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Relationship between water-soluble carbohydrate composition of cabbage (*Brassica oleracea* L. var. *capitata*) and damage levels of onion thrips

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ABSTRACT

The impact of water-soluble carbohydrate composition in relation to damage levels of onion thrips (*Thrips tabaci* Lindeman), were studied under field conditions at the Experimental Field of the Biotechnical Faculty in Ljubljana on 7 cabbage cultivar (*Brassica oleracea* L. var. *capitata*). Onion thrips showed weak preference on cabbage heads with high amount of total carbohydrate, fructose and glucose and higher preference on heads with high concentration of sucrose. While amount of total carbohydrate, fructose and glucose were negatively correlated with damage levels (r^2 = -0.7667; r^2 = -0.6947; r^2 = -0.8263), sucrose amount was not. There was a strong positively relationship between sucrose amount and the level of plants infested (r^2 = +0.7378). The cv.'Hinova', which had the highest amount of total carbohydrate, showed itself to be the most resistant to the onion thrips.

Key words: cabbage, *Brassica oleracea*, water-soluble carbohydrate, onion thrips, damage

IZVLEČEK

VPLIV VODOTOPNIH OGLJIKOVIH HIDRATOV V ZELJU (*Brassica oleracea* L. var. *capitata*) NA POŠKODBE, KI JIH POVZROČA TOBAKOV RESAR

Vpliv sestave vodotopnih ogljikovih hidratov na poškodbe, ki jih povzroča tobakov resar (*Thrips tabaci* Lindeman), smo proučevali na 7 kultivarjih zelja (*Brassica oleracea* L. var. *capitata*), vzgojenih na Laboratorijskem polju Biotehniške fakultete v Ljubljani. Tobakov resar je pokazal majhno preferenco do zeljnih glav, ki imajo visoko vsebnost skupnih ogljikovih hidratov, fruktoze in glukoze, in veliko preferenco do glav z visoko vsebnostjo saharoze. Medtem ko je vsebnost skupnih ogljikovih hidratov, fruktoze in glukoze negativno korelirala z indeksom poškodb (r^2 = -0,7667; r^2 = -0,6947; r^2 = -0,8263), pa to ni veljalo za saharozo. Med koncentracijo saharoze in poškodovanimi listi je bila namreč ugotovljena močno značilna

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pozitivna povezava (r^2 = +0,7378). Cv. ‘Hinova’, ki je vseboval največji delež skupnih ogljikovih hidratov, se je pokazal kot najbolj odporen kultivar na napad tobakovega resarja.

Ključne besede: zelje, *Brassica oleracea*, vodotopni ogljikovi hidrati, tobakov resar, poškodbe

INTRODUCTION

The onion thrips, *Thrips tabaci* Lindeman, is polyphagus pest which has been recorded from 29 plant families but is particularly damaging to Brassicaceae, Liliaceae and Solanaceae (Penzes et al., 1996; Theunissen and Schelling, 1998; Richter et al., 1999). *T. tabaci* has been distributed worldwide by the trade in plants and the plant products and can cause significant economic losses in countries where is established (Weber et al., 1999). Onion thrips feed by scraping the surface of plant cells and sucking out the cell contents (Commegys and Schmitt, 1965). Destruction of the epidermal cells is accompanied by whitening and scabbing of the outer surface. The resulting damage is usually measured as an overall reduction in head size and weight where cabbages are produced. The thrip's rasping of the leaves creates an injury spot which enables various plant pathogens to gain entry, thus increasing disease problems. In addition, thrips vector plant pathogens on their mouth parts from one plant to another (Chisolm and Lewis, 1984).

In the last 25 years in Europe, problems resulting from damage caused by the onion thrips on cabbage have been found in many European countries (Penzes et al., 1996; Giessmann, 1988; Kahrer, 1992; Herold and Stengel, 1993; Legutowska, 1997; Theunissen et al., 1992; Shatilova, 1991; Ellis et al., 1994). In the last decade, the onion thrips has also become a significant pest to cabbage in Slovenia (Trdan et al., 2004).

In spite of their pestiferous status in some cabbage fields, little is known about thrips biology in this crop and the relationship between their density and cabbage yield. Therefore, thrips controls often consist of automatic preventive chemical treatments early in the season. Generally, chemical control of thrips is difficult because of their wide geographic distribution, high reproductive and dispersal rates, and wide host range (German et al., 1992). In Slovenia growers normally spray insecticide 2 to 3 times per season for control (Trdan and Žnidarčič, 2004). Edelson et al. (1989) reported that one or more thrips per plant reduced yield enough to justify the expense of insecticide treatment. Insecticide application also negatively affects populations of natural enemies, and thus may induce secondary pest outbreaks and resurgence of target pests (Hardin et al., 1995).

During the last few decades, sustainable vegetable production has been attempted to minimize the increasing problems with the use of insecticides. In order to support sustainable vegetable production, it is important to develop alternative methods of pest control. This can be achieved through the use of cultural practices such as manipulation of plant density, interplanting, and host plant resistance as well as the use of other control options. Host plant resistance and biological control are central components of any viable sustainable program.

Host plant resistance in cabbage to onion thrips is important area of research for several reasons. The growing concern and regulation of pesticides in the environment is an importance issue (Hamilton and Pike, 1997). Advantages of host plant resistance include reduced expense to the growers (Stoner, 1970). Insects are becoming resistant to pesticides, which creates more problems for control (Debach and Rosen, 1991). Thrips hide between the leaves making it very difficult to reach them with pesticide (Metcalf and Metcalf, 1993).

In general, disturbances in host biochemical composition associated with thrips damage are still poorly understood. Our research has been oriented towards the study of relationship between the onion thrips damage and the biochemical composition of the cabbage plants, particularly soluble carbohydrates.

MATERIAL AND METHODS

Host plant preference trials in the field were conducted at the Experimental Field (46° 04' N, 14° 31' W, 300 m above sea level) of the Biotechnical Faculty in Ljubljana, Slovenia. Research was performed during the 2006 growing. The experimental plots consisted of a raised bed 10 m long with three rows per bed. The experiment were arranged in a randomized complete block design with seven cabbage cultivars ('Vestri', 'Delphi', 'Destiny', 'Hinova', 'Kranjsko okroglo', 'Varaždinsko' and 'Tucana').

Cabbage cultivars were planted in the greenhouse for about 6 weeks prior to transplanting into the field. Seedlings were transplanted by hand into the field in the late April in rows 0.4 m apart with 0.3 m between plants. The plants were grown under standard cultural practices except that no insecticide was used. Standard cultural practices including drip fertigation were employed and two drip lines were laid per bed. Droppers within the line were 30 cm apart. Water was supplied by a combination of drip irrigation and natural rainfall, according to evapotranspiration data.

Plant material was harvested at commercial maturity stage. Ten plants in each plot were randomly selected and recorded for damage incidence. The amount of leaf area damaged caused by onion thrips feeding was averaged over on the first 15 outer leaves of the head. Ratings of thrips feeding symptoms on the head's leaves were made using an index scale of 6 grades: 0 (non-damaged leaf), 6 leaf totally covered by verrucae) (Stoner and Shelton, 1988; Trdan et al., 2005).

Water-soluble carbohydrates were extracted from powdered plant material following methodology of Nii (1997) and Šircelj et al. (2005). Carbohydrates were extracted from the lyophilised leaf powder with bidistilled water on ice. A few drops of 2% (w/v) sulfosalicylic acid were added to the homogenate. Extracts were subjected to an isocratic HPLC analysis (column Aminex HPX-87C 300 x 7.8 mm) using bidistilled water as solvent, at flow rate of 0.6 mL min^{-1}, run time 60 min, detection with RI detector. Three sugars were selected for quantification, representing two sugars categories: disaccharides (sucrose), and monosaccharides (glucose and fructose). The amount of carbohydrates was expressed in mg/100 g of dry weight of tissue (mg/100 g dwt).

All measured and derived data, were analysed by analyses of variance (ANOVA) using Statgraphics Plus for Windows 4.0 computer program. Character means were separated by least significant differences (LSD, $P<0.05$) when sources of variation from ANOVAs were significant ($P<0.05$). A regression analyses was used to determine the relationship between water-soluble carbohydrates amount and onion thrips damage.

RESULTS AND DISCUSSION

There were significant differences in the level of damage between the seven cultivars of cabbage (Fig. 1). The cultivars which had a high index of damaged leaves had also very low yields (data not shown). Cv. ‘Hinova’ was being more resistant to onion thrips than the other cultivars. The index of feeding damaged leaf area (measured for the first 15 outer leaves of the head) by cv. ‘Hinova’ was 1.127. On the other side, the highest damage rating was found in cv. ‘Varaždinsko’ (cabbage for sauerkraut) with index damaged of 2.833. Both cultivars form head between middle of July and middle of August.

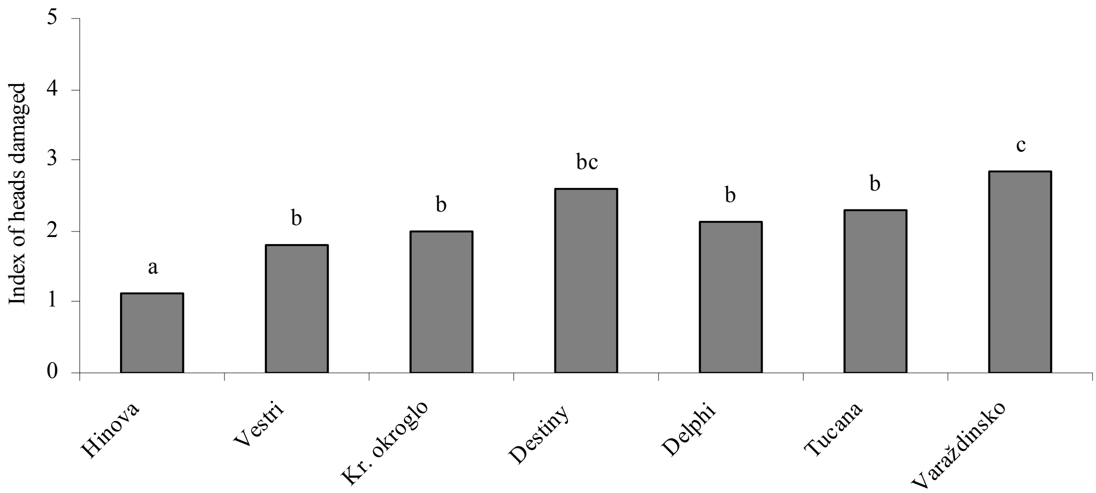

Figure 1: Mean index of heads damaged by onion thrips, *Thrips tabaci* Lindeman. Mean values followed by the same letter are not significantly different according to Duncan’s Multiple Range test at $P<0.05$.

Chemical composition of cabbage cultivars is shown in Table 1. There was a significant difference in the total water-soluble carbohydrates concentration and the concentration of each individual water-soluble carbohydrate between cabbage plants.
The ratio of total carbohydrates to glucose in the leaves of cabbage examined showed that glucose accounted fore more than 55% of the total sugar concentrations. Overall, higher concentration of sugars was present in the leaves of plants of cv. 'Hinova' (5389.9 mg/100 g dwt) and of cv. 'Delphi' (5256.5 mg/100 g dwt) compared to other cultivars. The greatest level of glucose was recorded in the cv. 'Hinova' (3042.1 mg/100 g dwt) and cv. 'Vestri' (2966.8 mg/100 g dwt). In contrast, cv. 'Vestri' contained the lowest level of sucrose (25.3 mg/100 g dwt). In the other cabbages the content of sucrose was relatively higher (between 30.4 mg g^{-1} dwt in cv. 'Kranjsko okroglo' and 90.6 mg/100 g dwt in cv. 'Tucana') There were significant differences among cultivars regarding fructose amount, too. The differences established the range from 1234.2 mg/100 g dwt (cv. 'Varaždinsko') to 2265.0 mg/100 g dwt (cv. 'Delphi').

The damaged leaves, compared to healthy one, exhibited more total water-soluble carbohydrates. A relationship between the mean index of heads damaged and amount of water-soluble carbohydrates in cabbage leaves is illustrated in Fig. 2. Based on the data, the relationship is satisfactorily described by a linear function of the general form: y = ax + b. The mean index of heads damaged was the dependant variable (y) and the soluble carbohydrates was the independent variable (x). A correlation coefficients of total and of the three carbohydrates indicated that there was a close correlation between the two variables. The amount of total carbohydrates, fructose and glucose in the leaves of cabbage plants correlated negatively with the damaged index (r^2 = -0.7667; r^2 = -0.6947 and r^2 = -0.8263). In contrast, damaged index was positively correlated to the sucrose level in the leaves (r^2 = +0.7378).

Table 1: Amount of water-soluble carbohydrates (mg/100 g dwt) in cabbage leaves

Cultivar	Water-soluble carbohydrates (mg/100 g dry weight tissue)			
	Glucose	Fructose	Sucrose	Total
Hinova	3042.1 c	2154.2 c	60.2 b	5389.9 d
Vestri	2966.8 c	1841.5 b	25.3 a	4833.6 c
Kranjsko okroglo	2581.4 b	1680.2 a	30.4 a	4292.0 b
Destiny	2461.8 ab	1782.4 ab	87.6 c	4331.8 b
Delphi	3062.4 c	2265.0 c	62.5 b	5256.5 d
Tucana	2341.1 a	1662.4 a	90.6 c	4094.1 b
Varaždinsko	2195.3 a	1234.2 a	86.4 c	3515.9 a

Within a column, values are not significantly different (*P<0.05*) if followed by the same letter

Previous researches have shown that most herbivorous insects use carbohydrates as feeding stimulants (Bernays and Simpson, 1982; Blaney and Simmonds, 1988) and as important nutrients needed to synthesize body tissue and serve as energy sources (Schoonhoven et al., 1998b). Derridj et al. (1996) reported that sugars have also been shown to promote oviposition in some species. However, the data above the effect of separated sugar categories on feeding preferences of onion thrips are scarce.

The outcome of onion thrips-cabbage interactions at high carbohydrate content is the product of three main factors. Firstly, carbohydrates may directly affect thrips level damage via changes in the nutritional quality of cabbage tissue during growing season. The second factor that affected the interaction between cabbage heads and thrips was direct effects of carbohydrates on plant growth rates and therefore plant biomass available for thrips. And at last but no least, the flavour and palatability of cabbage plants is a function of relative levels of total sugars (glucose + fructose + sucrose) or reducing sugars (glucose + fructose) and presence of various aromatic constituents.

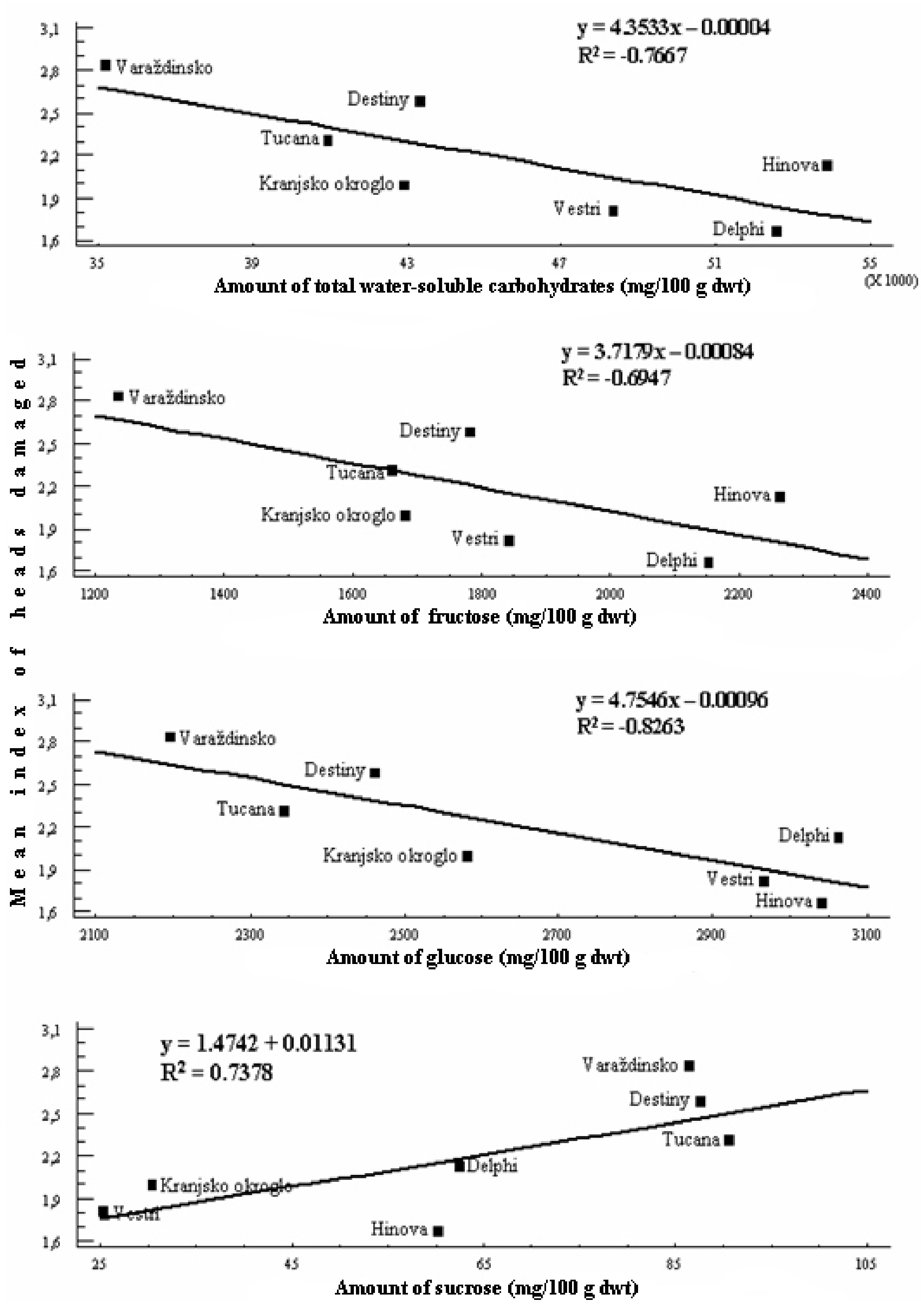

Figure 2: Regression analyses of the relationship of mean index of heads damaged to amount of water-soluble carbohydrates (mg/100 g dwt) in cabbage leaves

CONCLUSIONS

Plant-insect relationship may result in host defence, or in systemic symptoms. Our research suggests that the employment of resistant cultivars in the cultural control strategy for the long-term management of onion thrips is important. Onion thrips can discriminate among different cabbage cultivars, suggesting some kind of resistance in these cultivars that might be useful for controlling onion thrips damage in cabbage.

On the basis of our investigation of growing the cabbage the following could be concluded:

- the levels of soluble carbohydrates are dependent on cabbage cultivar;
- glucose was, on average, the major carbohydrate in the seven cultivars, followed by fructose;
- on the cv.'Hinova' the amount of damaged leaf area, due to onion thrips feeding, was substantially lower as compared with the other cultivars;
- between carbohydrates and damaged leaf area a statistically significant correlation was observed.

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