



# A scheme for Greenshoulder (GS) and Internal Greening (IG) development and control in processing carrots

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## Introduction

Greenshoulder (GS) (Fig 1) and Internal Greening (IG) (Fig 2) are physiological disorders in carrots caused by chlorophyll accumulation. GS and IG not only affect root appearance but also make it unfit for consumption due to its bitter taste. Nearly, 452 tonnes of carrots are culled out in the processing industry every year due to GS and IG. Photo-electronic sorters that are currently used in the freezing tunnels do not eliminate IG products completely. Carrot hypocotyl makes up about one inch of the upper part of the storage organ (Esau, 1940). The hypocotyl tissues synthesize chlorophyll when exposed to light (Anon, 2002). The light interception by the hypocotyls depends on the amount of leaf canopy quantified as Leaf Area Index (LAI) and is highly correlated to canopy chlorophyll content and net plant photosynthesis (Walker et al. 1988). A GS and IG model was developed based on the studies conducted to examine the potential trigger and modulators of GS and IG.

## Objectives

- Identify the genotypic variations in GS and IG.
- Investigate the effect of plant population densities on GS and IG.
- Determine the linkage between LAI and GS and IG.
- Determine the effect of light intensity on GS and IG.
- Evaluate the role of Linuron®, Fusilade® and Gesagard® in hypocotyl greening.
- Determine the effect of hilling on GS and IG.
- Determine the effect of hypocotyl etiolation on GS/or IG.

## Materials and Methods

- Thirty-four genotypes of processing carrots (slicers) were evaluated for GS and IG.
- Five different rates of Slicer (Caro Choice) and dicer (Red Core Chantenay) varieties were evaluated for GS and IG.
- Six different light intensities ( $50-320 \mu\text{mol m}^{-2} \text{s}^{-1}$ ) were tested for chlorophyll synthesis in hypocotyls of variety, Krakow.
- Herbicides Linuron®, Fusilade® and Gesagard® were tested for chlorophyll induction in hypocotyls of variety, Krakow.
- Hilling at early vegetative, initial bulking and final stages and several combinations were evaluated for reducing GS and IG.
- Etiolation effects on hypocotyls was also evaluated using Promix-Asgrow
- Chlorophyll indices were measured using chlorophyll meter CM1000 TM (Spectrum technologies, Inc., Plainfield, IL) for determining GS and IG.

Fig 1. Greenshoulder



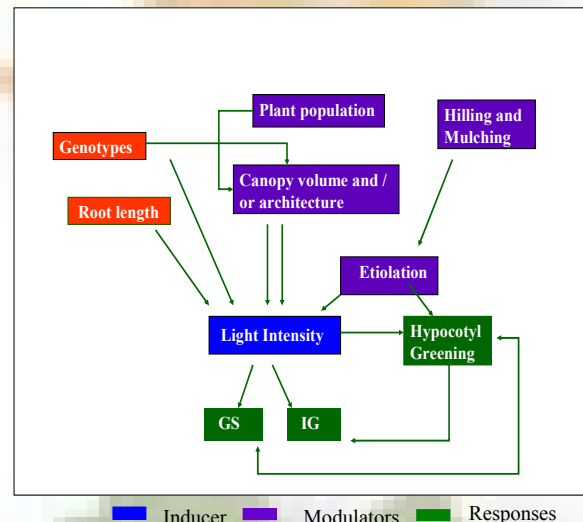
Fig 2. Internal Greening



Fig 3. Chlorophyll meter for measuring chlorophyll index



Fig 6. Potential inducer and modulators of GS and IG



- Leaf area index (LAI) was determined using the LAI-2000 Plant canopy analyzer (LI-COR Inc., Lincoln, NE, USA).
- The percentage length of the internal greening was measured using a Computer Image Analysis system (CIAS) (CI-400) CID, Inc. USA

Fig 4. Computer Image Analysis System in use



## Conclusion

- Light, as low as  $50 \mu\text{mol m}^{-2} \text{s}^{-1}$  triggered greening in hypocotyls *in vivo* (Fig 5).
- Increasing light intensity increased chlorophyll a, b and total chlorophyll concentrations.
- Genotypic response differed significantly between seasons.
- Genotypes, through their canopy volume, as measured as LAI, exerted a strong influence on GS and IG.
- An optimal LAI for control of GS was at or above 3.7.
- Canopy volume and root length exhibited significant relationships with GS and IG and modulated GS and IG.
- Plant population, through its effects on LAI, modulated GS and IG.
- Hilling three times reduced GS and IG significantly.
- IG appeared to be initiated at the hypocotyl stage of carrot growth.
- Herbicides, Linuron®, Fusilade® and Gesagard® did not trigger greening.
- These suggest that light triggers greening, possibly at the hypocotyls stage, and genotypes and plant population through their effects on LAI modulate GS and IG (Fig 6).

Fig 5. Early greening in carrot hypocotyls



## References

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