8800	9200	9054	77	220F	230F	233F
CAMEROON	11	17F	18F	19F	2553	3176	3111	3053	27	54F	56F	58F
CAPE VERDE					12186	13889	13889	13333	1	1F	1F	1F
CENT.AFR. REP.			1F	1F	1968	2000	2000	2000		1F	1F	1F
CHAD	3	3F	3F	3F	4747	4800	4800	4960	12	12F	12F	12F
CONGO					7083	5000	4680	5200	2	1	1	1
EGYPT	30	64	55	59	16570	15756	15963	16616	496	1011	885	977
ETHIOPIA	30	36F	37F	38F	5303	5972	6081	6184	161	215F	225F	235F
IVORY COAST			1F	1F		9000	10000	10000		2F	5F	10F
KENYA	29	47	48	48F	7145	7251	7516	7500	206	341	361	360F
LIBYA	2	8F	8F	8F	6450	11250	11250	11250	15	90F	90F	90F
MADAGASCAR	16	22	21	21F	6428	6778	6428	6431	106	148	132	134
MALAWI	25	28F	29F	30F	3387	3571	3621	3667	85	100F	105F	110F
MAURITANIA					20670	12500	16640	13333	2	3	4	4
MAURITIUS		1F	1F	1F	15027	16777	16923	17692	7	11	11F	12F
MOROCCO	28	17F	18F	20F	10119	10588	10556	10000	283	180F	190F	200F
MOZAMBIQUE	6	6F	6F	6F	6917	6667	6333	6333	40	40F	38F	38F
NIGERIA	2	2F	3F	3F	12514	13636	14000	14000	25	30F	35F	35F

Table 2.3. (Contd....)

	1969-71	1977	1978	1979	1969-71	1977	1978	1979	1969-71	1977	1978	1979
REUNION					11121	16679	20900	15000	1	2	4	3F
RWANDA	19	27	30	30F	7153	6612	6825	7073	134	177	206	214F
SENEGAL	1	1F	1F	1F	6543	6026	6000	5833	4	5F	5F	5F
S. AFRICA	44	50F	50F	50F	13374	15120	14345	15000	583	756	717	750F
SUDAN	1	1F	1F	1F	17446	16923	19231	19231	25	22F	25F	25F
SWAZILAND	2	3F	3F	3F	2960	2000	2000	2000	5	6F	6F	6F
TANZANIA	16	23F	22F	22F	3918	3826	3864	3864	61	88F	85F	85F
TUNISIA	4	5F	5F	5F	19829	17347	21000	22642	69	85	105	120
UGANDA	17	34	45F	45F	8800	6250	7333	7348	147	210	330F	334F
ZAIRE	5	6	6	6F	5377	5426	4905	4921	29	33	31	31F
ZAMBIA					8823	9000	8667	8667	3	3F	3F	3F
ZIMBAMBWE	2	2F	2F	2F	11167	11304	11304	11304	22	26F	26F	26F
N.C. AMERICA	762	752	764	726	22957	25980	26476	26914	17482	19547	20239	19551
SOUTH AMERICA	1038	975	1008	1017	8389	9416	9600	9928	8707	9181	9681	10093
ASIA	2672	2912	3043	3268	9482	10775	10956	11300	25339	31373	33335	36928
EUROPE	7173	6291	5986	5796	17655	18513	20251	21028	126640	116465	121217	121884
OCEANIA	52	44	46	45	20392	23215	22549	24195	1069	1033	1042	1086
DEV. PED. ALL	16149	14252	13924	13628	15013	15734	16639	17324	242444	224244	231685	236098
DEV. PING. ALL	3923	4298	4482	4722	8526	9629	9903	10245	33446	41391	44387	48373

Source: Adopted from F.A.O.Production yearbook, Vol. 33, 1979.
Table 19, pp. 112-113.

2.1.2. Weeds and their effects on potato production

Weeds cause greater loss in agriculture than either insects or plant diseases and weed control is one of the most expensive steps in crop production (Akobundu, 1978). Data from U.S.A. indicate losses to agriculture (annual averages 1945-51) as percent of total as 33.8, 16.7, 26.3, 9.6 and 13.6 due to weeds, livestock diseases, plant diseases, insects and soil respectively and costs of weed control in agricultural lands as U.S. $1,486,351. This exceeds by far the cost of controlling insects and diseases (Akobundu, 1978).

Subsistence farmers in the tropics spend most of their time and energy on weed control than on any other aspect of crop production and since weed control methods are still largely limited to hand pulling and hoeing,most farmers' time is spent fighting weeds (Akobundu, 1978; Kasasian, 1971).

Potato losses due to weeds in Kenya have not been explored yet, but reports from other parts of the world indicate that, losses could be as high as 50% (Furtick, 1970) in Colombia (Table 2.4). Some work in Britain indicated yield losses due to weeds to range from 16-76 percent (Neild and Proctor, 1962) /̄ as quoted by Makepeace and Holroyd (1978)_/. The effect of poor crop husbandry standards on crop yields in Kenya are clearly demonstrated by a comparison of actual average yields and the yield expected with good husbandry for different crops including potatoes (Table 2.5). The total world losses of potatoes from pests, diseases and weed infestations are estimated at 129.2 million tonnes worth U.S. $ 5,100 million per annum (Goffinet, 1979). This total loss corresponds to 48 percent of the actual current production and almost exactly equivalent to the present combined total production of the non-European regions including the Soviet Union (Goffinet, 1979).

Weeds can be defined as plants growing where they are not wanted. Weeds compete for nutrients, water, light and space. They have a high productive capacity, utilize the habitat very efficiently, can be quite persistent and resistant to control and eradication; they tend

Table 2.4. Crop Losses Due to Weeds in Colombia

Crop	Range of % Losses	Average % of Losses
Rice	30-73	54
Cotton	0-39	31
Maize	10-84	46
Beans	15-88	51
Wheat	0-90	29
Barley	0-63	19
Potatoes	0-53	17

Source: Furtick, W.R. 1970 - "Present and Potential Contributions of Weed Control to Solution of Problem' of Meeting the World's Food Needs".Proc. F.A.O. Internatl. Conf. on Weed Control. Davis, Calif., p. 1-6.

Table 2.5. Low National Average Yields of Various Crops Due to Poor Husbandry in Kenya.

Crop	Average Yield (Tonnes/ha)	Yield Expected with good husbandary (Tonnes/ha)
Wheat	1.0	4.5
Cotton	0.22	3.4
Potatoes	5.0	40.0
Pyrethrum	0.28	1.35
Maize	1.0	8.52
Beans	0.22	1.0
Coffee	0.6	2.5
Tea	1.3	2.5

Source: Acland, J.D. (1975). East African Crops, F.A.O./Longman.

to grow thickly around the economic plants, are adapted to overcrowding and can be harmful to man, animals and crops.

Types of weeds can simply be classified on the basis of their morphological features, e.g. grasses, sedges and broadleaved weeds or according to their life cycles, as annuals, biennials and perennials.

Weed competition for nutrients, water, light and space causes the heaviest losses (Ngugi, 1979a, Smith, 1977; Akobundu, 1978; Kasasian, 1971; Zimdahl, 1980; Makepeace and Holroyd, 1978; Sweep, 1971; Parihar and Mukerji, 1969; Kasasian and Seeyove, 1969). Crop losses may be reflected by a decrease in yields, high cost of production or through tuber damage during mechanical cultivation. Weeds also act as alternate hosts of pests and diseases (Kasasian, 1971; Thakur, 1977; Makepeace and Holroyd, 1978). They may also shelter birds, rodents and their predators, besides increasing crop protection costs and reducing human efficiency, increasing harvesting time and decreasing quality of produce.

Weed effects are greatest when root system is actively competing with crop roots for nutrients and moisture (Sing and Verma, 1969) and when they are large enough for light competition. The intensity of competition varies with stage of crop growth. Competition occurs when any or all of the essentials are inadequate for the optimal growth of the crop and weed (Dunham, 1973). According to Clements, Weaver and Hanson (1929), no weed effect of any magnitude occurs (exclusive allelopathy) until competition begins at the point when environmental resources (principally, water, nutrients and light) cease being adequate for the two or more plants in an area. Hence, the presence of a weed cannot automatically be judged to be damaging and in need of immediate control. One tonne of weed can remove 76.2mm of fall from the soil (Anon., 1957) and this means that, a crop can be stunted permanently during a dry weather. More water and nutrients are required to raise a tonne of weeds than of most crops (Muzik, 1970). Soerjani, Soetidgo and Soemarwoto (1969) working in Indonesia found that weeds do actually also absorb certain proportions of fertilizer applied.

2.1.3. Critical periods of weed competition

The determination of the critical period of weed competition is of paramount importance in developing weed control measures. However, most of the research show some ignorance on this vital period (Nieto, Brando and Gonzalez, 1968). From the definition that a weed is a plant growing where it is not wanted, it may be wrongly concluded that it is essential to maintain a weed free condition at all times. It is however, impractical and unnecessary (Gurnah, 1974). Complete weed control under tropical conditions may be undesirable as well as impracticable (Kasasian, 1971). There are certain stages of crop growth when presence of weeds no longer affects growth and yield of the crop adversely (Gurnah, 1974). Presence of weeds late in the season could still present harvesting problems.

Nieto, *et al.* (1968) defined critical weed competition as that period during the growth of the crop when the presence and competition of weeds is harmful to the crop or the point after which, weed growth does not affect final yield. It follows, therefore, that weed-free crop should be maintained only during this period in order to reduce weeding costs. By and large, weeds are most injurious early in the life of a crop and the precise time and duration of period of maximum competition depends on, for example, relative rate of growth of crops and weeds, density of planting, variety grown, time of moisture and nutrient stress, etc. (Kasasian, 1971). Hill and Santelman (1969) reported that critical weed competition period is affected by moisture and nutrient availability. Application of fertilizer which affect relative competition ability of crop and weeds may affect critical stage of competition (Kleinig and Noble, 1968). Temperature affects, the growth of crops and as a result influence the critical period. Seedbed preparation if done badly may cause emergence of weeds at the same time as the crop causing intensive competition during the early growth of the crop (Gurnah, 1974). The type of crop determines the length of weed competition period which differs in different types of crops and varieties.

Esipov and Shcherbakova (1970) working in U.S.S.R. reported that, since the relative competitive ability of the crop and the weed is affected by type of crop and planting density, it follows that high crop plant population has a better chance to successfully compete with weeds. Kasasian and Seeyove (1969) had earlier recommended that a crop should be planted at a high enough density to allow it to completely cover the ground during the first one third of its growth cycle and those which do not completely cover the ground should be interplanted. From this it may be generally inferred that high planting density may reduce amount of weeding necessary.

The competitive ability of weeds is also dependent on the type of weeds and their density. Thus, weed damage increases with increase of weed population. The density and type of weed flora in a given field depends very much on cropping history of the field and thoroughness of husbandry (Kasasian, 1971). Thus, in annual crops, the cultivation normally used has tended to result in annual weeds as the main problem whereas in plantation crops, the comparative absence of tillage has usually resulted in perennial weeds being the most troublesome.

The period from pre-and early emergence of the crop to the time when it covers the ground can be considered as the critical period of competition (Kasasian and Seeyove, 1969). This period constitutes 25-33 percent of the life of many annual crops. After the crop has fully covered the ground, it eliminates competition from weeds to a large extent by its smothering effect. However, when the crops are close to harvesting, they dry up and weeds can take over and sometimes smother the crop. Competition at this stage, however, does not lower yields directly, but may create harvesting difficulties especially where machinery is used (Kasasian, 1971); also quality may be affected. If an annual crop encounters competition during the first quarter of its life, it has suffered irreparably, but conversely if it has been well tended during this period subsequent weed growth is unlikely to have much effect on crop yields (Kasasian and Seeyove, 1969; Nieto, *et al*. 1968) This is one of the basis of effective weed control by use of chemicals especially the pre-emergence types of herbicides.

There is controversy as to what stage of growth that the weeds are detrimental to potato growth. Working on potatoes at Rothamsted, United Kingdom, Pereira (1941) showed that even small weeds at time of potato emergence can cause reduction in yields. Reviewing work by Everaarts and Satsyati (1977) who were working in Java on potatoes, Zimdahl (1980) showed that potatoes kept weed-free for the first four weeks after planting, experienced zero yield reduction but work by Saghir and Markoullis (1974) in Lebanon disagree with the finding slightly since they indicated 58 percent yield reduction when weeds competed all season. However, significant yield reduction could have occured early in the season. Full yield was obtained when plots were weeded for the entire 6-9 weeks after planting or if the weeds were removed at 6-9 weeks after planting. Hence, presence of weeds early in the season was not detrimental, unless permitted to remain past the 6-9 weeks point, after planting. This variation could be due to the nature of weeds and the ecology of the locality. Java is in the humid tropics while Lebanon is in a dry environment. Maturity period of varieties involved could also have caused the apparent contradiction. Smith (1977), contended that weed competition at all stages of potato growth is detrimental to potato yields. Zimdahl (1980) quoting Yip, Hatfield and Sweet (1974) reports that competitive ability directly correlates with early emergence, rapid early growth and maintenance of a dense leaf canopy throughout growing season, but potatoes have no vigorous early growth. Once the canopy has closed, most of the weeds especially the annuals are effectively supppressed (Makepeace and Holroyd, 1978). Hence, potatoes require good weed control between planting and closure of the leaf canopy. The main requirement of potato herbicides, is to control weed growth for the 7-12 weeks between planting and the closure of the leaf canopy (Makepeace and Holroyd, 1978).

In Kenya, most potato cultivars close their canopies at about 6-8 weeks after emergence.

2.1.4. Weed control methods in potatoes

Potato cultivation is aimed primarily at weed control (Smith, 1977; Pereira, 1941; Moore, 1937; Aldrich and Campbell, 1952; Cox and Elliot, 1965; Green, 1964A; Stephens, 1965) and other benefits are determined by specific soil conditions, as reported by Zimdahl (1971) reviewing weed control research in potatoes in Colorado. In the same paper, Zimdahl (1971) pointed out that, cultivation and hilling create and maintain irrigation furrows (where necessary), provide higher temperatures for tubers and prevent greening. Furthermore, hilling prevents attack of the tubers by potato tuber moth (*Phthorimaea operculella*). Kasasian (1971) states that cultivation can also induce beneficial nitrogen flush. However, cultivations may have deleterious effects (Kasasian, 1971; Zimdahl, 1971) which can decrease yields (Smith, 1977). This is due to loss of moisture at critical times (Cox and Elliot, 1965; Smith, 1977; Kasasian, 1971), high soil compaction and clod formation (Smith, 1977; Aldrich and Campbell, 1952; Flocker, Timm and Vomocil, 1960; Pereira, 1941; Kasasian, 1971) and hence poor aeration. Elliot and Boyle (1963) working in Britain found that cultivation increases frost susceptibility and Smith (1977) was in agreement. A soil that is not recently disturbed gives off more heat to air at night than a freshly cultivated soil and this extra heat radiation is sometimes sufficient to prevent frost damage to young potato plants (Robertson, 1960A; Smith, 1977). Cultivation increases incidence and spread of diseases (Cadman, 1963); can damage shoots, roots or tubers (Kasasian, 1971; Sawyer and Dallyn, 1963) and increases humus decomposition (Kasasian, 1971) which means an increased rate of organic matter loss as indicated by Dallyn (1971).

If correct plant population is used, weeding in potatoes is necessary before the closure of the canopy as indicated earlier. In Kenya, hand weeding using 'jembes', 'pangas', or by mere pulling of weeds is mostly used. By the time these control methods are employed, the weeds have already caused damage. Mechanisation is yet to be practised in the small scale farms, while use of chemical weed control is minimal. Survey conducted in some parts of Kenya (Durr, 1977)indicated that, 9 percent of farmers weed once, 75 percent twice and 16 percent three times. Time of cultivation is however, governed by locality depending on moisture, fertility of the soil, variety of potato grown, etc. However, with the increasing high cost of labour,hand weeding can only be feasible or economically sound at small scale level.

The preparation of seedbed should be done in good time for efficient weed killing particularly of perennial grasses such as Kikuyu grass (Pennisetum clandestinum) couch grass (Digitaria scalarum) and star grass (Cynodon dactylon) which are problematic. Many schools of thought consider weed control as the main justification for seedbed preparation except in special cases where tillage is required to break up impermeable sub-surface pans or surface capping in certain soils. Hence, land preparation provides physical conditions for germination and subsequent establishment of crop in addition to providing weed-free conditions at the time of planting.

Ridging of potatoes is also part of weeding and is usually done during the cultivation operations or sometimes once if chemicals are used. Ridging is important since it prevents greening of tubers and attack by potato tuber moth (Phthorimaea operculella). Beukema and Zaag (1979) contended that ridging reduces internal browning which is caused by high soil temperatures. Where drainage is a problem, ridging protects tubers from waterlogging since they are formed above the furrow. Ideally, for the ridge to be able to prevent waterlogging it should have a height of about 15cm.

Smith (1977) reported that weeds can be controlled without cultivation through use of herbicides whereby closer row spacing would be employed. Closer row spacing would allow shading out of the weeds (Kasasian, 1971).

Cultivation is impracticable on very stony, rough, steep ground and where soil is too dry or wet. This means that cultivation is dependent on soil conditions. In wet periods, regrowth of weeds may be so rapid that cultivation achieves very little and it is only possible to cut weeds and leave them on soil surface. Therefore, since an early and timely control of potato weeds is a pre-requisite to high yields, this can only be achieved through use of herbicides particularly the pre-emergence types. Working in Britain, Chancellor (1964) reported that cultivation stimulates germination of weed seeds and Roberts (1963) agrees with this. Hence, much of the effectiveness of pre-emergence application of herbicides is dependent upon this principle. Cultivation on too wet soil is not very effective and it is time consuming besides requiring reasonably skilled labour (Dallyn, 1971). This is not withstanding the promotion of germination of another crop of weeds even while killing the existing one whose growth is severe. Cultivation could be reduced and is decreasing in commercial practice in developed world, though it is not likely to be eliminated entirely at least in the foreseable future (Dallyn, 1971).

Chemical weed control is free from the above mentioned disadvantages of cultivation methods (Kasasian, 1971). Herbicides can increase agricultural productivity and rural welfare where agronomic or labour considerations favour their use. Young, Miller, Fisher and Shenk (1978) working in the United States of America indicated that ecological, social and economic conditions in developing countries often favour alternative weed control methods. Where labour is not limiting and it is cheap, labour intensive cultivation is employed rather than the expensive chemical weed control. However, with increase of wage incomes and labour becoming expensive, chemical weed control alternative is employed. When weeds are chemically controlled, there is little need for the presently accepted pattern of extensive post-planting cultivation. In many cases, particularly in the developed countries, growers have simply added herbicides to existing weed control programme with little or no reduction in tillage. In the developing countries where labour has not been a limiting factor and income per capita is low, use of labour intensive technology is favoured. However, with increase of incomes and labour becoming scarce, use of herbicides is increasingly becoming evident.

Use of herbicides for weed control is important where there is lack of labour or time for mechanical weed control. However, poor and wrong timing or residual effects of some herbicides can cause yield reduction. Kasasian (1971) emphasised that effectiveness of chemicals should never be exploited to permit a decline in husbandry to occur. Until residual and toxic problems are resolved, herbicides should only be used where other methods of weed control are impracticable. Periodic changing of weed control methods or the herbicides would help avoid the problem of weeds which are associated with a particular weed control method or herbicide.

Use of herbicides in potatoes is recent compared to use in cereals (Makepeace and Holroyd, 1978). Currently, there are almost no herbicides which are used post-emergence in the accepted sense in the potato crop. With possible exception of metribuzin, many are liable to cause at least temporary damage if applied when considerable proportion of the potato shoots have emerged (Makepeace and Holroyd, 1978). Most of the potato herbicides developed are for annual weeds.

In Kenya, very little use of herbicides in potatoes is noticeable. Table 2.6. shows that, among other chemicals e.g. insecticides and fungicides, herbicide consumption in Kenya lag behind. Compared with other countries, Kenya lags behind in pesticides consumption (Table 2.7). According to the 1968 estimates of world consumption of herbicides at the consumer level, Africa consumed the least (Table 2.8). Despite the fact that, it is not possible to single out consumption per crop due to the nature in which the data is given, it all points to the fact that herbicide use in Kenya in potatoes is minimal.

The need to grow more food and to ease the drudgery that is the lot of so much of mankind in the developing countries like Kenya calls for risk taking in the use of herbicides. Therefore use of herbicides is inevitable in order to achieve these aims. Proper recommendations

Table 2.6. Consumption of Pesticides in Kenya from 1971 - 1976 (Tonnes)

Year	Disinfectants	Fungicides	Herbicides	Insecticides	Others	Total
1971	171	821	346	2564	396	4298
1972	135	824	441	2233	301	3934
1973	157	2471	808	2639	339	6414
1974	171	2301	662	3492	1661	8287
1975	86	1070	247	470	1003	2876
1976	133	1389	438	1628	490	4076
Total	853	8876	2942	13026	13026	29908
Mean	142	1479	490	2171	698	4985

Source: Annual Trade Reports (after C.P.E. De Lima) 1979.

Table 2.7. Use of Pesticides by Countries.

Ranking country	Average Ingredient(g/ha)
Japan/N. America	
European countries	1223
S. Korea	214
India	50
Kenya	11

Source: C.P. De Lima (1979). Use of Pesticides.

Table 2.8. Estimated 1968 World Consumption of Herbicides at the Consumer Level (Furtick 1970)[a]

Area	Consumption (US$)
North America	550,000,000
Japan	70,000,000
Latin America	80,000,000
Near East, Southeast Asia and Oceania	80,000,000
Western Europe	60,000,000
Africa	40,000,000
Total	880,000,000

[a]Based on figures compiled by the International Plant Protection Centre, Oregon State University. From Industry, agricultural agency, and commerce agency sources.

to suit ecological zones concerned must be worked out. This is bearing in mind that climate, soils, varieties, type of weed problem, social-economic settings vary so widely between different localities. Possibilities of environmental pollution through increased use of pesticides add to the need for more research to ascertain the behaviour of the herbicides before embarking on their use wholesale.

CHAPTER 3

3.1. MATERIALS AND METHODS

3.1.1. Location

The trials were carried out at the National Potato Research Station - Tigoni. The station is 4km South East of Limuru town; Kiambu district in Central Province of Kenya. The station's coordinates are $1^{\circ}08'$ S - 36° $40'$ E. The physiography of the area is volcanic foot-ridge landscape with its geology comprising of Limuru trachytes (Siderius and Muchena, 1977). The altitude of the station is approximately 2100m above sea level. The soils are well drained; deep, dark reddish brown to dark red, firm and clayish while the soil reaction varies from pH 4.5 - 5.3 measured in Kcl solution while it varies from pH 5.3-6.5 when measured in water (Siderius and Muchena, 1977). The soils are deficient in calcium (Appendix A).

The area has a bimodal rainfall distribution (Appendix B and D) with the long rains and short rains from March to June and from September to December respectively. The mean monthly rainfall is 96mm. The minimum mean temperature occurs between June and August when temperatures reach 13.5^{o}C and a maximum mean temperature of 17.7^{o}C in February to March.

3.1.2. Materials

Uniform tubers (35-45mm diameter) of the variety Anett were used in the study.

The three herbicides used were:-

(a) Afalon (Linuron) 50% W.P. whose chemical name is, 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea.

(b) Sencor (metribuzin) W.P. 70, whose chemical name is, 4-amino-6-tert.-butyl-3-(methylthio)-1,2,4-triazin-5-(4H)-one.

(c) Galex- an emulsifiable concentrate (500 EC) containing 250g metobromuron (3-(4-bromophenyl)-1-methoxy-1-methyl-urea) and 250g metolachlor (2-ethyl-6-methyl-N-(2-methoxy-1-methyl-ethyl-α-Chloro-acetanilide)per litre.

The fertilizer applied was diammonium phosphate (18:46:0) at the recommended rate of 500kg ha^{-1}, applied in the furrows during planting.

3.1.3. Experimental Design and Treatments

A completely randomised block design with three blocks was used in Experiments I and II, while four blocks were used in Experiment III. The potatoes were planted in furrows at the recommended spacing of 75 x 30cm. Four rows of seven plants each were used giving a gross plot area of $6.3m^2$. The net plot size was $2.25m^2$ at the centre of the plot.

The treatments were:-

(1) Sencor (Low rate (L.R.)) 350g a.i. ha^{-1}

(2) Sencor (Medium rate (M.R.)) 875g a.i. ha^{-1}

(3) Sencor (High rate (H.R.)) 1400g a.i. ha^{-1}

(4) Afalon (Low rate (L.R.)) 500g a.i. ha^{-1}

(5) Afalon (Medium rate (M.R.)) 1250g a.i. ha^{-1}

6. Afalon (High rate (H.R.)) 2000g a.i. ha^{-1}
7. Galex (Low rate (L.R.)) 5ℓ ha^{-1}
8. Galex (Medium rate (M.R.)) 6.5ℓ ha^{-1}
9. Galex (High rate (H.R.)) 8.0ℓ ha^{-1}
10. Hand weeded
11. Weedy plot - non-weeded.

In Experiment III, the hand-weeded and non-weeded plots were evaluated at 3 plots each per replicate while one plot of each was used in Experiments I and II. The field layouts of the experiments are shown in Appendix H and I.

Time of planting and harvesting of the experiments is shown below:-

Experiment	Season	Date of planting	Date of harvesting
I	Short Rains	29th October,1979	1st February, 1980.
II	Long Rains	2nd April, 1980	9th July,1980
III	Short Rains	24th October, 1980	5th February, 1981

The herbicides were sprayed on 5th November, 1979 in Experiment I i.e. 8 days after planting. On 5th and 6th November, 1979, 28.4 mm and 23.5mm of rainfall was recorded respectively. Air temperature range of 12.5-21.0^{o}C was recorded during the day of herbicide application. The relative humidity ranged from 67.0 - 95% and 62-80% on 5th and 6th November, 1979 respectively. The weeds were at 2-leaf stage and well distributed.

In Experiment II, herbicides were sprayed also 8 days after planting on 10th April, 1980. In the morning of 10th April, 1980, 25.1mm of rainfall was recorded and there was no more rain till 13th April, 1980 when 15.4mm was recorded. Air temperature range of 12.5 - 22°C was recorded during herbicide application. The relative humidity ranged from 56-85% and 53-81% on 10th and 11th April, 1980. Most of the weed species were at 2-leaf stage.

Herbicides were sprayed 12 days after planting in Experiment III, on 6th November, 1980 and 7.0mm of rainfall was recorded. There was no rainfall recorded in the following day. The maximum air temperature at the time of herbicide application was 13-20°C. The relative humidity ranged from 70-95% on 6th and 7th November, 1980. The weeds were at 2-4 leaf stage.

A knapsack sprayer (CP3) was used in

applying the herbicides. In all cases one litre of water was applied per plot. Protective measures against diseases e.g. late blight (*Phytophthora infestans*) and early blight (*Alternaria solani*) and insects e.g. aphids were taken as recommended for potatoes. Dithane M-45 was sprayed at the rate of 2.5kg ha^{-1} against late and early blight whereas metasystox was applied against insect pests.

3.1.4. Data collected during the growth period and after harvest

(a) Percent emergence of potatoes

(b) Visual rating (scoring) of the effectiveness of the herbicides on weed kill and their effects on crop vigour by use of a 0-10 scale where:-

0 = Complete control (kill) of weeds and/or severe crop injury.

10 = Complete weed cover and/or full health and vigour of the crop.

This was done at an interval of approximately two weeks after herbicide application till harvest time .

(c) Potato stem counts per plant. All the above-ground stems in the net plot area were counted. In Experiments I and III, this was done 60 days after planting. Experiment II stem count was done at 90 days after planting.

(d) Plant height. This was done by getting the average of four stems in the net area which were measured randomly. Measurements were taken at the same time as (c) above. The method was as depicted in Plate I.

(e) Recording of weed species in order of predominance during the visual scoring in Experiment II and III. In Experiment I, the species were recorded in general at harvest.

(f) N, P, K, Ca and Mg determination in leaves, stems and tubers. This was to show the nutrient content among the treatments as affected by the degree of weediness. They were sampled at 60 days after planting in Experiments I and III, but at 50 days

Plate I. Measuring stem length

in Experiment II. Four stems were cut at the base randomly over the net plot area. Leaves were separated from the stems and both leaves and stems packed separately for analysis. An average of four tubers were scooped out randomly from the net plot area.

The N content was determined by Aluminium block method (Gitau, 1969);P by use of colorimetric method; K by flame photometry and Ca and Mg using Atomic absorption spectrophotometer.

(g) Yield of weeds (dry weight basis) from the net area harvested was determined. The cumulative weed yield per weed species of the hand weeded plot was also determined. However, only the total yield of weeds was recorded in Experiment I. The total weed yield was calculated by adding together the weight of all the species per given treatment. The small and few species were harvested as others. They were dried at 105°C to constant weight.

(h) Residual moisture content of soil at potato harvest time in the net plot area. Sampling was done randomly in the plots, one sample per plot and then oven-dried to constant weight at 105^{o}C.

(i) Total tuber yield and grading into:-

Chatts <25mm diateter

Seeds 25 - 55mm diameter

Ware >55mm diameter

(j) Yield of greened, rotten and damaged tuber.

(k) Number of tubers per plant by counting all the tubers in the net area and dividing by the number of plants harvested.

(l) Percent dry matter content (% D.M.) of tubers after harvest. This was determined by underwater weight method (Ludwig, 1972).

A potato starch measuring scale (Reimann type) (Plate II) was used. After placing the scale on level ground, the scale was adjusted when the drum was half-filled with water and two baskets to the drum. Five kilograms of potatoes were

Plate II. Potato starch measuring scale (Reimann type) weighed in the upper basket in air and then, the potatoes transferred into the lower basket. The underwater weight was determined and the percent dry matter content of the tubers read off from tables using the underwater weight (g) (Ludwig, 1972).

m) Crisp colour evaluation. Crisps were made by frying potato slices (1.5mm thick) from ten tubers in vegetable oil at an average of $180^{o}C$ till bubbling stopped. The colours were assessed using a scale of 1-9 on colour cards developed for the European Association for Potato Research, where colour score number one means very dark and nine very light. Colour number five and above was acceptable.

n) Partial budget calculation to evaluate the best weed control practice studied.

o) Weed flora of the National Potato Research Station, Tigoni (Appendix L).

3.1.5. <u>Statistical analysis:</u>

Most of the data collected was analysed as shown in Appendix J and K.

CHAPTER 4

4.1. RESULTS: Experiment I (Short Rains, 1979)

4.1.1. General observations

The first emergence of the potato plants was noticed 10 days after planting. However, the emergence records were taken at an interval of three days after the first count carried out on November 10, 1979. This continued till approximately 100 percent emergence was observed (Table 4.1). The approximate 100% emergence was observed between 15-20 days after planting on 13th to 19th November, 1979 (Table 4.1). Application of herbicides apparently had no effect on percent emergence.

4.1.2. Effect of treatments on weed and crop scores

Throughout the growing season, treatment effects on weed scores were significantly different (P = 0.05) (Table 4.2.). Sencor, afalon and galex were effective on weed kill in that order; whereas the high rates of sencor and afalon were more effective in weed control

Table 4.1. Percent emergence of potato plants

Treatments	Recording dates			
	10.11.79	13.11.79	16.11.79	19.11.79
1. Sencor (L.R.)	57	94	99	99
2. Sencor (M.R.)	49	96	99	100
3. Sencor (H.R.)	45	83	99	99
4. Afalon (L.R.)	42	88	100	100
5. Afalon (M.R.)	41	95	100	100
6. Afalon (H.R.	62	99	99	100
7. Galex (L.R.)	42	89	99	100
8. Galex (M.R.)	39	76	93	98
9. Galex (H.R.)	39	90	100	100
10. Hand weeded	55	96	98	99
11. Non-weeded	45	96	100	100

Table 4.2. Treatment effects on weed and crop scores

	Weed Scores				Crop Scores[1]
Treatments	1 22.11.79	2 6.12.79	3 21.12.79	4 25.1.80	
1. Sencor (L.R.)	2.3	1.7	1.7	1.7	10
2. Sencor (M.R.)	0.7	1.0	1.0	0.7	10
3. Sencor (H.R.)	1.3	1.3	1.3	1.0	10
4. Afalon (L.R.)	3.7	2.7	3.3	3.0	10
5. Afalon (M.R.)	3.0	2.0	2.0	2.0	10
6. Afalon (H.R.)	1.7	1.0	1.0	0.5	10
7. Galex (L.R.)	1.7	2.3	2.3	2.3	10
8. Galex (M.R.)	2.0	1.7	1.7	1.7	10
9. Galex (H.R.)	3.3	2.8	2.7	2.3	10
10. Hand weeded	*6.7	1.0	1.3	0.0	10
11. Non-weeded	5.7	6.0	6.0	6.0	10

*Weeding had not been done

[1]Mean of four scores

Table 4.2. (Contd....)

C.V. %	26	29
S.E. Single plot	0.77	0.60
S.E. of a mean	0.45	0.37
S.E. of a difference between two means	0.63	0.49
L.S.D. (P = 0.05)	1.32	1.02
S.E. of weedy vs. others	0.45	0.36
L.S.D. (P = 0.05)	0.94	0.76
S.E. of among others	0.63	0.49
L.S.D. (P = 0.05)	1.32	1.02
S.E. of hand weeding vs herbicides	0.47	0.37
L.S.D. (P = 0.05)	1.34	0.76
S.E. of among herbicides	0.37	0.28
L.S.D. (P = 0.05)	0.76	0.59

29	35	-
0.65	0.66	-
0.37	0.38	-
0.53	0.54	-
1.10	1.13	-
0.39	0.40	-
0.82	0.84	
0.53	0.54	-
1.10	1.13	-
-	0.40	-
-	0.84	
0.31	0.31	-
0.64	0.65	-

Table 4.2. (Contd....)

S.E. of among levels of sencor	0.63	-
L.S.D. (P = 0.05)	1.32	-
S.E. of among levels of afalon	0.63	0.49
L.S.D. (P = 0.05)	1.32	1.02
S.E. of among levels of galex	-	0.49
L.S.D. (P = 0.05)	-	1.02

-	-	-
-	-	-
0.53	0.54	-
1.10	1.13	-
-	-	-
-	-	-

than the medium and low rates of application. The medium rate of galex performed better than the low and high rates of application. Although hand weeding was effective on weed control, the effect was not uniform throughout the season as in herbicide applications. The non-weeded plots scored significantly (P = 0.05) higher weed score than the other treatments throughout the season.

No apparent herbicide damage to the crop was observed. (Table 4.1).

4.1.3. Effect of treatments on plant height and stem number per plant

The treatments did not have significant effect on plant height or stem numbers per plant 60 days after planting (Table 4.3).

4.1.4. Effect of treatments on percent N, P, K, Ca and Mg content of potato plant leaves, stems and tubers

No significant differences were observed between treatment effects on N, P, K, Ca and Mg content of leaves (Table 4.4). However, the low

Table 4.3. Mean effect of treatments on plant height and number of stems per plant

Treatments	Plant height (cm)	Stems per plant
1. Sencor (L.R.)	47.5	10
2. Sencor (M.R.)	49.2	12
3. Sencor (H.R.)	41.2	8
4. Afalon (L.R.)	48.0	10
5. Afalon (M.R.)	42.5	10
6. Afalon (H.R.)	45.8	10
7. Galex (L.R.)	41.8	9
8. Galex (M.R.)	45.8	8
9. Galex (H.R.)	46.7	11
10. Hand weeded	44.2	11
11. Non-weeded	45.8	9
C.V. %	10	28
S.E. Single plot	4.92	2.68
S.E. of a mean	2.84	1.55

Table 4.4. Mean effect of treatments on percent nutrient content of leaves, stems and tubers of potato plant

Treatments	Percent nutrients									
	Leaves					Stems				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
1. Sencor (L.R.)	3.44	0.12	8.27	2.83	0.64	1.94	0.21	7.80	1.43	0.24
2. Sencor (M.R.)	3.42	0.12	8.27	2.67	0.58	2.07	0.21	8.40	1.53	0.25
3. Sencor (H.R.)	3.69	0.13	7.80	2.73	0.58	1.75	0.21	8.17	1.37	0.23
4. Afalon (L.R.)	3.24	0.11	8.40	2.70	0.54	1.71	0.25	8.53	1.41	0.29
5. Afalon (M.R.)	3.51	0.12	8.07	2.67	0.56	1.68	0.20	8.07	1.36	0.30
6. Afalon (H.R.)	3.30	0.11	8.07	3.00	0.57	1.69	0.20	7.73	1.49	0.31
7. Galex (L.R.)	3.09	0.11	8.27	2.23	0.49	1.72	0.20	8.00	1.41	0.22
8. Galex (M.R.)	3.65	0.11	8.47	2.77	0.57	1.96	0.20	7.87	1.41	0.22
9. Galex (H.R.)	3.29	0.10	8.13	2.87	0.51	1.82	0.18	8.33	1.10	0.19
10 Hand weeded	3.58	0.12	7.80	2.57	0.60	2.08	0.22	7.80	1.33	0.20
11. Non-weeded	3.44	0.14	8.27	2.73	0.54	2.17	0.22	8.20	1.51	0.25

Table 4.4. (Contd.....)

Treatments	Percent nutrients (Tubers)				
	N	P	K	Ca	Mg
1. Sencor (L.R.)	1.73	0.10	2.17	0.04	0.12
2. Sencor (M.R.)	1.73	0.87	2.22	0.03	0.12
3. Sencor (H.R.)	1.77	0.10	2.87	0.03	0.15
4. Afalon (L.R.)	1.43	0.10	2.79	0.04	0.13
5. Afalon (M.R.)	1.56	1.11	2.91	0.03	0.14
6. Afalon (H.R.)	1.65	0.09	2.41	0.03	0.12
7. Galex (L.R.)	1.50	0.08	2.22	0.02	0.11
8. Galex (M.R.)	1.66	0.10	2.87	0.04	0.13
9. Galex (H.R.)	1.68	0.08	2.17	0.03	0.11
10. Hand weeded	1.57	0.09	2.12	0.03	0.12
11. Non-weeded	1.10	0.91	2.54	0.03	0.15

Table 4.4. (Contd....)

	Leaves				
	N	P	K	Ca	Mg
C.V. %	6	14	12	19	11
S.E. Single plot	0.20	0.02	1.00	0.51	0.06
S.E. of a mean	0.12	0.01	0.58	0.29	0.37
S.E. of a difference between two means					
L.S.D. (P = 0.05)					
S.E. weedy plot vs others	-	0.01			
L.S.D. (P = 0.05)	-	0.02			
S.E. among others	0.16				
L.S.D. (P = 0.05)	0.33				
S.E. hand weeding vs herbicides					
L.S.D. (P = 0.05)					

Stems					Tubers				
N	P	K	Ca	Mg	N	P	K	Ca	Mg
8	32	8	15	18	21	257	20	18	29
0.16	0.02	0.67	0.21	0.04	0.34	0.43	0.50	0.01	0.04
0.09	0.01	0.39	0.12	0.03	0.19	0.25	0.29	0.003	0.02
0.13									
0.27									
					0.20	0.26			
					0.43	0.54			
0.13									
0.27									
0.10									
0.20									

Table 4.4. (Contd......)

	Leaves						
	N	P	K	Ca	Mg	N	P
S.E. Among herbicides						0.07	
L.S.D. (P = 0.05)						0.16	
S.E. Among levels of galex	0.16						
L.S.D. (P = 0.05)	0.33						

Stems			Tubers				
K	Ca	Mg	N	P	K	Ca	Mg
		0.02					
		0.04					

and high rates of galex depressed N content in leaves compared to the medium rate of application (P = 0.05). Non-weeding enhanced P content in leaves slightly.

In general, the herbicides depressed nitrogen content of stems, while stems from plots treated with afalon had significantly higher (P = 0.05) percent magnesium than those from plots treated with sencor and galex (Table 4.4). No significant differences were observed on P, K, and Ca content of stems among the treatments.

Non-weeding depressed percent nitrogen content of tubers significantly (P = 0.05) but increased percent phosphorus content compared with the other treatments. No significant differences were observed on K, Ca and Mg content in tubers among the treatments (Table 4.4).

4.1.5. Effect of treatments on yield of weeds

Total dry weight of weeds at harvest time is shown in Table 4.5 (note: weed yield of the hand weeding treatment is cumulative). The treatments had significant (P = 0.05) effect on total dry weight of weeds. Non-weeded plot had

Table 4.5. Mean effect of treatments on total dry weight yield of weeds at harvest

Treatments	Dry weight of weeds (kg/ha)
1. Sencor (L.R.)	7.7
2. Sencor (M.R.)	3.8
3. Sencor (H.R.)	19.8
4. Afalon (L.R.)	33.9
5. Afalon (M.R.)	22.7
6. Afalon (H.R.)	1.7
7. Galex (L.R.)	23.7
8. Galex (M.R.)	15.6
9. Galex (H.R.)	13.4
*10. Hand weeded	39.2
11. Non-weeded	440.9

*Cumulative weed yield

C.V.%	255
S.E. of a single plot	89.62
S.E. of a mean	51.74
S.E. of a difference between two means	73.18
L.S.D. (P = 0.05)	152.65
S.E. of non-weeded vs others	54.27
L.S.D. (P = 0.05)	113.21

significantly higher (P = 0.05) weed yield than in the other treatments causing the coefficient of variation to be very high (255%). Although not statistically significant, hand weeding plot had higher weeds yields than the herbicide treated plots.

4.1.6. Effect of treatments on percent residual soil moisture content by weight

Significantly higher (P = 0.05) percent residual soil moisture content was observed in plots treated with afalon medium and high rates than in the plot treated with the low rate of application (Table 4.6). Almost significantly lower percent moisture in the non-weeded plot was observed than in the other treatments.

4.17. Effect of treatments on potato tuber yield

Total tuber yield, size grade distribution and tubers per plant are shown in Table 4.7. The effect of treatments on total tuber yield was not significant. However, the non-weeded treatment yielded the least (30.8t ha^{-1}) compared to the other treatments.

Table 4.6. Mean effect of treatments on percent residual soil moisture content by weight

Treatments	% residual soil moisture content
1. Sencor (L.R.)	16.69
2. Sencor (M.R.)	17.51
3. Sencor (H.R.)	17.65
4. Afalon (L.R.)	13.95
5. Afalon (M.R.)	18.39
6. Afalon (H.R.)	16.88
7. Galex (L.R.)	16.94
8. Galex (M.R.)	17.62
9. Galex (H.R.)	18.40
10. Hand weeded	17.36
11. Non-weeded	15.18
C.V. %	10
S.E. Single plot	1.61
S.E. of a mean	0.93
S.E. of among levels of afalon	1.32
L.S.D. (P = 0.05)	2.75

Table 4.7. Mean effect of treatments on tuber yield and number of tubers per plant

Treatments	Tubers per plant	Yield of tubers (t/ha)				
		Total	Seed	Ware	Chatts	Greened & damaged
1. Sencor (L.R.)	18	34.4	27.7	-	2.2	4.7
2. Sencor (M.R.)	15	36.8	29.7	-	2.5	4.8
3. Sencor (H.R.)	12	32.7	27.3	-	1.5	4.2
4. Afalon (L.R.)	14	34.2	27.3	-	1.5	5.7
5. Afalon (M.R.)	14	34.0	26.4	-	2.1	5.8
6. Afalon (H.R.)	14	32.7	24.6	-	0.9	7.3
7. Galex (L.R.)	12	32.1	25.0	-	1.3	5.8
8. Galex (M.R.)	13	34.3	27.0	-	1.5	5.9
9. Galex (H.R.)	14	36.5	28.6	-	0.7	7.4
10. Hand weeded	14	32.1	28.4	-	1.1	2.7
11. Non-weeded	12	30.8	25.3	-	0.9	4.7
C.V.%	16	8	11		69	43
S.E. of a single plot	2.22	2.76	2.88		0.89	2.27
S.E. of a mean	1.28	1.59	1.66		0.51	1.31
S.E. hand weeded vs herbicides.	-	-	-		-	1.38
L.S.D. (P = 0.05)	-	-	-		-	2.88
S.E. of among levels of sencor	1.81	-	-		-	
L.S.D (P = 0.05)	3.79	-	-		-	-

The yield of seed and chatt sized tubers was not significantly different among the treatments. There was no ware grade during this season. Hand weeding produced significantly (P = 0.05) lower green and damaged tubers than the herbicide treated plots.

The treatments did not have significant effect on tubers per plant. However, significantly (P = 0.05) lower tubers per plant was observed in plots treated with the lower rate of sencor than its high rate of application.

4.1.8. Effect of treatments on percent tuber dry matter content (% D.M.) and crisp colour

The results are given in Table 4.8. The effect of treatments on percent tuber dry matter content was not significant. However, percent tuber dry matter in the hand weeded treatments was significantly (P = 0.05) lower than in the herbicide treatments.

No significant effect of treatments on crisp colour was observed, but crisps of tubers from plots treated with high rate of sencor

Table 4.8. Effect of treatments on percent tuber dry matter content (%D.M.) and crisp colour

Treatments	% D.M.	Crisp colour
1. Sencor (L.R.)	19.3	7.1
2. Sencor (M.R.)	19.8	7.3
3. Sencor (H.R.)	19.8	6.6
4. Afalon (L.R.)	19.5	7.1
5. Afalon (M.R.)	19.4	7.2
6. Afalon (H.R.)	19.2	7.1
7. Galex (L.R.)	19.8	7.3
8. Galex (M.R.)	19.6	7.2
9. Galex (H.R.)	19.6	7.0
10. Hand weeded	18.8	7.0
11. Non-weeded	19.4	7.3
C.V. %	3	5
S.E. Single plot	0.51	0.30
S.E. of a mean	0.29	0.17
S.E. of hand weeded v.s. herbicides	0.31	-
L.S.D. (P=0.05)	0.65	-
S.E. of among levels of sencor		0.25
L.S.D. (P=0.05)		0.51

scored lower than those from the plots treated with the medium rate of application.

4.2. DISCUSSION OF RESULTS

4.2.1. Emergence of potato plants

The results indicated that the treatments did not affect potato emergence. The herbicides used in this study are absorbed through the roots and foliage and probably they could have affected the emergence of the potato plants if the potatoes were not tolerant to them.

4.2.2. Weed and crop scores

Throughout the season, the non-weeded plots were more heavily infested with weeds than the other treatments (Table 4.2). This could have largely contributed to the nearly significantly lower potato tuber yield in the non-weeded treatment compared to the other treatments. This signified weed competition for various crop needs such as nutrients, moisture, light and space.

The season was fairly dry (Appendix C) compared to the average over several years

(Appendix B and D). Only in the first month, November, of the crop season was rainfall higher than the expected; whereas, the rest of the season experienced lower precipitation than the expected. Throughout the season, the temperatures were higher (Appendix C) than the average over several years (Appendix B). This could have contributed to higher evapotranspiration, thereby reducing the available moisture to the crop and weeds. This led to low weed infestation even in the non-weeded treatment (Table 4.2). In addition to the smothering effects of potato crop on weeds, drought caused drying of young weed seedlings as clearly depicted by the last score (Table 4.2). In the last weed score, the potato crop was already mature thereby opening up the ground and hence making drought more effective in suppressing emerging weeds due to increased evaporation loss. If water stress was not severe, weeds would have been expected to take over vigorously with the senescence of the potato haulms.

Hand weeding and herbicidal sprays were effective on weed control. Among the herbicides, sencor was the most effective in weed control.

Generally, the higher rates of herbicides were more effective in weed kill than the lower rates. All the herbicides controlled Oxalis sp. and Galium spurium L. poorly. However, leaf chlorosis of Oxalis sp. was observed, but the plants recovered later in the season. These difficult-to-control weeds seemed to be suppressed by the more vigorous and taller weeds, especially by Amaranthus sp. which was dominant in the non-weeded treatment. Most of the annual weeds such as Amaranthus sp. Galinsoga parviflora Cav., Chenopodium sp. and the young perennial herb - Commelina benghalensis L. were well controlled by all the herbicides.

The herbicides caused no apparent crop damage even at the high rates (Table 4.2). This indicated that the potato plant (Solanum tuberosum L.) is fairly tolerant to the different herbicide treatments applied in this study at the pre-emergence stage. The herbicides used in the study are root and foliar absorbed to the action site where they inhibit photosynthesis through interference with the Hill reaction (Dubach, 1970). If the potato plant was not tolerant to the herbicides, they could have affected the plants despite the pre-emergence application by absorption through the roots. Rates used, soils and weather conditions and depth of planting vis-a-vis depth of herbicide movements could also have contributed to the tolerance.

4.2.3. Plant height and stems per plant

The treatments had no effect on plant height and stem numbers per plant. The findings in the present study indicated that Anett is tolerant to the types of herbicides and rates used. The results indicates that number of tubers per plant is directly proportional to the number of stems per plant.

4.2.4. N, P, K, Ca and Mg content in potato leaves, stems and tubers

Very little variation was observed on the effect of treatments on the nutrient contents of leaves. However, plant leaves from plots treated with the medium rate of galex had significantly higher percent nitrogen than those from the other rates of galex. Similarly, a higher percent phosphorus was recorded in the leaves from the non-weeded treatment. Despite the deficiency of calcium and phosphorus indicated by soil analysis (Appendix A, E, F & G), enough nutrients seem to have been supplied by the fertilizer applied for both the crop and weeds since there was no much variation as affected by the degree of weediness.

Higher percent nitrogen in the stems from the non-weeded and hand weeded treatments than those from the other treatments and herbicides respectively was noted. Similarly, sencor treatments seemed to increase percent nitrogen in the stems more compared to the other herbicides. Percent magnesium was higher in stems from afalon treated plots than those from the other herbicidal treatments. No variation among treatments on percent P, K and Ca was recorded.

Potato tubers from the non-weeded treatment had higher percent phosphorus compared to the other treatments; whereas, tubers from the non-weeded plot had lower percent nitrogen content in comparison to the other treatments. No significant effect on K, Mg and Ca content of tubers was noted among the treatments.

In general, the results demonstrated that the highest nitrogen content is in the leaves followed by stems and tubers respectively. The percent phosphorus content was almost similar in all the plant parts analysed, although fairly lower in leaves than in the stems. Potassium content was highest in the leaves and stems; whereas, it was almost four times lower in the tubers compared to that in leaves or stems. Percent calcium and magnessium was highest in leaves followed by stems, but very low in tubers. These observations are in fair agreement with the findings of Holler (1972) and as reported by Harris (1978). This experiment indicated higher percent nutrients in the foliage where they are required in the photosynthetic process. Smith (1977) reported that afalon can decrease phosphorus content in potato tubers as well as content of N, K and N-P-K ratio to varying degrees in some varieties. However, there was no clear evidence of this kind of effect in this experiment.

4.2.5. The total yield of dry weight of weeds

The non-weeded treatment had the highest yield of weeds followed by the cumulative weed yield in the hand weeded treatment. As observed in weed scores (Table 4.2) and the final yield of weeds (Table 4.5), the application of higher rates of herbicides was more effective in weed control. Generally, sencor was more effective on weed control than the other herbicides. The weed yield in the non-weeded treatment was about six times that of herbicide treatments (Table 4.5), but the tuber yield depression by weeds was not statistically significant. This finding underlined the observation that excess weeding at the slightest appearance of weeds may be unnecessary or unprofitable. Nevertheless a yield reduction of the order of 1.3-3.5 tonnes ha^{-1} can have big implications on farmers' profit.

4.2.6. <u>The percent residual soil moisture content by weight</u>

The plots which were more heavily infested with weeds, that is, the lower rate of afalon and non-weeded treatments (Table 4.2) had lower residual soil moisture content. As the season was fairly dry (Appendix C), this could explain the crop-weed competition for moisture observed in this experiment.

Similar observation is reported by various workers including Smith (1977).

4.2.7. Yield of potato tubers

Yield depression in the non-weeded treatment was recorded. However, this was not statistically significant despite the high weed yield (Table 4.5) this may be due to effective competition of potatoes with the weeds prevailing at the site (Table 4.2). It is also probable that the prevailing weed species were not very competitive. Although the correlation coefficient for total and saleable yields to weed yield was not significant (r = -0.55 and -0.35 respectively), Figure 4a indicates the general negative correlation. Slight yield depression was observed in the hand-weeded treatment in comparison to the herbicidal treatments, though not statistically significant. This may be due to weed competition before weeding occurred and probably due to possible damage of the roots and photosynthetic surface during weeding.

There was no yield of large-size tubers (>45mm) in all the treatments. This was almost certainly due to the drought conditions prevailing

Key

1-11 - Treatments as in materials and methods

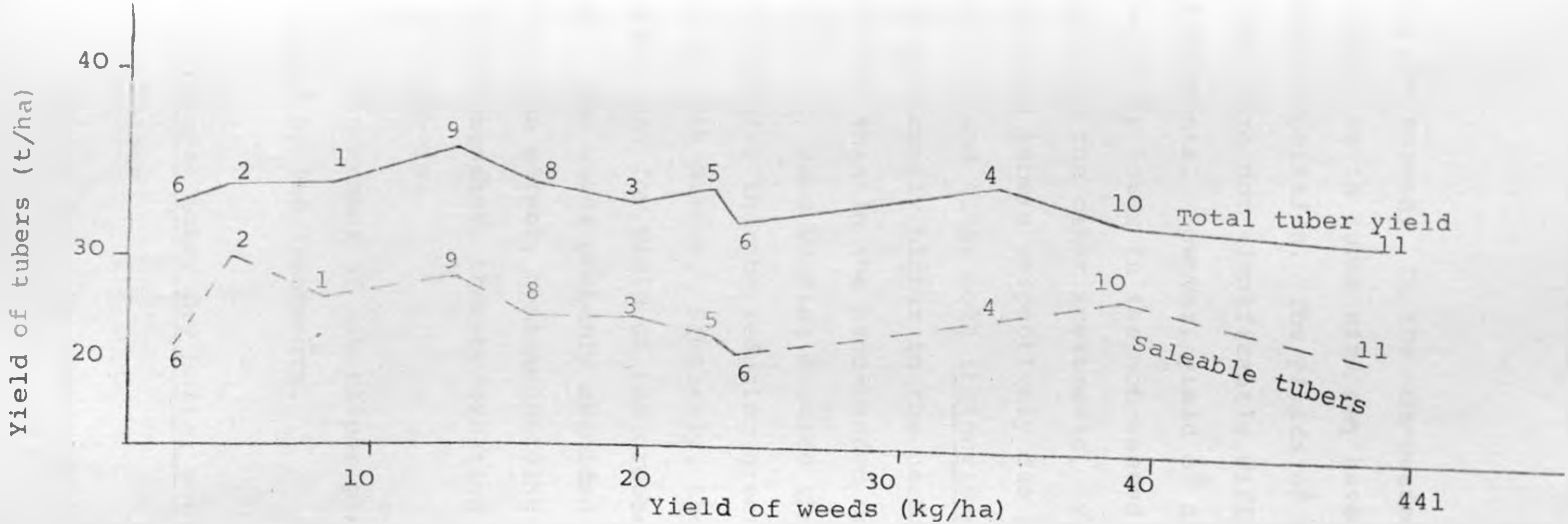


Fig. 4a. Relationship between total yield, saleable tubers and weed yield

during the season. In the non-weeded treatment, the reduction in tuber size may have been enhanced by weed competition. The yields of chatts (<25 mm) were not significantly different among the treatments. However, yield of seed size tubers was slightly lower in the non-weeded treatment compared to the other treatments. Yield of greened and damaged tubers respectively due to exposure to the sun and tuber moth (*Phthorimaea operculella*), was significantly higher in the herbicide treatments than in the hand-weeded ones (Table 4.7 Plate III). Hand weeding ensured the covering of the tubers, thereby reducing greening as well as tuber moth attack. Similarly, the non-weeded treatment had low yield of the greened and damaged tubers. The weeds probably shielded the tubers from the sun effect, besides holding the soil particles together, thereby creating a stable ridge over the tubers.

The number of tubers per plant was not influenced by the treatments.

4.2.8. Percent tuber dry matter content and crisp colour

Tubers from the herbicide treatments had

Plate III. Exposed tubers in a herbicide treated plot due to lack of earthing up later in the season.

significantly higher percent tuber dry matter content than in the other treatments. Eastwood (1952) and Eastwood and Cobb (1954, 1956) reported change of specific gravity of tubers due to herbicides though not consistently (Smith, 1977). Generally, the treatments did not have any effect on crisp colour and all of them produced acceptable crisps colour above the acceptable colour number five. The results therefore suggest that the herbicides used at the rates described do not affect tuber quality as reflected in crisp colour.

CHAPTER 5

5.1. RESULTS: Experiment II (Long Rains, 1980)

5.1.1. General observations

The emergence of potato plants was first noticed 10 days after planting. The first emergence count was however carried out on April 15, 1980 and continued at an interval of three days till approximately 100 percent was recorded (Table 5.1). The 100 percent emergence was attained 17 to 20 days after planting between 19th and 22nd April, 1980 (Table 5.1). At the time of herbicide application, most of the weed species were at 2 leaf stage (Plate IV) and the dominant ones were (*Amaranthus* sp. and *Oxalis* sp. in all the plots. Flowering of the potato was observed in some plots 45 days after planting.

5.1.2. Effect of treatments on weed and crop scores

Table 5.2 shows that the treatments were significantly (P = 0.05) different throughout the season. The herbicides and hand weeding were

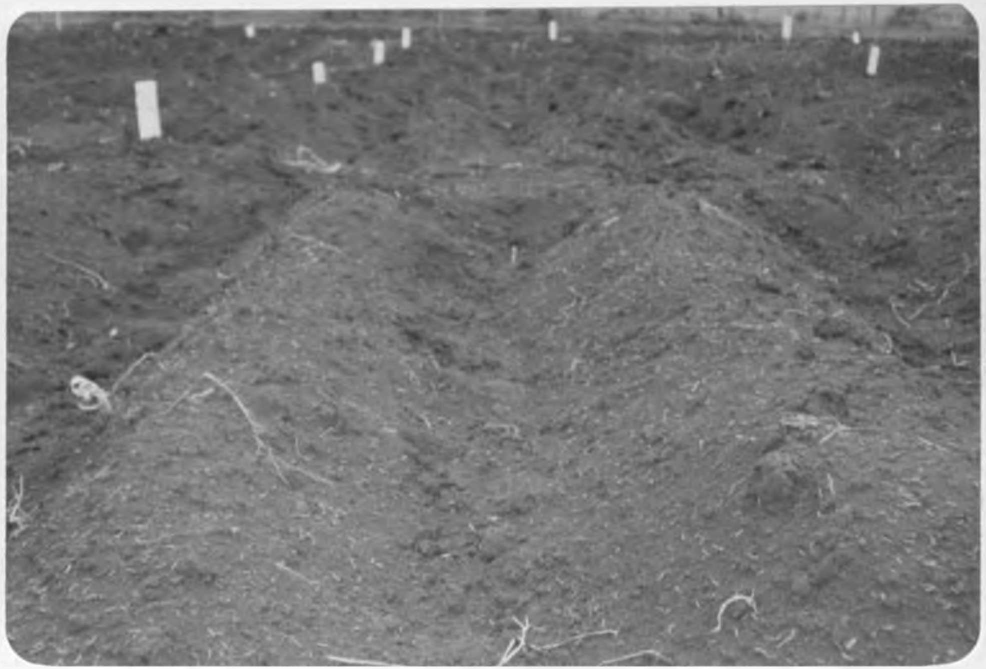


Plate IV. Stage of weed growth at time of herbicide applications

Table 5.1. Percent Emergence of Potato Plants

Treatments	Recording dates			
	15.4.80	17.4.80	19.4.80	22.4.80
1. Sencor (L.R.)	53	90	97	97
2. Sencor (M.R.)	70	100	100	100
3. Sencor (H.R.)	50	80	90	100
4. Afalon (L.R.)	53	77	97	100
5. Afalon (M.R.)	53	87	97	100
6. Afalon (H.R.)	30	80	97	100
7. Galex (L.R.)	53	100	100	100
8. Galex (M.R.)	47	90	97	97
9. Galex (H.R.)	63	93	100	100
10. Hand weeded	33	83	97	100
11. Non-weeded	63	83	93	100

Table 5.2. Treatment effects on weed and crop scores

Treatments	Weed scores						Crop score
	1 (20.4.80)	2 (4.5.80)	3 17.5.80)	4 31.5.80)	5 15.6.80)	6 (1.7.80)	
1. Sencor (L.R.)	1.7	3.5	2.2	2.8	2.8	4.0	10
2. Sencor (M.R.)	2.7	1.7	2.7	2.8	3.3	4.0	10
3. Sencor (H.R.)	3.0	2.2	3.5	3.0	3.7	4.7	10
4. Afalon (L.R.)	3.0	3.0	4.0	4.7	5.7	6.3	10
5. Afalon (M.R.)	3.0	2.3	5.0	4.2	4.7	6.7	10
6. Afalon (H.R.)	3.0	2.0	4.0	3.3	3.8	4.7	10
7. Galex (L.R.)	4.0	3.7	6.3	5.0	5.7	7.0	10
8. Galex (M.R.)	2.3	1.5	2.2	2.5	3.0	3.3	10
9. Galex (H.R.)	3.0	2.7	4.8	4.3	4.5	5.3	10
10. Hand-weeded	5.7	0.7	2.7	0.7	1.5	2.0	10
11. Non-weeded	6.3	8.2	8.3	8.3	8.8	9.7	10

Table 5.2. (Contd.....)

C.V. %	33	37	34
S.E. single plot	1.17	1	1.43
S.E. of a mean	0.68	0.58	0.82
S.E. of a difference between two means	0.96	0.82	1.17
L.S.D. (P=0.05)	1.99	1.70	2.43
S.E. of weedy vs others	0.71	0.13	0.86
L.S.D.(P=0.05)	1.48	0.28	1.80
S.E. of among others	-	-	-
L.S.D.(P=0.05)	-	-	-
S.E. hand weeding vs herbicides	0.71	0.61	-
L.S.D.(P=0.05)	1.49	1.27	-
S.E. of among herbicides	-	-	-
L.S.D. (P=0.05)	-	-	-

17	32	22	-
0.81	1.19	1.17	-
0.47	0.69	0.68	-
0.66	0.97	0.96	-
1.37	2.03	2.00	-
-	0.72	0.71	-
-	1.51	1.48	-
0.66	-	0.96	-
1.37	-	2.00	-
0.49	0.73	0.71	-
1.02	1.51	1.49	-
0.38	-	0.55	-
0.79	-	1.16	-

Table 5.2. (Contd.....)

S.E. of among levels of sencor	-	-
L.S.D.(P=0.05)	-	-
S.E. of among levels of afalon	-	-
L.S.D.(P=0.05)	-	-
S.E. of among levels of galex	-	0.82
L.S.D.(P=0.05)	-	1.70

-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
1.17	0.66	0.97	0.96	-
2.43	1.37	2.03	2.00	-

effective on weed control. The non-weeded treatment had significantly (P = 0.05) higher weed scores than the other treatments throughout the season. Sencor was generally superior on weed control than afalon and galex. In general, the application of the lower rates of herbicides was less effective than the higher rates of application.

Oxalis sp., *Tagetes minuta* L. and isolated *Pennisetum clandestinum* Chiov. dominated in the herbicide treatments throughout the season. However, most of the annual broad leaved weeds were well controlled by the herbicides. Sencor was superior to the other herbicides in controlling *Tagetes minuta* L. while it caused only leaf chlorosis on *Oxalis* sp. which recovered later in the season. The *Tagetes minuta* L. in the non-weeded treatment flowered earlier than that in the other treatments and was more vigorous.

No crop injury was observed (Table 5.2)

5.1.3. Effect of treatments on plant height and stem number per plant

The plant height was measured at about 90 days after planting (Table 5.3) on 1st to 2nd

Table 5.3. Mean effect of treatments on plant height and number of stems per plant

Treatments		Plant height (cm)	Stems per plant
1.	Sencor (L.R.)	67.8	6
2.	Sencor (M.R.)	75.0	6
3.	Sencor (H.R.)	68.8	5
4.	Afalon (L.R.)	75.4	5
5.	Afalon (M.R.)	68.1	5
6.	Afalon (H.R.)	62.7	5
7.	Galex (L.R.)	72.1	5
8.	Galex (M.R.)	66.8	5
9.	Galex (H.R.)	68.3	5
10.	Hand-weeded	61.4	5
11.	Non-weeded	66.1	4

Table 5.3. (Contd.....)

C.V. %
S.E. Single plot
S.E. of a mean
S.E. of a difference between two means
L.S.D. (P = 0.05)
S.E. of among others
L.S.D. (P = 0.05)
S.E. hand weeding vs herbicides
L.S.D. (P = 0.05)
S.E. of among levels of afalon
L.S.D. (P = 0.05)

7	17
4.72	0.82
2.72	0.47
3.85	
8.04	
3.85	
8.04	
2.87	
5.99	
3.85	
8.04	

July, 1980. The treatments had significant (P = 0.05) effect on plant height. The plant height in the hand weeded treatment was about 8cm lower than in the herbicide treatments (Table 5.3); while the plant height in the plots treated with the lower rate of afalon was significantly (P = 0.05) lower than in the plots treated with the high rate of afalon.

Stem numbers per plant were recorded about 95 days after planting (Table 5.3). Although no significant treatment effects on stem numbers per plant was observed, lower numbers were recorded in the non-weeded treatment, compared to the other treatments (Table 5.3).

5.1.4. Effect of treatments on percent N, P, K, Ca and Mg content of potato plant leaves, stems and tubers

Sampling was done 50 days after planting on May 22, 1980.

No significant effect on percent N, P, K and Mg content of the leaves was observed, except percent Ca content (P = 0.05) among the treatments (Table 5.4). The non-weeded treatments gave

Table 5.4. Mean effect of treatments on percent nutrient content of leaves, stems and tubers of potato plant

Treatments	Percent nutrients									
	Leaves					Stems				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
1. Sencor (L.R.)	5.18	0.22	4.43	1.50	0.53	2.12	0.14	9.27	0.93	0.22
2. Sencor (M.R.)	5.57	0.25	4.83	1.41	0.54	2.68	0.14	9.53	0.84	0.24
3. Sencor (H.R.)	5.19	0.27	4.50	1.47	0.53	2.36	0.14	9.33	0.91	0.24
4. Afalon (L.R.)	5.37	0.25	4.83	1.40	0.51	2.43	0.11	8.60	0.79	0.17
5. Afalon (M.R.)	5.03	0.23	4.70	1.59	0.54	2.68	0.17	8.87	0.79	0.22
6. Afalon (H.R.)	5.05	0.23	4.60	1.30	0.53	2.31	0.12	8.60	0.76	0.19
7. Galex (L.R.)	5.38	0.25	4.93	1.43	0.50	2.74	0.15	8.93	0.88	0.24
8. Galex (M.R.)	5.37	0.22	4.43	1.30	0.49	2.28	0.12	9.47	0.86	0.20
9. Galex (H.R.)	5.56	0.22	4.53	1.41	0.49	2.52	0.13	9.27	0.92	0.23
10. Hand-weeded	5.12	0.24	4.97	1.37	0.45	2.47	0.17	8.97	0.87	0.22
11. Non-weeded	4.91	0.26	5.63	0.50	0.45	2.62	0.15	9.09	0.99	0.25

Table 5.4. (Contd.......)

Treatments		Percent nutrients (Tubers)				
		N	P	K	Ca	Mg
1.	Sencor (L.R.)	2.08	0.21	3.43	0.07	0.16
2.	Sencor (M.R.)	2.22	0.20	3.07	0.06	0.15
3.	Sencor (H.R.)	1.96	0.16	2.70	0.06	0.11
4.	Afalon (L.R.)	2.12	0.20	2.67	0.06	0.13
5.	Afalon (M.R.)	2.03	0.21	3.53	0.06	0.18
6.	Afalon (H.R.)	2.05	0.23	3.23	0.04	0.16
7.	Galex (L.R.)	1.89	0.21	3.60	0.06	0.15
8.	Galex (M.R.)	1.73	0.23	3.50	0.06	0.17
9.	Galex (H.R.)	0.89	0.19	3.57	0.06	0.15
10.	Hand-weeded	2.24	0.22	3.30	0.07	0.17
11.	Non-weeded	1.79	0.23	3.30	0.06	0.18

Table 5.4. (Contd......)

	Leaves				
	N	P	K	Ca	Mg
C.V. %	9	14	9	20	8
S.E. single plot	0.50	0.03	0.43	0.27	0.04
S.E. of a mean	0.29	0.02	0.25	0.16	0.02
S.E. of a difference between two means				0.22	
L.S.D(P=0.05)				0.46	
S.E. weedy vs others			0.26	0.16	0.02
L.S.D. (P=0.05)			0.55	0.34	0.05
S.E. among others					
L.S.D. (P=0.05)					
S.E. hand weeding vs herbicides					0.02
L.S.D. (P=0.05)					0.05

Stems					Tubers				
N	P	K	Ca	Mg	N	P	K	Ca	Mg
15	24	4	10	11	10	19	16	25	27
0.38	0.03	0.41	0.09	0.24	0.20	0.04	0.52	0.02	0.03
0.22	0.02	0.24	0.05	0.01	0.12	0.02	0.30	0.01	0.02
				0.02					
				0.04					
			0.05	0.02					
			0.11	0.03					
				0.02					
				0.04					

Table 5.4. (Contd.....)

	Leaves					Stems					Tubers				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
S.E. among herbicides								0.19	0.04	0.01	0.10				
L.S.D(P=0.05)								0.40	0.09	0.017	0.20				
S.E. among levels of afalon										0.02					
L.S.D.(P=0.05)										0.04					

significantly lower (P = 0.05) percent Ca and Mg content in leaves than in the other treatments; whereas percent K content was significantly higher (P = 0.05). Significantly (P = 0.05) lower percent Mg content of leaves in the hand weeded treatment was observed than in the herbicide treatments.

No significant effect on N, P, K and Ca content of the stems was observed among the treatments (Table 5.4). However, significant effects (P = 0.05) on percent Mg was noticed among the treatments (Table 5.4). Sencor and galex treated plots had stems with significantly (P = 0.05) higher percent K, Ca and Mg than those from afalon treatments. The non-weeded treatment had significantly (P = 0.05) higher percent Ca and Mg content of stems than in the other treatments. There was no significant differences on percent N, P, K, Ca and Mg between hand weeding and the other treatments.

No significant differences were observed on percent N, P, K, Ca and Mg of the tubers among the treatments (Table 5.4). However, tubers from sencor and afalon treatments, had significantly

(P = 0.05) higher percent N content than those from galex treatment.

5.1.5. Effect of treatments on yield of weeds

The treatments had significant (P = 0.05) effect on total yield of weeds (Table 5.5). Yield of the hand weeded treatment was cumulative. Significantly lower (P = 0.05) weed yield was observed in the medium rate of galex than its higher rate of application. The lower and medium rates of afalon treatments had significantly (P = 0.05) higher weed yield than its high rate of application. Generally, sencor treatment had lower total weed yield than the other herbicides and hand weeded treatments; whereas, the non-weeded had significantly (P = 0.05) higher total weed yield than the other treatments.

The main Oxalis sp- observed was *Oxalis latifolia*, although *Oxalis corniculata* was present in small quantity. There was significant (P = 0.05) effect on yield of *Oxalis* sp. among the treatments (Table 5.5). The non-weeded treatment had significantly (P = 0.05) lower yield of *Oxalis* sp. than yield from the other

Table 5.5. Mean effect of treatments on dry weight yield of weeds

Treatments	Dry weight of weeds (kg/ha)					
	Total	*Oxalis* sp.	*Tagetes minuta* L.	*Amaranthus* sp.	*Galinsoga parviflora*	Others
1. Sencor (L.R.)	126.5	105.8	-	-	-	20.7
2. Sencor (M.R.)	143.0	128.2	-	-	-	14.8
3. Sencor (H.R.)	290.8	189.8	-	-	-	71.0
4. Afalon (L.R.)	462.8	180.6	259.7	-	-	22.2
5. Afalon (M.R.)	355.0	393.7	69.6	-	-	71.8
6. Afalon (H.R.)	198.4	145.8	26.5	-	-	25.2
7. Galex (L.R.)	493.6	382.6	106.6	-	-	4.4
8. Galex (M.R.)	118.8	74.0	12.6	-	-	45.2
9. Galex (H.R.)	317.5	181.3	127.3	-	-	13.3
10. Hand-weeded	215.9	120.7	22.1	32.2	-	39.9
11. Non-weeded	2161.5	54.0	1277.2	576.5	48.8	205.0

Table 5.5. (Contd....)

C.V. %	44	65
S.E. Single plot	203.76	116.31
S.E. of a mean	117.64	67.15
S.E. of a difference between two means	166.37	94.97
L.S.D. (P=0.05)	347.05	198.11
S.E. weedy vs. others	123.38	-
L.S.D. (P = 0.05)	257.38	-
S.E. of among others	-	94.97
L.S.D. (P = 0.05)	-	198.11
S.E. of among herbicides	-	-
L.S.D. (P = 0.05)	-	-
S.E. among levels of afalon	-	94.97
L.S.D. (P = 0.05)	-	198.11
S.E. among levels of galex	-	-
L.S.D. (P = 0.05)	-	-

169	-	-	159
292.66	-	-	76.40
168.97			44.11
238.96			-
498.46			-
177.22			46.26
369.67			96.51
-			-
-			-
-			36.02
-			75.13
-			-
-			-
-			-
-			-

treatments; whereas, galex low rate treatment had significantly (P = 0.05) higher Oxalis sp. dry weight than the medium rate of application.

The treatments had significant (P = 0.05) effect on yield of Tagetes minuta L. (Table 5.5). The highest yield of Tagetes minuta L. was recorded in the non-weeded treatment while sencor treatment had the lowest yields. Significantly (P = 0.05) lower Tagetes minuta L. yield was recorded in the lower rate of afalon treatment than in the medium and high rates of its application. The high yields in the non-weeded and the low yields in sencor treatments probably contributed to the high coefficient of variation (169%).

Table 5.5 shows that Amaranthus sp. was only harvested in the non-weeded and hand weeded treatments.

Galinsoga parviflora was only recorded in the non-weeded treatment (Table 5.5).

The non-weeded treatment had significantly (P = 0.05)more quantities of dry weight of other weeds than in the other treatments which contributed to the very high coefficient of variation (159%) Table 5.5). Galex treatments had lower yield of other weeds than sencor and afalon treatments.

5.1.6. Effect of treatments on percent residual soil moisture content by weight

The treatments had significant (P = 0.05) effect on percent residual moisture content of soil by weight (Table 5.6). Significantly (P = 0.05) lower percent moisture content was recorded in the non-weeded treatment compared to the other treatments. Similarly, the hand weeded treatment had significantly (P = 0.05) lower percent moisture content than in the herbicide treatments.

5.1.7. Effect of treatments on potato tuber yield

Table 5.7 shows total tuber yield, grades and tubers per plant. Significantly (P = 0.05) lower total tuber yield was recorded in the non-weeded treatment than in the other treatments.

The treatments had no significant effect on seed sized tubers (25-55mm) and chatts (<25mm). However, significant (P = 0.05) effects among the

Table 5.6. Mean effect of treatments on percent residual soil moisture content by weight

Treatments	Percent residual soil moisture content
1. Sencor (L.R.)	19.45
2. Sencor (M.R.)	16.75
3. Sencor (H.R.)	16.71
4. Afalon (L.R.)	17.28
5. Afalon (M.R.)	16.45
6. Afalon (H.R.)	16.26
7. Galex (L.R.)	16.99
8. Galex (M.R.)	16.40
9. Galex (H.R.)	16.57
10. Hand-weeded	13.11
11. Non-weeded	14.64
C.V.%	3
S.E. Single plot	1.47
S.E. of a mean	0.85
S.E. of a difference between two means	1.20
L.S.D. (P = 0.05)	2.50
S.E. weedy vs others	0.89
L.S.D. (P = 0.05)	1.86
S.E. Among others	1.20
L.S.D. (P = 0.05)	2.50
S.E. hand weeded vs. herbicides	0.64
L.S.D. (P = 0.05)	1.34

Table 5.7. Mean effect of treatments on tuber yield and number of tubers per plant

Treatments	Tuber yield (t/ha)					
	Total	Seed	Ware	Chatts	Greened and damaged	Tubers/plant
1. Sencor (L.R.)	34.2	28.6	2.2	1.0	2.3	10
2. Sencor (M.R.)	45.1	32.6	10.2	1.1	1.2	11
3. Sencor (H.R.)	39.2	27.2	8.9	1.3	2.1	11
4. Afalon (L.R.)	37.3	25.2	9.0	0.6	2.5	10
5. Afalon (M.R.)	34.2	23.5	6.8	1.5	2.4	9
6. Afalon (H.R.)	35.5	29.7	2.9	1.2	1.7	12
7. Galex (L.R.)	37.3	29.1	5.3	1.0	2.0	10
8. Galex (M.R.)	35.7	30.3	2.0	1.8	1.6	11
9. Galex (H.R)	36.7	27.2	4.0	1.5	4.0	12
10. Hand-weeded	31.2	28.7	3.0	1.5	1.7	11
11. Non-weeded	30.0	26.1	0.7	1.0	1.1	10
C.V.%	19	15	103	44	62	16
S.E. Single plot	5.23	4.45	4.07	0.50	1.12	1.66
S.E. of a mean	3.02	2.57	2.35	0.29	0.65	0.96
S.E. of weedy vs others	3.17	-	-	-	-	
L.S.D. (P = 0.05)	3.61	-	-	-	-	
S.E. of among levels of galex	-	-	-	-	0.92	
L.S.D. (P = 0.05)	-	-	-	-	1.02	

treatments on ware tubers (>55mm) was observed. The non-weeded treatment had significantly (P = 0.05) lower yield of ware than the other treatments. High coefficient of variation (103%) was attributed to the large quantities of ware tubers in the medium and high rates of sencor treatments; low and medium rates of afalon treatments; and the low yield of ware in the non-weeded treatments.

Although not statistically significant, the non-weeded and hand weeding treatments had relatively lower quantities of the greened and damaged tubers than in the herbicide treatments.

There were no statistical differences among the treatments, although the non-weeded treatment gave less tubers per plant than in the other treatments.

5.1.8. Effect of treatments on percent tuber dry matter content (% D.M.) and crisp colour

The treatments had no significant effect on percent tuber dry matter content and crisp colour (Table 5.8). However, tubers from galex treatments had slightly better crisps than those from sencor treatments. Sencor low rate treatment had very

Table 5.8. Effect of treatments on percent tuber dry matter content (% D.M.) and crisp colour

Treatments	% D.M.	Crisp colour
1. Sencor (L.R.)	16.93	8.2
2. Sencor (M.R.)	17.27	6.1
3. Sencor (H.R.)	17.43	6.0
4. Afalon (L.R.)	17.57	6.4
5. Afalon (M.R.)	16.77	6.6
6. Afalon (H.R.)	17.33	6.0
7. Galex (L.R.)	17.37	6.8
8. Galex (M.R.)	17.13	6.5
9. Galex (H.R.)	17.27	6.4
10. Hand-weeded	17.13	6.4
11. Non-weeded	17.70	6.7
C.V. %	3	5
S.E. single plot	0.62	0.32
S.E. of a mean	0.36	0.18
S.E. of a difference between two means	NS.	NS
S.E. among herbicides		0.15
L.S.D. (P = 0.05)		0.31

good crisp colour compared to all the other treatments.

5.2. DISCUSSION OF RESULTS

5.2.1. Emergence of potato plants

The treatments did not affect plant emergence significantly despite the probable absorption of the herbicides through the roots. This indicates no adverse effects on potato emergence by the herbicides under the conditions of the study.

5.2.2. Weed and crop scores

In this season, the non-weeded treatment was more heavily infested with weeds than in the previous season (Tables 4.2, 5.2 and Plates V). This caused high weed competition and tuber yield was significantly (P = 0.05) reduced (Tables 5.7). Sencor was the most effective on weed control among the herbicides. In terms of the herbicidal activity, the higher doses of the herbicides were more effective.

Oxalis sp. was poorly controlled by the herbicides. The herbicides only caused temporary leaf chlorosis from which the plants recovered later in the season. Sencor appeared more effective on

<u>Plate V</u>. Non-weeded plot heavily infested with weeds, particularly *Tagetes minuta* L. late in the season.

causing leaf chlorosis on *Oxalis* sp. (Plates VI and VII) than the other herbicides. Similarly, the *Tagetes minuta* L. was also poorly controlled by the herbicides. However, its growth vigour was fairly checked by the herbicides with sencor application being the most effective. Isolated *Pennisetum clandestinum* Chiov. appeared not to be checked by the herbicides. Suppression of *Oxalis* sp. by the tall vigorous weeds in the non-weeded treatments like *Tagetes minuta* L., *Amaranthus* sp., etc was noted. Efficient control of most of the annual broad leaved weeds by the herbicides was observed. The rainfall was more during this season than in the short rains during which Experiment I was conducted (Appendix C & D) with a peak in May when it reached 304.8mm. The highest peak during the short rains was 138.3mm in November 1979. This means that the rainfall exceeded the mean monthly potential evaporation (Appendix C & D) during the long rains and hence more moisture was made available to the plants. This also could cause the nutrients to be more available to the plants. As a result this season's experiment, experienced heavy weed infestation than during Experiment I (Tables 4.2 and 5.2).

No crop injury by the herbicides was observed. Hence, it would appear that under the conditions of this study, potatoes are fairly tolerant to the applied herbicide treatments.

5.2.3. Plant height and stems per plant

Taller plants were observed in the herbicide treated plots than in the hand weeded treatments. This could be due to less disturbance of the crop in the herbicide treatments. The high dose of afalon seemed to suppress the crop.

Generally, the treatments had no significant effect on stems per plant. However, fewer stems per plant were recorded in the non-weeded treatment. This could be due to competition for essential crop growth requirements. Early shading of young stems by weeds would have caused premature death of some of the young stems.

5.2.4. N, P, K, Ca and Mg content in leaves, stems and tubers

The percent N and P content in leaves were not significantly different among the treatments. Higher percent K and lower percent Ca and Mg was noted in the non-weeded treatment than in the other treatments. Similarly, lower percent Mg was observed in the hand weeded treatment than in the leaves from the herbicide treatments.

Conversely, higher percent Ca and Mg content of stems was noted in the non-weeded treatment. Lower percent K, Ca and Mg was noticed in the stems from afalon treatments compared to the other herbicide treatments.

In the tubers, sencor and galex treatments gave a significantly higher percent N than afalon treatments; whereas, the treatments had no effect on percent K, P, Mg and Ca. In general, the nutrient content in the various plant components analysed follow similar trend as in Experiment I (Tables 4.4 and 5.4). The percent phosphorus content was almost similar in all the plant parts analysed, but slightly lower in stems. Potassium content was highest in the stems followed by leaves as reported by Harris (1978); whereas, it was almost three times lower in the tubers compared to that in stems. Percent calcium and magnessium was highest in leaves followed by stems and tubers respectively. Generally, the nutrient content in the various plant components was higher in this season than in Experiment I. This could be due to the higher rainfall experienced in this season leading to more vigorous crop plants able to compete effectively for the nutrients. Furthermore, nutrient availability to the plants could have been enhanced. The samples taken were 10 days younger than in the previous season and this could have contributed to the difference in nutrient content of the plant parts. Nutrient levels in the different plant parts are related to time of sampling for example, potassium is highest in stems in the early stages of growth (Harris, 1978).

5.2.5. The yield of dry weight of weeds

Significantly (P = 0.05) higher yield of weeds in the non-weeded treatment was harvested compared to the other treatments (Table 5.5). This was directly related to the weed scores (Table 5.2). This was mainly contributed by the dominant weed species viz. Tagetes minuta L., Amaranthus sp. and Galinsoga parviflora Cav. in the non-weeded treatment. The few and small weed species which were difficult to identify were harvested as others and their yield was substantial in the non-weeded treatment. This might have contributed to the significant depression of tuber yield (Table 5.7).

The _Oxalis_ sp. was the dominant weed species in the herbicide treatments; whereas suppression of the weed in the non-weeded treatment was observed being a low growing weed.

As in Experiment one, sencor application as well as the high rates treatments of herbicides had more herbicidal activity compared to the other treatments.

5.2.6. The percent residual soil moisture content by weight

A significantly lower percent moisture was noted in the soil from the non-weeded treatment. This suggested that there was moisture competition between the crop and weeds. Similar results were observed in the hand weeded treatment in comparison to the herbicide treatments. The growth of weeds before weeding could have contributed to the reduced soil moisture content in the hand weeded treatment together with soil disturbance during cultivation.

5.2.7. Yield of potato tubers

The high yield of weeds (Table 5.5) in the non-weeded treatment probably could have been the main cause of the significantly lower yield of the total tubers and the large sized tubers compared to the other treatments. The higher the yield of weeds the lower the yield of tubers as depicted in Figure 5a. However, the negative correlation coefficient of total and saleable yields ($r = -0.50$ and -0.56 respectively) was not significant. An average of 2-10 tonnes ha^{-1} of tubers difference between the various treatments and the non-weeded treatment was realised. In general, the yield of tubers in this season was higher than in the first season apart from a slight decrease in the hand weeding and non-weeded treatments (Tables 4.7 and 5.7). This could be due to the more available moisture which in turn made the nutrients more available during this seasons experiment. The slight depression in the hand weeding and non-weeded treatments could be due to the high weed density in the non-weeded treatment and soil and crop disturbance during weeding in the hand weeding treatment. A yield of 37.2t/ha was recorded by Holler (1974) for

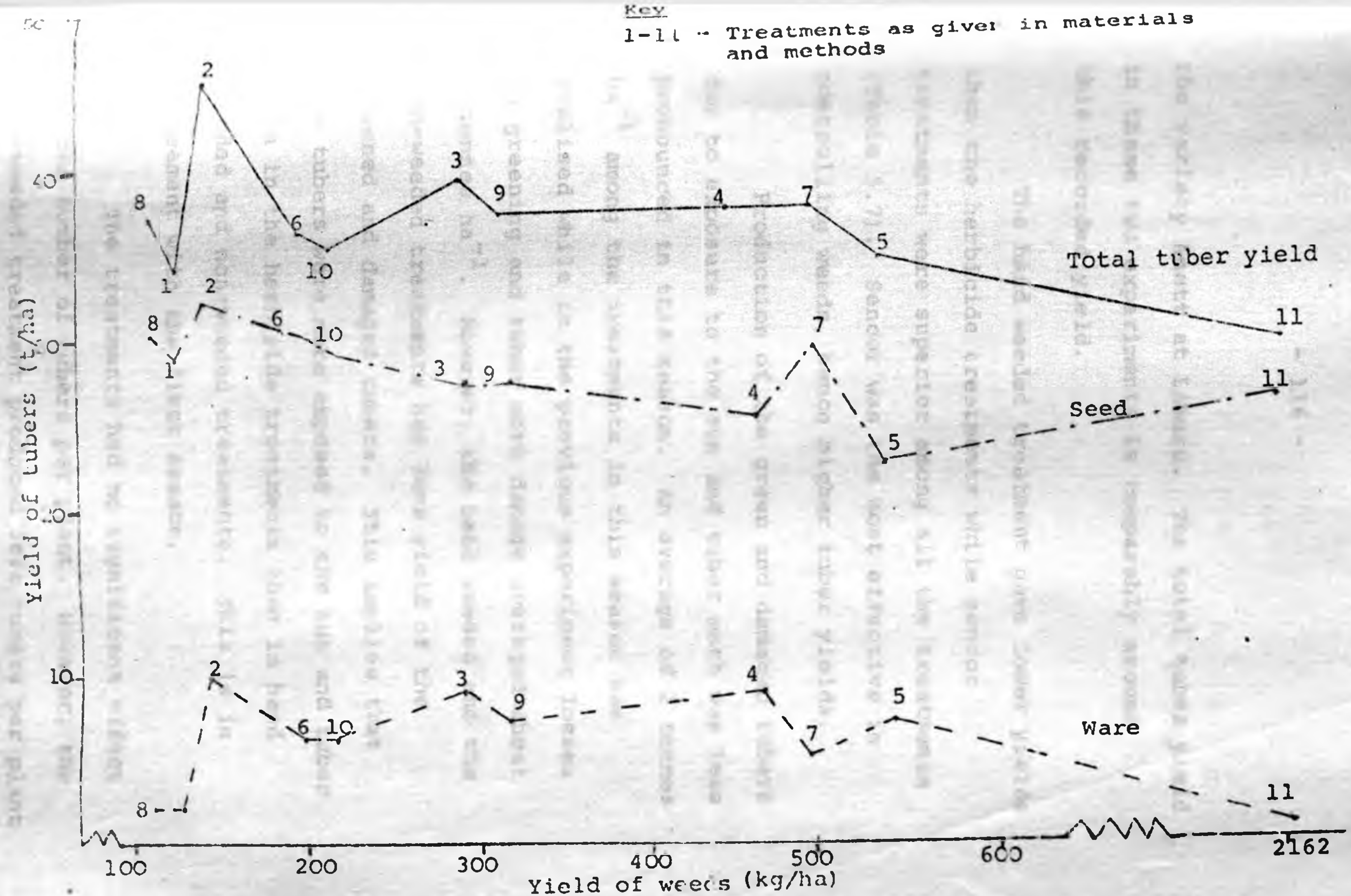


Fig. 5a. Relationship between total yield, seed and ware tubers and weed yield.

the variety Anett at Limuru. The total tuber yield in these two experiments is comparably around this recorded yield.

The hand weeded treatment gave lower yields than the herbicide treatments while sencor treatments were superior among all the treatments (Table 5.7). Sencor was the most effective in controlling weeds, hence higher tuber yields.

Production of the green and damaged tubers due to exposure to the sun and tuber moth was less pronounced in this season. An average of 2 tonnes ha^{-1} among the treatments in this season was realised while in the previous experiment losses to greening and tuber moth damage averaged about 5 tonnes ha^{-1}. However, the hand weeded and the non-weeded treatments had less yield of the greened and damaged tubers. This implies that the tubers were more exposed to the sun and tuber moth in the herbicide treatments than in hand weeded and non-weeded treatments. This is in agreement with the first season.

The treatments had no significant effect on the number of tubers per plant. However, the non-weeded treatment produced less tubers per plant which could be a reflection of the lower number of stems per plant in this treatment (Table 5.3). Fewer tubers per plant were produced in cases where few stems per plant were recorded.

5.2.8. Percent tuber dry matter content and crisp colour

The treatments had no effect on quality of tubers as denoted by the percent tuber dry matter content of the tubers and the crisp colour (Table 5.8). However, the percent tubers dry matter and crisp colour were generally lower than in the first season (Tables 4.8) which was fairly dry (Appendix C & D). This could have caused accumulation of more dry matter content and hence better crisps in the first season. The crisp colour in all the treatments was above the acceptable colour number five.

CHAPTER 6

6.1. RESULTS: Experiment III (short rains, 1980)

6.1.1. General observations

Potato plants emergence was first observed 15 days after planting, but emergence records were taken at an interval of 2-3 days after the first count, which was on November 15, 1980. This continued till approximately 100 percent emergence was observed about 26-28 days after planting (Table 6.1.).

At time of herbicide application most of the weeds were at 2-leaves stage, some particularly *Tagetes minuta* L., were at 3-4-leaf stage. The weeds were evenly distributed. The dominant weeds which could be identified at this stage were *Oxalis* sp. and *Tagetes minuta* L. Flowering of the potato plants was observed at about 45-50 days after planting.

6.1.2. Effect of treatments on weed and crop scores

The treatments had significant (P = 0.05) effect on weed scores throughout the season (Table 6.2). Sencor was more efficient on weed control than the other treatments. Although hand-weeding was effective on weed control, its effect was not continuous throughout the season as in

Table 6.1. Percent Emergence of Potato Plants

Treatments	Recording dates			
	15.11.80	17.11.80	20.11.80	22.11.80
1. Sencor (L.R.)	50	83	95	98
2. Sencor (M.R.)	35	75	95	95
3. Sencor (H.R.)	53	83	98	98
4. Afalon (L.R.)	58	80	100	100
5. Afalon (M.R.)	75	93	93	98
6. Afalon (H.R.)	65	90	93	93
7. Galex (L.R.)	40	78	88	100
8. Galex (M.R.)	53	80	95	98
9. Galex (H.R.)	45	83	95	93
10. Hand-weeded	58	75	97	94
11. Non-weeded	68	86	98	98

the case of herbicide treatments. The higher rates of application of herbicides were more effective on weed control than the medium and low rates. Non-weeded treatment was heavily infested with weeds throughout the season.

Tagetes minuta L. and *Oxalis* sp. were the main dominant weed species in the herbicide treatments throughout the season. The former weed was more vigorous in the non-weeded treatment. Leaf chlorosis of *Oxalis* sp. was observed in the herbicide treatments especially sencor treatments. In the non-weeded treatment, *Oxalis* sp. was suppressed by the taller weeds while *Tagetes minuta* L., *Erucastrum arabicum* L., *Bidens pilosa* L. and *Amaranthus* sp. were dominant.

No apparent crop injury by herbicides was observed (Table 6.2) in this trial.

6.1.3. Effect of treatments on plant height and stem number per plant

The plant height and stems per plant were recorded 65 and 66 days after planting respectively. Both were not significantly affected by the treatments (Table 6.3).

Table 6.2. Effect of Treatments on Weed and Crop Scores

Treatments	Weed Scores					Crop Score
	1	2	3	4	5	
	20.11.80	6.12.80	19.12.80	2.1.81	16.1.81	
1. Sencor (L.R.)	1.6	1.8	2.8	2.6	2.1	10
2. Sencor (M.R.)	1.6	1.6	2.8	2.6	1.5	10
3. Sencor (H.R.)	1.1	0.9	1.5	1.5	0.9	10
4. Afalon (L.R.)	3.9	4.5	6.1	5.9	6.0	10
5. Afalon (M.R.)	4.6	4.5	5.5	4.5	3.5	10
6. Afalon (H.R.)	3.3	3.8	4.5	3.5	3.1	10
7. Galex (L.R.)	4.3	5.8	7.5	7.1	7.8	10
8. Galex (M.R.)	3.5	4.0	5.5	5.5	5.5	10
9. Galex (H.R.)	3.4	3.1	4.1	4.6	5.4	10
10. Hand-weeded	6.3	0.0	0.5	0.6	0.6	10
11. Non-weeded	7.1	8.8	9.6	9.9	9.9	10

Table 6.2. (Contd.....)

C.V.%	30	41
S.E. single plot	1.33	1.54
S.E. of a difference between two means	0.77	0.89
L.S.D. (P = 0.05)	1.60	1.85
S.E. of weedy vs others	0.43	0.50
L.S.D. (P = 0.05)	0.90	1.04
S.E. of among others	0.77	0.89
L.S.D. (P = 0.05)	1.60	1.85
S.E. hand weeding vs herbicides	0.44	0.51
L.S.D. (P = 0.05)	0.93	1.07
S.E. Among herbicides	0.54	0.63
L.S.D. (P = 0.05)	1.13	1.31

33	28	112	-
1.57	1.57	1.29	5.00
0.91	0.74	2.89	-
1.90	1.55	6.02	-
0.51	0.42	1.61	-
1.06	0.87	3.43	-
0.91	0.74	-	-
1.90	1.56	-	-
0.52	0.43	1.67	-
1.09	0.90	3.48	-
0.64	0.53	-	-
1.34	1.10	-	-

Table 6.2. (Contd.....)

S.E. Among levels of Sencor	-	-
L.S.D. (P = 0.05)	-	-
S.E. of among levels of afalon	-	-
L.S.D. (P = 0.05)	-	-
S.E. among levels of galex	-	-
L.S.D. (P = 0.05)	-	-

-	-	-	-
-	-	-	-
-	0.91	-	-
-	1.90	-	-
1.11	0.91	-	-
2.32	1.90	-	-

Table 6.3. Mean Effect of Treatments on Plant Height and Number of Stems per Plant

Treatments	Plant height (cm)	Stems per plant
1. Sencor (L.R.)	48.3	2
2. Sencor (M.R.)	46.2	3
3. Sencor (H.R.)	47.1	3
4. Afalon (L.R.)	44.2	3
5. Afalon (M.R.)	42.2	3
6. Afalon (H.R.)	39.0	3
7. Galex (L.R.)	43.5	3
8. Galex (M.R.)	41.9	3
9. Galex (H.R.)	42.6	3
10. Hand-weeded	41.3	3
11. Non-weeded	44.0	3
C.V. %	15	25
S.E. Single plot	6.51	0.72

6.1.4. <u>Effect of treatments on percent N, P, K, Ca and Mg content of potato plant leaves, stems and tubers.</u>

The treatments had significant effect (P = 0.05) on N, P, Ca and Mg except K content of potato leaves (Table 6.4). The non-weeded treatment significantly (P = 0.05) enhanced per cent N and Ca in leaves but significantly depressed percent Mg content compared to the other treatments. Hand weeding significantly (P = 0.05) increased percent N and P and decreased percent Mg content in leaves than in the herbicide treatments. Afalon and galex treatments depressed percent N content in leaves compared to sencor treatments while galex increased percent N more than afalon treatments did. Significantly (P = 0.05) higher percent P in leaves was observed in galex treated plots than in sencor and afalon treatments. The high rate of sencor treatment depressed percent Mg content in leaves than the low and medium rates of sencor.

Significant (P = 0.05) differences among the treatments on percent P, Ca and Mg content of stems was observed while no significant effect

Table 6.4. Mean Effect of Treatments on Percent Nutrient Content of Leaves, Stems and Tubers of Potato Plant

Treatments		Percent nutrients									
		Leaves					Stems				
		N	P	K	Ca	Mg	N	P	K	Ca	Mg
1.	Sencor (L.R.)	4.43	0.19	6.70	1.72	0.70	1.93	0.08	8.65	1.57	0.41
2.	Sencor (M.R.)	4.68	0.22	6.70	1.77	0.90	1.76	0.07	9.35	1.44	0.39
3.	Sencor (H.R.)	4.51	0.19	6.85	1.98	0.47	1.70	0.07	8.45	1.41	0.38
4.	Afalon (L.R.)	4.18	0.19	6.90	1.84	0.86	1.69	0.07	7.68	1.04	0.43
5.	Afalon (M.R.)	4.25	0.19	7.18	1.71	0.73	1.71	0.07	8.05	1.02	0.27
6.	Afalon (H.R.)	3.70	0.21	6.58	1.79	0.75	1.74	0.08	8.05	1.18	0.34
7.	Galex (L.R.)	4.40	0.22	7.10	1.63	0.83	1.54	0.07	8.78	1.42	0.36
8.	Galex (M.R.)	4.13	0.21	7.30	1.46	0.84	1.91	0.07	8.65	1.32	0.33
9.	Galex (H.R.)	4.39	0.22	7.35	2.00	0.88	1.75	0.07	9.15	1.46	0.36
10.	Hand-weeded	5.30	0.23	6.82	1.93	0.66	1.63	0.09	8.53	1.16	0.25
11.	Non-weeded	5.88	0.22	6.57	2.43	0.54	1.59	0.08	8.73	1.33	0.12

Table 6.4 (Contd........)

Treatments		Percent nutrients (Tubers)				
		N	P	K	Ca	Mg
1.	Sencor (L.R.)	1.57	0.13	2.55	0.05	0.11
2.	Sencor (M.R.)	1.61	0.16	2.50	0.06	0.10
3.	Sencor (H.R.)	1.63	0.14	2.88	0.07	0.15
4.	Afalon (L.R.)	1.70	0.13	1.93	0.04	0.10
5.	Afalon (M.R.)	1.68	0.14	2.50	0.05	0.12
6.	Afalon (H.R.)	1.71	0.11	2.30	0.05	0.11
7.	Galex (L.R.)	1.57	0.15	2.40	0.05	0.13
8.	Galex (M.R.)	1.41	0.13	2.40	0.05	0.12
9.	Galex (H.R.)	1.56	0.45	1.93	0.04	0.11
10.	Hand-weeded	1.65	0.15	2.37	0.06	0.10
11.	Non-weeded	1.63	0.14	2.49	0.04	0.10

Table 6.4. (Contd.......)

	Leaves					Stems					Tubers				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
C.V. %	10	9	10	23	20	43	14	10	12	43	18	83	8	31	20
S.E. Single plot	0.48	0.02	0.67	0.44	0.14	0.70	0.01	0.82	0.15	0.13	0.29	0.11	0.20	0.02	0.02
S.E. of a difference between two means	0.27	0.01		0.25	0.08		0.01		0.09	0.07			0.11		0.01
L.S.D.(P = 0.05)	0.57	0.02		0.53	1.72		0.01		0.17	0.15			0.23		0.03
S.E. Weedy plot vs others	0.15			0.14	0.05		0.003		0.05	0.04					
L.S.D.(P = 0.05)	0.32			0.30	0.10		0.007		0.10	0.08					
S.E. among others	0.27	0.01			0.08		0.01		0.09				0.11		0.01
L.S.D.(P = 0.05)	0.57	0.02			0.17		0.01		0.17				0.23		0.03

able 6.4. (Contd........)

	Leaves				
	N	P	K	Ca	Mg
.E. hand weeding vs herbicides	0.16	0.01			0.05
L.S.D. (P=0.05)	0.33	0.01			0.10
.E. among herbicides	0.34	0.01			0.06
L.S.D. (P= 0.05)	0.676	0.015			0.12
.E. among levels of sencor					0.10
.S.D. (P =0.05)					0.21
.E. among levels of afalon					
.S.D. (P=0.05)					
.E. among levels of galex					
.S.D. (P = 0.05)					

Stems					Tubers				
N	P	K	Ca	Mg	N	P	K	Ca	Mg
	0.004			0.01					
	0.007			0.08					
		0.33	0.11				0.08		
		0.67	0.21				0.16		
							0.14		0.02
							0.28		0.03
							0.14		
							0.28		
							0.14		
							0.28		

of the treatments was observed on percent N and K content (Table 6.4). The non-weeded treatment had higher (P = 0.05) percent P and Ca in stems than in the other treatments; whereas, stems from the hand weeded treatment had higher percent P content in stems than in herbicide treatments. Afalon treatments depressed percent K and Ca in stems compared to the sencor and galex treatments (P = 0.05). Percent Mg content of stems was significantly (P = 0.05) lower in the non-weeded and hand weeded treatments compared to the other treatments and herbicide treatments respectively.

No significant effects among the treatments on percent N, P and Ca content of tubers was observed (Table 6.4). However, significant (P = 0.05) differences among the treatments was observed on percent K and Mg content of tubers. Galex and afalon treatments significantly (P = 0.05) depressed percent K content in tubers compared to sencor treatments. The low and medium rates of sencor depressed percent K and Mg content in tubers significantly (P = 0.05) compared to sencor at the high rate. High rate of galex application depressed (P = 0.05) percent

K in tubers compared to the medium and low rates of application. Afalon at the low rate significantly (P = 0.05) depressed percent K in tubers compared to the application at the high and medium rates.

6.1.5. Effect of treatments on yield of weeds

Effect of treatments on the total dry weight yield of weeds at harvest is shown in Table 6.5. In the hand-weeded treatement, the recorded dry weight yield was cumulative. There was significant (P = 0.05) difference among the treatments in their effect on dry weight yield of weeds. The hand weeded treatment had significantly (P = 0.05) lower total dry weight of weeds compared to the herbicide treatments. Sencor at all rates was significantly (P = 0.05) more effective on weed control than galex, afalon and hand weeding. The application of the high rates of herbicides gave better weed control than the low rates irrespective of the herbicide used.

The yields of the dominant weed species in the treatments are shown in Table 6.5. The control of Oxalis sp. by the different weed control methods was very poor. However, suppression

Table 6.5. Mean effect of treatments on dry weight yield of weeds

Treatments	Total[1]	Dry weight of weeds (kg/ha)					
		Oxalis sp.	Bidens pilosa	Amaranthus sp.	Erucastrum arabicum	Tagetes minuta L.	Others
1. Sencor(L.R.)	185.3	36.7	-	-	-	-	149.3
2. Sencor(M.R.)	173.8	61.4	-	-	-	-	112.2
3. Sencor (H.R.)	91.1	40.0	-	-	-	-	51.1
4. Afalon (L.R.)	1149.3	-	103.8	-	-	680.7	364.7
5. Afalon (M.R.)	1178.0	228.7	20.0	-	-	408.0	521.3
6. Afalon (H.R.)	540.2	118.2	-	-	-	193.2	228.8
7. Galex (L.R.)	2361.9	140.5	194.8	-	-	1717.7	308.9
8. Galex (M.R.)	1357.2	39.4	90.0	-	-	1038.4	189.4
9. Galex (H.R.)	1619.3	10.11	107.2	-	-	1229.6	271.5
10. Hand-weeded[2]	246.6	22.8	1.8	1.18	9.7	51.7	161.8
11. Non-weeded	3972.2	65.5	277.7	276.5	701.6	1744.0	1183.6

[1]C.V.% = 63

S.E. Single plot = 893.13

S.E. of a difference between two means = 773.47
L.S.D(P = 0.05) =1613.46

S.E. Weedy vs others = 288.26; L.S.D.(P = 0.05) = 601.30

S.E. Among others = 773.47; L.S.D.(P = 0.05) =1613.46

S.E. hand weeding vs herbicides = 297.71; L.S.D.(P = 0.05) = 621.02

S.E. Among herbicides= 364.62; L.S.D.(P = 0.05) = 760.59

[2]Cumulative dry weight.

of *Oxalis* by other weeds in the non-weeded treatment was observed. *Amaranthus* sp. and *Erucastrum arabicum* were well controlled by the herbicides irrespective of the rates used. *Bidens pilosa* and and *Tagetes minuta* L. were equally well-controlled by the three rates of sencor. These weeds were, however, poorly controlled by afalon and galex especially at the low rates of application. Galex in particular gave very poor control of *Tagetes minuta* L. (59.5-98.5 percent of the non-weeded treatment).

6.1.6. Effect of treatments on percent residual soil moisture content by weight

The treatments were not significantly different in their effects on the percent residual soil moisture content (Table 6.6). However, almost significantly (P = 0.05) lower percent residual soil moisture content in the non-weeded treatment than in the other treatments was observed. Similarly, although not significant, the galex treatments had lower percent moisture content compared to the other herbicide treatments.

Table 6.6. Mean effect of treatments on percent residual soil moisture content by weight.

Treatments	Percent residual soil moisture content
1. Sencor (L.R.)	7.20
2. Sencor (M.R.)	7.05
3. Sencor (H.R.)	6.69
4. Afalon (L.R.)	7.19
5. Afalon (M.R.)	7.11
6. Afalon (H.R.)	6.48
7. Galex (L.R.)	6.83
8. Galex (M.R.)	7.28
9. Galex (H.R.)	6.61
10. Hand weeded	7.19
11. Non-weeded	6.56
C.V. %	10
S.E. Single plot	0.72

6.1.7. Effect of treatments on potato tuber yield

Total tuber yield,size-grades and tubers per plant are shown in Table 6.7. The treatments produced significantly ($P = 0.05$) different total tuber yield. The non-weeded treatment had significantly ($P = 0.05$) lower total tuber yield compared to the other treatments. Although not statistically significant, the sencor treatments produced comparatively higher tuber yields than the other herbicide and hand-weeded treatments. Sencor treatments were followed by hand-weeding, afalon and galex (29.5, 27.7, 26.1 and 24.4 tonnes ha^{-1}, respectively).

The yield of seed and chatt sized tubers was not significantly different among the treatments. However, the yield of ware sized tubers was significantly ($P = 0.05$) different among the treatments. The non-weeded treatment had significantly lower ($P = 0.05$) yield of ware sized tubers. Sencor treatments significantly ($P = 0.05$) produced the highest yield of ware sized tubers among the herbicide treatments.

The effect of the treatments on yield of green and damaged tubers was not significant. However, the medium rate of sencor treatments had

Table 6.7. Mean effect of treatments on tuber yield and number of tubers per plant

Treatments	Tuber yield (t/ha)					Tubers per plant
	Total	Seed	Ware	Chatts	Greened & damaged	
1. Sencor (L.R.)	28.1	17.8	5.1	1.3	4.0	9
2. Sencor (M.R.)	28.8	19.8	5.6	1.9	1.5	9
3. Sencor (H.R.)	31.8	19.8	7.2	1.3	3.4	10
4. Afalon (L.R.)	25.5	17.4	2.9	1.5	3.6	9
5. Afalon (M.R.)	27.5	21.1	2.9	1.7	1.9	11
6. Afalon (H.R.)	25.3	17.2	3.7	2.4	1.5	10
7. Galex (L.R.)	22.4	17.2	2.3	1.3	1.6	10
8. Galex (M.R.)	23.9	17.3	1.9	2.2	2.5	9
9. Galex (H.R.)	27.0	22.5	1.2	0.9	2.5	10
10. Hand-weeded	27.7	19.5	3.8	1.6	2.2	9
11. Non-weeded	23.0	18.0	1.4	1.8	1.8	10

Table 6.7. Mean effect of treatments on tuber yield and number of tubers per plant

Treatments		Tuber yield (t/ha)					Tubers per plant
		Total	Seed	Ware	Chatts	Greened & damaged	
1.	Sencor (L.R.)	28.1	17.8	5.1	1.3	4.0	9
2.	Sencor (M.R.)	28.8	19.8	5.6	1.9	1.5	9
3.	Sencor (H.R.)	31.8	19.8	7.2	1.3	3.4	10
4.	Afalon (L.R.)	25.5	17.4	2.9	1.5	3.6	9
5.	Afalon (M.R.)	27.5	21.1	2.9	1.7	1.9	11
6.	Afalon (H.R.)	25.3	17.2	3.7	2.4	1.5	10
7.	Galex (L.R.)	22.4	17.2	2.3	1.3	1.6	10
8.	Galex (M.R.)	23.9	17.3	1.9	2.2	2.5	9
9.	Galex (H.R.)	27.0	22.5	1.2	0.9	2.5	10
10.	Hand-weeded	27.7	19.5	3.8	1.6	2.2	9
11.	Non-weeded	23.0	18.0	1.4	1.8	1.8	10

Table 6.7. (Contd....)

C.V.%	20	25	100
S.E. Single plot	5.18	4.62	3.23
S.E. of a difference between two means	2.98	-	1.86
L.S.D. (P=0.05)	6.24	-	3.88
S.E. Weedy plot vs others	1.67	-	1.04
L.S.D. (P=0.05)	3.49	-	2.17
S.E. Among herbicides	-	-	1.32
L.S.D. (P=0.05)	-	-	2.75
S.E. of among levels of sencor			
L.S.D. (P = 0.05)			

64	59	16
1.05	1.36	1.51
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
-	-	-
	0.96	
	1.94	

significantly (P = 0.05) lower greened and damaged tubers than the other sencor treatments. Generally, the non-weeded treatment had lower yield of greened and damaged tubers than the other treatments. Similarly, the medium and high rate treatments of afalon had higher yield of the greened and damaged tubers than the low rate of application.

Generally, there was no much variation of total tuber yield, grades and green and damaged tubers within the rates of a given herbicide, although the total yield, seed, ware and chatt sized tubers were slightly higher at the higher rates of herbicide application.

No significant effect of the treatments was observed on the number of tubers per plant. (Table 6.7).

6.1.8. Effect of treatments on percent tuber dry matter content (%D.M.) and crisp colour

The treatments had no significant effect on percent tuber dry matter content (Table 6.8). However, significant (P = 0.05) differences among the treatments on crisp colour was observed. The lower rate of sencor treatment gave significantly

Table 6.8. Effect of treatments on percent tuber dry matter content (%D.M.) and crisp colour

Treatments	% D.M.	Crisp colour
1. Sencor (L.R.)	20.90	5.5
2. Sencor (M.R.)	21.55	7.5
3. Sencor (H.R.)	21.63	7.0
4. Afalon (L.R.)	21.55	6.8
5. Afalon (M.R.)	20.93	7.0
6. Afalon (H.R.)	21.43	6.0
7. Galex (L.R.)	21.08	6.8
8. Galex (M.R.)	21.68	6.8
9. Galex (H.R.)	21.23	6.8
10. Hand-weeded	21.38	7.0
11. Non-weeded	21.22	6.7
C.V.%	2	10
S.E. Single plot	0.48	0.69
S.E. of a difference between two means	NS	0.40
L.S.D.(P = 0.05)	-	0.83
S.E. Among others		0.40
L.S.D.(P = 0.05)	NS	0.83
S.E. Among levels of sencor.	NS	0.49
L.S.D. (P = 0.05)		1.01

(P = 0.05) lower crisp colours than the medium and high rates of application. Nevertheless, all the treatments gave tubers of acceptable crisp colours (Table 6.8).

6.2. DISCUSSION OF RESULTS

6.2.1. Emergence of potato plants

The results indicate no treatment effects on the emergence of potato plants despite herbicides possible absorption through the roots.

6.2.2. Weed and crop scores

As portrayed by weed scores (Table 6.2), the herbicides and the hand weeding had fairly good control of weeds. Sencor was particularly effective in weed control. The herbicides gave season-long control of weeds compared to hand-weeding. However, due to poor control of *Tagetes minuta* L. by galex, high weed scores were observed in this treatment. The non-weeded treatment had high weed scores throughout the season. This could have been the main cause of the significant tuber yield depression observed in the treatment. The herbicides were observed to have good herbicidal activity on most of the annual broadleaved weeds such as *Amaranthus* sp and Erucastrum arabicum. Tagetes minuta L. was suppressed by the herbicides particularly sencor. Herbicides caused leaf chlorosis in Oxalis sp. The effect was particularly marked in the use of sencor application (Plates VI and VII). Galex was not an effective control for Bidens pilosa (Table 6.5). The weed infestation during this season was fairly high compared to the first season (Plate VIII). The non-weeded plots scored on average 6, 8 and 9 during the first, second and third season, respectively. The fairly wet season reaching a peak of 330mm in November, 1981 (Appendix C & D) could have contributed to the dense weed growth. The rainfall receipt exceeded potential evaporation (Appendix B & D) probably leading to more moisture being available to both the crop and weeds. Favourable rainfall may have made soil nutrients more available to the plants and weeds.

No apparent crop damage by the herbicides under the conditions of this experiment was observed although the herbicides could have been absorbed through the roots.

<u>Plate VI.</u> Leaf chlorosis of <u>Oxalis</u> sp. and excellent control of other weeds by sencor low rate of application.

<u>Plate VII</u>. Leaf Chlorosis of <u>Oxalis</u> sp. and good control of other weeds by application of sencor high rate.

Plate VIII. Heavy infestation of weeds in the non-weeded plot early in the season.

6.2.3. Plant height and stems per plant

The treatments applied in this experiment showed no effect on plant height or number of stems per plant. The stem numbers per plant were fairly constant among the treatments.

6.2.4. N, P, K, Ca and Mg content in potato leaves, stems and tubers

The percent nitrogen and phosphorus, and Calcium were higher in the leaves from non-weeded plot than those from herbicide treatments and in the other treatments, respectively. The hand weeded and galex treatments produced leaves with higher N content than those from the herbicide treatments. Magnesium content was lower in leaves from the non-weeded and hand weeded treatments from the other treatments and herbicide treatments respectively.

Lower percent magnesium and higher percent P and Ca of stems from the non-weeded treatment was noted than those from other treatments. The hand weeded treatment depressed percent P and Mg in stems than the herbicide treatments; percent Ca and K were lower in afalon treatments than in the other herbicide treatments. Nitrogen content was not significantly different among the treatments.

In tubers, percent N, P and Ca were not significantly different among the treatments. However, among the herbicides, higher percent K was recorded in the sencor treatments than in the other herbicide treatments; galex high rate and afalon low rate, and sencor high rate treatments had low and high percent K in tubers than in the other rates of application, respectively. Magnesium content was observed to be significantly higher in the tubers from the high rate of sencor treatment than its other rates of application.

Generally, the highest percent nitrogen content is in the leaves followed by stems and tubers respectively. The percent P content was lowest in stems. Potassium content was highest in stems followed by leaves; whereas, it was almost three and four times lower in tubers compared to that in leaves and stems, respectively. Percent Ca and Mg was highest in leaves followed by stems, but low in tubers.

6.2.5. The yield of dry weight of weeds

Sencor, afalon and galex were effective on weed control in that order. The hand weeding treatment was also good in weed control. The significantly large quantity of weeds in the non-weeded plot (Table 6.5) probably contributed to the yield depression of tubers (Table 6.7). Moisture was not very limiting in this season and could have largely contributed to the high weed scores and weed yield at harvest (Tables 6.2 and 6.5). *Oxalis* sp. was dominant in most of the treatments while most of the annual broad-leaved weeds were well controlled by the herbicides. However, *Bidens pilosa* and *Tagetes minuta* L. were poorly controlled by galex and afalon. The higher rates of herbicides generally, performed better than the lower rates.

6.2.6. The percent residual soil moisture content by weight

The plots infested with heavier weed densities were observed to have low percent residual soil moisture content (Tables 6.2 and 6.6). In turn, the treatments with the high weed densities resulted in lower tuber yield probably due to competitive effects.

6.2.7. Yield of potato tubers

Weeds reduced total tuber yield as well as the yield of the large sized tubers as depicted by the tuber yield in the non-weeded treatment. (Table 6.7, Figures 6a and 6b). There was a significant negative correlation coefficient between total tuber yield, saleable yields and yield of weeds (r = -0.76 and -0.62 respectively). However, there was no complete linear relationship. Sencor treatment gave the highest yield of tubers as well as the highest yield of large sized tubers followed by hand weeding, afalon, galex and non-weeded treatments, respectively. In general, this followed similar trend with the yield of weeds and weed scores in that order (Tables 6.2 and 6.5). The high infestation of weeds could have caused stiff competition for factors such as light and space apart from moisture and nutrients. Shading of the potato plants could have largely contributed to the early death of potato plants in the heavily weed-infested plots and hence restricting increase of tuber size. The total yields were slightly lower in this season than in

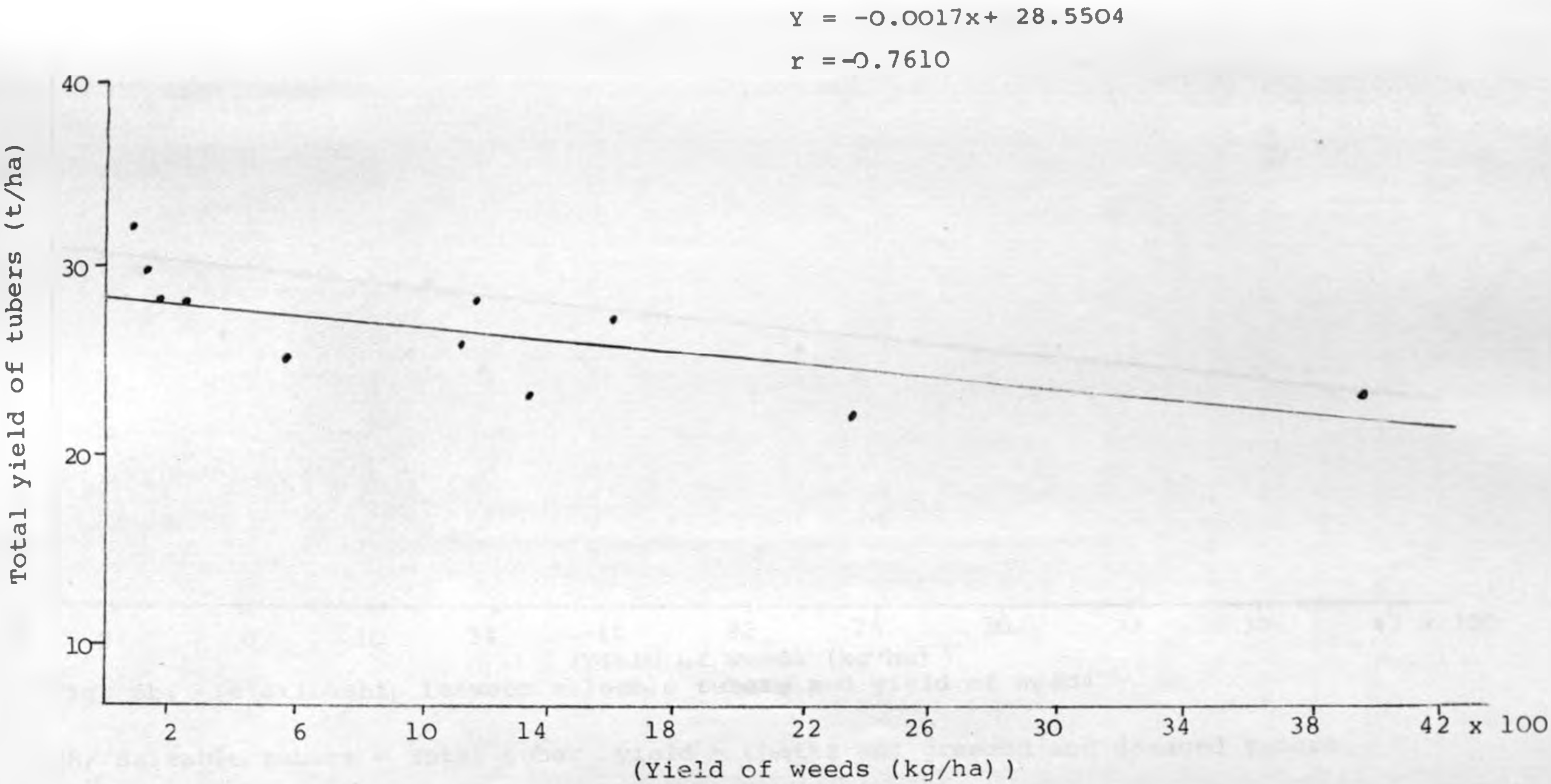


Fig. 6a. Relationship between total yield of tubers and weed yield

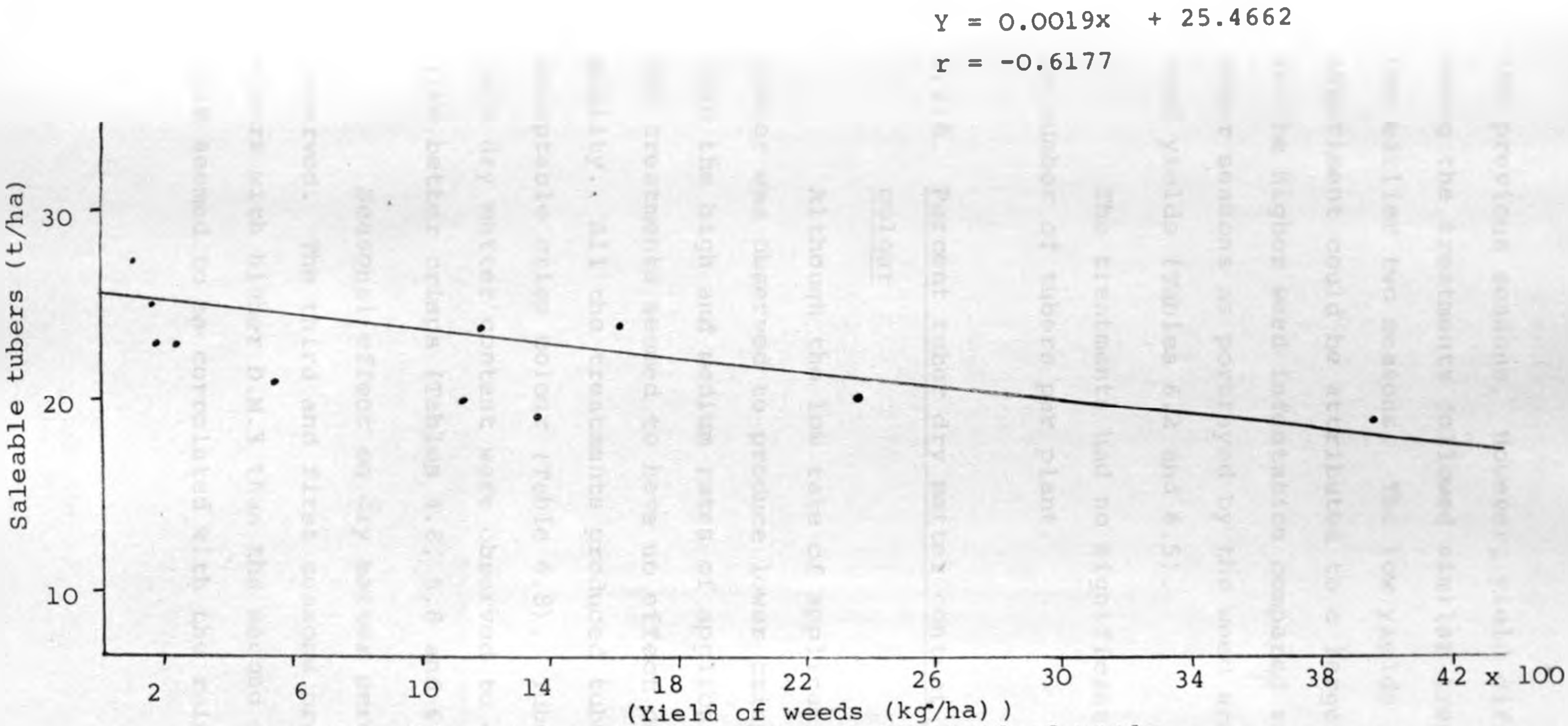


Fig. 6b. Relationship between saleable tubers and yield of weeds

NB/ Saleable tubers = Total tuber yield - Chatts and greened and damaged tubers the previous seasons. However, yield differences among the treatments followed similar trend as the earlier two seasons. The low yields in this experiment could be attributed to a large extent to the higher weed infestation compared to the other seasons as portrayed by the weed scores and weed yields (Tables 6.2 and 6.5).

The treatments had no significant effect on number of tubers per plant.

6.2.8. Percent tuber dry matter content and crisp colour

Although the low rate of application of sencor was observed to produce lower crisp colour than the high and medium rates of application, all the treatments seemed to have no effect on tuber quality. All the treatments produced tubers with acceptable crisp colour (Table 6.8). Tubers with high dry matter content were observed to generally give better crisps (Tables 4.8, 5.8 and 6.8).

Seasonal effect on dry matter percent was observed. The third and first seasons produced tubers with higher D.M.% than the second season. This seemed to be correlated with the rainfall conditions (Appendix C and D). A dry condition was observed to cause production of high percent dry matter probably due to moisture loss from the tubers in the field.

CHAPTER 7

7.1. EXPERIMENT IV

7.1.1. Introduction

In the cause of the three experiments between 1979 and 1981, it was observed that the herbicides used in the study controlled *Tagetes minuta* L. poorly (Tables 5.5 and 6.5). Sencor was observed to cause more intense chlorosis on *Oxalis* sp. (Plates VI and VII). It was therefore hypothesised that the non-effectiveness of these herbicides on *Tagetes minuta* L. was probably associated with timing of herbicide application. It was also possible that a higher rate of sencor application could have been more effective on *Oxalis* sp. control. Hence, it appeared logical to conduct observational trials to test these hypotheses.

The residual effects of herbicides on subsequent crops is of paramount importance to the farmers. This is particularly so, for the small scale farmers. Most of the small scale farmers in the tropics, intercrop their crops in various ways, such as, relay cropping, planting other crops or similar crops soon after the first crop, etc. In view of this, the residual effect of the herbicides on subsequent maize crop after potatoes and the effect of the herbicides on beans and maize in polythene bags experiments where *Tagetes minuta* L. was being studied was looked into.

7.1.2. Materials and Methods

7.1.2.1. Experiment IVa

The same plots where Experiment III was in the previous season were planted with maize (Hybrid 614C) on 2nd April, 1981. All plots were hand weeded. However, the first weeding was done after the weed species which had come up were assessed. Visual crop scores were made on a scale of 0-10 as in the previous experiments. This was done three weeks after crop emergence.

7.1.2.2. Experiment IVb

Approximately equal amounts of *Tagetes minuta* L. seeds were planted on 20th March, 1981 in 30cm diameter polythene bags giving a surface area of 707.0cm^2 Sterilised soil medium composed of gravel, sand, coffee husks and sub-soil at 1:1:1:2 ratio plus 28g of diammonium phosphate (18: 46: O) per bucket (25kg) of the mixture used. They were kept in a glasshouse. The treatments were as given below:-

Herbicide	rate
Sencor	350 g a.i. ha^{-1}
Sencor	875 g a.i. "
Sencor	1400 g a.i. "
Afalon	500 g a.i. "
Afalon	1250 g a.i. "
Afalon	2000 g a.i. "
Galex	5.0ℓ ha^{-1}
Galex	6.5ℓ "
Galex	8.0ℓ "
Control (No spray of herbicides)	

The herbicides were sprayed on 25th March, 31st March, 4th April and 12th April 1981. This was 5 days, 10 days, 15 days and 23 days after planting respectively. In each case the herbicides were applied in 100ml of water. Beans and maize were planted in the same bags on 25th April, 1981 after the final weed scoring which was done on 24th April, 1981. Two beans and two maize seeds were planted per bag. The weeds and crop plants were visually scored for the effect of the herbicides on a scale of 0-10 as in the other experiments.

7.1.2.3. Experiment IVc

About 10 bulbs of *Oxalis latifolia* were planted in polythene bags on 20th March, 1981. The soils used were similar as in Experiment IVb with similar fertilizer applications. The bags were kept in the glass house. Visual scores were done on a scale of 0-10. The treatments applied were:- Sencor at 350, 875, 1400, 1925, 2450 g a.i. ha^{-1} rates and control where no herbicide was applied. The treatments were applied at different times on 25th March, 31st March, 8th April and 25th April, 1981, that is, 5 days, 10 days, 18 days and 35 days after planting.

7.1.3. RESULTS

7.1.3.1. Experiment IVa

Approximately 100 percent emergence of maize was observed 8 days after planting. Visual scoring on maize was done 22 days after planting or 14 days after about 100 percent emergence was observed. All the plots scored 10. This signified no apparent crop injury was caused by the herbicide treatments. Similar weed flora as in the previous season was recorded 36 days after planting before the hand weeding was carried out.

7.1.3.2. Experiment IVb

Table 7.1 indicates complete control of Tagetes minuta L. by all the herbicide treatments irrespective of spraying time. However, it was observed that the herbicides were more effective at the early growth stage of weeds particularly at the 1-2 leaf stage. Galex was observed to act faster at this time than sencor or afalon. Tagetes minuta L. died slowly when the herbicides were sprayed at more than 3-leaf stage of growth. Sencor was observed to be more effective at this stage compared to the other herbicide treatments.

Table 7.2 depicts the effect of the herbicides on beans. Sencor was observed to kill the beans irrespective of the time when the herbicide treatments were applied in this experiment followed by afalon treatments. Galex treatments did not cause much damage to the beans particularly those in the bags where the herbicide was applied

Table 7.1. Mean effect of treatments on *Tagetes minuta* L. Scores

Herbicides	Herbicide spraying dates							
	25/3/81 Scoring dates		31/3/81 Scoring dates		4/4/81 Scoring dates		12/4/81 Scoring dates	
	6/4/81	24/4/81	6/4/81	24/4/81	6/4/81	24/4/81	6/4/81	24/4/81
Sencor 350g a.i./ha	1.0	0	0.5	0	8	0	-	0
Sencor 875g a.i./ha	0.5	0	0.5	0	9	0	-	0
Sencor 1400g a.i./ha	0.5	0	0.1	0	8	0	-	0
Afalon 500g a.i./ha	1.0	0	3.0	0	9	0	-	2
Afalon 1250g a.i./ha	0.5	0	2.0	0	9	0	-	0
Afalon 2000g a.i./ha	0.5	0	2.0	0	9	0	-	0
[1]Galex 5.0ℓ /ha	1.0	0	3.0	0	9	0	-	0
Galex 6.5ℓ /ha	0.5	0	3.0	0	9	0	-	0
Galex 8.0ℓ /ha	0.5	0	0.5	0	9	0	-	0
Control	9.0	10	9.0	10	9	10	-	10

[1]Product in liters per hectare.

Table 7.2. Mean effect of treatments on bean scores

Herbicides	Herbicide spraying dates							
	25/3/81		31/3/81		4/4/81		12/4/81	
	Scoring dates		Scoring dates		Scoring dates		Scoring dates	
	16/5/81	24/5/81	16/5/81	24/5/81	16/5/81	24/5/81	16/5/81	24/5/81
Sencor (L.R.)	1	0	1	0	1	0	1	0
Sencor (M.R.)	1	0	0	0	2	0	1	0
Sencor (H.R.)	1	0	1	0	0	0	3	1
Afalon (L.R.)	1	0	3	0	9	9	0	0
Afalon (M.R.)	1	0	2	0	10	9	9	4
Afalon (H.R.)	1	0	3	0	3	2	1	0
Galex (L.R.)	10	10	5	5	10	10	10	10
Galex (M.R.)	8	8	6	0	9	9	0	0
Galex (H.R.)	7	10	6	10	8	8	2	0
Control	10	10	10	10	10	10	10	10

early, that is, 23 days before the beans were planted. Generally, effect of the herbicides on maize was observed to be similar to that on beans.

7.1.3.3. Experiment IVc

Table 7.3 shows a fairly good suppression of Oxalis latifolia by the different sencor treatments. The higher rates appeared to be more effective.

7.1.4. DISCUSSION OF RESULTS

7.1.4.1. Herbicides residual effect on maize growth

All the herbicides were observed to have no apparent effect on subsequent maize crop, unless final yield is affected. This means that under the conditions of this study, planting maize after a crop of potatoes where sencor, afalon and galex were used on weed control may have no problems. Maize was planted approximately 5 months after herbicide applications. Also, the herbicides seem to have no residual effects on subsequent weed re-growth from about 3 months after herbicide applications. Similar weed flora appeared

Table 7.3. Mean effect of sencor treatments on Oxalis latiforia Scores

Sencor treatments rates (g a.i./ha^{-1})	Spraying dates 25/3/81 Scoring dates*			31/3/81 Scoring dates			8/4/81 Scoring dates			25/4/81 Scoring dates		
	1	2	3	1	2	3	1	2	3	1	2	3
350	3	2	0	3	3	0.5	3	3	0	4	2	0
875	2	1	0	2	0	0	3	2	0	3	1	0.5
1400	3	1	o	2	1	0	3	2	0	0	0	0
1925	0	0.5	0	2	1	0	2	1	0	2	1	0
2450	0	0.5	0	1	1	1	1	1	0	3	1	0
Control	10	10	10	10	10	10	10	10	10	10	10	10

* 1-16/5/81

2-24/5/81

3-24/6/81

after this duration as was recorded before herbicide applications. These results seem to indicate fast degradation of sencor, afalon and galex under the studied conditions. Galex gives weed control of up to 10 weeks depending on soil type (Anon.,1978); in numerous expiments in Europe, it was established that no more active ingredient of sencor was present in the soil 90-100 days after application (Anon., 1972); and under normal climatic conditions, afalon is degraded within one growing season (Anon., 1974). These reports seem to conform with the findings of this study. Although, the persistence of the active ingredients in soil is more or less highly dependent upon weather conditions and soil type, these herbicides seem to undergo relatively fast degradation in soil and there is no danger of phytotoxicity to subsequent crops in normal cropping systems.

7.1.4.2. Effect of herbicides on Tagetes minuta L., beans and Maize

Experiment IVb indicated that, improper timing of herbicide application could have been the main cause of poor control of Tagetes minuta L.

particularly by galex application in the previous experiments. Tagetes minuta L. appeared to be well controlled by all the herbicides used in the study provided they are applied soon after emergence of the weeds,one to two leaf stage.

Beans and maize planted soon after herbicide application may be damaged by the herbicides. Complete kill of the beans and maize in all sencor treatments applied in this study was observed (Table 7.2). Afalon was also observed to kill beans and maize. Beans and maize seemed fairly tolerant to the galex treatments applied, apart from the medium and high rates applied near planting time (Table 7.2.). No sign of recovery was observed in plants damaged by sencor and afalon. The manufacturers recommend application of afalon and galex at pre-emergence stage (Anon., 1974; Anon., 1978) particularly not later than one day after planting or sowing. Galex can be used in maize/bean intercrop at pre-emergence stage. Sencor is applied preemergence in soyabeans (Anon., 1972). Depth of planting is of paramount important where herbicides are used for weed control and the manufacturers recommend planting as deep as possible and carefully covering with soil to protect them against any damage following pre-emergence spraying. The crops in this experiment were planted 2-3cm deep which could not have been deep enough to avoid herbicide damage. Furthermore, planting after herbicide applications could have contributed to the herbicide effects on the crop. However, this may demonstrate the possibility of not exploiting relay planting or planting crops at different times in an intercrop where herbicides were used in the first crop.

7.1.4.3. Sencor effects on *Oxalis latifolia*

All the rates of sencor applied in Experiment IVc suppressed the *Oxalis latifolia* (Table 7.3) irrespective of the spraying time. The higher rates appear to be more effective than the lower rates. Repeated applications may eventually kill all the bulbs which might survive after the first spraying. However it is a difficult weed to control.

CHAPTER 8

8.1. GENERAL DISCUSSION AND CONCLUSIONS

The experiments in this study demonstrated reduction of potato tuber yields due to weeds. Comparing the non-weeded with the hand-weeded and the treatment with the highest yields the yield depression ranged from 4-42 percent (Table 8.1). This agrees with the findings of other workers (Furtick, 1970; Makepeace and Holroyd, 1978). The yield of chatts and seed-sized tubers varied only slightly among the treatments, but the yield of ware was considerably lower in the non-weeded control (Table 8.2). In general, the results indicated a negative correlation coefficient between weed and tuber yield.

The depression of yield of ware tubers was most probably a result of weed competition and accelerated maturity due to the smothering effect of weeds. There was a higher percent of greened and tuber-moth damaged tubers in the herbicide treatments (Table 8.2). This effect was due to the exposure of the tubers to the surface arising from lack of re-earthing up. Although ridging was adequate initially, the tubers seemed

Table 8.1. The mean effect of treatments on total tuber yield (t/ha) and as percent of hand weeded treatment

Treatments	Experiment I		Experiment II		Experiment III	
	Mean total tuber yield	% of hand weeding yield	Mean total tuber yield	% of hand weeding yield	Mean total tuber yield	% of hand weeding yield
1. Sencor (L.R.)	34.44	107	34.23	98	28.06	101
2. Sencor (M.R.)	38.78	115	45.06	129	28.80	103
3. Sencor (H.R.)	32.74	102	39.19	113	31.78	115
4. Afalon (L.R.)	34.15	106	37.29	107	25.51	92
5. Afalon (M.R.)	34.04	106	34.18	98	27.54	99
6. Afalon (H.R.)	32.74	102	35.51	102	25.30	91
7. Galex (L.R.)	32.07	100	37.32	107	22.44	81
8. Galex (M.R.)	34.26	107	35.69	102	23.89	86
9. Galex (H.R.)	38.48	114	36.65	105	27.04	98
10. Hand-weeded	32.11	100	34.83	100	27.70	100
11. Non-weeded	30.81	98	29.00	83	23.01	83

Table 8.2. Mean effect of treatments on tuber grades, greened and tuber moth-damaged (*P. operculella*) tubers (percent of the total tuber yield).

Tuber grades and greened/damaged tubers	TREATMENTS										
	Sencor			Afalon			Galex			Hand-weeding	Non-weeding
	L.R.	M.R.	H.R.	L.R.	M.R.	H.R.	L.R.	MR.	H.R.		
Experiment I:											
Seeds	81.0	80.0	83.0	79.0	77.0	75.0	78.0	79.0	78.0	89.0	82.1
Ware	-	-	-	-	-	-	-	-	-	-	-
Chatts	6.0	7.0	4.0	4.0	6.0	3.0	4.0	4.0	2.0	3.0	2.9
Greened/damaged	13.0	13.0	12.7	17.0	17.0	22.0	18.0	17.0	20.0	8.0	15.0
Total(t/ha)	34.4	38.8	32.7	34.2	24.0	32.7	32.0	34.3	36.5	32.1	30.8
Experiment II:											
Seeds	85.0	73.0	69.0	66.0	67.0	83.0	78.0	83.0	74.0	83.0	90.0
Ware	6.0	23.0	23.0	23.0	20.0	9.0	14.0	5.0	11.0	9.0	3.0
Chatts	3.0	2.0	3.0	3.0	3.0	3.0	3.0	5.0	5.0	3.0	4.0
Greened/ damaged	6.0	2.0	5.0	8.0	6.0	6.0	5.0	6.0	10.0	5.0	3.0
Total (t/ha)	34.2	45.1	39.2	37.3	34.2	35.5	37.3	35.7	36.7	34.8	29.0
Experiment III:											
Seeds	64.0	69.0	65.0	66.0	76.0	69.0	77.0	73.0	82.0	70.0	78.0
Ware	18.0	21.0	28.0	11.0	10.0	17.0	9.0	9.0	5.0	15.0	4.0
Chatts	4.0	7.0	3.0	7.0	7.0	9.0	4.0	9.0	5.0	8.0	9.0
Greened/damaged	14.0	3.0	9.0	16.0	7.0	5.0	10.6	9.0	8.0	7.0	9.0
Total (t/ha)	28.1	28.8	31.8	25.5	27.5	25.3	22.4	23.9	27.0	27.7	23.0

to have been formed near the surface at the base of the stems in this particular variety. Also with increase in tuber size, the tubers forced themselves to the surface. The non-weeded plot probably had lower percent of the greened tubers and tuber-moth-damaged ones due to coverage of the potatoes by weeds. Further, the weeds may have held the ridges together by their root systems. The results indicated higher potato yields from herbicide treatments compared to hand weeding. Green (1964), Robertson (1962) and Blake, French and Nylund (1962) found similar results when working on cultivation studies of potatoes. This effect was attributable to the ability of the herbicides to control the weeds and therefore reduce competition. The herbicides were so effective as to maintain a clean field throughout the season. Possible root damage during cultivation could also have contributed to depression of tuber yield in the hand-weeded plots. In addition to depressing yields through competition for nutrients, moisture, light and space (Smith, 1977; Kasasian, 1971; Zimdahl, 1980; Makepeace and Holroyd, 1978; Sweep, 1971; Parihar and Mukerji, 1979; Kasasian and Seeyove, 1969), there seems to be an interaction between weeds and their smothering effects on potatoes which caused early drying of the potato haulms. This could have partly accounted for the smaller tuber sizes. Non-weeding was observed to reduce the number of above-ground stems per plant, resulting in few tubers per plant. This could probably have been due to shading out of young stems by weeds. However, the herbicides and hand-weeding had no significant effect on stems and tubers per plant. In general, it was noticed that higher number of stems per plant gave rise to higher tubers per plant. Similar results are reported by Allen and Scott (1980).

The results indicate excellent weed control by sencor at all the rates (Plates IX, X and XI) used. These findings concur with results from other areas like Colorado, United States of America (Zimdahl, 1971). Mannal (1977) indicated similar results. Afalon and galex were also fairly good in their weed control effect in that order (Plates XII to XX). Work in Minnesota, United States of America (Nylund, Sanders and Quisumbing, 1971) and Finland (Syvalahti, Ylanen and Leskela, 1975) showed good weed control by use of afalon.

Plate IX. Poor control of *Oxalis* sp.
of application

by sencor high rate

Plate X. Poor control of *Oxalis* sp. by sencor medium rate of application

Plate XI. Poor control of *Oxalis* sp. by sencor low rate of application

<u>Plate XII</u>. Poor control of *Oxalis* sp. by afalon high rate of application

Plate XIII. Poor control of *Oxalis* sp. by afalon medium rate of application

Plate XIV. Poor control of Tagetes minuta L. by application of afalon low rate.

<u>Plate XV</u>. Excellent weed control by afalon high rate

Plate XVI. Poor control of Tagetes minuta L. and Oxalis sp. by afalon low rate, but good control of most of the other weed species.

Plate XVII. Poor control of Tagetes minuta L. and Oxalis sp. by galex high rate of application.

Plate XVIII. Poor control of *Oxalis* sp. and *Tagetes minuta* L. by galex low rate of application.

<u>Plate XIX</u>. Fairly clean plot with spots of *Oxalis* sp. after application of galex medium rate.

Plate XX. Dominance of *Oxalis* sp. after most of the other weeds have been controlled by galex low rate of application.

Oxalis sp. (mainly _Oxalis latifolia_) was the main weed species which was difficult to control by any of the weed control methods. _O. corniculata_ L., was also present but not to the same extent as _O. latifolia_. Sencor caused comparatively more intense Chlorosis of Oxalis leaves, especially at the highest rate of application (1400g a.i. ha^{-1}) compared to the other herbicides. Most of the weed recovered later in the season. Under glasshouse conditions in polythene bags, all the rates of sencor applied at various times suppressed _Oxalis latifolia_ to some extent. The higher doses and early application before emergence or in the early stage of the weed growth seemed to be more effective (Table 7.3) than lower doses.

Sencor application was also more effective on _Tagetes minuta_ L. than afalon and galex treatments in the field. However, Experiment IVb indicated excellent control of _Tagetes minuta_ L. by all the herbicides under the glasshouse conditions. Early time of application particularly just before weed emergence and at about 1-2 leaf stage was the most effective. Galex application which was rather poor on _Tagetes minuta_ L. control in the field was very effective if applied at the very early stage. Galium spurium L and Pennisetum clandestinum Chiov. were not effectively controlled by the herbicides. In general, most of the annual broad-leaved weeds were well controlled by the herbicides (Table 8.3).

The herbicides particularly sencor and afalon injured beans and maize by scorching effects if these were planted fairly soon after the herbicide application. However, after 3-5months, there seems to be no residual effect on maize.

The content of various nutrients in the leaves: N, P, K, Ca and Mg, were comparable to the figures quoted by Harris (1978) for potato plant parts. However, their concentrations are expected to differ with growth stage and plant components (Harris, 1978). Also varietal differences, soil properties and other cultural practices may cause variation in nutrient content in different parts of the plant. Lack of consistent effect of treatments on nutrient contents suggests that sufficient nutrients were supplied for weeds and the crop; the herbicides may have no effect on plant nutrients analysed.

Table 8.3. Mean effect of treatments on dry weight ($kg\ ha^{-1}$) of weeds as per cent of non-weeded plot

Mean yield of weeds as % of non-weeded plot	TREATMENTS										
	Sencor			Afalon			Galex			Hand-weeded*	Non-weeded
	L.R.	M.R.	M.R.	L.R.	M.R.	H.R.	L.R.	M.R.	H.R.		
Experiment I:											
Total[1]	1.7	0.9	4.5	7.7	5.1	0.4	5.4	3.5	3.0	8.9	440.88
Experiment II:											
Oxalis sp.	195.9	237.3	406.8	334.2	728.8	269.9	708.9	100.0	335.6	223.4	54.02
T. minuta L.	0.0	0.0	0.0	20.3	5.4	2.1	8.3	0.1	10.0	0.2	1277.24
Amaranthus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	576.46
G. parviflora	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.84
Others[2]	10.1	7.2	34.7	10.8	35.0	12.8	2.2	22.0	6.5	19.5	204.98
Total	5.9	6.6	13.5	21.4	24.8	9.2	22.8	5.2	14.9	10.0	2161.54
Experiment III:											
Oxalis sp.	65.7	93.7	61.0	0.0	349.2	180.5	214.5	60.2	0.0	34.7	65.50
T. minuta L.	0.0	0.0	0.0	39.0	23.4	11.1	98.5	59.5	70.5	3.0	1744.03
Amaranthus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.4	276.46
E. arabicum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	701.59
B. pilosa	0.0	0.0	0.0	37.4	7.2	0.0	70.2	32.4	38.6	0.7	277.69
Others[3]	117.7	88.5	40.3	287.6	411.1	180.4	243.5	149.3	214.1	127.6	1183.57
Total	4.4	4.1	2.1	27.0	27.7	12.7	55.6	31.9	37.9	5.8	4248.84

*Cumulative dry weight of weeds in the hand-weeded plot

[1] Included Galium spurium L., Amaranthus sp., Chenopodium sp. and others in the herbicide and hand weeded treatment plots and Amaranthus sp., Galium spurium L., Oxalis sp., G. parviflora Cav., Chenopodium sp., C. benghalensis sp. and others in the weedy plot.

[2,3] Others included the few and too young weed species.

It has been demonstrated that competition occurs only when the immediate supply of a single necessary factor falls below combined demands of the plants (Zimdahl, 1980). However, Zimdahl (1980) quoting Vengris, Colby and Drake (1955) contended that weeds compete for essential nutrients and decrease crop yields even at high rates of fertilization. This may not be surprising since other forms of competition, such as, for light, allelopathy, etc. could independently lead to crop yield reduction. Although there was no consistent herbicide effect on nutrients, there was ample evidence of tuber yield advantage where the herbicides, particularly sencor controlled the weeds (Tables 8.1 and 8.3). Generally, higher nutrient content in herbicide treatments compared to the other treatments were observed though the effect was not consistent (Table 8.4). This could be due to better weed control throughout the seasons, thereby reducing weed competition for the nutrients. Some seasonal variations were observed (Table 8.4) probably due to time of sampling for nutrients analysis and differences in climatic conditions over the seasons influencing weed-crop competition

Table 3.4. Mean effect of herbicides on nutrient contents

Herbicide	Percent nutrients														
	Leaves					Stems					Tubers				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Experiment I															
Sencor	3.52	0.12	8.11	2.74	0.60	1.92	0.05	8.12	1.44	0.24	1.74	0.36	2.42	0.03	0.13
Afalon	3.35	0.11	8.18	2.79	0.56	1.69	0.05	8.11	1.42	0.20	1.55	0.10	2.70	0.03	0.13
Galex	3.34	0.11	8.29	2.62	0.52	1.83	0.04	8.07	1.31	0.21	1.61	0.08	2.42	0.03	0.12
Hand-weeded	3.58	0.12	7.80	2.57	0.60	2.08	0.05	7.80	1.33	0.20	1.57	0.09	2.12	0.03	0.12
Non-weeded	3.44	0.14	8.27	2.73	0.54	2.17	0.05	8.20	1.51	0.25	1.10	0.91	2.54	0.03	0.15
Experiment II															
Sencor	5.55	0.24	4.59	1.46	0.52	2.58	0.14	9.37	0.89	0.23	2.09	0.19	3.07	0.06	0.14
Afalon	5.15	0.24	4.71	1.43	0.53	2.47	0.13	8.69	0.78	0.19	2.07	0.21	3.56	0.07	0.16
Galex	5.42	0.23	4.63	1.38	0.49	2.51	0.13	9.22	0.89	0.22	1.83	0.21	3.13	0.06	0.16
Hand-weeded	5.12	0.24	4.97	1.37	0.45	2.47	0.17	8.97	0.87	0.22	2.24	0.22	3.30	0.07	0.17
Non-weeded	4.91	0.26	5.63	0.50	0.45	2.62	0.15	9.09	0.99	0.25	1.79	0.20	3.30	0.06	0.18

Table 8.4. (Contd.......)

Experiment III															
Sencor	4.54	0.20	6.75	1.82	0.69	1.80	0.07	8.82	1.47	0.39	1.60	0.14	2.64	0.06	0.12
Afalon	4.04	0.20	6.89	1.74	0.78	1.71	0.07	7.93	1.08	0.35	1.70	0.13	2.24	0.05	0.11
Galex	4.31	0.22	7.22	1.70	0.85	1.77	0.07	8.86	1.40	0.35	1.51	0.24	2.24	0.05	0.12
Hand-weeded	5.30	0.23	6.82	1.93	0.66	1.63	0.09	8.53	1.16	0.25	1.65	0.15	2.37	0.06	0.10
Non-weeded	5.88	0.22	6.57	2.43	0.54	1.59	0.08	8.73	1.33	0.12	1.63	0.14	2.49	0.04	0.10

for the nutrients. Experiment II was sampled ten days younger than the other two experiments while Experiment II and III experienced wetter conditions than Experiment I (Appendix C and D).

Herbicides may not have effect on quality of the tubers (Nylund, Sanders and Quisumbing, 1971). Similar results were shown in these experiments since the treatments had no significant effects on percent tuber dry matter content and crisp colour scores. The percent tuber dry matter content was higher during Experiments I and III than in Experiment II signifying drought effects. Experiments I and III were in the short rains while Experiment II was in the long rains season (Appendix C and D).

The per hectare partial budget (Table 8.5) indicates that herbicide weed control was comparatively less expensive than the hand weeding. However, it must be remembered that net benefits are not the same thing as profits, because many costs have been left out of the budget because they are irrelevant to this particular decision (Perrin, Winkelmann, Moscardi and Anderson, 1976). The budget ignores some crucial aspect of farmer

Table 8.5 Per hectare partial budget

	TREATMENTS										
	Sencor			Afalon			Galex			hand-weeded	Non-weeded
	L.R.	M.R.	H.R.	L.R.	M.R.	H.R.	L.R.	M.R.	H.R.		
Benefits											
net yield (t/ha)	27.1	32.6	30.1	27.3	26.9	26.0	26.3	26.2	27.8	27.8	23.8
value (Ksh/t)	1875	1875	1875	1875	1875	1875	1875	1875	1875	1875	1875
total (Ksh/ha)	50,812.50	61,125	56,437.50	51,187.50	50,437.50	48,750	49,312.50	40,125	52,125	52,125	44,625
Variable costs											
herbicides:											
amount (kg or ℓ/ha)	0.5kg	1.25kg	2.0kg	1.0kg	2.5kg	4.0kg	5.0ℓ	6.5ℓ	8.0ℓ	-	-
value (Ksh/ℓ or kg)	247.14	247.14	247.14	102	102	102	72.50	72.50	72.50	-	-
total (Ksh/ha)	123.50	308.75	494	102	255	408	362.50	471.25	580	-	-
Labour for application:											
amount (man days/ha)	5	5	5	5	5	5	5	5	5	-	-
value (ksh/man day)	15	15	15	15	15	15	15	15	15	-	-
total (Ksh/ha)	75	75	75	75	75	75	75	75	75		
Labour for hand-weeding:											
amount (man days/ha)	-	-	-	-	-	-	-	-	-	100	-
value (ksh/man day)	-	-	-	-	-	-	-	-	-	15	-
total (Ksh/ha)	-	-	-	-	-	-	-	-	-	1500	-
Total variable costs (Ksh/ha)	198.5	383.75	569	117	330	483	437.50	546.25	655	1500	-
Net benefit (Ksh/ha)	50,614	60,741.25	55,868.50	51,010.50	50,107.50	48,267	48,875	48,878.75	51,470	50,625	44,625

Table 8.5. (Contd.....)

Note: 1. Costs not affected by the decision e.g. ploughing, seed,planting, pesticides and their application and harvesting were regarded as fixed costs since they would be incurred regardless of the decision.

2. It was assumed that the potatoes were not stored and were sold in the farm. Therefore no storage losses and transportation costs

3. Net yield = Total tuber yield minus chatts and greened and damaged tubers.

conditions, namely capital scarcity, yield uncertainty and risk arversion. Although the non-weeding treatment had the lowest net benefit, it was reasonably high. However, it should be pointed out that if herbicides are used or no weed control is practiced, the potatoes must be ridged. Final ridging immediately after planting well sprouted potatoes in combination with timely harvesting appear to be fairly good. In normal practice, ridging is usually done during the hand weeding. Hand weeding or cultivation appear to be important by allowing earthing up in addition to controlling the weeds. Ridging reduces greening of tubers and tuber-moth damage. There are other advantages of ridging e.g. prevention of waterlogging, machine harvesting, preventing internal brown spot, etc. Some work by the author (unpublished data) indicate that harvest losses by greening and damage by potato tuber moth can be as high as over 90 percent if potatoes are not ridged, particularly under drought conditions.

Yields have often been reduced by an excessive number of post planting cultivations (Stephens, 1965). Excessive cultivation of potatoes has often been shown to be directly harmful to the crop, although a limited amount has sometimes been beneficial. Other undesirable side effects of cultivation have been demonstrated e.g. formation of stable soil clods, spreading of virus diseases, damage of plant root system and reduced protection from radiation frosts. If herbicides are to replace cultivation as a method of weed control, they must be effective, leave no toxic effects in the tubers and have no long term soil residual effects as potato is a short term crop and most farmers in the tropics plant other crops almost immediately or even before harvesting. For the intercropping systems, the herbicides must be compatible with the different crops in the mixture. Precise recommendations must be worked out to suit local requirements because the climate, soils, varieties, type of weed problem encountered and other factors vary so widely between different regions. Hence, the recommendations must be tailored to suit the recommendation domain under consideration. Nevertheless, it is likely that even if chemical weed control methods are a little cheaper than traditional methods of cultivations, they may eventually become widely adopted because of the other advantages which the system offers.

However, it should be noted that no single herbicide or mixtures of herbicides are likely to be successful under the wide range of growing conditions and weed problems met in practice.

Appendix A. Soil analysis of the National Potato Research Station - Tigoni

LABORATORY DATA			PROFILE NO 148/1-2+3		AREA:		TIGONI				
lab. no.	depth in cm	horizon	profile	particle size distribution (mu) weight %							
				sand					silt		clay
				2000-1000	1000-500	500-250	250-50	100-50	50-20	20-2	<2
757	0-15	A1)			17				30		53
-8	15-52	AB)	2		5				26		69
-9	52-82	B21)			7				20		73
760	82+	B22)			11				8		81
	0-40	A1)			5				30		65
	40-70	B21)	3		11				24		65
	70-160	B22)			13				20		67

depth in cm	pH H_2O 1:5	pH KCL	C %	N %	C/N	exchangeable cations meq/100g soil Ca	Mg	K	Na	sum	CEC	Base Sat. %	P ppm
0-15	6.1	5.1	5.9	0.71	8	17.4	3.6	3.0	0.3	24.3	36.0	68	59
15-22	5.9	5.3				11.6	2.9	1.1	0.2	15.8	32.0	49	59
52.82	5.9	4.9				5.6	2.7	0.6	0.2	9.1	28.6	32	60
82+	5.3	4.5				3.6	2.2	0.1	0.2	6.1	28.6	21	59
0-40	6,2	5.3	2.52	0.36	7	11.2	1.8	2.0	0.1	15.1	38.0	40	56
40-70	6.5	5.2				8.8	1.6	1.2	0.1	11.7	32.0	37	58
70-160	6.5	5.2				8.8	2.1	0.6	0.1	11.6	25.8	45	57

depth in cm	EC mmhos/ 1:5 cm	KSP	$CaCO_3$ %	available nutrients m.e.% Na (mehlich)	K	Ca	Mg	Mn	Hp
0-15	0.14	0.82		0.18	2.90	10.0	2.9	0.90	-
15-52	0.10	0.62		0.14	0.84	2.8	2.2	0.92	-
52-82	0.05	0.69		0.04	0.41	0.4	2.3	0.92	0.5
82+	0.04	0.69		0.06	0.10	0.2	1.9	0.64	1.0
0-40	0.06	0.26		0.04	1.52	5.6	2.4	1.10	
40-70	0.05	0.31		tr	0.92	1.8	1.7	1.30	
70-160	0.09	0.38		0.02	0.44	1.2	2.4	1.26	

Remarks: Soil 148/1-2: the soil reaction is medium to slightly acid
Ca is deficient in the subsoil

Soil 148/1-3: the soil reaction is neutral; Ca is deficient throughout

Appendix B. Climatic data[1] for potato research station - Tigoni

Month	$T^{o}C$ max	$T^{o}C$ min	$T^{o}C$ mean	P	Eo(mm)	Et(mm)
January	22.4	11.1	16.8	41	188	125
February	23.2	11.4	17.3	58	174	116
March	23.1	12.3	17.7	96	179	119
April	21.4	12.5	17.0	290	125	83
May	19.8	11.6	15.7	234	101	67
June	19.0	9.7	14.4	67	90	60
July	18.2	8.7	13.5	29	84	56
August	18.8	9.0	13.9	34	95	63
September	21.0	9.5	15.3	39	142	95
October	22.0	11.1	16.6	54	171	114
November	20.6	11.8	16.2	124	135	90
December	21.2	11.3	16.3	90	163	109
Y	20.9	10.8	15.9	1155	1647	1097

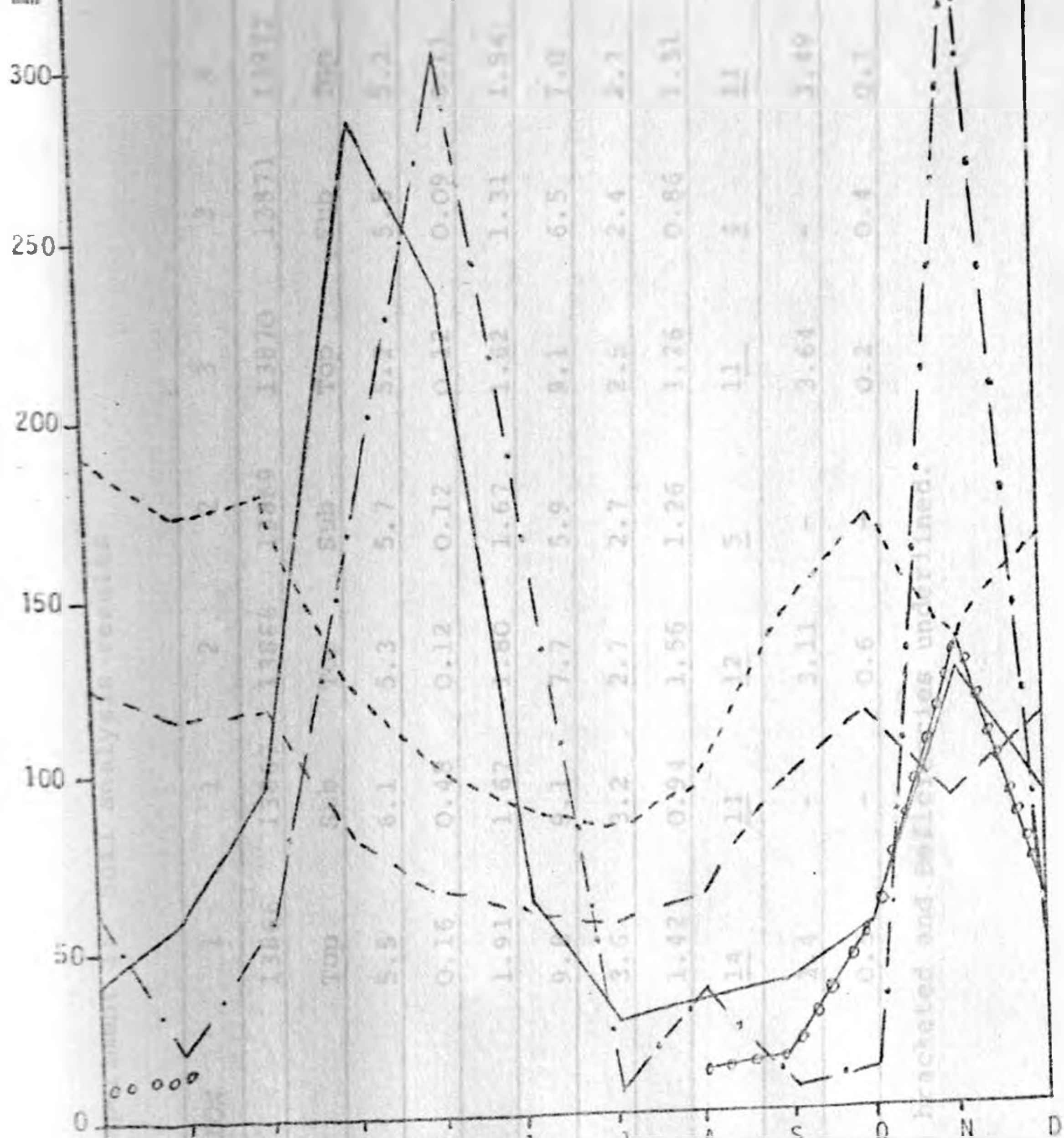
[1] Climatic data: Rainfall data from Tigoni Police Station for a period of 21 years (EAMD, 1960). Temperature and evaporation data derived from data recorded at Muguga over the period 1953-1970 and 1963-1970 respectively (EAMD, 1975). Open pan A evaporation is concerned.

Appendix C. The total monthly rainfall, mean monthly relative humidity (R.H.) and temperature data - National Potato Research Station - August 1979 - February 1981[1].

Month	1979			1980			1981		
	Rainfall (mm)	R.H. (%)	Temp. (°C)	Rainfall (mm)	R.H. (%)	Temp. (°C)	Rainfall (mm)	R.H. (%)	Temp (°C)
Jan.				66.5	72.89	17.75	11.0	68.34	22.94
Feb.				19.7	70.31	17.83	11.30	80.0	19.17
March				57.3	63.88	16.54			
April				163.5	72.87	17.95			
May				304.8	84.57	18.64			
June				15.19	80.69	14.82			
July				5.80	80.85	14.39			
August	14.5	84.21	14.32	33.94	84.37	15.23			
Sept.	15.3	78.57	16.25	6.80	72.83	16.49			
Oct.	52.5	74.35	17.72	11.40	65.81	17.77			
Nov.	138.3	72.10	17.79	333.10	79.20	16.92			
Dec.	61.8	74.87	17.42	51.20	84.85	19.49			

[1] Experimental duration.

Appendix D. The total monthly rainfall during the experimental period superimposed over the climatic graph - Tigoni.



P mean monthly rainfall in mm

Eo mean monthly potential evaporation

Et mean monthly evapotranspiration in mm

Total monthly rainfall 1980 in mm

Total monthly rainfall Aug. - Dec.1979 in mm

Total monthly rainfall Jan-Feb 1981 in mm.

Appendix E. Experiment I: Soil analysis results

FIELD DESIGNATION	1	1	2	2	3	3	4	4-5	5
LAB. NO. /79	13866	13867	13868	13869	13870	13871	13872	13873	13874
Depth	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top
pH	5.5	6.1	5.3	5.7	5.2	5.5	5.2	5.6	5.3
Na m.e.%	0.16	0.48	0.12	0.12	0.12	0.09	0.11	0.06	0.12
K m.e.%	1.91	1.67	1.80	1.67	1.62	1.31	1.54	1.38	1.88
Ca m.e.%	9.8	9.1	7.7	5.9	9.1	6.5	7.0	5.1	8.3
mg m.e.%	3.6	3.2	2.7	2.7	2.5	2.4	2.7	2.2	2.5
Mn m.e.%	1.42	0.94	1.56	1.26	1.26	0.86	1.31	0.84	1.20
P. p.p.m.	14	11	12	5	11	4	11	3	5
C%	3.4	-	3.11	-	3.64	-	3.49	-	0.52
Hp m.e.%	0.5	-	0.6	-	0.2	0.4	0.7	.	0.7

NB/ Toxicities bracketed and Deficiencies underlined.

Appendix F. Experiment II: Soil analysis results

FIELD DESIGNATION	1	2	3	4	5	6	7	8
Lab. No./80	2648	2649	2650	2651	2652	2653	2654	2655
DEPTH	TOP	TOP	TOP	TOP	TOP	TOP	TOP	TOP
pH	5.2	5.2	5.2	5.6	5.5	5.1	5.2	5.1
Na m.e.%	0.14	0.18	0.18	0.21	0.18	0.28	0.18	0.14
K m.e.%	1.42	1.18	1.22	1.48	1.26	1.03	1.26	1.07
Ca m.e. %	6.0	6.3	4.7	8.9	7.8	5.5	7.8	5.5
Mg m.e.%	2.7	2.5	2.1	3.0	2.5	2.0	2.5	2.3
Mn m.e.%	(2.34)	1.18	(2.24)	(2.00)	(2.20)	(2.50)	1.96	(2.06)
P. p.p.m.	20	18	16	21	21	20	24	18
C %	3.54	3.23	2.92	2.92	3.20	3.09	3.40	3.29
H.P m.e.%	0.2	0.1	0.2	-	0.4	0.2	0.4	0.3

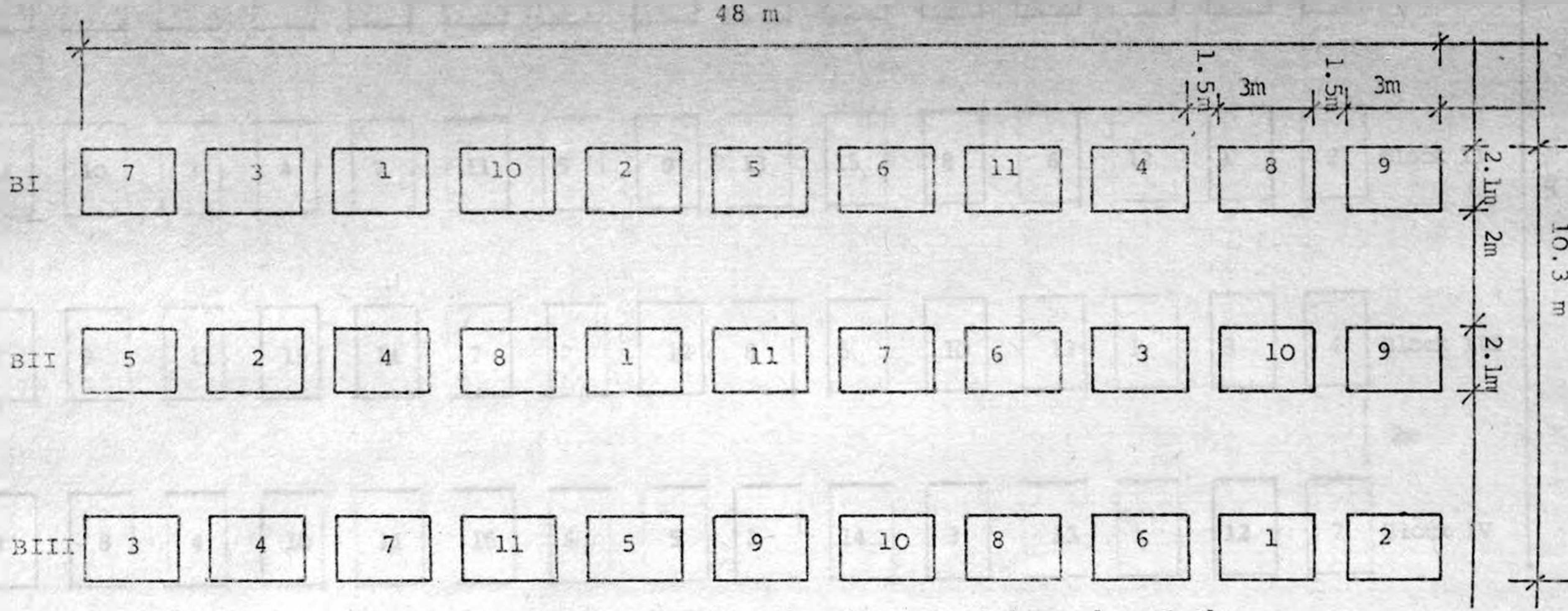
NB: Toxicities Blacketed and Deficiencies underlined

Appendix G. Experiment III. Soil snalysis results

FIELD DESIGNATION	1	2	3	4	5	6	7	8
Lab. No. /80	10660	10661	10662	10663	10664	10665	10666	10667
Depth								
pH	5.6	5.7	5.3	5.5	5.6	5.3	5.7	5.8
Na m.e.%	0.24	0.20	0.20	0.20	0.24	0.15	0.23	0.23
K m.e.%	1.60	1.64	1.14	1.27	2.10	0.98	1.32	1.50
Ca m.e.%	9.2	8.0	5.0	10.0	9.2	7.4	11.6	11.6
Mg m.e.%	4.0	3.2	3.0	3.6	3.8	2.5	3.2	3.0
Mn m.e.%	1.50	1.69	1.57	1.46	1.35	1.68	1.68	1.30
P. p.p.m.	22	22	16	22	20	31	31	26
C %	3.38	2.77	2.90	2.38	2.70	2.67	2.61	2.70
Hp m.e.%	-	-	0.2	0.2	-	0.1	-	-

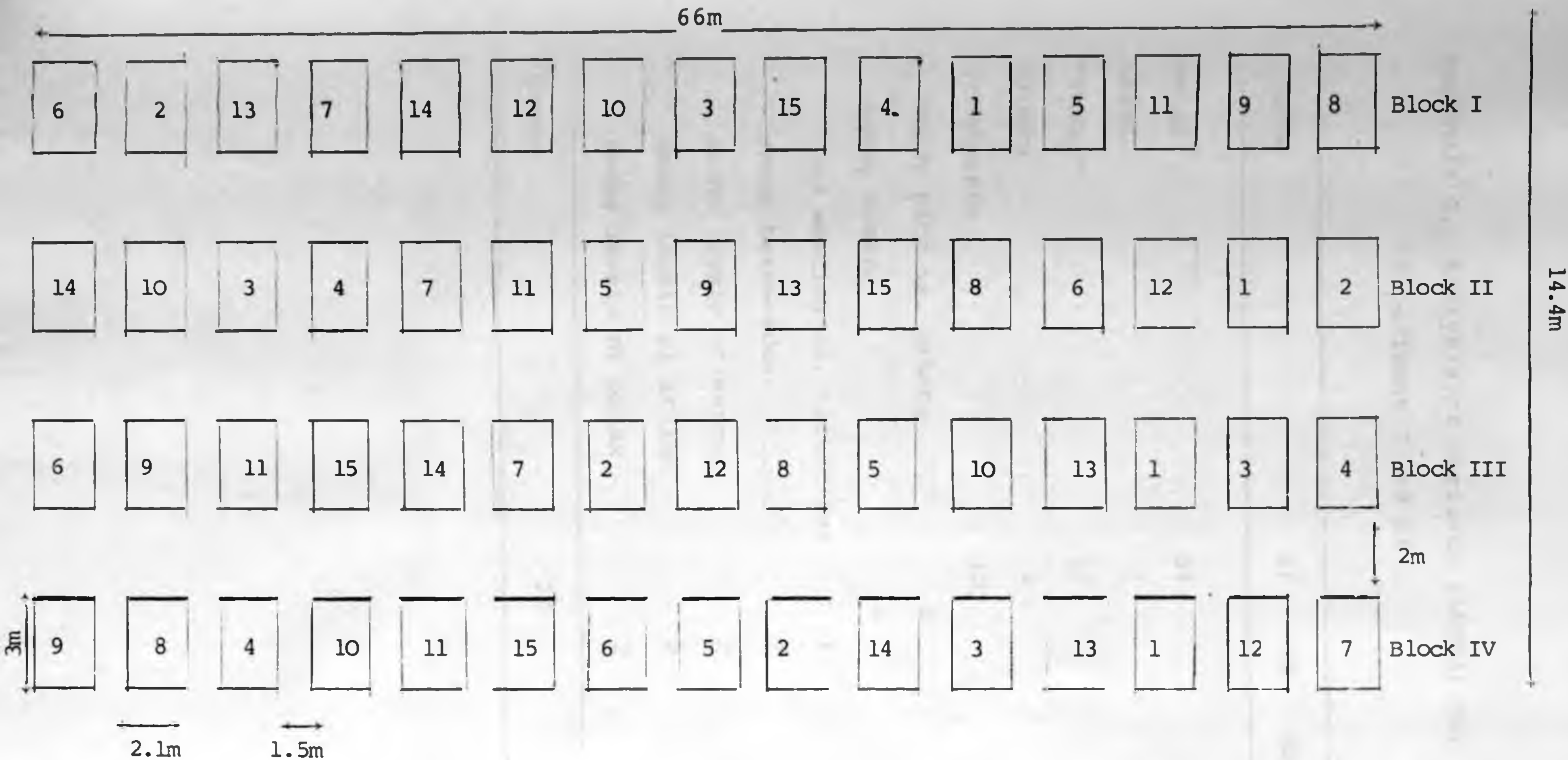
NB : (Toxicities Blacketed and Deficiences underlined.

Appendix 8. Field Plan for experiment I and II



NB. Numbers are as given in the treatments, in the materials and methods

Appendix I. Field plan for Experiment III



NB: 1-9: as given in the treatments in the materials and methods
10-12: Hand weeding plots
13-15: Non-weeded plots

Appendix J. Analysis of variance (ANOVA) for Experiment I and II

Source	df	SS	MS	F
Total	33			
Level	1			
"Total"	32			
Blocks	2			
Treatments	10			
Weedy plot vs. others	1			
Among others	9			
hand weeding vs. herbicides	1			
among herbicides	2			
among levels of sencor	2			
among levels of afalon	2			
among levels of galex	2			
Error	20			

Appendix K. Analysis of variance (ANOVA) for Experiment III

Source	df			SS	MS	F
Total	60					
Level	1					
"Total"	59					
Blocks	3					
Treatments	10					
weedy plot vs. others		1				
among others		9				
hand weeding vs. herbicides			1			
among herbicides			2			
among levels of sencor			2			
among levels of afalon			2			
among levels of galex			2			
Error	46					

Appendix L. The common weed flora* at the National Potato Research Station, Tigoni.

Spilanthes mauritiana (Pers.) DC.	Compositae.
Crassocephalum vitellinum (Benth.) S. Moore	"
Conyza floribunda H.B.K.	"
Ageratum conyzoides L.	"
Dichrocephala interifolia O. Kuntze	"
Sonchus oleraceus L.	"
Senecio discifolius Oliv.	"
Bidens pilosa L.	"
Galinsoga parviflora Cav.	"
Tagetes minuta L.	"
Hypochoeris glabia L.	"
Richardia braziliensis Gomez.	Rubiaceae
Galium spurium L. Var. Africanum Verdc.	"
Achyranthes aspera L.	Amaranthaceae
Amaranthus graecizans L.	"
Amaranthus hybridus L.	"
Amaranthus spinosus L.	"
Malva verticillata L.	Malvaceae
Erucastrum arabicum Fisch & Mey.	Cruciferae
Coronopus didymus (L.) SM.	"
Raphanus raphanistrum L.	"
Chenopodium sp.	Chenopodiaceae
Orobanche minor Smith	Orobanchaceae

Appendix L (Contd.....)

Datura stramonium L.	Solanaceae
Nicandra physalodes Scop.	"
Solanum incanum L.	"
Solanum nigrum L. form "A" of Polhill in EA.	"
Pennisetum clandestinum Chiov.	Gramineae
Phalaris minor Retz.	"
Lolium multiflorum Lam.	"
Cynodon dactylon	"
Commelina benghalensis L.	Commelinaceae
Oxalis latifolia H.B.K	Oxalidaceae
Oxalis corniculata	"
Cyperus rotundus L.	Cyperaceae
Spergula arvensis L.	Caryyophyllaceae
Silene gallica L.	"
Corrigiola litoralis L.	"
Geranium arabicum Forsk.	Geraniaceae
Rumex acetosella L.	Polygonaceae
Polygonum convolvulus L.	"

*The flora is also found in most of the high potential areas of Kenya where potatoes do well.

Source: Collection by Njoroge, J.M. of the common weed flora found at the National Potato Research Station - Tigoni.

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