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MANUAL

**MECHANICAL STRESS
IN TOMATOES**

**MINIMIZE YOUR
CROP'S STRESS
USING**



Supporting your growth



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A NOTE OF THANKS

Thanks to HORTOMALLAS® and to the support of all the tomato farmers (*Solanum lycopersicum* L.), this manual has been compiled to provide information about the mechanical stress experienced by tomato plants during cultivation.

OVERVIEW

WHAT IS MECHANICAL STRESS?

Mechanical stress is the cause of reduced yields in farming, due to natural factors and agricultural tasks carried out in the field. It is important to point out that the damages occur during the developmental stages of the crop's growth.

In Mexico, each hectare of tomato plants produces 39.5 tonnes per hectare in open fields and sheltered crops can yield up to 350 tonnes per hectare. Tomatoes are sold for US\$1.25 (based on the average price per kilogram) in boxes of 25lb (11.33 kg) for a price of US\$14.16 per box (figures taken from INFOACERCA). Given that up to 18% of the yield can be lost due to mechanical stress, we could be talking about losses of up to 7,100 kg per hectare, with a value of US\$8.887.50.

As well as providing an excellent tutoring support system, HORTOMALLAS® support netting also reduces the handling of the plants and reduces both labour costs and mechanical stress caused by tutoring. Additionally, using support netting facilitates farming duties such as pruning and clearing the undergrowth.

INTRODUCTION

The tomato (*Solanum lycopersicum* L.) is a plant from the Solanaceae family, a shrub with initially upright vegetation whose leaves consist of various alternating folioles (small leaves).

According to FAO figures , between the 50 main producers of the plant, 156,574,846 tonnes of tomatoes were produced in 2016. China was top of the list with 50,552,200 tonnes and the United States was in third place with 12,574,550 tonnes. Mexico is among the major producers: in first place as an exporter of tomatoes, annually distributing around 50% of the 3,282,583 tonnes of tomatoes it produces (1). The importance of this crop lies in its culinary use as an accompaniment in salads and as a condiment in sauces. For all of the above reasons, we must find solutions for the factors that reduce the yields of this crop.



HORTOMALLAS® support netting in greenhouse tomato cultivation

Mechanical stress in plants can be caused by wind and rain but is principally due to handling the plants when carrying out agricultural and horticultural tasks (2). These factors cause significant losses of up to 18% in the yields of each crop cycle.

As with horticulture in general, alternative technological innovations exist which can enable a farmer to exceed average crop yields of tomatoes. Tutoring with support netting is an alternative technology within any farmer's reach since, unlike other options, it does not require a large financial investment.



Using HORTOMALLAS® in open-field tomato production

Implementing this tutoring technique reduces the mechanical stress caused by maintenance activities which are necessary to care for the plants as well as various environmental factors such as the rain and wind, which affect crops in open fields.

When support netting is used instead of raffia for example, it assists the growth of the plant by providing good support. It also facilitates processes such as fertilization, fumigation, clearing of undergrowth, pruning and harvesting, and reduces the occurrence of mechanical stimuli which reduce yields.



Installing HORTOMALLAS® support netting in open air tomato cultivation

THE CROP

THE IMPORTANCE OF TOMATOES

The tomato is one of the most important crops in terms of financial revenue and dietary importance. As one of the most cultivated crops, it is famed as the most consumed fruit eaten by man and is used as an accompaniment and condiment in a multitude of dishes around the world.

Botanical features of the tomato

Its scientific name is *Solanum lycopersicum* L. and it is a semi-erect shrub-like plant. Its growth depends on the genetic make-up of the hybrid or variety being cultivated.

Taxonomic classification

Kingdom:	Plantae
Division:	Tracheophyte
Class:	Magnoliopsida
Order:	Solanales
Family:	Solanaceae
Genus:	<i>Solanum</i>
Species:	<i>Solanum lycopersicum</i> L.



Tomato plant tutored using double rowed support netting

Seed

The tomato seed is flat and lenticular with the approximate dimensions of 3 x 2 x 1 mm. For longterm preservation a 5.5% humidity level is recommended.

Germination

Germination usually occurs in three stages:

- Quick absorption of water 20 hours.
- Rest for 40 hours.
- Growth resulting from the germination of the plant.

Morphology

The roots of the plant have ramification and its angled stems are semi-ligneous, hairy and have a very distinctive smell. It is an erect, angiosperm plant, with hermaphrodite flowers which means that when it enters the reproductive stage its flowers contain both the male and female parts.

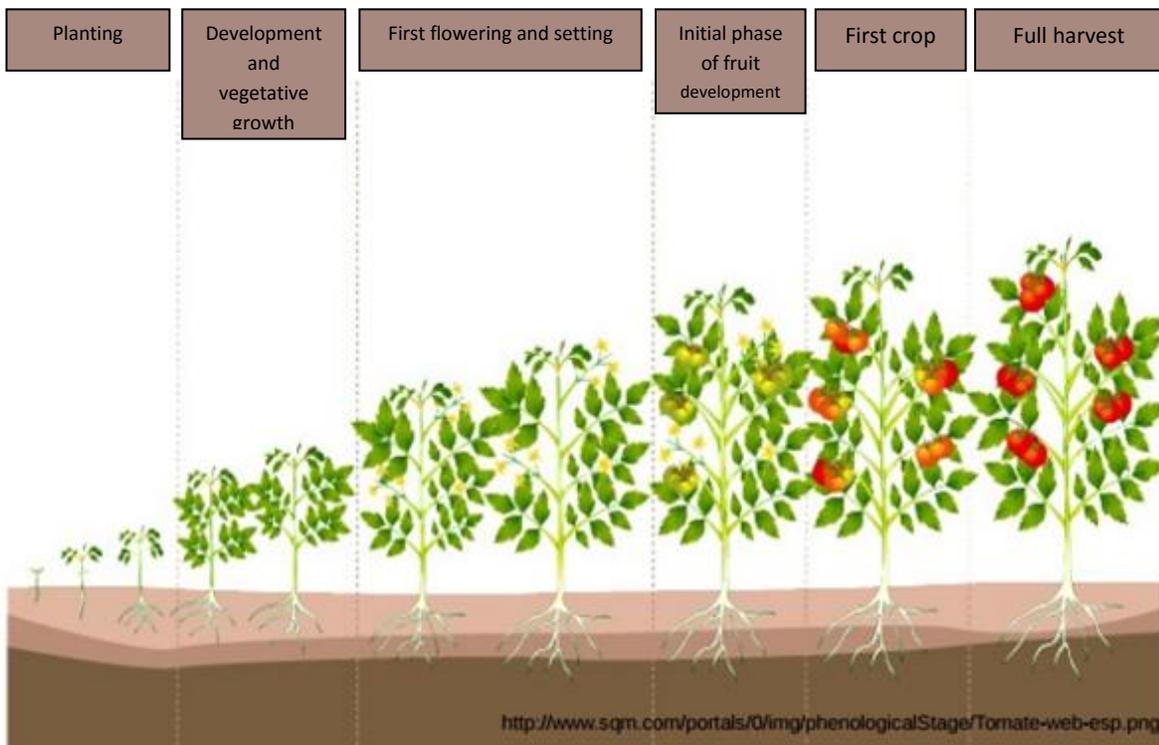
Requirements for tomato cultivation

The conditions needed for optimal development of tomato plants are as follows:

- Tomato plants can be cultivated from 20 MAMSL up to 2,000 MAMSL, depending on its potential and its genetic variety.
- The optimal temperature for cultivations is 30°C and 16°C overnight. However, if the temperature gets close to 30°C it can adversely affect the colour of the fruit.
- Good sunlight is required, so pruning and tutoring is recommended to enable the plants to harness as much light as possible (10).

Flat or semi-flat ground is needed with an appropriate drainage system which allows the crop to retain the moisture it needs. As regards the soil, clay loam soil is recommended as the most suitable for tomato cultivation (10).

Phenological stages of tomato growth (graphic)



Cultural management of tomato crops

Tomatoes are one of the plants species which can be cultivated both in open fields and in greenhouses. Cultivation in controlled environments can improve production by 100% or more, thanks to better control of the variables which directly affect the efficiency of the crop, such as temperature, moisture levels and amount of sunlight received.

Tutoring with support netting is a horticultural practice that can be employed both in protected and open air environments. This practice allows us to reduce the negative effect of mechanical stress that the plants suffer from environmental factors such as wind and rain, and also improves the efficiency of horticultural tasks such as transplanting, tutoring, handling of the plants until fruits grow on the first raceme, detaching, pruning, handling whilst applying fertilizers and whilst watering, harvesting and sorting of the fruits – these are all tasks which could affect the yield when not carried out properly.



Tomato saplings (*Solanum lycopersicum* L.) can be planted out in the open air or inside greenhouses.

Key points for tomato crop management

Transplantation

Transplantation, or planting out the tomato sapling, is recommended when the plants has 3 or 4 leaves which are 30 days old. The crop density will depend on the type of planting system chosen.

- In hot climates, it is best to do the planting out after the sun has gone down to minimise the heat and other factors.
- Each plant should be placed with its leaves facing the walkways so that the clusters of flowers will be on the same side, making the harvesting of their fruits easier later on.
- The seedlings should be planted with the same depth that they have in the seedbeds.
- Each transplanted plant should be watered with 500 ml of water.
- Regular applications of trademarked tomato products should be carried out to control plant pathogens and insects.

Tutoring

Once the plant has reached a height of 25 to 30cm, it becomes necessary to provide it with supports, requiring its main stem to be attached in order to keep the direction of growth and support the plant. The exact fastening method and positioning of the plant will depend on the tutoring method chosen by the farmer.

Traditional tutoring

Rods (made from whatever material is available) are positioned directly alongside each seedling and between every four leaves or every two clusters it is fastened to the rod (11, 13).

"Dutch" or "hanging" tutoring method

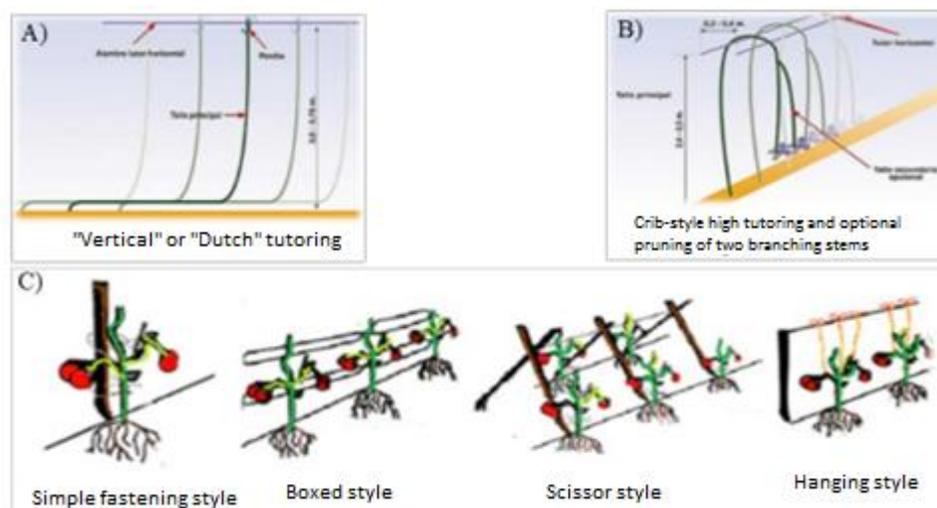
With this method the upper section of the stem is fastened using raffia hanging from a metal hook, held in place by the steel cables above the furrows and down the length of the greenhouse. The raffia is then gradually adjusted as the plants get taller.

"Boxed" tutoring

A post is positioned every four or six plants and stakes are positioned at the edge of each furrow to reinforce the posts. The yarn or raffia is fastened around the plants to provide better support (11).

Tutoring with single row support netting

Posts are positioned along the furrow between 1.5 meters and 8 meters apart. Tensor wire is fastened to the upper part of the posts along the length of the furrow and then the support netting can be put in place (15).



Types of tomato tutoring (*Solanum lycopersicum* L.)

Diagrams A and B taken from Salas et al. (17).

Diagram C taken from Vallejo and Estrada (11).

Pruning

Pruning is carried out between 10 to 15 days after planting out and gives shape to the plant and helps its fruits to develop. Among the types of pruning carried out is that which is known as “phytosanitary pruning” (11). This practice is necessary to keep the growth of the stems, leaves, branching stems and fruits under control. Each cut made must be clean to avoid the plant becoming infected with plant pathogens which cause disease. To that end, each tool must be sharpened and treated with some type of fungicide or bactericide.



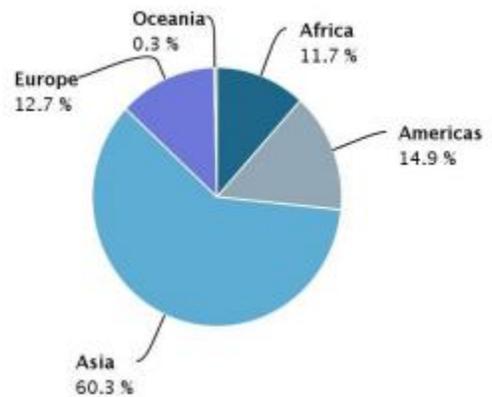
The traditional tutoring method can be seen here as well as the way the tomato plants are pruned.



Pruning tomatoes that are being tutored using double rowed support netting.

Economic and industrial importance of tomato cultivation

Tomatoes, as with the majority of crops, are recognized for their richness in vitamins, minerals and amino acids, which are essential nutrients for our balanced diet as humans. Tomatoes are grown the world over and used as an accompaniment in salads and as an essential ingredient for sauces. In 2014, the FAO (Food and Agriculture Organization) reported that the continent producing the greatest amount of this crop was Asia, with just over 60% of the worldwide production and with China as the principal producer. In Mexico, the tomato is the second most exported product, with almost 2 million tonnes per cycle (FAO, 2016).



Pie chart showing the percentage of tomato production worldwide

Principal causes of loss of tomato crops

The tomato crop is prone to different factors which can deplete its yields. Due to its significant role as a food source and to the economy, alternative strategies are needed to curb the loss in yields and keep this crop in optimum conditions for its development.

FACTORS THAT CAN REDUCE TOMATO CROP YIELDS:	
Biotic factors	Abiotic factors
Phytopathogen funguses	Water
Bacteria	Temperature
Mechanical stress	Light
Infestations	PH levels
Humans and animals	Soil

General points about stress

What is stress?

Stress is the state of disturbance that can occur when the environmental conditions are not optimal for a plant's development. To be more precise, it can be defined as "the combination of biochemical and physiological responses of an organism that differentiate themselves from those observed under optimal condition" (3).

Types of stress

There are various factors which can give rise to stress in plants and they can be categorised into distinct groups. These factors can be environmental, physiological, biochemical, mechanical, amongst many others. Within these groups, we find various types of stress:

- Water stress
- Saline stress
- Temperature stress
- Nutritional stress
- Hormonal stress
- Heavy metal stress
- Mechanical stress

Distinctive features of mechanical stress

Mechanical stress

Mechanical stress appears as a physical alteration in the plant or in one of its parts (5) and is serious given the potential repercussions to tomato crop yields. It can appear naturally as a result of wind or rain, or be caused by the farmer when carrying out agricultural tasks such as transplantation, pruning, harvesting, or when installing or maintaining the tutoring system employed (6, 5, 2).

Mechanical stress in tomato crops

Mechanical stress can affect plants at any stage of their development but it causes the most damage when the plants are still seedlings. Mechanical stress will adversely affect their development and hinder their stem and leaf growth. The damage caused can be observed in the plant's soft tissue and in whichever area was exposed to the stress (5), causing a diminished stem thickness in some vegetable species (6).

Consequences of crop stress

Studies where plants were submitted to mechanical stress (the plants were shaken for several seconds each day), showed that the "Supersonic" and "Rutgers" varieties of tomato plants had their stem and leaf size reduced in comparison with plants that weren't subjected to mechanical stress (6). Another study showed that shaking the plants twice a day during their growth stage resulted in 25% smaller plants with 23% less leaf area and generating 18% less fruit in the final harvest yield (7, 5).

Alternatives

As has already been mentioned, tomato cultivation is extremely important, and therefore its **profitability** is a subject of great interest. When methods of tutoring tomato crops are discussed, often the traditional raffia support system is what comes to mind. Given that mechanical stress affects every stage of the plant's growth, it is vitally important to reduce its causes and the impact it has when carrying out agricultural tasks.

HORTOMALLAS® Support Netting

The traditional tutoring method using raffia requires a great deal of manpower and this in turn causes mechanical stress to the plants. In addition to the labour costs, materials are a large expense as the raffia has to be replaced for each crop cycle. In contrast, tutoring with a support net means that both labour costs and the handling of the plants are reduced, making it a great alternative for crop tutoring.

HORTOMALLAS® support netting is comprised as follows:

- Made from unmodified polypropylene
- Treated with a UV-resistant coating.
- White in color
- 7 threads length-wise
- 6 frame heights
- Box dimensions of 25 x 25 cm
- Bi-orientated allowing it to hold up to 61.2Kg/m².

Uses and field applications

Support netting can be used to tutor a wide variety of crops such as:

- Tomato
- Pumpkin
- Chilli
- Zucchini (courgette)
- Peppers
- Melon
- Eggplant (aubergine)
- Cucumber
- Chayote
- Green beans

The nets can be adapted to suit each farmer's preferences and can be installed in a vertical or horizontal manner. They are quick and easy to install – posts are put in place along the length of the furrows, the net is unwound and fastened to the posts with raffia (ties made from plastic or other materials can also be used if preferred).



To see a detailed explanation of how to install support netting, see the [TUTORING SOLANACEAS WITH HORTOMALLAS® MANUAL](#).

HORTOMALLAS Vs. Traditional tutoring

Traditional tutoring requires a lot of labour to fasten each seedling with raffia and position them uniformly. Also, if one of the threads were to split, the crop could collapse potentially causing some of the plants to be ruined.

Another major disadvantage of using raffia as a support system is that it retains moisture between its threads, providing the perfect conditions for the spread of plant pathogens.

On the other hand, when HORTOMALLAS® support netting is used as a support system, savings are made on all fronts: the installation time, labour costs, the fact that the netting lasts for several cycles of crops and has a low risk of breaking due to being made as a single piece.

HORTOMALLAS® support netting can be positioned in single or double rows (in sandwich or “V” patterns). Double rowed netting greatly facilitates agricultural tasks thanks to the plants being neatly boxed by the netting, allowing for more space between the furrows.



Tomato crops inside a greenhouse, using double-rowed support netting



Tomato crop in open fields tutored using HORTOMALLAS® support netting in a double rowed formation.

It is recommended that the stakes are put in place a few days before planting out the seedlings so that their roots are not damaged by installing the stakes, avoiding causing them mechanical stress.

Surveying the damages

Every plant lost due to mechanical stress caused from carrying out agricultural tasks results in decreased production. Perhaps some farmers wouldn't be overly concerned about losing a few plants whilst pruning (contaminating the plants), when fastening the plants to a tutoring system (strangling their stems) or from constantly handling the plants whilst tutoring them (vibrating movement).

However, SIAP reported in its preliminary data that 39.5 tonnes of tomatoes per hectare were produced in 2009. That means 25,000 plants per hectare producing 1.58 kg per plant. It has been reported that up to 18% of the yield can be lost due to mechanical stress caused during the production stage. This equates to 7,110 kg per hectare, with a value of US\$ 8, 887.50.

For this reason, it is important for every farmer to ask himself: When did decreases in production start to occur? Based on that, the methods needed to carry out agricultural tasks more efficiently and to reduce crop losses can be identified and refined.

Mechanical conditioning

As we've seen, mechanical stress can be damaging to crops. However, it occurs in the daily life of any plant. As a result of studies on the effects of mechanical stress on plants, it has been noted that mechanical stress can be used to the plant's advantage. Using mechanical stress as "mechanical conditioning" is a method used to control the growth of the seedlings, specifically their size and the thickness of their stems (5, 2) prior to their being planted out. This type of mechanical stress can be used by seedling production companies without causing long-term damage to their crops and can be adapted to different production processes. Among its benefits are uniform seedling height, increased resilience during transportation and a greater ability to adapt to environmental conditions in open fields (5, 2).



Seedling tomato plants being exposed to mechanical conditioning (mechanical stress) using a roller to make their growth uniform.
Photo taken from Garner and Björkman (16).

The types of mechanical conditioning used by companies are vastly different from the mechanical stress that we see in the field. Their methods consist of rubbing the plants with different materials, even shaking the seedlings lightly to stimulate more positive responses when they are planted out (5, 2).

Once the seedlings that have received the mechanical conditioning treatments are planted out, they are more resilient to the handling they naturally suffer during this process. However, it is extremely important to reduce mechanical stress to a bare minimum during the plant's developmental and fruit-bearing stages.



Tomato fruits being supported by HORTOMALLAS® support netting.



HORTOMALLAS® support netting being installed in a double-rowed formation for a crop of tomato plants.

HORTOMALLAS® support netting helps to reduce the mechanical stress caused by excessive handling of the plants, is easy to install and offers a complete support system that is robust enough to support your crops. It is essential for tomatoes to have a good support system during cultivation so that the weight of their fruits do not cause their branching stems to break.

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