EFFECT OF METHOD OF STAND ESTABLISHMENT, PRUNING, STAKING AND MULCHING ON YIELD OF TOMATO (*Lycopersicon esculentum* Mill. var. 'Money-Maker')

By

MUNGA, LUVUNO THERESIA

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DECLARATION

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

Date 18/9/91 ---------- Signature ----------

MUNGA LUVUNO THERESIA

This thesis has been submitted for examination with our approval as University supervisors.

Date 18/9/91 ---------- Signature ----------

DR. J.A. CHWEYA
DEPT. OF CROP SCIENCE

Date 18/9/91 ---------- Signature ----------

PROF. KIMANI WAITHAKA
DEPT. OF CROP SCIENCE

DEDICATION

This thesis is dedicated to my dear children

Vicky

and

Ken

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ABSTRACT

Two experiments were conducted between September, 1987 and May, 1988 at the Field Station Vegetable Unit, Faculty of Agriculture, College of Agriculture and Veterinary Sciences, University of Nairobi, to study the effects of method of stand establishment, pruning, staking and mulching on total and marketable yields of tomato (Lycopersicon esculentum Mill.var.'Money-Maker'). The four factors;- stand establishment, pruning, staking and mulching each at two levels were combined factorially and arranged in a Randomized Complete Block Design (RCBD) with three replicates.

Direct seeding 'Money-maker' significantly increased total and marketable yields in both experiments, but fruit weight was not improved significantly. However, pruning significantly reduced marketable and total yields, trusses and fruits per plant but significantly improved fruit weight.

Staking significantly increased total and marketable yields in experiment 2 but did not improve fruit weight. Staking reduced fruit rot. Mulching increased total and marketable yields, fruit weight but the effect was only significant during experiment 2. Mulching reduced percentage unmarketable yield due to fruit rot and cracking.

The interaction between mulching and staking was significant during experiment 2 for total yield. Mulching and staking increased total yield more than mulching and not staking. Also, interaction between method of stand establishment and mulching was significant for total yield in experiment 2. Direct seeding and mulching increased total yield more than transplanting and mulching.

Interaction between method of stand estblishment and staking was significant for marketable yield in experiment 2. Staking and direct seeding significantly increased marketable yield more than transplanting and staking.

INTRODUCTION

The tomato plant (Lycopersicon esculentum Mill.) is a member of the Solanaceae family. Lycopersicon species are indigenous to Peru and Ecuador, but the ancestral form of the cultivated tomato is presumed to have migrated to Mexico, where the plant was first domesticated (Jenkins, 1948). It was suggested that the tomato found its way to East Africa from India by way of Malaysia and Philippines Islands to where it had been carried by the Spaniards in the early 17th Century (Greenway, 1945).

Before the nineteenth century, the tomato was grown as an ornamental plant due to its colourful fruit. As a food, it was avoided because of the toxicity of some members of the Solanaceae family such as mandrake (Mandragora officinarum L.) which contained high quantities of alkaloids. However, after it had been established that the predominant alkaloid in tomatoes was tomatine which is less toxic even at high concentrations, tomatoes became one of the most commonly and widely grown vegetables world wide (Villareal, 1980).

In the temperate regions, transplanting is adopted because seedlings can be raised during unfavourable weather conditions in greenhouses to be transplanted when weather becomes favourable. Also transplanting may be beneficial in areas with short rainfall duration as transplants can be raised in the nursery during the dry period and take advantage of the limited moisture.

In Kenya, it is a recommendation to transplant, prune, stake and mulch fresh market tomatoes. Processing tomatoes are normally not pruned, staked or mulched but may be transplanted. Pruning and staking for fresh market production have been adopted mainly because they ease cultural practices such as spraying, weeding and harvesting (Campbell, 1961). However, where growers do not spray tomato plants against diseases such as late and early blights, pruning is disadvantageous because it creates avenues for pathogen entry, therefore, increasing disease incidence (Tite, 1983). Staking involves extra cost in acquiring the stakes and training the tomato plants but it is not known whether these cultural practices result in a yield increase or are economic to warrant their adoption.

Increasing production cost require that tomato yields be increased. Information on relationship between yield and cultural systems is, therefore, required. There is very little information regarding these cultural practices of tomatoes under Kenyan conditions. Transplanting, staking, pruning and mulching have been suggested to the growers based on results mainly from temperate regions where climatic conditions and methods of production are totally different from those of Kenya.

The objectives were therefore to study the influence of method of stand establishment, pruning, staking, and mulching on total and marketable yield of tomato in an attempt to establish the comparative benefits of these cultural practices under Kenyan conditions.

LITERATURE REVIEW

2.1 Production and Utilization

In the world, tomatoes thrive at many altitudes, under a wide range of soil types, temperatures, daylengths and methods of cultivation. In the tropics, tomatoes are grown both in highland and lowland areas (Villareal, 1980).

Table 1: Tomato production in Kenya.

Region	Area (Hectares)	Production (tonnes)	Yield (tonnes/ha)*
Kiambu	1147.0	22381	19.5
Kirinyaga	480.0	9120	19.0
Kisii	543.0	10860	20.0
Machakos	4249.0	127470	30.0
Muranga	948.0	13324	14.1
Meru	348.6	8510	24.4
Nyeri	522.0	10800	20.7
Siaya	741.0	7410	10.0
South Nyanza	533.0	3588	6.7
Taita	200.0	2,000	10.0

Source: Annual reports of the Provincial Agricultural Officers, Min. of Agric., Nairobi, Kenya, (Anon., 1986).

* Computed data.

In Kenya, tomatoes for fresh market are grown all over the country. However, major producing areas are shown in table 1.

Tomato is a widely grown crop both as a backyard crop as well as a commercial one. Commercial farmers grow it on an individual basis but market it either collectively through a co-operative or individually.

Most of the tomatoes for fresh market are used in preparation of salad and cooked for flavouring sauces. The tomato fruit is not particularly very nutritious (see table 2). However, it can be a major source of vitamins A and C if consumed (Villareal, 1980).

Table 2: Chemical composition of a ripe tomato fruit.

Component	Amount
Water	94.0 %
Protein	1.0 %
Fat	0.1 %
Carbohydrate	4.3 %
Fibre	0.6 %
Vitamin A	250.0 l.u
Ascorbic acid	25 mg/100g

Source: Purseglove (1983). Tropical crops. Dicotyledons. pp.535.

2.2 Method of Stand Establishment

Injury to tomato plants at the time of field transplanting may result in smaller yields due to inhibited plant development (Iverson, 1936). Haber (1941) working with tomato varieties reported that transplanted plants of the 'Harris Early Stone' and 'Indian Baltimore' varieties in the USA produced significantly more tomatoes than those directly seeded. The decrease in yield was because seedlings for transplanted plants were raised in the greenhouse during the unfavourable weather conditions shortening the growing season and fruits ripened during summer. However, because the direct seeded plants were seeded at the onset of summer, fruits started ripening when unfavourable autumn conditions were beginning to set in and hence proper ripening was interrupted, therefore, yield was low.

In central Poland, Skapski and Lipnski (1978) reported that direct seeded tomatoes gave lower yields than transplanted tomatoes. This reduction was attributed to the relatively short growing season and low temperature in September when the direct seeded tomato fruits were starting to ripen. However it should be noted that direct seeding was done when seedlings to be transplanted were already six weeks old. Consequently, Skapski and Lipnski (1978) experiment was designed in such a way that separation of effects of environmental differences and method of planting was not possible. Under temperate conditions in Southwestern Ontario, Liptay, et al., (1982) reported that early yields were significantly lower for the direct sown tomatoes than for the transplanted ones whose seedlings had been started earlier in the greenhouse. Similar results were obtained for total yield although the yields were not statistically different. These effects were due to the fact that the growing season was short and hence by the time direct seeded fruits were starting to ripen, the temperature was too low to allow proper ripening of the fruits.

Under tropical conditions of the Sudan, El-Hassan (1986) reported that direct sowing and transplanting gave equal marketable yield. The direct seeded plants however, gave bigger fruits than transplanted ones. It was also noted that direct planted plants had a lower incidence of leaf curl disease than transplanted plants.

When removing seedlings from the seedbed, the roots may be damaged and when root hairs are damaged or shocked, they stop absorbing water and nutrients for the plant, and the plant growth is slowed down (Vickery and Vickery, 1978). Producing transplants permits the plants to grow during unfavourable weather conditions and production of maximum numbers of plants from costly seeds. However, sterile media and a hardening period is needed (Splittstoesser, 1979).

2.3 Staking and Pruning

Pruning reduces the number of branches and foliage and also number of fruit clusters (Hawthorn, 1939). Magruder (1924) and Currence (1941) indicated that pruning tomato plants tended to increase average fruit weight, promote earliness and reduce total yield of tomatoes. However, Deonier *et al*., (1944) showed that greater total yields were obtained from staked and pruned than from staked and not pruned or not staked and not pruned tomato plants.

In India, Campbell (1961) indicated that neither staking nor pruning were economic methods of growing tomatoes. Chapman and Acland (1965) working with different plant population in Trinidad reported decreased fruit yield with decreasing plant population when tomato plants were staked and pruned. Chapman and Acland (1965) drew attention to the fact that Campbell's (1961) results were related to the use of one population density, while Deonier *et al*., (1944) designed their experiment in a way that separation of effects due to population density and pruning was not possible.

In Sudan, Abdel-Al *et al*., (1971) working with 'Marmande Extra' and 'Money-maker' varieties reported that there were no significant differences in total yield due to different pruning techniques although the pruned plants gave relatively larger fruits than the not pruned ones but the effect was not significant. Under tropical conditions in Nigeria, Adelana (1976) working with two varieties, 'Ife' and 'Pusa Early Dwarf' showed that staking increased marketable yield significantly although differences between staking and not staking for total fruit yield were not significant. Staking prevents the fruits from coming into contact with the wet soil, therefore, reducing fruit rot. Where there is a high incidence of rodent damage, the damage is higher in the not staked plants probably due to easy reach by these pests (Adelana, 1976).

Pruning is disadvantageous because it creates avenues for pathogen entry increasing disease incidence (Tite, 1983). Pruning and staking results in greater loss from blossom-end rot, more sunburn injury to the fruit and greater loss from cracking of the fruit (Thompson and Kelly, 1957). Pruning and staking allow more moisture to escape from the surface of the soil. The not pruned and not staked plants act as a mulch on the soil restricting movement of air and shading the surface so that less moisture is lost by evaporation (Thompson and Kelly, 1957).

In Uganda, Huxley (1962) showed that the yield of staked and pruned tomatoes were much lower than those of not staked and not pruned ones. Also in Uganda, working with different tomato cultivars, Wurster and Nganga (1970) reported that significantly greater total yields were obtained from not pruned and not staked plants than either pruned and staked or not pruned and staked plants. However, pruned and staked plants produced significantly less percentage of defective fruits than not pruned and not staked during the rainy season when foliar diseases were a limiting factor. Quinn (1975) also reported significantly higher marketable yield of staked and not pruned 'Ronita' and 'Piacenza 0164' under wet conditions in Nigeria.

Pruning and staking allows for higher plant population density, increase leaf efficiency in photosynthesis due to improved exposure to sunlight and elimination of the shading effects of branches and leaves resulting in increased yield (Abdel-al et al., 1971). The reported effects of staking and pruning on yield of tomatoes are therefore contradictory.

2.4 Mulching

Geraldson (1962) suggested that plastic mulch conserved soil moisture which made possible the efficient utilization of nitrogen by plants. Under tropical conditions at Samaru, Nigeria, Quinn (1973) working with cultivar 'Harvest' a determinate paste-type, showed no significant differences between mulched and not mulched tomatoes for marketable yield. Percentage marketable yield was, however, lower in the not staked and not mulched treatment than the not staked and mulched ones. Similar trends were observed even when, higher rainfall was received although the yields were lower than before due to wetter conditions which increased soil splash and subsequently fruit rot and foliage diseases (Quinn, 1973). Working with grass and groundnut shells as mulch, Quinn (1975) confirmed that the differences between the mulched and the not mulched treatments for marketable yield was not significant though, marketable yield was higher in the mulched than the not mulched tomato plants. Groundnut shell-mulch was not beneficial under heavy rains because it was washed away. The grass mulch provided a well drained layer for the fruits of the not staked plants to rest on hence reducing fruit rot (Quinn, 1975).

Mulching reduces water loss by evaporation from the soil and, therefore, increasing yields (Jones et al., 1977). Jones and Jones, (1978) using plastic polyethylene mulch showed that the yield of tomatoes was higher during the winter and the effect was highly significant. However, during the dry years the benefit of mulch was diminished due to high temperature build up within the polyethylene plastic mulch.

Organic mulch materials contain minerals and plant nutrients which add to soil fertility. The materials protect plants from harsh temperatures by preventing the hot drying sun and winds from penetrating the soil thus conserving moisture and coolness in hot climates (Vickery and Vickery, 1978). Use of decomposed sugarcane baggase increased total yield, number of flowers per plant and dry matter of tomato plants in Philippines (Famosa and Bautisia, 1983). It was noted that the thicker the mulch the greater the effect from nitrogen application (Famosa and Bautisia, 1983).

Recent studies on benefits of mulching tomatoes have produced inconclusive results. In a study to evaluate the net economic values of eight soil management practices used in staked tomato production in the USA, Estes et al.,

(1985) reported that maximum marketable yields were obtained by using fumigation with straw mulch. Estes *et al*., (1985) noted that the use of straw mulch to control weeds increased fruit yield over standard cultivation practices.

In Sudan, El-Hassan (1986) studying the effects of different types of mulch on the yield and quality of 'Pearson V.F.' variety reported that clear plastic mulch gave higher marketable yield and lower defective fruits than either straw or not mulching, with the not mulched treatment having the lowest marketable yield. Plastic mulch prevents the fruits from coming in contact with wet soil or irrigation water which usually causes fruit rot (El-Hassan, 1986).

MATERIALS AND METHODS

3.1 Site

The two experiments were conducted at the Kabete Campus Field Station Vegetable Unit, Faculty of Agriculture, College of Agriculture and Veterinary Sciences, University of Nairobi. The altitude of the station is approximately 1940 metres above sea level and lies at latitude 1° 15′ S and longitude 36 ° 44′ E.

The rainfall pattern at the station is bimodal with peaks in April and November during the long and short rains, respectively. The average annual rainfall is 1000 mm. The mean monthly maximum and minimum temperatures are 23°C and 12°C, respectively.

Weather data during the experimental period are shown in Appendix 1. The average maximum temperature was 24.6°C and 24.1°C for experiment 1 between September and January and experiment 2 between January and May, respectively. The evaporation rate was higher in experiment 1 than experiment 2. The first experiment was characterized by very low rainfall except for November when 182.1 mm was received. In the second experiment however, the noticeably dry month was February with April having received the highest amount of rainfall (466.6 mm) accompanied with hailstones on second of same month.

The soils at the station as described by Nyandat and Michieka (1970), are dark reddish brown clays. They are deep, well drained and have a fairly higher water holding capacity. Soil structure is blocky. The clay minerals are predominantly kaolin with about 15% illite. The soil properties during the period of the two experiments are shown in Appendix 2. The top soil was slightly acidic averaging pH 5.4 and 5.02 for experiments 1 and 2, respectively.

3.2 Planting Material

Seeds of tomato 'Money-maker' were obtained from the East African Seed Company, Nairobi. Same seedlot was used in both direct seeding treatments, and in raising transplants.

3.3 Treatments and Experimental Design

There were four factors each at two levels:-

a. Method of stand establishment -direct seeding versus transplanting
b. Staking - staking versus not staking
c. Pruning - pruning versus not pruning
d. Mulching - mulching versus not mulching

The four factors were combined in a factorial arrangement to give 16 treatment combinations which were randomly arranged in a randomized complete block design (RCBD) with 3 replicates. Each plot measuring 3 by 4 metres had four rows of tomato plants.

3.3.1 Method of stand establishment

Direct seeding and raising of transplants in the nursery were done concurrently. For direct seeding, six seeds per planting hole were used.

Transplants were raised in an open field nursery where potatoes, brinjals, pepper and cape gooseberries had not been grown in the last three years as recommended by the Ministry of Agriculture (Anon, 1981) because of disease risk. The seeds were sown in drills which were 20 cm apart and about 1 cm deep. This was achieved by covering the seed with fine soil along the drills. Two weeks after emergence, seedlings in the nursery were thinned out to 7 cm apart so as to get sturdy seedlings. Three days before transplanting, watering was withdrawn in order to harden the transplants. The seedlings were transplanted four weeks after emergence. This was the same time the direct seeded plants were thinned. Only healthy and sturdy seedlings were selected for transplanting. Transplanting was done later in the afternoon to minimize transplanting shock. Gaping was done daily for one week following transplanting. The spacing in the field for both direct seeded and transplanted plants was 1 m between and 50 cm within rows as recommended by the Ministry of Agriculture (Anon, 1981).

3.3.2 Staking and pruning

In order to get two stems of uniform size, the tips of the tomato plants to be pruned were nipped off after transplants had established in the experimental plots. Two stems were selected and thereby all other axillary shoots were removed at a weekly interval. Each branch, in all pruned and staked plants, was supported by an individual stake. In not pruned and staked plants, each main branch was tied to its own stake. The axillary branches were tied to the stakes supporting the major branches. The plants were tied to the stakes using sisal twine as growth proceeded.

3.3.3. Mulching

Dry grass mulch composed mainly of Kikuyu grass (Pennisetum clandestinum) which is the most abundantly available grass at the station, was spread uniformly to a depth of 4 cm over the soil surface in the mulched tomato plants a week after transplanting or five weeks after emergence for the direct seeded plots.

3.4 Land Preparation and Fertilization

The land was ploughed and disc harrowed thrice. Prior to marking and laying out the plots, the field was irrigated to further break the clogs that were not broken by harrowing. In order to achieve a fine seedbed, plots where the seeds were to be directly sown were raked.

For direct seeded plots, each planting hole received 6.8 g of di-ammonium phosphate (18% N, 46% P_2O_5) at sowing time. In the nursery, 1 kg/m^2 of diammonium phosphate was incorporated during seedbed preparation. At transplanting time, each transplant received 6.8g DAP. Four weeks after transplanting, all plots were top dressed with calcium ammonium nitrate (26% N) at a rate of 100 kg CAN/ha.

3.5 Other Routine Cultural Practices

In the early stages of plant growth, weeds in the directly sown plants were pulled by hand as they emerged. Later, weeding was done using both forked 'jembes' and 'pangas' at two weeks interval because of high incidence of nutgrass until the not staked tomato plants formed a canopy over the ground. Cultivation to control weeds was then suspended and weeds were subsequently controlled by hand pulling.

Moles, rats, cutworms and birds were the most threatening pests of tomatoes at Field station. Moles,rats and birds were not controlled, because their effects on yield were to be assessed. Cutworms were controlled using Furadan at a rate of 2 g per planting hole. Fruits were sprayed with Rogor-L at a rate of 14 ml per 20 litres of water every fortnight to control the American bollworms (*Heliothis armigera*).

Disease incidences were high during the experimental period especially during experiment 2 and a strict spraying regime was observed. Benlate at a rate of 1 g/litre (water) was sprayed biweekly during the dry weather and weekly during rainy season to prevent attack by early and late blights caused by *Alternaria solani* and *Phytophthora infestans*, respectively.

The first trial was sprinkler-irrigated. Watering was done every other day until seeds emerged both in the field and nursery. Prior to field transplanting, the experimental site was thoroughly irrigated. Immediately after transplanting, the field was again irrigated. Watering continued on daily basis until transplants were fully established in the field. The field was sprinkler-irrigated whenever the plants showed slight signs of water stress. The second experiment was partially irrigated whenever it was necessary but after flowering the rainfall was sufficient and, therefore, irrigation was unnecessary.

3.6 <u>Data Collection</u>

3.6.1 Soil sampling

Four random samples of soil were taken from the experimental site at 0 - 15cm depth after marking the experimental plots. The soil samples were air dried, and sieved using a two millimetre sieve. The sieved fraction was used to analyse for total nitrogen, organic carbon and pH (using potassium chloride) as described in the analytical methods used in Soil Science Department, Faculty of Agriculture, University of Nairobi (Ahn, 1975). Soil analytical data is presented in appendix 2.

3.6.2 Weather data

Weather data was collected from the Agro-meteorological station Kabete for the months of September 1987 upto May, 1988 and is presented in Appendix 1.

3.6.3 Total yield

Ten plants per treatment were randomly selected and tagged using small sisal strings tied at the base of the stems for the not staked tomato plants. Half to full ripe fruits were harvested from tagged plants twice a week on every four days. All fruits harvested from tagged tomato plants were put in polyethylene bags and weighed. The total weight from the ten plants was converted to total yield in tonnes per hectare. Harvested tomato fruits were sorted out to marketable and unmarketable fruits after taking the total yield.

3.6.4 Marketable yield

Marketable fruits, were fruits of good quality in firmness with no blemishes. Fruits graded as marketable were weighed and recorded. The total marketable weight from ten plants was used to calculate marketable yield in tonnes per hectare.

3.6.5 Unmarketable fruits

Unmarketable fruits were further sorted out into the following components:

a) Sun-scalded: these were fruits with whitish areas appearing on the exposed surface.

b) Fruits eaten by rodents (moles and rats): mainly the half-ripe fruits.

c) Fruits eaten by birds: mainly full ripe tomatoes.

d) Fruit with rot: were fruits which showed signs of rotting either from blossom-end rot or other rots.

Total weight of fruits for each category of unmarketable fruits was summed up at the end of the experiments. Total weight for unmarketable fruits was used to calculate percentage unmarketable fruits based on total yield of each treatment.

3.6.6 Number of trusses and fruits per plant

After the final harvest all tagged plants were uprooted and number of fruit clusters per plant was counted. Number of fruits per plant was obtained by counting the number of pedicel on each truss.

3.6.7 Fruit weight

Fruit weight was measured in grammes per fruit from the marketable fruits. Five fruits from each sampling plants were randomly selected and weighed after sorting. The mean fruit weight was obtained by averaging the weekly mean fruit weights after the final harvest.

3.7 <u>Data Analysis</u>

Analysis of variance was computed for number of trusses and fruits per plant, fruit weight, marketable and total yield with respect to direct seeding, transplanting, staking and pruning. Means were separated using Modified Duncan's Multiple Range Test at 5% probability level (Gomez and Gomez, 1984).

RESULTS

4.1 Number of Trusses and Fruits Per Plant

The influence of method of stand establishment on number of trusses and fruits per plant was not significant in both experiments. However, the effect of pruning on the number of trusses and fruits per plant was highly significant in both experiments (Table 3). Pruning significantly reduced number of trusses and fruits per plant. The effect of staking on number of trusses and fruits per plant was not significant in both experiments. Mulching effect on number of trusses per plant was not significant in experiment 1. However, the influence of mulching on number of fruits per plant was significant in experiment 2. Mulched plants gave significantly more fruits per plant than the not mulched ones.

Table 3 shows that the number of trusses and fruits per plant in experiment 1 were significantly more than they were in experiment 2.

There were no significant interactions between method of stand establishment, pruning, staking and mulching on number of trusses and fruits per plant in both experiments.

4.2 Fruit Weight

There was a significant effect of method of stand establishment on fruit weight in experiment 1 but not in experiment 2 (Table 4). Direct seeded plants gave significantly heavier fruits than transplanted ones in the

Table 3: Effect of method of stand establishment, pruning, staking and mulching on number of trusses and fruits per plant.

Treatments	Trusses		Number of fruits	
	Exp*. 1	Exp. 2	Exp. 1	Exp. 2
Direct seeded	18.0a**	11.0b	93.0a	41.0a
Transplanted	17.0a	11.0b	85.0a	35.0a
Pruned	10.0b	8.0b	60.0b	28.0b
Not pruned	25.0a	14.0a	118.0a	48.0a
Staked	17.0a	11.0a	87.0a	38.0a
Not staked	18.0a	11.0a	91.0a	38.0a
Mulched	17.0a	12.0a	87.0a	42.0a
Not mulched	18.0a	10.0a	91.0a	34.0a
S.E	0.9	1.2	5.4	6.0

Exp*.= Experiment;

** Means followed by same letter down the column within each treatment are not significant according to the F-test) P < 0.05)

Table 4: Influence of method of stand establishment, pruning, staking and mulching on fruit weight.

Treatments	Fruit weight (g/fruit) Experiment 1	Experiment 2
Direct seeded	50.3a	64.0a
Transplanted	46.5b	64.0a
Pruned	50.3a	65.0a
Not pruned	46.5b	63.0a
Staked	48.1a	63.9a
Not staked	48.7a	63.1a
Mulched	49.1a	64.4a
Not mulched	47.7a	62.1b
S.E	0.99	1.48

Means with same letter down the column within each treatment are not significant according to the F-test ($P < 0.05$).

experiment 1. Pruning had a significant effect on fruit weight in both experiments. Table 4 shows that pruning significantly improved fruit weight.

Staking effect on fruit weight was not significant (Table 4) but the influence of mulching on fruit weight was significant in experiment 2 only. Table 4 shows that mulched plants gave significantly heavier fruits than the not mulched ones.

Generally, the seasonal effect on fruit weight as affected by method of stand establishment, pruning, staking and mulching was highly significant. Fruits were significantly heavier in experiment 2 than in experiment 1 (Table 4) but interactions between the factors studied were not significant in both experiments for fruit weight.

4.3 Yield

The influence of method of stand establishment was significant for both total and marketable yields in both experiments. Table 5 shows that direct seeding resulted in significantly higher total and marketable yields than transplanting. Transplanting tended to reduce the amount of unmarketable fruits in both experiments. The data reported in Table 5 suggest that the percentage marketable yield was almost similar for direct seeded and transplanted plants. Direct seeded plants gave 98.43 and 72.93 while transplanted plants had 98.03 and 71.13 percentage marketable yield for experiment 1 and 2, respectively.

Table 5: The effect of method of stand establishment, pruning, staking and mulching on yield (Tonnes/ha).

	Yield (Tonnes/ha).					
	Experiment 1			Experiment Two		
Treatment	Total	Market-able	unmark-etable	Total	Market-able	Unmarketable
Direct seeded	73.06a	71.91a	1.15a	50.86b	37.09d	13.77a
Transplanted	57.49b	56.51b	0.98a	22.76b	16.19c	6.57b
Pruned	44.21b	43.51b	0.70b	28.64b	19.17b	9.47a
Not pruned	86.34a	84.34a	1.43b	44.99a	34.11a	10.88a
Staked	65.31a	64.04a	1.27a	39.10a	30.00a	9.10b
Not staked	65.24a	64.38a	0.86a	34.52b	23.28b	11.24a
Mulched	69.40a	68.28a	1.12a	41.50a	32.51a	8.99b
Not mulched	61.20a	60.14a	1.06a	32.20b	20.77b	11.43a
S.E	3.36	3.34		1.06	1.05	

Means with same letter down the column within each treatment are not significant according to the F-test ($P < 0.05$)

Pruning effect on total and marketable yield was highly significant in both experiments. Table 5 shows that pruning significantly reduced total and marketable yields. Data presented in Table 5 also indicate that pruning significantly reduced the amount of unmarketable yield. Percentage marketable yield was not affected by pruning in experiment 1.

However, in experiment 2 plants that were not pruned tended to give a higher (75.8%) percentage of marketable yield than those that were not pruned which gave 66.9% of the marketable yield. The effect of staking on total and marketable yields was not significant in the first experiment but was in the second experiment. Table 5 shows that in the second experiment, total and marketable yields were significantly increased by 11 and 22.4%, respectively by staking. However, marketable yield was slightly reduced by staking in the first experiment.

The influence of mulching on total and marketable yields was significant in experiment 2 but not in 1. Data reported in table 5 show that total and marketable yields were significantly increased by mulching in experiment 2.

Seasonal effects on total and marketable yields were highly significant. Table 5 shows that there were significantly more total and marketable yields in experiment 1 than in experiment 2.

Interactions between method of stand establishment, pruning, staking and mulching on total yield were not significant. However, interaction between staking and mulching on total yield was significant in experiment 2. Table 6 shows that staking and mulching tomato plants significantly gave higher total yield than mulching alone. Staking and not mulching was not significantly different from not staking and not mulching. Interaction between method of stand establishment and mulching was also significant in experiment 2 only. Table 7 shows that mulching and direct seeding significantly increased total yield than either not mulching and direct seeding or mulching and transplanting. However, there was no significant difference between transplanting and mulching and transplanting and not mulching.

Interactions between method of stand establishment, pruning, staking and mulching on marketable yield was not significant in both experiments. However, the interaction between method of stand establishment and staking on marketable yield was significant in experiment 2. Staking and direct seeding increased marketable yield significantly than staking and transplanting, transplanting and not staking and direct seeding and not staking (Table 8). The treatment combinations effects on total and marketable yields were significant in both experiments. Tables 9 and 10 give the effects of the 16 treatment combinations on total and marketable yield for experiment 1 and 2 respectively. Mulching, staking, direct seeding and not pruning was the best treatment combination for total and marketable yields in both experiments. Table 9 shows that

Table 6: Interaction between staking and mulching on total yield (tonnes/ha). Experiment 2.

		Mulched	Not mulched	Means
Staked		45.53a*	32.68c	39.10
Not staked		37.55b	31.50c	34.52
Means		41.54	32.09	
SE	Interaction	1.50		
SE	Mulching	1.05		
SE	Staking	1.05		

Table 7: Interaction between method of stand establishment and mulching on total yield (tonnes/ha). Experiment 2.

	Direct seeded	Transplanted	means
Mulched	59.23a	23.78c	41.51
Not mulched	42.43b	21.74c	32.09
Means	50.33	22.76	
SE Interaction	1.50		
SE Method of planting	1.05		
SE Mulching	1.05		

*Means followed by same letter(s) are not significant according to Duncan's New Multiple Range Test.

Table 8: Interaction between method of stand establishment and staking on marketable yield (tonnes/ha). Experiment 2.

	Staked	Not staked	Means
Direct seeded	42.54a*	31.64b	37.09
Transplanted	7.47c	14.92c	16.19
SE Interaction	1.48		
SE Staking	3.34		
SE Method of planting	3.34		

*Means followed by same letter(s) are not significant according to Duncan's New Multiple Range Test.

Table 9: Effect of method of stand establishment, pruning, staking and mulching on total and marketable yield (tonnes/ha). Experiment 1.

Treatments	Yield (Tonnes/ha) Total	Marketable
Mulched, staked, direct seeded, Not pruned	101.92 a*	100.39 a
Not mulched, staked, direct seeded, Not pruned	99.05 ab	97.25 ab
Mulched, Not staked, direct seeded, Not pruned	99.48 ab	98.08 ab
Mulched, Not staked, transplanted, Not pruned	88.02 abc	87.02 ab
Not mulched,Not staked,direct seeded,Not pruned	88.02 abc	81.79 abc
Mulched, staked, transplanted, Not pruned	77.24 abcd	75.55 abcd
Not mulched, staked, transplanted, not pruned	71.99 abcde	70.08 abcde
Not mulched, Not staked, transplanted Not pruned	69.99 bcde	69.09 abcde
Mulched, staked, direct seeded, pruned	54.29 cdef	53.07 cdef
Mulched, Not staked, direct seeded, pruned	51.00 def	50.42 def
Not mulched, Not staked, direct seeded, pruned	49.74 def	49.00 def
Not mulched, staked, direct seeded, prune	45.97 def	45.32 def
Mulched, Not staked, transplanted, pruned	44.53 ef	43.83 ef
Mulched, staked, transplanted, pruned	38.56 f	37.86 f
Not mulched, Not staked, transplanted, pruned	36.13 f	35.79 f
Not mulched, staked, transplanted, pruned	33.48 f	32.83 f
S.E	9.51	9.46

*Means with the same letters within a column are not significant (P<0.05) according to Duncan's New Multiple range test.

Table 10: Effect of method of stand establishment, pruning, staking and mulching on total and marketable yield (tonnes/ha) Experiment 2.

	Total yield	Marketable yield
Mulched, staked, direct seeded, not pruned	75.08 a	63.71 a
Mulched, not staked, direct seeded, not pruned	61.88 b	48.90 b
Not mulched, staked, direct seeded, not pruned	57.56 b	45.28 b
Mulched, staked, direct seeded, pruned	54.34 bc	41.04 b
Not mulched, not staked, direct seeded, not pruned	48.06 c	31.09 c
Mulched, not staked, direct seeded, pruned	45.89 c	31.53 c
Not mulched, not staked, direct seeded, pruned	33.70 d	15.02 efg
Mulched, staked, transplanted, not pruned	31.89 d	25.09 cd
Not mulched, staked, direct seeded, pruned	30.40 de	20.14 de
Not mulched, not staked, transplanted, not pruned	30.26 de	18.35 def
Not mulched, staked, transplanted, not pruned	27.51 de	18.63 def
Mulched, not staked, transplanted, not pruned	26.67 de	21.86 d
Mulched, staked, transplanted, pruned	20.82 ef	16.69 defg
Not mulched, staked, transplanted, pruned	15.22 f	9.46 fg
Mulched, not staked, transplanted, pruned	14.75 f	11.28 efg
Not mulched, not staked, transplanted, pruned	13.98 f	8.18 g
S.E	3.00	2.95

*Means with same letter(s) within a column are not significant (P<0.05) according to Duncan's New Multiple Range Test.

in experiment 1 the worst treatments for total and marketable yields were those that included pruning. However, in experiment 2 the worst treatment combinations were those in which plants were pruned and transplanted (Table 10). Table 10 also indicates that the not mulched, not staked, direct seeded and pruned plants gave very low marketable yield.

4.4. Percentage composition of unmarketable yield

The percentage composition of unmarketable yield for experiments 1 and 2 respectively, is shown in table 11. Direct seeding resulted in plants having a higher percentage of unmarketable yield as a result of fruit rot, bird and rodent damages but a lower percentage due to sun scalding than transplanting in experiment 1. In experiment 2, transplanted plants had higher percentage of unmarketable yield due to fruit rot and bird damage but lower percentage of cracked fruits than direct seeded plants.

Not pruning increased the percentage of unmarketable fruits due to bird damage in both experiments. Percentage unmarketable fruits due to fruit rot was lowered by staking. Bird damage was increased by staking. Not staking increased unmarketable yield percentage due to rodent damage.

Mulching reduced the percentage unmarketable yield as a result of fruit rot. Percentage unmarketable yield due to

Table 11: Effect of method of stand establishment, pruning,staking and mulching on percentage composition of unmarketable yield.

Treatments	Percentage composition of unmarketable yield						
	Experiment 1.				Experiment 2.		
	Fruit rot	Birds damage	Rodents damage	Sun scalded	Fruit rot	Birds damage	Cracked fruits
Direct seeded	13.04	54.52	11.65	20.79	34.31	12.30	53.39
Transplanted	9.79	46.33	16.02	27.86	49.45	12.38	38.17
Pruned	14.00	42.42	14.57	29.01	43.68	8.20	48.12
Not pruned	10.34	54.90	13.21	21.55	35.36	15.90	48.74
Staked	7.40	62.36	7.48	22.76	34.57	18.19	47.24
Not staked	17.47	33.33	22.52	26.68	42.95	7.58	49.47
Mulched	9.55	15.35	53.92	21.18	37.13	15.50	47.37
Not mulched	13.11	11.22	45.09	30.58	58.75	9.74	49.01

birds and rodents damage was higher in mulched plants than in the not mulched ones. Mulched plants had lower percentage of sun-scalded and cracked fruits than the not mulched ones.

There was no data on cracked fruits during the first experiment because the tomato plants were raised under irrigation and therefore moisture fluctuations were minimized. There were no incidences of rodent damaged fruit in experiment 2 since the experimental area was surrounded by cultivated fields unlike in experiment 1 where it was bordered by fallow land on two sides.

DISCUSSION

5.1 Method of stand establishment

The influence of method of stand establishment on number of trusses and fruits per plant was not significant although there were more fruits per plant in the direct seeded plants than in the transplanted plants.

Direct seeded plants gave significantly heavier fruits in experiment 1 and higher total and marketable yields in both experiments than transplanted plants. El-Hassan (1986) had also reported that direct seeded plants gave heavier fruits than transplanted ones. This was contradictory to the findings of Skapski and Lipnski (1978) and Liptay et al., (1982). It should be noted however, that in Skapski and Lipnski (1978) experiment, transplants were six weeks old when the tomato seeds were direct seeded in the field. Consequently, their experiment was designed such that separation of environmental effect and method of stand establishment was not possible. The reduction in total and marketable yields was probably due to transplanting shock which may have caused check of growth (Iverson, 1936) resulting in less fruits per plant as was observed in the study. Direct planted plants had continuous growth.

5.2 Pruning

Significantly less number of trusses and fruits per plant were obtained by pruning. Similar results were obtained by Hawthorn (1939) who noted that pruning reduced the number of branches. Fruit clusters are borne on the internodes of branches and therefore reduced fruit clusters and fruits per plant would be expected in the pruned plants.

Pruning significantly improved fruit weight in both experiments. Magruder (1924) and Currence (1941) reported similar findings. Pruning reduces the number of trusses and fruits per plant (Hawthorn, 1939) probably, therefore reducing competition for photosynthates between clusters and fruits. This may lead to heavier fruits.

Significantly low total and marketable yields were obtained from the pruned plants. Currence (1941) reported similar results. This could have been due to limitation of growth (Jones and Rosa, 1928), reduced number of branches (Hawthorn, 1939) and therefore reduced number of trusses and fruits per plant as has been reported above. Furthermore during pruning plants were nipped therefore limiting growth. This could have further reduced yield.

5.3 Staking

Staking did not significantly increase number of trusses and fruits per plant. This was not expected because the main effect of staking on yield is to improve fruit quality (Adelana, 1976). Total yield was significantly increased in experiment 2 by staking. Abdel-al, et al. (1971) also reported increased total yield by staking. Staking increases leaf efficiency in photosynthesis due to improved exposure of plant leaves to sunlight and elimination of shading effects of branches and leaves (Abdel-Al et al., 1971). Furthermore, since cell division and enlargement depends on imported photosynthates, increased growth is expected and hence the increased total yield.

Marketable yield was significantly increased by staking in experiment 2 but not in 1. Staking significantly increased marketable yield in experiment 2 which was characterized by high rainfall accompanied by hailstones after fruit set. Quinn (1973) reported similar results under wet conditions. Staking prevents tomato fruits from coming into contact with wet soil (Adelana, 1976) and, therefore, reducing the percentage unmarketable yield due to fruit rot (Campbell, 1961) as was also observed in this study. The insignificant effect of staking on marketable yield in experiment 1 could have been due to the fact that tomatoes were raised under irrigation and there was less damage resulting from fruit rot.

5.4 Mulching

Mulching significantly increased number of fruits per plant, total and marketable yields and it improved fruit weight especially in experiment 2. This could probably be because of the ability of organic mulch to control weeds (Estes, et al., 1985) and conserve soil moisture (Chapman and Acland, 1965). The improvement may also be attributed to the effects of mulching on nitrogen availability (Famosa and Bautisia, 1983) and possibly to reduced competition for soil nutrients through reduced weed competition (Estes et al., 1985) and moisture loss (Vickery and Vickery, 1978). Organic mulch materials contain minerals and plant nutrients which add to soil fertility when rain water washes some nutrients from the mulch into the soil (Vickery and Vickery, 1978). This could have also increased the total yield observed. Mulching is beneficial to plant growth (Van Doren et al, 1973).

Mulching also significantly increased marketable yield. Grass mulch may have provided a well drained layer for fruits of the not staked plants to rest on (Quinn, 1975) and, therefore, reduced fruit loss due to rotting. Percentage unmarketable yield attributed to rodent damage was higher in mulched plants than in the not mulched ones. This could have been so because rodents could have easily hidden in the mulch. Organic mulch materials protect plants from harsh temperatures by stopping the hot drying sun and wind from penetrating the soil thus conserving moisture and reducing moisture fluctuations (Vickery and Vickery, 1978) hence reducing percentage unmarketable yield due to fruit cracking.

5.5 Interactions

Interaction between staking and mulching was significant in experiment 2. Mulching and staking outyielded mulching and not staking. This could have been due to increased efficiency in photosynthesis (Abdel-Al *et al.*, 1971) and positive mulching effects as has been discussed above (Vickery and Vickery 1978).

The interaction between method of stand establishment and mulching was significant in experiment 2. Direct seeding and mulching significantly increased total yield more than direct seeding and not mulching, transplanting and mulching, and transplanting and not mulching. This was probably because of transplanting shock that may have checked growth in transplanted plants (Iverson, 1939). The transplanting shock was too great to be offset by the benefits of organic mulch on soil fertility (Vickery and Vickery, 1978) and reduced weed competition (Estes *et al.*, 1985).

Interaction between method of stand establishment and staking was significant for marketable yield in experiment 2. Staking and direct seeding significantly gave higher marketable yield than staking and transplanting, not staking and transplanting or not staking and direct seeding. The effects of staking in reducing fruit rot and the unchecked growth may have contributed to the observed results .

There were more total and marketable yields in experiment 1 than in experiment 2. Reasons for this include damage of the hailstones received after fruit set in experiment 2 in which damage caused on the tomato plants increased incidences of early and late blights of the tomato plants.

6.0 CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH

6.1 Conclusions

Direct seeding 'Money-maker' variety increased total and marketable yields and improved fruit weight. However, pruning reduced total and marketable yield but improved fruit weight in both experiments.

When variety 'Money-maker' was raised during the dry season under controlled irrigation, staking did not significantly increase total and marketable yields. However, staking increased percentage of bird damaged fruits. Staking increased total and marketable yields and reduced rodent damage during the rainy season.

Mulching 'Money-maker' tomato plants was beneficial but much more so during the wet conditions. Mulching improved fruit quality. Mulching also reduced percentage unmarketable yield due to fruit cracking and rotting but increased percentage unmarketable yield attributed to rodent damage.

In the experiment 2, mulching and staking, mulching and direct seeding increased total yield whereas direct seeding and staking increased marketable yield.

There was more total and marketable yields when tomato plants were raised during the dry season under irrigation in experiment 1 than when raised under rainfed conditions in experiment 2.

6.2 Recommendations

The most important concern of any tomato grower is to achieve better quality fruits in order to fetch highest market prices. On the basis of results obtained during this study, it is recommended that farmers adopt direct seeding of tomato plants. Sixty grammes of seeds will provide sufficient plants for one hectare if tomato plants are transplanted (George, 1985). Using six seeds per hole required 300 g of seeds. Since direct seeding increased marketable yield and improved fruit weight which plays a major role in price determination in most markets, the extra seed cost of 240 g/ha may be compensated for.

Pruning involves extra labour and drastically reduced yield in this study. Therefore, farmers can grow 'Moneymaker' tomato variety without pruning.

Staking significantly increased marketable yield under wet conditions. These results suggest that staking will be beneficial under wet conditions and where incidence of rodents are high. Again, staking may be necessary even during the dry season, where there is the possibility of fruit being infected with soil borne diseases which cause rotting.

Mulching significantly increased marketable yield especially in experiment 2. Organic mulch materials could be used in dry seasons to help in moisture conservation and in wet seasons to reduce fruit loss by fruit rot and cracking.

Direct seeding and staking are recommended for production of higher marketable yield under rainy seasons. Tomato plants should be given supplemental irrigation for maximum marketable yield when soil moisture is insufficient.

6.3 Further research work

1. Mulching increased marketable yield. Work may be done to study the effect of time of mulch application on fruit quality.
2. Use of transplants resulted in lower yield, therefore, studies may be carried out to find the effect of raising seedlings in containers, like speedling trays or soil blocks on yield.
3. The effect of pruning may be studied with increasing plant population.
4. The effects of method of stand establishment, pruning, staking and mulching could be studied with different tomato varieties.

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APPENDICES

Appendix 1: Weather data between September 1987 and May 1988 (Agromet Station, Kabete).

Temperature °C Month	Evaporation Max	Rainfall Min	Rate	mm/day (mm)
September	24.8	12.1	4.6	17.4
October	25.8	13.2	5.3	5.7
November	23.6	14.0	4.2	182.1
December	23.8	13.4	4.6	15.3
January	25.1	14.0	3.6	96.2
February	25.8	13.4	5.8	20.5
March	23.8	14.6	4.7	172.0
April	23.5	14.7	4.3	466.6
May	22.3	13.9	3.2	245.9

Appendix 2: Some soil chemical properties before planting

Nutrient/Soil Reaction	Experiment 1	Experiment 2
pH (Potassium chloride)	5.40	5.02
Total Nitrogen (ug/g soil)	343.0	327.6
% Carbon	2.11	1.79

Appendix 3: Summary of ANOVA Tables for fruit weight

Source of variation	df	MEAN SUM OF SQUARES Experiment 1	Experiment 2
Replication	2	5.90	68.40*
A	1	30.70	123.50*
B	1	5.10	0.02
AB	1	9.00	13.02
C	1	164.30**	1.02
AC	1	15.40	0.19
BC	1	14.20	7.52
ABC	1	3.20	0.02
D	1	164.30**	88.02**
AD	1	15.40	6.02
BD	1	14.20	2.52
ABD	1	32.73	0.52
CD	1	8.70	0.18
ACD	1	5.70	0.02
BCD	1	4.20	0.02
ABCD	1	42.50	9.19
Error	30	13.6	6.53

** Significant at ($p<0.01$) and ($p<.05$)

* Significant at ($p<0.05$)

A - Mulching

B - Staking

C - Method of stand establishment

P - Pruning

Appendix 4: Summary of ANOVA Tables for marketable yield

Source of variation	df	MEAN SUM OF SQUARES Experiment 1	Experiment 2
Replication	2	296270156.3	456734240.1
A	1	793683205.3	1655316764.2**
B	1	1358114.1	542992633.1**
AB	1	93158268.8	27337945.9
C	1	2849000833.3*	5239143095.4**
AC	1	11603333.3	533613357.1**
BC	1	244812366.8	209210927.9**
ABC	1	14007602.1	815210.8
D	1	20561899985.3**	2679758052.1**
AD	1	79495416.3	427329.3
BD	1	55715370.8	23459255.1
ABD	1	156970566.8	4634410.8
CD	1	149629656.3	345656288.9**
ACD	1	800.3	124786.4
BCD	1	77576760.1	57926524.8
ABCD	1	18842614.1	1261142.1
Error	30	26851725.2	26451264.5

** Significant at (P<0.01) and (P<0.5)

* Significant at (P<0.05)

A-Pruning

B-Staking

C-Method of stand establishment

D-Pruning

Appendix 5: Summary of ANOVA Tables for Total Yield

Source of variation	df	MEAN SUM OF SQUARES Experiment 1	Experiment 2
Replication	2	265677398.4**	555139766.7**
A	1	808437084.9	1071788727.1**
B	1	63495.9	251645354.4**
AB	1	96027001.7	139146685.6*
C	1	2908286054.1**	9476365134.8**
AC	1	11585440.5	659601374.2**
BC	1	235065759.1	68096139.4
ABC	1	17212622.1	2428700.8
D	1	21296049597.3**	3208641769.6**
AD	1	71711355.5	16459332.7
BD	1	661422683.1	25725115.2
ABD	1	170011587.4	6569717.9
CD	1	146425850.8	123729434.8*
ACD	1	782.4	10466.3
BCD	1	6845485.2	102508426.2
ABCD	1	23520284.4	19428777.3
Error	30	27436286.2	27004159.3

** Significant at ($P < 0.01$) and ($P < 0.5$)

* Significant at ($P < 0.5$).

A - Mulching

B - Staking

C - Method of stand establishment

D - Pruning