Earliness, Leaf Surface Wax and Sugar Content Predict Varietal Differences for Thrips Damage in Cabbage

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Abstract

When cabbage is cultivated for storage in the Netherlands, it is usually harvested around mid-October. This type of cabbage crop may be severely damaged by thrips (*Thrips tabaci*). The thrips population on the plants and the more severe symptoms develop mostly during September and October. Also during cold storage symptoms continue to develop. The damage caused by thrips is due to the symptoms that develop after feeding, which are small callus-like growths that will turn brownish after some time and which may cover substantial amounts of leaf area.

Large differences exist between cabbage varieties in their susceptibility to thrips damage. It is not clear whether these differences are due to resistance (affecting the thrips population in the plant) or to tolerance (affecting the development of symptoms upon thrips feeding). Further, not much is known about plant traits affecting the resistance or tolerance to thrips. In order to guide selection and breeding for resistance to thrips, this study aimed to identify plant traits causing these differences. In the years 2005, 2006 and 2007 we performed field experiments with collections of varieties differing in a number of plant traits, with earliness varying from moderately late to very late. In the field experiments we relied upon natural infestation by thrips.

Several times during the period August-October plants were harvested and assessed for the amount of thrips damage and the number of thrips, as well as for several morphological and physiological traits, including head circumference, leaf thickness, developmental stage, head compactness, leaf surface wax, and Brix value as an indication of the content of soluble sugars.

One factor affecting the amount of thrips damage was the timing of the development of the head. Regression studies showed that more advanced plant development at the end of August increased thrips damage at the final harvest. Other plant traits affecting thrips damage were Brix and the amount of leaf surface wax.

However no single plant trait explained more than 45% of the variation in thrips damage at the final harvest. Optimal regression models, explaining up to 75% of the variation in thrips damage included Brix and leaf surface wax late in the season, as well as an indicator of plant development earlier in the season, and in 2005 also leaf thickness. The possible role of these plant traits in relation to thrips is discussed.

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata*) is an important field crop in the Netherlands, cultivated by conventional as well as organic growers. Cabbage cultivated for storage is usually harvested around mid-October. This type of cabbage crop may be severely damaged by thrips (*Thrips tabaci*). The damage caused by thrips is due to the symptoms that develop after feeding, which are small callus-like growths (intumescences) that will turn brownish after some time. These symptoms force growers to remove the outer leaf layers before marketing, leading to increased labor costs and yield losses.

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Among red and white cabbage varieties, large differences have been reported in the amount of thrips damage (Shelton et al., 1983; Stoner and Shelton, 1988; Van de Steene et al., 2003) and in the numbers of thrips observed on the plants (Stoner and Shelton, 1986; Van de Steene et al., 2003). However, the genetic background of tolerance or resistance to thrips is not clear, and breeding for resistance or tolerance to thrips is difficult. One of the problems is the large variability between years and locations in the severity and timing of thrips infestation. Also within genotypes in the same experiment, large plant to plant variations can occur in damaged or thrips population size. Also, it is not easy to have all the accessions in a comparable developmental stage throughout the evaluation period, which is a requirement for reliable comparisons.

Indirect selection might help to overcome these problems. One possibility is to identify plant traits that are associated with the level of thrips damage. That was the main aim of the research described in this paper. Also knowledge of agronomically undesirable traits associated with trips resistance would be important, as these must be avoided while selecting for resistance.

MATERIALS AND METHODS

Field Experiments

In 2005, 2006 and 2007, field experiments were conducted at two locations (in 2007: one location) in the Netherlands. Small cabbage plants were planted in the field in the last week of May. The experimental fields were divided into three blocks, with one plot per accession per block. At four harvest dates between mid-August and mid-October three plants were harvested from each plot.

Harvested plants were scored for several traits including developmental stage, circumference of the head (cm), openness around the stem (visual scores, 0=fully closed, 3=very open) when observed from below, leaf thickness (mm), wax layer, compactness and Brix. One half of each head was peeled and assessed for thrips damage and the number of adult thrips.

Plant Material

The plant material consisted of medium to late white cabbage varieties, including F_1 hybrids and classical open-pollinated varieties. In 2006 and 2007 a few crosses between OP varieties were included as well. Three F_1 hybrids were included as standards, as it was known that they were highly susceptible (Bartolo and Slawdena) or resistant (Galaxy) to thrips damage.

RESULTS AND DISCUSSION

Genotypic Differences for Thrips Damage and Number of Thrips

Large differences between genotypes were observed for both thrips damage and number of adult thrips per plant. For the accessions tested in two or three years the relative ranking was very similar over the years. The numbers of thrips per plant were more variable than the damage scores, which resulted in a better discrimination of accessions for damage score than for thrips numbers. However, for both traits Galaxy, Langendijker Bewaar and Amager Hoj-Gron Grami stood out as the most resistant or least damaged accessions, while Bartolo, Bewama and Slawdena were the most susceptible. The differences between these two groups were consistent over all harvest dates, although not at all dates the differences were significant.

The damage and number of thrips of the F_1's from the resistant x susceptible crosses (Langendijker Bewaar x Bewama and Amager Hoj-Gron Grami x Bewama) were intermediate between the parents. In the resistant x resistant cross (Langendijker Bewaar x Amager Hoj-Gron Grami) the damage and number of thrips were higher than those on the parents, but lower than in the resistant x susceptible crosses. This last result indicates that resistance and/or tolerance in both resistant parents is probably caused by (partly) different genes, some of which are recessive in expression.

Relation between Thrips Population Size and Thrips Damage

In all three years, thrips damage was observed to increase with increasing numbers of thrips per plant (Fig. 1). While sometimes considerable damage was observed even with very low numbers of thrips, the opposite (low damage at elevated numbers of thrips) was not observed. This indicates that differences in thrips damage were predominantly influenced by differences in resistance between the accessions, and not by differences in tolerance.

The thrips infestation varied much over the three years (Fig. 1). Also the amount of damage varied somewhat between the years corresponding with the thrips infestation, but the differences in damage between the years were smaller than those between the thrips populations. In years with less thrips infestation, the damage inflicted per thrips individual appears to be higher. Whether this is generally true or just a coincidence in the three years studied remains unclear.

Relations between Plant Traits and Thrips Damage

The final harvest date in October corresponded to the normal harvest date of storage cabbage in the Netherlands. Therefore we attempted to correlate the thrips damage in the October harvest with the plant traits measured at any of the harvest dates. Individual traits measured at any harvest showed only limited correlations with thrips damage at October harvest, with maximum $R^2 = 0.45$ (2008, Leaf surface wax third harvest). Using all-subsets regression we identified improved predictors for thrips damage while avoiding over-fitting (Voorrips et al., 2008). The selected models with the highest proportion of variance explained were (Fig. 2):

2005:
Damage4 = -1.23 + 0.23*Brix4 + 0.019*Circ2 - 0.22*Wax3 + 0.66*Thick4 ($R^2 = 0.75$)
2006:
Damage4 = -2.73 + 0.34*Brix3 + 1.8*Stage2 - 0.16*Wax4 ($R^2 = 0.74$)
2007:
Damage4 = -5.42 + 0.40*Brix2 + 2.8*Stage2 - 0.18*Wax3 ($R^2 = 0.75$)

where Damage is thrips damage, Circ is circumference, Wax is the amount of leaf surface wax, Thick is leaf thickness, Stage is developmental stage, and the figure (1–4) indicates the harvest.

However, in each year several other models with the same number of parameters explained almost the same proportion of the variance as the optimal models shown above. These models always included Brix and leaf surface wax in the third or fourth harvest and a trait indicative of development of the head (i.e. the score of developmental stage, compactness or circumference) in the first or second harvest. In 2005 but not in 2006 and 2007 leaf thickness occurred in all models. Apart from leaf thickness, the role of each trait was the same in all models and all three years: damage was increased in varieties with high Brix levels and a further advanced development in the first two harvests, but decreased in varieties with a high amount of leaf surface wax. These same relations were found when investigating the correlations between individual plant traits and thrips damage. In contrast, correlations of thrips damage and leaf thickness over different harvests and between years vary much and both positive and negative correlations are found.

It should be noted that some of the plant traits are correlated in the studied accessions. This is obviously the case for the different traits that are indicative for development of the head. However, among the accessions in our experiments there was also a correlation between leaf surface wax and these development indicators: accessions with early head development tended to have less leaf surface wax than later maturing accessions.

A biological interpretation of the effect of Brix could be that a higher sugar content improves the nutritional value for the thrips and stimulates their settling, survival and reproduction. An earlier head development might offer earlier protection against predators and might also induce the trips to settle and reproduce. Leaf surface wax has been shown to hamper the movement of small insects (e.g. Eigenbrode et al., 1996). To our knowledge no earlier publications report an effect of surface wax on thrips in cabbage. A biological interpretation of the effect of leaf thickness is less clear; as the correlations of leaf thickness with damage are more erratic than those of the other factors it is conceivable that the leaf thickness effect is just a statistical artifact.

CONCLUSIONS

- Differences in thrips damage between varieties are mostly due to differences in resistance rather than tolerance;
- Early head development and increased Brix levels are associated with increased thrips damage;
- Increased amounts of leaf surface wax are associated with reduced thrips damage;
- A combination of these three traits can account for about 75% of the variation for thrips damage between varieties.

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Figures

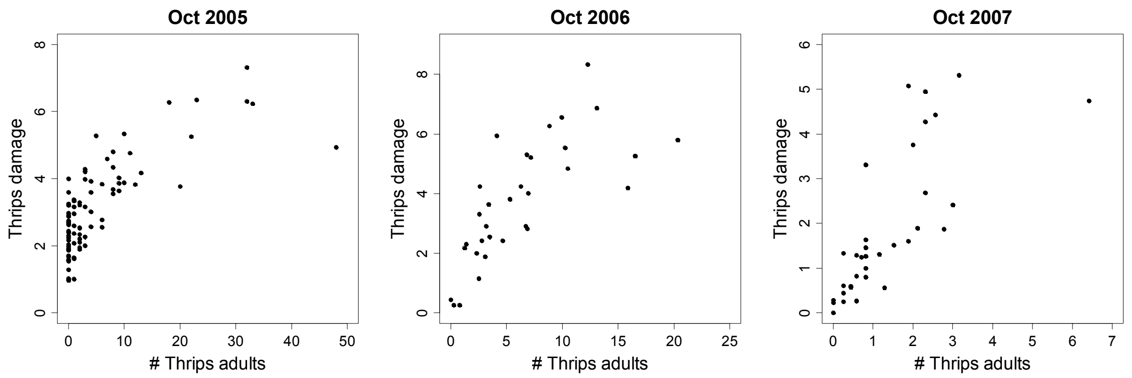

Fig. 1. Relation between thrips damage and number of thrips per plant in the October harvest of three years. Each dot represents one plot.

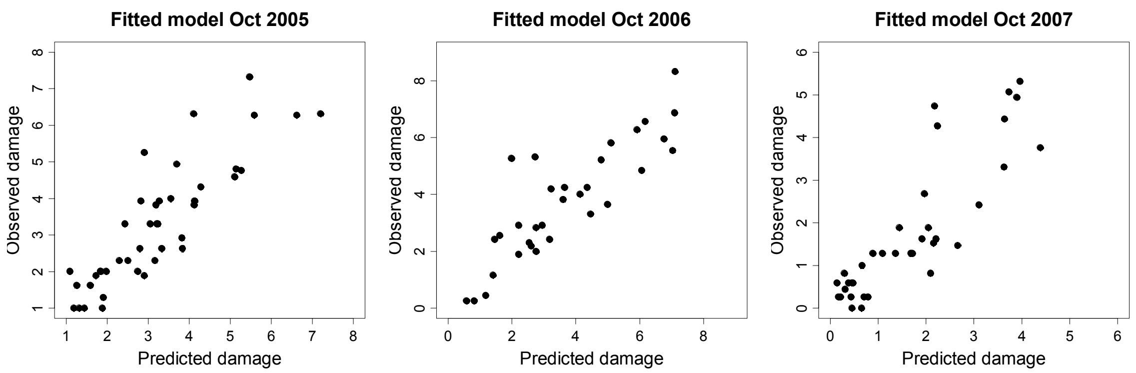

Fig. 2. Correspondence between damage predicted by the models (see text) and observed damage. Each dot represents one plot.