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Yellow Shoulder: A Ripening Disorder of Greenhouse Tomato Fruit

A common fruit ripening disorder in greenhouse tomato production is yellow shoulder also called green shoulder. In this disorder the top, or "shoulder", of the fruit adjacent to the truss stem fails to properly ripen resulting in yellow or green regions (Fig. 1). Leaving the fruit on the vine to ripen longer does not alleviate these symptoms. Yellow shoulder/green shoulder is a physiological disorder that is not well understood. The disorder is prevalent in greenhouse / high tunnel tomato production and can also be found under field conditions. This article will discuss causes of yellow shoulder and cultural management steps that can be taken to reduce its prevalence.

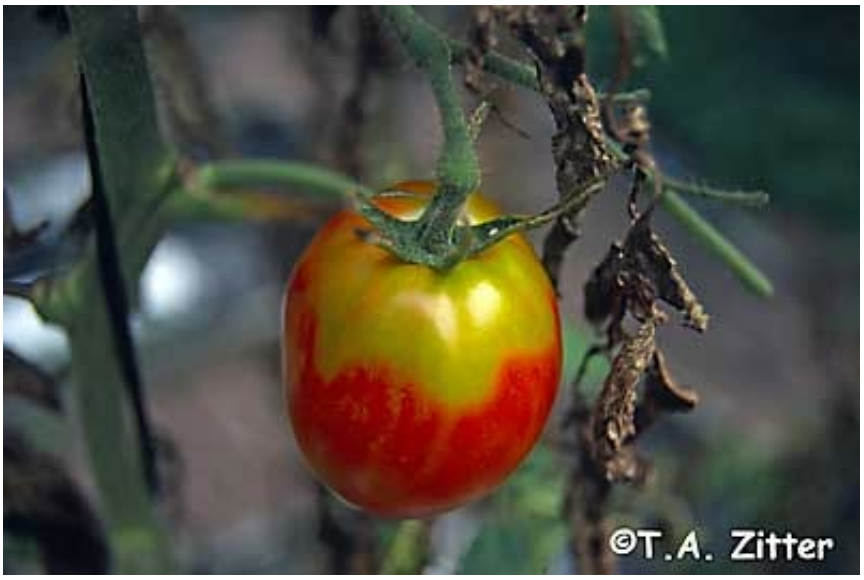

Figure 1. Yellow/green regions around the upper collar of tomato fruit is a fruit ripening disorder. Photo courtesy of T.A. Zitter, Cornell University, Ithaca, NY.

Symptoms of yellow shoulder

Yellow shoulder appears as yellow, green, or orange regions that fail to ripen and occur on the upper part of the tomato fruit surrounding the stem. The regions may appear as a ring around the entire upper part of the fruit or they may be more isolated as separate region(s) (Fig. 2). Upon slicing through the fruit, the internal yellow/green/orange regions are visible (Fig. 3). The cells in the affected region may be smaller than normal and a more random arrangement. Green chlorophyll in the affected region fails to develop a red pigment. This process appears to happen early in fruit development. The rest of the fruit will ripen to red, but the affected green/yellow/orange regions will not further ripen. Therefore, simply leaving the fruit on the vine longer (hoping the affected regions will ripen and turn red) will not solve this disorder and will only result in over mature fruit.

Related blotchy ripening disorders appear to have similar causes to yellow shoulder and overall all of these are referred to as physiological fruit ripening disorder. The other examples include *internal whitening* in which inner and outer fruit walls become white and corky, and *gray wall* in which the outer fruit wall turns brown/gray and collapses. Collectively, these ripening disorders may render fruit unmarketable or may reduce the fruit quality grade.

Yellow shoulder and the related ripening disorders should not be confused with blossom end rot. Blossom end rot occurs on the bottom, or blossom, end of the fruit and is the opposite end of the fruit than the shoulder (or top) of the fruit. Blossom end rot appears as water soaked regions on the bottom of the fruit that can expand and progress to become a large necrotic (brown) region. Blossom end rot is associated with poor calcium supply to fruit (primarily due to cultural factors such as poor irrigation management or conditions that limit plant transpiration).

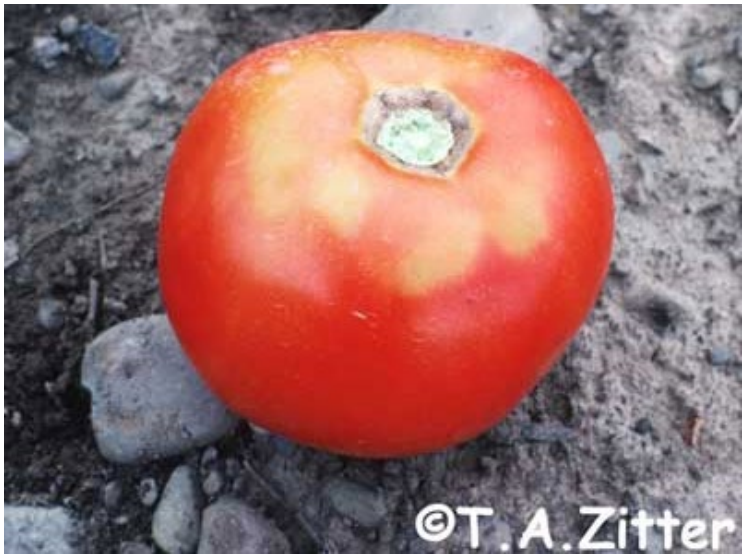

Fig. 2. Yellow/green regions around the shoulder of the tomato fruit. Photo courtesy of T.A. Zitter, Cornell University, Ithaca, NY.

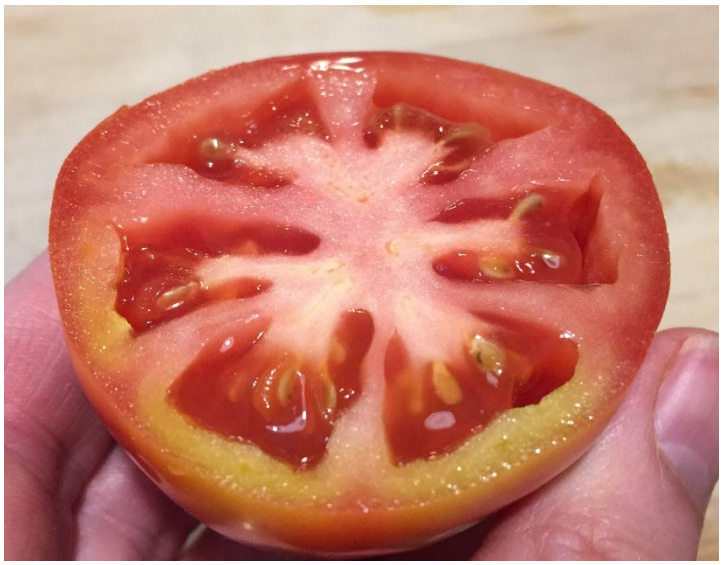

Fig. 3. Cells internal to the fruit surface are yellow/green. Photo courtesy of Neil Mattson, Cornell University, Ithaca, NY.

Element	Tomato at Stage 1	Tomato at Stage 2	Tomato at Stage 3
NO3-N	90	120	190
NH4-N	0	0	0
P	47	47	47
K	144	350	350
Ca	144	160	200
Mg	60	60	60
S	116	116	116
Cl	89	89	89
Fe (EDTA)	2	2	2
Mn	0.55	0.55	0.55
Zn	0.33	0.33	0.33
Cu	0.05	0.05	0.05
B	0.34	0.34	0.34
Mo	0.05	0.05	0.05

Table 1. Three stage nutrient solution for greenhouse tomatoes in soilless culture from the University of Arizona CEAC (Controlled Environment Agriculture Center). Details on preparing the fertilizer are available from Kroggel and Kubota (2018) at https://ohioline.osu.edu/factsheet/hyg-1437 Stage 1 is from seedling until the 2nd truss (flower cluster) is at anthesis (shedding pollen), State 2 is from the 2nd truss until 5th truss is at anthesis, and stage 3 is after the 5th truss is at anthesis through fruiting.

	Tomato sufficiency ranges (transplants)		Tomato sufficiency ranges (plants for fruiting)	
	Min	Max	Min	Max
N %	2.5	5	4.0	5.5
P %	0.3	1.0	0.3	1.0
K %	4.0	7.0	4.0	7.0
Ca %	0.9	3.0	1.2	5.0
Mg %	0.4	1.5	0.8	3.0
S %	---	---	---	---
Fe ppm	50	100	100	250
Mn ppm	40	100	40	300
B ppm	30	75	30	120
Zn ppm	30	100	30	150
Cu ppm	5	15	5	30
Mo ppm	0.15	1	0.15	5
Na ppm	< 200		< 500	

Table 2. Sufficiency ranges for elemental tissue analysis of tomato at the transplant stage and for mature plants for fruiting. Adapted from: Dr. Cari Peters, J. R Peters Laboratory. 6656 Grant Way, Allentown, PA 18106; and adapted from: Jones, J.B. Jr., W. Wolf and H.A. Mills. 1991 Plant analysis handbook. Micro-Macro Publications, Inc. 185 Paradise Blvd, Suite 108, Athens, GA 30607.

Causes of yellow shoulder

Yellow shoulder appears to be associated with conditions that cause poor potassium (K) supply to the fruit, however the full cause of yellow shoulder and associated ripening disorders has not been fully worked out. Yellow shoulder appears to be exacerbated by high temperatures (>90 °F), low temperatures (<60 °F) or overall variable temperatures. Some cultivars are more sensitive to yellow shoulder than others. Tomato mosaic virus can also cause uneven fruit ripening and growers should rule this out as a cause in their crop by working with a pathology lab or local extension personnel which may have access to a virus test kit (i.e. ELISA immunoassay test strips specific for TMV).

Several factors can limit potassium availability to the plant including: low supply in the fertilizer which may be exacerbated by high plant demands for K in the mid to late fruiting stage, a high Ca:Mg ratio (>4:1), excessive Ca or Mg in the root-zone which can antagonize or reduce K uptake, excess supply of nitrogen, high humidity and low light.

Cultural control and prevention

It is not possible to correct yellow shoulder (and associated ripening disorders) once the symptoms have developed and progressed. Therefore prevention of the disorder through cultural control and careful attention to the plant nutrient management are key. Cultivar plays a strong role in prevalence of yellow/green shoulder. Work with your seed supplier to select cultivars that are not sensitive to this disorder.

Next, one should ensure proper potassium supply to the plant and conduct regular leaf tissue analysis to verify plant K status well-before and during the fruiting stage. Tomato plants have a higher need for potassium in the fruiting stage and it is important to ensure proper K supply prior to early fruit set. Nutrient solution recipes formulated for tomatoes take this into account and increase the potassium levels as the plant goes into the fruiting stage (Table 1). Note that the K target is 144 ppm when the plant is at stage 1 (seedling stage until 2nd truss is at anthesis) and then increases to 350 ppm K to support the additional need for K as the plant goes into the fruiting stage.

Regularly sampling leaf tissue for laboratory analysis (especially by the time of first flower and repeatedly as the crop is in the fruiting stage) is an important step to ensure the plant has sufficient potassium. For tomatoes, potassium levels of 4-7% of the most recently mature leaves are considered sufficient (Table 2) and it is important to keep tissue K levels above the minimum threshold to reduce prevalence of yellow/green shoulder. Note that recommendations from different commercial testing laboratories may vary as they may have different sampling methodologies and analytical equipment. Therefore, it is important to check with your lab as to their recommended sampling procedures, timeline, and recommended tissue levels. The crop can be visually inspected for leaf symptoms of K deficiency which appears as marginal chlorosis (leaf edge yellowing) of lower/mature leaves which can progress to scattered chlorotic and necrotic spots across lower leaves. Excessive supply of magnesium (Mg) in proportion to calcium (Ca) has been reported to be play a role in yellow shoulder prevalence.

The recommendation is to ensure the Ca:Mg ratio is not lower than 3:1 in the root-zone. Overall excessive levels of other cations such as calcium, magnesium, and sodium (Na) can also limit potassium availability to the plant.

Other cultural factors to reduce yellow shoulder include keeping air temperatures below 90 °F which in warm climates may require increased ventilation, evaporative cooling pads and/or greenhouse shading. Low temperatures (<60 °F) or widely fluctuating temperatures are also associated with yellow shoulder. The disorder also seems to be exacerbated by high humidity or low light. Maintain good air flow through the plant canopy during warm or humid conditions. Overall careful selection of cultivars, maintaining proper nutrition (especially K), and avoiding extreme environmental conditions will help avoid this common tomato fruit ripening disorder.

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