

## SOIL FACTORS ASSOCIATED WITH THE DISEASE STATUS, PRODUCTIVITY AND SUSTAINABILITY OF CARROT PRODUCTION IN AUSTRALIA

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### INTRODUCTION

Anecdotal evidence suggests that declining soil health has become a major issue for Australia's vegetable industries. However, there is a lack of understanding of which soil factors are involved and how they impact on soilborne diseases and crop productivity. Therefore, a survey study was conducted on 96 sites in Queensland and southern Australia (New South Wales, Victoria and Tasmania) to compile data on soil microbiological, chemical and physical properties and collect field information that may relate to soil health, in order to gain a better understanding of their impact on crop health and yield (1). Capsicum and carrot were used as benchmark crops in the study. This paper presents our study on the effects of soil factors on carrot disease and quality in Tasmanian Ferrosols.

### MATERIALS AND METHODS

Soil biological, chemical and physical properties and field information from 35 sites were examined. All the carrot sites were in north-west Tasmania and the soils were all classified as Ferrosols (2). Biological tests included estimates of bacterial and fungal populations (colony forming units on agar), microbial activity (hydrolysis of fluorescein diacetate), composition of the microbial community (PL-FAME) and populations of free-living and plant parasitic nematodes. Chemical analysis included microbial biomass carbon, permanganate oxidisable carbon fractions, total organic carbon, total nitrogen, C:N ratio, and soil pH and EC at 0-15cm and 45-60cm. For physical properties, soil penetration resistance, soil structure score and the percentage of aggregate stability were measured. Field information on site history, soil preparation, and crop management was also collated. Carrot yield and quality were determined on carrots harvested from 3 x 1 m<sup>2</sup> subplots within the test area.

A total of 88 sets of data values were compiled for analysis. A matrix of all possible pair-wise simple correlation coefficients was used to compare data. Correlation coefficient values in the matrix which exceeded the necessary value for significance at  $P=0.05$  were considered of interest and worthy of further investigation with multiple regression analysis. The final regression model was accepted at the step for which the next variable to be selected was not significant at  $P=0.05$ .

### RESULTS

#### Carrot quality

The multiple linear regression model that best describes carrot quality, as determined by the carrot packout rate is:

$$y = 76.40 - 0.67 x_1 - 0.91 x_2 + 0.25 x_3, \text{ where}$$

$y$  = % packout (percentage of carrots that are marketable)

$x_1$  = % misshapen carrots

$x_2$  = % diseased carrots

$x_3$  = Total organic carbon in topsoil (0 to 150 mm depth)

The main factors that affected carrot quality ( $P < 0.01$ ) were % misshapen carrots, % diseased carrots, and total organic carbon in topsoil. The R-squared statistic indicates that the model as fitted explains 68.1% of the variability in % packout. Further analysis was conducted to identify soil factors that influence misshapen carrots and carrot root disease.

#### Diseased carrots

The multiple-linear regression model that best describes the influence of soil factors on diseased carrots is:

$$y = 10.98 + 0.018 x_1 - 5.68 x_2, \text{ where}$$

$y$  = % diseased carrots

$x_1$  = Soil penetration resistance over 0-150 mm

$x_2$  = Soil erosion (where 1 =severe erosion, 2=moderate erosion, 3=topsoil resists erosion)

The main factors that influenced % diseased carrots ( $P < 0.01$ ) were the soil penetration resistance and soil erosion. The R-squared statistic indicates that the model as fitted explains 42.2% of the variability in % diseased carrots. Soil penetration resistance is a quantitative measurement, whereas soil erosion is a qualitative rating. These two values indicated that structural properties of topsoil have a direct influence on disease development in carrots, because % diseased carrots increased with an increase in topsoil penetration resistance, and an increase in topsoil erosion.

#### Misshapen carrots

The multiple-linear regression model that best describes the influence of soil factors on misshapen carrots is:

$$y = 8.56 + 1.36 x_1 - 1.75 x_2, \text{ where}$$

$y$  = % misshapen carrots (bending of carrots, excludes forked carrots)

$x_1$  = Total number of weed types

$x_2$  = Total number of passes with rotary hoe or power harrow

The main factors that influenced % misshapen carrots ( $P < 0.01$ ) are the total number of passes with a rotary hoe or power harrow, and the total number of weed types. The R-

squared statistic indicates that the model as fitted explains 26.4% of the variability in % misshapen carrots. Percentage misshapen carrots was positively correlated to the total number of weed types, but negatively correlated to the total number of rotary passes. The total number of weed types present could be an indirect indicator of poor soil management and preparation, as well as poor crop management.

The significant effect of the number of passes with a rotary hoe suggests that the soil preparation is important in affecting the physical shape of the root growth. Thus, a fine soil tilth could help reduce misshapen carrots.

#### DISCUSSION

This study showed that the soil factors identified as having the greatest influence on carrot production were related to soil structure. This result is not surprising, as the appearance of carrots produced for the fresh market is highly critical and the marketable product is produced in soil. The main factors associated with reduced carrot packout or quality in Red Ferrosols in Tasmania were levels of root disease, misshapen carrots and total soil carbon. All these factors can be linked to soil structural conditions.

The shape of carrots produced for the fresh market is extremely important. Any carrots that are obviously misshapen are unacceptable for the fresh market, and are often discarded for stockfeed or downgraded for use in processing (juicing or diced vegetables). Misshapen carrots are a common problem in carrot crops in Red Ferrosols in Tasmania, with losses ranging from 0.3% to 19.5%, and an average loss of 8.2%. Almost all misshapen carrots had the disorder at depths of between 40 to 85 mm. Often, the soil depth where the disorder occurred was similar for all carrots at the one site.

The positive correlation between misshapen carrots and total number of passes with a rotary hoe was an indication of impeded root growth caused by the close packing of resistant soil aggregates. The number of cultivations required in the Red Ferrosols could be indicative of soil structural decline, where a poor soil requires an increasing number of passes with a rotary hoe to generate suitable soil conditions for carrot production. Soil preparation for a fine tilth could help reduce the density of resistant soil aggregates and therefore reduce the percentage of misshapen carrots.

It is interesting that the average topsoil penetration resistance over 0-150 mm is not correlated to % misshapen carrots. An explanation for this lack of relationship is that unlike a rigid penetrometer, a root can diverge from its direct line of advance when a resistant aggregate (e.g. small hard clod) is in its way (3). Under dry soil moisture conditions, many of these small clods become very hard, making it difficult for the fine tap root of carrots to grow through the clod. This causes roots to twist or bend around them, and hence results in misshapen carrots. Some cultivation equipment, such as rotary hoes have also been noted for their tendency to re-sort small soil clods and concentrate them in the zone where impeded root growth occurs.

Apart from misshapen carrots, root disease is the other major cause of loss in carrot packout. The appearance of fresh market carrots is critical, and therefore any obvious rot or lesions due to root diseases is unacceptable. Most diseased carrots observed in this study had superficial lesions that developed at the crown. The direct link

between diseased carrots and topsoil penetration resistance and topsoil erosion suggested that disease development is influenced by soil structural properties. Slow water infiltration with some run-off or ponding was recorded in 50% of the sites surveyed in Tasmania. Wet soil conditions and slow infiltration favour many root pathogens. Growers often overlook the impact of temporary flooding and the prolonged period of saturation that can occur following heavy rainfall or overhead irrigation in soils with structural decline.

The focus of most plant disease control programs in horticulture is on controlling the pathogen with pesticides. Yet, the ultimate impact that these pathogens have on plants will depend on a favourable soil environment for the pathogens. This dependency could provide an opportunity to modify soil conditions with different management practices for long-term control through suppression of soilborne pathogens.

Soil carbon, primarily through the labile (readily oxidisable) fraction, has effects on key soil structural, chemical and biological properties (4). In the Ferrosols of Tasmania, total organic carbon is positively correlated to carrot quality and the close correlation between total organic carbon and labile carbon in these soils ( $P > 0.001$ ,  $r = 0.879$ ) may have masked differences in the relative importance of labile and stable carbon to soil properties. Comparisons with non-cropped reference soils provide an indication of carbon depletion. In Tasmania, the average total carbon in cropped sites was 4.35% compared with 6.3% in reference sites, which signifies a 31% decline in the total carbon level. Therefore, for sustainable crop production, soil management practices that help maintain soil carbon should be adopted, and practices that result in its decline should be discouraged. Such practices include green manure cropping, addition of composted organic waste, application of organic fertilisers, and reduced tillage.

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