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NEW INSIGHT INTO THE *DELIA PLATURA* MEIGEN CAUSED ALTERATION IN NUTRIENT CONTENT OF SOYBEAN (*GLYCINE MAX* L. MERILL)

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Climate change has brought about an increasing level of seedcorn maggot (*Delia platura* Meigen, 1826) (*Diptera: Anthomyiidae*) damage in Hungary. In order to have a more accurate understanding of the effects of these plant injuries induced by the larvae of *D. platura*, the nutrient content of soybean (*Glycine max* L. Merill.) was studied. Our results show that the moisture, raw fat, raw fibre, and raw ash content of the batches damaged by *D. platura* were significantly less in comparison with that of the control samples. In response to the deleterious effect of the insect, the infected soybean plants showed forced ripening ($P = 0.004$) ($P > 0.05$). The difference of moisture content between damaged and control samples was 2.30% on average. The fact of nutritional value loss was also reflected by the alteration of sugar mobilisation. As the result of this experiment the sucrose breakdown to glucose and fructose during the germination was significantly slower in the damaged seeds than that of the control ones. Overall, this late and surprising damage caused by *D. platura* led to the forced ripening of the affected soybean plants and a significant change in their nutritional values. Based on the herein reported results, it is presumable that in cases when the current climatic extremities, which are envisaged to occur more frequently in the future, and effects of agricultural practices will be coincided in the future a qualitative change of the produced soybean batches can be expected through the damage caused by this fly species.

Keywords: Sugar mobilization – protein change – soybean – seedcorn maggot – *Delia platura*

INTRODUCTION

Owing to the efforts of the EU, i.e. the reduction of the imported soybean batches, and the ban on protein components of animal origin used as feeding stuff, the sowing areas of soybean is expected to with continuously grow in Hungary as well as in other European countries [6]. The value of soybean is given by its high protein content (38–40%) and its outstanding oil production (18–22%) [9, 23]. Although soybean is an extensively cultivated plant in the Carpathian Basin, it has a wide-range of pests [8, 16, 18, 21]. The pests of soybean cultivated for the purpose of use as a forage, may cause a 10–15% crop failure, yet the effect deteriorating the seed quality may be even larger than this [1, 4]. In Central Europe, in the plant protection technology of soybean there is no insecticidal protection planned in advance because the foreseeable

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expenditures are not in proportion with the achievable surplus projected to be achievable in crop yield [4, 6]. However, in the last few years the meteorological anomalies, the loosening of discipline in the field of agricultural engineering, and the non-compliance with the adequate rules of crop rotation have started to reach substantial dimensions [4].

So far the seedcorn maggot (*Delia platura* Meigen) (*Diptera: Anthomyiidae*) has been known as a periodical pest causing sporadically damage to soybean [16]. It has three generations, and it spends the winter in the soil in the form of pupae. The first generation occurs in April and May, the individuals of which lay their eggs onto the germinating plants. The larvae hatching from the eggs burrow themselves into the main root or the hypocotyl of the plant. As a result, the damaged plant may fall behind in its development or may even die. The second generation swarm and cause damage in June and July, while the third generation does so in September [13, 16]. The maggot-type larvae damage the rootlets first, then the main root, and later on they invade the stem. Consequently, the development of the damaged plants slow down (at this stage of the infection they can be pulled out from the soil), and subsequently they die [13, 15, 16]. In the case of *D. platura* the generation causing the most considerable damage up to now have always been the first generation occurring in May [10].

A number of results have proven that the damage caused by *D. platura* is assisted not just by mild meteorological conditions, but also by the loosening of discipline in the field of agricultural engineering [5, 11, 12, 13, 14, 21]. In addition to the aforementioned facts, it is presumable that the damage induces some changes in the nutritional values of the affected plant [3].

The aim of this study was to gain a more profound insight into the changes of nutrient content of soybean concerning especially the carbohydrate and protein alteration caused by *D. platura*. Our results can contribute to the exploration of the trends of nutrient content alteration in arthropod-damaged soybean.

MATERIALS AND METHODS

Damaged and intact soybean samples were collected form the arable land of Dráva-Coop Zrt. in Barcs (GPS co-ordinates: X521739, Y69328) on 16 July 2014. Prior to the sample collection no insecticidal chemical prevention was performed on the area. Damaged or control samples for the experiment, both from the underlying Isidor soybean variety.

Both the intact and the damaged seeds were removed from the pods by strength of arm, subsequently the seeds harvested in this manner were taken to the laboratory; and the analyses were performed at the Physiology and Biochemistry Laboratory of the Faculty of Agricultural and Environmental Sciences of the University of Kaposvár (Kaposvár, Somogy county). Moisture content [(MSZ 6496:2001)] [19], and raw protein content [(MSZ EN ISO 5983-2-:2009)] [19] were investigated in 10 damaged and intact (further: control) samples. Total amino acid content [(MSZ EN ISO 13903:2005)] [19], amino acid analyser happened to the test, as well as the total fibre fractions [(MTK-1990. II.8.2. MTK)] [19] were also determined. Furthermore the fatty acid composition of the samples was also analysed [(FAME-001:2001; FAME)] [19].

In order to compare the germination process, sugar mobilisation was also followed up in the damaged *versus* control samples. After surface sterilization (3% hypochloric acid), the seeds were soaked in sterile distilled water for 24 hours, prior to germinating them for 7 days in Petri dishes between double layers of filter papers humidified with sterile water in the dark thermostat at 25 °C. Samples were taken every day at the same time. During the sugar content determination the germinating seeds were extracted under reflux of distilled water. The combined fractions were filtered, and dried under vacuum (40 °C), and then solved in distilled water. Determination of glucose, fructose and sucrose content were performed by using the Boehringer Mannheim GmbH test kit.

Nutrient values of different samples were statistically analysed by one-way ANOVA by using the R software package. For the statistical evaluation of the results of the analyses of sugar mobilisation two-sample t-test was used. For each treatment, six samples were examined.

RESULTS

As it had been expected, damage caused by *Delia platura* Meigen induced some discernible changes in Weendei analysis parameters of soybean seeds. Moisture, raw protein, raw fat, raw fibre and raw ash were evaluated by one-way analysis of variance (Table 1). Soybeans damaged by the fly were seen to be forced in ripening, a fact also reflected by the P = 0.003 value, which can be described as strongly significant. The trend in raw protein content, however, contrary to our expectations, cannot be described as significant (P = 0.455); raw protein content in the damaged batches could be found to be decreased by only 1–1.5% on the average. The raw fat content showed significant values in the damaged batches in comparison with the control a deviation of 1.5–2.0% (P = 0.006) on the average could be detected. The raw fibre content reached a similar significance level in comparison with the healthy soybean

Table 1
Results of Weendei analysis of damaged and control soybean batches in%

		Moisture content	Raw protein content	Raw fat content	Raw fibre content	Raw ash content
Control	$\bar{X}$	14.00	35.95	20.00	5.75	4.87
	SE	0.058	0.044	0.07	0.029	0.037
Damaged	$\bar{X}$	11.70	35.35	18.65	4.15	4.45
	SE	0.072	0.375	0.039	0.035	0.115
Absolute differences in $\bar{X}$		2.30	0.60	1.35	1.60	0.40
P		0.003*	0.455	0.006*	0.001*	0.029*

*Statistical significant relationship (P≤0.05).

Table 2
Proportion of amino acids and ammonium occurring in the damaged and control soybean (g AA/100 g pattern)

	Control (±SE)	Damaged (±SE)
Aspartic acid	4.02±0.23	4.25±0.19
Threonine	1.30±0.41	1.36±0.32
Serine	1.72±0.33	1.79±0.45
Glutamic acid	6.61±1.34	6.76±1.94
Proline	1.75±0.21	1.79±0.33
Glycine	1.47±0.11	1.55±0.23
Alanine	1.44±0.18	1.53±0.09
Cysteine	0.50±0.28	0.50±0.31
Valine	1.67±0.41	1.72±0.36
Methionine	0.47±0.11	0.46±0.08
Isoleucine	1.58±0.24	1.66±0.19
Leucine	2.66±0.41	2.76±0.37
Tyrosine	1.16±0.20	1.25±0.22
Phenilalanine	1.75±0.15	1.83±0.18
Histidine	0.98±0.11	1.04±0.17
Lysine	2.20±0.09	2.30±0.10
Arginine	2.68±0.24	2.66±0.13
Ammonium (NH_3)	0.35±0.05	0.39±0.11

batches (P = 0.001). The last parameter of the Weendei analysis concerns raw ash content, and this also showed significant difference in comparison with the undamaged, control soybean (P = 0.029).

Amino acid analysis of damaged and control soybean batches was also carried out. As the data in Table 2 shows, in the majority of amino acids a non-characteristic deviation can be seen in the damaged batches with the exception of cysteine, arginine, and methionine. All these three are α amino acids; cysteine is not essential, arginine and methionine are essential amino acids. Cysteine and methionine are two sulphur-containing amino acids, which have an important role in the construction of proteins.

The germination process was followed through carbohydrate metabolism. As Fig. 1 shows well, the sucrose breakdown of control samples was faster, therefore values of glucose and fructose were intensively increased. Conversely, the sucrose breakdown of damaged samples was much slower. This tendency was observed from the 3rd day. From our data it is conspicuous the germination processes started slower than in the damaged seeds as compared to the control. However, characteristic deviation was observed neither in the case of fructose (P = 0.165), nor in the case of glu-

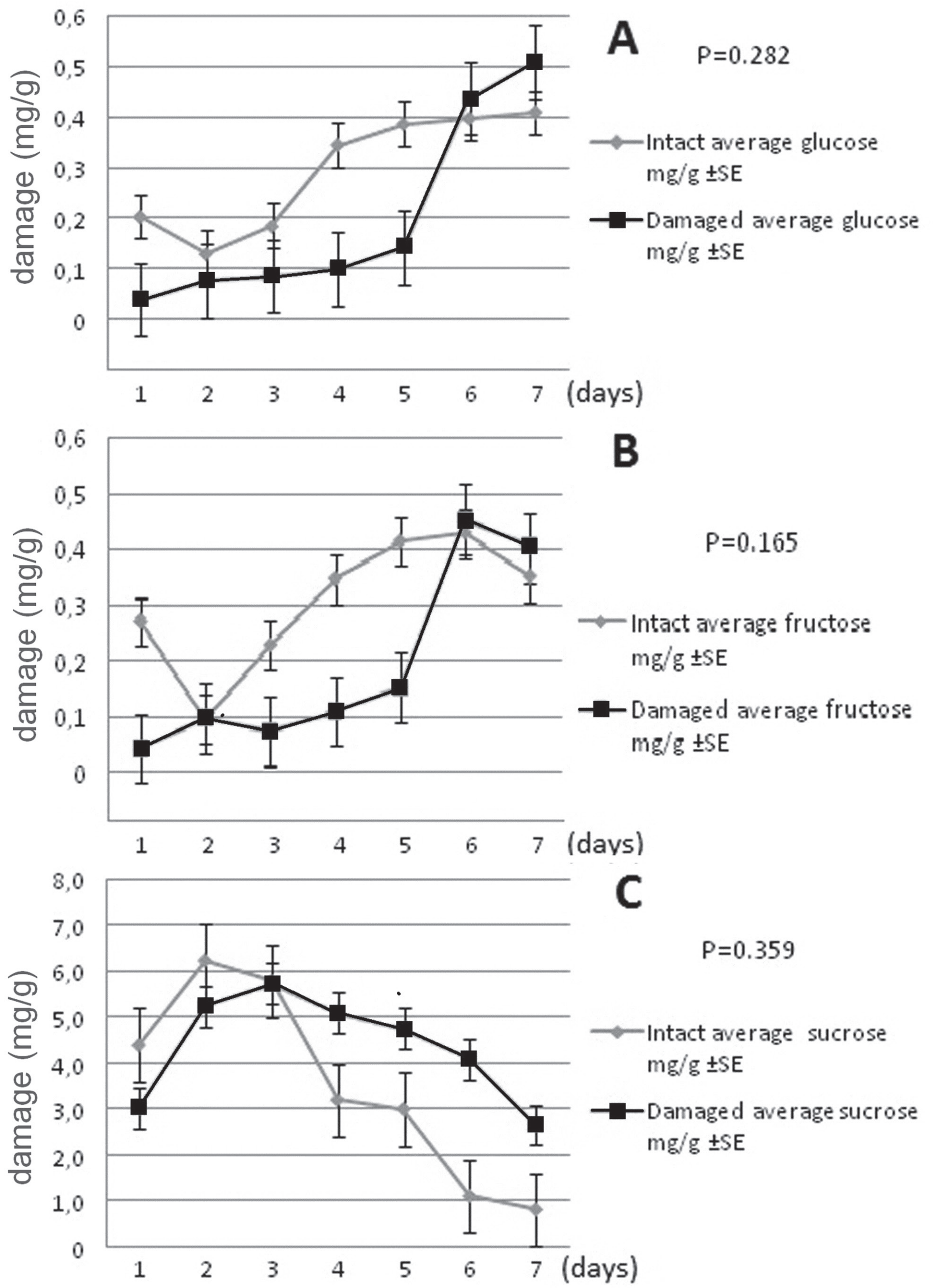

Fig. 1. Results of sugar mobilisation in the damaged and control soybean batches A: glucose; B: fructose; C: sucrose

cose (P = 0.282), the deviation between the control and the damaged batches is not significant. Sucrose content decreasing in 3rd day was confirmed (P = 0.359) both control and damaged samples. The diagram therefore shows no significant deviation in the cases of either sugar type.

DISCUSSION

According to our investigations, the damage caused by *Delia platura* Meigen reduced the raw protein (–0.60%), raw fat (–1.35%), raw fibre (–1.60%), raw ash (–0.40%), and moisture (–2.30%) content of soybean in a verifiable manner. Statistical evaluations performed on the data of the analyses did not verify clearly the pronounced reduction of the raw protein content.

Carbohydrate metabolism is a central biological process, because the synthesis and the breakdown of lipids, nucleotides and proteins are coupled to it by means of several metabolites. Therefore, the disruption of this important process impacts on several physiological cycles which can be manifested in size, composition and adaptive ability of plants [2, 22] among other parameters. On the other hand, some parameters of carbohydrate metabolism are quick and sensitive indicators of biotic and abiotic stress [17], as it is highlighted by our data. Our results also shown that in the case of these mainly protein storing seeds the carbohydrate metabolism seems a very sensitive indicator of the germination processes. Decreasing intensity of sucrose breakdown may hint at some kind of disturbance in the germination and subsequently in the homogeneity of crop emergence.

In summary, our findings suggest that late damaging of soybeans cultivated in the Carpathian Basin caused by *D. platura* may and should be expected due to meteorological anomalies occurring due to climate change, therefore soybean will provide lesser yields per hectares, as well as deteriorations in the nutritional values which is likely to cause loss in the feedstuff of soybean. All these considerations support the notion of Balikó [4] stating that "in the structure of plant cultivation soybean could play a role that can hardly be substituted by any other crop".

Helicoverpa zea Boddie can cause damage similar to that caused by the *D. platura*. Bi et al. [7] analysing soybean batches showed that due to the damage by this owlet-moth the quality of protein was decreased. In addition, the damage increased lipoxygenase activity (53%), the proportion of lipid peroxidation products (20%), and the trypsin inhibitor content (34%) was also higher than in the control plant. Further, a 5.9% loss in the content of free amines, and a 19% loss in the content of total thiols could be observed in the damaged batch. This is supported by the results of Oerke [20], showing that the potential loss caused by weeds may reach as high as 34% whereas concerning animal pests and pathogens this data is close to 16–18% in soybean. Based on our results it can be predicted that in the light of drought summers occurring due to climate change plant protection, interventions cannot be avoided in the future even in the case of soybean.

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