Game browse and its impact on selected grain crops

R. Cerkal[1], K. Vejražka[1,4], J. Kamler[2,3], J. Dvořák[2]

[1]*Faculty of Agronomy, Mendel University of Agriculture and Forestry in Brno, Czech Republic*
[2]*Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry in Brno, Czech Republic*
[3]*Institute of Vertebrate Biology, v.v.i., Academy of Sciences of the Czech Republic, Brno, Czech Republic*
[4]*Agricultural Research Ltd., Troubsko, Czech Republic*

ABSTRACT

This work presents the results of a survey that studied simulated plant browsing by herbivores. In 2004–2006, winter wheat, spring barley, and maize field trials were founded in order to monitor the impact of different levels of defoliation (leaf area reduction) on the yield and grain quality. The defoliation was carried out by means of mechanical removal of plant parts in the early growth stages. Selected qualitative parameters were determined in the harvested grain of wheat and barley. Statistically significant influence of leaf area reduction (LAR) on grain yield (decrease by 4–14%) was found only in maize in 2004. No statistically significant influence of the leaf area reduction on thousand grain weight (TGW) was found in any of the studied crops. The leaf area reduction in barley did not affect grain characteristics; however, it had a statistically significant influence on the quality of wheat grain. Moreover, wheat reduction statistically significantly increased the falling number (by 29–39 s) and decreased SDS test values (by 8–9 ml).

Keywords: game damages; herbivores; defoliation; compensatory response; leaf area reduction

Field crops are considerably damaged by biotic factors every year. FAO has estimated that these losses reach 35% of potential yields. A large part of the production losses (approx. 12%) has been caused by pathogenic microorganisms (viruses, bacteria, fungi), approximately 10% of damage has been put down to weeds, and approximately 14% to animal pests.

Field crops are also often consumed by large wild herbivores that cause extensive damage in many localities of the Czech Republic. Populations of large herbivores are managed by hunters but unfortunately, maintenance of the tolerable intensity of the damage has been lacking. One of the main problems is the system of public ownership of game and private ownership of land, which complicates comprehensive solution to the issue of the coexistence between game and agriculture (Conover et al. 1995) and lack of information about interactions between herbivores and crops. Crops that are most seriously damaged by game are cereals (Tzilkowski et al. 2002). The yield loss depends mainly on the intensity of the damage and the growth stage in which the damage took place. Identifying periods in which crops are sought after by herbivores is therefore crucial in order to limit the yield losses. The prevention measures currently in use are expensive and have only temporary effect (Belant et al. 1997, Gilsdorf et al. 2004). Cereals are damaged by herbivores in two main periods: the early stages of growth when the game feeds on leaves and in the maturing stage, when the herbivores browse on spikes and cobs (Obrtel and Holišová 1983). While browsing on spikes or cobs leads to irreversible yield decrease (Diekmann 1983), leaf area damage inflicted at the beginning of growth does not necessarily lead to drop in the yield or the quality of the grain under certain conditions

Supported by the Ministry of Agriculture of the Czech Republic, Projects No. QF4192, MSM 2629608001 and by the Ministry of Agriculture of the Czech Republic, Project No. 1M0570.

(Shapiro et al. 1986). Winter is also a critical period as there are not enough natural food sources available. During this season, herbivores concentrate primarily on overwintering arable crops and permanent grass lawns (Skládanka 2005) that are often damaged irreversibly.

Because the responses of plants that were damaged on their vegetative parts by game browsing at the beginning of growth vary, it is impossible to simply predict the effects of this type of damage on the yield. The only realistic ways to improve the estimation of grain yield decrease caused by browsing on leaves are trials in which the damage on selected crop species is simulated. Regarding the yield-influencing factors, it is necessary to monitor the impact of the damage in relation to its intensity, the crop species, and the growth stage.

Our objective was to determine the ability of selected field crop species to recover after simulated game browsing and to quantify the effect of defoliation on the yield and quality.

MATERIAL AND METHODS

The defoliation impact was monitored in these model crops: winter wheat (*Triticum aestivum* L. emend. Fiori et Paol.), maize (*Zea mays* L.) and spring barley (*Hordeum vulgare* L.). Field experiments were conducted by means of the Latin square in the locality of Žabčice near Brno (Czech Republic; average altitude 179, latitude N 49°01', longitude E16°36', maize production region) in 2004 and 2005 (wheat, barley), and in 2004–2006 (maize). The soil type was classified as gley fluvisoil with high fertility. The fore crops for the individual species were – maize (for spring barley), pea (for winter wheat), and early potatoes (for maize). The crops were treated with pesticides in the course of vegetation. Nitrogen fertilisation was implemented based on the content of N_{min} in the soil (maize), and in case of wheat and barley also on the basis of an inorganic analysis of the plants (doses are displayed in Table 1).

The acreage of the harvest area of each plot was 20 m^2 (wheat, barley) and 25 m^2 (maize). The leaf area reduction was carried out in the following growth stages – wheat and barley BBCH 30 (beginning of stem elongation) and maize BBCH 16 (6 leaves unfolded). The leaf area was reduced from 0, 25, 50 and 75% by scissors (maize) and by lawn mower (other species) in the whole trial plot. The real reduced leaf area was established by ratio on the basis of the plant height (wheat, barley) and number

Table 1. Agrotechnical trial data

Crop	Year	N uptake			Days		
		dose (kg/ha)	BBCH growth stage	sowing rate (per ha)	from sowing to LAR	from LAR to harvest	of vegetative period
Winter wheat	2004	30	BS	4 MGS	210	94	306
		40	R				
		30	30				
		30	51				
	2005	30	BS		200	96	296
		40	R				
		30	30				
		30	51				
Spring barley	2004	15	23	4.5 MGS	38	87	125
	2005	0			41	76	117
Maize	2004	30	BS	80 thousand	48	120	168
	2005	40	BS		34	129	163
	2006	40	BS		49	127	176

BS – before sowing; R – regeneration dose of N (early in spring); MGS – millions of germinative seeds; LAR – leaf area reduction and size of leaves (maize). It was observed in practice that plants are highly attractive for herbivores during the above stated growth stages (Obrtel and Holišová 1983). The removed plant parts were taken away from the plots. The monitored parameters in all crops were the yield (t/ha) and TGW (g). In the case of wheat, the grain over sieve 2.5 mm (%), grain protein content (%), falling number (s), sedimentation test by Zeleny (ml) and bulk density (g/l) were also determined. The following qualitative parameters were monitored in the grain of barley: grain over sieve 2.5 mm (%), grain protein content (%), starch content (%) and extract in congress mash (%). These qualitative parameters were determined by commonly used laboratory methods.

The obtained data were evaluated using the analysis of variance and the Tukey HSD test using the statistical program Statistica ver. 7.0. (level of significance $P \leq 0.05$).

RESULTS AND DISCUSSION

The established yield and TGW for individual crops and trial variants are displayed in Table 2. To provide a better clarity, the comments of the results are presented separately for each crop.

Winter wheat

The risk of the winter wheat damage is substantial due to the long vegetation period of this crop. Determining the contribution of individual factors to the yield and qualitative loss is complicated. In the past, experiments with simulated leaf stem and spike damage were conducted in order to quantify losses caused by hailstorms (Sanchez et al. 1996, Stülpnagel et al. 2005). Nowadays, a similar problem is being solved in connection with the damage inflicted by game.

In the scope of our trial series, no statistically significant influence of the leaf area reduction on the grain yield was found (Table 2). Moreover, it was evident that, provided the conditions are optimum, the leaf apparatus damage (in BBCH 30) can even "stimulate" the production processes. Results acquired in 2005 (yield after reduction greater by 3 to 7%) are the proof of this finding. In this year, the plant regeneration process was

Table 2. Crop's yield and TGW (14% moisture) and the results of testing of differences among individual factors levels (n = 4)

Crop	Year		Yield (t/ha)				TGW (g)			
			leaf area reduction							
			0%	25%	50%	75%	0%	25%	50%	75%
Winter wheat	2004	abs.	10.03^{a}	10.27^{a}	10.05^{a}	10.16^{a}	36.5^{a}	37.0^{a}	37.3^{a}	36.9^{a}
		% rel.	*100*	*102.4*	*100.2*	*101.3*	*100*	*101.4*	*102.2*	*101.1*
	2005	abs.	8.16^{a}	8.71^{a}	8.61^{a}	8.40^{a}	35.6^{a}	36.7^{a}	36.5^{a}	37.1^{a}
		% rel.	*100*	*106.7*	*105.5*	*102.9*	*100*	*103.1*	*102.5*	*104.2*
Spring barley	2004	abs.	8.33^{a}	7.60^{a}	7.42^{a}	7.51^{a}	51.6^{a}	51.2^{a}	52.2^{a}	51.7^{a}
		% rel.	*100*	*91.2*	*89.1*	*90.2*	*100*	*99.2*	*101.2*	*100.2*
	2005	abs.	6.40^{a}	6.67^{a}	6.93^{a}	6.82^{a}	50.9^{a}	52.7^{a}	51.2^{a}	52.4^{a}
		% rel.	*100*	*104.2*	*108.3*	*108.1*	*100*	*103.5*	*100.6*	*102.9*
Maize	2004	abs.	14.32^{a}	13.70^{ab}	13.26^{ab}	12.22^{b}	420.0^{a}	386.4^{a}	420.3^{a}	403.3^{a}
		% rel.	*100*	*95.7*	*92.6*	*85.3*	*100*	*92.0*	*100.1*	*96.0*
	2005	abs.	10.90^{a}	10.77^{a}	10.59^{a}	9.64^{a}	412.3^{a}	426.1^{a}	415.4^{a}	426.7^{a}
		% rel.	*100*	*98.8*	*97.2*	*88.4*	*100*	*103.3*	*100.8*	*103.5*
	2006	abs.	9.26^{a}	10.07^{a}	9.72^{a}	9.94^{a}	417.6^{a}	433.3^{a}	423.2^{a}	406.4^{a}
		% rel.	*100*	*108.7*	*105.0*	*107.3*	*100*	*103.8*	*101.3*	*97.3*

Average values marked with different letters represent statistically significant differences at the significance level of 95%

favourably influenced by regular and sufficient precipitation.

A study of the transport of photosynthates to the grains has shown that most of the reserve materials stored in the grains are the products of photosynthesis in the apical parts of the plant. Most of the photosynthates accumulated in the grains originate from the ear, awns, leaf blades and sheaths of the upper leaves, and from the upper internodes of the culm (Petr 1988).

TGW values are closely related to leaf area duration (LAD) values. The leaf area loss was always sufficiently compensated for until the flowering period, therefore, there was no TGW drop registered after the leaf apparatus reduction (Table 2).

No conclusive changes in most of the monitored quality parameters values were found as a result of the leaf area reduction (Table 3). However, the plants' stress expressed itself by the rise of the falling number values and drop in the sedimentation test values. The usage of such grain in bakery might be difficult.

Spring barley

Due to the shortness of its vegetation period, spring barley is very sensitive to the factors of the external environment (Richter et al. 2006). The attractiveness of barley plants for game is high (early sowing, early emergence of the green mass). The damage is caused not only in the early stages of growth but also later, often repeatedly (Selting and Irby 1997). In 2004, grain losses by 9, 11, and 10% were observed (in case of 25, 50 and 75% leaf area reduction, Table 2). The losses were also put down to the relatively unfavourable weather conditions during the time after the damage. In 2005, the most "damaged" variants had a yield increase of more than 8% after plentiful precipitation. Like at wheat, barley grain weight gained during the time of its filling depends on the activity of the organs located in the upper third of the plant (e.g. Tambussi et al. 2007). Furthermore, barley plants have the ability to form phytomass intensively in a very short time (Richter et al. 2006). As a result, the loss of assimilatory organs is quickly compensated without the negative impact on the yield (Cerkal et al. 2006).

TGW is a very variable parameter in spring barley. At the same time, it is also a parameter that correlates with certain markers of malting quality such as the starch content and extract. No direct effect of the leaf area reduction on the TGW values was proved in our experiments (Table 2). Likewise, the impact of the reduction on other monitored quality parameters was not verified (Table 4). In 2005, an inconclusive tendency of drop in the content of N substances in the grain in all variants with the reduced leaf area was registered. Nevertheless, it is important to emphasize that the content of N substances is primarily influenced by agroecological conditions of growing. A statistically inconclusive increase in the extract values occurred in 2005 as a result of greater leaf reduction (50 and 75%).

No tendentious dependence between the yield of the grain over sieve 2.5 mm (neither relative nor absolute), the starch content in the grain and level of the leaf reduction was proved.

Table 3. Average values of monitored quality parameters of winter wheat and the results of testing of differences among individual factors levels (n = 4)

Year	LAR (%)	Grain over sieve 2.5 mm (%)	Grain protein content (%)	Bulk density (g/l)	Falling number (s)	Sedimentation test by Zeleny (ml)
2004	0	91.82[a]	10.70[a]	819.83[a]	339.38[b]	34.38[a]
	25	91.94[a]	10.57[a]	819.25[a]	378.50[a]	34.38[a]
	50	91.55[a]	10.25[a]	818.45[a]	368.63[ab]	33.00[a]
	75	91.75[a]	10.41[a]	818.85[a]	373.56[a]	33.69[a]
2005	0	77.61[a]	10.74[a]	772.50[a]	388.88[a]	55.75[a]
	25	78.79[a]	10.31[a]	773.25[a]	384.00[a]	47.38[b]
	50	81.04[a]	10.52[a]	778.50[a]	411.13[a]	46.38[b]
	75	80.48[a]	10.35[a]	777.50[a]	393.13[a]	46.13[b]

LAR – leaf area reduction; average values marked with different letters represent statistically significant differences at the significance level of 95%

Table 4. Average values of monitored quality parameters of spring barley and the results of testing of differences among individual factors levels (n = 4)

Year	LAR (%)	Grain over sieve 2.5 mm (%)	Grain over sieve 2.5 mm (t/ha)	Grain protein content (%)	Starch (%)	Extract (%)
2004	0	93.15[a]	7.76[a]	9.50[a]	63.48[a]	82.43[a]
	25	92.82[a]	7.05[a]	9.55[a]	63.60[a]	82.38[a]
	50	93.07[a]	6.91[a]	9.43[a]	63.38[a]	82.58[a]
	75	92.95[a]	6.98[a]	9.49[a]	63.49[a]	82.48[a]
2005	0	90.26[a]	5.78[a]	12.33[a]	63.25[a]	80.20[a]
	25	89.74[a]	5.99[a]	11.90[a]	62.88[a]	80.40[a]
	50	90.36[a]	6.26[a]	11.68[a]	63.13[a]	81.00[a]
	75	93.32[a]	6.36[a]	11.68[a]	62.88[a]	81.00[a]

LAR – leaf area reduction; average values marked with different letters represent statistically significant differences at the significance level

Maize

Unlike the thick-sown cereals (wheat, barley), maize has a very limited ability to compensate for its yield-generating elements. Negative influence on the grain yield of the maize hybrid was conclusive in some trials that examined different ranges of simulated leaf area damage (e.g. Vasilas et al. 1991). On the contrary, other studies show that this type of damage does not have to be the cause of the drop in the grain yield (e.g. Vasilas and Seif 1985). Precipitation amount and generally weather during the time after the damage, when the plants "regenerate", has been considered to be the decisive factor (e.g. Kosová et al. 2005). The extent of the leaf area loss also plays a crucial role, which was established in our trials, too. Our results did not show direct statistically significant influence of the progressive leaf area reduction on the grain yield. However, the tendency to yield decrease after the reduction (4–15% and 1–12%, Table 2) was observed during years with low precipitation amounts that followed the simulated damage (2004, 2005). On the other hand, in 2006, when the precipitation amount was greater, an increase in the grain yield in the range of 5–9% (Table 2) occurred in spite of the leaf area reduction. Similar results were acquired by Yang and Midmore (2004) who found distinctive yield loss after the leaf area reduction was inflicted upon plants with moisture deficiency. The above stated fact corresponds with the finding that approximately 10% of the grain dry mass is made of so-called mobile assimilates that are retranslocated from vegetative organs (Vidovič 1988). During ontogenesis, the plants must, however, form a sufficiently large and photosynthetically efficient leaf area as well as an adequate number of flower primordia of female inflorescence, and subsequently cereal grains – the acceptors of assimilates (sink). This is only possible if the sufficient moisture supply and available nutrients are provided from the very beginning of vegetation (El Hallof and Sarvari 2006). No statistically significant differences in TGW values among the variants were found during any of the trial years (Table 2).

The results proved that the simulated leaf apparatus reduction in spring barley and winter wheat plants that took place at the time of transition from the vegetative to the generative phase (BBCH 30-31) was not fatal nor did it have statistically conclusive influence on the yield and TGW. Statistically significant influence of the barley leaf apparatus reduction on the monitored qualitative parameters of the grain was not found. The wheat grain quality was conclusively influenced by the leaf area reduction.

Appeal of maize to game is low until the cob formation stage so the plants serve mainly as a game shelter. Maize has a long vegetation period during which it is able to produce a great volume of phytomass. It was proved that maize plants possess a high ability to regenerate the leaf area and to completely replace its loss in a very short time. Therefore, the leaf apparatus reduction of the maize plants in the growth stage of six leaves unfolded

(BBCH 16) did not cause any yield loss or TGW values decrease during any of the trial years.

REFERENCES

Belant J.L., Ickes S.K., Tyson L.A., Seamans T.W. (1997): Comparison of four particulate substances as wildlife feeding repellents. Crop Protection, *16*: 439–447.

Cerkal R., Dvořák J., Kamler J., Vejražka K. (2006): Damage to spring barley plants caused by herbivores. In: Zimolka J. et al. (eds): Barley – forms and utility trends in Czech Republic. 1st edition. Profi Press, s.r.o. Prague: 120–125. (In Czech)

Conover M.R., Pitt W.C., Kessler K.K., Dubow T.J., Sanborn W.A. (1995): Review of human injuries, illnesses, and economic-losses caused by wildlife in the United-States. Wildlife Society Bulletin, *23*: 407–414.

Diekmann M. (1983): Influence of browsing on the harvest of various cultivated agricultural plants – results of experiments with simulated browsing. Zeitschrift fur Jagdwissenschaft, *29*: 95–110.

El Hallof N., Sarvari M. (2006): Effect of different fertilizer doses on yield, LAI and photosynthetic activity of maize hybrids. Cereal Research Communications, *34*: 441–444.

Gilsdorf J.M., Hygnstrom S.E., Ver Cauteren K.C., Clements G.M., Blankenship E.E., Engeman R.M. (2004): Evaluation of a deer-activated bio-acoustic frightening device for reducing deer damage in cornfields. Wildlife Society Bulletin, *32*: 515–523.

Kosová K., Haisel D., Tichá I. (2005): Photosynthetic performance of two maize genotypes as affected by chilling stress. Plant, Soil and Environment, *51*: 206–212.

Obrtel R., Holišová V. (1983): Assessment of the damage done to a crop of maize (*Zea mays*) by roe deer (*Capreolus capreolus*). Folia Zoologica, *32*: 109–118.

Petr J. (1988): Yield Formation in Cereals. In: Petr J., Černý V., Hruška L. et al. (eds): Yield formation in the main field crops. Developments in Crop Science 13. Elsevier Ltd., Amsterdam: 154–172.

Richter R., Hřivna L., Ryant P. (2006): Plant nutrition and fertilization of spring barley. In: Zimolka J. et al. (eds): Barley – forms and utility trends in Czech Republic. 1st edition. Profi Press, s.r.o. Praha: 59–85. (In Czech)

Sanchez J.L., Fraile R., DelaMadrid J.L., DelaFuente M.T., Rodriguez P., Castro A. (1996): Crop damage: The hail size factor. Journal of Applied Meteorology, *35*: 1535–1541.

Selting J.P., Irby L.R. (1997): Agricultural land use patterns of native ungulates in South-eastern Montana. Journal of Range Management, *50*: 338–345.

Shapiro C.A., Peterson T.A., Flowerday A.D. (1986): Yield loss due to simulated hail damage on corn – a comparison of actual and predicted values. Agronomy Journal, *78*: 585–589.

Skládanka J. (2005). Effect of utilisation date on the yield and quality of a semi-natural grass stand in winter. In: XX. International Grassland Congress: Offered papers. Wageningen Academic Publishers, Wageningen: 454.

Stülpnagel R., Piepho H.P., Scheffer K. (2005): Simulation der durch Hagel verursachten Knickung der Halme von Wintergerste, Winterroggen und Winterweizen. Pflanzenbauwissenschaften, *9*: 9–18.

Tambussi E.A., Bort J., Guiamet J.J., Nogues S., Araus J.L. (2007): The photosynthetic role of ears in C-3 cereals: Metabolism, water use efficiency and contribution to grain yield. Critical Reviews in Plant Sciences, *26*: 1–16.

Tzilkowski W.M., Brittingham M.C., Lovallo M.J. (2002): Wildlife damage to corn in Pennsylvania: Farmer and on-the-ground estimates. Journal of Wildlife Management, *66*: 678–682.

Vasilas B.L., Fuhrmann J.J., Taylor R.W. (1991): Response of 3 corn hybrids to defoliation of neighboring plants. Canadian Journal of Plant Science, *71*: 311–315.

Vasilas B.L., Seif R.D. (1985): Defoliation effects on 2 corn inbreds and their single-cross hybrid. Agronomy Journal, *77*: 816–820.

Vidovič J. (1988): Yield Formation in Maize. In: Petr J., Černý V., Hruška L. et al. (eds): Yield formation in the main field crops. Developments in Crop Science 13. Elsevier Ltd., Amsterdam: 154–172.

Yang Z., Midmore D.J. (2004): Experimental assessment of the impact of defoliation on growth and production of water-stressed maize and cotton plants. Journal of Experimental Agronomy, *40*: 189–199.

Received on October 9, 2008

Corresponding author:

Ing. Radim Cerkal, Ph.D., Mendel University of Agriculture and Forestry, Faculty of Agronomy, Zemědělská 1, 613 00 Brno, Czech Republic
phone: + 420 545 133 322, e-mail: cerkal@mendelu.cz