STARKE AYRES®

TOMATO

PRODUCTION GUIDELINE

TOMATOES

1. HISTORY AND BACKGROUND

The tomato species *Lycopersicon esculentum* (formerly *Solanum lycopersicon* belongs to the Solanacea family). This is an herbaceous, usually sprawling plant of the nightshade family that is typically cultivated for its edible fruit. The scientific species name *Lycopersicon* means "wolf peach", and comes from German werewolf myths. These said that deadly nightshade was used to summon werewolves, so the tomato's similar but much larger fruit was called the "wolf peach" when it arrived in Europe from the New World.
It presents itself in different shapes, sizes and colours with different brix or sugar levels. Tomatoes have very high lycopene content, which has several health benefits. Some plants have a self-pruning gene responsible for determining the determinate growth habit. Ripening inhibitor (*rin*) and non-ripening (*nr* and *nor*) genes are responsible for determining shelf life, but is not a GMO (genetically modified organism) trait. Nowadays long shelf life (LSL) tomatoes are available without these genes.

The tomato was originally taken from Central America. The first selections where done in Mexico. It was brought to Europe by the Spaniards shortly after 1535 and then by the Portuguese to the East before 1604. The Portuguese also took it to their territories around Southern Africa at an early date: explorers found it there around 1850. There is evidence that it was also brought to the Cape from the East: the Afrikaans name for the vegetable "tamatie" probably origin ates from the Malay word "tamatte". From a very humble start the tomato grew to one of the most popular vegetable crops in the world today; bringing Joseph B. Feldt's prophesy of 1845 to fulfilment: "Like the potato slow in its rise, it is likely to be slow in its fall."

2. ADAPTABILITY

2.1 CLIMATIC REQUIREMENTS

Climate is one of the most important factors when determining planting times. The wide variation in climate in South Africa allows the planting and production of good quality fresh tomatoes in open fields in various parts of the country all year. Tomatoes are known to be a warm season crop. It can survive certain amounts of cold units, but are intolerant of very low temperatures. A tomato crop requires very stable temperature ranges with minimums and maximums not being too wide apart. Temperature variation might result in poor fruit quality or reduced yields. The minimum temperature is around 10°C with the maximum being 34°C. Optimum temperatures are around 26 - 29°C.

Table 1: Required temperature ranges per development stage for optimum tomato production.

	Temperatures (˚C)		
Developmental Stage	**Minimum**	**Optimum**	**Maximum**
Germination	11	16 - 29	34
Vegetative Growth	18	21 - 24	32
Fruit set – night	10	14 - 17	20
- day	18	19 - 24	30
Red Colouring	10	20 - 24	30
Yellow Colouring	10	21 - 32	40
Cold Damage		under 6	
Frost Damage		under 1	
Terminal Damage		-2	

2.2 SOIL REQUIREMENTS

A very high level of soil fertility is required for the profitable production of a successful tomato crop. The quality and quantity of tomato fruits are of crucial importance and are greatly influenced by the fertility and nutrient levels of the soil. Tomatoes will grow moderately well over a wide range of soil types. However certain criteria have to be satisfied in terms of the soil structure and content to make it commercially viable. These factors include:

Nutrient composition
Compaction
Effective soil depth
pH
Crop rotation
Herbicide residues
Water holding capacity

All these factors can have major influences on the resulting yield. The soil must permit adequate root growth to support the plant and supply water, oxygen and mineral nutrients and must be free of toxic elements. The rate of root growth is dependent on the degree of compaction or bulk density of the soil. The degree of soil compaction varies with soil type and location. The rate of aerial and root growth of tomato plants increases with the oxygen contents of the soil. Root density is highest where there is a high rate of diffusion. Root development of tomato plants can be extensive if soil water and plant conditions are optimal. They can be as deep as 1.5 m and as wide as plant spacing will allow. Early root development should be encouraged, because nearly all root growth occurs before fruit set. The importance of organic matter cannot be over emphasized. Organic matter in the form of decayed leaves, compost, sawdust or animal manure is a source of plant nutrients and acts as a soil conditioner. It increases the capacity of the soil to retain water and nutrients. It also promotes root growth and the infiltration of water and air into the soil.

2.3 PRODUCT TYPES

Until about a decade ago the tomato range consisted mostly of fresh market and processor types only. Today there are numerous types of tomatoes marketed and many shops even like to sell only their own brand. The following are some of the different types of tomatoes for which seed companies must cater in South Africa:

Indeterminate fresh, Long Shelf Life, large
Indeterminate fresh, Long Shelf Life, medium size
Indeterminate fresh, Long Shelf Life, small
Indeterminate fresh, red cherries, round
Indeterminate fresh, red cherries, oval
Indeterminate fresh, yellow cherries, round
Indeterminate fresh, yellow cherries, oval
Indeterminate fresh, yellow cocktail, round
Indeterminate fresh, yellow cocktail, oval
Indeterminate fresh, red cocktail, round
Indeterminate fresh, red cocktail, oval
Indeterminate fresh, saladette, cylindrical
Indeterminate fresh, saladette, blocky
Indeterminate fresh, truss tomatoes
Determinate, fresh, Long Shelf Life, large
Determinate, fresh, Long Shelf Life, medium size
Determinate, fresh, red cherries, round
Determinate, fresh, red cherries, oval
Determinate, fresh, saladette, cylindrical
Determinate, fresh, saladette, blocky
Determinate, processors
Determinate fresh tomatoes suitable for non-trellising

3. CULTIVATION PRACTICES

3.1 SOIL PREPARATION

Soil preparation improves the potential for profitable production of tomatoes. Any primary soil preparation must be aimed at creating growing conditions for tomato plants to develop the optimal root system in a specific soil profile. Although the root structure of a tomato plant can penetrate various soil types up to depths of 2 meters, the highest percentage roots will be found in the top 600mm of the soil. The advantages of soil preparation are:

No restrictions on root development.
Less chance of compaction.
More oxygen in the soil creating better root development.
Higher yield.
Reduction in production costs.
More vegetative growth.
More tolerance to drought and stress.
Less root disease prevalence.
Horizontal and vertical compaction layers broken.
Better water retention.
Increased uptake of moisture and nutrients.

The choice of preparation systems should be determined by the plant requirements and the soil type. Thereafter, economic factors should be considered. No standard system can be recommended on all soil types. The choice of preparation method should be made based on the clay content of the soil. For example on sandy soils the focus should be to reduce compaction and erosion, where on heavier soils it will be to reduce crust formation. Soil preparation should be done to depths varying between 200 – 400mm. Ridging is highly recommended, and should be done according to the land contours. The main advantage of ridging a tomato crop is to keep excess water away from the plant, improved oxygenation of the root zone, increased soil depth in the growing bed, to promote root development.

3.2 PLANTING PERIODS

A number of factors should be taken into consideration when determining planting times. These factors are:

<u>The effect of temperature on plant growth, flowering and fruit set</u>
Tomatoes grow and produce the best when the mean temperatures are between 20 and 24˚C. This is however a very general statement, as the effect of high temperature in the day can be offset by a lower night temperature or in some cases by lower light intensity. The plant has the ability to grow well at temperatures well above 30˚C; but these temperatures have a negative effect on fruit set. The critical factor with regard to fruit set is the night temperature, which should be from 15-20˚C for the optimum set. When the average daily temperature is above 32˚C and the night temperature is above 21˚C fruit set is poor. Fruit set generally fails below 13˚C.

The **earliest period** for seedling establishment would be when the soil and air temperatures at least meet the minimum requirements for plant growth.
The **latest seedling** establishment period would be after allowance has been made for the growth and harvest periods to be completed before adverse conditions sets in.

Due to the effect of certain factors being prevalent at specific locations, within each of these areas the planting times may be earlier or later than the times given below.

<u>Establishment periods for the main production areas of South Africa will then be:</u>
1. Lowveld (frost free areas) – Feb to May
2. Middleveld (moderate areas) – Sept to Dec
3. Highveld (cold areas) – Oct to Nov
4. Western Cape – Oct to Dec

crop is transported to its destiny). The farmer must always bear in mind that quality is profitability. The qualities that attention should be paid to include: pack-out, uniformity, fruit shape, ripening ability, firmness and flavour. The specific characteristic required will depend on the market requirements, as dictated by the packer, shipper, wholesaler, retailer and consumer.

Worldwide Long Shelf Life (LSL) tomatoes are picked at the red to full ripe stage. This is done in order to utilise its full potential on colour and taste. South Africa is one of only a few countries in the world that pick their fruit at mature green to colour break stage. This is due to consumers not being aware that varieties have changed and can now easily be picked at full ripe stage. They still have the perception that a red ripe tomato is over mature. The fruit size of a tomato rarely indicates the maturity stage as some varieties are genetically larger in size than others.

A tomato has 7 identification and marketing classification stages of the ripening process:

Green
Mature Green
Colour Breaker
Half Ripe
Ripe
Red Ripe
Full Ripe

And a tomato has 7 identification and marketing classification stages of the size grades:

Cocktail:	0-30 mm
Small:	35 mm and smaller
Medium:	56 – 63 mm
Large:	73 – 82 mm
Extra Large:	83 – 94 mm
Double XL:	95 mm and larger

Tomatoes are sensitive to cold and should not be stored below 13˚C. The taste of a tomato will not improve once refrigerated as warmer temperatures, as explained above, are required until full ripe stage. Tomatoes are sensitive to ethylene (ripening hormone) and should not be stored with fruit that produce ethylene, such as bananas, avocados, and kiwi fruit.

Under Protection

Growing tomatoes under protection provides possibly the ultimate level of control currently available to producers. Protection against the natural elements and pests is obtained by the use of a transparent material that allows sunlight to enter the structure and then converting the trapped solar energy to heat, thus providing increased temperatures for continued production. In advanced structures, humidity and even light can be controlled to ensure maximum crop yields.

3.3 SEEDLING PRODUCTION

Seedling establishment:

Model 128 or 200 seedling trays are the most popular.
Although more expensive, larger seedling trays lead to better and more root development.
Seedlings take 4 – 6 weeks in summer to reach transplant maturity.
Seedlings take about 8 weeks in winter to transplant maturity.
Deep sowing: More advantageous in warmer conditions.
Seed takes longer to surface due to cooler temperatures and longer growing distances.
Shallow sowing: More advantageous in cooler conditions.
Seed surface quicker due to warmer temperatures and short growing distances. Efficient levels of moisture are necessary.

The effect of soil- or growth media temperature on seed germination

Table 2 gives a good indication of the best temperature ranges for seed germination. At the optimum soil or growth media temperatures of 20 to 30˚C it will take tomato seeds 6 -8 days to germinate. At temperatures ranges of 0-5˚C, 40˚C and above no germination is expected with seed being dormant.

Table 2: The effect of soil temperature on seedling emergence.

Soil Temperatures (˚C)	0	5	10	15	20	25	30	35	40
Germination (days)	NG	NG	43	14	8	6	6	9	NG

Seedlings should be grown in a well-aerated medium, which has good water holding capacity and at a pH of around 6.5. Generally, peat, bark and vermiculite mixes are used. Media problems typically include excessive tannins and low air filled porosity, which results in poor drainage and the buildup of green mould. The medium should be pre-enriched and the seedlings should be fertilized.

Seedling management is a critical factor, and the following points may result in physiological disorders:

Incorrect sowing time.
Cold temperatures, particularly below 7 °C.
Cold grown seedlings.
Over-fertilization of seedlings.
Oversized seedlings at transplant.
Temperature differences between the seedling nursery and the farm.

A precision seeder is recommended to place single seedlings at a uniform depth.

3.4 PLANT POPULATION AND SPACING

Plant populations differ hugely from area to area and region to region. The lowest commercial plant population is around 8 000 to 10 000 plants per Ha. This is mainly done in areas where grapes or citrus are grown and farmers need to adapt their tomato system around the more permanent crops. The highest plant populations are around 25 000 to 35 000 plants per Ha. This is mainly done in greenhouses and farmers producing open land processing types for paste. The single most important factor when making a decision around plant population is the type of chemical spraying system- or method that the grower is going to use for the duration of the crop. Everything should be designed around this implement so as to get in between rows to effectively control pests and diseases. It is highly recommended to try and keep the between row spacing at 1.8 to 2.5 meters. Tomatoes grown on the ground for informal and fresh markets should have enough inter row spacing (minimum 1.8m)

as to not damage plants when harvesting. Plants with vigorous growing habits are recommended with in row spacing of not closer than 35 – 40cm. The closer the distance in between plants, the more concentrated it will bear and other way around. Plant population under protection is usually up to two times higher than open field production. With varieties that have a determinate habit the yield per plant will stay relatively constant to different plant populations, but too high populations will make a difference. A recent intensive trial study was done at Starke Ayres and the following observations were made: Determinate varieties showed no significant differences in fruit size between the different planting densities. Indeterminate varieties definitely showed an increase in fruit size but only to a certain level. Looking at marketable yields as well as the yields of large fruit, it was clear that the trend on the determinate types was towards yielding the best at the highest plant population. The indeterminate types had no significant effect. Farming in general requires producing the highest yield of saleable product. The best yield of saleable product was generally achieved at the higher plant populations.

These recommendations are followed for Starke Ayres material:

Open land: 12 – 18 000 plants /ha.
Open land untrellised: 15 000 plants /ha
Under protection: 20 – 28 000 plants/ha.
Open land processing: 28-35 000 plants/ha

Table 3: Plant population guide

Between Rows (cm)	Between plants (cm)					
	20	**25**	**30**	**35**	**40**	**50**
150	33 000	26 400	22 000	19 000	16 500	13 200
175	28 500	22 800	19 000	16 300	14 285	11 400
200	25 000	20 000	16 700	14 300	12 400	10 000
225	22 000	17 600	14 600	12 700	11 000	8 800
250	20 000	16 000	13 300	11 400	10 000	8 000

The plant population table above can be used as a quick guideline. For example: if the distance between rows is 2 meters with the distance between plants 30 cm, one will have a plant population of 16 700 plants per ha.

Production under protection
The planting density should be around 3-4 plants/m². This is mainly done where medium to smaller fruit is needed for speciality and high quality markets. Plants are trained to single, double or three stems on supporting strings and stopped at a height of 2 meters or more.

3.4.1 TRANSPLANTING SEEDLINGS

The production of good quality, healthy seedlings require the correct choice of both variety and seedling grower. The correct soil preparation, analyses and fertilizer application prior to planting also needs to be done. Before seedlings are collected from the nursery, land preparation should be completed and irrigation systems should be in place. At this point some growers already install the trellising system such as poles and first wires. Seedlings must be hardened off before leaving the nursery. This is done by making sure that excessive nitrogen and irrigation is kept to a minimum. Two to five days before collecting the seedlings, they must be taken out of the nursery and placed in a position where more sunlight is prevalent.

It is highly recommended to always establish seedlings in wet soil. Always make sure that the holes on the ridges where seedlings are about to be transplanted are exactly the same size as the seedling plugs. This will prevent issues such as J-rooting where seedling plugs are forced into the soil and roots are bent over resulting in seedling uniformity issues and yield losses. Although it is not recommended to establish these plants, it happens from time to time that a grower receives over mature or taller plants than normal. In this instance it is recommended to sterilize the stem with a

fungicide and plant the seedling deeper into the soil than normal. This is not the best thing to do, but lateral roots will shoot from the stem to help the plants. Sometimes seedlings are received with flowers or buds already setting, it is recommended to remove them at planting in order to give the plant more energy to establish itself.

3.5 FERTILIZATION

In the production of tomatoes, this is the single most important factor that determines the success rate of a crop. With good management practices tomatoes could be produced under a wide range of different conditions, however some conditions are more favourable to grow tomatoes than others. In order to calculate the correct nutrient requirement, the following aspects need to be available and taken into consideration:

Nutrient withdrawal figure that 1 ton of tomato fruits removes:
N – 2 to 4 Kg
P – 0.5 to 1 Kg
K – 3 to 5 Kg
Nutrient withdrawal figures that 1 ton tomato fruits including the plants removes:
N – 5 to 6 Kg
P – 2 to 3 Kg
K – 7 to 8 Kg
Fertilizer used in the past on the specific area intended to be planted.
Soil Type.
Soil Analyses.
Soil Acidity (pH).
Irrigation water.
Micro elements.

The ideal soil analyses or soil status for tomato production should be:

pH (H_2O): 5.6 – 6.8 (NB!! MUST BE CORRECT.)
P: 30 – 60 mg/Kg (Bray1)
K: 100 – 250 mg/Kg
Ca: 300 – 2000 mg/Kg
Mg: 120 – 300 mg/Kg
Na: 10 – 50 mg/Kg

3.5.1 FERTILIZATION GUIDELINE

Requirement stages:

0 – 5 weeks: Vegetative growth occurs with high Nitrogen requirements.
6 – 12 weeks: The flowering stage with high Potassium requirements.
12 – 20 weeks: The fruit set and fill stage with high Calcium, Magnesium requirements.

Due to their vigorous growing habit and exceptional root structure (up to 2 metres) all STAR varieties react extremely well to Nitrogen applications and this must be taken into consideration when planning.

Ideal fertilization levels:

N:	180 – 200 Kg/ha
P:	60 – 100 Kg/ha
K:	300 – 400 Kg/ha
Ca:	250 – 300 Kg/ha
Mg:	50 – 60 Kg/ha

Above quantities are calculated over a 17 – 22 week application cycle and soil analyses not taken into consideration.

Table 4: Nutrient requirements of the Starke Ayres strong determinate range of tomatoes

HABIT	CYCLE	N	P	K	Ca	Mg	N:K
STRONG DETERMINATE	Preplant	50	50	65	0	0	1.3
	Week 0-6 (Transplant to flowering)	45	18	65	10	8	1.4
	Week 6-12 (Flowering to Fruiting)	55	18	110	70	13	2
	Week 12-18 (Harvest)	70	12	120	55	3	1.7
	TOTAL	**220**	**98**	**360**	**135**	**24**	1.6

COMMENTS:

Strong determinate types produce over 4-6 weeks.
Nutrient requirements peak earlier due to early maturity.
N & K levels peak earlier to help plants develop a strong plant canopy and in production of a concentrated set.
Program is developed for and needs to be spread over a 18 week period.
Program is developed for 100 t/ha yields aim.
NB! Take the soil status or analyses into account.

Table 5: Nutrient requirements of the Starke Ayres semi determinate range of tomatoes

HABIT	CYCLE	N	P	K	Ca	Mg	N:K
SEMI DETERMINATE	Preplant	35	50	60	0	0	1.7
	Week 0-7 (Transplant to flowering)	35	18	60	5	3	1.7
	Week 7-13 (Flowering to Fruiting)	70	18	110	70	15	1.6
	Week 13-21 (Harvest)	96	22	152	70	7	1.6
	TOTAL	**236**	**108**	**382**	**145**	**25**	1.6

COMMENTS:

Semi determinate types produce over 6-8 weeks.
Most STAR varieties in this class are highly reactive to N and this should be monitored closely.
STAR 9011 & STAR 9065 are classed between strong and semi determinates, meaning that they
might require their N earlier.
Program is developed for and needs to be spread over 20 week period.
Program is developed around 120 t/Ha yield aim.
NB! Take the soil status or analyses into account.

Table 6: Nutrient requirements of the Starke Ayres indeterminate range of tomatoes

HABIT	CYCLE	N	P	K	Ca	Mg	N:K
INDETERMINATE	Preplant	35	50	60	0	0	1.7
	Week 0-7 (Transplant to flowering)	35	18	60	5	3	1.7
	Week 7-13 (Flowering to Fruiting)	70	18	110	70	15	1.6
	Week 13-25 (Harvest)	144	33	228	80	10	1.6
	TOTAL	**284**	**119**	**458**	**155**	**28**	1.6

COMMENTS:

Indeterminate types produce over 12 weeks.
Most STAR varieties in this class are highly reactive to N and should be monitored closely.
Program is developed for and needs to be spread over 25 week period.
Program is developed around 150 t/ha yield aim.
NB! Take the soil status or analyses into account.

3.6 IRRIGATION

The supply of adequate water to the roots of a tomato plant is critical. Under- or over irrigation can have a devastating effect on the outcome of the crop. It is therefore very important to apply water at optimal times.

Too little water might lead to:

- Sub-optimum yields.
- Decrease in the photosynthetic rate.
- Plants developing stunted growth.
- No production of flowers.
- Low percentage fruit set.
- Slow fruit development.
- Small fruit sizes.
- Poor quality.
- Flower abortion.

Too much water might lead to:

- Not enough oxygen in the soil.
- Plants becoming wilted.
- Root diseases becoming prevalent.
- No plant development.

When scheduling irrigation, the size of the root system at the time of irrigation needs to be taken into account. In general, the root system can be compared to the aerial growth of the plant. The roots spread into the soil at a similar rate to which the aerial growth develops. Most tomato roots occur in the top 500 – 600 mm of soil level, even at maturity. For this reason irrigation should be monitored at this level with irrometers. Deep, thorough irrigations are preferable to light and regular watering intervals. Drip or flood irrigation is preferable to overhead irrigation, due to susceptibility to foliar diseases. The amounts of water used will vary depending on the climatic conditions. During the cooler months tomatoes require about 25mm per week and this might increase to 50mm under very hot, windy and dry conditions. For irrigation purposes, the growth of tomatoes can be divided into four growth stages.

Stage 1: Establishment

Can last up to 4 weeks.

Seedling establishment takes place and plants start to grow actively.
Low amounts of water are used.

Stage 2: Vegetative growth
Development of first flowers and fruit.
Double the amount of water is used compared to the previous stage.

Stage 3: Fruit set
Growth is at its highest.
Water usage at this stage is at its highest during the lifespan of the crop.

Stage 4: Ripening and harvesting
Very high loads carried on the plant.
Water usage starts to decrease.

4. OTHER CULTURAL PRACTICES

4.1 TRELLISING

This is one of the most expensive factors contributing to tomato production costs. Costs will directly be linked to the chosen variety. Strong determinate types will use less input compared the taller growing indeterminate types.

For open field trellising poles should be between 1.7 - 2.0 meters long. Treated poles last longer, but caution should be taken with Creosote treated poles as this might burn some of the plants on hot days. Poles should be planted directly after seedling transplantation. Some growers even do the planting of poles before the time. Wire or rope can be used and should be done at first flowering stage or around one month after transplant. Although more expensive, wires last longer and don't have the ability to gather diseases. Rope could be infected with bacterial spores and should be sterilized after use. Poles should be planted around 40 – 50 cm into the soil and not more than 3 meters apart. It is essential that the end or corner poles are supported. Poles should be able to carry the plant and its fruit, and withstand side winds. When rows are 1.5 meters apart and the crop is planted in a 1 hectare square block, one would need 2200 poles and around 17 – 20 000 meters of wires if 4 sets or 8 lines of wire are used.

A tomato plant has the ability to grow up to 15cm per week and constant trellising should be done. The plant will make side shoots that grow to the sides of the main plant. These shoots should be neatly tucked in between the wires and not damaged. This should at least be done on a weekly basis. Trellising under protection could be done in two ways. One way would be to do it the same way as the conventional open field method, or what growers refer to as the Spanish method. This is done by trellising a steel wire at 2 – 2.5 meters above the row. Rope or twine is then hung down from this wire for the plant to be able to be guided up against the rope. As the plant matures, the rope would then be shortened or rolled up at the top. With this method, only one or two stems are allowed to grow, and all suckers are removed.

4.2 PRUNING

To maximize photosynthetic efficiency and minimize risk of disease, the suckers that form in the axils between the leaves and the main stem of indeterminate tomato types may be pruned. A strong main stem is encouraged by removing all suckers below the first flower cluster. It is recommended to remove side shoots before they are 5 cm in length. Scissors or finger tips can be used to remove the side shoot. Smaller wounds will heal faster. A disinfectant should be used to prevent the spread of disease. If too many stems are allowed to develop, energy is used in developing the multiple growing tips and fruit production may be slowed. More stems will however result in more, smaller fruit, produced increasingly later in the season. The indeterminate tomatoes can have one to many stems (commonly not more than four). Fewer stems will produce fewer, though larger, fruit, and the plant will take less space. For a multi-stemmed indeterminate plant, allow the second stem to grow from the first node above the first fruit. A third stem can be allowed to develop from the second node