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Leaf colour can be a factor for varietal preference of onion thrips (*Thrips tabaci* Lind.) among eight onion varieties (*Allium cepa* L.)

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Introduction

Onion thrips, *Thrips tabaci* Lindeman 1889 is a global pest and also represents a serious threat to onion production in Poland. The negative effects of onion thrips are reflected in both the quantity and quality of the crop. The demand for high-quality onions, produced to the highest standards, is growing continually. For this reason, an increasing number of onion growers are choosing more environmentally friendly methods of cultivation, which allow the use of fewer pesticides. The choice of a cultivar characterized by a higher degree of resistance to the important pest species for the particular crop is one of the most important agrotechnical measures and an element of integrated pest management (IPM).

Plant characteristics make herbivores prefer one cultivar to another. Studies of visual plant characteristics have largely focused on the plant colour, brightness (intensity of perceived reflected light), the polarization of foliar reflectance, saturation (hue clearness), and shape. Colour and colour contrast are used by some thrips species to distinguish between a host and the surrounding environment. Behavioural studies of the colour preference of *T. tabaci* have provided variable results, but generally agree that greater numbers of thrips are caught by low UV-reflective white, blue, yellow, and fluorescent yellow traps than are caught by green, red, black, and high UV-reflective white traps. Green is regarded as one of the least attractive colours for *T. tabaci*; however, few studies have looked at differences in preference based on a green hue. Onion thrips show a significant preference for both light green and mid-green over dark green. Leaf colour has been advocated as an influential factor in determining thrips resistance in onion. Varietal preference and the susceptibility of onion to *T. tabaci* have been documented in Poland by Pobożniak but no traits were investigated to explain this preference.

The detailed objectives of the study were to identify cultivars with a high level of non-preference (antixenosis) that can be cultivated by farmers as a tool of IPM and can also be used by plant breeders as a source of resistance to onion thrips in plant breeding programmes.

Materials and Methods

In two years (2015–2016) of field studies were conducted at the Experimental Station of the University of Agriculture in Krakow, located in Mydlniki. Eight cultivars of *Allium cepa* (Alibaba, Bila, Karmen Kristine, Niagara F_1, Polanowska, Tęcza and Wenta). Thrips sampling consisted of two methods: one in which thrips were collected with a sweeping net and the second in which plants were bagged into plastic bags. The actual count and the proportional abundance of adult thrips collected from onion leaves during plant colonization by insects were both used to express the preference of thrips for different onion cultivars.

Onion leaf samples for colour measurements were collected consistently for all varieties before sampling of thrips for preference evaluation. The middle leaves from six randomly selected onion plants from each experimental plot were collected and gently wrapped in parchment paper, labelled precisely, and transported to the laboratory. Then, 10 cm sections were cut out of the middle of the leaves very carefully, so as not to damage the wax coating. The sections were placed back into the parchment paper and foil string bags to avoid excessive loss of water and volatile compounds contained in the onion leaves. A total of 192 (6 leaves × 4 blocks × 8 cultivars) sections of onion leaves were prepared for analysis. The colour was measured with a portable Konica Minolta Chroma Meter spectrophotometer (CM-2600d with 8 mm aperture diffuse illumination and 8 degree (d/8°); Konica Minolta, Inc., Tokyo, Japan), a contact-type colour measuring device commonly used in scientific works. Colour measurements were analysed by considering the CIELAB (CIE 1976 L*a*b*) and CIE L*C*h* colour spaces. The instrument was calibrated with reference to the white porcelain tile provided by the instrument manufacturer. Each measurement of the object was made from two angles three times, from which the device automatically calculated the average.

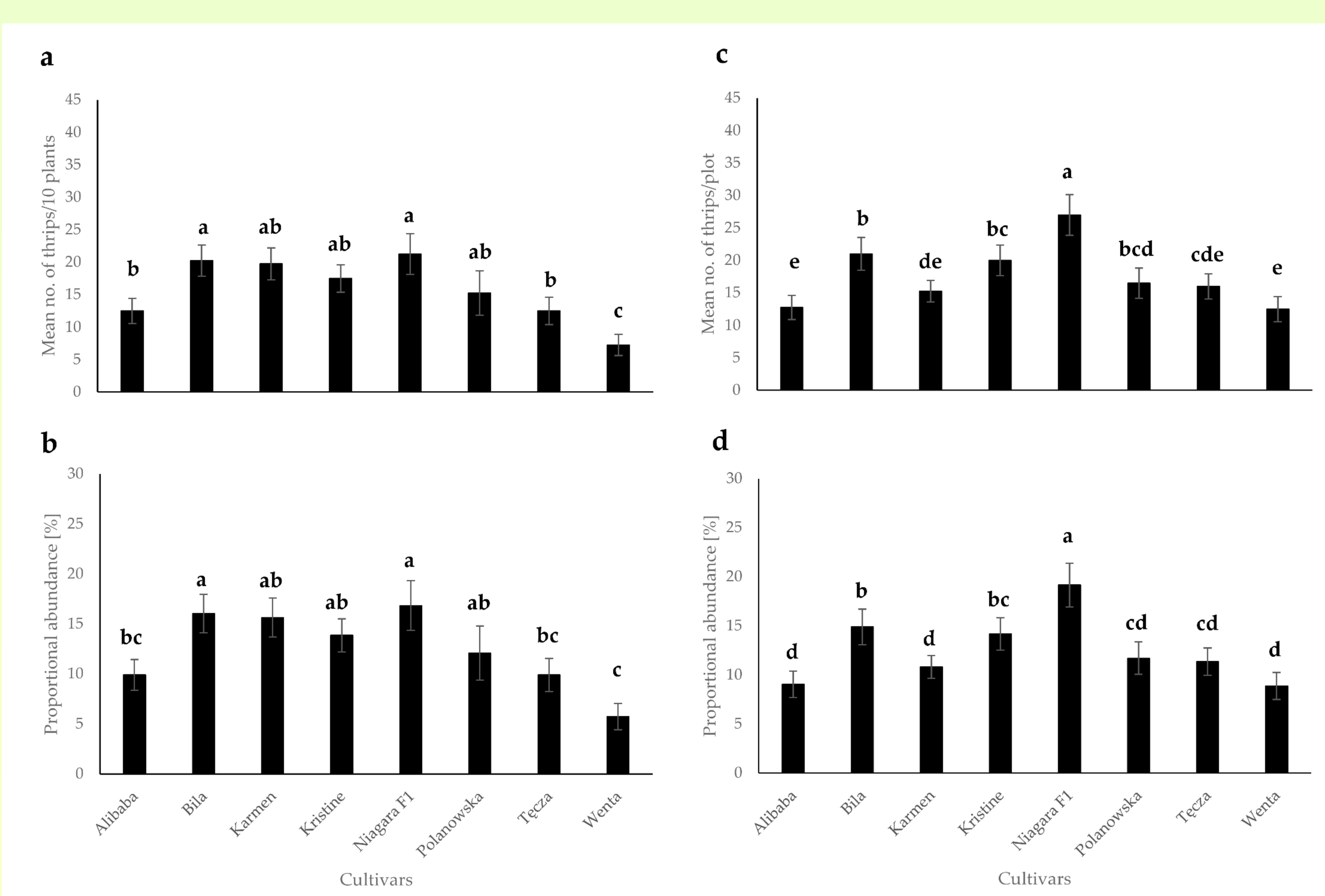

Figure 1. Actual count (mean ±SE) and proportional abundance of *Thrips tabaci* adults collected **(a, b)** directly from plants and **(c, d)** with sweeping net during onion plant colonization by thrips in 2015. Means with the same letters on each bar are not significantly different (Duncan's Multiple Range Test P< 0.05).

Statistical analyses were performed with Statistica 13 software (Dell Inc. 2016). One-way ANOVA (the factor was onion cultivar) was performed on the thrips actual count, the proportional abundance of thrips, and the colour measurement data (L*, a*, b*, C*, and h). For statistical analysis, the data regarding the thrips actual count were normalized using log10(x + 1) transformation; for the proportional abundance of thrips (%), arcsine transformation was used. The Shapiro–Wilk test was used to check the distribution of the data, and Levene's test was used to check homogeneity of variance. Multiple comparisons were computed by using Duncan's multiple range test ($p < 0.05$). To examine the relationship between the actual count and proportional abundance of thrips and leaf colour parameters; Pearson's correlation coefficient (r) was calculated, and significance was set at $p < 0.05$.

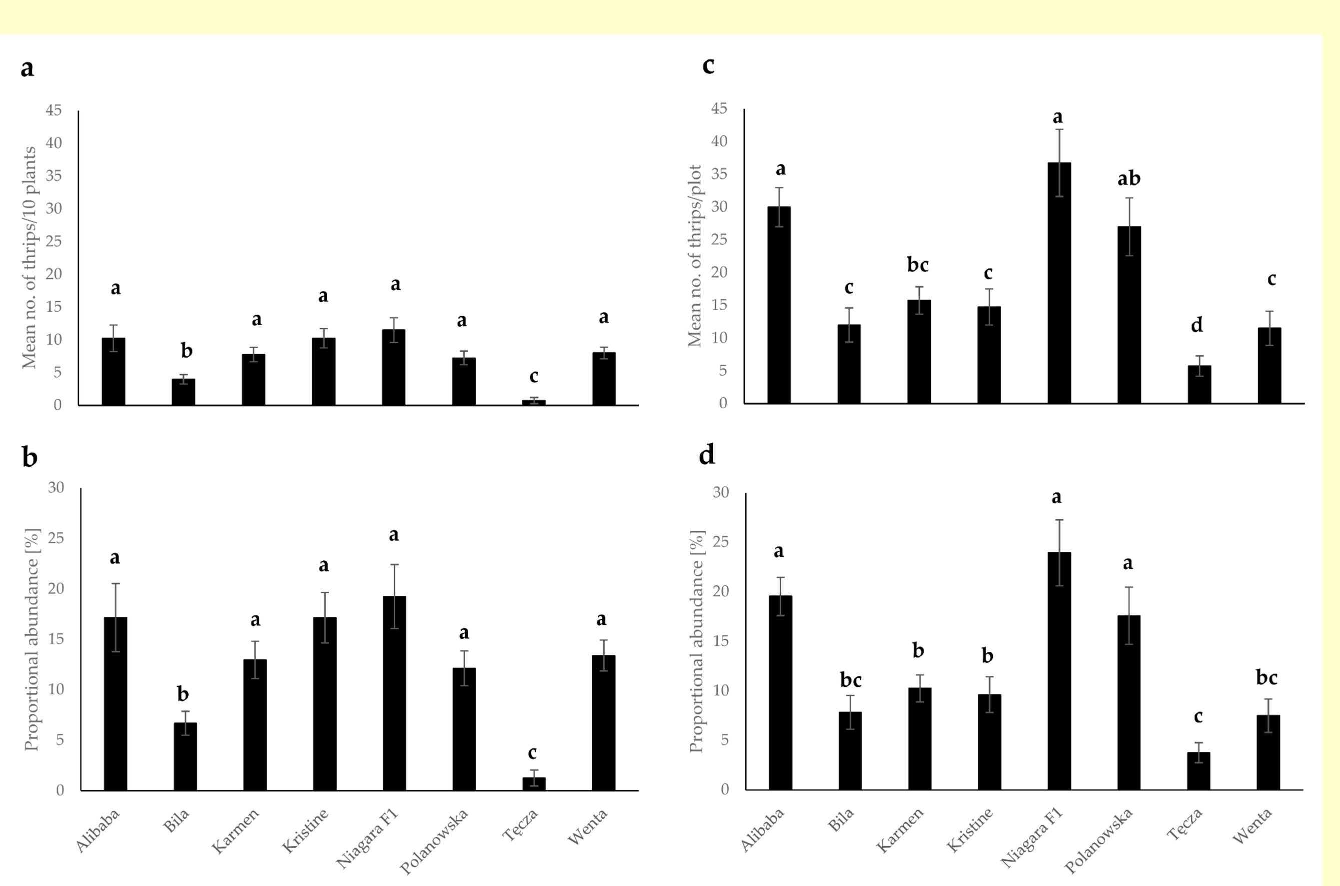

Figure 2. Actual count (mean ±SE) and proportional abundance of *Thrips tabaci* adults collected **(a, b)** directly from plants and **(c, d)** with sweeping net during onion plant colonization by thrips in 2016. Means with the same letters on each bar are not significantly different (Duncan's Multiple Range Test P< 0.05).

Results

In two consecutive years, 2015 and 2016, a different order of the level of susceptibility of onion cultivars to *T. tabaci* was established. In 2015 [Fig. 1], the cultivar Wenta followed by Alibaba showed a low level of susceptibility to colonization by onion thrips which was reflected in both low actual count and proportional abundance of thrips collected directly from plants and with a sweeping net. In 2016 [Fig. 2], the cultivars Tęcza and Bila were the least susceptible. The proportional abundance of onion thrips collected directly from Tęcza in 2015 and collected from Wenta with a sweeping net in 2016 also indicated a low level of attractiveness of these cultivars to onion thrips. In contrast, the cultivars most susceptible to onion thrips infestation were Niagara F_1 and Bila in 2015, and Alibaba and Kristine in 2016.

We found distinct differences in some computed colour variables between the leaves of the onion cultivars most and least susceptible to *T. tabaci* infestation but because of the discrepancy in the results between the two years of the study, the role of visual cues for thrips must be interpreted with caution. By analysing the results for the eight onion cultivars, we have ascertained that leaf colour may influence colonization by thrips. In both years, the cultivars with the highest value for lightness (Bila and Niagara F_1 in 2015 [Tab. 1], and Alibaba and Niagara F_1 in 2016 [Tab. 2]) were very attractive to *T. tabaci*.

Table 1. Colorimetric characteristics of onion leaves in 2015.

Cultivar	L*[1]	a*	b*	C*	h*
	L*a*b* colour space			L*C*h colour space	
	Mean [± SE]				
Alibaba	45.98±1.04 bc2	-6.89±0.18 b	9.88±0.88 c	12.07±0.82 c	-54.75±1.76 c
Bila	48.64 ±0.45 a	-7.44±0.24 a	15.08±1.04 a	16.82±1.03 a	-63.58±0.84 a
Karmen	46.61±0.39 bc	-6.41±0.19 b	10.16±0.68 c	12.02±0.68 c	-57.56±1.09 bc
Kristine	44.89±0.58 c	-6.88±0.22 b	10.64±0.52 c	12.68±0.54 c	-57.03±0.84 bc
Niagara F1	47.68±0.73 ab	-6.57±0.13 b	10.54±0.12 c	12.42±0.16 c	-58.07±0.30 b
Polanowska	45.29±0.98 c	-6.39±0.08 b	9.20±0.71 c	11.22±0.62 c	-54.89±1.08 c
Tęcza	45.80±0.36 c	-6.83±0.08 b	13.36±0.67 b	15.01±0.64 b	-62.78±0.90 a
Wenta	44.79±0.36 c	-6.61±0.16 b	9.54±0.56 c	11.62±0.55 c	-55.12±2.14 bc
F cultivar	5.740	4.520	13.384	12.183	13.170
p cultivar	0.000	0.003	0.000	0.000	0.000
F blocks	4.010	2.380	5.344	4.961	5.230
p blocks	0.02	0.098	0.006	0.009	0.007

Note: [1]L* in L*a*b* colour space is the same as the L*of the L*C*h colour space;
[2]means within a column followed by the same letter(s) are not significantly different (Duncan's Multiple Range Test P<0.05).

Table 2. Colorimetric characteristics of onion leaves in 2016.

Cultivar	L*[1]	a*	b*	C*	h*
	L*a*b* colour space			L*C*h colour space	
	Mean [± SE]				
Alibaba	50.24±0.72 a	-9.87±0.13 a	22.27±0.63 a	24.36±0.63 a	-66.05±0.38 a
Bila	46.05±0.23 b	-8.98±0.07 b	17.75±0.47 b	19.92±0.45 b	-63.14±0.46 b
Karmen	46.04±0.41 b	-8.88±0.22 b	17.69±0.76 b	19.79±0.77 b	-63.28±0.55 b
Kristine	49.10±0.80 a	-9.78±0.21 a	20.51±1.18 a	22.73±1.16 a	-64.37±0.78 ab
Niagara F_1	47.18±0.66 b	-8.73±0.25 b	17.90±1.22 b	19.93±0.55 b	-63.95±1.02 ab
Polanowska	46.11±0.28 b	-9.05±0.07 b	17.45±0.39 b	19.66±0.36 b	-62.56±0.48 b
Tęcza	46.15±0.66 b	-8.76±0.20 b	16.83±2.23 b	18.98±1.08 b	-62.34±0.97 b
Wenta	46.82±0.35	-8.92±0.15 b	17.90±0.75 b	20.01±0.75 b	-63.44±0.50 b
$F_{cultivar}$	8.040	6.270	4.961	5.230	2.660
$p_{cultivar}$	0.000	0.000	0.001	0.001	0.039
F_{blocks}	0.760	1.440	0.193	0.266	0.260
p_{blocks}	0.526	0.259	0.900	0.849	0.851

Note: [1]L* in L*a*b* colour space is the same as the L*of the L*C*h colour space;
[2]means within a column followed by the same letter(s) are not significantly different (Duncan's Multiple Range Test P<0.05).

In contrast, the resistant cultivars Wenta in 2015 and Tęcza in 2016 were darker and had low L* values. A negative coordinate a* value indicates a green colour; for susceptible cultivars, namely Bila in 2015, and Alibaba and Kristine in 2016, its value de-creased, so the tonality of the colour shifted to greener. In turn, the increasing positive value of coordinate b* (yellowness) indicated that the leaf colour of susceptible cultivars was oriented towards yellow. In contrast, the increasing value of a* in resistant cultivars, Wenta in 2015 and Tęcza in 2016, and lower value of b* indicated a less in-tense green colour oriented towards yellow-grey. The lower value of C* in these resistant cultivars means that their colour is less saturated in comparison to susceptible ones with a high chroma. Estimation of the hue difference (ΔH*ab) and hue angle h* indicated that the colour of the cultivars most colonized by onion thrips had a more yellowish hue while that of the least infested plants was more grey [Tab. 1, 2]. Colorimetric values of leaf colour were correlated with attractiveness to thrips: typically, higher b*, C*, and h* values and lower a* attracted more thrips; therefore, we concluded that the vivid, in-tense green-yellowish leaf colour of susceptible varieties might have been the cause of the observed thrips preference [Tab. 3].

Table 3. Pearson's correlation between colorimetric characteristics of onion leaves and actual count and proportional abundance of adults *Thrips tabaci* in 2015 (n = 32) and in 2016 (n = 32).

Colour coordinates	Thrips adults collected directly from plants				Thrips adults collected with sweeping net			
	Actual count		Proportional abundance		Actual count		Proportional abundance	
	r	p	r	p	r	p	r	p
	2015							
L*	**0.739**	0.000	**0.759**	0.000	**0.644**	0.000	**0.625**	0.000
a*	**-0.441**	0.011	**-0.454**	0.009	**-0.365**	0.040	-0.343 ns	0.055
b*	**0.471**	0.006	**0.464**	0.007	**0.0466**	0.007	**0.428**	0.014
C*	**0.472**	0.006	**0.467**	0.007	**0.460**	0.008	**0.423**	0.016
h*	**0.448**	0.010	**0.448**	0.010	**0.441**	0.011	**0.441**	0.011
	2016							
L*	**0.390**	0.027	**0.526**	0.002	0.255 ns	0.158	0.198 ns	0.275
a*	-0.333 ns	0.062	**-0.417**	0.017	-0.174 ns	0.341	-0.732 ns	0.691
b*	**0.371**	0.036	**0.463**	0.008	0.316 ns	0.078	0.255 ns	0.157
C*	**0.372**	0.036	**0.464**	0.007	0.305 ns	0.089	0.239 ns	0.186
h*	**0.410**	0.020	**0.410**	0.020	**0.365**	0.039	**0.365**	0.039

Note: bold r coefficient values designate significant correlation at $p < 0.05$; ns - not significant at $p<0.05$.

Conclusions

Despite the complication of interaction, we ascertained that plant colour significantly influences the level of varietal infestation by onion thrips. We identified useful genotypes, Tęcza and Wenta, for host plant resistance in onions to *T. tabaci*, and suggest a link between colour and antixenotic resistance, so that breeding for host plant resistance can be advanced more quickly. Direct evidence of preference by *T. tabaci* for a vivid, intense green-yellowish colour on onion was determined while the resistant cultivars had darker, green-grey-yellowish leaves. Additionally, the genetic basis of colour in onions and its influence on the behaviour of *T. tabaci* warrant further investigation. We acknowledge that additional factors, including foliar volatiles, are likely to further influence host choice. At the same time, it should also be realized that antixenosis may not be the only resistance mechanism at work in onion thrips resistance in onion.

Keywords: antixenosis; CIELAB; CIE L*C*h* colour space; chroma; hue; resistance; yellowness

Pobożniak, M.; Olczyk, M.; Wojtowicz, T. Relationship between Colonization by Onion Thrips (*Thrips tabaci* Lind.) and Leaf Colour Measures across Eight Onion Cultivars (*Allium cepa* L.). Agronomy 2021, *11*, 963. https://doi.org/ 10.3390/agronomy11050963