# DISEASES, PESTS AND PHYSIOLOGICAL DISORDERS IN TOMATO (*Solanum lycopersicum L.)*

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## ABSTRACT

The tomato (*Solanum lycopersicum* L.) is essential for the economy and food in Brazil, but it faces several agronomic problems requiring efficient management. Thus, the objective of the present study was to carry out a bibliographic survey on the main phytosanitary and physiological problems that affect tomato crops, identifying their symptoms, signs and management strategies. Selected according to their severity and impact, the following agronomic problems were identified, categorized into their respective group: I- Diseases (fungal, bacterial, viral and nematodes): early blight, late blight, bacterial canker, bacterial wilt, golden mosaic, head turnover and nematode-root lesion; II- Pests (mites, insects and others): whitefly and tomato moth; III- Physiological disorders (nutritional, phytotoxicity and others): calcium, nitrogen, boron, copper, water stress and heat stress. The systematization of this knowledge allowed the understanding of the challenges faced in tomato production, but also contributes to the organization of the respective most effective control and management strategies. The efficient application of corrective measures is essential to avoid production losses and environmental impacts, highlighting the importance of technical knowledge in the search for sustainable and high-quality production.


**Keywords:** Tomato. Plant health. Fertility.

## 1 INTRODUCTION

In Brazil, tomatoes (*Solanum lycopersicum* L.) are one of the five main vegetables grown and consumed in the country (CONAB, 2021). An important source of vitamins, minerals and antioxidants, it is a very present food in Brazilian cuisine, playing an essential role in the healthy diet of the population (Ministry of Health, 2015). In 2016, the planting area in the country reached approximately 64 thousand hectares, of which about 35% was destined for industrial tomato cultivation and the rest for *fresh* consumption (CONAB, 2019). The production of 3,809,986 tons in 2022 represented an increase of 22.76% compared to 2001 (IBGE, 2022). In this way, the tomato production chain has significant job creation and movement of the agricultural economy, contributing to the income of many farmers.

Considering the economic importance, there should be constant studies that are dedicated to investigating biotic and abiotic factors that can affect production (Böhm et al., 2024). Despite being cultivated in different regions of Brazil, this vegetable of Andean origin (Peixoto et al., 2017) is subject to several diseases, pests, and physiological disorders that can have significant impacts on production.

Diseases such as downy mildew, powdery mildew and late blight can reduce the quality and quantity of fruits, harming the harvest (Embrapa, 2000). Pests such as aphids, whiteflies, and spider mites can also cause severe damage, resulting in economic losses for farmers (Pratissoli & Carvalho, 2016). In addition, physiological disorders, such as extreme temperatures, non-nutrient chemical elements in the soil that cause phytotoxicity, excess or lack of light and water, in addition to nutritional imbalance, such as lack of calcium, potassium or magnesium, can affect growth and development, leading to lower quality fruits and lower productivity (Rezende, 2007).

Tomato production in Brazil requires continuous research to address phytosanitary and soil fertility challenges, ensuring quality and sustainability (Embrapa, 2022). Lack of accurate diagnosis of diseases, pests, and physiological disorders can lead to inappropriate use of agrochemicals, waste of resources, and environmental degradation. In addition, the incorrect application of fertilizers compromises crop productivity and quality (Embrapa, 2016). Inadequate management also affects the soil, causing nutritional imbalances, increased salinity, and reduced microbial biodiversity, undermining fertility and long-term agricultural sustainability (Guerra & Jorge, 2014).

To diagnose diseases, pests, and physiological disorders in agricultural crops, various techniques and methods are used. The collection of soil and plant samples is essential for laboratory analyses that identify the presence of pathogens, nutritional deficiencies, and other physiological disorders. The use of traps and baits is also a common practice to monitor and identify specific pests. However, the basic approach starts from direct observation of plants in search of visible symptoms, such as leaf spots, deformations or the presence of insects (Ministry of Agriculture and Livestock, 2022).

The accurate identification of diseases, pests and physiological disorders that affect tomato is essential for the adoption of effective management and control strategies, ensuring the productivity and sustainability of the crop. Therefore, the objective of this study was to carry out a bibliographic survey on the diseases, pests and physiological disorders that affect tomato (*Solanum lycopersicum* L.), identifying the main agronomic problems associated with each group and analyzing their symptoms, signs and control and management strategies.

## 2 METHODOLOGY

The databases for consulting the technical and scientific contents used in the preparation of this work are mainly publications of national public research and technical assistance agencies, scientific journals and books. In each group addressed: diseases (I), pests (II) and physiological disorders (III), the main occurrences affecting tomato in Brazil are presented as a function of the causative agent, which delimit the subgroups. For each subgroup, two agronomic problems of greater attention were detailed.

Thus, the diseases were organized into fungal (a), bacterial (b), viral (c) and nematode (d); pests were subdivided into mites (a), pest insects (b) and other organisms (c), such as birds and mollusks; and physiological disorders were separated according to nutritional deficiencies (a), phytotoxicities (b) and other factors (c).

The choice of the two most prominent problems in each subgroup was based on criteria of severity and impact. Severity is related to the degree of damage caused to the plant, which can lead to death, flower abortion or total loss of fruit. The impact concerns the influence on productivity and commercial quality of production, being determining factors for agricultural management. Thus, the most recurrent problems that require greater attention from producers were prioritized.

## 3 TOMATO CROP (*SOLANUM LYCOPERSICUM* L.)

### 3.1 *BOTANICAL CHARACTERISTICS*

*Solanum lycopersicum* is a dicotyledonous plant belonging to the Solanaceae family, with erect or prostrate growth, whose phenology includes the stages of germination, vegetative growth - with increase of leaves and stem, flowering, fruiting and maturation. The leaves are compound, alternate, and with serrated margins, while the flowers are small, yellow, and arranged in clusters. The tomato fruit is a juicy berry, with a varied shape, size and color, and can be round, oval, elongated, and with colors such as red, orange, yellow, green or even purple, depending on the cultivar. The tomato plant has pivoting and deep roots that facilitate the absorption of nutrients and adaptation to different soils and climates, as long as management is adequate (Filgueira, 2003).

Tomato varieties, although diverse in size, shape, color, and flavor, are subject to the same agronomic problems. Considering the difficulty in accurately identifying cultivars, due to the lack of standardization of popular names (Peña-Lomelí et al., 2014), the characteristics of the commonly cultivated varieties are shown in Chart 1.

**Table 1.** Tomato varieties and related information.

| Variety | Features | Uses | Advantages |
|---|---|---|---|
| Yellow Tomato | As the name implies, it has a yellow or orange color, which makes it visually distinctive. It has a milder and less acidic flavor than traditional tomatoes. | Consumed *in natura*, in salads or for recipes that call for a more delicate flavor. | It usually has lower acidity and can be a good alternative for people with digestive problems. |
| Tomato Beefsteak | Large tomato, with a dense and juicy pulp. Its shape is irregular, with an appearance of layers or "stripes" on its surface. | Widely used for sandwiches due to its size, dense flesh, and strong flavor. | Its large size makes it an excellent choice for commercial crops, although its disease resistance needs special care. |
| Persimmon Tomato | Large, flattened and slightly oval tomato. It has a thick skin and a firm pulp. | It is excellent for consumption *in natura* or in sauces. It can also be used for drying. | It has good resistance to dehydration and storage. |
| Cherry Tomatoes | Small and round, with a thin rind and a sweet texture. The flavor is quite sweet, which makes it popular in salads. | Ideal for fresh consumption, in salads, or as an aperitif. It is also often used in canning. | High resistance to diseases and pests. |
| Buffalo Heart Tomato/Carmen Tomato | Large, heart-shaped, and fleshy texture. It has fewer seeds and a firmer pulp. | Used for fresh consumption or to prepare sauces. | Its juicy flesh and sweet flavor make it ideal for direct consumption. |
| Salad Tomato/Table Tomato | Varieties such as "Santa Cruz" are rounder and larger, with smooth skin and a mild flavor. These tomatoes are juicy and | Consumed *in natura*, in salads, sandwiches and side dishes. | It usually has good resistance to pests, but requires more |

| | | | |
|---|---|---|---|
| | have a good balance of acidity and sweetness. | | care regarding the management of fungal diseases. |
| Indigo Tomato | It has a unique coloration, with a dark purple almost black tone at its ends, due to the presence of anthocyanins, antioxidant compounds. | In addition to being consumed *in natura*, it is sought after for its high nutritional value. | Rich in antioxidants and easy to adapt to different climates. |
| Italian Tomato | Large, round and quite fleshy. This tomato is characterized by dense flesh and low seed content. | Ideal for preparing sauces and also for fresh consumption. | Quite resistant to common diseases such as powdery mildew and late blight. |
| Italian Tomato/Roma Tomato | It has an oblong, more elongated, and less juicy shape, with a significant amount of pulp. Its skin is thicker, which makes it ideal for processing, especially for the production of sauces and pastes. | Widely used in the processing industry due to its consistency and low water content. | Resistant to various diseases and adverse weather conditions. |
| Long Life Tomato | It has a thick shell, which contributes to its durability and strength during transportation. | Mainly aimed at commercialization, due to its longer shelf life, being used both in natura and in processing. | Resistant to diseases and has excellent conservation. |
| Pomodoro Tomato | Medium in size, rounded shape and smooth skin. It has a good amount of juice and pulp. | Used for sauces | Ideal for processing due to the balance between acidity and sweetness. |
| Green Tomato | They are still immature tomatoes, with an intense green color. Its taste is acidic and more bitter. | Often used in preserves or in dishes that require a firmer, acidic-tasting tomato. | Used especially when you want to capture the acidic freshness of an unripened tomato. |

## 4 GROUP I: TOMATO DISEASES

Tomato production is often threatened by a wide range of diseases caused by fungi, bacteria, viruses and nematodes, which compromise plant health and, consequently, fruit productivity and quality. These diseases can manifest themselves in different parts of the tomato plant from root to fruit, causing from light spots to complete destruction of the plant (Kimati et al., 2005). Chart 2 shows the list of diseases that can affect the crop, categorized according to the causal agent.

**Table 2.** Tomato (*Solanum lycopersicum* L.) diseases according to the causal agent.

| Diseases | |
|---|---|
| Fungal (a) | Anthracnose (*Colletotrichum* spp.) |
| | Stem Canker (*Alternaria alternata* f. sp. *lycopersici*) |
| | Damping-off (polyphagia) |
| | Cladosporium leaf spot (*Cladosporium fulvum*) |
| | Corynespora spot (*Corynespora cassiicola*) |
| | Stemphylium spot (*Stemphylium solani*) |
| | White Mold/Sclerotinia Rot (*Sclerotinia sclerotiorum* and *Sclerotinia minor*) |
| | Grey Mold (*Botrytis cinerea*) |
| | Fruit Black Mold (*Alternaria alternata*) |
| | Verticillium wilt (*Verticillium dahliae*) |
| | Fusarium wilt (*Fusarium* spp.) |
| | Powdery mildew (*Oidiopsis sicula* and *Oidium lycopersici*) |
| | **Black Spot/Alternaria Spot (*Alternaria solani*)*** |
| | Corticose Root Rot (*Pyrenochaeta lycopersici*) |
| | Botrytis rot (*Botrytis cinerea*) |
| | Phoma rot (*Phoma destructive*) |
| | Sclerotium rot (*Sclerotium rolfsii*) |
| | Fusarium Root and Neck Rot (*Fusarium oxysporum* f. sap. *Radicis-lycopersici)* |
| | Sorrel Rot (*Geotrichum* spp.) |
| | Rhizopus rot (*Rhizopus stolonifer*) |
| | Soft rot (*Erwinia* spp.) |
| | **Late Blight (*Phytophthora infestans*)*** |
| | Septoria *(Septoria lycopersici*) |
| Bacterial (b) | **Bacterial Canker (*Clavibacter michiganensis* subsp. *Michiganensis*)*** |
| | Giant Goblet (Phytoplasma) |
| | Bacterial Spot (*Xanthomonas* spp.) |
| | **Bacterial wilt (*Ralstonia solanacearum*)*** |
| | Dry Necrosis of the Marrow (*Pseudomonas corrugata*) |
| | Bacterial Spot/Lesser Bacterial Spot (*Pseudomonas syringae* pv. *Tomato*) |
| | Bacterial Burn (*Pseudomonas syringae* pv. *Syringae*) |
| Viral (c) | Yellows (ToYTV and TBYLV) |
| | Curly Sprout (Geminivirus) |
| | Mosaic (ToMV) |
| | **Golden Mosaic (Geminivirus)*** |
| | Stripe/Mosaic Y (PVY) |
| | **Head-turner (Tospovirus)*** |
| Nematodes (d) | **Root-knot nematode (*Meloidogyne* sp.)*** |
| | Citrus Nematode (*Tylenchulus semipenetrans*) |
| | Dagger nematode (*Xiphinema* spp.) |
| | Cyst nematode (*Globodera* spp.) |
| | Stem-and-Seed Nematode (*Aphelenchoides* spp.) |
| | Spiral Nematode (*Helicotylenchus* spp.) |
| | **Nematode-Lesion-Radicular (*Pratylenchus* spp.)*** |
| | Rheniform nematode (*Rotylenchulus reniformis*) |
| **Caption:** *Biotic diseases that most affect tomato crops. | |

**Source:** Prepared by the authors from: Embrapa, 1993; and Kimati et al., 2005.

The diseases have a great impact on the tomato crop, and can cause significant losses in productivity and economic viability. Integrated control and accurate identification of these diseases are essential to ensure the sustainability of production and reduce management costs (Kimati et al., 2005).

## 4.1 SUBGROUP IA: EARLY BLIGHT/ALTERNARIA SPOT (ALTERNARIA *SOLANI)*

Caused by the fungus *Alternaria solani*, Alternaria leaf spot affects leaves, stems and fruits of the tomato plant. On the leaves, dark spots with yellowish areas and necrosis appear, leading to defoliation. On stems, necrotic lesions and fissures appear, while on fruits, depressed lesions and necrosis appear. At high humidity, black spores can be observed in the lesions, indicating sporulation of the fungus (Kimati et al., 2005).

The control of tomato early blight involves chemical, biological and cultural methods. Chemical control is one of the most used tools, involving protective fungicides, such as mancozeb, chlorothalonil and copper-based compounds, which protect plants and inhibit the growth of the fungus, and it is important to rotate them to avoid pathogen resistance. Biological control uses antagonistic microorganisms such as *Trichoderma* spp. or *Bacillus subtilis* to combat the pathogen, while cultural control includes crop rotation, balanced fertilization, and adequate spacing.

Other practices include removal of crop residues, use of resistant cultivars, and soil cover. Drip irrigation and climate monitoring are also key to reducing infection. The combination of these strategies forms an integrated management to control the disease (Menten & Oliveira, 2020).

## 4.2 SUBGROUP IA: LATE BLIGHT (*PHYTOPHTHORA INFESTANS)*

Late blight is caused by the oomycete *Phytophthora infestans* and is a highly destructive disease for tomatoes. Initially, dark spots appear on the leaves, surrounded by yellowish areas, which evolve to necrosis and intense defoliation. On stems, necrotic lesions appear that can cause fissures, and on fruits, depressed and moist lesions that progress quickly to total rot. In humid conditions, white mold forms on the lesions, signaling the sporulation of the pathogen (Kimati et al., 2005).

The control of tomato late blight requires an integrated approach for effective management, with fungicides (chlorothalonil, mancozeb, copper oxychloride, metalaxyl, fluopicolide and propamocarb), biological control (*Trichoderma spp.* and *Pseudomonas fluorescens),* crop rotation and resistant varieties. Measures such as removal of infected leaves, drip irrigation, and climate monitoring help reduce damage and ensure productivity (Lopes & Ávila, 2005).

## 4.3 SUBGROUP IB: BACTERIAL CANKER (*CLAVIBACTER MICHIGANENSIS* SUBSP. *MICHIGANENSIS)*

Bacterial canker, caused by *Clavibacter michiganensis*, severely affects tomato plants, generating leaf spots, wilting, lesions on stems and fruits, which can become necrotic or sticky in humid conditions. These symptoms compromise nutrient transport and fruit quality, requiring strict control measures (Kimati et al., 2005). Bacterial canker spreads through contaminated seeds, soil, and splashes of water.

The use of copper-based bactericides in chemical control has low efficacy when the infection is advanced, reinforcing the need for preventive management. Additional measures include biological control with *Bacillus subtilis* and *Pseudomonas fluorescens*, and cultural practices such as the use of certified seeds free of contamination and crop rotation with non-host species, such as grasses. Removal of infected plants, drip irrigation, and disinfection of farming tools are essential. Integrated management, combining prevention and cultural strategies, is essential to control the disease and preserve productivity (Lopes & Ávila, 2005).

## 4.4 SUBGROUP IB: BACTERIAL WILT (*RALSTONIA SOLANACEARUM*)

Caused by the bacterium *Ralstonia solanacearum*, bacterial wilt causes progressive wilting in the tomato plant, darkening of tissues and vascular collapse. Its management requires an integrated approach, as the bacterium persists in soil, water and crop residues. Chemical control is limited, but the use of copper and biocontrol with *Bacillus subtilis* and *Pseudomonas fluorescens* may be effective. Cultural practices, such as crop rotation, resistant varieties, and removal of diseased plants, are essential. In addition, drip irrigation, soil solarization, and molecular monitoring help contain the disease (Kimati et al., 2005).

## 4.5 IC SUBGROUP: GOLDEN MOSAIC (GEMINIVIRUS)

Golden mosaic, caused by Geminivirus and transmitted by whitefly, affects tomatoes with chlorosis in a mosaic pattern on the leaves, which become deformed and wrinkled. The plant shrinks, loses vigor and the fruits become smaller and deformed. Intense whitefly infestation aggravates symptoms, reducing production and requiring effective vector control.

Golden mosaic control involves whitefly management with insecticides, biological control with predators and microorganisms, and cultural practices such as planting resistant varieties, crop rotation, and eliminating host plants. Preventive measures include the use of certified seedlings and protective screens. Mechanical and physical control, such as removing infected plants and covering the soil with silver plastic, are also important.

Continuous monitoring and integrated practices are essential to reduce the impacts of the disease (Kimati et al., 2005).

## 4.6 IC SUBGROUP: HEAD TURNER (TOSPOVIRUS)

The head turnaround is caused by the virus of the genus Tospovirus and transmitted by thrips, affecting the development of plants, resulting in symptoms such as leaf necrosis, deformations, and a decrease in the size of the plants, with an atrophied appearance. Young leaves may show chlorosis, and necrotic lesions may appear on stems and petioles. The flowers deform and the fruits have circular spots with central necrosis. The disease can cause early fall of flowers and fruits, and, in severe cases, lead to the death of the plant, requiring integrated management for control (Kimati et al., 2005).

The control of the golden mosaic includes the management of whitefly with insecticides, biological control with predators and parasitoids, and cultural practices such as crop rotation and the use of resistant varieties. The elimination of host plants and the use of certified seedlings are also important. Mechanical practices include the removal of infected plants, while physical control may involve barriers and the use of silver plastic to disorient the whitefly. Continuous monitoring and integration of these strategies are essential to minimize harm (Menten & Oliveira, 2020).

## 4.7 ID SUBGROUP: ROOT-KNOT NEMATODE (*MELOIDOGYNE* SPP.)

The root-knot nematode (*Meloidogyne*) causes symptoms such as chlorosis in the leaves, deformations, atrophied plants and smaller and deformed fruits. However, the main symptom is the formation of galls on the roots, which are reduced in volume, thin and with necrotic areas. Thus, the infestation compromises the absorption of water and nutrients, leading to wilting and, in severe cases, the death of plants (Kimati et al., 2005).

The control of root-knot nematode foresees the use of nematicides such as fluopiram and abamectin, but with caution, due to environmental impacts and resistance. Biological alternatives include nematophagous fungi, and bacteria such as *Bacillus firmus*. Cultural practices such as crop rotation and the use of antagonist plants reduce *Meloidogyne* populations. The adoption of resistant tomato varieties and nematode-free seedlings are additional preventive measures, combined with soil solarization and adequate preparation. Constant monitoring of the crop is essential to detect and manage the infestation effectively (Lopes & Ávila, 2005).

## 4.8 ID SUBGROUP: NEMATODE-ROOT LESION (*PRATYLENCHUS* SPP.)

The root-lesion nematode, of the genus *Pratylenchus*, is a pathogen that mainly affects the roots of plants, with a reduction in volume and length, the thinned and poorly branched roots acquire a rough appearance with darkened necrotic areas, characterizing the characteristic symptom of the disease. The roots, then unable to adequately absorb water and nutrients, compromise the development and production of the plant (Kimati et al., 2005). In the aerial parts, yellowing of the leaves (chlorosis) is observed, with deformations that make the leaves smaller, wrinkled and wrinkled. The plant has a reduction in general size, acquiring an atrophied appearance, while the fruits become smaller, deformed and irregularly colored. In severe infestations, the total collapse of the plant and its death can occur (Kimati et al., 2005).

Control includes nematicides, crop rotation, resistant varieties, and biological control. Soil preparation through plowing and harrowing can expose nematodes to the surface, increasing their vulnerability to adverse environmental conditions (Menten & Oliveira, 2020). The sustainable productivity of the tomato crop also includes preventive measures, such as soil solarization and the use of certified seedlings, in addition to regular monitoring.

## 5 GROUP II: TOMATO PESTS (*SOLANUM LYCOPERSICUM* L.)

Tomato production faces serious threats caused by a variety of pests that compromise plant health, fruit quality and productivity. These pests affect different parts of the tomato plant, from leaves and stems to roots and fruits, resulting in damage ranging from mild lesions to severe losses, depending on the intensity and type of infestation (Gallo et al., 2002). Chart 3 lists the pests that affect the tomato crop, with emphasis on the group of insects, discussed in the present work.

**Table 3.** Tomato Pests (*Solanum lycopersicum* L.).

| Pests | |
|---|---|
| **Mites** | White Spider Mite (*Polyphagotarsonemus latus*) |
| | Two-spotted spider mite (*Tetranychus urticae*) |
| | Micromite/Tanning Mite (*Aculops lycopersici*) |
| **Insects** | Elephant Trunk Buggy (*Phyrdenus divergens* and *Faustinus* sp.) |
| | Great Fruit Borer (*Helicoverpa zea*) |
| | Lesser Fruit Borer (*Neoleucinodes elegantalis*) |
| | Black Cricket (*Gryllus assimilis*) |
| | Screwworm (*Agrotis ipsilon*) |
| | **Whitefly (*Bemisia tabaci*)*** |
| | Leaf Miner (*Liriomyza* sp.) |
| | Paquinha (*Neocurtilla hexadactyla* and *Scapteriscus* spp.) |
| | Patriota/Brasileirinho (*Diabrotica speciosa*) |
| | Tomato Bug (*Phthia picta*) |
| | Lacy Bed Bug (*Corythaica cyathicollis*) |
| | Aphid (*Myzus persicae*) |
| | Confused Tiger (*Machanitis lysimnia*) |

| | |
|---|---|
| | **Tomato Moth (*Tuta absoluta* and *Phtorimaea operculella*)*** |
| | Thrips (*Frankliniella* spp.) |
| | Potato Cow (*Epicauta atomaria*) |
| **Other** | Snails |
| | Slugs |
| | Birds |
| **Caption:** *Pests that most affect the tomato crop. | |

**Source:** Prepared by the authors from: Embrapa, 1993; and Gallo et al., 2002.

## 5.1 WHITEFLY (*BEMISIA TABACI)*

Qualified as one of the main pests of tomato crops, given its severity and impact on productivity, the whitefly (*Bemisia tabaci*) causes direct damage by sucking plant sap, and indirect, as a vector of several serious viral diseases. The insect, small and white, concentrates on the lower leaves and shoots, resulting in chlorosis, leaf deformation, wilting and smaller fruits; and it also secretes molasses, favoring the growth of black fungi on the leaves.

Whitefly management combines chemical, biological, cultural and preventive control. Insecticides should be rotated to prevent resistance. Natural enemies, such as parasitoid wasps (*Encarsia formosa* and *Eretmocerus spp.*), ladybugs (*Coccinellidae*), lacewings (*Chrysoperla spp.*) and entomopathogenic fungi (*Beauveria bassiana* and *Metarhizium anisopliae*), have demonstrated efficacy in reducing insect populations. These agents can be released in the field or conserved through practices that stimulate their natural presence (Leite & Fialho, 2017). Practices such as crop rotation, host elimination, and the use of aphid nets reduce infestations. Constant monitoring and the application of integrated strategies ensure better control and productivity (Leite & Fialho, 2017).

## 5.2 TOMATO MOTH (*TUTA ABSOLUTA*)

*Tuta absoluta and Phtorimaea operculella, both popularly known as tomato moth, represent one of the most destructive pests of tomatoes and other nightshades. Attacking all parts of the plant, especially the fruits, leaves, and stems, cause chlorosis, deformation, and reduced plant growth. The larvae form galleries on leaves, stems, and fruits, leading to necrosis and rotting. Small moths (6 to 9 mm), with light to dark brown wings, indicate infestation* (Gallo et al., 2002).

The ability of the tomato moth to develop resistance to insecticides makes its control extremely challenging. However, chemical control is often used and involves insecticides based on diamides, pyrethroids and neonicotinoids, applied alternately and at the appropriate time, according to the stage of development of the pest.

Another option in the management of *Tuta absoluta* is biological control. Natural enemies such as parasitoid wasps (*Trichogramma spp.*, *Gonatocerus spp.*), predators such as lacewings (*Chrysoperla spp.*) and entomopathogenic fungi such as *Beauveria bassiana,* can be introduced to reduce the larval population in an effective and sustainable manner (Leite & Fialho, 2017). It should be noted that cultural control, with crop rotation and elimination of harvest residues, in addition to constant monitoring are basic measures. There is also the possibility of adopting complementary physical measures, such as screens and traps (Leite & Fialho, 2017).

## 6 GROUP III: PHYSIOLOGICAL DISORDERS OF TOMATO (*SOLANUM LYCOPERSICUM* L.)

The tomato crop is sensitive to a variety of physiological disorders that can compromise plant health, fruit quality, and crop productivity. As noted in Table 4, these disorders are not caused by infectious agents, but by nutritional imbalances, unfavorable environmental conditions or inappropriate cultural practices, requiring careful management to avoid significant losses (Minami & Haag, 1980). Among them, nutritional deficiencies are one of the main causes of disorders in tomato plants.

**Table 4.** Physiological Disorders of Tomato (*Solanum lycopersicum* L.).

| **Physiological Disorders** | |
|---|---|
| **Nutritional Deficiencies (a)** | Boron (B) |
| | **Calcium (Ca)*** |
| | Copper (Cu) |
| | Sulphur (S) |
| | Iron (Fe) |
| | Phosphorus (P) |
| | Magnesium (Mg) |
| | Manganese (Mn) |
| | Molybdenum (Mo) |
| | **Nitrogen (N)*** |
| | Potassium (K) |
| | Zinc (Zn) |
| **Phytotoxicity (b)** | **Boron (B)*** |
| | Calcium (Ca) |
| | **Copper (Cu)*** |
| | Sulphur (S) |
| | Iron (Fe) |
| | Phosphorus (P) |
| | Magnesium (Mg) |
| | Manganese (Mn) |
| | Molybdenum (Mo) |
| | Nitrogen (N) |
| | Potassium (K) |
| | Zinc (Zn) |
| **Other (c)** | Deriva a Agroquímicos |
| | Excess Water |

| | |
|---|---|
| | Excess Light |
| | **Lack of Water*** |
| | Lack of Light |
| | **High Temperatures*** |
| | Low Temperatures |
| **Caption:** *Physiological disorders that most affect tomato crops. | |

**Source:** Prepared by the author from: Embrapa, 1993; and Minami & Haag, 1980.

## 6.1 SUBGROUP IIIA: CALCIUM DEFICIENCY (CA)

Often associated with the problem known as "apical rot" or "blossom-end rot", the deficiency of the nutrient is characterized by the appearance of necrotic areas in the fruits, especially at the lower end, as calcium is essential for the integrity of the cell wall and the functioning of cell membranes. However, calcium deficiency also causes deformation in the leaves, reduction of the root system and premature fall of flowers (Rezende, 2007), directly affecting the quality and productivity of the plant.

Regularly monitoring plant health, through soil and leaf analyses, is essential to detect any calcium deficiency early. The problem can occur even when the soil contains adequate amounts of calcium, due to the poor distribution of the nutrient in the plant. In dry soils, calcium uptake can be hampered, so irrigation systems such as drip irrigation are highly recommended as they ensure that calcium is absorbed efficiently by plants. When deficiency is identified early, foliar application of calcium can be an effective solution. In addition, the use of growth regulators, such as gibberellic acid, can help improve the absorption and distribution of calcium in plants (Lopes & Ávila, 2005).

Soil management practices are also important to ensure that calcium is available. The incorporation of organic matter into the soil improves its structure, promoting greater aeration and water retention capacity, which facilitates the absorption of the nutrient by the roots. The use of soil cover with organic *mulches* can help keep soil moisture and temperature stable, creating a favorable environment for nutrient absorption (Embrapa, 1993).

## 6.2 SUBGROUP IIIA: NITROGEN DEFICIENCY (N)

Nitrogen deficiency in tomato is a common nutritional problem that directly affects fruit growth, production, and quality. Nitrogen is one of the most important nutrients for plants, as it is involved in the formation of proteins, chlorophyll, and other compounds that are essential for vegetative growth and photosynthesis. In this way, the lack of the nutrient causes marked chlorosis in older leaves, stunted growth and smaller fruits.

Management includes balanced fertilization with urea or ammonium nitrate; adequate irrigation to avoid leaching and favor the maintenance of moisture for nutrient absorption by the roots; and sustainable strategies, such as green manure and incorporation of leguminous plants that fix nitrogen in the soil. Finally, continuous monitoring allows for early correction and ensures efficient production (Minami & Haag, 1980).

### 6.3 SUBGROUP IIIB: PHYTOTOXICITY BY BORON (B)

Boron at high levels in the soil or plants can cause toxicity symptoms, such as chlorosis on the margins of older leaves, which can develop into necrosis. This occurs due to boron's interference in the regulation of the cell wall, impairing the transport of water and essential nutrients for plant development. Thus, boron (B) phytotoxicity causes damage such as dark spots, deformations on leaves and fruits, wilting, irregular coloration, and reduction in plant size. The fruits may have cracks and lesions, and there is a decrease in flower production due to floral abortion.

Proper management of boron fertilization is essential to avoid these problems and ensure healthy plant growth. (Minami & Haag, 1980). To control boron phytotoxicity, it is essential to analyze the soil, adjust fertilization, and monitor the pH, keeping it between 6 and 6.5. Boron fertilizers should be applied with caution, avoiding foliars. The use of slow-release fertilizers and balanced irrigation help to avoid toxicity (Embrapa, 1993).

### 6.4 SUBGROUP IIIB: PHYTOTOXICITY BY COPPER (CU)

Excess copper (Cu) causes dark spots, deformed leaves, stunted growth, weak roots, plant wilt, and fruits with depressed brown or black lesions. In young plants, copper phytotoxicity can even cause systemic toxicity, affecting their growth and development. In addition, high levels of copper in the soil interfere with the absorption of other micronutrients, such as iron and zinc, further compromising the health of the plant.

Soil analysis and pH control are essential to avoid copper toxicity (Embrapa, 2022). Soils with a low pH tend to release more copper, which increases the risk of toxicity, so it's critical to monitor the pH and adjust as needed. The use of fertilizers should be cautious, preferring slow-release fertilizers. Balanced irrigation helps to reduce the accumulation of the metal in the soil (Lopes & Ávila, 2005).

### 6.5 SUBGROUP IIIC: LACK OF WATER

As it is a plant with high water consumption, the lack of water is one of the main limiting factors for the healthy development of the tomato crop, with the formation of good quality fruits and good productivity (Dodds et al., 1997). The lack of water results in a series of symptoms that reflect water stress and the inability of the plant to perform its vital functions, leading, in periods of extreme drought, to the rapid death of plants. Characteristic symptoms include wilting, chlorosis, defoliation, flower drop, as well as cracking, malformation, and fruit drop.

The main management strategy to avoid this damage is the adoption of appropriate irrigation practices, such as controlled irrigation (drip), soil cover (mulches), moisture monitoring, and choice of tolerant cultivars (Lopes & Ávila, 2005). The choice of tomato varieties that are more resistant to water stress can be an alternative for regions with water scarcity or in more limited irrigation systems.

### 6.8 SUBGROUP IIIC: HIGH TEMPERATURES

The tomato plant is a plant that adapts best to moderate temperatures, with an optimal ideal range between 18°C and 25°C (FAO, 2025), being sensitive to temperature variations, especially high (Böhm et al., 2024). Heat stress by high temperatures results in a reduction in the size and stunted appearance of the plant, generalized wilting and apical necrosis in the fruits, an increase in floral abortion and irregular fruit maturation, with cracks and burning of the leaves and fruits. The phenomenon of the "green shoulder", characterized by necrosis at the ends of the fruits, is also common.

Management includes choosing varieties that are more tolerant of high temperatures, shading, adequate irrigation, *mulches*, and ventilation. Growth and pruning regulators also help in adapting to heat (Lopes & Ávila, 2005).

## 7 FINAL CONSIDERATIONS

The bibliographic survey conducted in this study allowed the identification and systematization of the main diseases, pests and physiological disorders that affect the tomato plant, as well as their symptoms and signs. In turn, the understanding of the phytosanitary challenges expressed in an accurate diagnosis is an essential step in the definition of control strategies and the adoption of integrated management practices. The efficient application of corrective measures is essential to avoid production losses and environmental impacts, highlighting the importance of technical knowledge in the search for sustainable and high-quality production.

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