A COMPARISON OF TWO TILLAGE SYSTEMS IN BEAN (*Phaseolus vulgaris* L.) PRODUCTION

BY

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DECLARATION

I declare that this thesis is my original work and has not been submitted for a degree in any other University.

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

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ABSTRACT

Two trials on bean (*Phaseolus vulgaris* L.) production under minimum and conventional tillage systems were conducted during the short and long rain seasons of 1984 and 1985 at the Faculty of Agriculture farm Kabete of the University of Nairobi.

Glyphosate was used to kill the existing vegetation in minimum tillage plots. Conventional tillage plots were prepared in the normal way by cultivating once and then harrowing to produce a clean seedbed. Alachlor, metolachlor and metribuzin were used as preemergence herbicides to control annual weeds. The effect of these treatments on weeds and the crop were evaluated on a split plot design replicated four times with tillage system alloted to main plots and herbicide treatments alloted to subplots.

Results indicated that uniform bean germination was established in both tillage systems. The preemergence herbicides controlled weeds better in conventional tillage system than in minimum tillage system, however, more herbicidal damage to beans was at the same time observed in conventional tillage system. Alachlor and metolachlor caused

temporary damage to beans while metribuzin caused complete kill of the bean plants. Even though injurious to beans, metribuzin effected a better weed control in both tillage systems during the initial and critical weed stages than alachlor and metolachlor. Alachlor had an edge over metolachlor in controlling the weeds. Hand weeding (farmer's practice) both in conventional and minimum tillage systems controlled the weeds better than all the preemergence herbicides used and resulted into the highest bean yield followed by alachlor and metolachlor at higher rates of application. Metribuzin at all the rates used reduced bean yield below the unweeded control mainly because of its damage on the bean plants. In general bean yield was lower in minimum tillage system, however, the profit margin between the two tillage systems was not significantly different.

INTRODUCTION

Beans (*Phaseolus vulgaris* L.) is an important leguminous crop grown in East Africa. In Kenya, it is extensively grown by small scale farmers who normally interplant it with maize (*Zea mays* L.). Mukunya (1984) estimated seasonal production of 300,000 ha to 500,000 ha grown mainly in Eastern, Central, Western and Nyanza provinces of Kenya. The common cultivars are Canadian wonder, Rose coco, Red haricot and Mwezi moja.

In dry form, beans yield almost as many calories per unit weight as cereals. The protein content is about 22% which is two to three times the protein value of cereal grains and slightly higher than that of meat, fish and eggs but lacking in the essential amino acids methionine, cystine and tryptophane (Doughty *et al*., 1966; Purseglove, 1968; Mtenga *et al*., 1973). Young pods, leaves, ripe seeds and to a lesser extent green shelled seeds are eaten (Westphal, 1974).

The yield of beans is generally low in the advancing countries ranging from 560 kg/ha to 1120 kg/ha as compared to the advanced countries such as the United States of America (USA) with an average yield of 1350 kg/ha (Purseglove, 1968). In Kenya yields range from 300 kg/ha to 500 kg/ha in mixed stands with maize, to about 800 kg/ha in pure stands (Van Eijnatten, 1975). Low yield of beans in the advancing countries is attributed mainly to poor standards of husbandry practices including weed control (Acland, 1975).

Hoe weeding is the most commonly used method of weed control, however, it is not only tedious but also uneconomical when labour is not abundant. The availability of farm labour at the critical times needed for weeding crops is often limiting. In Kenya farm labour is becoming increasingly difficult to get and is expensive (Laycock, 1974; Ngugi et al., 1978). Under these circumstances use of herbicides would become an alternative method of weed control if rightly used. Unfortunately it has been reported that the use of herbicides is expensive for the small holders (Druijft et al, 1970). Further, the use of herbicides would enable production of crops under reduced tillage system which is known to cut down crop establishment costs amongst other merits. Soybeans (*Glycine max* L), a legume like beans has been successfully produced under reduced tillage system elsewhere (Staniforth et al, 1975).

The objective of this study was to investigate the growth and yield of beans under minimum tillage system as compared to the conventional system taking into consideration the economics of production under both tillage systems.

LITERATURE REVIEW

Effect of weeds on beans:

Weeds compete with crops for light, water and soil minerals. These factors are needed by the crop in definite proportions, thus if any one of them is inadequate, the other two cannot be effectively used even when present in abundance (Crafts and Robbins, 1962). The magnitude of competition depends on the weed density, weed and crop species and the stage of growth of both the crop and the weeds. Competition generally occurs quite early in the life cycle of annual crops such as beans and the damage done is irreversible (Vega, 1982).

Weeds that grow taller than the crop and those with large coarse leaves if not controlled early enough will reduce crop yields through shading effect. Staniforth *et al*, (1956) working with soybeans found that weeds that topped and hence shaded the crop reduced the yield by twice as much as those which did not shade the crop. They further found out that competition for water and mineral nutrients was principally from lower growing weeds.

Several workers have reported on the magnitude with which weeds reduce crop yieds. These include Ashby et al, (1956), Hampson, (1956), Kasasian et al, (1969), Young et al, (1978), Parker et al, (1975), De groot, (1979) and Gooding, (1983). Hampson (1956) stated that losses caused by weeds far exceed the losses caused by any other agricultural pests including insects, diseases and rodents and may in actual fact exceed the combined losses caused by all other agricultural pests together. Ashby et al,(1956) stated that losses due to weeds are even higher in tropical countries and are estimated to be two to three times greater than in the temperate zones.

Weeds as well as crops respond favourably to improved growing conditions and when other husbandry practices such as fertilizer application are introduced the weed problem often is intensified (Young et al, 1978). De groot (1979) working in Kenya reported that where big plants like Tagetes minuta L., Leonotis mollisima Guercke, Nicandra physalodes (L.) Gaertn and Datura stramonium L. are present, if no weeding is done, can reduce bean yield to zero. Weeds reduce bean yield by affecting yield components. One such yield component is the number of pods per plant and has the largest effect on bean yield according to Westerman et al,(1977). Aguilar et al, (1977) working with beans in Mexico found the number of pods per plant to be very sensitive to interplant competition between five and eleven weeks after planting.

Subsistence farmers spend more time and energy on weed control than any other aspect of crop production. Akobundu (1980), stated that 50% or more of the total labour required for producing a crop goes into the control of weeds. Hoe weeding is the most commonly used method for weed control by subsistence farmers. It is a slow process and usually starts when weeds have begun to depress crop yields (Moody, 1973; Moody et al, 1974).

Yield of beans like any other crop would be greatly increased when grown without any weed competition. If this cannot be achieved, weed control in the early stages of growth is essential, as the most serious losses from weeds generally occur during this period which is the maximum duration that weeds can be tolerated without affecting crop yields. This period is often referred to as the critical weed competition period. Kasasian et al, (1969) and Akobundu (1983) stated that the critical weed competition period for beans occurs during the first four weeks after germination. The availability of farm labour at this time may be limiting and herbicides can often give efficient weed control at comparable costs. The use of herbicides thus can overcome the absolute labour constraints that may exist during peak weed control periods and cropped land can be expanded if land is not limiting (Young et al, 1976). Krochmal (1966) stated that the transition from hoe to herbicides generally applied by back-pack sprayer can reduce labour requirements twenty fold in short cycle crops and upto thirty five fold in long cycle crops.

The use of herbicides is a rapid method of weed control. It is said that a man using a knapsack sprayer can cover at least ten times the area that a man can hoe-weed (Moody et al, 1974). Herbicide application is however, a relatively complicated and demanding operation which may injure the crop if not properly applied. Kasasian (1971, 1972) pointed out the risks associated with herbicides utilization as crop injury or damage from improper applications in the short run, to development of resistant weed species over the long run. Inadequate protection and carelessness in handling herbicides is another risk especially in developing countries (Taylor, 1970; Yates, 1971).

Alachlor, metolachlor and metribuzin for weed control in beans:

Alachlor in general is used for control of most annual grasses and certain broadleaf weeds and has activity on nutgrass (*Cyperus spp*). Tolerant crops are maize, soybean, cabbage, beans, potatoes, peanuts, cotton, sunflower, tobacco and sugarcane (Anonymous, 1983). Bean tolerance to alachlor is marginal as compared to soybeans. Preplant incorporation as compared to surface preemergence treatment improves crop safety. Wetala (1976) working in Tanzania reported a generally good weed control and only a temporary control of perennial weeds like *Cyperus spp*. and *Oxalis latifolia* L. when he used alachlor at 2.75 kg/ha on soybeans. Kahurananga *et al*, (1974) also working in Tanzania reported good weed control in beans using alachlor at 2.0 and 4.0 kg/ha. Alachlor applied preemergence at 1.7 kg/ha gave at least six weeks of satisfactory weed control without perceptible bean damage and alachlor at 3.3 kg/ha did not improve weed control compared with the lower rate and resulted into slight crop damage. This was reported by Hammerton, (1971) while working in West Indies. The same author observed that alachlor applied at 2.2 kg/ha to beans gave a good weed control and crop score but the yield was significantly less than that of clean weeded control (Hammerton, 1972) Michieka (1981) working in Kenya, observed a temporary damage to beans when he used alachlor at 2.5 kg/ha.

Metolachlor is a selective herbicide for control of annual grasses, nutgrass and certain broadleaf weeds in maize, peanuts and soybeans. A wider range of weed control is effected when metolachlor is combined with a herbicide which affords control of broadleaf weeds not controlled by metolachlor, for example, tank mixture of metolachlor and metribuzin is effective on weed control in soybeans (Anonymous, 1983). Jordan et al, (1980) working with peas, observed a better performance of alachlor over metolachlor in controlling both broadleaf weeds and grasses using similar rates of 2.2 and 4.5 kg/ha applied preemergence to peas. Similar findings were reported by Wanjala et al, (1981).

He found that alachlor at 1.5 kg/ha performed better than metolachlor at the same rate in controlling weeds in beans.

Metribuzin is effective against annual grasses and numerous broadleaf weeds. Applications may be made pre-plant, pre-emergence or post-emergence (Anonymous, 1983). Littlejohns, et al, (1977) using three rates of metribuzin 0.56, 0.84 and 1.12 kg ai/ha on soybeans in Canada, reported slight injury on foliage and stand reduction at 0.56 kg ai/ha. Plant height and lowest pod height were also reduced as metribuzin rate was increased. He further found that metribuzin at 1.12 kg/ha reduced yield of soybeans. Hammerton (1974) working in West Indies found metribuzin to be unsafe for beans when applied pre-emergence at 0.6 and 1.2 kg/ha though weed control was very good. Mburu et al, (1983) working in Kenya, reported complete kill of beans by metribuzin at 0.35, 0.875 and 1.40 kg/ha.

No sign of recovery was observed in plants damaged by metribuzin. In view of the above literature review, alachlor has merit as a pre-emergence herbicide for weed control in beans followed by metolachlor.

Bean production under minimum tillage:

Minimum tillage or reduced tillage is a tillage system which creates suitable soil conditions for crop seed germination and growth by using a minimum number of operations. An example would be to prepare a seedbed in planting rows only, leaving the area between rows undisturbed. Weed control is facilitated by spraying contact herbicides and soil residual herbicides on the land immediately following planting or before planting to eliminate existing weeds and to prevent further germination of the weeds and/or slashing or a minimum amount of hoeing. This is in contrast with zero tillage where the crop is planted directly into an undisturbed or unprepared seedbed. All the previous residue is left on the surface. Weeds are controlled by use of herbicides, burning or slashing.

A lot of work on zero tillage and/or minimum tillage has been done in many countries. Maize and soybeans are the most widely grown crops under these tillage systems with a greater part of the area currently under cultivation being in the United States of America (Lessiter, 1979) cited by

(Hayward et al, 1980). Several authors have reported on soybean production under zero tillage or minimum tillage systems. These include Royster et al, (1975), Stiniforth et al,(1975), Walker et al, (1975), Harcastle (1976), and Kapusta, (1979). Molberg et al, (1967), Sanford et al, (1973) and Kapusta (1979) reported low level of weed control in reduced tillage soybean production. The latter attributed the poor weed control to incomplete contact kill of emerged weeds due to large sizes of the weeds during the time of herbicide application and because the plots were not cultivated. Erbach et al, (1975) reported that excess plant residue may intercept preemergence herbicides and thus reduce herbicide efficacy. Deat (1982) stated that the use of preemergence herbicides requires a clean and well prepared seedbed. Sanford et al, (1973) found significant yield differences between soybean under reduced tillage and conventional tillage. He attributed this to poor weed control in the former system. Molberg et al, (1967, 1968) and Anderson (1971) found water conservation to be equal in both conventional tillage and reduced tillage systems whereas Hayward et al, (1980) found soybean yield generally being equal in both tillage systems mainly through moisture conservation. In Kenya, most of the work has concentrated mainly in minimum tillage production of maize both in small scale and large scale sectors (Macqueen, 1976; Brown, 1979; Wood et al, 1981; Keighley, 1985; Hutchinson, 1981; Njeru, 1981; and Michieka, 1985).

Reduced tillage system decreases time and number of operations required to establish a seedbed. It also reduces soil erosion and moisture loss from the soil and may enable quick and safe use of steep land scapes as pointed by Wood et al (1981). One major problem associated with reduced tillage as cited by Njeru (1981), is the shifts in weed flora in favour of perennial weeds. However, this may not become a serious problem if proper crop husbandry practices are undertaken.

Beans are not drought tolerant. Ideally they need moist soil throughout the growing period. As has been stated before, bean production is second to none in Kenya in terms of grain legumes. However, in Eastern province of Kenya, moisture is often limiting and land preparation activities need to be undertaken early enough in order to utilize all the moisture available. Muchiri et al, (1981) describes this area as having small to medium farm sizes where use of hand tools for land preparation is common and labour availability is medium. The authors further state that the use of oxen for cultivation is uncommon. Land in this region becomes very hard during drought and oxen are often weak at the start of the season due to inadequate feed. Use of hand tools becomes a slow process under such conditions. Reduced tillage would become handy in that it would reduce much dependence on weather and the little rainfall available would be conserved to carry the crop throughout the season.

In Kisii District in South West Kenya, most of the landscape is undulating and steep necessitating the use of hand tools in preference to oxen plough (Muchiri et al, 1981, Michieka, 1985). Even though labour and rainfall are adequate in this area the use of hand tools slows down land preparation activities. Small scale farmers in this region would expand land under cultivation if a quicker means of primary tillage was not limiting. It is with these ideas in mind that necessitated research on minimum tillage in beans. Adequate information is already known in maize production under minimum tillage and hence facts can be borrowed from this crop.

MATERIALS AND METHODS

Two field trials were conducted during the short and long rains of 1984 and 1985 respectively at Kabete farm, University of Nairobi (Lat 1^{o} 15' S, and Long 36^{o} 44' E). The elevation is 1941 metres above mean sea level and the land is generally flat with a gentle slope. The climate is a tropical rainy type with pronounced wet and dry seasons. The rainfall pattern is bimodal with the short rains lasting from October to December and long rains from March to June. The mean annual rainfall amount is 1000 mm and mean monthly maximum temperatures are $33^{o}C$ and $12^{o}C$ respectively. The soil type is a dark reddish brown clay with a pH of 5.7 and 2.5% organic matter.

The conventionally tilled plots were prepared by performing primary and secondary tillage operations resulting into a clean well prepared seedbed. The minimum tillage plots were prepared by digging furrows in the planting rows only, leaving the area between rows undisturbed. All minimum tillage experiments were treated with glyphosate product at 3 litres per hectare with a CP3 knapsack sprayer,adjusted to deliver

300 litres of water per hectare to kill the existing vegetation. Spraying was done soon after bean planting. All the experimental areas were treated with alachlor, metolachlor and metribuzin preemergence for annual weed control using a Gloria 172 sprayer adjusted to deliver 300 litres of water per hectare. Table 1 shows a list of treatments used.

The tests were conducted in a randomized block, split-plot design with four replications. Methods of preparing the land i.e. conventional and minimum tillage systems were used as main plot treatments and control of annual weeds as the sub-plots. Individual sub-plots were 8 rows 5 metres long with plants spaced 15 cm in the row. Each main plot measured 30 metres by 6 metres.

Field operations per treatment were recorded in minutes and converted to man-days per hectare. Each man-day was taken as work done by an adult person in 8 hours. Time spent on refilling the sprayer tank and mixing herbicides was taken as 20% of the time used in actual spraying. Cost of land preparation, herbicides and labour required for spraying, and labour for hoe weeding (farmers' practice) were taken as variable costs. All other

Table 1. Weed control treatments for 1984 and 1985 in conventional and minimum tillage plots

	Treatments	Rates (Kg ai/ha)
1.	Alachlor	1.5
2.	Alachlor	2.0
3.	Alachlor	2.5
4.	Metolachlor	2.0
5.	Metolachlor	2.5
6.	Metolachlor	3.0
7.	Metribuzin	0.3
8.	Metribuzin	0.5
9.	Metribuzin	0.7
10.	One weeding 3 W.A.P.*	
11.	Two weedings 3 and 5 W.A.P.**	
12.	No weeding	

* - Weeks after planting

** - Weeding in minimum tillage plots was done intrarows.

costs were regarded as fixed costs since they applied to all the treatments. An economic analysis on both tillage systems was then performed.

Data collected included bean germination, bean vigour, weed control, bean height, number of pods per plant, 100 bean seed weight, and bean yield. Percent bean germination and bean vigour were based on actual counts of the crop in each treatment over the theoritical population per treatment, whereas the percent weed control was based on quadrat counts from each treatment over quadrat counts from the unweeded check plots. Bean yield from each treatment was obtained by harvesting the four centre rows and discarding 0.5 metres on both sides of the treatments leaving 4.8 square metres as the harvestable area. Analysis of variance was conducted on all data according to Little et al, (1977). Data on bean germination, bean vigour and weed control percentages were transformed using angular transformation tables for accurate statistical analysis.

RESULTS

Effect of tillage system on beans and weeds:

Dominant weed species during the study period included *Tagetes minuta* L., *Nicandra physalodes* (L) Gaertn, Datura stramonium L., *Emex australis* Steinh, *Asystasia schimperi* T. Anders, *Lactuca* capensis Thumb, *Erucastrum arabicum* Fisch and Mey, *Brassica napus* L., *Bidens pilosa* L. and *Conyza bonariensis* (L.) Cronq.

Table 2: shows summaries of percent bean germination, percent bean injury, percent weed control, bean height, number of pods per plant, 100 seed weight and bean yield under conventional and minimum tillage systems in 1984.

It is obvious from the table that tillage system did not have any effect on bean germination. Herbicides caused significant more injury to beans in conventional tillage system than in minimum tillage system. A better weed control was achieved in conventional tillage system than in minimum tillage system. Plant height at maturity was observed to be taller in minimum tillage system than in conventional tillage system. There were

Table 2. Effect of tillage system on beans and weeds, short rains 1984.

Tillage system	Percent germination	Percent bean injury	Percent weed control	Bean height(cm)	Number of pods per plant	100.seed weight(gm)	bean yield (Kg/ha).
Conventional	79.8	25.5	69.5	31.7	6.3	39.3	963.2
Minimum	79.3	21.0	44.3	36.5	4.9	38.6	813.0
F.test	NS	*	*	*	*	*	*
SEm	±0.4	±0.28	±0.76	±0.75	±0.12	±0.11	±1.17
Cv%	3.49	7.14	9.29	15.31	14.86	1.87	0.91
LSD (0.05)	1.80	1.24	3.59	3.39	0.54	0.47	5.27

NS = Not significant

* - significant at 5% level.

significant differences in number of pods per plant, seed weight and bean yield caused by the different tillage systems.

Similar trends between conventional and minimum tillage systems were observed in the 1985 long rain season (Table 3). In general a better weed control, more number of pods per plant, heavier seeds and higher bean yield were observed in the long rains of 1985. There were no significant differences in bean injury, plant height and seed weight in the 1985 season between the two tillage systems.

Effect of herbicides on beans and weeds:

As can be observed in table 4, all the herbicides used did not affect bean seed germination. Alachlor and metolachlor at all the rates used exhibited temporary damage to beans than alachlor and metolachlor. Metribuzin at all the rates used caused bean injury of over 50% and this was reflected in the final bean yield.

Metribuzin despite being injurious to beans effected a better initial weed control than alachlor and metolachlor. Metribuzin at 0.7kg

Table 3. Effect of tillage system on beans and weeds, long rains 1985.

Tillage system	Percent germination	Percent bean injury	Percent weed control	Bean height(cm)	Number of pods per plant	100.seed weight (gm)	Bean yield (Kg/ha).
Conventional	74.8	22.3	74.2	43.2	8.3	51.7	1480.3
Minimum	73.8	22.3	48.7	46.2	6.3	49.4	1251.5
F.test	NS	NS	*	NS	*	NS	*
S^{Em}	±0.51	±0.65	±1.28	±0.86	±0.11	±0.80	±14.04
CV%	4,78	17.51	14.46	12.83	10.60	10.96	7.12
$LSD_{(0.05)}$	2,31	2.93	6.03	3.85	0.50	3.60	63.19

NS = Not significant.

* - significant at 5% level.

Table 4. Effect of herbicides on beans and weeds, short rains 1984.

Herbicides (Kg ai/ha)	Percent germination	Percent bean injury	Percent weed control	Bean height (cm)	Number of pods per plant	100 seed weight (gm)	Bean yield (Kg/ha)
Alachlor 1.5	78.6	6.6	53.2	35.9	4.5	38.3	1025.8
Alachlor 2.0	79.3	8.0	56.0	34.6	6.0	38.2	1072.1
Alachlor 2.5	81.5	9.9	60.5	33.5	6.5	38.7	1171.6
Metolachlor 2.0	80.0	6.6	46.6	37.0	5.0	39.0	1000.0
Metolachlor 2.5	79.4	8.2	52.5	35.1	5.5	38.5	1064.6
Metolachlor 3.0	79.0	9.6	55.2	34.3	6.5	38.3	1132.4
Metribuzin 0.3	78.7	44.1	55.3	32.8	5.5	39.5	528.9
Metribuzin 0.5	81.0	53.2	60.9	30.0	6.0	38.0	281.4
Metribuzin 0.7	78.2	62.7	66.7	29.4	6.0	39.4	207.8
One weeding	80.3	-	51.1	35.1	6.0	39.2	1257.1
Two weedings	73.3	-	68.2	33.3	7.0	39.2	1320.8
No weeding	79.2	-	-	38.0	2.5	40.8	587.9
F. test	NS	*	*	*	*	*	*
SEm	±0.84	±1.28	±2.74	±1.07	±0.33	±0.36	±17.77
CV%	2.99	15.63	13.64	8.87	16.59	2.60	5.66
$LSD_{(0.05)}$	2.37	3.64	7.76	3.02	0.93	1.01	71.07

NS = Not significant. * - significant at 5% level.

ai/ha was comparable to two hand weedings at three and five weeks after planting. The two treatments gave 84% and 86% weed control respectively in the 1984 season. Alachlor had an edge over metolachlor in controlling the weeds. The heights of beans tended to have been related to the herbicide dosage rates. Higher rates of herbicides tended to reduce the heights of the crop. Similarly treatments which effected better weed control tended to have shorter and stout plants.

Weeds significantly suppressed the number of pods per plant as was exhibited by the unweeded control treatment. This was reflected in the final bean yield in which plots with better weed control resulted into significantly higher bean yields than plots in which weeds were poorly controlled.

Similar trends on the effect of herbicides used on beans and weeds were observed in the 1985 season Table (5). A better weed control was however, observed during this season than during the 1984 season. Bean crops were also taller during this season than in the 1984 season. Similarly an increase in the number of pods per plant and heavier seeds observed in 1985 season resulted into higher bean yields observed during the season.

Table 5. Effect of herbicides on beans and weeds, long rains 1985.

Herbicides (Kg ai/ha)	percent germination	percent bean injury	percent weed control	Bean height(cm)	Number of pods per plant	100.seed weight(gm)	Bean yield (Kg/ha).
Alachlor 1.5	74.4	8.1	56.4	45.6	7.3	53.6	1568.5
Alachlor 2.0	74.8	9.5	60.1	45.4	8.0	51.6	1660.9
Alachlor 2.5	74.4	13.0	67.6	41.8	8.5	51.1	1809.5
Metolachlor 2.0	73.7	8.6	51.9	51.5	6.5	51.1	1542.1
Metolachlor 2.5	74.7	9.4	55.1	48.6	7.3	50.0	1616.9
Metolachlor 3.0	75.2	10.4	60.6	45.9	8.0	50.5	1765.0
Metribuzin 0.3	73.6	31.9	65.3	42.6	7.0	50.4	809.9
Metribuzin 0.5	73.9	49.4	66.7	36.6	7.5	49.4	428.1
Metribuzin 0.7	73.0	55.6	68.2	33.6	7.5	49.5	322.5
One weeding	74.6	-	54.9	46.4	7.5	49.4	1951.4
Two weedings	74.7	-	69.3	43.6	8.5	49.1	2015.8
No weeding	73.9	-	-	54.9	4.5	51.8	900.0
F. test	NS	*	*	*	*	NS	*
SEm	±0.77	±1.29	±2.23	±0.10	±0.37	±1.01	±21.47
CV%	2,92	16.33	10.24	6.10	14,22	5.63	4.45
$LSD_{(0.05)}$	2.17	3.66	6.30	2.82	1.04	2.85	60.72

Effect of herbicides on beans and weeds under conventional and minimum tillage systems:

Table 6 summarises the effect of alachlor, metolachlor and metribuzin on weeds and beans under conventional and minimum tillage systems. As has been already observed these herbicides did not have any significant effect on bean germination under the two tillage systems.

It is obvious from this table that herbicides caused more injury to beans in conventional tillage system than in minimum tillage system. Injury caused by metribuzin at all the rates used drastically reduced final bean yield.

A significant lack of control of weeds was observed under minimum tillage system causing a trend towards reduced bean yield. Preemergence application of herbicides studied in the conventional tillage system in 1984 gave 71 - 98% weed control six weeks after application. The same herbicides in the minimum tillage system in 1984 gave 35 - 61% weed control six weeks after application.

Plants grown under minimum tillage conditions

Table 6: Effect of herbicides on beans and weeds under conventional and minimum tillage systems, 1984

Herbicides (kg ai/ha)		Percentage						
		Germination	Bean injury	Weed control	Bean ht. (cm)	No. of pods per plant	100-seed wt. (gm)	Bean yield (kg/ha)
Conventional Tillage								
Alachlor	1.5	79.4	7.4	67,9	32.3	5.0	39.0	1115.3
Alachlor	2.0	78.7	9.2	71.3	31.8	7.0	39.6	1166.3
Alachlor	2.5	82.0	11.1	74.9	31.3	7.0	38.2	1278.8
Metolachlor	2.0	80.7	7.2	57.1	33.8	6.0	39.9	1078.3
Metolachlor	2.5	80.3	8.3	58.0	31.2	6.0	39.1	1157.0
Metolachlor	3.0	79.4	10.7	63.7	31.0	7.0	37.9	1248.8
Metribuzin	0.3	77.9	45.7	61.6	31.0	6.0	40.0	577.5
Metribuzin	0.5	81.6	59.1	72.4	28.8	6.0	37.6	296.3
Metribuzin	0.7	78.6	70.6	82.3	26.0	6.0	39.6	221.3
One weeding		78.6	-	67.3	35.5	8.0	39.4	1362.5
Two weedings		80.5	-	88.2	31.8	9.0	39.4	1425.8
No weeding		79.8	-	-	34.8	2.0	41.1	636.3

Table 6: Cont.

Herbicides (kg ai/ha)		Percentage						
		Germination	Bean injury	Weed Control	Bean ht. (cm)	No of pods per plant	100-seed wt. (gm)	Bean yield (kg/ha)
Min. Tillage								
Alachlor	1.5	77.9	5.7	38.5	38.5	4.0	37.5	936.3
Alachlor	2.0	79.8	6.8	40.7	37.5	5.0	36.7	978.0
Alachlor	2.5	80.9	8.7	46.1	35.8	6.0	39.2	1069.5
Metolachlor	2.0	79.4	5.9	36.0	40.3	4.0	38.2	921.8
Metolachlor	2.5	78.6	8.1	47.1	38.8	5.0	37.8	972.3
Metolachlor	3.0	78.7	8.6	46.6	37.5	6.0	38.5	1030.0
Metribuzin	0.3	79.5	42.5	49.0	34.5	4.0	39.0	480.3
Metribuzin	0.5	80.3	47.2	49.3	31.3	6.0	38.4	266.5
Metribuzin	0.7	77.9	54.8	51.1	32.8	6.0	39.2	194.3
One weeding		79.6	-	34.9	34.8	4.0	39.0	1151.8
Two weedings		80.1	-	48.3	34.8	5.8	39.0	1215.8
No weeding		78.9	-	-	41.3	3.0	40.1	539.5

Table 6: Cont.

Herbicides (kg ai/ha)	Percentage						
	Germination	Bean injury	Weed control	Bean ht. (cm)	No of pods per plant	100-seed wt. (gm)	Bean yield (kg/ha)
F-test	NS	*	*	*	*	*	*
SEM (1) + or -	1.19	1.81	3.88	1.51	0.46	0.50	25.13
SEM (2) + or -	1.21	2.45	3.79	1.63	0.46	0.49	24.09
CV %- +	2.99	15.63	13.64	8.87	16.59	2.60	5.66
Level 0.05							
LSD (1) +	3.36	5.15	10.98	4.27	1.31	1.43	71.07
LSD (2) +	3.63	4.99	10.98	5.19	1.37	1.44	68.23

1 = between herbicides for the same tillage system.

2 = between herbicides for different tillage systems.

tended to be significantly taller than those grown under conventional tillage system. Also observed was that a higher number of pods per plant and heavier seeds were obtained from plants grown under conventional tillage system than those grown under minimum tillage system thus resulting into a higher bean yield under conventional tillage system.

A summary of effects of herbicides on beans and weeds in conventional and minimum tillage systems in 1985 is shown in table 7. As observed in 1984, the herbicides did not affect bean seed germination significantly under the two tillage systems.

Metribuzin caused slightly less injury to beans in both tillage systems in the 1985 than in the 1984 season. There was no significant differences in herbicidal injury to beans in the two tillage systems in 1985.

Weed control in general was beeter in 1985 than in 1984. However, a significant lack of weed control in minimum tillage system still remained. Preemergence application of the herbicides studied in conventional and minimum tillage systems in 1985 gave 81 - 98% and 41 - 67% weed control six

Table 7: Effect of herbicides on beans and weeds under conventional and minimum tillage systems, 1985.

Herbicides (ka ai/ha)		Percentage						
		Germination	Bean injury	Weed control	Bean ht. (cm)	No. of pods per plant	100 -seed (gm)	Bean yield (kg/ha)
Confentional Tillage								
Alachlor	1.5	75.2	8.0	66.7	42.5	8.0	55.9	1698.3
Alachlor	2.0	74.5	10.0	71.8	42.5	9.0	53.2	1798.8
Alacholr	2.5	76.6	13.4	75.2	40.0	9.0	51.1	1966.5
Metolachlor	2.0	73.2	9.3	64.0	52.0	7.0	52.8	1664.3
Metolachlor	2.5	75.0	9.3	66.3	47.5	9.0	50.6	1759.5
Metolachlor	3.0	75.6	11.5	69.3	43.5	9.0	52.2	1910.0
Metribuzin	0.3	74.2	30.8	80.5	42.8	7.0	51.6	877.3
Metribuzin	0.5	73.6	52.0	81.2	33.3	8.0	52.2	461.3
Metribuzin	0.7	73.3	56.9	81.9	33.3	8.0	50.7	352.5
One weeding		74.8	-	71.3	46.3	10.0	50.1	2116.5
Two weedings		74.2	-	88.2	41.3	11.0	50.2	2178.5
No weeding		75.8	-	-	53.8	5.0	50.2	980.0

Table 7: Cont.

Herbicides (ka ai/ha)		Percentage						
		Germination	Bean injury	Weed control	Bean ht. (cm)	No. of pods per plant	100-seed (gm)	Bean yield (kg/ha)
Min.Tillage								
Alachlor	1.5	73.7	8.2	46.2	48.8	6.0	51.2	1438.8
Alachlor	2.0	75.1	9.1	48.4	48.3	7.0	50.0	1523.0
Alachlor	2.5	72.1	12.6	60.1	43.5	8.0	51.0	1652.5
Metolachlor	2.0	74.2	7.9	40.0	51.0	6.0	49.3	1420.0
Metolachlor	2.5	74.5	9.5	43.9	49.8	6.0	48.5	1474.3
Metolachlor	3.0	74.8	9.3	52.0	48.3	7.0	48.7	1620.0
Metribuzin	0.3	73.1	33.0	50.0	42.5	7.0	49.3	742.5
Metribuzin	0.5	74.2	46.8	52.2	40.0	7.0	46.7	395.0
Metribuzin	0.7	72.6	54.3	54.6	34.3	7.0	48.3	292.5
One weeding		73.1	-	38.6	46.5	5.0	48.7	1786.3
Two weedings		75.0	-	50.5	46.0	6.0	48.0	1853.0
No weeding		73.7	-	-	56.0	4.0	53.4	820.0

Table 7: Cont.

Herbicides (ka ai/ha)		Precentage						
		Germination	Bean injury	Weed control	Bean ht. (cm)	No. of pods per plant	100-seed (gm)	Bean yield (kg/ha)
F-test		NS	NS	*	NS	*	NS	*
SEM (1)	+ or -	1.08	1.82	3.15	1.41	0.52	1.42	30.36
SEM (2)	+ or -	1.16	1.84	3.29	1.60	0.51	1.58	32.28
CV %	+	2.92	16.33	10.24	6.1	14.22	10.96	6.72
Level 0.05								
LSD (1)	+	3.06	5.17	8.90	3.99	1.47	4.03	85.87
LSD (2)	+	3.65	5.59	10.21	5.29	1.48	5.14	101.53

1 = between herbicides for the same tillage system.

2 = between herbicides for different tillage systems.

weeks after herbicide application respectively. As was observed in 1984, intrarow hand weeding was not effective in controlling the weeds in 1985.

Bean plants grown under minimum tillage system appeared taller than those grown under conventional tillage system though the difference in height was not significant. Similarly the weight of seeds in 1985 was not significantly different between the two tillage systems.

In general more number of pods per plant and heavier seeds were obtained in the 1985 season than in the 1984 season. This resulted into more final bean yield being obtained in the 1985 season. Bean yield under conventional tillage system in 1985 season was more than the corresponding yield under minimum tillage system just like in 1984 season.

Dry matter yield of weeds:

The dry matter yield of weeds was measured at the end of each growing season. Table 8 shows the dry matter yield of weeds under conventional tillage system during the short rains of 1984.

Table 8. Dry matter yield of weeds under conventional tillage system, 1984 (Kg/ha).

Herbicides (Kgai/ha)	Assc.	Dast.	Emau.	Niph.	Tami.	Mean
Alachlor 1.5	242	156	456	191	225	254.0
Alachlor 2.0	326	95	423	13	199	211.2
Alachlor 2.5	252	69	130	103	104	131.6
Metolachlor 2.0	156	243	768	188	313	333.6
Metolachlor 2.5	212	217	274	101	261	213.0
Metolachlor 3.0	258	87	261	9	139	150.8
Metribuzin 0.3	607	130	621	52	24	286.8
Metribuzin 0.5	139	254	272	669	26	412.0
Metribuzin 0.7	600	407	769	606	69	490.2
One weeding	61	61	167	52	73	82.8
Two weedings	24	50	75	42	60	50.2
No weeding	341	1666	2083	2000	1986	1615.2
Mean	261.5	160.8	446.9	184.2	135.7	

	Herbicides	Weed spp
F. test	*	*
SEm	±73.94	±49.85
SEd	±104.57	±70.50
LSD(0.05)	211.34	142.49

* = significant at 5% level.

Key to weed abbreviations: Asystasia schimperi, T. Anders Datura stramonium L., Emex australis Steinh, Nicandra physaludes L. and Tagetes minuta L.

Emex australis Steinh was particularly tolerant to the three herbicides used. The higher rates of alachlor and metolachlor were generally effective on the broadleaf weeds. All metribuzin treated plots indicated a very high yield of weeds despite a better control at the initial and critical weed control stages than the other herbicides used. Hand weeded plots resulted into very low yield of weeds particularly where weeding was done two times.

A similar trend was observed under minimum tillage system during the same season (Table 9). *Emex australis* Steinh and *Asystasia schimperi* T. Anders remained the dominant weed species. In general dry matter yield of weeds was higher under minimum tillage system than in the conventional tillage system, an indication that there was poor weed control by the herbicides under the former tillage system. Alachlor and metolachlor at higher rates used resulted into lower yield of weeds than the hand weeded treatments.

A comparatively less dry matter yield of weeds was observed in the 1985 season than in the 1984 season. The control of *Asystasia schimperi* T.

Table 9. Dry matter yield of weeds under minimum tillage, 1984 (Kg/ha).

Herbicides (Kg ai/ha)		Assc.	Dast.	Emau.	Niph.	Tami.	Mean
Alachlor	1.5	308	195	282	124	300	241.8
Alachlor	2.0	303	86	304	16	265	194.8
Alachlor	2.5	275	119	100	230	139	172.6
Metolachlor	2.0	295	204	450	226	317	298.4
Metolachlor	2.5	265	271	167	121	348	234.4
Metolachlor	3.0	260	163	174	21	185	160.6
Metribuzin	0.3	574	109	414	62	47	241.2
Metribuzin	0.5	600	318	513	600	40	414.2
Metribuzin	0.7	750	400	648	540	87	485.0
One weeding		136	494	350	400	530	382.0
Two weedings		130	165	145	171	480	218.2
No weeding		409	2083	1506	2400	2511	1781.8
Mean		354.2	229.5	322.5	228.3	248.9	

	Herbicides	weed spp
F. test	*	NS
SEm	±69.92	±47.14
SEd	±98.88	±66.66
LSD(0.05)	199.83	134.73

* = significant at 5% level

NS - Not significant.

Key to weed abbreviations: Asystasia schimperi T. Anders, Datura stramonium L., Emex australis steinh, Nicandra physalodes L. and Tagetes minuta L.

Anders, _Emex australis_ Steinh, and _Tagetes minuta_ L under conventional tillage system in 1985 was poor (Table 10). However, _Lactuca capensis_ Thunb, _Erucastrum arabicum_ Fisch and Mey and _Bidens pilosa_ L. were fairly well controlled by alachlor, metolachlor and metribuzin at higher rates of application. Statistical analysis revealed that there was not significant differences among the weed control treatments in terms of dry matter yield of weeds at the end of the growing season of 1985. Hand weeded plots gave very little yield of weeds at the end of the season.

A similar trend of dry matter yield of weeds was observed in minimum tillage system in 1985 (Table 11). _Tagetes minuta_ L. and _Asystasia schimperi_ T. Anders were not controlled by the three herbicides used. Alachlor at the highest rate used resulted into less dry matter yield of weeds at the end of the growing season than intrarow handweedings. Again at the end of the growing season no weed control treatment performed significantly better in terms of dry matter yield of weeds.

Table 10. Dry matter yield of weeds under conventional tillage system, 1985 (Kg/ha).

Herbicides (Kg ai/ha)	Assc.	Bipi	Emau	Tami	Erar.	Laca.	Mean
Alachlor 1.5	161	8	219	368	86	0	168.4
Alachlor 2.0	282	0	121	196	110	8	143.4
Alachlor 2.5	168	0	149	149	78	8	110.4
Metolachlor 2.0	141	67	106	457	90	35	149.3
Metolachlor 2.5	125	35	313	360	86	28	157.8
Metolachlor 3.0	172	12	227	344	102	12	144.8
Metribuzin 0.3	414	16	63.	227	55	78	142.2
Metribuzin 0.5	446	31	196	242	86	16	169.5
Metribuzin 0.7	446	16	168	242	31	47	158.3
One weeding	55	28	0	164	70	82	79.8
Two weedings	39	8	0	46	16	4	22.6
No weeding	227	39	47	1531	164	55	343.8
Mean	222.6	24.6	173.6	254.1	73.6	31.8	
			Herbicides		weed spp		
F. test			NS		*		
SEm			±34.10		±25.36		
SEd			±48.56		±35.86		
LSD(0.05)			97.50		72.0		

NS = Not significant * - significant at 5% level.

Key to weed abbreviations: *Asystasia schimperi* T. Anders, *Bidens pilosa* L., *Emex australis* Steinh, *Tagetes minuta* L., *Erucastrum arabicum* Fisch and Mey and *Lactuca capensis* Thunb.

Table 11. Dry matter yield of weeds under minimum tillage system, 1985 (Kg/ha)

Herbicides (Kg ai/ha)		Assc.	Bipi.	Cobo	Emau	Laca.	Tami	Mean
Alachlor	1.5	206	63	74	266	12	617	206.3
Alachlor	2.0	78	159	31	32	43	438	130.2
Alachlor	2.5	152	63	24	47	47	258	98.5
Metolachlor	2.0	250	71	61	39	63	555	173.2
Metolachlor	2.5	184	102	39	39	36	539	156.5
Metolachlor	3.0	230	16	24	9	75	496	141.7
Metribuzin	0.3	184	16	98	31	43	446	136.3
Metribuzin	0.5	328	47	109	31	74	539	188.0
Metribuzin	0.7	297	0	157	35	102	454	209.0
One weeding		83	76	24	26	54	390	108.8
Two weedings		227	110	16	63	70	156	107.0
No weeding		250	78	39	0	102	1180	329.8
Mean		201.7	72.3	59.4	56.2	56.3	417.1	

	Herbicides	weed spp
F. test	NS	*
SEm	±36.33	±26.84
SEd	±51.39	±37.95
LSD(0.05)	103.19	76.21

NS = Not significant. * - significant at 5% level.

Key to weed abbreviations: Asystasia schimperi, T. Anders., Bidens pilosa L., Conyza bonariensis (L.) Cronq. Emex australis steinh, Lactuca capensis, Thunb and Tagetes minuta L.

Economic analysis for conventional and minimum tillage bean production:

The cost of land preparation was based on the local tractor hire service while the cost of herbicides and the selling price of beans were based on the charges from the Kenya Grain Growers Cooperative Union stores and the National Cereals and Produce Board of Kenya respectively as at 1985. Costs and benefits were calculated on per hectare basis.

Results shown in table 12a indicate that both hand weeded treatments produced the highest bean yield followed by alachlor and metolachlor at 2.5 and 3.0 kg ai/ha respectively. All the metribuzin treatments gave bean yields less than the unweeded control.

The revenue accrued from the sales of beans shows a similar trend. The use of preemergence herbicides elevated the cost of production more than hand weeding. A second hand weeding operation raised the cost of production to a level comparable to where herbicides were used. The second hand weeding operation thus increased the cost of production more than the increase in revenue.

Table 12a. Revenue and Costs per hectare of beans grown under conventional tillage system, 1984.

Herbicides (Kgai/ha)		Bean yield (Kg/ha)	Revenue (Kshs)	Cost (Kshs)	Margin (Kshs)
Alachlor	1.5	1115.3	4684.10	1442.00	3242.10
Alachlor	2.0	1116.3	4898.30	1570.00	3328.30
Alachlor	2.5	1273.8	5349.80	1698.00	3651.80
Metolachlor	2.0	1078.3	4528.70	1442.00	3086.70
Metolachlor	2.5	1157.0	4859.40	1538.00	3321.40
Metolachlor	3.0	1248.8	5244.80	1630.00	3614.80
Metribuzin	0.3	577.5	2425.50	1258.00	1167.50
Metribuzin	0.5	296.3	1244.30	1408.00	-163.80
Metribuzin	0.7	221.3	926.30	1558.00	-628.80
One weeding		1362.5	5722.50	1275.00	4447.50
Two weedings		1425.8	5988.20	1650.00	4338.20
No weeding		636.3	2672.30	900.00	1772.30

NB. The revenue per Kg of beans is Kshs 4.20, so the revenue in the third column is obtained by multiplying the yield from column two by 4.20. The margin in the fifth column is simply revenue minus cost.

This resulted into a lower margin than where one hand weeding operation was performed. Alachlor at 2.5 kg ai/ha and metolachlor at 3.0 kg ai/ha gave a higher revenue than the same herbicides at lower rates. Metribuzin treatments at 0.5 and 0.7 kg ai/ha resulted into negative margins. All the metribuzin treatments namely, 0.3, 0.5 and 0.7 kg ai/ha gave lower margins than the unweeded control.

Table 12b summarises the yield, revenue, cost and margin involved in minimum tillage system in 1984. A similar trend was observed as in the conventional tillage system in 1984, however bean yield was generally lower in the minimum tillage system. Use of glyphosate in the minimum tillage system raised the cost of production more than the inputs in the conventional tillage system. This tended to lower the margins in minimum tillage system.

Table 12b. Revenue and Costs per hectare of beans grown under minimum tillage system, 1984.

Herbicides (Kgai/ha)		Bean yield (Kg/ha)	Revenue (Kshs)	Cost (Kshs)	Margin (Kshs)
Alachlor	1.5	936.3	3930.30	1624.90	2307.40
Alachlor	2.0	978.0	4107.60	1752.90	2354.70
Alachlor	2.5	1069.5	4491.90	1880.90	2611.00
Metolachlor	2.0	921.8	3871.40	1624.90	2246.50
Metolachlor	2.5	972.3	4083.50	1720.90	2362.60
Metolachlor	3.0	1030.0	4326.00	1816.90	2509.10
Metribuzin	0.3	480.3	2017.10	1440.90	576.20
Metribuzin	0.5	266.5	1119.30	1590.90	-471.60
Metribuzin	0.7	194.3	815.90	1740.90	-925.05
One weeding		1151.8	4837.40	1465.90	3367.50
Two weedings		1215.8	5106.20	1690.90	3415.30
No weeding		539.5	2265.90	1240.90	1025.00

An analysis of variance was performed to find out whether there were any significant differences between the margins in the two tillage systems in 1984. Statistical analysis revealed that there was not significant difference between the margins in the two tillage systems (Table 12c). Thus even though the margins from conventional tillage system looked superior to the minimum tillage system, the two tillage systems were comparable.

Cost-benefit considerations for the 1985 season showed a similar trend to that of 1984 season (Table 13a). Due to ample rainfall and cold temperatures that prevailed during the 1985 season, the final bean yield was observed to be higher than the corresponding conventional tillage system in 1984. This resulted into improved margins as compared to the previous season. Metribuzin treatments, however, still gave lower margins than the unweeded control. Metribuzin at 0.7 kg ai/ha gave a negative margin.

Table 12c. Comparison of profit margins (Kshs) for conventional and minimum tillage systems, 1984.

Herbicides (Kgai/ha)		Margins for conventional tillage (Kshs).	Margins for minimum tillage (Kshs)
Alachlor	1.5	3242.10	2307.40
Alachlor	2.0	3328.30	2354.70
Alachlor	2.5	3651.80	2611.00
Metolachlor	2.0	3086.70	2246.50
Metolachlor	2.5	3321.40	2362.60
Metolachlor	3.0	3614.80	2509.10
Metribuzin	0.3	1167.50	576.20
Metribuzin	0.5	-163.80	-471.60
Metribuzin	0.7	-628.80	-925.05
One weeding		4447.50	3367.50
Two weedings		4338.20	3415.30
No weeding		1772.30	1025.00
Mean		2598.20	1781.50
F. test		NS	
SEd		634	

Table 12c. Comparison of profit margins (Kshs) for conventional and minimum tillage systems, 1984.

Herbicides (Kgai/ha)	Margins for conventional tillage (Kshs).	Margins for minimum tillage (Kshs)
Alachlor 1.5	3242.10	2307.40
Alachlor 2.0	3328.30	2354.70
Alachlor 2.5	3651.80	2611.00
Metolachlor 2.0	3086.70	2246.50
Metolachlor 2.5	3321.40	2362.60
Metolachlor 3.0	3614.80	2509.10
Metribuzin 0.3	1167.50	576.20
Metribuzin 0.5	-163.80	-471.60
Metribuzin .0.7	-628.80	-925.05
One weeding	4447.50	3367.50
Two weedings	4338.20	3415.30
No weeding	1772.30	1025.00
Mean	2598.20	1781.50
F. test NS		
SEd 634		

Table 13a. Revenue and Costs per hectare of beans grown under conventional tillage system, 1985.

Herbicides (Kgai/ha)		Bean yield (Kg/ha)	Revenue (Kshs)	Cost (Kshs)	Margin (Kshs)
Alachlor	1.5	1698.0	7132.70	1442.00	5690.70
Alachlor	2.0	1798.8	7554.80	1570.00	5984.90
Alachlor	2.5	1999.5	8259.30	1698.00	6561.30
Metolachlor	2.0	1664.3	6989.90	1442.00	5547.90
Metolachlor	2.5	1759.5	7389.90	1538.00	5851.90
Metolachlor	3.0	1910.0	8022.00	1630.00	6392.00
Metribuzin	0.3	877.3	3684.50	1285.00	2426.50
Metribuzin	0.5	461.3	1937.30	1408.00	529.30
Metribuzin	0.7	352.5	1480.50	1558.00	-77.50
One weeding		2116.5	8889.30	1275.00	7614.30
Two weeding		2178.5	9149.70	1650.00	7499.70
No weeding		980.0	4116.00	900.00	3216.00

Table 13b presents the data on bean yield, costs of bean production, revenue derived from the sales of beans and the profit margins for weed control treatments under minimum tillage system in 1985. The final bean yield under minimum tillage system was found to be lower than the bean yield obtained under conventional tillage system in the same year. As a result of the low final bean yield obtained under minimum tillage system in 1985, lower revenue and a corresponding lower profit margins were observed than in conventional tillage system in the same year.

Table 13c shows a pairwise comparison of profit margins between conventional tillage and minimum tillage systems in 1985. Analysis of variances did not reveal any significant differences between the two tillage systems just like in 1984 season.

Table 13b. Revenue and costs per hectare of beans grown under minimum tillage system,1985.

Herbicides (Kgai/ha)	Bean yield (Kg/ha)	Revenue (Kshs)	Cost (Kshs)	Margin (Kshs)
Alachlor 1.5	1438.80	6042.80	1624.90	4417.90
Alachlor 2.0	1523.0	6396.60	1952.90	4643.70
Alachlor 2.5	1652.50	6940.50	1880.90	5059.60
Metolachlor 2.0	1420.0	5964.00	1624.90	4339.10
Metolachlor 2.5	1474.2	6191.90	1720.90	4471.00
Metolachlor 3.0	1620.0	6804.00	1816.90	4987.10
Metribuzin 0.3	742.5	3118.50	1440.90	1677.60
Metribuzin 0.5	395.0	1659.00	1590.90	68.10
Metribuzin 0.7	292.5	1228.50	1740.90	-512.40
One weeding	1786.3	7502.30	1405.90	6036.40
Two weedings	1853.0	7782.60	1690.90	6091.70
No weeding	820.0	3444.00	1240.90	2203.10

Table 13c: Comparison of profit margins (Kshs) for conventional tillage and minimum tillage systems, 1985.

Herbicides (Kg ai/ha)		margins for conventional tillage (Kshs)	margins for minimum tillage (Kshs)
Alachlor	1.5	5690.70	4417.90
Alachlor	2.0	5984.90	4643.70
Alachlor	2.5	6561.30	5059.60
Metolachlor	2.0	5547.90	4339.10
Metolachlor	2.5	5851.90	4471.00
Metolachlor	3.0	6392.00	4987.10
Metribuzin	0.3	2426.50	1677.60
Metribuzin	0.5	529.30	68.10
Metribuzin	0.7	-77.50	-512.40
One weeding		7614.30	6036.40
Two weedings		7499.70	6091.70
No weeding		3216.00	2203.10
Mean		4169.70	3623.60
F. test		NS	
SEd		989.17	

DISCUSSION

Tillage systems and herbicides used:

The furrows dug in minimum tillage plots produced a narrow seedbed similar to normal tillage system and in addition there was enough moisture in the soil at planting time, hence no significant difference was observed between the two tillage systems in terms of bean germination. These results also show that preemergence herbicides did not have detrimental effects on bean seed germination. Similar results were observed by Otoo (1976) who found no significant difference in soybean emergence under different tillage systems.

Most legumes are susceptible to metribuzin with an exception of soybeans. In this trial metribuzin at all the rates used, i.e. 0.3, 0.5 and 0.7 kg ai/ha caused complete kill of most of the bean plants resulting into significantly low final bean yield, infact lower bean yields than where weeding was not done at all. Hammerton (1974) found snap beans to be very unsafe to metribuzin when applied preemergence at 0.6 and 1.2 kg ai/ha. A similar finding was reported by

Mburu *et al*, (1983), who observed complete kill of beans by metribuzin at 0.3, 0.875 and 1.4 kg ai/ha without any sign of recovery. Alachlor at 1.5, 2.0 and 2.5 kg ai/ha and metolachlor at 2.0, 2.5 and 3.0 kg ai/ha exhibited temporary bean damage which disappeared after the bean plants had attained the trifoliate leaf stage. Malformation and marginal necrosis of leaves were observed. Similar findings were reported by Hammerton (1971) and Michieka (1981) who while using alachlor at 3.3 and 2.5 kg ai/ha respectively reported only temporary damage to bean plants.

The observed poor weed control under minimum tillage system could be attributed to incomplete contact kill of the small weeds that escaped glyphosate damage, the preemergence herbicides and also by the fact that the plots were not cultivated. There is also some indication that plant residue may have intercepted preemergence herbicides and thus reduced herbicide efficacy. Low weed control under reduced tillage systems has been reported by Erbach *et al* (1975), Staniforth *et al* (1975), Walker *et al* (1975) and Kapusta (1979) amongst others. The cool and wet conditions which prevailed during the 1985 growing season enabled the bean plants and weeds to grow vigorously absorbing more herbicides which selectively killed the weeds except for metribuzin which had little selective kill. This accounts for the better weed control in the 1985 season. The preemergence herbicides gave at least six weeks of satisfactory weed control. However, as has been reported from the results, metribuzin was detrimental to the bean plants. Lower yields of beans observed in metribuzin treated plots was mainly due to its damage on bean crop. Metribuzin at all rates tested gave comparable weed control to clean weeded control (two hand weedings). Alachlor at 2.5 kg ai/ha and metolachlor at 3.0 kg ai/ha gave a satisfactory weed control in conventional tillage system, however, bean yield was significantly less than clean weeding. These findings are in line with the work of Hammerton (1972) who reported that clean weeding performed better than the herbicides he used.

Weed control by all the herbicides used in this trial was poor under minimum tillage system. This is why very low bean yield was observed under minimum tillage system compared to clean hand weeded control in both seasons. Sanford et al, (1973) working with soybeans and grain sorghum reported significant low yields under reduced tillage system. The authors attributed the low yields mainly to poor weed control. It follows then that weeds can significantly reduce crop yields. Results from this trial revealed that weeds reduced bean yield by 55% and 62% over clean weeded control in conventional tillage and minimum tillage systems respectively in 1985.

Herbicides can influence the growth of any crop on which they are applied. This is further complicated by the fact that growth may also be influenced by the competition between the crop and weeds and final growth that occurs may be due to a combination of the two. The extent to which the height of any crop is influenced depends on the density and height of the weeds in relation to the crop. Staniforth _et al_, (1956) stated that high weed density and taller weeds compete with the desired crop through shading effect which may lead to etiolation of the crop and on the other hand shorter weeds compete mainly for water and mineral salts which may retard the growth of the desired crop. Balah (1981) reported a decrease in bean height with increasing weed infestation. Almost all the weed species encountered in this trial were much taller than the bean crop and offered competition mainly through the shading effect. This resulted into taller bean plants being observed especially under minimum tillage system in the 1984 season and in the plots which were not weeded. The 1985 season was wetter and cooler and hence both weeds and beans grew taller. The observation that plots in which higher rates of herbicides were applied had shorter beans could have been as a result of either a better weed control hence less etiolation or direct effect of the herbicides used on the beans. Littlejohns et al (1977) observed a reduction on soybean height with increasing rate of metribuzin.

Pods per plant have the largest effect on bean yield (Westernman et al, 1977). As was observed, plots in which weeds were poorly controlled gave significantly low number of pods per plant especially in the minimum tillage system. This is in line with the finding of Balah (1981) who reported a reduction in pod number per plant under weedy conditions. Similarly, Aguilar (1977), working with dry beans found pods per plant to be very sensitive to interplant competition between five and eleven weeks after planting. Less moisture stress and cooler temperatures that prevailed in the 1985 season resulted into higher pod number per plant than the previous season. Insect and rodent damage to bean pods in unweeded check plots contributed further to very low pod number observed in these plots.

High moisture stress and hot day temperatures that prevailed in the 1984 season could have interfered with the grain filling stage leading to significantly lighter seeds as observed in the minimum tillage system. Seeds from the following season crop were heavier and there was no significant difference between the two tillage systems. Aguilar (1977) and Balah (1981) reported that seed weight was not sensitive to interplant competition and could be even heavier in weedy conditions.

Significant low yield difference observed under minimum tillage system as compared to conventional tillage system is attributed mainly to poor weed control in the former system. The yield difference was more pronounced in the 1984 season which was characterised by prolonged hot and dry weather conditions resulting into poor growth of the crop and a reduction of the herbicide efficacy. Jordan et al, (1978) and Putnam et al, (1979) reported on reduced activity of herbicides when low soil moisture and high temperatures proceed application. Higher yields obtained in the 1985 season was due to cool temperatures and good rainfall which carried the crop through to physiological maturity. Elnadi (1969) reported that cool climate and good precipitation can keep a plant green for long periods resulting into increased photosynthetic period. Low crop yield under reduced tillage system has been reported by many authors including Sanford et al (1973) who when working with soybeans and grain sorghum reported significant low yield differences in reduced tillage system. He attributed this observation to poor weed control under reduced tillage system. Alachlor and metolachlor both at higher rates were found to be good and safe in bean production especially under conventional tillage system. Metribuzin as has already been discussed was found to be very unsafe for beans. As recommended by De groot (1975), two hand weedings under conventional tillage system resulted into technically higher final bean yields than the rest of the treatments. Similarly two intrarow hand weedings in minimum tillage system gave the highest bean yield under this tillage system. However, bean yield got from the minimum tillage system under two intrarow hand weeding operations was significantly less than the bean yield got from two conventional hand weedings by about 315 kg/ha in the 1985 season. It is supposed that complete hand weeding of the minimum tillage crops could have greatly reduced this difference in bean yield. Intrarow hand weeding was done in minimum tillage plots to reduce the cost of weeding taking into account the fact that weeds within the crop row compete more effectively with the crop than weeds between the rows, since they are positioned very closely to crop plants.

Weed dry matter shortly before or after bean harvest in general may not be a very valid method of evaluating herbicide trials, however, it can be useful in assessing the duration of activity. Depending on the soil type and climatic conditions persistance of alachlor and metolachlor is six to ten weeks while that of metribuzin is four to eight weeks under normal rates (Anonymous, 1983). It may be because of this shorter duration of activity that high dry matter yield of weeds was observed in metribuzin plots even though weed counts at six weeks after application rated metribuzin second best to hand weeding. Alachlor and metolachlor at the higher rates of application had a comparatively lower dry matter yield of weeds, an indication of their longer persistance in the soil. Due to high temperatures and moisture stress in the 1984 growing season, competition for moisture was apparent. The high temperatures and moisture stress might also have reduced the herbicides' efficacy. This led to the high dry matter yield of weeds observed during the 1984 season. There are reports that weeds have an edge over cultivars in cases of extreme moisture stress (Gurnah, 1974 and Putnam _et al_, 1979). In contrast, low dry matter yield of weeds observed in the 1985 season, could be attributed to cool temperatures and ample rainfall which increased the efficacy of the herbicides thus resulting into selective control of weeds within the crop. All the herbicide treatments in

1985 did not show any significant difference in dry matter weight of the weeds that was taken shortly after bean harvesting in both tillage systems. A re-establishment of young weeds was observed in almost all the herbicide plots during the final month of bean growth. More rainfall received during this season could have promoted the disappearance of the herbicides from the soil by dissipation thus reducing the duration of activity. However, the initial weed control was better than the previous season and the young re-established weeds had low dry matter thus explaining the low dry matter yield of weeds in this season in both tillage systems as compared to the 1984 season. Dry matter yield of weeds in minimum tillage system was higher than the corresponding conventional tillage system in both seasons. Generally there was poor weed control in minimum tillage system as has been explained before.

Economic analysis for minimum and conventional tillage systems:

The costing did not take into consideration other variable costs such as seeds, labour charges for planting, fertilizers, harvesting and post-harvest handling costs which were common to both tillage systems and were therefore taken to be fixed. The costs included in the economic analysis were considered sufficient for comparisons.

Glyphoste is expensive and its use increased the minimum tillage bean production costs over the conventional system. However, the use of glyphosate was necessary since patches of difficult to control weeds like Kikuyu grass (Pennisetum clandestinum Chiov), Couch grass (Digitaria scalarum (Schweinf) Chiov) and Star grass (Cynodon dactylon (L.) Pers existed in the experimental site.

The preemergence herbicides used in this trial did not control weeds effectively under minimum tillage system in both seasons thus resulting into low final bean yield and therefore less revenue. Generally bean yield was lower in 1984 season due to prolonged drought, high temperatures and also poor weed control.

Two hand weeding operations under conventional tillage system in both seasons gave the highest bean yield hence the highest revenue. However, the cost of production per hectare was more than where one hand weeding operation was done. Consequently one hand weeding operation resulted into a bigger margin. Two hand weeding operations pay in medium to high potential areas with ample rainfall amount (Degroot, 1979). In this trial however, rainfall amount was not adequate in both seasons. This resulted into the second weeding operation adding more to the production cost at the expense of the revenue thus reducing the profit margin in conventional tillage. Application of alachlor despite raising the production costs more than metolachlor resulted into a better margin at all rates used. Infact alachlor was second best to hand weeding operations in both seasons in conventional tillage system. Metribuzin as was expected decreased final bean yield not through ineffective weed control but due to actual plant kill. Metribuzin at 0.5 and 0.7 kg ai/ha resulted into negative profit margins in both tillage systems in 1984. A negative profit margin occured when metribuzin was used at 0.7 kg ai/ha in both tillage system in 1985. It is evident from these results that it is more profitable not to weed at all than to use metribuzin on beans at higher levels.

In contrast, two intrarow hand weeding operations under minimum tillage in both seasons were more profitable than one intrarow hand weeding and all other pre-emergence herbicide treatments. Use of glyphosate and preemergence herbicides in minimum tillage system raised the production costs per hectare compared to the use of glyphosate alone reinforced by quick intrarow hand weedings. This explains why all the treatments in which the preemergence herbicides were used in minimum tillage system in both seasons had lower profit margins.

The final profit margins from each treatment in both seasons in conventionally tilled plots were more than in the corresponding minimum tillage plots. However, statistical analysis revealed no significant difference in the profit margins in the two tillage systems. Based on this finding, and taking into consideration the merits of minimum tillage, there is room for further research in minimum tillage production of beans. Soybean, a legume like beans has been successfully produced under this tillage system.

CONCULUSION

Results from this trial, indicate comparable profit margins between the two tillage systems of bean production. However the farmers' current limitations and capability of handling minimum tillage operation should be taken into considerations. Use of a herbicide is faster, less laborious method of weed control and can lead to accumulation of organic matter under reduced tillage conditions. Herbicides used in this trial i.e. alachlor and metolachlor with the exception of metribuzin performed comparatively well in both tillage systems. The use of glyphosate however, raised the cost of production resulting in low profit margins in minimum tillage systems. Herbicides are costly and farmers my not be able to afford them. Furthermore the use of herbicides is associated with rainfall which may make them an option that is too risky in places of unreliable rainfall. Hand weeding operations were found to be more economical in the trial in both tillage systems. Intrarow hand weeding was cheaper and more profitable than the use of residual herbicides. Development of minimum tillage equipment for faster and more accurate land preparation, planting and weeding while at the same time conserving water and soil would be an achievement to farmers. Minimum tillage equipment involving use of animal pulled equipment such as chisel, light weight plough, ridgers and furrow openers require the presence of health draught animals. Feed storage strategies and pasture improvement would ensure adequate feed supply to draught animals even at critical times thus leading to more timely seedbed preparation and faster weeding. Of course a parmanent water source on or near the farm is necessary to reduce time and effort needed to water the animals.

Research emphasis thus should be on the development of faster and less labour intensive technology which takes into account soil and water conservation. This emphasizes on reduced tillage systems for annual crop production with either the use of herbicides or improved reduced tillage equipment or both depending on the farmers capability, their current limitations and ecology of the environment. An integrated work involving Agricultural engineers, soil, crop and animal scientist is required to this end. Where herbicides are used, appropriate combinations of contact and residual herbicides should be further worked on. The aim is to increase effective weed control at low costs to make reduced tillage more profitable and attractive to farmers.

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Appendix 1. Calender of field activities

Date	Month and Year	Field activity
16th - 17th	October, 1984	Planting of beans
19th	October, 1984	Preemergence herbicide application
7th	November, 1984	First hand weeding
21st	November, 1984	Second hand weeding
16th - 17th	January, 1985	Bean harvesting
29th - 30th	March, 1985	Planting during the long rains.
1st	April, 1985	Application of preemergence herbicides.
20th	April, 1985	First hand weeding
4th	May, 1985	Second hand weeding
15th	July, 1985	Bean harvesting

Appendix II (a). Environmental data (1984/85)

Month	Temperature (^oC)			Monthly rainfall (mm)	Total monthly evaporation (mm)	Daily mean evaporation (mm)
	Maximum	Minimum	Mean			
October	21.9	13	17.5	62	56.2	4.01
November	21.6	17.4	19.5	132	104.4	3.48
December	22.4	12.7	17.6	64.7	131.3	4.38
January	24.6	12.5	18.6	0	177.0	5.71
Total	22.6	13.9	18.3	258.7	468.9	4.40

Appendix II (b). Environmental data (1985)

Month	Temperature (^oC)			Total monthly rainfall (mm) (mm)	Total monthly evaporation (mm)	Daily mean evaporation (mm)
	Maximum	Minimum	Mean			
March	22.9	14.3	18.6	18.1	6.6	3.3
April	22.8	13.9	18.4	200.1	122.4	3.9
May	21.7	13.0	17.4	80.3	95.8	3.09
June	21.1	11.1	16.1	16.2	90.7	3.02
Total	22.1	13.1	17.6	314.7	315.5	3.33

Appendix II (b). Environmental data (1985)

Month	Temperature (^{o}C)			Total monthly rainfall (mm) (mm)	Total monthly evaporation (mm)	Daily mean evaporation (mm)
	Maximum	Minimum	Mean			
March	22.9	14.3	18.6	18.1	6.6	3.3
April	22.8	13.9	18.4	200.1	122.4	3.9
May	21.7	13.0	17.4	80.3	95.8	3.09
June	21.1	11.1	16.1	16.2	90.7	3.02
Total	22.1	13.1	17.6	314.7	315.5	3.33

Appendix III. Table of angular transformation of percentages to degrees[a] of Little and Hills: Design and analysis; Published by Wiley.

%	0	1	2	3	4	5	6	7	8	9
0	0	5.7	8.1	10.0	11.5	12.9	14.2	15.3	16.4	17.5
10	18.4	19.4	20.3	21.1	22.0	22.8	23.6	24.4	25.1	25.8
20	26.6	27.3	28.0	28.7	29.3	30.0	30.7	31.3	31.9	32.6
30	33.2	33.8	34.4	35.1	35.7	36.3	36.9	37.5	38.1	38.6
40	39.2	39.8	40.4	41.0	41.6	42.1	42.7	43.3	43.9	44.4
50	45.0	45.6	46.1	46.7	47.3	47.9	48.4	49.0	49.6	50.2
60	50.8	51.4	51.9	52.5	53.1	53.7	54.3	54.9	55.6	56.2
70	56.8	57.4	58.1	58.7	59.3	60.0	60.7	61.3	62.0	62.7
80	63.4	64.2	64.9	65.6	66.4	67.2	68.8	68.9	69.7	70.6
90	71.6	72.5	73.6	74.4	75.8	77.1	78.5	80.0	81.9	84.3
100	90.0	-	-	-	-	-	-	-	-	-

(a) - A bridged from Table X of Fisher and Yates: Statistical Tables for Biological, Agricultural, and Medical Research, published by Longman Group Ltd., London.

Appendix IV. Soil analysis data

Field Designation	A		B		C		Mean	
Depth	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Na m.e. %	0.34	0.42	0.27	0.34	0.34	0.44	0.32	0.4
K. m.e. %	1.01	0.76	1.32	0.64	0.86	0.66	1.06	0.69
Ca m.e. %	7.2	7.0	7.6	8.0	6.8	7.6	7.2	7.5
Mg m.e. %	3.1	3.0	3.7	3.4	3.6	3.7	3.5	3.4
Mn m.e. %	1.57	0.87	1.46	1.36	1.84	1.57	1.62	1.27
P p.p.m.	29	26	29	29	32	26	30	27
C%	1.65	-	1.65	-	1.19	-	1.5	-
% OM = %CX 1.724	2.8	-	2.8	-	2.1	-	2.6	-
pH water	5.6	5.7	5.7	5.5	5.7	5.6	5.7	5.6
pH kcl	4.8	4.8	4.9	4.7	5.0	5.0	4.9	4.8
% Sand	18	16	14	12	14	16	15	15
% Clay	58	56	58	54	62	60	59	57
% Silt	24	28	28	34	24	24	25	29
Texture	clay	clay	clay	clay	clay	clay	clay	clay

Appendix V (a). Analysis of variance on percent bean germination (1984)

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	550.35			
Main plots	7	67.30			
Blocks	3	38.37	12.79		
Tillage system (TS)	1	5.92	5.92	0.77	10.13
Main plot error	3	23.01	7.69		
Weed control method (w.c.m.)	11	83.43	7.58	1.34	1.94
TS x wcm	11	27.54	2.50	0.44	
Subplot error	66	372.08	5.64		

Appendix V (b). Analysis of variance cn percent bean germination (1985)

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	457.61			
Main plots	7	59.29			
Blocks	3	4.60	1.53		
Tillage systems (TS)	1	16.85	16.85	1.34	10.13
Main plot error	3	37.84	12.61		
Weed control method (wcm)	11	35.04	3.19	0.68	1.94
(TS x wcm)	11	53.96	4.91	1.05	
Subplot error	66	309.32	4.69		

Appendix VI (a). Analysis of variance on % bean injury (1984)

Source of variation	df	ss	ms	Observed F	Required F 5%
Subplots	71	35650.43			
Main plots	7	420.0			
Blocks	3	42.16	14.05		
Tillage system (TS)	1	369.60	369.60	134.4	10.13
Main plot error	3	8.24	2.75		
Weed control method (Wcm)	8	34136.40	4267.05	324.0	2.14
(TS x wcm)	8	461.74	57.72	4.38	
Subplot error	48	632.29	13.17		

Appendix VI (b). Analysis of variance on % bean injury (1985)

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	71	238332.42			
Main plots	7	80.67			
Blocks	3	10.74	3.58		
Tillage system (TS	1	24.20	24.20	1.59	10.13
Main plot error	3	45.73	15.24		
Weed control method (wcm)	8	23044.50	2880.56	217.24	2.14
(TS x wcm)	8	70.57	70.57	0.67	
Subplot error	48	636.68	636.68		

Appendix VII (a). Analysis of variance on % weed control (1984)

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	87	23212.88			
Main plots	7	14512.56			
Blocks	3	446.93	148.98		
Tillage system (TS)	1	13981.72	13981.72	499.88	10.13
Main plot error	3	83.91	27.97		
Weed control method (wcm)	10	3457.90	345.79	5.74	1.99
(TS x wcm)	10	1627.57	162.76	2.70	
Subplot error	60	3614.85	60.25		

Appendix VII (b). Analysis of variance on % weed control (1985)

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	87	21080.82			
Main plots	7	14670.07			
Blocks	3	161.70	53.90		
Tillage system (TS)	1	14271.35	14271.35	180.63	10.13
Main plot error	3	237.02	79.01		
Weed control method (wcm)	10	3124.63	312.46	7.88	1.99
(TS x wcm)	10	907.49	90.75	2.29	
Subplot error	60	2378.63	39.64		

Appendix VIII (a). Analysis of variance on bean height (cm) 1984

Source of variation	df	ss	Ms	Observed F	Required F (5%)
Subplots	95	2402.49			
Main plots	7	922.57			
Blocks	3	294.78	98.26		
Tillage system (TS)	1	546.26	546.26	20.13	10.13
Main plot error	3	81.53	27.18		
Weed control method (wcm)	11	569.61	51.78	5.68	1.94
(TS x wcm)	11	308.37	28.03	3.07	
Subplot error	66	601.94	9.12		

Appendix VIII (b). Analysis of variance on bean height (cm) 1985

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	4001.40			
Main plots	7	361.66			
Blocks	3	37.11	12.37		
Tillage system (TS)	1	219.01	219.01	6.23	10.13
Main plot error	3	105.54	35.18		
Weed control method (wcm)	11	2959.53	269.05	33.84	1.94
(TS x wcm)	11	155.61	14.15	1.78	
Subplot error	66	524.60	7.95		

Appendix IX (a). Analysis of variance on number of pods per plant (1984).

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	275.33			
Main plots	7	46.17			
Blocks	3	1.42	0.47		
Tillage system(TS)	1	42.67	42.67	61.84	10.13
Main plot error	3	2.08	0.69		
Weed control method (wcm)	11	123.33	11.21	13.03	1.94
(TS x wcm)	11	49.33	4.48	5.21	
Subplot error	66	56.50	0.86		

Appendix IX (b). Analysis of variance - Number of pods per plant (1985)

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	326.62			
Main plots	7	99.96			
Blocks	3	6.12	2.04		
Tillage system (TS)	1	92.04	92.04	153.4	10.13
Main plot error	3	1.79	0.60		
Weed control method (wcm)	11	100.33	9.12	8.44	1.94
(TS x wcm)	11	55.25	5.02	4.65	
Subplot error	66	71.08	1.08		

Appendix X (a). Analysis of variance on 100 bean seed weight (gm), 1984

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	169.63			
Main plots	7	20.88			
Blocks	3	6.87	2.29		
Tillage system (TS)	1	12.42	12.42	23.43	10.13
Main plot error	3	1.59	0.53		
Weed control method (wcm)	11	53.27	4.84	4.75	1.94
(TS x wcm)	11	28.07	2.55	2.50	
Subplot error	66	67.41	1.02		

Appendix X (b). Analysis of variance on 100 bean seed weight (gm), 1985

Sourse of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	1045.58			
Main plots	7	247.91			
Blocks	3	27.21	9.07		
Tillage system (TS)	1	128.46	128.46	4.18	10.13
Main plot error	3	92.24	30.75		
Weed control method (wcm)	11	149.05	13.55	1.67	1.94
(TS x wcm)	11	112.63	10.24	1.26	
Subplot error	66	535.99	8.12		

Appendix XI (a). Analysis of variance on bean yield (kg/ha), 1984.

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	13731566.96			
Main plots	7	548996.96			
Blocks	3	6998.21	2332.74		
Tillage system (TS)	1	541801.50	541801.5	8240.33	10.13
Main plot error	3	197.25	65.75		
Weed control method (wcm)	11	12905443.46	1173494.86	464.65	1.94
(TS x wcm)	11	107441.0	2525.54		

Appendix XI (b). Analysis of variance on bean yield (kg/ha), 1985.

Source of variation	df	ss	ms	Observed F	Required F (5%)
Subplots	95	32478838.50			
Main plots	7	1323432.0			
Blocks	3	38739.50	12913.17		
Tillage system (TS)	1	1256295.04	1256295.04	132.72	10.13
Main plot error	3	28397.46	9465.82		
Weed control method (wcm)	11	30700644.75	2790967.70	757.0	1.94
(TS x wcm)	11	211428.71	19220.79	5.21	
Subplot error	66	243333.04	3686.86		

Appendix XII (a). Analysis of variance on dry matter yield of weeds (kg/ha) in conventional tillage system, 1984.

Source of variation	df	ss	ms	Observed F	Required F (5%)
Total	54	2718567.53			
Weed spp	4	698614.44	174653.61	6.39	2.61
Herbicides	10	926406.33	92640.63	3.39	2.08
Error	40	1093546.76	27338.67		

Appendix XII (b). Analysis of varance on dry matter yield of weeds (kg/ha) in minimum tillage system, 1984.

Source of variation	df	ss	ms	Observed F	Required F (5%)
Total	54	1688434.44			
Weed spp	4	147912.25	36978.06	1.51	2.61
Herbicides	10	562837.64	56283.76	2.30	2.08
Error	40	977684.55	24442.11		

Appendix XII (c). Analysis of variance on dry matter yield of weeds (kg/ha) in conventional tillage system, 1985.

Source of variation	df	ss	ms	Observed F	Required F (5%)
Total	65	1025368.26			
Weed spp	5	542866.44	108573.20	15.35	2.45
Herbicides	10	128848.42	12884.84	1.82	2.08
Error	50	353653.39	7073.07		

Appendix XIII (d). Analysis of variance on dry matter yield of weeds (kg/ha) in minimum tillage system, 1985.

Source of variation	df	ss	ms	Observed F	Required F (5%)
Total	65	1686534.67			
Weed spp	5	1215134.06	243026.81	30.68	2.45
Herbicides	10	75286.33	7528.63	0.95	2.08
Error	50	396104.27	7922.09		