

## SENSITIVITY OF RADISH TO VOLATILE ORGANIC COMPOUNDS: TOLUENE, ETHANOL, AND ACETONE

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### ABSTRACT

NASA has intensively studied the use of plants to regenerate the atmosphere, purify water and produce food within a bioregenerative life support system (BLSS) for a number of years (Wheeler et al., 2004). A unique aspect of growing plants in the closed atmosphere of a space-based system is chronic exposure to low levels of atmospheric contaminants produced by the crew, hardware, and operations (Stutte, 1999). Routine monitoring of NASA spacecraft (SkyLab, Space Shuttle, and International Space Station) has detected over 280 VOCs (Perry, 1998) and nearly 100 biogenic volatile organic compounds (VOCs) were identified from crops being considered for BLSS applications (Batten et al, 1995, 1995). NASA has established Spacecraft Maximum Allowable Concentrations (SMAC) to use as a guideline for crew exposure to VOCs. The SMAC levels were established to protect crew health (Perry, 1998) and the effects on crop growth and development are generally unknown (Stutte, 1999).

A series of experiments were conducted at Kennedy Space Center, FL to determine whether crop growth and morphology was affected at the SMAC levels of three common spacecraft contaminants: ethanol, toluene, and acetone. Specialized growth chambers were used to expose three cultivars of *Raphanus sativa* L., cv.'s Sora, Cherry Bomb Hybrid II, and Cherry Belle, to different concentrations of the VOC (Table 1). The plant growth conditions were maintained at 23°C, 75% RH, 18/6 photoperiod under T-8 cool white fluorescent lamps at 300  $\mu\text{mol m}^{-2} \text{s}^{-1}$ , and 1500  $\mu\text{mol m}^{-1} \text{CO}_2$  for 21 days. The control and monitoring of the VOCs in each chamber was achieved with an SCR 8610-C GC using LabView<sup>TM</sup> and PeakSimple<sup>TM</sup> software (Stutte et al., 2004).

The VOC treatments were determined as a fraction of the 180 day SMAC level, so the concentrations tested differed for each compound. A summary of treatments and results is shown in Table 1. Chronic exposure of radish to toluene vapors up to the SMAC level (15 ppm) had no effect on growth rate, crop yield, harvest index, or chlorophyll fluorescence. Dry mass was reduced 30% and harvest index lowered 15% at 10X the toluene SMAC (150 ppm). Severe leaf chlorosis and epinasty were also observed. Severe stunting and/or death of plants were observed at 100X the toluene SMAC (1500 ppm).

Chronic exposure of radishes to acetone vapors up to the SMAC level (22 ppm) had no detectible effect on growth rate, crop yield, harvest index or chlorophyll fluorescence. The response to acetone concentrations greater than SMAC was not tested.

In contrast, a 30% reduction in total biomass, 12% reduction in leaf area and 6% reduction in harvest index was observed at only 0.1 X SMAC (100 ppm) for ethanol. Extreme stunting, chlorosis and plant death were observed at 0.5 the SMAC (500 ppm) and exposure to the SMAC concentration (1000 ppm) was lethal. The response to ethanol contamination was similar for all cultivars with Cherry Bomb Hybrid II being slightly less sensitive than either Sora or Cherry Belle.

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**Table 1: Effects of 21-day exposure to atmospheric contamination with toluene, ethanol and acetone at different percentages of NASA’s Spacecraft Maximum Allowable Concentrations (SMAC) on growth and develop of radish.**

Treatment	Concentration	Results
	<b>Toluene</b>	
Control	0 ppm	No phytotoxicity
0.1X SMAC	1.5 ppm	No phytotoxicity
1.0X SMAC	15 ppm	No phytotoxicity
10X SMAC	150 ppm	Reduce dry mass and HI.
100X SMAC	1500 ppm	Stunting, necrosis, plant death
	<b>Ethanol</b>	
Control	0 ppm	No phytotoxicity
0.1X SMAC	100 ppm	Reduce biomass, leaf area and HI
0.5X SMAC	500 ppm	Reduce biomass, chlorosis, death
1.0X SMAC	1000 ppm	Very low germination, plant death
	<b>Acetone</b>	
Control	0 ppm	No phytotoxicity
0.1X SMAC	2.2 ppm	No phytotoxicity
1.0X SMAC	22 ppm	No phytotoxicity

These results indicate that existing NASA SMAC recommendations for spacecraft VOC concentrations to not ensure plant systems will able to thrive during long duration missions. The biogenic VOC threshold for plant systems needs to be established for space habits utilizing bioregenerative life support.

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