FIELD GROWN TOMATOES PRODUCTION TECHNOLOGY GUIDE

MADANAPALLE, ANDHRA PRADESH

Technical partnership to support the Green Innovation Centre for the Agriculture and Food Sector - tomato value chain

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Acronyms

°C	Degree Celsius
%	Per cent
ai	Active ingredient
L/ha	Litres per hectare
g/ha	Grams per hectare
g/L	Grams per litre
CEC	Cation Exchange Capacity
EC	Electrical Conductivity
pH	Potential of Hydrogen
dS/m	DeciSiemens per metre
mm	Millimetres
ICAR	Indian Council of Agricultural Research
FYM	Farm Yard Manure
Spp.	Species
N	Nitrogen
P	Phosphorus
K	Potassium
PSB	Phosphate Solubilizing Bacteria
ft	Feet
cm	Centimetres
m	Metres
g	Grams
Kg	Kilograms
L/m_2	Litres per square metre
m_3/ha	Cubic metre per hectare
L/h	Litres per hour
t/ac	Tonnes per acre
kg/ac	Kilograms per acre
$CaCO_3$	Calcium carbonate
K_2O	Potassium oxide
P_2O_5	Phosphorus pentoxide
ml/L	Millilitres per litre
% EC	Per cent Emulsifiable Concentrate
% SC	Per cent Suspension Concentrate
w/w OD	Weight by weight Oil dispersible
WP	Wettable powder
SP	Soluble powder
Spp.	Species
ppm	Parts per million
WG	Wettable granules
NSKE	Neem Seed Kernel Extract
Sq m	Square metre

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1. INTRODUCTION

Tomato is one of the most important, nutritious and versatile vegetables widely used in Indian cooking for soups, salads, pickles, ketchup, puree, sauces, curries and in many other ways.

India is the world's second largest tomato producer both in terms of area and the tonnage of tomato grown. Tomato ranks third in priority after potato and onion within India. Major tomato growing states are Andhra Pradesh, Karnataka, Odisha, Maharashtra, West Bengal, Bihar, Gujarat, Chattisgarh, Tamilnadu and Jharkhand.

Andhra Pradesh is one of the leading producers of tomato. In 2013/14 Andhra Pradesh produced 3,354 thousand metric tonnes, accounting for 18% of all Indian produce. The main production districts are Anantapur, Kurnool, Chittoor, Visakhapatnam and Prakasam[1]. Recent trends in state tomato production showed a fall in the area and yields and there has been a falling trend in the tomato area and production in Chittoor district from 2002 onwards[2].

The municipality of Madanpalle in Chittoor district is one of the largest tomato production districts in India where tomatoes can be grown year-round. The tomato market in Madanpalle is one of the largest tomato markets in India and Asia. This guide is focused on local production issues in Chittoor district, but many of the principles in it will apply to other locations as well.

Figure 1-1 shows several factors related to production and marketing might have led to this situation.

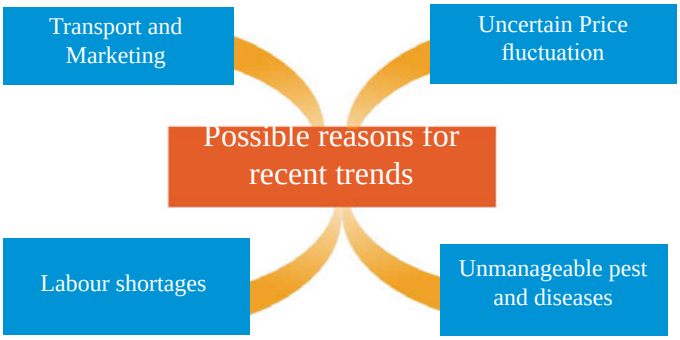


Figure 1-1 Present day challenges for tomato production.

[1]www.mapsofindia.com
[2]Horticultural statistics at a glance 2015
https://data.gov.in/catalog/district-wise-season-wise-crop-production-statistics

The first step to reversing this decline and to increase the area and production of tomato could be adoption of a good package of practices by farmers at three different levels.

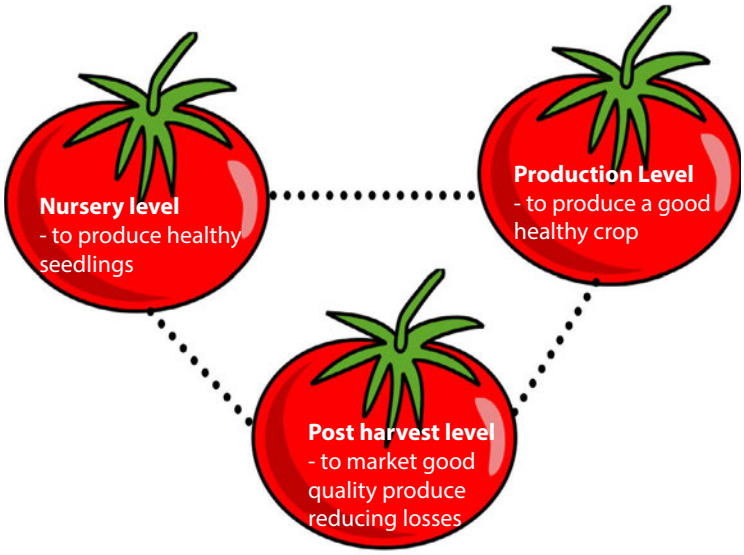


Figure 1-2 Triangle of good practices in tomato production

Healthy seedling production is the first essential step for higher tomato production, followed by farmers using a reliable production package and good harvesting practices (Figure 1-2).

In the past, farmers grew their own seedlings, but in recent years there has been a major shift to buying seedlings from commercial nurseries. Farmers and nurseries need to know how to grow, recognize and demand high quality seedlings, how to produce a good crop, and then how to maximize their returns by considering their postharvest management.

This guide compiles practical technical inputs from research, teaching and extension institutes working in the municipality of Madanapalle in Chittoor district along with best practices from nursery owners, farmers and traders. It aims to maximize the incomes of farmers growing tomatoes.

2. LAND SELECTION AND PREPARATION

The selection of the field site is crucial for the success of the grower. The exposition of the crop to any biotic (pests and diseases) and abiotic (water, nutrients, temperature) stress depends on the site properties. However, in practice the grower is commonly restricted to his land property and choices are limited.

2.1 Growing season

2.1.1 Tomato physiology

Tomato originated in the mountains of Mexico, with a generally hot and dry climate and well-drained soils. Today, tomato is grown nearly everywhere around the globe, but it thrives best in a warm and dry environment. For high yields and good fruit quality a good supply with water and nutrients is also important.

Temperatures below 13°C reduce fruit set and can lead to misshapen fruit, and below 10°C fruit set is poor. The optimum temperature for fruit set is between 18°C and 26°C. Above 35°C fruit set is reduced. Temperatures above 40°C affect growth and plant fitness negatively.

Most tomato varieties are susceptible to water logging. This can be remediated to a certain extent by grafting. High levels of air humidity (> 85% relative humidity of the air) have a negative impact in pollination. Generally, water logging and high humidity levels promote fungal diseases and at high temperatures reduce the ability of the tomato plants to transpire and, therefore limit nutrient uptake.

Generally, tomato plants transplanted between December and March provide good reliable marketable yields because of favourable weather conditions and a low incidence of pests and diseases. Although tomato is a winter season crop, it can be cultivated in any season using proper management, as discussed in the following pages.

2.1.2 Market price situation in Madanapalle

The market price for one metric tonne of tomato at Madanapalle averaged at INR 1350, INR 1291 and INR 2154 in 2015, 2016 and 2017, respectively. There is no long-term declining trend in tomato prices, but average prices are only a rough guide when there is a large price fluctuation on a daily basis.

Figure 2-1 presents the trends in market price fluctuations over the last three years. Rather than showing the actual price, this graph shows the relation of the market price in different months to the yearly
average.

With reference to the average market price, in the initial four months of the year January to April, the market price showed down-trend and was lower than the average. In the next three months May, June and July, prices trended above average while the price remained at average in the second half of the year, August to December.

However, the prices between September and January appear highly unpredictable-going either too high or too low. It is clear that on season production is favourable in terms of crop growth conditions, but market prices at harvest are normally low, while off-season production is more difficult, but is often rewarded with higher prices. Farmers who can produce good quality tomato at any time of the year, may expect a good income.

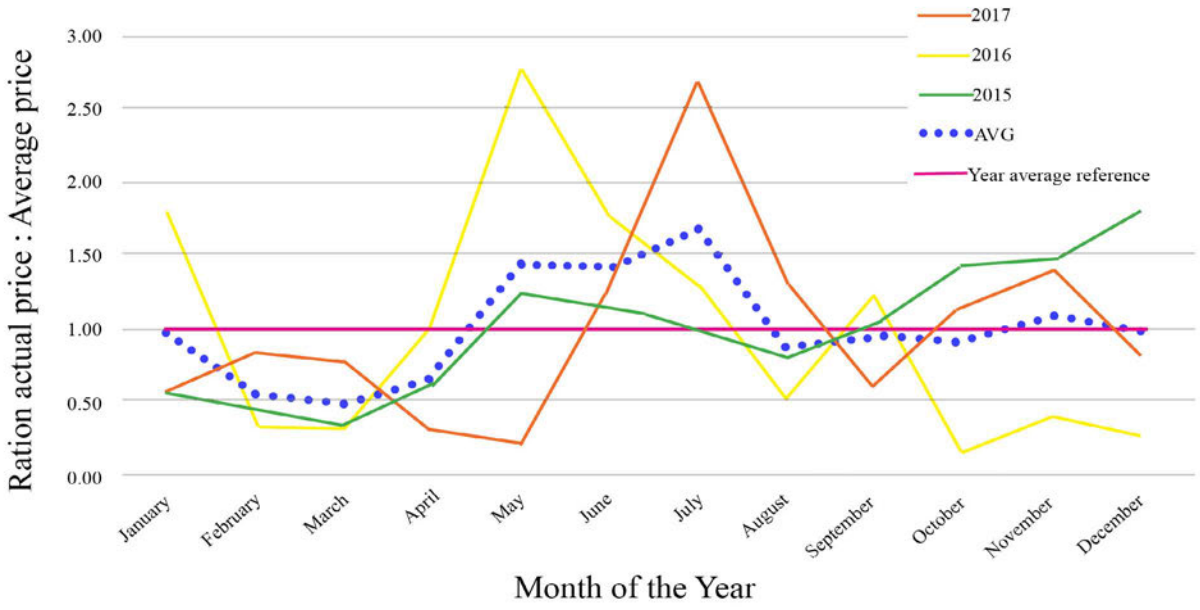


Figure 2-1 Price trends over three years (2015-2017) in relation to a yearly price average[3]

Based on this analysis of the current market situation, transplanting at different times of the year can be ranked as shown in Table 2-1.

[3]Data analysis by WorldVeg based on data obtained from: Agmarknet (www.agmarknet.nic.in)

Table 2-1 Months for transplanting ranked according to price expectations at the Madanapalle market

Highly prioritized planting months	Months that can be given medium priority	Least prioritized months for transplanting
March	June	December
April	July	January
May	August	February
	September	
	October	
	November	

Market prices are the complex interaction between offered and demanded quantities, infra-structure for distribution, transparency and power. To positively interact with the market, Farmer Production Organizations (FPO) should be well-organized to distribute their production over different seasons and to increase the market power of their members. Given the rapid daily fluctuation in prices, daily and historic market prices can be made available to the producer via smart phones in real-time.

Madanapalle market

2.2 Field selection

2.2.1 Soil properties

The soil is a very important factor in agricultural production. It provides the space for the roots, which give the physical hold to plants and work on water and nutrient uptake and gas exchange. During the early development of the plants, loose topsoil supports the root growth.

A slightly recompacted subsoil then gives a good hold for the bigger root system and is a good storage for water and nutrients.

A finely tilled light clay textured soil is preferred in summer to retain moisture for a long period. In the rainy season, lighter sandier soils are preferred to allow good drainage of excess water.

2.2.2 Crop rotation

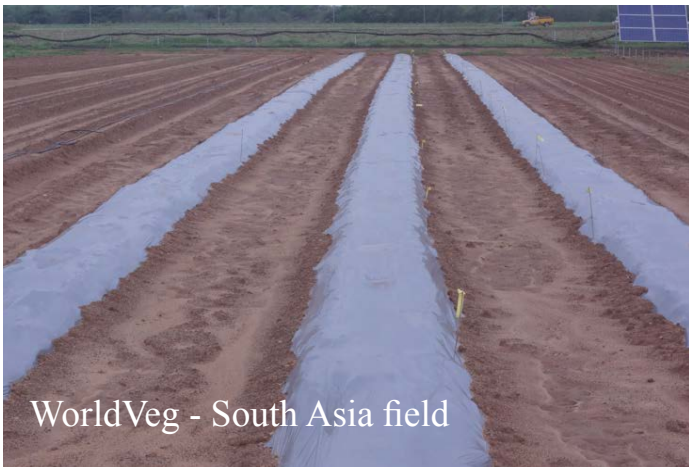
Crop rotation is a traditional method of conserving soil fertility and reducing pest and disease pressure. By planting crops with different nutrient demands in a sequence, the soil fertility is maintained. Furthermore, rotating crops breaks reproductive cycles of micro-organisms and insects, which are detrimental to the crop. Tomatoes are susceptible to a wide range of soil-borne diseases so it is important to not plant tomatoes in the same field year after year. Tomatoes also get many of the same diseases as chili and brinjal, so avoid planting tomatoes in a field that grew these crops in the previous season. Farmers, who – due to economic or social conditions – do not practice crop rotation must rely on other measures to avoid carry-over effects, which often involves a more intensive use of agro-chemicals.

2.3 Tillage and field preparation

2.3.1 Tillage and weed control

Weed control before planting is best done mechanically. Therefore, the field is not worked for about two weeks in order to allow weeds to germinate. After that the field is ploughed with a mouldboard plough or a disc plough, which mechanically destroys the germinated weeds and incorporates them into the soil. Afterwards, a light harrow is used for producing a fine crumble structure, before the actual ridges are made. On small fields, the use of power tiller is recommended for mechanical weed control and seedbed preparation (Figure 9-1). If mechanical weed control is performed, there is no need for a general application of herbicides.

Mulching (see sub-chapter 2.6) is an effective protection against weeds. Generally, the application of plastic mulch suppresses weeds after planting, at least to the point that the fast-growing tomato plants will outcompete weeds in search of light. Manual removal of individual weeds protruding the mulch may be more advisable and not more labour intensive than herbicide application.


WorldVeg - South Asia field

Where mechanical weed-control cannot be practised and where severe weed problems can be expected, applying a pre-emergence herbicide 2 to 3 months before transplanting may be helpful to reduce the weed pressure. The trade names are, however, not protected and may change according to producer and formulation. Thus, it is important to observe the active ingredient when selecting an appropriate herbicide.

Remember: All herbicides are toxic to plants, animals or human beings at different levels and may accumulate in the environment. Consider advantages and disadvantages when choosing your herbicide. Observe the recommended dose and wear protective gear during application. Some possible herbicides are listed below.

Pendimethalin @ 3 L/ha, kills mainly grasses and to a lesser extent broad leaved weeds. It is slightly toxic if ingested, inhaled or absorbed through the skin.

It is highly toxic to fish and aquatic invertebrates. Do not contaminate open waters during cleaning of equipment or disposal of wastes.[4]

Metribuzin @ 750 g/ha with a recommended dosage of 30 g/10 L of water. It is used for control of annual grasses and numerous broad leaved weeds in field and vegetable crops. It is slightly to moderately toxic to humans by oral or skin contact or inhalation. It is moderately toxic to birds and slightly toxic to fish. It is highly soluble in water and has a high potential for leaching into and contaminating, groundwater.[5]

Glyphosate @ 800 g/ha is a broad-spectrum, non-selective systemic herbicide. It is moderately toxic and carries the signal word WARNING on the label. There is an ongoing discussion, whether it is carcinogenic in humans. It is slightly toxic to birds and non-toxic to fish. Problems may arise from high doses of glyphosate over longer periods, as the substance is mobile within the plants and in part transported to weed roots. It may accumulate there and harm the following crop.[6,7]

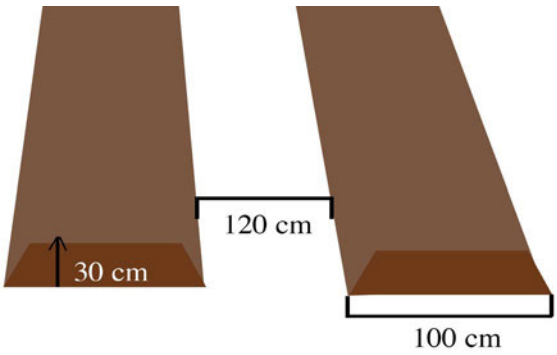
2,4-Dichlorophenoxyacetic acid (usually called 2,4-D) @ 1500 g/ha is a systemic herbicide which selectively kills most broad leaved plants but leaves most grasses unaffected. It is a part of many commercial weed control products. It is marked with DANGER as it causes eye and skin irritation at direct contact. Depending on the formulation it is moderately toxic to humans and birds and moderately to highly toxic to fish. It is toxic for tomatoes and should not be applied shortly before or after planting.

To avoid residual injury to seedlings it is important to avoid applying these herbicides within the recommended application period before transplanting.

No herbicide application can be recommended after transplanting the seedlings as it may cause toxic effect on the crop. Mulching is one of the strongly recommended solutions for weed problems. Mulch will prevent the weeds from emerging out. If a few weed plants such as Cyperus rotundus (Nut grass) emerge out of the mulch sheet, they may be hand pulled.

2.3.2 Raised bed preparation

Raised beds of 3 feet (100 cm) wide and 1 foot (30 cm) high are recommended with a distance of 4 feet (120 cm) in between the adjacent beds. Raised beds are particularly important if transplanting during the rainy season.



Although raised beds are important when planting in rainy season, they are advantageous in any season over planting on flat bed as there will be enough space for the roots to grow well in the undisturbed soil of the raised bed. When grown on flat beds, the rootzone is likely to get disturbed with the movement of workers and implements in between the plant rows and the compacted soil will limit the crop's ability for gas exchange.

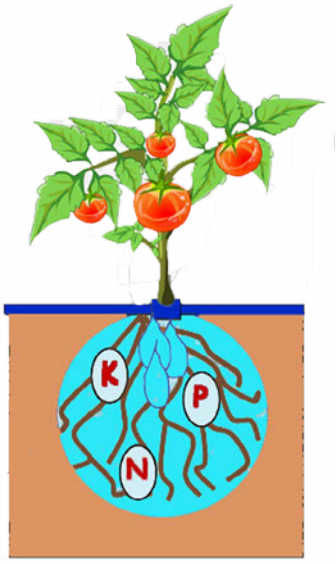
Making raised beds by use of hand implements is very labour intensive. By use of a ridge plough, raised beds can be created faster. A tractor operated ridge plough has a series of parallel implements that can be modified in their distance to create several raised beds in one passage (Figure 2-2, left). If animal traction or a one-axe tractor ("iron buffalo") is used, one single implement has to be used and each raised bed is formed by a back and forth passage. In order to create a flat top of the raised bed, a shaper can be used on a tractor pulled ridge plough (Figure 2-2, right).

[4]http://pmep.cce.cornell.edu/profiles/extoxnet/metiram-propoxur/pendimethalin-ext.html
[5]http://pmep.cce.cornell.edu/profiles/extoxnet/metiram-propoxur/metribuzin-ext.html
[6]Neuman, G. et al. (2006) Relevance of glyphosate transfer to non-target plants via the Rhizosphere.J PLANT DIS PROTECT, Spec. issue XX, pp. 963-969
[7]http://pmep.cce.cornell.edu/profiles/extoxnet/dienochlor-glyphosate/glyphosate-ext.html

Figure 2-2 Implements of a tractor pulled ridge plough.

2.4 Soil fertility management

Soil fertility depends on many factors, such as its organic matter content, cation exchange capacity (CEC), pH value and salinity (determined by its electrical conductivity (EC). For the grower the important questions related to soil fertility management comprise the stock of nutrients in the soil and their availability to the plants. The adequate supply with water and the most important nutritional elements, as well as their uptake by the plants will be discussed in sub-chapter 5.3. In the following paragraph the basic concepts about soil fertility, the use of organic fertilizers and soil amendments for base fertilization will be discussed.



2.4.1 Soil chemical properties and soil testing

2.4.1.1 Cation exchange capacity (CEC) and Organic matter

A soil with a high "cation exchange capacity (CEC)" is defined by a good ability of the soil particles to hold plant nutrients in the soil matrix. The chemical details of CEC will not be discussed in this manual (it is worthwhile noticing that the term CEC should not be mixed with EC, which is a measure for salinity and nutrient concentration in water).[8]

In general, a high CEC is correlated with a high clay content of the mineral soil. For a quick assessment of the clay content, take a portion of moderately moist soil and rub it between your palms: Clay particles remain in the profile of your skin. If you can role the soil between thumb and forefinger to create a ribbon of more than 5 cm length, the clay content is high . Clayey soils hold more nutrients. Fertilizer applications can be done in longer intervals.

A high organic matter content can further improve CEC. A dark, brown colour of the soil indicates high organic matter contents, pale colours indicate a lack in organic matter. Besides its effect on nutrient storage, organic matter positively influences soil biological activities, which are important for plant fitness and resistance against soil borne diseases.

2.4.1.2 pH and electrical conductivity (EC)

In order to take up nutrients, plants' roots create an acid environment around the fine root hairs. Thus, the ability of plants to acquire nutrients depends on the pH of the surrounding soil material. At a low pH plant roots are unable to remove nutrients from the soil matrix. That means: even if nutrients are there, the crop cannot benefit from them. The optimal pH for most crops is between 5.5 and 7.0, for tomato the recommended pH is 6.0 to 6.8. At a soil pH below 5.5, liming (paragraph 5.3.2) is recommended. A pH level above 7.5 may cause the release of plant toxic elements (e.g. Al++) or elements that compete with nutrients in the process of the crop's nutrient acquisition (e.g. Na+). A high soil pH is often associated with a high salt content.

Salt content is expressed by the electrical conductivity of the soil solution (EC). An EC level of higher than 2.5 dS/m will negatively affect tomato production (at 12 dS/m no tomato cropping is possible). In areas with more than 1,000 mm annual precipitation, soil salinity is general not a problem. Temporarily, high levels of salinity can occur as a result of excessive fertilizer application, water logging or the use of saline irrigation water. Water with an EC of more than 1.0 dS/m reduces its suitability for fertigation (see sub-chapter 5.6), an EC level above 3.0 dS/m makes it unsuitable for irrigation.

2.4.1.3 Soil testing

A soil test can be useful to assess the soil's nutritional status. Among the macronutrients (see paragraph 5.3.1) especially phosphorus (P) can be influenced on a long-term base and fertilizer applications can be based on soil test. Nitrogen and potassium are more mobile and strip trials may be more useful to determine the fertilizer requirement (see sub-chapter 5.4), which gives a more detailed explanation of crop nutrients requirements and fertilization strategies. With respect to micronutrients (e.g. Boron (B) or Zinc (Zn)), soil tests are particularly useful to detect deficiencies.

[8]A guide to texture by feel: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054311

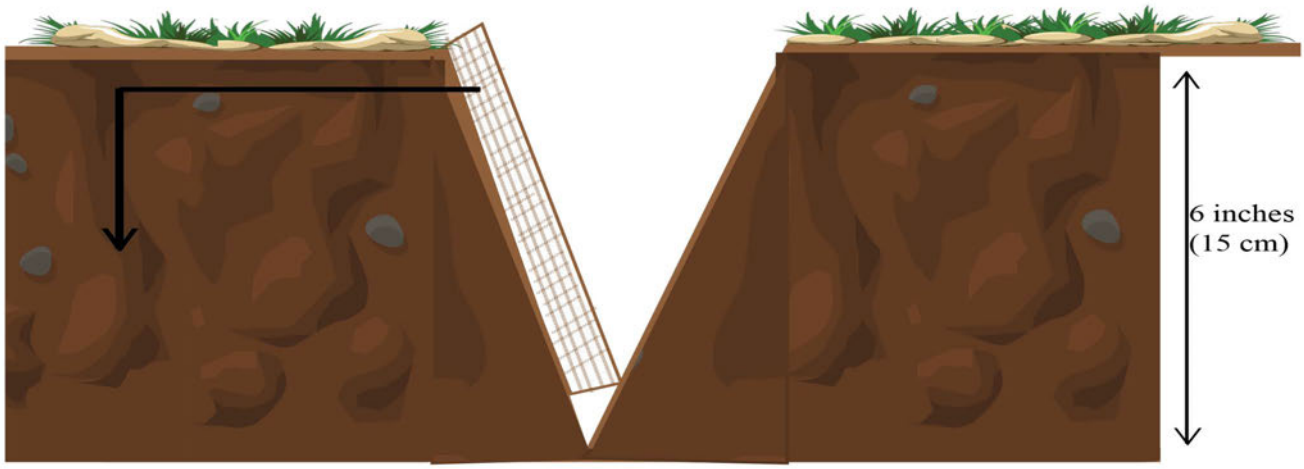


Figure 2-3 Cross section of a soil sample collection point

How to do a soil test?

1. Select 10-15 sampling spots in the field and remove the litter on the surface to get the sampling done.

2. Collect the soil sample unit by making a 'V' shaped cut to a depth of 15 cm in the sampling spot using spade to scrape the thick slices of soil on the surface as shown in the Figure 2-3. Then place the samples in a tray or a bucket.

3. Mix the samples thoroughly and remove any roots, stones, pebbles and gravels. To get the final sample for testing, it is required to go for mixing and dividing. To do this, spread this combined large sample on a clean hard surface or plastic sheet. Then divide it into four parts, discard the two opposite parts and select the remaining two. Mix them again thoroughly and repeat this process. Continue doing so till the entire sample reduces to around half to one kilogram of soil.

4. Collect this final sample in a clean cloth or polythene bag. Label the bag with information such as name of the farmer, location of the farm, survey number, previous crop grown, present crop, crop to be grown in the next season, date of collection, name of the sampler etc. and hand over at the soil testing laboratory to get the fertility status of the field.

ICAR- Indian Institute of Soil Science in Bhopal has developed a soil testing mini-lab called 'Mridaparikshak' and is supplying through 'Nagarjuna agrochemicals' in Hyderabad. They will help establish the minilab in the village, where soil testing can be done by a person trained by the vendor. This equipment is designed in such a way that it gives the nutrient recommendations separately for each crop.

Soil test results should be interpreted by an expert, but critical levels for a range of key elements are shown in Table 2-2.

Table 2-2 Nutrient levels in soil analysis.[9]

	Deficit	Desirable level		Toxicity
	Critically low	Lower	Upper	Critically high
P (mg/kg)	<16	60	70	
K (mg/kg)	<25	600	700	
Mg (mg/kg)	<30	350	700	
Ca (mg/kg)	<400		1000	
N (mg/kg)		50	100	
B (mg/kg)	0.2	1.5	2.5	>3
Mn (mg/kg)		5	20	>80
pH (--)	5.5	6	6.8	7.5
EC (dS/m)		0.8	1	3

The agricultural field is a biological system which consists of many components. Only one cubic meter of soil contains a number of micro-organisms which is beyond counting, including the crop and competing plants, the climate and water supply, management aspects other environmental influences, it is impossible to predict the actual nutrient requirement of the crop in a particular field exactly. Nutrient supply, availability and losses determine the fertilization requirements. Data given in this manual are based on a series of recommendations from the literature and practitioners. However, for a good fertilization program, it is necessary to keep in mind all important aspects, rather than following one single recommendation. A soil test based nutrient recommendation should be treated as one component of a fertilization plan.

[9]Sainju, UM et al. (2003) Mineral Nutrition of Tomato. J. of Food, Agriculture and Environment 1: pp. 176-183

2.4.2 Organic fertilizer

The use of organic fertilizer is particularly important, as it does not only supply a variety of nutrients, especially phosphorus and micronutrients, but it also adds organic matter to the soil, which improves the general soil fertility (see paragraph 2.4.1.1).

2.4.2.1 Kinds of organic fertilizer

The richest organic fertilizer is farm yard manure (FYM). FYM refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to cattle. It contains substantial amounts of all macroelements (N, P, K) and traces of many micronutrients. For hygienic reasons and for a good nutrient availability it must be well composted. The nutritional contents may vary, and so a nutrient analysis of FYM to be used as fertilizer may be useful.

Organic fertilizer can also be applied in the form of compost or vermi-compost from composting plant residues. There are different ways of producing compost for the use in tomato production. It is important to ensure that the composting process has taken place completely, destroying all pathogens and avoiding carry over effects. This is especially important, if the compost contains plant material from tomato, chilli or brinjal plants.

2.4.3 Amendments

In principle, soil amendments may have two functions: a. Improve the soil sanitary status and
b. Improve fertilizer availability.

Nowadays, with advances in agricultural research, improved records of agricultural practices and better understanding of soil biology, a big amount of different soil amendments are available in the market. Among these amendments there is a considerable number of proven benefits in general agriculture, while others may work under specific conditions only and some have a rather spiritual impact on cropping. A complete review would be beyond the scope of this manual. Instead, some examples will be provided of soil amendments with rather well documented effects.

2.4.3.1 Amendments to improve the soil sanitary status

Neem cake is the residual product from neem-oil production, a bio-pesticide. Apart from its nutritional benefits, neem cake contains residues of neem oil, which kills insect eggs and pest insects that seek cover in the soil.

Trichoderma harzianum, Trichoderma viridae are fungi, which are not harmful to the crop, but compete with fungal pathogens, preventing fungal diseases. Being a fungus itself *Trichoderma* is susceptible to fungicides.

The underlying functions are not yet completely understood, but it has been shown that *Pseudomonas fluorescens* is effective against some *Fusarium* spp. and reduces the nematode population.

Paecilomyces lilacinus, Pochonia chlamydosporia are fungi, which parasitize and kill eggs, juveniles and young adults of phytophagous nematodes.

2.4.3.2 Amendments to improve the nutrient availability of the soil

Azotobacter spp., *Azospirillum* spp. are free-living, nitrogen-fixing bacteria. They can fix nitrogen from the air and make it available for plant nutrition. Air consists of 78% nitrogen, one of the most important plant nutrients (see paragraph 5.3.1) but its chemical form (N_2) makes it inert, so that plants cannot use it. *Rhizobium* bacteria that live in symbiosis with legume plants, are well-known for taking N from the air and making it available to the host plant. Phosphate Solubilizing Bacteria (PSB) are beneficial bacteria capable of solubilizing inorganic phosphorus from insoluble compounds. Thereby, these bacteria improve the P availability for the crop (e.g. *Pseudomonas fluorescens, Bacillus subtilis*).

These microbial cultures are available in powder form with different trade names from local fertilizer and pesticide shops. Farmers who would like to use these may have to check in their local shop in Madanapalle or get from bigger shops in Bengaluru.

2.4.4 Basal fertilization of the soil before planting

In rainfed tomato production basal fertilization is the main source of nutrients for the plants. In irrigated crops, nutrients can be applied with the irrigation water (see sub-chapter 5.6) during the cropping period to meet the crop's changing nutrient requirements. However, even under fertigation a basal fertilization containing organic fertilizer and appropriate amendments is beneficial for crop production.

Both farm yard manure and neem cake: When enriched with the commercially available bio-agents and applied to the raised beds, the combination helps in protecting young seedlings from soil borne diseases. While FYM supplies more nitrogen and organic carbon, neem cake kills the insect eggs in the soil preventing their fast multiplication. Farmers may choose to enrich either the FYM or the neem cake, or a combination. When combining the total application of neem cake and FYM should not be more than the amount for a single component recommended. Excess application reduces the efficiency and may have a negative effect on soil biology.

IIHR, Bengaluru recommends application of either enriched FYM or enriched neem cake during bed preparation. The process of enrichment has been explained here.

Basal FYM enriched with microbial agents: One tonne of well decomposed FYM is thoroughly mixed with one or more of the following amendments: *Azotobacter or Azospirillum,* Phosphate Solubilizing Bacteria *(Pseudomonas fluorescens* or *Bacillus subtilis), Trichoderma harzianum* or *Trichoderma viridae, Paecilomyces lilacinus* or *Pochonia chlamydosporia* @ 1 kg each. Which and how many of the amendments are used in the mixture depends on other aspects of farm management, as well as on availability and cost of the respective amendment. The mixture is moistened by sprinkling water and covered with wet gunny cloth and kept to incubate for about 3- 4 weeks (20-28 days) under partial shade. For better aeration and decomposition, turn the FYM after about 10-12 days. This one tonne of enriched FYM should be mixed with nine tonnes of straight FYM to make it to ten tonnes of FYM mixture for broadcasting on one hectare in the main field.

Basal neem cake enriched with Bio-fertilizers and Bio-pesticide: Powdered neem cake (100 kg) with an oil content of 10 to 12 % is thoroughly mixed with *Azotobacter* or *Azospirillum,* Phosphate Solubilizing Bacteria *(Pseudomonas fluorescens or Bacillus subtilis), Trichoderma harzianum* or *Trichoderma viridae, Paecilomyces lilacinus* or *Pochonia chlamydosporia* @ 1 kg each. This is then moistened by sprinkling water and covered with wet gunny cloth before allowing it to incubate for about 10 to 12 days under partial shade. If it is to be stored for a few more days, it is advised to give a turn for better aeration and decomposition. This enriched neem cake can be applied to the main field along with 10 tonnes of straight FYM at the time of bed preparation for planting.

2.5 Seedling treatment

If commercial seedlings are used, farmers do not need to apply any seed treatments, but the application of bio pesticides mixed into enriched FYM can provide protection from a range of seedling diseases that can affect the crop after transplanting.

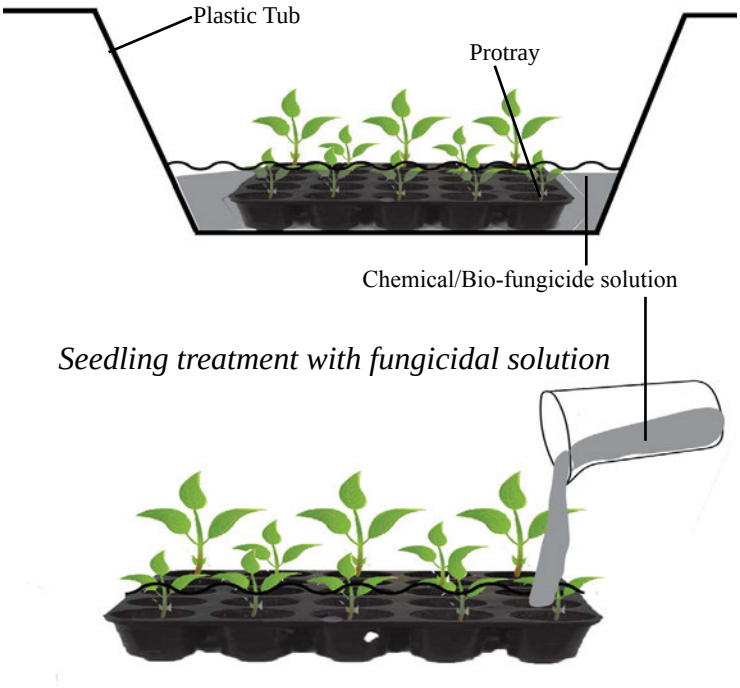
Dipping the seedling roots in a biopesticide solution mix of *Trichoderma harzinum* @ 10 g/L + *Pseudomonas flourescens* @ 10 g/L of water will protect the seedlings initially from seed borne fungal and bacterial diseases such as damping off, root rot, crown rot and bacterial wilt.

Seedlings can also be dipped in fungicide solution of thiram or carbendazim @ 2.5 g/L followed by dipping in thiamethoxam 25 WG @ 1 g/L water for10-15 minutes. However it may not be practical to take individual seedlings from the tray and dip them in the solution as the medium surrounding the roots may get washed off leaving the bare roots behind. When such seedlings are transplanted, they may either take a longer time to establish or will not establish well.

To reduce this risk, two methods can be suggested.

> Prepare the biopesticide solution in a large tub that has enough room for the seedling tray to be dipped. Then dip the protray in the solution, take it out and dry it in the shade for 5 to 10 minutes before transplanting.

> Prepare the solution in a plastic bucket, take a small quantity in a disposable tumbler and drench the medium in which the seedlings are held.



Seedling treatment with fungicidal solution

2.6 Mulching

Mulching is the process of covering the soil around the plants to improve plant growth. It has multiple benefits for the growing crop (Figure 2-4) and can later protect fruits from coming in contact with the soil. Mulch is thin layer of any substance spread over the soil near the plants' root zone. A range of different mulches can be used, but the most common are organic and plastic mulches.

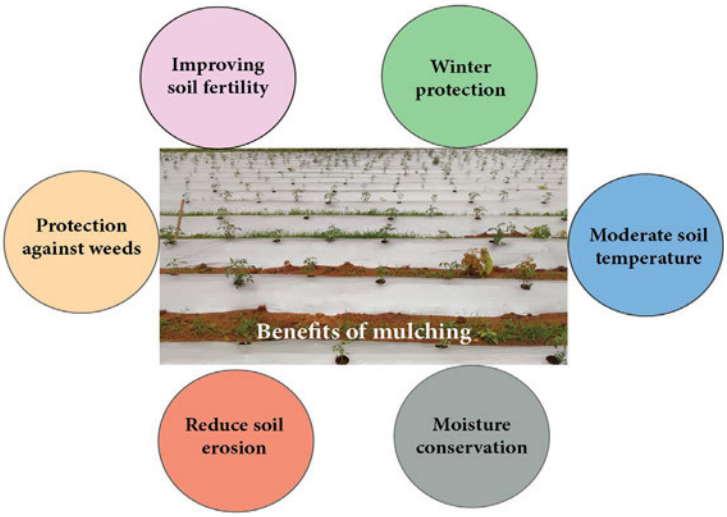


Figure 2-4 Benefits of mulching. Depending on the site of production and the kind of mulch used, several of these benefits may apply.

2.6.1 Organic mulch

Organic mulches (Figure 2-5) are bio-degradable. They stay in place for one cropping season, performing as a protective layer. After the cropping season, they are typically incorporated into the soil by basic tillage and to add some nutrients and organic matter to the soil. Farmers usually use farm wastes such as dried leaves, fallen branches, hay, grass, finely cut dried bark, jowar trash, paddy husk, dried sugarcane leaves, dry coconut leaves, coconut husk and compost to maintain micro-climatic conditions congenial for good plant growth.

Traditionally, farmers in the Madanapalle region have been using organic materials as mulch. The benefits are that they keep soil temperatures cool and they are inexpensive, natural and bio-degradable. The disadvantages are a lack of sufficient material to cover large crop areas and the danger of spreading pathogens through any undecomposed plant wastes applied near the root zone. It is, therefore recommended not to use organic mulch originating from tomato, chili or brinjal plants in tomato production.

Figure 2-5 Organic mulching with straw.

Table 2-3 Comparison between organic mulch and plastic mulch

Organic mulch	Plastic mulch
Cheap, if available on farm	Costly, depending on thickness and colour
Labour intensive in handling and storage	Easy handling
Labour intensive at field application	Easy application, mechanisation possible
Risk of carry-over of pests and diseases	Inert material, no carry over effects
Good for weed suppression	Very good for weed suppression
Biodegradable	Waste must be disposed off
Adds organic matter to the soil, when incorporated after the season	---
Suppresses a substantial share of evaporation	Suppresses evaporation completely

The question, whether to use organic mulch or plastic mulch cannot be answered definitively. In general, the advantages of organic mulch (cheap, biodegradable) tend to be more important on small farms, while the advantages of plastic mulch (easy handling, suppression of evaporation and weeds) become more important with increasing farm size and level of mechanisation (Table 2-3).

2.6.2 Plastic mulch

Polythene sheets of 25-30 micron thickness are spread on the raised beds as mulch. Generally, plastic mulches have the best properties for soil moisture conservation, as evaporation under the mulch is completely suppressed. They need safe disposal methods as they are non- biodegradable.

A good recycling technique is essential to protect the environment.

Some farmers have experienced weeds emerging through these mulch sheets. Using a thicker mulch sheet of 40 microns has been reported to solve the problem. But the use of thicker films has not been widely adopted, as the higher material cost doubles the total cost of mulching.

Safe disposal of used plastic mulches

To remove the mulch completely without tearing, wet it before removal. Dispose the mulch sheet for recycling to buyers who collect used mulch sheets from the field.

Plastic mulches are available in the market in different colours. The most common one used is all black, but this is gradually being replaced by the black and silver coloured plastic sheets. Different colours have an influence on light absorbance and reflectance and therefore influence the temperature of the soil underneath. Advantages and disadvantages of different plastic mulches are discussed below

2.6.2.1 Black plastic mulch (Figure 2-6 a)

This plastic mulch absorbs most incident solar radiation, including visible, infrared and ultraviolet light. Although much of the heat absorbed is lost to the atmosphere through convection and re-radiation soil temperatures will be increased under black mulch and it is therefore not recommended during summer months.

As black film does not allow the sunlight to pass through, it stops weed growth by preventing photosynthesis, unless germinating weeds (nut grass etc) are strong enough to penetrate the plastic film.

2.6.2.2 White plastic mulch (Figure 2-6 b)

Light is reflected back into the atmosphere or the plant canopy from a white plastic mulch, resulting in slightly cooler soil temperatures (-1 °C at 2.5 cm depth). White plastic mulches can be used to establish crops in the summer, when a reduced soil temperature can be beneficial.

(a) Black plastic mulch is the most common

(b) White plastic mulch for lower soil temperature

(c) Silver mulch is increasingly used

(d) Red plastic mulch

Figure 2-6 Plastic mulches with different colours have different light absorption properties and, therefore, different effects on the temperature of the soil underneath.

2.6.2.3 Plastic mulch that is black on one side and silver on the other (Figure 2-6 c)

These have gained acceptance in the recent past. The silver side is exposed to the sun with black side touching the soil surface. It slightly cools the soil and repels aphids and thrips to a considerable extent, so reducing the incidence of insect-borne diseases. It is slightly more expensive than single coloured plastic mulches.

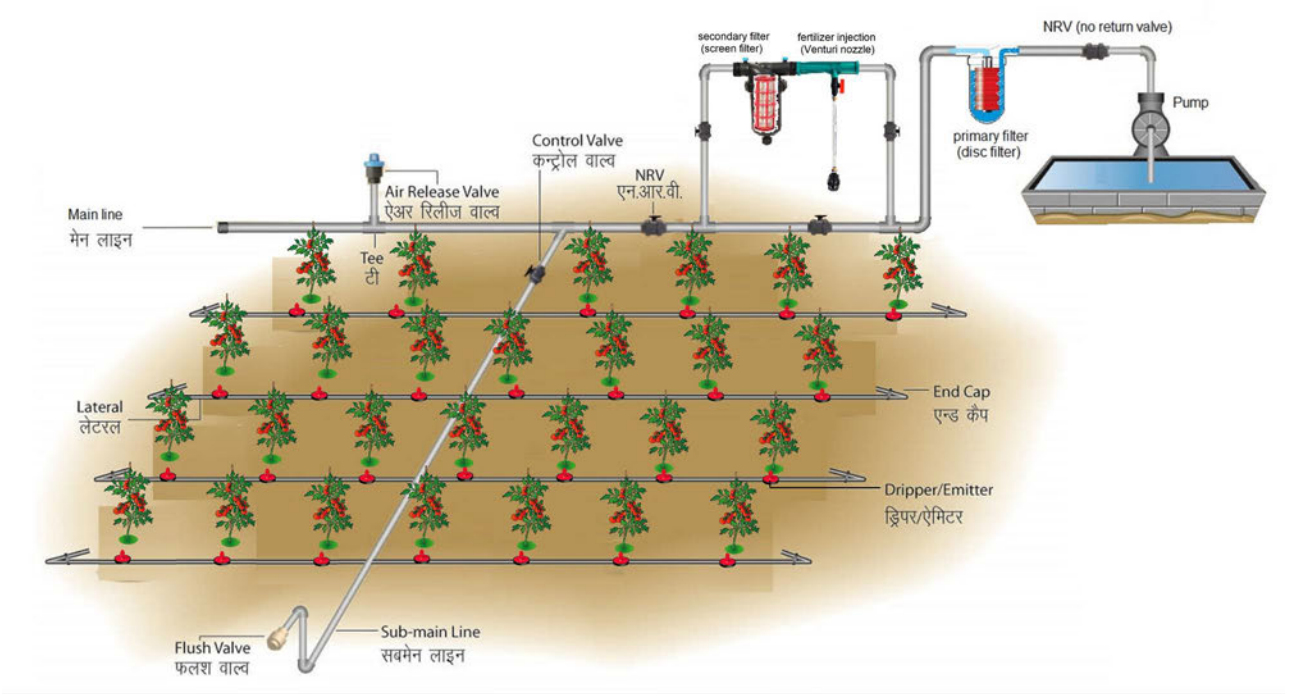
2.6.2.4 Red plastic mulch (Figure 2-6 d)
It is partially translucent allowing radiation to pass through, but also reflects radiation back into the plant canopy resulting in changes in vegetative and flower development, with earlier fruiting and potential yield increases. Red plastic mulch has been shown to increase tomato yields and quality in some trials and to reduce the severity of early blight in others, but it is yet to gain in popularity.

2.6.2.5 Laying of plastic mulch

Plastic mulch is laid before transplanting and after the bed preparation. Doing this manually and anchoring the edges is time consuming, tedious and expensive. If available, a tractor mounted mulching laying machine can be an easy way of doing this. Soil needs to be hilled up around the edges of the mulch on all sides to keep it in place.

As a regular practice, drip lines are laid under the plastic mulch. The spacing provided between two adjacent emitters is around 40 cm, which suggests the farmers to adopt the same spacing for their crop.

The easiest way to avoid blocking of the drippers may be to clean them with plain water once in 10 days by opening the end cap and allowing the water pass through the drip lines for 45 to 60 minutes once in 10 days will help in washing away all the impurities, resulting in a clean system. It may also be important to follow the guidelines provided by the installation company for the drip system maintenance.



Layout of drip irrigation system

2.7 Transplanting

2.7.1 Recommended spacing of transplanted seedlings

Two kinds of planting can be recommended for tomato based on the season, land preparation and the variety grown.

2.7.1.1 Single row of seedlings on each bed

Generally, semi-determinate varieties that have a rigorous growing habit are planted in a single row on a raised bed / flat bed. The recommended distance between the rows is 4 feet (120 cm) and the spacing between the plants in the row is 1.5 feet (40 cm) (Figure 2-7).

When mulching is done manually on the raised beds, round holes are made as per the recommended spacing (4 ft x 1.5 ft, or 120 cm x 45 cm) using a punch or a large diameter pipe and a hammer. In case of machine laying, holes are cut in the mulch by the machine.

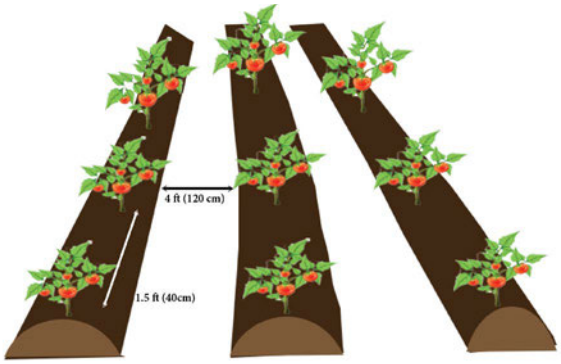


Figure 2-7 Sketch of 4 x 1.5 ft planting pattern for 18,500 plants per hectare. Single row of the plants on a raised bed.

2.7.1.2 Two rows of seedlings on each raised bed:

Determinate varieties that grow to a set height of 2-3 feet can be planted in a paired row on a raised bed. 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 populations.[10] The typical spacing between the paired rows on a bed is 50 cm and 120 cm between two raised beds. The spacing between the plants in the row is 40 cm.

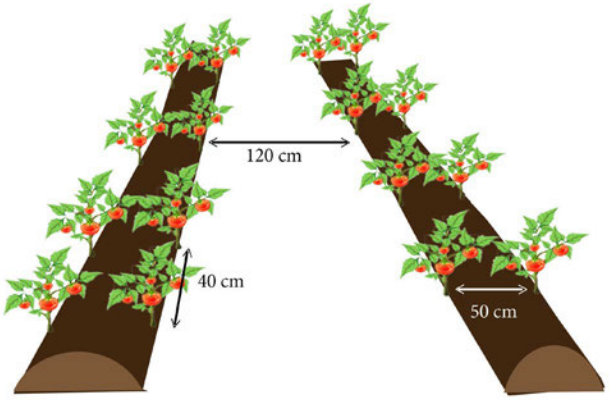


Figure 2-8 Seedlings planted in paired rows on a raised bed

How to transplant seedlings

Seedlings are transplanted into the holes either manually or with the help of an easy planter, as explained in the last chapter.

[10]Tomato Production guide 2014 www.starkeayres.co.za

3. SELECTION OF VARIETIES AND SEEDLINGS

3.1 How to select a suitable variety

Choosing a variety mainly depends on market preferences, and generally, farmers have a very limited choice. They grow the varieties that are provided by nurseries and preferred by the traders in the local market, which in turn depend on consumers' preferences. Traders generally consider size, shape and colour of fruit as well as the skin thickness and whether the fruit is lustrous or shiny.

The main difference is that the Madanapalle market prefers round shaped fruit while the Kolar market prefers oblong shaped fruit.

There are two main types of tomatoes based on their growth habit (Determinate or Indeterminate), with the special type of semi-determinate, and two types based on what they are used for (fresh market or processing). Most tomatoes currently grown in Madanapalle are semi-determinate fresh market types, but there are opportunities for other types.

3.2 Types of tomato based on their growth habit

3.2.1 Determinate varieties

They have a determined height and grow 2 to 3 feet tall (60-90 cm), then stop growing and have one determined time of flowering, fruit set and fruit development. They are bushy in appearance and the entire crop ripens in a short window of 4 to 6 weeks, so they are normally harvested once. The fruits can be easily picked and these are suitable for open field conditions (Figure 3-2).

3.2.2 Indeterminate and semi-determinate varieties

These varieties keep on growing until they are killed by disease. The plants set and ripen fruit continuously, which means the harvest season can extend for many months and the total yield from a single plant can be very large. In good conditions, indeterminate tomato plants can grow up to 30 feet tall (10 m). These are most suited for cultivation under protected conditions and are not recommended for open field cultivation (Figure 3-2).

There are, however, varieties which in their habitus resemble indeterminate varieties, but they produce most of their fruit within one month after their first flowering. Commonly, they are called "semi-determinate", even so this term is not officially accepted. They are well adapted for open-field cultivation and produce between 3 and 5 pickings, before the yields decrease considerably.

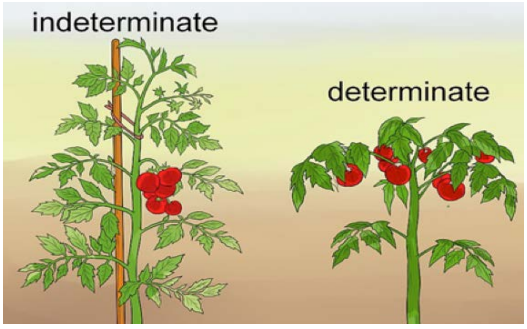


Figure 3-1 Schematic representation of determinate and indeterminate tomato plants.

3.3 Types of tomato based on their use

3.3.1 Fresh market types

In India most of these are acidic, round or oblong and suited to use in cooking or salads. Almost all the tomatoes currently grown in Madanapalle are these types.
Consumers of fresh market tomatoes prefer familiar looking varieties and expect specific quality attributes, such as taste and texture. With a good harvest and post-harvest handling, these varieties are appropriate for high value markets.

3.3.2 Processing types

These have a deeper red colour and a higher solids content than fresh market types, as these are the most important quality attributes in the processing industry. However, dark red tomatoes with a firm texture can be very attractive for the fresh market as well as for processing. Therefore, they are often called "dual-purpose" varieties. At present there are very few of these grown in Madanapalle, but there is a rapidly expanding market for such types in India. WorldVeg is trialing types of tomatoes in Madanapalle that are better suited to processing than current market types.

3.4 Commercial tomato hybrids suitable for the region

Name	Producer	Characteristics
Abhinav	Syngenta Seeds	Semi determinate with vigorous plant habit. Broad leaves with excellent foliage cover. Very firm fruits with good keeping quality, square shape and medium size (80 -100g). Fruit harvesting starts 60-65 days after transplanting. Uniform fruit ripening with attractive deep red and glossy.[11]
US-440	US-Agri	Determinate type. First harvesting starts from 60-65 days after transplanting. Very firm fruits with flat round shape, medium size (80-100 g) and excellent shelf life. Tolerant to tomato leaf curl virus and heat.
PHS-448	Rasi HyVeg	Semi determinate plants with good foliage cover. First harvesting starts from 60-65 days after transplanting. Rectangular/square/oval red fruits. Average fruit weighs 90-100 gm. Fruits are very firm and good for shipping. Intermediate resistance for bacterial wilt and tomato leaf curl virus. High yielding and long crop duration.
Prabhav	Nongwoo Seed India Pvt Ltd.	Semi determinate, Vigorous and strong with good foliage. First marketable produce starts from 60-65 days after transplanting. Round with firm Fruit, attractive dark red colour and uniform white shoulder (average Fruit Weight: 90-95 g) Good yielding, good tolerance for Tomato Yellow leaf curl virus and medium tolerance for Early Blight. Good for longer distance transportation. Fruit tastes sweet and sour. The sowing season is from February to June.
Arka Rakshak	Indian Institute of Horticultural Research (IIHR)	Dark red and oval shaped fruit and on an average can produce 75 tonnes per hectare. It cannot be recommended where temperatures exceed 36°C. Triple disease resistant F1 hybrid that can yield up to 18 kg/plant. It has resistance to tomato leaf curl virus, bacterial wilt and early blight in open field crops.
Arka Samrat	Indian Institute of Horticultural Research (IIHR)	High yielding F1 hybrid, oblate to high round in shape. Triple disease resistance to tomato leaf curl virus, bacterial wilt and early blight. It yields up to 80-85 tonnes per hectare in 140 days. This may be acceptable to Madanapalle market due to its round fruit.


IIHR-Arka Rakshak variety


US-440 tomato hybrid

[11]https://www.syngenta.co.in/tomato

3.5 Choosing a good source of seedlings

Choosing the right variety and the right nursery to provide healthy seedlings are essential for a good crop. How the seedlings are grown affects how fast they recover from transplanting shock, and their susceptibility to pests and diseases. Good seedlings can make all the difference to growing a healthy crop, so choosing a reliable nursery is essential. Farmers often take the variety provided by a nursery, but if they prefer to cultivate a particular variety, they will need to work with a nursery to grow the seedlings correctly. In choosing a reliable nursery, farmers should look for the following things.

How to select healthy seedlings

Observe the hygiene of the nursery: It is always important to obtain seedlings from a clean and well maintained nursery. Even if the seedlings appear healthy, they can still harbour viruses if the surroundings are not clean. Check for fine-meshed and undamaged insect netting on the side walls, properly closed double doors, weed free surroundings, the installation of sticky traps inside the nursery and no water stagnation under the seedling trays in the nursery.

Read the label on the trays: Check for the variety and the date of sowing on the label.

Avoid the biggest and tallest: Never believe that the biggest and tallest seedlings will establish faster in the field. They may have weak stems and take a long time to establish.

Look at the roots: A poor root system will produce a weak plant. Pick the seedlings that have a strongly developed root system to help them perform better in the field.

Avoid over-aged seedlings: It is recommended to transplant 25-30 days old seedlings. Older transplants may produce earlier yields, but may bring more pest and disease problems.

Check the foliage: Pale and yellow foliage might indicate a nitrogen deficiency. Look for a uniform colour on all the leaves- whether dark or light green. Avoid vary pale and dark green seedlings.

Avoid seedlings with their roots protruding out of the cavities: When such seedlings come into contact with the soil, they are more likely to carry soil borne pathogens.

Inspect the seedlings for any insect pests or diseases: Make sure that the leaves are not carrying any eggs and larvae of insect pests or any diseased spots.

Check for the moisture in the coco peat: If there is excess moisture in the growing medium, it may hinder the uptake of nutrients due to the build-up of salts or attract fungal spores as soon as the seedling is transplanted.

4. CULTURAL PRACTICES FOR HIGHER PRODUCTION

4.1 Staking

Staking tomatoes improves fruit quality by keeping plants and fruits off the ground and by providing better spray coverage. It is also easier to harvest staked tomatoes than tomatoes growing across the ground.

Vigorous cultivars may require larger and longer stakes. A stake placed between every other plant is adequate to support most determinate varieties. Stakes can be driven a foot deep into the soil with the help of a crowbar.

In general, growing plants have to be staked as soon as the branches start developing around 25-30 days after transplanting. This may vary slightly with the growth habit of the variety.

Different staking practices have been explained here.

4.1.1 Galvanised poles supporting the plants:

These are very expensive, but can be used repeatedly for many years. These poles are placed on either side of the tomato plant rows. Plants tied with a twine or jute thread to these poles will be able to stand erect (Figure 4-1, left).

4.1.2 Wooden poles:

Strong wood or bamboo poles over 7 feet (210 cm) long are fixed on both sides of the plant rows and brought together to be tied into an inverted V shape. A strong thread or metal wire is run across the joined portion, and each individual plant is tied to this with the help of jute or nylon thread. This provides strong support to the plants helping them withstand heavy winds. Depending on the kind of wood used, the poles are disposed after use. While bamboo poles generally only stand one season, other types of wood may be more resistant (Figure 4-1, right).

Figure 4-1 (left) Support with galvanized poles (right) bamboo poles inverted v-shape

4.1.3 Single pole in between the rows:

This is a low cost practice adopted by many farmers. Bamboo or eucalyptus poles are fixed in between the rows in the ridges at a pole to pole distance of about 10 feet (3 m). Metal wires or strings are run across horizontally at a uniform height connecting all the poles. Each plant is tied up vertically with the help of a thread to these horizontal strings (Figure 4-2). This provides a very good support system for determinate types of tomatoes.

Figure 4-2 Threads run across the poles

4.2 Pruning

Pruning helps maintain a balance between vegetative and reproductive growth.

If you do not prune or prune very little, your tomato plants will produce excessive vegetative growth with reduced fruit size. Moderate pruning will leave your plants with smaller vines and larger fruit that will mature earlier. Pruning keeps plants and fruit off the ground, helping to control diseases. Although pruning requires a lot of effort, the benefits of doing so are more marketable fruit, easier harvesting, and reduced injury to plants when multiple harvests are being made.

This practice is most profitable when a long harvest season is possible and when there is uniform fruit production over the season.

The most common method is pruning to produce a two-stemmed plant by pinching off lateral branches, known as suckers, as they appear in the axils of each leaf. If it is piratically difficult, it may be recommended to prune up-to four to five stems.

To achieve this balance, remove all the suckers up to the one immediately below the first flower cluster (Figure 4-3).

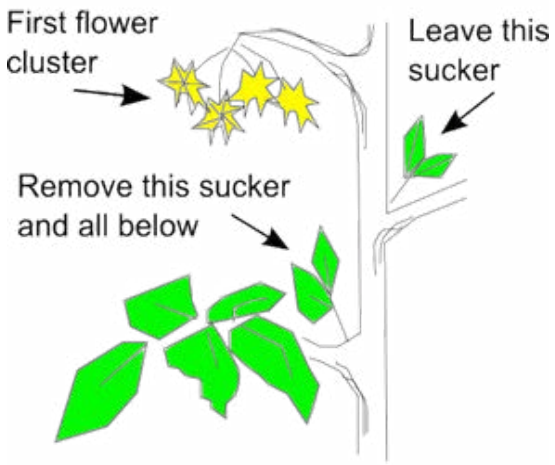


Figure 4-3 Pruning of tomato plants

A single pruning will usually be adequate, although a later pruning may be needed to remove suckers growing from the ground at the base of the plant. Suckers should be removed when small, no more than 2 to 4 inches in length.

Pruning should be done in the early morning or on a dry day, when leaves are just visible with a very small wound. This will allow for a good heal and low risk of infections.

5. WATER AND NUTRIENT MANAGEMENT

5.1 Crop water requirement

5.1.1 Why is water important for tomato cropping?

Water is important for plants in many ways: It gives stability to the cells, so that the plants remain firm, is involved in the photosynthesis which makes the plants grow and nutrients are taken up by the roots only when dissolved in water. Most of the water is used for processes that keep the plants alive and then it is released to the air as an invisible water vapour. Less than 2% of the water that a plant uses is kept in its tissue. This explains why we have to irrigate a lot, even though we don't see much of that water in the plants on our field.

"Drought stress" and "water logging"
If a plant does not receive enough water, it is called "drought stress". Similar to human beings, stress of any kind makes the body more fragile, less resistant to diseases and shortens the life. During different growth stages, "drought stress" has different effects. During the early growth, it makes the plant grow slowly and smaller plants have less yield. During flowering it can cause flowers to drop. "Drought stress" during fruit set reduces the number of fruit and later also the fruit size and can lead to deformation of fruit. If there is too much water in the soil, it is called "water logging". It can happen on the top of the soil, so that water can actually be seen, but it can also happen inside the soil, so that we cannot see it. When there is "water logging" in the root zone, plants cannot breathe, roots die and start to rot.
Follow the instructions given in this manual or provided by irrigation companies to avoid both "drought stress" and "water logging"!

During a drought, leaves will go limp and they stop to grow. But sometimes, lack of water is not visible to the naked eye. Plants that receive not enough water close their stomata, which they use for gas exchange. They will use less water and less nutrients are taken up. If this is the case, the crop grows less and makes less yield. So, even though no physical change in the crop can be seen, yield is reduced and all other inputs applied to the plants – effort for weeding and pruning, chemical application, fertilizer – are lost because it cannot make more yield. On the other hand, when the crop is damaged by pests or diseases, applying more water and fertilizer doesn't produce more yield. So, only if all aspects are managed well, there will be a good tomato yield at low production cost.

5.1.2 Methods to determine crop water requirement

In general, there are three ways to find out, how much water needs to be applied to a field: Calculate, how much water the plant needs according to the weather, check, how much water is in the soil or check for the crop water status.

Checking the crop water status can be done by looking at the crop. If there is not enough water, leaf angles change, the leaves "hang" down. Finally, plants without water wilt. If we can see this signs, it is too late. By then the crop has already been damaged. So, this kind of observation is not useful in farming. Scientists know many more methods to exactly determine crop water status: They check for the force the plant uses to keep water in the tissue, measure the amount of water vapour coming out of the leaves, measure the reflection of light in the green leaves, or determine the temperature of the canopy. These methods are good for science, but not for farmers, as they are complicated and expensive.

Checking, how much water is in the soil, is the most important way that farmers have been using for centuries to see, if the crops have enough water or not.

A farmer, who has experience and knows his soil, can find out, if it has enough water in it so plants can grow, by squeezing the soil between the fingers. But often farmers only check on the surface and don't know what happens at 40 cm in the ground. Pushing a metal rod into the soil until feeling resistance is a method which can give information on how deep down the soil is well supplied with water. A simple tool to find out if there is water down in the soil, is called "tensiometer". It is a pipe which can be inserted in the soil and it can show, if the soil needs irrigation or not.[12]

Another method to check water in the soil is based on electromagnetic measurements. In high-tech agriculture it is often used for automatic irrigation. Nowadays, this is still too expensive for most tomato growers in Madanapalle. But in the not so far away future, automatic irrigation will be as normal as a motorbike with electric starter is today.

Where weather data is available, the plant water needs can be estimated. Therefore, a mathematical formula is used that processes temperature, relative humidity of the air, wind speed and solar radiation, to find out the plants' needs and considering the rainfall, the needed amount for irrigation is known. Many smart-phone based apps can do this calculation nowadays.

5.2 Tomato irrigation in Madanapalle

How much water the tomato plant needs, depends on its variety, the season, weather and the stage of growth. The water that needs to be given to the crop also depends on the soil and the weeds. Weeds also take up water and release it to the air. So, weed control saves water. Water evaporates from the uncovered soil, especially while the crop is still small. Using drip irrigation under mulch can avoid this kind of water loss. Also, drip irrigation is the best method of watering tomatoes for a high yield, because it brings water and nutrients right to the rootzone.

If there is not enough rainfall, water is best provided by drip irrigation. During the rainy season irrigation can provide nutrients to the plants.

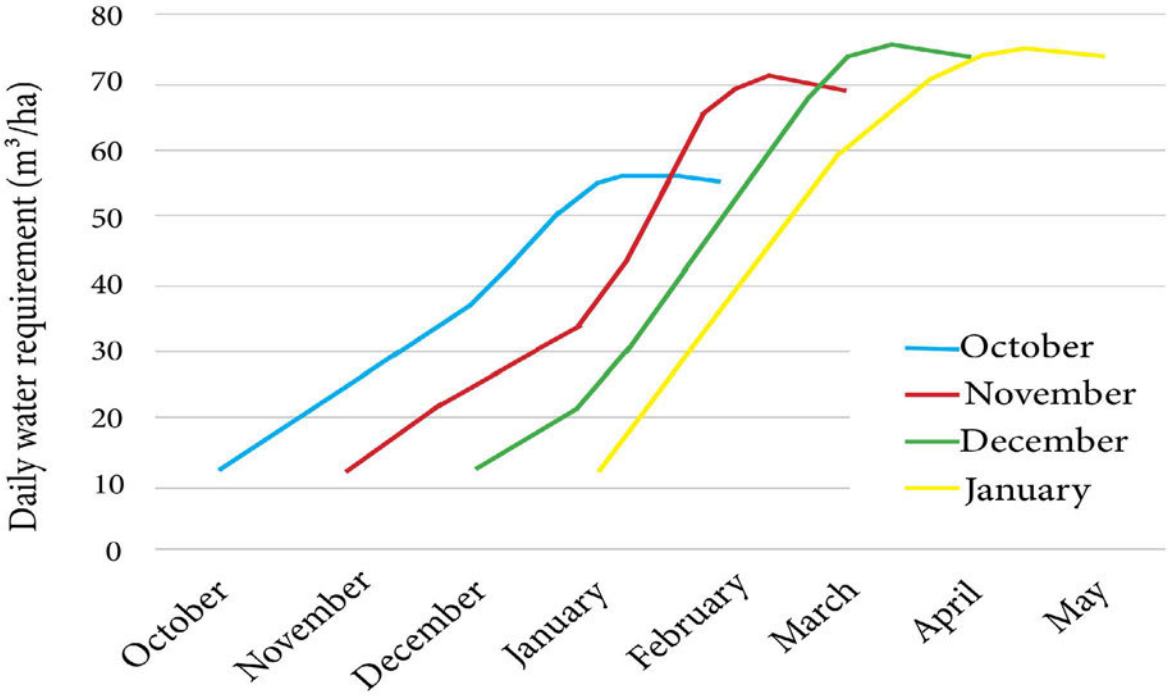


Figure 5-2 Daily water requirement for tomatoes transplanted at different dates.[13]

[12] Spreer W et al. (2017) Irrigation manual for mango production in Southern Shan State. GIZ Tech. Report, Eschborn, Germany. pp. 39-43 www.wospweb.de
[13] Irrigation rates are based on data provided by Jain Irrigation Systems Ltd. in the writeshop at Madanapalle

Table 5-1 Conversion between irrigation recommendation based on volume per area and operation time of a drip irrigation system, using 4 L/h drippers at different spacings

				operation time (minutes)			
				a	b	c	d
volume per area			row spacing (m)	1.2	1.2	1.5	1.5
mm	m^3/ha	L/acre	dripper spacing (m)	0.3	0.4	0.3	0.4
1	10	4,040		5	7	7	9
2	20	8,080		11	14	14	18
3	30	12,120		16	22	20	27
4	40	16,160		22	29	27	36
5	50	20,200		27	36	34	45
6	60	24,240		32	43	41	54
7	70	28,280		38	50	47	63
8	80	32,320		43	58	54	72
9	90	36,360		49	65	61	81
10	100	40,400		54	72	68	90

As important as to avoid drought stress is to avoid excessive irrigation. Applying excess water than the sum of water storage in the rootzone and the uptake by plants during the irrigation interval, does not only waste water resources and energy necessary for pumping, it also leaches nutrients (i.e. nitrogen) below the rootzone. Further, water logging leads to oxygen stress, root diseases such as damping off and other fungal infections.

In general, irrigation recommendations are given in mm (the same as L/m^2), m^3/ha or L/acre. That is sometimes not useful for farmers who work with irrigation systems that do not have a flow meter mounted. These farmers need to know, how long they must operate the irrigation system. The following table gives an overview on the correlation between recommendation on water volume to time to operate an irrigation system. The times are based on different examples: (a) row spacing 1.2 m (4 feet) and distance between the drippers 0.3 m (1 foot), (b) row spacing 1.2 m (4 feet) and distance between the drippers 0.4 m (1.5 feet), (c) row spacing 1.5 m (5 feet) and distance between the drippers 0.3 m (1 foot) and (d) row spacing 1.5 m (5 feet) and distance between the drippers 0.4 m (1.5 feet). The conversion is given, if the nominal flow rate of the drippers is 4 L/h (Table 5-1). The nominal flow rate is an information provided by the producer or distributor of the irrigation system. If drippers with a nominal flow rate of 2 L/h are used, double time as given in the table must be irrigated and if the nominal flow rate is 8 L/h only half the time must be irrigated.

Based on the data presented in table 5.1, the table below shows, how many minutes per day an irrigation system needs to be operated to apply the necessary amount of water. This data is based on an irrigation system using drip line with a dripper spacing of 40 cm and a nominal discharge rate of 4 L/h and a distance of 120 cm between the drip lines (Table 5-2).

Table 5-2 An example for the time schedule for irrigation on different planting dates

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Planting month	irrigate (minutes/day)							
October	9	18	27	40	40			
November		9	18	27	49	49		
December			9	18	35	53	53	
January				9	27	43	53	53

All these figures are given on a daily basis. Depending on the soil, daily irrigation may not be necessary. In this case multiply the figures given with the amount of days between two irrigation events minus the rainy days during that period.

Irrigation water quality is important for a good crop, water with a pH of 6-7 is preferable. High alkalinity will lead to problems such as the accumulation of carbonates and bicarbonates in the drip lines, and blockages. In this case the lines must be flushed regularly with a light acid, such as acetic acid or citric acid. An analysis of the water at the beginning of using the irrigation is good to know about the pH of the water. Often in areas where such problems are relevant, people have experience such as white deposits on water heaters.

5.3 Crop nutrient requirement

Plants need many different nutrients. Macronutrients are the nutrients that plants need in high quantities.

5.3.1 Macronutrients I

The principle macronutrients are nitrogen (N), phosphorus (P) and potassium (K). Their roles in plants are listed here:

Nitrogen (N)

Component of amino acids, protein and chlorophyll. Important for biomass formation. Deficiency symptoms: stunted growth, slow growth, and chlorosis

Phosphorus (P)

Component of many hormones and biomolecules. Important for plant growth and seed formation. Deficiency symptoms: intensive green, sometimes purple color of leaves, necrosis in older leaves

Potassium (K)

Metabolic nutrient. Improves plant growth, fitness and stress tolerance. Deficiency symptoms: Pathogens, wilting, chlorosis, brown spotting

All standard fertilizers are defined by the three principle macronutrients. Urea, common fertilizer, is described with 46:0:0, which means that urea has 46% of N, but no phosphates or potash. This means, if we fertilize 10 kg of urea, that adds 4.6 kg N to our field. A fertilizer marketed as 19:19:19 fertilizer contains 19% of nitrogen (N), 19% of phosphates (P_2O_5) and 19% of potash (K_2O). Observe: Most fertilizer recommendations are given in phosphate (P_2O_5) and potash (K_2O) rather than phosphorus (P) and potassium (K).[14] This manual follows this standard.

How much fertilizer the plant needs, depends on its variety and the yield expectation. It is useful to calculate the fertilizer requirement based on the amount of previous harvests during a comparable season.

Table 5-3 Nutrient requirement based on yield expectation[15]

yield	N	P_2O_5	K_2O	urea	DAP	MOP
t/acre	kg/acre	kg/acre	kg/acre	kg/acre	kg/acre	kg/acre
10	32.5	5.0	32.5	50	10	50
20	65.0	10.0	65.0	100	20	100
30	97.5	15.0	97.5	170	25	160
40	130.0	20.0	130.0	220	40	220
50	162.5	25.0	162.5	280	45	270

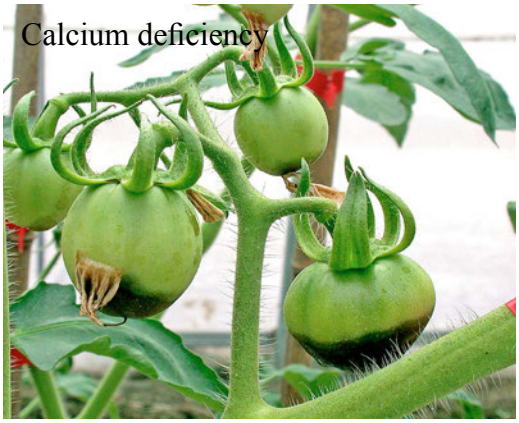
It is important to observe the yield level, because sometimes the farm may have problems, such as water shortage or pest and diseases reducing the yield expectations. In order to avoid wasting money, the fertilizer should be reduced. On the other hand, an optimum managed field can increase the production with higher application of macronutrients. To find out the appropriate levels of macronutrients, strip trials are particularly helpful (see paragraph 5.4)

5.3.2 Macronutrients II

There are four more macronutrients, namely sulphur (S), calcium (Ca), magnesium (Mg), and silicon (Si). The latter is of no importance in tomato production. The remaining three are characterized as follows:

Calcium (Ca)

Regulates transport of other nutrients into the plant and is also involved in the activation of certain plant enzymes. Involved in photosynthesis and plant structure. Deficiency symptoms: Stunting, growth disorders, BER.



[14] P_2O_5 contains 44% P, K_2O contains 83% K

[15] Hedge DM (1997) Nutrient Requirements of Solanaceous Vegetable Crops, Food and Fertilizer Technology Center for the Asian/Pacific Region http://www.fftc.agnet.org/library.php?func=view&id=20110801133428

Sulphur (S)
Sulphur is a structural component of some amino acids and vitamins, and is essential in the manufacturing of chloroplasts. It is immobile and deficiency therefore affects younger tissues first. Deficiency symptoms: yellowing of leaves and stunted growth.
Magnesium (Mg)
Constituent of the chlorophyll molecule. Promoter of enzyme reactions. Magnesium is very mobile in plants, and, like potassium, when deficient, is translocated from older to younger tissues, so that signs of deficiency appear first on the oldest needles and then spread progressively to younger and younger tissues and is also a very important part of our body. Deficiency symptoms: Discoloration


Magnesium deficiency

In most cases these nutrients do not have to be supplied by chemical fertilizers, if FYM is used as organic base fertilizer (paragraph 2.4.4). However, it is useful to have the soil tested for deficiencies (paragraph 2.4.1.3). A common problem in some parts of India is that of acid soils. These are soils with a low pH value (see paragraph 2.4.1.2). This problem can be overcome by application of lime ($CaCO_3$), called "liming". Calcium is also critical tomato production, as Ca-deficiency is thought to produce blossom end rot (BER).

5.3.3 Micronutrients

Finally, there is a number of micronutrients, which are important in plant nutrition. However, as the name says, they are needed in very small amounts. FYM, neem cake and biochar are excellent sources of micronutrients and unless severe deficits are found through soil testing (paragraph 2.4.1.3), the general application of micronutrients to the soil is not necessary and even discouraged. In the following, there is a list of micronutrients:

Iron (Fe)
Necessary for photosynthesis. Deficiency Symptoms: decoloured or dead parts between the leaf veins.

Molybdenum (Mb)
Required for building amino-acids.
Boron (B)
Cell wall stability, uptake of nutrients. Deficiency symptoms: Stunted growth, deformation.
Copper (Cu)
Important for photosynthesis. Deficiency symptoms: Decoloured leaves.
Manganese (Mg)
Photosynthesis and building of chloroplasts. Deficiency symptoms: Discoloured spots on the foliage.
Zinc (Zn)
Important for enzymes. Deficiency symptoms: stunted growth of leaves.

In the region, there is reportedly a problem with boron (B) deficiency. If B deficiency is detected, the application of Borax or boric acid is recommended. Many producers offer mixtures of micronutrients, that can be sprayed on the leaves which improves the uptake by the plants. Warning: Soil application shouldn't be done with Boron, but as foliar spray during fruit formation.

5.4 Strip trials

If introducing a new variety with an unknown yield potential or if working on a new plot of land with no prior experience for planting tomato, strip trials are particularly useful to determine the response of the crop to fertilizer.

The set-up is simple: Three to four rows of one field are marked as the trial. They are looked after in the same way as the rest of the field, but each line receives a different level of fertilizer. Typically, one would choose the fertilizer rate which is normally used and compare it to 50% (half the fertilizer dose), 150% (one half more than normal) and 200% (double the normal dose).

It is important that the differences between the strips are clear, such as the different levels of fertilizer, and all other parameters are just the same. Different rates of N fertilizer are particularly useful, as N makes plants grow and produce high yields. If different levels of N fertilizer are mixed with other aspects, such as different varieties, the result is unclear, as the influence on yield could be from variety or fertilization. If both parameters should be tested, the double amount of strips is needed and both varieties need to receive all levels of fertilizer.

A strip trial is useful, if it is frequently observed and differences are recorded in certain intervals (e.g. one week). Observation may be plant growth, pest/disease infestation, deficiency symptoms or final yield. From a well-done strip trial, a farmer or extension officer can get valuable information about the performance of a variety or the impact of a particular management method. A strip trial is not a scientific method.

5.5 Fertilization principles

There are two important elements of fertilization: Basal fertilization, which is applied to the soil before transplanting and fertilization during production.

5.5.1 Basal fertilization

Basal fertilization is important to provide a nutritional base for the crop and to maintain long-term fertility of the soil. Therefore, it is good to use organic fertilizers (paragraph 2.4.2), which are incorporated into soil. They contain organic matter and offer a habitat for soil micro-organisms that chemical fertilizers cannot provide. For strategies for organic basal fertilization and useful soil amendments refer to paragraph 2.4.4.

Table 5.4 gives a general recommendation about the amounts of fertilizer to be applied as a basal dressing and fertilization during cropping. A simple rule of thumb is to apply the mobile macronutrients and highly consumptive nutrients N and K_2O frequently in small portions during cropping and to apply most of the P_2O_5, which is less mobile in the base dressing (Table 5-4).

5.5.2 Fertilization during cropping

Even though organic mulching may provide a certain amount of nutrients, fertilization during cropping is based on chemical fertilizers, which are applied by broadcasting, fertigation or leaf sprays.

Granular fertilizer can be broadcasted by hand or by a mechanical fertilizer spreader. It is only recommended in rainfed agriculture, as rain is necessary to dissolve the fertilizer grains and to move them into the rootzone. Drip irrigation normally does not provide enough water to dissolve granular fertilizer on the top of the soil.

Table 5-4. Proportion between base dressing and fertigation[16]

Proportion of base dressing and fertigation (%)			
	N	P_2O_5	K_2O
Base dressing (%)	30	60	40
Fertigation (%)	70	40	60

5.6 Fertilization with irrigation: Fertigation

'Fertigation' is the application of plant nutrients through the irrigation system. The best means of fertilization is fertigation. Fertilizer is applied with the irrigation water in dissolved form. If applied in the correct intervals, it is directly available to the plant in the root zone and can be taken up immediately (Figure 5-3).

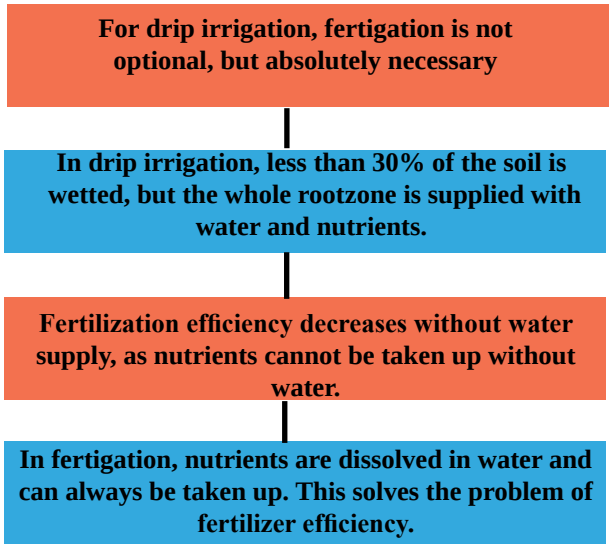


Figure 5-3. Characterisation of fertigation

In a drip irrigation system, the water is taken from a canal, a well or a water reservoir. Technically, it does not make sense trying to mix the fertilizer at the source. **So, do not mix fertilizer to a storage tank, reservoir or natural water body!** Instead, a "stock solution" is prepared by dissolving the required amount of fertilizer in a small amount of water. This "stock solution" is then injected in the pipeline which feeds the irrigation system. In the following chapter, there is information on how the stock solution can be injected, what fertilizers are suitable and how much should be fertigated.

[16] Netafim irrigation India pvt ltd

5.6.1 Fertilizer injection

For fertilizer injection in this manual, only one example will be presented: The Venturi nozzle and pressure differential tank. Both are cheap and reliable ways to inject fertilizer. The reason is that fertigation in the open field follows a different design and calculation principle as fertigation in a greenhouse. In a greenhouse, fertigation is applied continuously at a constant concentration. In a field, fertilization is done sporadically and the rest of the time irrigation is done with the clear water. The soil acts as a nutrient storage.

Typically, a **Venturi nozzle** is made from plastic, is cheap, sturdy and has a long life-span. The nozzle contracts the water flow through a small orifice. The contraction of flow creates a suction where the nozzle opens again (Figure 5-4). The Venturi nozzle does not need external power, but decreases the pressure in the injection line considerably.

A **Pressure differential tank** is a tank made of steel in which the fertilizer solution can be prepared. It can be easily transported to the sub-field where it is needed and it is connected by specially designed valves (Figure 5-5). It is more expensive than are Venturi nozzle, but it produces less pressure drop during operation and is in general easier to handle for untrained operators.

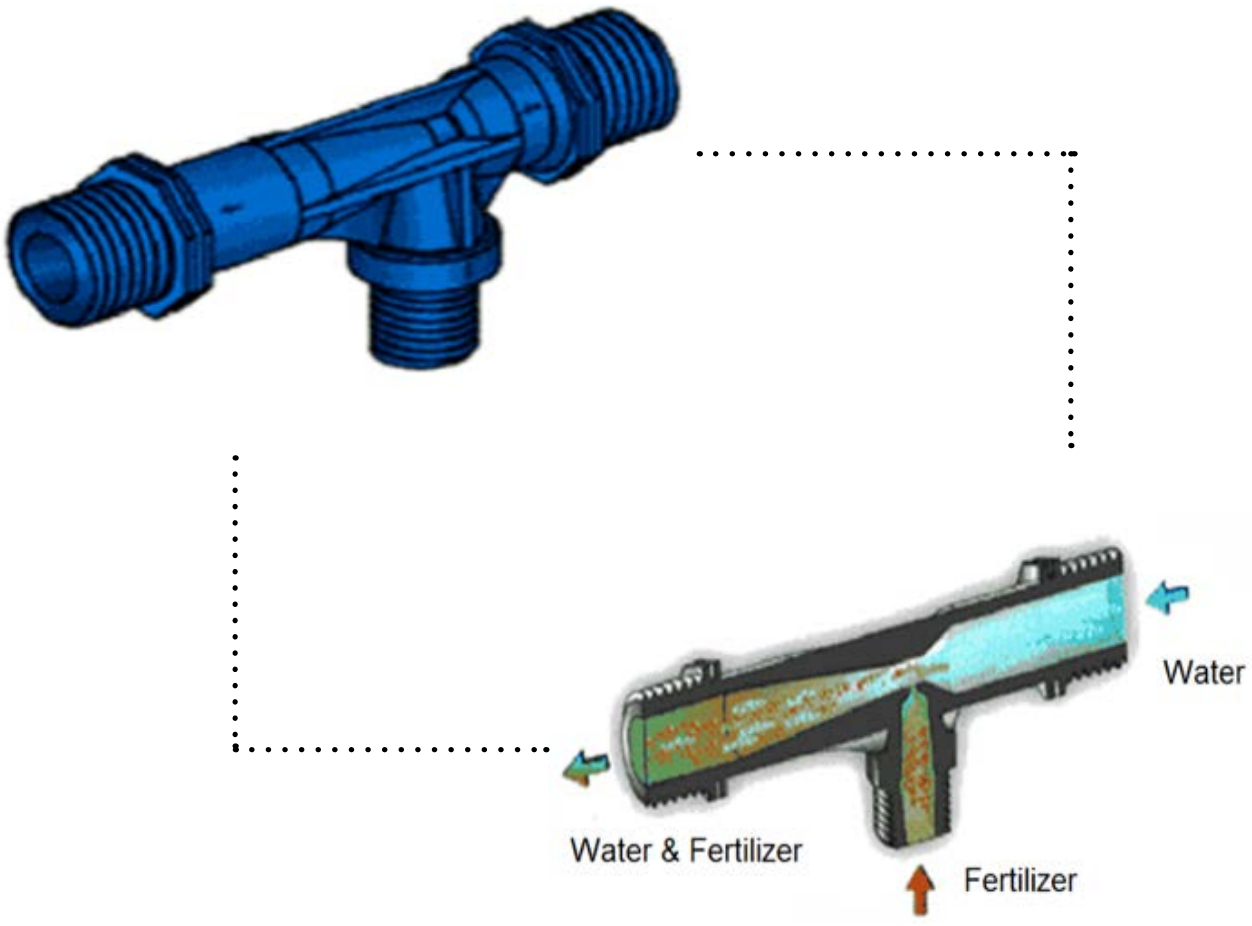


Figure 5-4 (left) A venture nozzle for fertilizer injection (right) the functioning principle of a Venturi nozzle.[17]

[17] pictures: http://irrigationdirect.com.au

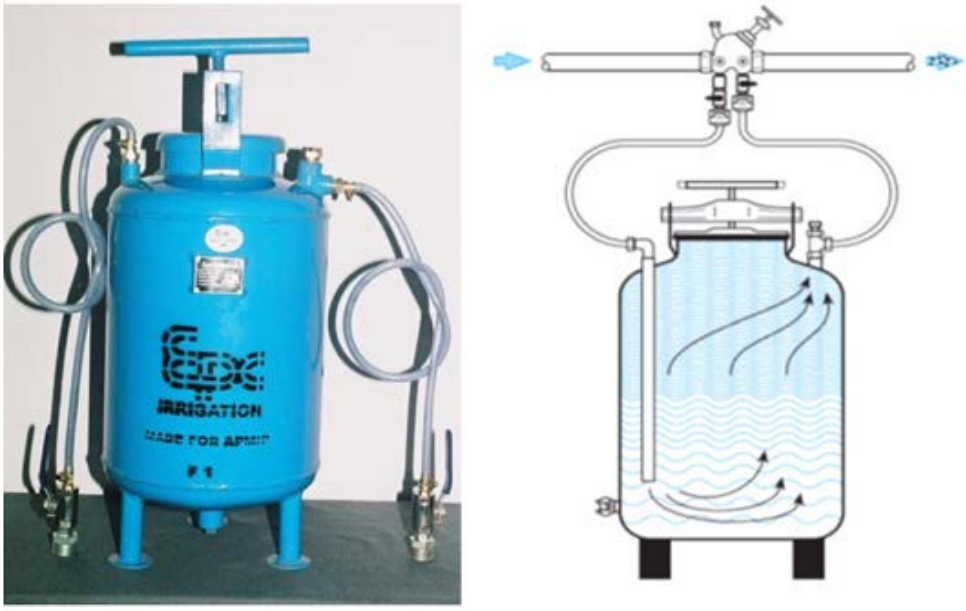


Figure 5-5 (left) Pressure differential tank (right) Cross section of a pressure differential tank.[18]

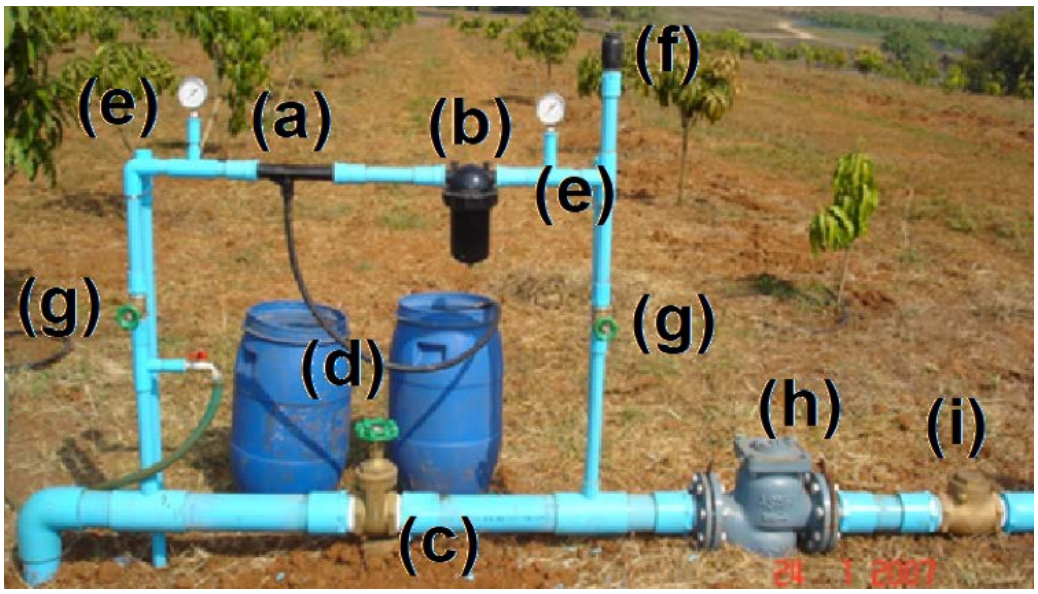


Figure 5-6 Set-up of a fertilizer injection for a sub-field (picture: S. Chotivan)

The setting up of a pressure differential tank and a Venturi nozzle follows the same principal rules and can be seen in figure 5-6. The fertilizer injection (a) is never mounted on the main line, but rather on a bypass with a smaller diameter. It is important to have a secondary filter after the fertilizer injection as some non-dissolved fertilizer particles or dirt may clog the drippers. A valve (c) on the main line is needed to reduce the pressure in the main line. By partially closing the valve the pressure before the valve is increased and reduced behind it. Then the fertilizer injection works and sucks the fertilizer solution from the tank (d). With two manometers the pressure drop can be checked at any time (e). An air-release valve makes sure that there are no major entries of air bubbles in the irrigation water. After the fertigation event two valves (g) at the inlet and outlet of the fertigation by-pass allow closing of the system and irrigation with clear water. A flow-meter (h) is not necessary, but it helps to better calculate the amount of irrigation water. A no-return-valve (i) protects the installation from the water hammer, which can occur when switching off the water flow.

[18]http://ecoursesonline.icar.gov.in

5.6.2 Suitable fertilizers for fertigation

Never use organic fertilizers for fertigation! Only soluble chemical fertilizers can be used for fertigation.

Most commonly used N-fertilizers are appropriate for being used in fertigation, among them are: urea, ammonium nitrate, ammonium sulphate, calcium ammonium sulphate, calcium ammonium nitrate. Special fertilizers like mono ammonium phosphate (nitrogen and phosphorus), poly feed (nitrogen, phosphorus and potassium), Multi K (nitrogen and potassium), potassium sulphate (potassium and sulphur) are highly suitable for fertigation as they are highly soluble in water.[19]

The application of super phosphorus through fertigation must be avoided as it tends to precipitate phosphate salts damaging the drip system. Phosphoric acid, available in liquid form is better suited for use with fertigation.

In principle, fertilizers for fertigation can be mixed. This is practised in greenhouse fertigation, rather than in open field fertigation. In this case there need to be two different stock solutions in order to avoid precipitation of fertilizers. However, this is difficult to handle with the injection methods described above. Therefore, mix only fertilizers that contain macronutrients N, P, K. If in doubt, test the solubility of 500 g of each fertilizer in 10 L of water. It should dissolve completely and not form precipitations within one hour.

5.6.3 Fertigation rates

Mixing the fertilizer solution and connecting the fertilizer injection to the system is not a hard work. The distribution of the fertilizer is done by the water. Therefore, one major advantage of fertigation is that small quantities can be applied frequently. In this way the crop receives a continuous supply of readily dissolved fertilizer and there is no risk of losing fertilizer due to heavy rain. Nitrogen and potassium should be applied often and in small quantities.

Table 5-5 shows a fertigation schedule for field-grown tomato. In this example, no chemical base dressing is necessary, assuming that organic basal fertilization has taken place according to the recommendations in paragraph 2.4.4.

Table 5-5 Fertigation schedule for one acre of field-grown tomato in Madanapalle.[20]

Name of fertilizer	Urea	Mono Ammonium phosphate	Potassium chloride (MOP)
composition	46 : 0 : 0	12 : 61 : 0	0 : 0 : 60
Kg of fertilizer to be applied every 4th day			
10 – 40 DAP	3	1	2
41 – 70 DAP	6	2	3
71 – 90 DAP	4	1	8
91 – 120 DAP	3	1	4
Total requirement per acre	110 kg	36 kg	100 kg
	N	P_2O_5	K_2O
Total nutrients applied	63.8 kg	21.4 kg	64.5 kg

This fertilizer recommendation covers the expected nutrient extraction at a fresh tomato yield of 20 t/acre, which is slightly above the official average of tomato production in Madanapalle. It also considers that the soils in the area have a low organic matter content and, therefore, lack fertility. Consequently, a P_2O_5 application higher than the expected extraction has been applied. MOP in Table 5-5 can be replaced by SOP (potassium sulphate / sulphate of potash (0:0:50)). As the latter has a slightly lower P_2O content, it is recommended to increase the dose by 10-20%.

[19] Tamil Nadu Agriculture University
[20] Jain Irrigation Systems Limited

5.7 Foliar application

Foliar application means spraying fertilizer on the leaves. Technically, it is done in the same way as spraying pesticides. The same sprayer can be used for both purposes, if it is thoroughly cleaned after each use, making sure that it is free of pesticide residues. It's better to use different sprayers. Spraying of fertilizers is in general not harmful to human health, however, avoid skin, mouth or eye contact as some fertilizers may contain acids or alkaline solutions.

For a better efficiency, use surfactants, which make the fertilizer solution stick better to the leaves. Locally available surfactants are Dhanuvit or Wetcit of Dhanuka Agritech Ltd or Qualibra of Syngenta.

A surfactant breaks the surface tension of the water, so that the active ingredients of any spray application are more evenly distributed on the leaf surface. Dish washing liquid may help, if surfactants are not accessible. To find the right concentration, place a drop of the spray solution on a tomato leaf, if the drop remains, add more surfactant / soap .

5.7.1 Recommended foliar application schedules

Nutrients applied to the leaves are taken up by the plant faster. The effects can be seen immediately on the leaves and fruits. Especially with K-containing sprays, there is an immediate colour change. In general, foliar sprays of micronutrients promote fruit growth and quality. Whether and how much to spray depends mainly on the costs. Generally, it is most useful, when access to high value markets is given with a price premium for high quality fruit.

When high yielding varieties are used and yield expectations are high, weekly sprays with calcium containing fertilizers and several applications are mandatory. As Boron deficiency occurs in the area, Boron sprays are also recommended.

The recommendations given in Table 5-6 are for intensively managed fields with high yield expectations.

Table 5-6 Schedule for foliar application

When	What	How much
40, 65 DAP	Micronutrients Formula-4	5 kg/ha
65 DAP	Zinc Sulphate (chelated)	5 g/L of water
75 DAP	Borax	5 g/L of water
75, 85, 90 DAP	13:0:45 (Multi-K)	5 g/L of water
Weekly after fruit set	Calcium Chloride ($CaCl_2$)	5 g/L of water

5.8 Principles of nutrient deficiency

When nutrients are not applied in the required doses, the crop may exhibit deficiency symptoms. The different typical deficiency patterns vary depending upon the function and the mobility of the nutrient and are shown in the stylized images in Figure 5-7.

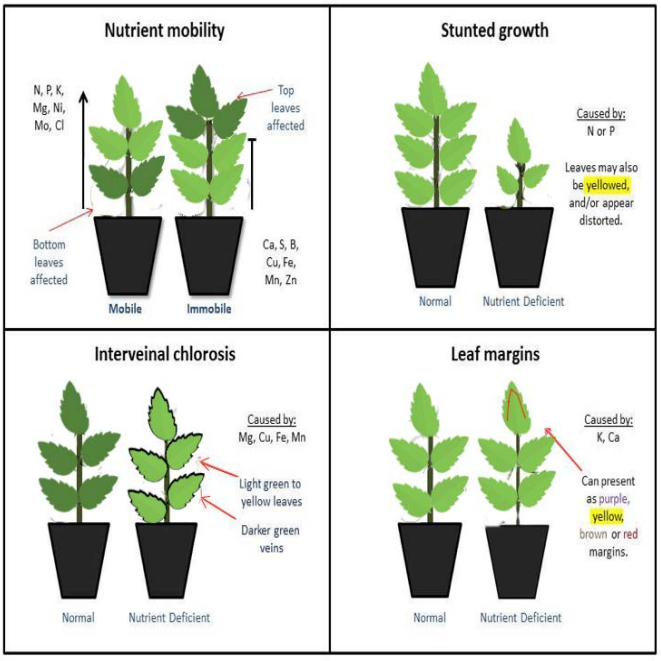


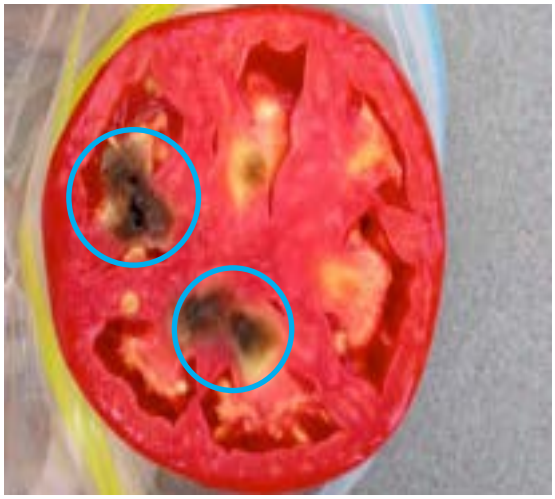
Figure 5-7 Systematics of the occurrence of deficiency symptoms

5.9 Nutrient deficiency symptoms and other commonly observed problems

Nutrient deficiencies affect the overall fitness of the plants, meaning that plants become more susceptible to pest and disease problems or react more intensely to adverse environmental conditions. In the following, there is a list of disorders that are caused by abiotic stress factors.[21]

Symptom	Description	Possible reasons
	Failure to set fruit	Night temperatures above 21 or below 13 °C. Day temperatures above 32 °C combined with low humidity and/or drought. Hot and dry winds can add to the problem. Dry soil can cause blossoms to dry up and drop. Too much nitrogen fertilizer produces leafy growth at the expense of flowers and fruits. Viral diseases such as, curly top, mosaic viruses, etc can affect flowering and fruit set.
	Uneven or blotchy ripening	Compacted soil and overly wet soil inhibit the root system which restricts fruit ripening. Low potassium (K) levels inhibit proper fruit growth and maturity; however, too much potassium can reduce the absorption of calcium and magnesium.
	Area around the stalk hard and yellow or green	Temperatures below 16 °C. Compacted soil and overly wet soil inhibit the root system which restricts fruit ripening. Viral diseases. Heavy whitefly infestation. Looks like sunscald.

[21]http://www.missouribotanicalgarden.org/gardens-gardening/your-garden/help-for-the-home-gardener/advice-tips-resources/visual-guides/tomato-fruit-problems.aspx

	Internal black mould	Soils with low potassium levels, low organic matter, and high pH. Adverse weather conditions. Secondary infection after blossom end rot. Black mould entering at wounds and through growth cracks.
	Cracking	Overfertilization. Extreme fluctuations in temperature. Extreme fluctuations in soil moisture. Not enough foliage to protect fruit. Looks like mechanical damage.
	Blossom end rot (BER)	Calcium deficiency. Often associated with a lack in calcium uptake due to fast growth. Foliar application of calcium essential.
	Sunscald	With continued exposure to the sun, white or yellow blisters develop and the damaged areas may become papery, flattened, and grayish white. Sensitivity to sun light is often attributed to Zn deficiency. Looks like spotted wilt virus.

6. IDENTIFYING AND MANAGING COMMON PESTS AND DISEASES

Insect pests and diseases are a major constraint in tomato production. Any part of the tomato plant may be affected by insect pests and diseases, but it is important to assess whether the damage has crossed an economic threshold or when it reaches the economic threshold to apply control measures. Regular inspection and observation of the field is the essential first step.

Chemical dealers are usually the main sources of advice on controlling insect pests and diseases. But applying inappropriate chemicals to the crop not only increases the intensity of the problem, but can also kill natural enemies and pollinators, creating long term problems.

The following simple guidelines can help in easy identification of the main symptoms of a range of common problems found in Madanapalle by referring the symptoms. The later section provides a full list of all pests and diseases found in the district and how to recognize and manage them.

6.1 Most commonly observed symptoms and their causal organisms

Figure 6-1 shows a broad classification of disease symptoms on leaves stems and roots, and the causal organisms.

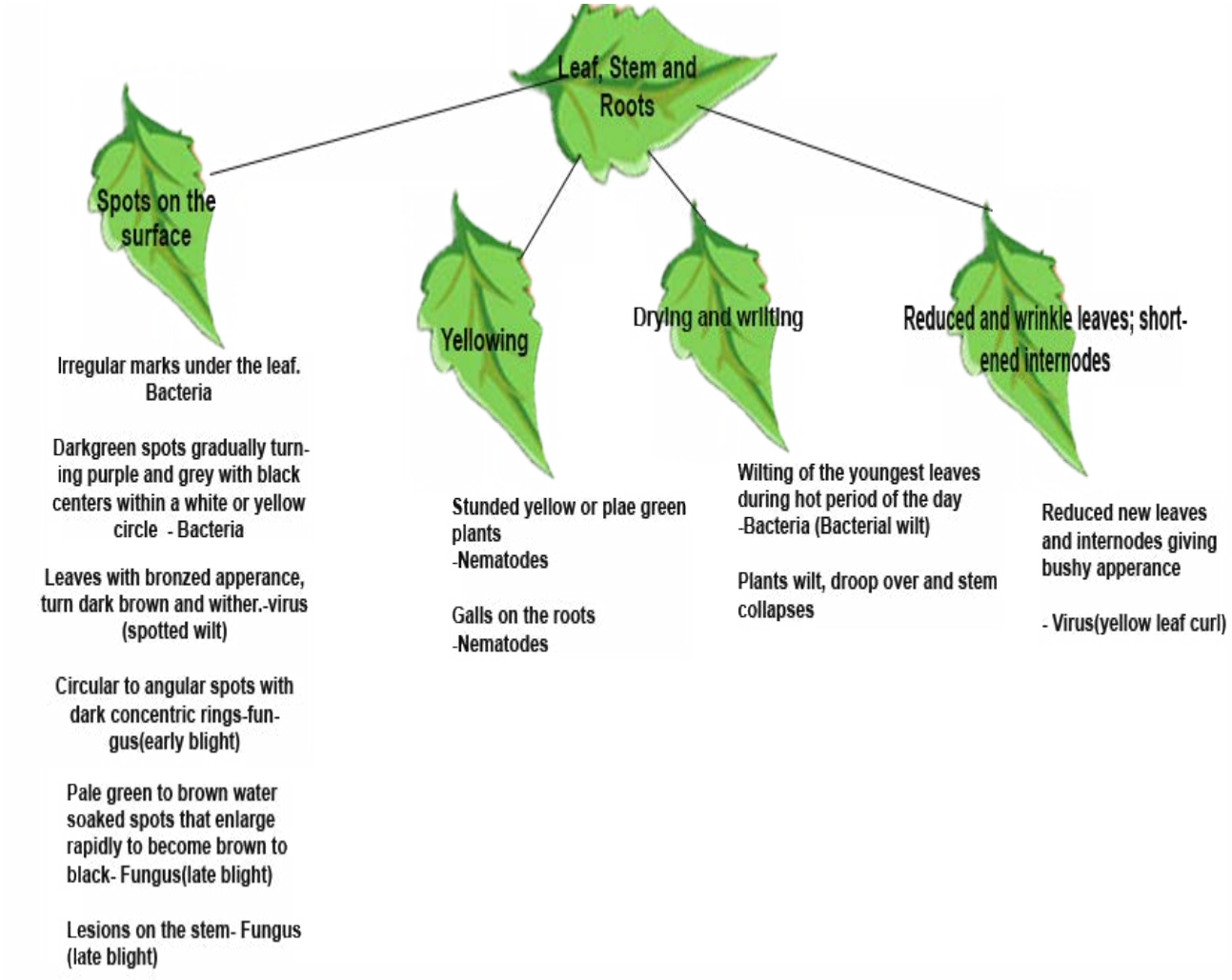


Figure 6-1 Schematic overview on disease symptoms on leaves stems and roots and the causal organisms

Figure 6-2 shows a broad classification of damage symptoms on fruits, and the causal organisms.

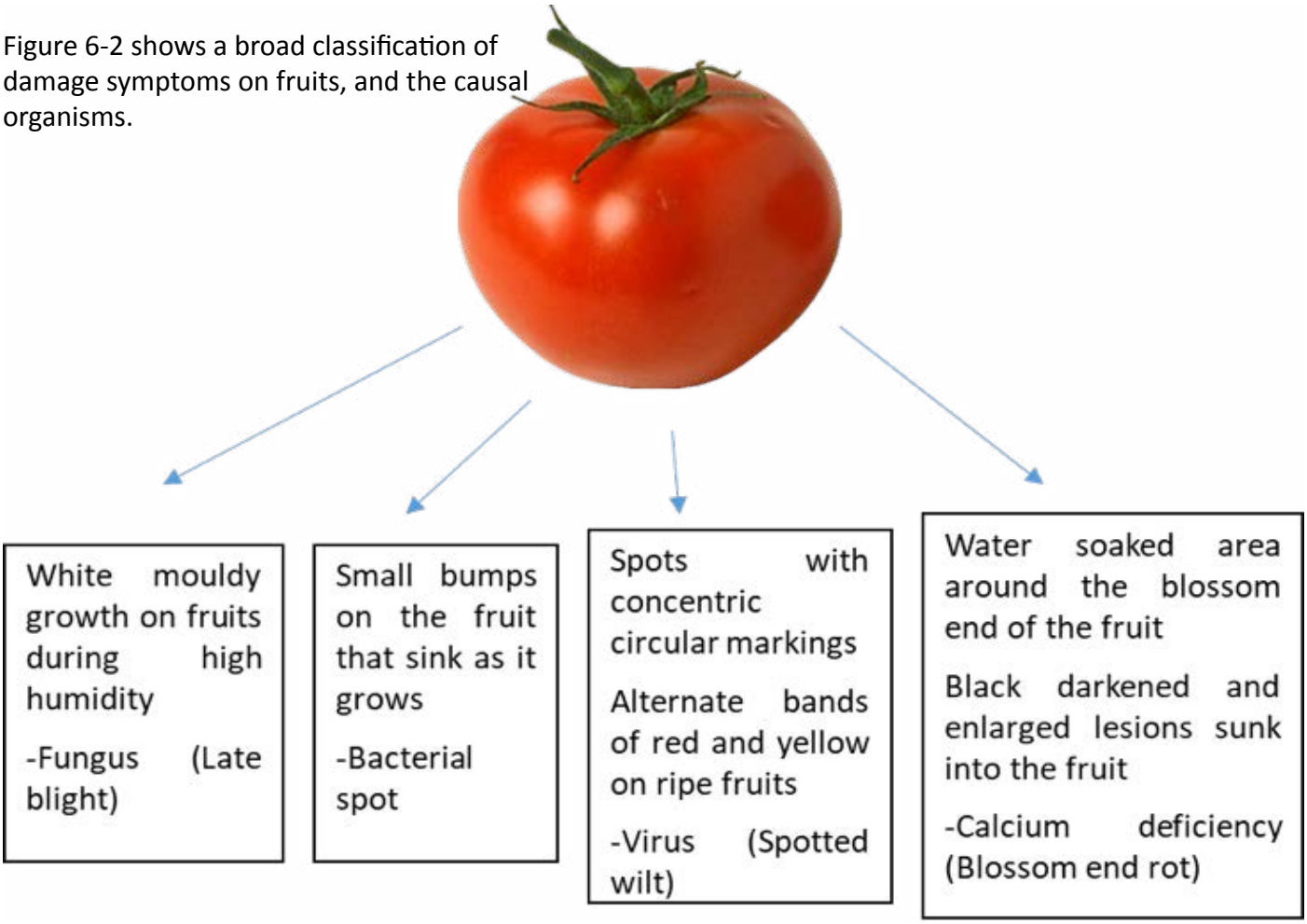


Figure 6-2 Schematic overview on symptoms on the fruit and the causal organisms

6.2 Symptoms specific to major insect pests

The correct identification of insect pests and diseases is very important for their management. The following images can help in proper identification of pest and disease in the Madanapalle region.

6.2.1 On leaves and stems

Symptom	Description	Insect Pest
	Yellowing, Curled leaves Honeydew (white, sticky residue)	Aphids Whiteflies, Thrips
	Tunnels or zigzag patterns in leaves on the upper side	Leafminer
	Blotch/leaf mines visible from both sides of the leaf. The larva consumes all the leaf tissue leaving behind a skeletonized leaf.	American pin worm
	Extensive galleries of larvae in the stem	American pin worm

6.2.2 On Fruit

Symptom	Description	Insect Pest
	Small and large holes in the fruit	Fruit borer
	Black frass on the fruits	American pin worm
	Concentric rings	Virus carried by thrips

6.3 Symptoms of important diseases in tomato

Symptom	Description	Disease
	Foliar lesions are dark circular, water soaked and usually smaller than 3 mm in diameter.	Bacterial leaf spot (*Xanthomonas campestris pv. vesicatoria*)
	Rapid and complete wilting of normal grown up plants.	Bacterial wilt (*Ralstonia* solanacearum)
	Yellowing starts with the lower leaves, downward curling, browning and drying of leaves.	Fusarium wilt (*Fusarium oxysporum*)

	A bright white, silky, mould growth develops on the rotted areas of stem/roots.	Stem rot/Sclerotium rot (*Sclerotium rolfsii*)
	Dark brown to black concentric rings of leaf spots are formed on leaves.	Early blight (*Alternaria solani*)
	This will initially appear as gray areas on the leaves. These areas will then spread and a mould will develop on the lower surfaces of the leaves.	Late blight (*Phytophthora infestans*)
	Leaf curling	Tomato leaf curl virus disease

6.4 General IPM practices

Here is a list of major insect pests in tomato:

- Fruit borer
- Whitefly
- Serpentine leafminer
- American tomato pin worm
- Tobacco caterpillar
- Thrips
- Mites: Red spider mite
- Nematode: *Meloidogyne* spp.

Some measures help to reduce the general population of insect pests. Combined with the natural occurrence of predators, in many cases, there is no need for chemical pest control, as the damage is below the threshold to cause economic losses.

•Deep summer ploughing to expose insect pupae/ soil borne pests to sunlight and natural enemies.

• Soil solarisation (with polythene sheet of 45 gauge (0.45 mm) thickness for three weeks before sowing under hot sunny conditions) to kill insect pupae and pathogens in the soil.

• Follow crop rotation with non-host crops such as cereals and legumes. Avoid solanaceous crops such as chili and eggplant after tomato.

• Use healthy seedlings for transplanting. Carefully observe the seedlings while purchasing from the nursery.

• Plastic mulch helps to reduce pupation in the soil.

• Remove and destroy infected leaves, shoots and fruits.

• Use sticky traps, yellow for leafminer/whitefly/leaf hopper/aphids, and blue sticky traps for thrips @ 25-30 traps/hectare. Empty tins can be painted yellow or blue and coated with grease/ Vaseline/ castor oil on the outer surface and used as sticky traps.

• Use light traps @ 3/hectare and operate after 6 pm.

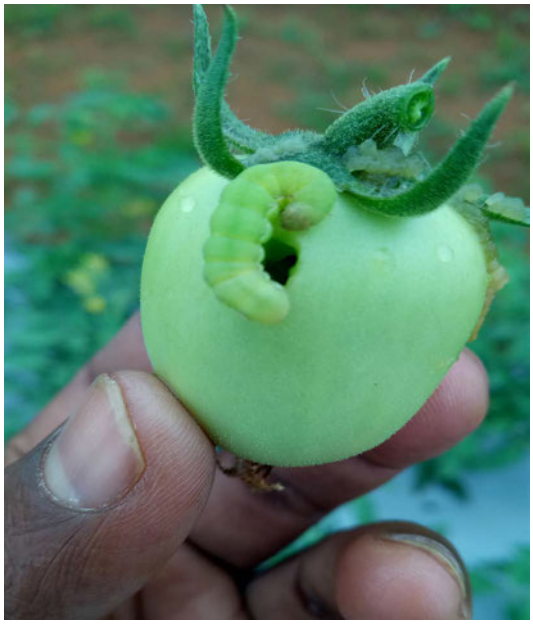
• Using marigold as trap crop is highly effective in the management of fruit borer.

• Install pheromone traps @ 10-12/hectare for monitoring/mass trapping of tomato pin worm and fruit borer adults (replace the lures with fresh ones after every 2-3 weeks). Specific lures are available in the market. To control both these pests, 5-6 traps may be installed with pin worm lures and 5-6 with fruit borer lures.

• Dip seedling roots in water mixed with 1 g/L of Thiamethoxam 25 WG for 10-15 minutes before transplanting to reduce the incidence of sucking pests such as leafminer, whitefly, thrips.

Note: While treating the seedlings with fungicide and insecticide, dip them first in the fungicide solution such as *Trichoderma+Pseudomonas*, after 10-15 minutes dip them again in insecticide solution such as Thiomethoxam and then transplant after 10-15 minutes.

6.5 Management practices for specific insect pests

Pest	Nature of damage	Management
Tomato fruit borer (*Helicoverpa armigera*) 	The larvae feed on leaves and floral buds, flowers and fruits. They feed on fruits by inserting their heads inside the fruit. Infested fruits rot and fall.	Mechanical collection and destruction of bored fruit at periodic intervals (3-4 times) brings down the borer incidence to less than 2 per cent. Install pheromone traps @ 10-12/hectare for monitoring/mass trapping of tomato fruit borer adults (replace the lures with fresh ones after every 2-3 weeks). Biological control agent: Spray Ha NPV (@250 LE/ha) with 1% jaggery at 28, 35 and 42 days after planting in the evening. (commercially available as SOMSTAR TM –Ha by Agri Biosolutions or BIOKILL-H by Ganesh Bio control systems or BIOVIRUS - H by Biotech International Ltd). These formulations may be obtained from IIHR or any commercial biofertilizer shop in Bengaluru. Under heavy incidence, spray Indoxacarb 14.5% SC @ 0.8 ml/L of water or Emamectin benzoate 1.9% EC @ 0.3 ml/L of water..

Whitefly *(Bemisia tabaci)* 	Both nymphs and adults feed on lower surface of the leaves causing deformation of young leaves. Leaves become yellowish, wrinkle and curl downwards. It is a well-known vector of leaf curl virus. Whitefly also excretes honeydew, causing sooty mould.	Install yellow sticky traps in the field @ 25-30 traps/hectare after transplanting. A fortnight (15 days) after transplanting, give need-based sprays of Thiomethoxam 25% WP @0.4 g/L or Dimethoate 30% EC @ 1 ml/L or Lastraw @ 5 ml/L (Apply 2-3 times at weekly intervals for effective control).Do not repeat at the fruiting stage as this may leave harmful residues in fruits. Rogue out the virus affected plants as soon as the symptoms are observed.
Serpentine Leafminer *(Liriomyza trifolii)* 	This pest infests the crop from seedling stage to the harvest. Typical serpentine shaped mines are formed in the leaf lamina indicating the path of feeding by the maggots.	Install yellow sticky traps @25-30 traps/hectare just after transplanting. Spray Cyantraniliprole 10.26 w/w OD @ 1.2 ml/L (commercially available as Benevia by Dupont). Apply neem cake @ 250 kg/ha at 20 days after planting.
American pin worm *(Tuta absoluta)* 	Larvae feed on leaves, stems, buds, calyces, and fruit. They form mines on leaves and act as borers on stem and fruit. Affected leaves show white patches that later dry giving a burnt appearance. Affected fruits show fine pin holes at the site of entrance and exit which lead to secondary infection and rotting. Affected stems dry up and droop down.	Check the seedlings before transplanting to ensure they are free from Tuta eggs and larvae. Install pheromone traps @ 10-12/hectare for monitoring/mass trapping of tomato pinworm (replace the lures with fresh ones after every 2-3 weeks). Under severe infestation, spray Cyantraniliprole 10.26 w/w OD @ 1.2 ml/L or Spinosad 45% SC @ 0.4 ml/L or Indoxacarb 14.5% SC @ 0.8 ml/L water.

Thrips (*Thrips tabaci*) 	Thrips pierce plant cells with their mouth parts and feed on plant juices. The collapse of plant cells can result in the formation of deformed flowers, leaves, fruit, stems and shoots. In severe infestation, seedlings may be killed.	Install blue sticky traps @25-30 traps/hectare. Under severe infestation, spray dimethoate 30% EC @1ml/L or Lastraw @ 5 ml/L (Apply 2-3 times at weekly intervals for effective control).
Red spider mite (*Tetranychus* spp.) 	Affected parts become reddish brown and bronzy, wither and dry. Both larvae and adults feed on leaves by constructing spider like webbing on leaves. Initially white speckling found on upper surface of leaves, which turn into bronze colour due to development of necrotic patches.	Spray dicofol 18.5% EC @ 2.5ml/L + pongamia or neem Soap @ 5g/L of water. In severe incidence, apply fenazaquin 10% EC @ 2.5 ml/L or spiromesifen 22.9% SC @ 1.5 ml/L or Lastraw @ 5 ml/L.
Nematode (*Meloidogyne* spp.) 	Root galls, stunted plant growth, chlorosis. The affected plants show a tendency to wilt or die during hot, dry weather. Under high population, plants may die before reaching matu-rity.	Apply Farm Yard Manure @ 25-35 MT/ha + neem cake 500-750 kg/ha. Application of Paecilomyces lilacinus as seed treatment @ 10 gm/kg of seeds or seedling @100 g/ liter prior to planting or soil application @ 6-8 kg/hectare mixed with organic fertilizer/well decomposed organic manure/field soil (MYSIS by Varsha biosciences and technology, Nalgonda, Telangana and BIO-NEMATON by T. Stanes & Company Limited, Coimbatore, Tamil Nadu). If possible, avoid growing tomato in fields infested with root knot nematodes.

6.6 General IDM practices

The major diseases observed in the Madanapalle region are:

- Bacterial leaf spot
- Bacterial wilt
- Fusarium wilt
- Early blight
- Late Blight
- Tomato leaf curl virus disease

Some general phytosanitary practices can keep the disease pressure on the field low, just in the same way as general hygiene keeps disease pressure low in a human population.

- In general, ploughing the soil deep in summer will kill the soil borne pathogens.
- Promptly destroy or remove finished crops.
- Remove and destroy infected fruits and plant parts as well.
- Remove all weeds, volunteer crop plants and ornamentals, especially if vegetatively propagated, regardless of virus symptoms in and around the crop field.
- Purchase seedlings for transplanting from virus-tested, accredited nurseries.
- Growing the crop on raised beds with plastic mulch and adopting staking will help in lowering the infections.
- Sowing with 3 to 4 rows of non-host border crops such as jowar, miaze and bajra before transplanting will protect the crop from virus.
- Maintaining an optimal irrigation schedule will help reduce dampness in the root zone.
- Rotating the tomato crop with cereal crops such as rice, maize, jowar and bajra will reduce the spread of infection as the pathogens cannot survive on these crops.
- Treat the seedlings with Copper Oxychloride @ 2.5 g/L for the bacterial leaf spots and or *Trichoderma viride* @ 10 g/L of water one hour for the fungal wilt before transplantation.
- Seedlings can also be dipped in fungicide solution of thiram or carbendazim @ 2.5 g/L for 10-15 minutes.
- Staking tomatoes and using a system of drip irrigation will reduce the potential for leaf dampness, as well allowing enough space for aeration.

6.7 Management practices for specific diseases

Disease	Nature of damage	Management
Bacterial leaf spot (Xanthomonas campestris pv. vesicatoria) 	Foliar lesions are dark circular, water soaked and usually smaller than 3 mm in diameter. The lesions become brown-black and angular in shape. Lesions may coalesce and give plants a blighted appearance. Affected leaves may turn yellow and drop off or become dry and remain on the plant. Immature fruits bear lesions that begin as small, raised, black specks surrounded by a water soaked border.	Avoid overhead watering. Give prophylactic sprays with copper oxychloride 50% WP @2 g/L of water + Agrimycin 100 @ 100 ppm on dry seedlings before transplanting and continue in the main fields when the plants are dry at 5 day intervals or spray streptomycin sulfate 9% + tetracycline hydrochloride 1% SP solution (streptocycline) 40-100 ppm in fields after the appearance of first true leaves. Two sprays, one before transplanting (seed beds) and another after transplanting (main field)

Bacterial wilt (Ralstonia solanacearum) 	Rapid and complete wilting of normal mature plants. Lower leaves may drop before wilting. When infected plant parts are cut and immersed in clear water, a white streak of bacterial ooze is seen coming out from the cut ends.	Avoid growing tomato crop in the same field season after season. Apply neem cake @ 250 kg/ha 1-2 week before transplanting. If infection occurs after transplanting, remove the infected plants and drench the soil with copper oxychloride solution @ 2g/L of water.
Fusarium wilt (F*usarium oxysporum*) 	Yellowing starts with the lower leaves, downward curling, browning and drying of leaves. The top of the vine wilts during the day and recovers at night, but subsequently the vine is permanently wilted. Vascular browning can be seen in infected stems. Affected plants and root systems are stunted.	Remove the infected plants and drench the soil with thiram/ carbendazim 50% WP @ 1g/L of water.
Stem rot/Sclerotium rot of tomato (*Sclerotium rolfsii*) 	A bright white, silky, mould growth develops on the rotted areas of stem/roots. Numerous sclerotial bodies, which are initially white and later turn brown to black, develop on the mould areas. Infected plants are dry and wilted.	Remove the infected plants and drench the soil with thiram/ carbendazim 50% WP @ 1g/L of water.

Early blight (*Alternaria solani*) 	Dark brown to black concentric rings of leaf spots are formed on leaves. Tissue surrounding the lesions becomes yellow and the spots later become irregular in shape. Defoliation occurs under prolonged periods of leaf wetness and high temperatures. Mature and ripe fruits are also affected, lesions on fruits are large and they lead to wounds or cracks on the fruit that are large, dark, leathery, sunken areas with concentric rings.	Spray Copper oxychloride 50% WP@ 5g/L (200 litres of solution per acre).
Late blight (*Phytophthora infestans*) 	This will initially appear as gray areas on the leaves. These areas will then spread and mould will develop on the lower surfaces of the leaves. Brown spots on the plant stems, as well as the loss of foliage, are also indications of late blight.	In severe incidence, spray Copper hydroxide @2g/L. They should be usually applied every seven to ten days for best protection.
Tomato leaf curl virus disease 	Leaf curl disease is characterized by severe stunting of the plants with downward rolling and crinkling of the leaves. The nodes and internodes are significantly reduced in size. The infected plants look pale and produce more lateral branches giving a bushy appearance. The infected plants remain stunted. It is transmitted by whitefly.	Install yellow sticky traps 20-25 traps/hectare to control whitefly. If the incidence is high, spray Dimethoate 30% EC @ 1 ml/L or neem seed kernel extract 4% (NSKE) or neem oil @8-10 ml/L or neem soap @10 g/L. The best long term controls are to use resistant varieties and to buy seedlings from a nursery that fully protects seedlings from early whitefly infestations.

7. POSTHARVEST MANAGEMENT

Postharvest losses of tomato are one of the most important economic losses for farmers, but are often the least considered. WorldVeg research across three countries in South Asia found average postharvest losses of tomatoes of 25%. These losses occur after all the expenses of growing the crop have been made. Poor harvest timing, transport and storage mean that farmers lose a significant part of their crop when it is most valuable.

Tomatoes have a very short market life if harvested fully ripe. Mature-green or breaker stage fruit may last for several weeks. Tomato fruits are very delicate and can quickly be injured by rough harvesting and handling practices. The fruit is also damaged by holding at either too low or too high a temperature. Proper postharvest handling and storage methods are essential for maintaining acceptable quality and extending the market life.

Madanapalle market

7.1 Harvest Maturity Indices

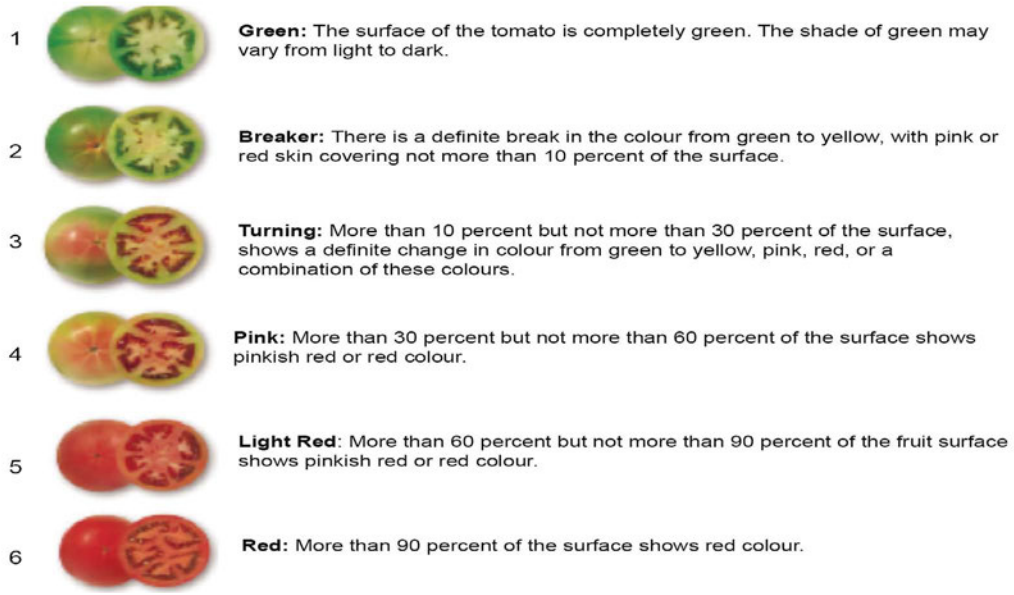
The most widely used index of tomato maturity is skin colour. Distinct changes in external colour occur in tomato fruit that can be used to determine harvest maturity.

With red skinned cultivars, after the mature-green stage the tip of the blossom end will change to a pinkish-yellow colour, which is commonly referred to as the 'breaker stage'. The breaker stage usually occurs within a day after the mature-green stage. The entire fruit then turns colour to pink, followed by light red, and finally deep red.

The ripening stages of mature tomato fruit are categorized as green, breaker, turning, pink, light red, and red. Knowing the maturity index and harvesting accordingly will help the farmer decide on the suitable market. For example, Madanpalle market prefers fully ripe red colored fruits at stage-6.

Madanapalle market

Figure 7-1 How to determine the right maturity for different purposes



7.2 How to harvest

Tomatoes should be removed from the plant by gently twisting or rotating them in order to cleanly remove the stem from the fruit. Harvesting during the heat of the day should be avoided where possible. Harvested fruit should be cooled down as much as possible to prolong the shelf life. Although the main grading on-farms is usually to remove the most damaged fruit, further grading for quality can make a big difference in market. Buyers only examine a fruit lot for a few seconds before deciding on price.

For Local markets
Mature- 4 green stage (can be held for a week or more)

Allowed to develop more colour before picking, if buyers prefer.

For distant markets
Mature-green stage, or the breaker stage to market as vine-ripe avoiding damage during shipping

7.3 Preparing for Market

The harvested tomatoes are usually packed in crates to transport them to the market. It is not advisable to pack them either in gunny bags or any other closed container to prevent damage to the fruits. During all operations, from harvest through packing, the fruit should be handled carefully to avoid bruising and injury to the tissue.

Bruises can affect ripening and cuts or injuries to the skin and predispose the fruit to invasion of decay-causing organisms. The fruit should be kept cool in a well-ventilated shaded area during market preparation. Avoid over packing in each crate.

Figure 7-2 Crates in which tomatoes are packed at the Madanapalle market

7.4 Cleaning

The initial step in preparing tomatoes for market is to clean the surface of the fruit and remove any dirt, surface stains, or adhering leaf tissue. This will help in preventing further damage to the fruit during transportation.

7.5 Grading

The harvested tomatoes must be sorted and graded before packing for market. Sorting should remove fruit that is too old, insect damaged, with broken skins or fruit that is too large or too small.

It is suggested to go for the first level of grading, of removing the damage and bruised fruits at the farm level, to retain the quality of healthy produce. As a general practice at Madanapalle, grading is taken up by the traders at the market engaging some skilled labour who are paid by the farmers.


Madanapalle market


Madanapalle market

8. MACHINERY AND TOOLS

8.1 Easy planter

This is a simple implement used to transplant tomato seedlings.

Manual transplanting is very tedious. Initially the mulch sheet has to be punched and the seedlings have to be planted manually into the hole. To transplant an area of 4000 sq m in a day, about 10-12 people will be required.

With the help of an easy planter, transplanting in the same area can be done in around 4 hours with just three persons; one person to bring the seedlings, another one to carry the trays and the third one to operate the planter. The cost of planter is affordable to small and marginal farmers.

The easy planter is a 3 foot (100 cm) long hollow tube supported with a lever. The hollow tube is open at one end into which the seedlings are dropped. The other end tapers down to insert the seedling into the soil.

A seedling is dropped into the tube after it has been pushed through the mulch and creating a planting hole where the seedling is to be transplanted. When the lever is pressed the seedling drops into the hole created by the tube.

The operator does not need to bend over, and by standing and transplanting there is less back strain.

Figure 8-1 Operating an easy planter

8.2 Mulching machine

A simple plastic mulch laying machine works well with a small tractor to reduce labour costs. It can be used for bed preparation, mulch and drip pipe laying, and evenly spaced hole punching for transplanting

8.3 Power tiller

This is a farm implement for stirring and pulverizing the soil, either before planting or to remove weeds and to aerate and loosen the soil after the crop has begun to grow.
It can be used in fields where the recommended spacing is adopted.

Figure 8-2 Power tiller for seedbed preparation

9. FREQUENTLY ASKED QUESTIONS AND ANSWERS

1. How long in a day should we irrigate the tomato crop through drip?

How long to irrigate with drip irrigation system depends on the following things:
- What is my crop?
- In what development stage is the crop?
- How are the weather conditions?
- What kind of drippers am I using?
- What is the distance between the drippers?

Refer to paragraph 5.2 in the manual for closer information. A short calculation can be derived from Figure 5-2. Showing the amount of irrigation in m3/ha for different months depending on the plant ing time. Table 5-1 shows, how long one needs to irrigate depending on the kind of drippers used and the dripper spacing. Observe: If you have a uniform lay-out of the irrigation system, the duration of irrigation is independent of the area irrigated.

2. How to control Blossom end rot in Tomato?

Blossom end rot comes from calcium (Ca) deficiency. In general, spraying Ca-containing fertilizers is most effective.
Soil based Ca-fertilization may help, but often, if the crop grows fast, Ca does not reach the fruit quick enough. Therefore, foliar application is recommended.

3. How to control viral diseases in Tomato Crop?

As in human medicine there is no real remedy to viral diseases. Some precautions can be taken:
- Avoid vector pests, such as white fly or thrips
- Remove infected plants / plant parts and destroy them (burning, burying)
- Clean your pruning tools when moving from one plant to the next

Refer to section 6.6 in the manual

4. How to prevent and control late blight in tomato?

Prevention: staking helps for creating a good microclimate.
Treatment: Copper hydroxide, see 6.7.5

5. What is the fertigation schedule for tomato to get 40 tons per acre?

A yield of 40 metric tonnes would extract approximately 130 kg N, 20 kg P_2O_5 and 130 kg K_2O. Follow the field preparation as in chapter 2, including a basal organic fertilization. Then apply the same fertigation schedule as in table 5-5, but double the amount of urea and MOP(if SOP is used 10-20% of higher dose is recomended. If your soil has a very low organic matter content, add a base dressing of 10 kg MAP/acre.

6. How to control bacterial wilt in tomato?

As most bacterial infections they are carried over from infected plants to healthy plants. Remove and destroy infected plant material. Avoid planting tomato after tomato, brinjal, chili or potatoes. It's better to avoid the plot infested by bacterial wilt. If not possible, apply enriched neem cake @1000kg per acre See 6.7.2

7. How to control *Tuta absoluta*?

At the moment, there is no reliable remedy against the South American pin worm. Refer to the sections 6.5 to identify an early infestation of the leaves. Even it looks similar to the leaf miner, it can be distinguished by the clustered damage and the absence of labyrinth-like patterns on the leaf surface. Remove and destroy infected leaves and fruit. (see 6.5.3)

8. In our area the tomatoes turn into pink color, what is the reason?

The phenomenon is not well researched and there is no clear answer to this question.
However, there are some possible reasons. Discoloration can be a sign of nutrient deficiency, espe cially potassium (K). So, if more than 50% of the fruit in a particular area are affected, check the N and K supply. High temperatures could be a reason. Possibly, a lower number of affected fruit could be a normal phenomenon during the months of April to June.

9. How much farm yard manure can be applied for tomato crop?

FYM, if well composted has no negative effects and excessive application is no problem to the plants. However, incompletely fermented FYM may have low pH and may harm the seedling when getting in contact. A thick layer of FYM may negatively influence the aeration of the soil and lead to rot and fungal diseases.
Excessive application of FYM means that the efficiency of nutrient use decreases. There are more nutrients applied, that can be turned over in one year. This is an economic loss.
Follow paragraph 2.4 and apply 10 metric tonnes FYM / ha (4 t/acre) along with other soil amendments, if possible.
(see 2.4.2)

10. How to differentiate between powdery mildew and late blight disease in Tomato?

Late blight can be identified by characteristic brown spots on the vines. However, distinction is not so important as control measures are basically the same, see 6.7.6

11. How do you select good transplants at nurseries?

Refer to paragraph 3.5 in this manual. Basically select a good nursery.

12. How often fertilizer application is needed?

N and K fertilizers, e.g. urea and MOP should be applied often and in small quantities. If using ferti gation, follow the instructions in table 5-5. If broadcasting, use the quantities given in table 5-3 and split the total amount of urea and MOP in three to four applications per season.

13. Does the fertigation schedule vary for different soil types?

The fertigation schedule is the same for all common soils. Refer to table 5-5.

14. Under what conditions tomatoes will not set flowers?

- Night temperatures above 21 or below 13 degrees C.
- Day temperatures above 32 degrees C combined with low humidity and/or drought. Hot drying winds can add to the problem.

• Dry soil can cause blossoms to dry up and drop.
• Too much nitrogen fertilizer produces leafy growth at the expense of flowers and fruits.
• Viral diseases, such as, curly top, mosaic viruses, etc. can affect flowering and fruit set.
(see 5.9)

15. Can I save seeds from current tomato seedlings for next season's plantings?

Not, if they are hybrids.

16. What happens if tomato plants are not staked?

They grow slower and make less use of the space on the field, so there is less yield
There is less wind and air circulation, increasing fungal diseases
Some fruit is on the ground, thus, diseases and mechanical damage. (see section 4.1)

17. What are the benefits of mulching in tomato crop?

Refer to section 2.6 in the manual

18. How to prevent bird damage to tomato crop?

Either scare crows or mechanical protection (Nets, guns…)

19. What causes blossom end rot in tomatoes?

It is calcium deficiency (see question 2)

20. What is the best time to harvest tomatoes? Early morning, early evening etc.

This depends on the handling chain. The time between harvesting and selling should be short.
Avoid high temperatures, so morning and evening are good.
Do not expose the harvested tomatoes to direct sunlight.
Cool them if possible.

21. What is the color of tomatoes for harvesting?

Depends on the use. Refer to section 7.1 in the manual

22. Why do tomatoes crack and how to prevent this problem?

Cracking is a problem of excessive growth, which can be due to excessive fertilization or a period of drought followed by quick re-watering. See 5.9

23. What causes tomato leaves to curl?

Leaf curl virus, see section 6.7.7

24. How do you identify a tomato variety as determinate or indeterminate?

Section 3.2

25. What are the common weeds of tomato?

There are no specific weeds associated with tomato. For weed management refer to section 2.3.1

26. What is the best season of growing tomato?

See Section 2.1

27. What are the important pests and diseases of tomato?

All listed in Section 6

28. How do we do soil solarisation? What are its benefits?

Irrigate the field. Cover the soil with plastic mulch (best is black) for about two weeks and expose to radiation in dry weather conditions. The soil will heat up to the point that freshly germinated weeds die during their most vulnerable stage of development.

29. What is the difference between breeder seed, foundation seed and certified seed?

A breeder's seed is an offspring of a genetically pure seed; produced by mutual multiplication of three different lines which are denoted by A line, B line and R line. A line is female, while B and R line are male sterile. The seeds from their off springs with best and desired quality are selected and certified as Breeder seeds.
The Breeder seed is further multiplied into the foundation and certified seeds.
Offspring of the Breeder seed that can be clearly traced to Breeder seed are called Foundation Seeds. Certified seed is the progeny of foundation seed which actually reaches to a farmer and must meet the standards of seed certification prescribed in the Indian Minimum Seeds Certification Standards, 1988.

30. Why is it important to have crop rotation?

Most importantly: By crop rotation we avoid the carry-over of pests and diseases from one season to the other. (e.g. bacterial wilt, early blight and nematodes)
Different crops have different nutrient requirements, so the soil is not depleted.
Integration of legumes creates a N input.
See section 2.2.2

31. What is the optimum temperature for tomato crop?

Temperatures below 13°C negatively affect fruit set and can lead to misshapen fruit. Below 10°C, fruit set is poor. The optimum temperature for fruit set is between 18°C and 26°C. Above 35°C fruit set is reduced. Temperatures above 40°C affect growth and plant fitness negatively. (see 2.1.1)

Common problems that can be easily overcome

Practice	Practical impacts
Not pre-ordering of seedlings	Lack of available seedlings of the preferred variety for timely transplanting, leading to a delay in the cropping season, a compromise on seedling quality and reduced returns
No emphasis on quality seedlings	Poor crop stand,High mortality at a young age High incidence of viral diseases
Dense planting of seedlings	Allows no free circulation of air, encourages pests and diseases
Transplanting immediately after herbicide application	Detrimental effect on seedlings leading to high mortality
Over fertilization	High vegetative growth and a few flowers, Scorching and burning of leaves Cracking of fruits, Unwanted expenditure, Soil pollution
Repeated planting of tomato in the same field season after season	Carrying over of pests and fungal bacterial spores to the next crop reducing yields and returns
Excess irrigation	Increased occurrence of damping off and other fungal diseases
Mixing many chemicals to be sprayed at once	Incompatibility of chemicals reduces their effectiveness. Increased costs with poor control, wasted chemicals and increased resistance of pests
Contacting input dealers for technical advice	Inappropriate diagnosis based on what they have to sell rather what will work best and most economically. Poor advice resulting in unnecessary purchases, over-use of chemicals and damage to natural enemies
No precautionary measures taken while spraying	Health hazards to the sprayer, farmer and consumers with potential severe impacts on health.
Not discarding the pruned affected plant parts well away from the field or destroying them	Increased spread of disease
Leaving damaged plants and fruits in the field itself	Greatly increased spread of pests and diseases
After final harvest, leaving dead plants and roots in field without uprooting them	spread of pathogens to the next crop

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