TOMATO DEVELOPMENT AND RESEARCH IN THE SOUTHERN HIGHLANDS OF TANZANIA

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ABSTRACT

In the Southern Highlands of Tanzania, fresh market tomatoes are produced throughout the year but production constraints and poor management practices limit the yields. Increases in production will depend on access to improved varieties and the use of recommended cultural practices. Tomato research at Uyole Agricultural Centre (UAC) has been directed towards variety evaluation for good yield potential and wider adaptation. Research on the effects of fertilization, spacing and plant population has also been done. On the basis of this research, recommendations have been developed to optimize economic yield. In future, research in UAC's tomato programme will be directed towards the breeding of high yielding disease-resistant varieties, the development of integrated management techniques to relieve production constraints, and improvements in fruit quality.

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is the most important vegetable crop in Tanzania. Tomatoes are produced for home consumption in home gardens and the excess crop is sold mainly to nearby markets or on roadside stands. Where reliable market and quick transport are available, for example on the periphery of small towns and major highways, market gardens exist.

Because of the subsistence nature of production and the unorganized marketing system, there are no reliable data on yields and the area under production. FAO (1988) estimated the total production at 1,800 t per year and the area under production at 2,000 ha. Yields of tomato in Tanzania are poor. Estimated yields range between 7.5 and 8 t ha^{-1} (FAO, 1988). Production is held down by biotic, abiotic and institutional constraints.

The emphasis in tomato research is to intensify activities that promote high yield and quality. Tomato research at Uyole Agricultural Centre (UAC) began in 1974 with the aim of developing improved and adaptive cultivars for the Southern Highlands and providing a package of recommendations on cultural practices. Emphasis was given to variety testing for high yield, and to fertilization, spacing and plant population experiments.

This paper reviews past research achievements and present constraints, suggests a sequence of priorities for the introduction of innovations to farmers, and proposes strategies for future research.

RESEARCH REVIEW

Variety evaluation

As a result of research at UAC, five high yielding cultivars have been identified (Table 1). Of these, Moneymaker, Monprecoss and Marglobe are now widely cultivated in the Southern Highlands. Moneymaker and Monprecoss cultivars consistently yield well (above 50 t ha^{-1}), in both the wet and dry seasons, although protection against late blight is necessary during the rainy season (Nsemwa, 1981; Jakobsen, 1975). Marglobe is the most susceptible to late blight, so it is grown during the dry season. The other two cultivars, Floradel CFS and Marmande, are grown only in limited quantity.

Table 1. The yield (t ha^{-1}), fruit weight (g) and fruit set of five tomato cultivars in the Southern Highlands of Tanzania, (means of six years and three sites)

	Yield	Fruit weight	Fruit set[1]
Floradel CFS	31.0	101	2.1
Moneymaker	53.7	63	4.1
Monprecoss	51.9	65	4.1
Marmande	33.6	96	3.0
Marglobe	28.0	92	2.5

[1]Scored as follows: 1 = poor, 2 = poor/moderate, 3 = moderate, 4 = moderate/heavy, and 5 = heavy.

Attempts to identify useful hybrids, carried out between 1983 and 1985, gave disappointing results. Fruit set in the hybrids was poor, they were susceptibile to late blight, and there were problems with obtaining seeds (Table 2). Subsequent testing was restricted to open-pollinated cultivars, several of which yielded significantly better than Moneymaker and Monprecoss. Promising lines from the Asian Vegetable Research and Development Centre (AVRDC), yielding more than 60 t ha^{-1}, have been obtained and these have shown a combination of high yield, good adaptation and other desirable traits when grown at UAC (Tables 3 and 4). Lines and cultivars such as Caraibo and Romitel, which can be grown without the need for staking, have produced quite good yields (Table 4).

Table 2. The yield (t ha^{-1}), fruit weight (g) and fruit set of five hybrid tomatoes, compared with Moneymaker at Uyole Agricultural Centre, 1983-1985 (mean annual rainfall over the period, 1057 mm)

	Yield	Fruit weight	Fruit set[1]
Granada	58.0	162	2.5
Fiesta	43.9	182	2.0
Marca	54.8	173	2.5
Dombo	29.7	253	2.0
Dombito	38.6	179	2.0
Moneymaker	81.0	66	4.5

[1]Fruit set scored as in Table 1.

Table 3. The yield (t ha^{-1}), fruit weight (g) and fruit set of nine indeterminate AVRDC tomato lines over two seasons (1990-1991) at Uyole Agricultural Centre (mean annual rainfall over the period, 793 mm)

	Yield	Fruit weight	Fruit set[1]
CLN95-244 D4-1-1-0	48.8	50.0	4.0
CL5915 - 39 D4-1-2-0-1-0	51.8	77.3	4.0
CLN229 B1F2-4-1-4-4	72.7	66.5	4.5
CL5915-206 D4-2-5-0	69.6	104.3	3.0
CL5915-206 D4-2-1-0	97.8	55.9	4.5
CL5915-39 D4-1-2-0	79.3	71.8	3.0
FMTT 94	28.5	65.0	3.0
FMTT 138	25.8	73.5	3.0
FMTT 22	31.8	72.8	3.0

[1]Fruit set scored as in Table 1.

Table 4. The yield (t ha^{-1}), fruit weight (g) and fruit set of two cultivars and seven determinate AVRDC tomato lines at Uyole Agricultural Centre (1990-1991)

	Yield	Fruit weight	Fruit set[1]
CLN65-349 D5-2-06	41.9	50.5	3.0
CL5915-93- D4-1-0-C-1	52.0	74.5	3.0
CL8d -0-7-1	60.0	41.8	3.5
CLN236 B1F2-26-3-3-15	50.9	54.4	3.0
CL2729-0-2-1-12	44.1	33.2	3.0
CL5915-93D4-1-0-12	31.4	45.2	3.0
CLN698 B9F2 - 3578-4-13	39.7	59.2	2.5
Romitel	39.6	60.6	3.0
Caraibo	40.6	73.7	3.0

[1]Fruit set scored as in Table 1.

Fertilizer and spacing trials

Nitrogen. Fertilizer trials over a three year period (1989-91) showed that high doses of nitrogen enhance yield and improve fruit quality. Inadequate fertilization can limit yield. Skirbic (1989) indicated that inadequate nitrogen supply resulted in nitrogen deficiency occurring during and late in the season, reducing fruit quality and resulting in early senescence.

Studies conducted at two sites, UAC and Mbimba, during the 1989-1990 seasons, on the influence of nitrogen dose and frequency of application showed no significant effect on total yield per hectare or on fruit size (Table 5). Although nitrogen promotes yield and fruit quality, other environmental factors, such as drought and excessive rainfall, can drastically reduce its effect. Yield response to added nitrogen was limited by excessive rainfall in 1989 and by drought in 1990. It is possible that the fertilizer rates of 400 and 600 kg N ha^{-1} were excessive, and had detrimental effects, as mentioned by Coltman (1988) and Lorenz and Bartz (1968). The optimum level of nitrogen application appeared to be between 200 and 400 kg ha^{-1}. There was no significant interaction between nitrogen rate and frequency of application, but 200 kg ha^{-1} applied in four to six splits at three to four week intervals gave the best yields.

Table 5. Effect of nitrogen fertilizer rate (kg ha^{-1}) and frequency of application on tomato yield (t ha^{-1}) and fruit weight (g) at two sites in the Southern Highlands in the 1989-1991 seasons (mean annual rainfall over the period, 1002 mm at UAC and 1322 at Mbimba)

	UAC			Mbimba			Mean fruit wt
	1989	1990	1991	1989	1990	1991	
N level (kg ha^{-1})							
100	-	-	33.0	-	-	7.9	61.9
200	8.0	67.5	33.4	4.1	55.7	9.2	59.3
300	-	-	34.3	-	-	8.5	65.7
400	7.7	68.8	-	5.4	47.5	-	55.3
600	8.3	63.2	-	4.8	44.1	-	53.8
SE	-	±3.63	±4.23	-	±6.11	±2.64	-
Frequency of application							
1	-	-	29.8	-	-	8.6	61.4
2	7.6	67.9	31.3	4.5	47.2	8.2	54.2
3	-	-	36.4	-	-	8.4	63.7
4	8.1	70.5	36.9	4.6	58.2	8.9	57.2
6	8.2	73.0	-	5.3	47.0	-	54.1
8	8.1	64.1	-	4.7	44.1	-	53.5
SE	-	±3.62	±3.57	-	±2.02	±1.90	-

Phosphorus. Phosphorus is known to enhance fruit set, yield and quality in tomatoes. Studies conducted in the 1986/87 and 1987/88 seasons at UAC indicated that phosphorus application up to 100 kg P ha^{-1} increases yield significantly as a result of an increased number of fruits set per plant (Table 6).

On the basis of the results so far, tentative fertilizer recommendations for tomatoes grown on the volcanic soils in the Southern Highlands (in particular the haplic Phaeozem soils of Uyole and the haplic Acrisols of Mbimba) are 200-400 kg N and 40-80 kg P ha^{-1}.

Table 6. Effect of phosphorus fertilizer rate (kg ha^{-1}) on tomato yield (t ha^{-1}), number of fruits per plant and fruit size (g) at Uyole Agricultural Centre, 1986/87 and 1987/88 (mean annual rainfall over the period, 1197 mm)

	1986/87			1987/88		
	Yield	Fruits per plant	Fruit size	Yield	Fruits per plant	Fruit size
0	9.9	13.7	65.3	26.6	17.4	47.5
20	10.3	13.6	62.7	28.9	16.2	55.2
40	9.5	14.6	65.0	58.4	27.9	65.1
60	11.8	15.5	67.6	55.1	24.6	69.6
80	12.1	15.5	68.2	59.2	28.7	64.0
100	12.9	16.0	66.8	57.9	27.2	66.0
120	11.6	15.4	67.9	45.4	22.4	62.9
140	11.0	15.2	65.7	48.3	23.9	62.8
SE	±0.84	-	±1.31	-	-	-

Spacing. Studies on intra-row spacing, with one plant per hill in rows 50 cm apart, were tested in the 1986 season using the indeterminate cultivar Moneymaker. Spacing affected flowering, fruit set, severity of late blight, yield and fruit size (Table 7). Narrow-spaced plants flowered early, but had a poor rate of fruit set when compared with wide-spaced plants. With narrow spacing, the incidence of late blight was severe, possibly because of poor air circulation. The yield differences between the narrow and wide treatments were not significant, although wide spacing tended to result in higher yields, a greater percentage of marketable yield, and bigger fruits than narrow spacing. Spacing greater than 60 cm tended to reduce yield, because of the low plant density. High population density tended to compensate for low yield per plant in the overall yield per hectare, but taking into consideration the effect on yield components and the number of plants required, planting at spacings less than 40 cm is not recommended. Similar results were obtained by Abdel-Al (1975) and Sajjapongse *et al.*, (1988) when evaluating the effect of spacing on determinate tomato cultivars. Comparing 30 and 60 cm spacings, they found that narrow spacing significantly reduced the number of fruits and yield per plant, but had little effect on overall yield per hectare.

Interaction of population density and fertilizer. Although high plant population densities increase yield per hectare, they tend to reduce yield per plant (Abdel-Al, 1975; UAC, 1984/85; Sajjapongse *et al.*, 1988). This yield reduction is attributed to competition for space and nutrients (Stoffella *et al.*, 1988; Shibli and Suwwam, 1987; Rumpel and Babile, 1988). However, application of nitrogen can help reduce these effects (Shibli and Suwwam, 1987). Interactions between population densities and nitrogen application rate were tested at UAC in 1990 and 1991. The interaction effect was not significant, although the results tended to support the idea that high plant population densities should be accompanied by high rates of nitrogen application if good yields are to be obtained (Table 8). For optimum economic yield 40,000 plants and 200 kg N per ha^{-1} are therefore recommended.

Table 7. Effect of row spacing (cm) on tomato yield and its components at Uyole Agricultural Centre, 1985/86 (mean annual rainfall over the period, 1263 mm)

Spacing	Days to 50% flowering	Fruit set[1]	Late blight rating (0-5)	Yield (t ha^{-1})	Fruit size (g)
50 x 30	65	1.0	4.0	15.2	64.9
50 x 40	64	1.8	4.0	20.9	76.9
50 x 50	64	2.0	3.3	25.6	90.4
50 x 60	71	2.3	3.0	27.1	85.4
50 x 75	71	2.5	3.0	22.4	77.9
SE	-	-	-	$\pm$4.63	-

[1]Fruit set scored as in Table 1.

Table 8. Effect of plant population density and rate of fertilizer application on tomato yield and its components at UAC, 1990/91 (mean annual rainfall over the period, 793 mm)

	1990		1991	
Nitrogen (kg ha^{-1})	Yield (t ha^{-1})	Fruit size (g)	Yield (t ha^{-1})	Fruit size (g)
		66.7 x 10^3 plants ha^{-1}		
100	52.4	63.7	51.7	69.2
200	59.8	64.9	58.3	68.0
300	58.8	66.5	52.5	69.0
		40.0 x 10^3 plants ha^{-1}		
100	50.2	64.7	41.2	71.1
200	68.0	68.0	39.9	65.5
300	63.5	67.5	35.5	66.7
		26.7 x 10^3 plants ha^{-1}		
100	67.1	67.1	27.7	71.3
200	66.4	66.4	35.4	71.1
300	66.1	66.1	28.0	69.2
SE				
Nitrogen	$\pm$2.84		$\pm$4.84	
Plant Density	$\pm$2.94		$\pm$4.39	

ACHIEVEMENTS AND CONSTRAINTS

The production of tomatoes in the Southern Highlands is increasing steadily. However, the full potential of the crop has not yet been exploited for the following reasons:

- *Varieties.* Most farmers still grow local varieties. Varietal improvement has been limited and the range of improved varieties is still small. Varieties adapted to lowland or highland conditions, or to excessive rainfall or drought, are not yet available.

- *Quality seed.* Seeds of imported cultivars are of good quality, but are expensive and irregular in supply. The farmers of the Southern Highlands currently produce and collect their own seed, without regard to seed quality. The lack of a developed vegetable seed industry in Tanzania is one of the major constraints on tomato production.

- *Preparation of nursery and fields.* To realize the full potential of improved varieties the seedlings should be raised in nursery plots, protected from diseases, pests and weeds. Most smallholder nursery plots are poorly managed, with weak seedlings often affected by diseases and pests, mainly because there are overlapping labour requirements for other farming operations. Transplanting is often delayed because of late field preparation.

- *Diseases.* The major diseases affecting tomatoes include leaf blights, leaf spots and wilts. Late blight (*Phytopthora infestans*), bacterial wilt (*Pseudomonas solanacearum*) and fusarium wilt (*Fusarium oxysporum*) are widespread and constitute major hazards to tomato production. Late blight can be controlled by the use of fungicides, for example Mancozeb applied twice a week at 1.44-2.4 kg active ingredient (a.i.) ha^{-1} or Metalaxy/Mancozeb applied twice a week at 2.5 kg a.i. ha^{-1}. However, few smallholders use fungicides because of their expense and of those that do, a considerable proportion handle the chemicals poorly and do not apply the recommended dose. A strict crop rotation programme is necessary to control wilt diseases. However this is not perceived as economically feasible by many smallholders, because of the scarcity of land.

- *Insects.* The most important insect pests in the Southern Highlands are African bollworm (*Heliothus amigera*), tobacco whitefly (*Bemisia tobaci*) and root knot nematodes (*Meloidogyne* spp). Control measures depend on regular spraying with insecticides, for example Thiodan 35%, Actellic 50, or Malathion applied at 40 ml 20 l^{-1} water against African bollworm and whitefly. Strict crop rotation is required for controlling nematodes. As in the case of diseases, the recommended protection measures are rarely used.

- *Adoption of improved technology.* Information about improved practices has reached many growers, but lack of adequate resources limits the rate of adoption. A high priority is assigned to the production of cereals, so that when resources are limited, few if any are assigned to tomatoes.

- *Environmental stress.* Excessive rainfall in some areas in some years causes a high incidence of disease and nutrient leaching, leading to poor fruit set and serious yield loss. Drought and lack of irrigation facilities also lead to poor plant development and yields.

- *Socio-economic and marketing aspects.* The majority of farmers grow mainly traditional cereal crops. Only a small proportion are engaged in tomato growing, largely because of the need for frequent weeding, irrigation, staking, removal of side shoots, and insect and disease control. The fruits have to be transported promptly to the market, which for many smallholders is not possible. Prices fluctuate considerably, sometimes enabling middlemen to offer unreasonable prices to the growers.

SEQUENCE OF INNOVATIONS

A suggested sequence of innovations for adoption by smallholder farmers is listed below and summarized in Table 9. Subsistence farmers could be advised to adopt the new technology in a sequential manner, singling out those innovations that they can afford at any particular time.

1. *Traditional management.* Under traditional management, farmers do not use any form of improved technology. Farmers use local varieties of unknown identity. Tomatoes are mixed with other vegetables in one plot. Irrigation may or may not be used, depending on where the plot is located. Yields are about 2-4 t ha^{-1}.

2. *Improved varieties.* Improved varieties with qualities attractive to farmers, such as large fruit size, good fruit set and good taste, can be grown. Moneymaker (open pollinated) is an example.

Seedlings can first be raised in the nursery before being planted out in the field. Monocropping can be practised, and staking and debudding of side shoots done. Yields should range from 4 to 13 t ha^{-1}, depending on the incidence of disease, which is very much influenced by the environmental conditions.

3. *Disease control.* Late blight during the rainy season can be controlled. Cultural practices such as pruning and weeding can be combined with fungicide spraying, for example Dithane M 45 at 1.44-2.4 kg a.i ha^{-1} applied twice per week. Yields should increase from 13 to 18 t ha^{-1}.

4. *Improved fertility.* Most farmers use farmyard manure for fertilizing their vegetable gardens, especially where livestock are kept. The limited use of mineral fertilizers at rates of 100 kg N and 25 kg P ha^{-1}, with improved variety and disease control, could increase yields from 18 to 42 t ha^{-1} and 50 kg P ha^{-1} could increase yields to 54 t ha^{-1}.

5. *Increased plant population.* Poor plant populations occur as a result of both an insufficient number of seedlings used at the time of transplanting and poor field establishment after transplanting. Improving nursery management would increase the number of seedlings available for transplanting. Increasing the field plant population to 40,000 plants ha^{-1} would increase yields to 67 t ha^{-1}.

Table 9. Suggested sequence of innovations for adoption by smallholder farmers, and the anticipated tomato yield

Management	Characteristics	Anticipated yield (t ha^{-1})
Traditional management	Local varieties, mixed croppping, with or without irrigation, low plant populations	2.4
Use of improved varieties	Improved varieties, such as cv. Moneymaker (open polinated), monocropping, improved management	4-13
Control of disease	Fungicide such as Dithane M 45 at 1.44-2.4 kg a.i. ha^{-1} applied twice a week, weeding, removal of side shoots	13-18
Improved fertility	100 kg N ha^{-1} + 25 kg P ha^{-1}	18-42
Further improved fertility	200 kg N ha^{-1} + 50 kg P ha^{-1}	42-54
Increased plant population	Improved nursery management, increased field plant population to 40,000 plants ha^{-1}	67

PRIORITIES AND STRATEGIES FOR FUTURE RESEARCH

The following is a list of proposals for future research, in order of priority:

1. Develop varieties with a high yield potential and wider adaptation. This will involve testing introductions, lines and cultivars in various localities representing different climatic conditions in the Southern Highlands. The emphasis should be on open-pollinated varieties so that farmers can produce their own seed.

2. Evaluate varieties suitable for growing without stakes.

3. Evaluate cultivars suitable for processing. There is an increasing demand for tomatoes as raw material for processing, but few suitable cultivars have yet been developed.

4. Develop recommendations for the complete range of agro-ecological zones and soil types of the Southern Highlands that are suitable for tomato cultivation.

5. Screen introductions in order to develop cultivars resistant to late blight and wilts. In the absence of resistant cultivars, the use of integrated management practices to help control diseases and insects should be emphasized.

6. Study economic and marketing strategies to improve production efficiency.

7. Encourage the development of the national vegetable seed programme. UAC should continue with its small scale seed production programme of popular vegetables including tomatoes. It should continue to provide information on the best locations and growing time to avoid diseases, and on processing, storage and packing techniques. Testing of seed quality should be carried out.

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