Feeding Preferences in Greylag Geese and the Effect of Activated Charcoal

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ABSTRACT Greylag geese (*Anser anser*) can cause serious damage to agricultural fields near wetlands that are attractive for resting and nesting but not for feeding. Alternative plantings or spraying fields may prevent goose damage. We randomly designed 64 plots in spring 2004 and prepared plantings of white clover (*Trifolium repens*), white clover with perennial ryegrass (*Lolium perenne*; mixture), fertilized perennial ryegrass (grass), or unfertilized perennial ryegrass. We measured goose-dropping densities in plots as a measure of feeding preference in autumn 2004 (7 weeks), spring 2005 (6 weeks), and autumn 2005 (7 weeks) following removal of a protective fence and vegetation sampling for content analysis in 2004. We also sprayed activated charcoal (20 kg/ha) in a suspension on 32 plots (8/planting) to deter geese in autumn 2004 only. In a second experiment we examined pairs of greylag geese in cages for preferences between grass treated with or without activated charcoal. Charcoal did not deter geese in either experiment. However, dropping density averaged highest for clover (1.01/m^2), followed by the mixture (0.65/m^2), then fertilized (0.23/m^2) and unfertilized grass (0.16/m^2). Preferences were consistent in all 3 experimental periods. Fertilized grass reached 31.8 cm in height on average in spring, whereas clover measured 15.4 cm. Crude protein and water-soluble carbohydrate content (g/kg dry matter) was 294 and 49, respectively, in white clover and 183 and 139, respectively, in fertilized grass. We found a positive partial correlation independent of vegetation type between dropping densities and crude protein and a negative correlation with water-soluble carbohydrate content. Thus, to prevent grazing damage to agricultural fields, we recommend planting white clover, strongly preferred by feeding geese, in areas (fallow agricultural or nonagricultural) adjacent to their habitat and not in agricultural fields under production. (JOURNAL OF WILDLIFE MANAGEMENT 73(6):924–931; 2009)

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Populations of Canada goose (*Branta canadensis*), snow goose (*Chen caerulescens*), Ross's goose (*C. rossii*), and white-fronted goose (*Anser albifrons*) in North America and brent goose (*Branta bernicla*), greylag goose (*A. anser*), and pink-footed goose (*A. branchyrhynchus*) in Europe have expanded during the last 30 years (Ankney 1996, Van Eerden et al. 1996, Jefferies et al. 2003, Tombre et al. 2005, Wisz et al. 2008). Typical reasons include increased availability of grasses and grains of cultivars with improved yield, increased application of nitrogen fertilizers, and conversions of natural feeding sites to farmland (Van Eerden et al. 1996, 2005; Jefferies et al. 2003; Tombre et al. 2005; Van der Jeugd et al. 2006). Moreover, migrating geese have changed their staging sites from nonagricultural to agricultural regions. These changes have caused conflicts with agricultural interests in Europe and North America (Ankney 1996, Madsen 2001, Jefferies et al. 2003, Tombre et al. 2005, Hauser et al. 2007). Destruction of habitat and subsequent concentration of geese in remaining habitat have led to comparable conflicts in East Asia and Japan in particular (Amano et al. 2004). Management strategies to address these conflicts include shooting large numbers of geese (Amano et al. 2004, Hauser et al. 2007), scaring geese from fields with inter-alia, gas guns, scarecrows, tapes strung across fields, human bird-scarers (possibly augmented by shooting some geese), and managing agricultural land as alternative feeding areas (McKay et al. 2001; Amano et al. 2004, 2007).

Dutch authorities promote alternative feeding areas for geese by paying farmers who voluntarily tolerate geese on their land, but only between 1 October and 1 April. This measure is aimed at staging geese that feed in the Netherlands during migration, but resident geese also benefit from this tolerance. However, if they want to be compensated for damage that either migrating or resident geese may cause, farmers must apply shooting and scaring measures before 1 October and after 1 April. This compensation rule also applies for farmers who do not tolerate geese in the October–April period. Thus, the Dutch policy is ambiguous for geese, because half the year they are reinforced for foraging in some agricultural fields but chased and killed in others and the other half the year they are chased and killed in all agricultural fields. Such local shifts from tolerance to intolerance are particularly inconsistent for resident geese, such as the greylag goose. The greylag goose is the most common breeding goose in the Netherlands and accounted for 55% to 73% of annual agricultural damage from 2000 to 2004 (Van der Jeugd et al. 2006). However, crop damage by greylag geese occurs in all northwestern and in some central European countries as well (Van der Jeugd et al. 2006).

Greylag geese find excellent feeding habitat in Dutch pastures (Van Eerden et al. 1996, 2005), which are mostly planted with fertilized perennial ryegrass (*Lolium perenne*). In addition, nearby wetlands may provide good habitat to rest or breed, in particular if dominated by tall grasses, shrubs, and trees (e.g., willow [*Salix* sp.], birch [*Betula* sp.],

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or common alder [*Alnus glutinosa*]; Van Oene et al. 1999). Not surprisingly, greylag geese commonly migrate from wetlands to adjacent fields to forage. Local farmers report this as an increasing nuisance.

Consistent management is needed for resident greylag geese. Providing attractive alternative food sources for geese only in fallow areas and not reinforcing geese for feeding in areas under cultivation might alleviate conflicts between geese and farmers. White clover (*Trifolium repens*) is of interest as an attractive alternative food source for greylag geese, because brent geese prefer white clover over several species of fertilized grass (McKay et al. 2001). White clover is also preferred by white-fronted geese (Owen 1976), and barnacle geese (*Branta leucopsis*) feed on clover stolons in autumn in the marshes of Scotland's Solway Firth (Owen and Kerbes 1971). Moreover, white clover grows in symbiosis with *Rhizobium* bacteria, which are found in the roots and are able to fix atmospheric nitrogen (Høgh-Jensen and Schjoerring 2001), which is an additional value if clover is applied in areas reserved for geese, where man-made fertilizer is not applied.

However, nitrogen-fixation and the high protein content in cultivars of red clover (*Trifolium pratense*) and white clover have led to increasing use of clover–grass mixtures in temperate agricultural fields, which is seen as a solution to the growing environmental controversy arising from the application of nitrogen from agricultural sources (De Wit et al. 2004, Schils and Snijders 2004, Abberton and Marshalla 2005). Yet if clover–grass mixtures prove to be more attractive than fertilized grass to geese, problems farmers experience with geese may intensify. We, therefore, examined preferences in wild greylag geese in a controlled-choice situation offering white clover alone, clover–grass mixture, and grass alone, fertilized and unfertilized.

An additional measure for addressing the conflict between farmers and geese is to stop reinforcement of feeding on cultivated grass and, thus, to decrease or eliminate their preference for it. Geese may select against vegetation that is treated with activated charcoal; Mason and Clark (1995) found that such treatment reduced presence of snow geese. Other birds also do not prefer food that is treated with activated charcoal (Mason and Clark 1994). Thus, we also sought to determine preferences in greylag geese in choice situations offering vegetation treated and not treated with activated charcoal.

STUDY AREA

We conducted our study with wild geese in a field planted with perennial ryegrass in Marle, The Netherlands, on one bank of the river IJssel bounded by a dyke within an area designated as important habitat according to the European Union Bird directive. The river bank was high; flooding occurred only during part of winter, which did not kill the grass. A dairy farm operated on the same side of the river; on the other bank was the Buitenwaarden, a nature area consisting of different inlets fed by the river, patches of unfertilized grass, and bushes of mainly willow and common alder. The Buitenwaarden was frequented by resident breeding and migrating greylag geese, as well as white-fronted geese. Migrating greylag geese were present between September and April (Nilsson 2006). Geese crossed the river to forage in the agricultural fields along the river.

We conducted our experiment with caged geese on a field on a dairy farm 8 km south of the Dutch city of Groningen. The farmer planted perennial ryegrass in 2003 and cut it before the start of our experiment in May 2004.

METHODS

Alternate Food Sources

There were 3 experimental periods: autumn 2004, spring 2005, and autumn 2005. In March 2004, we defined a 10-ha experimental area between the river and dyke. Within that area we prepared a plot 14 m × 256 m parallel to the river bank and divided it into 64 test plots, each measuring 4 m × 14 m. The farmer killed the grass in the full plot area with 3 L/ha Roundup® Max (Monsanto Company, St Louis, MO) and subsequently ploughed and prepared the soil for sowing. On 26 April, we planted 32 test plots with perennial ryegrass (35 kg/ha), cultivar BG3 (Barenbrug BV, Oosterhout, Netherlands), 16 with white clover (10 kg/ha), large-leaved cultivar Alice (Barenbrug BV), and 16 with a mixture of both (clover: 5 kg/ha; grass: 30 kg/ha). On 30 August, we fertilized 16 of the 32 grass test plots by hand, at a rate of 80 kg N/ha. The result was a randomized block design of 16 fertilized and 16 unfertilized grass plots, 16 plots with white clover and 16 plots with clover–grass mixture. Immediately after sowing we fenced the full plot area to keep the geese out while vegetation grew. Fencing consisted of wire mesh 1 m in height, with wooden pole supports (8 cm in diam) every 4 m. The roof of the full plot area consisted of 6 evenly spaced 2-mm stainless-steel wires that we snared across the full length of the plot and supported every 50 m by plastic poles. The farmer regularly cut the growth in the pasture surrounding the 64 test plots for silage, according to normal farming practice, and cut the test plots 3 times through 30 August.

We sampled each type of vegetation in test plots on 1 November 2004 by cutting a strip measuring 0.8 m × 2 m out of 8 random plots. A forage evaluation laboratory (BLGG BV, Oosterbeek, Netherlands) dried, weighed, and analyzed samples for concentrations of crude protein, crude fiber, crude ash, and water-soluble carbohydrates, according to the Central Bureau for Livestock Feeding (2002), and for digestibility in vitro of organic matter (Tilley and Terry 1963) by applying methods and standards described by Tamminga et al. (1994). The laboratory also analyzed proportion of clover (% dry wt) in samples from clover–grass-mixture plots.

Experiments in 2005 followed cutting on 15 April and 20 September, fertilizing 3 days later, and fencing on 28 April and 27 September, respectively. Experiments started when we removed all wire mesh and fencing, but not the supporting wooden poles around the test plots, on 3 November 2004, 19 May 2005, and 8 November 2005. Experiments ended after 7 weeks, 6 weeks, and 7 weeks, respectively.

Table 1. Sample sizes of alternate food plots for greylag geese providing white clover (Cl), fertilized (Fert gr) or unfertilized perennial ryegrass (Unfert gr), or an unfertilized mixture (Cl and gr), and of plots in surrounding fertilized perennial ryegrass (Sur gr), observed at the bank along the river IJssel in Marle, the Netherlands, for 1) 7 weeks in autumn 2004 starting 3 November and including from week 4 onwards treatment of vegetation in test plots with activated charcoal, 2) 6 weeks in spring 2005 starting 19 May, and 3) 7 weeks in autumn 2005 starting 8 November.

		Period			
		Autumn 2004		Spring 2005	Autumn 2005
Vegetation	Treatment	Week 1–3	Week 4–7	Week 1–6	Week 1–7
Cl	no	16	8	4	4
	charcoal		8		
Cl and gr	no	16	8	4	4
	charcoal		8		
Fert gr	no	16	8	4	4
	charcoal		8		
Unfert gr	no	16	8	4	4
	charcoal		8		
Sur gr	no	10	10		30

Weekly observations followed fence removal. Each observation day started at 0900 hours, by first counting geese in the experimental area from the dyke at a distance of 150 m. Subsequently the observer counted and removed goose droppings from a 4-m^2 circular subplot located in the middle of each plot, 3 m from the riverside edge of the plot, and, as controls, from locations in the pasture surrounding test plots. Control locations were at regular distances from each other and 20–100 m from test plots (Table 1).

Dropping density was a measure of vegetation consumption (Owen 1971, Summers 1990, McKay et al. 2001, Loonen and Bos 2003). The observer also measured vegetation height in autumn 2004 and spring 2005 to the nearest 0.5 cm with a polystyrene disc (24 g, diam 20 cm), sliding along a calibrated stick (diam 1.5 cm) placed vertically on the ground. Leaves supported the disc, and the observer measured its height from the scale on the stick. The observer measured height at the top, middle, and bottom of the plot and calculated an average height/plot.

In autumn 2004 we sprayed 8 random plots/vegetation type (32 plots in total) with an activated charcoal suspension immediately after the observations of the third week of the experiment (Table 1) to test whether geese were deterred by charcoal on the vegetation. We applied a suspension of water with Norit SA 4 (Norit Nederland BV, Amersfoort, Netherlands; 20 g/L) and 3% (vol) Wilt-Pruf (Wilt-Pruf Products, Inc., Essex, CT) with a 10-L garden spray (Gardena Manufacturing GmbH, Ulm, Germany) at 2–3 bars pressure with a nozzle opening of 1 mm. Activated charcoal was a powdered, steam-activated carbon suitable for a large range of applications in the food industry. Median particle size was 30 μm. Wilt-Pruf is di-1-p-menthene, a major constituent of pine oil, and was used to fix the activated charcoal to the blades of grass. Mason and Clark (1995) had also used Wilt-Pruf for this purpose. We sprayed 1 L of the suspension over 10 m^2, which corresponded with 20 kg/ha activated charcoal, 6 times more than used by Mason and Clark (1995).

In 2005 we maintained 16 test plots (4/vegetation type) out of the 64 test plots. We had not treated these 16 plots in autumn 2004, and did not treat them in spring 2005 and autumn 2005 (Table 1). We did not maintain the rest of the test plots, because we treated these in 2005 with 2 other methods to deter geese (D. W. van Liere, CABWIM Consultancy, unpublished data).

In October 2006 we estimated the rate of activated charcoal loss from the grass leaves in a 20-m^2 patch in the experimental area. We treated this plot with activated charcoal suspension as described earlier and randomly selected 12 grass leaves coated with activated charcoal. We identified each blade by placing a small stick next to it. After the spray dried, we photographed the blade surface the same day, with a mm measure added to the photo for scale. We photographed the same leaf 1 week later and again 2 weeks later, and we recorded the amount of precipitation and wind on a daily basis. We calculated the surface covered with activated charcoal of the same part of the blade from the top to about one-third of the length in the 3 weekly photos. We used the object identification routine of JMicroVision v1.22 software (JMicroVision, Geneva, Switzerland), which selected the charcoal-covered surfaces, and calibrated the software by the width of the leaf against the mm measure in the photo.

We also investigated survival of clover facing persistent pressure from geese in the unfenced area after the autumn experiments. Thus we also measured the relative amount of soil covered by clover and its height in the clover plots on 1 February 2005 and 2006. We also measured height of the clover on 21 April 2006 (farm practice disallowed this measurement in 2005). We estimated the relative amount of clover cover with a 0.8 m $\times$ 0.8-m frame placed over the vegetation at an arbitrary location in the plot. We subdivided the frame with strings into equal squares of 8 cm $\times$ 8 cm and counted how many of the 100 squares were covered by clover. We measured vegetation height as described earlier.

We used SPSS 11.5 software (SPSS Inc., Chicago, IL) and analyzed forage qualities, with vegetation type as a fixed effect, with an analysis of variance (ANOVA) and compared means with a t-test ($n = 32$). For the first 3 weeks in the 2004 experiment we calculated partial correlations controlling for vegetation type between 1) average dropping

Table 2. Averages and standard deviation of dry matter (dm) content (% of fresh wt), amount (t, dm/ha), crude protein, crude fiber, crude ash and water-soluble carbohydrate (wsc, g/kg dm), and in vitro organic matter digestibility (ivomd, % of dm) of white clover (Cl), fertilized (Fert gr) or unfertilized perennial ryegrass (Unfert gr), or an unfertilized mixture (Cl and gr) sampled on 1 November 2004, 27 weeks after sowing, from test plots providing alternate food for greylag geese at the bank along the river IJssel in Marle, Netherlands.

	Dm		Amt		Protein		Fiber		Ash		Wsc		Ivomd		
Vegetation	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	n
Cl	13.7 a[a]	1.2	2.0 a	0.4	294	9	178	4	122 a	6	49	5	83	1	8
Cl and gr	14.3 a	1.0	2.0 a	0.3	265	26	197	12	123 a	3	67	13	81 b	1	8
Fert gr	18.3	1.5	2.4	0.4	183	10	224	5	113 b	3	139	19	80 b	1	8
Unfert gr	22.1	2.8	1.3	0.3	170	13	216	9	112 b	5	175	27	80 b	1	8

[a] Averages followed by the same letters in a column are not different ($P > 0.05$).

density/week and forage qualities of plots ($n = 32$), and 2) average dropping density/week and average height of the vegetation of plots ($n = 64$). We analyzed vegetation type and the spray of activated charcoal in an ANOVA as fixed effects on the dropping density/week averaged over the 4 weeks following spraying ($n = 64$). We analyzed the fixed effect of vegetation type on dropping density and vegetation heights with the plots as subjects and the 3 periods as repeated measurements. Estimates were the averages of measurements of each plot over the observation days within a period. We only included in the analyses the 16 untreated plots (see Table 1).

Deterrence of Caged Geese

We housed 14 1-year-old greylag geese in pairs in 7 cages. We obtained the geese from a group of about 100 animals that the University of Groningen kept for several generations in a 1-ha waterfowl enclosure. We spaced cages (2 m × 2 m × 1 m) 1 m apart in one row in the experimental area with fertilized perennial ryegrass that was 12 cm tall. A cage consisted of an aluminum frame with ribs of 2 cm. A black nylon net (mesh-width 3 cm) covered the top and sides. Half of the cage was on an untreated strip, the other half was on a strip of perennial ryegrass sprayed 1–3 days before with the same suspension of activated charcoal at the same rate as previously described (see Alternate Food Sources). We moved the cage with the 2 birds daily at 0900 hours and 1700 hours, sliding it gently to the adjacent 2 m × 2-m fresh plot of grass with one-half untreated and the other half sprayed with activated charcoal. Each day the treated grass alternated sides in the cage. We positioned a bowl of drinking water (25 cm × 25 cm × 10 cm) on the border between the treated and untreated strip of grass and against the cage wall. After 5 days, we assumed that geese were adjusted to the experimental situation and procedure, and we recorded our observations for 5 consecutive days. It did not rain during this period. As previously described we measured grass height of the plot offered between 0900 hours and 1700 hours, 2 days after geese were removed, which allowed grass to recover from trampling by the geese. We averaged the height of 5 locations in the 1 m × 2-m half of the plot. We used an ANOVA for repeated measures to test for the fixed effect of treatment on grass height with the 5 days as repetitions and cages as subjects. Our investigation protocol was approved by the Animal Experiments Ethical Commission of the University of Groningen (DEC no. 4105A).

RESULTS

Alternate Food Sources

All forage qualities differed among vegetation types (Table 2; dry matter content $F_{3,28} = 38.6$, amt of dry matter $F_{3,28} = 14.2$, crude protein $F_{3,28} = 118.3$, crude fiber $F_{3,28} = 49.3$, crude ash $F_{3,28} = 12.0$, water-soluble carbohydrate $F_{3,28} = 89.3$, in vitro organic matter digestibility $F_{3,28} = 11.3$, $P \leq 0.001$ in all cases). Dry matter, crude fiber, and water-soluble carbohydrate contents were lowest in white clover (75%, 79%, and 35%, respectively, of the amt found in fertilized grass; Table 2). Crude protein was highest in white clover (1.6 times the amt in fertilized grass). The amounts of clover and the clover–grass mixture were 2.0 t/ha, whereas the amount of fertilized and unfertilized grass was 2.4 t/ha and 1.3 t/ha, respectively (Table 2). The clover–grass mixture consisted on average of 53% (dry wt) clover (SD = 16), and had intermediate values of crude protein, fiber, and water-soluble carbohydrate contents.

During the experiment we observed 25–691 greylag geese in the experimental area. We observed an average of 130 geese (SD = 53) in 3 out of 7 visits made in autumn 2004 (in all 3 visits we observed all geese in the test-plot area) and 159 (SD = 93) in 5 out of 6 visits in spring 2005 (in one case we observed geese in the test-plot area). In autumn 2005, we observed 691 geese in 1 out of 7 visits (which also included geese in the test-plot area). Together with the observed greylag geese we also saw 2 white-fronted geese once in autumn 2004, 3 barnacle geese and 1 white-fronted goose once in spring 2005, and 682 white-fronted geese and 2 barnacle geese in autumn 2005.

Average density of droppings in a week was highest in white clover in all periods, followed by the clover–grass mixture, then fertilized grass and unfertilized grass, respectively. Density of droppings in white clover was 4.4 times the amount in fertilized perennial ryegrass, as calculated over all periods (Fig. 1; vegetation: $F_{3,12} = 78.2$, $P \leq 0.001$; period: $F_{2,24} = 1.6$, $P = 0.22$; vegetation × period: $F_{6,24} = 0.55$, $P = 0.76$). Weekly density of droppings in the grass in the pasture around the test plots did not differ from that in the fertilized grass plots (t-test; $t_{42} = 0.8$, $P = 0.41$) and tended to be higher than in unfertilized plots ($t_{42} = 1.9$, $P = 0.07$). Partial correlations between density of droppings and results of the vegetation analyses, controlling for vegetation type, were absent except

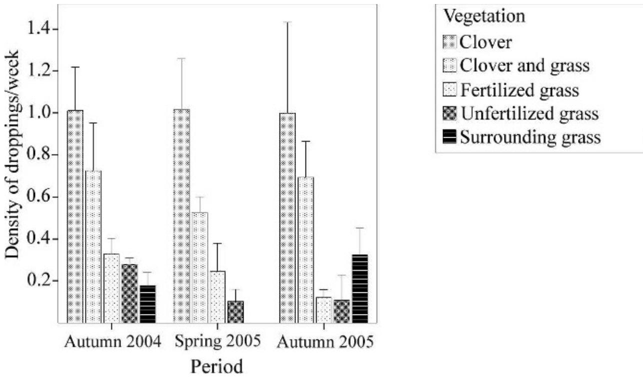

Figure 1. Average density (and SD) of greylag goose droppings accumulated in a week in test plots in autumn 2004 and 2005, beginning 3 November and 8 November, respectively, and in spring 2005, beginning 19 May (n = 4/vegetation type, 7 weekly observations in autumn and 6 in spring), and in fertilized grass surrounding test plots (n = 10 in autumn 2004 and n = 30 in autumn 2005) at the bank along the river IJssel in Marle, Netherlands.

for a positive correlation with crude protein ($r_{29} = 0.59$, $P \leq 0.001$) and a negative correlation with water-soluble carbohydrate contents ($r_{29} = -0.40$, $P < 0.05$).

Average height was 5.0 (SD = 2.8) cm and 15.4 (SD = 2.9) cm for white clover in autumn 2004 and spring 2005, respectively, but 11.0 (SD = 0.8) cm and 31.8 (SD = 8.5) cm in fertilized grass for these 2 experimental periods, respectively. The clover and grass mixture was 6.0 (SD = 2.1) cm and 26.6 (SD = 7.4) cm in autumn 2004 and spring 2005, respectively, and unfertilized grass was 10.3 (SD = 2.4) cm and 33.0 (SD = 2.4) cm, respectively (vegetation: $F_{3,20} = 13.6$, $P \leq 0.001$; period: $F_{1,20} = 122.3$, $P \leq 0.001$; vegetation × period: $F_{3,20} = 3.1$, $P = 0.05$). Fertilized grass in the pasture around the test plots averaged 5.1 (SD = 0.4) cm in autumn 2004. Partial correlation between average height of vegetation in the first 3 weeks of autumn 2004 and average density of droppings/week was negative ($r_{66} = -0.61$, $P \leq 0.001$).

On 1 February 2005 47% (SD = 9) of white clover plots was barren soil. Vegetation height was 2.1 (SD = 0.9) cm. In April 2005 there was no follow-up measurement, but clover had recovered on 25 May 2005, 6 days after we removed protective fencing, to 12.3 (SD = 1.8) cm and coverage was 100%. On 1 February 2006 37% (SD = 12) of the plot surface was barren soil and vegetation height was 1.7 (SD = 0.7) cm. On 21 April 2006, clover height was 3.3 (SD = 0.4) cm and 11% of the plot surface (SD = 7) was barren. All paired comparisons between the February and April measurements in 2006 were significant (Paired-sample t-test: $t_{15} \geq 5.8$, $P \leq 0.001$).

Dropping density did not differ between test plots with or without activated charcoal in 2004 and differed between vegetations, but there was no interaction (charcoal: $F_{1,56} = 0.4$, $P = 0.54$; vegetation: $F_{3,56} = 13.6$, $P \leq 0.001$; charcoal × vegetation: $F_{3,56} = 1.2$, $P = 0.34$), even as early as one week after we applied activated charcoal. Amount of charcoal on grass blades declined, but we still saw charcoal on the blades 4 weeks after application. Rain and wind action could have removed charcoal from the blades; weekly total precipitation was 7 L/m^2, 3 L/m^2, 0 L/m^2, and 18 L/m^2, respectively, in the weeks following application in 2004, and daily maximum wind speed averaged 6.3 m/second, 6.3 m/second, 5.6 m/second, and 9.9 m/second, respectively. We estimated the rate of loss based on the 12 treated blades we observed over 2 weeks in October 2006, which had more rain and wind than during the tests in autumn 2004 (weekly precipitation was 13 L/m^2 and 5 L/m^2, respectively, and daily max. wind speed averaged 15.0 m/sec and 9.9 m/sec, respectively). We identified each treated grass blade with certainty in 8 out of the 12 selected swards; we used only these 8 for our calculations. Average relative blade surface covered with activated charcoal calculated from the top one third of the blade declined from 9.5% (SD = 3.1) to 4.3% (SD = 2.0) in the first week and to 3.2% (SD = 1.6) in the second week (Friedman test, $\chi^2_2 = 16$, $P \leq 0.001$).

Deterrence of Caged Geese

Geese in all cages consumed both treated and untreated grass. Grass height did not differ between untreated (ht = 14.0 cm, SD = 1.3 cm) and activated charcoal treated grass (ht = 12.4 cm, SD = 1.6 cm; $F_{1,12} = 2.50$, $P = 0.14$).

DISCUSSION

Greylag geese preferred white clover over fertilized perennial ryegrass, corresponding to brent geese preferring white clover over different species of fertilized grass (McKay et al. 2001). White-fronted geese also prefer white clover (Owen 1976). We do not know which causal factors determine the choice of clover for greylag geese, but several (Owen 1972) and mutually related factors are likely, such as intensity of the green color of the vegetation (Owen 1976, Summers and Critchley 1990, McKay et al. 2001), taste of leaves (Owen 1976), tactile properties like roughness or waxiness of a leaf (Lieff et al. 1970, Owen 1976, Williams and Forbes 1980), or tensile strength of leaves that geese experience by the amount of force needed to break a leaf (Owen 1980), or at severing leave tissue (Conover 1991). Like Owen (1976) we assume that such immediate factors link with functional properties, such as low water-soluble carbohydrate and fiber content, and high nitrogen content in particular, which we found in white clover. High protein or nitrogen content correlates positively with preferences of geese in general (Sedinger 1997) and more specifically with preferences of barnacle geese (Ydenberg and Prins 1981, Prins and Ydenberg 1985, Stahl et al. 2006), brent geese (Stahl et al. 2006), and white-fronted geese (Owen 1975, Mathers and Montgomery 1997, Amano et al. 2004) in temperate winters and in spring, in snow geese in the Arctic summer (Harwood 1977), and in Canada goose before fledging (Sedinger and Raveling 1984). However Gauthier and Bédard (1991) did not find this in captive snow geese, nor do geese always prefer high-protein vegetation (Sedinger and Raveling 1984, Amano et al. 2004). Geese utilize the protein reserves they build up before migration in egg production and during incubation at the breeding grounds, even before food is available (Drent and Daan 1980, Ydenberg and Prins 1981). Nitrogen requirements would be the main drive to select nutrient-rich vegetation, but geese may also build reserves at the breeding grounds in spite of primary productivity lacking above ground (Arzel et al. 2006, Drent et al. 2006).

Density of droppings correlated negatively with vegetation height, suggesting that height either resulted in the observed preferences, or resulted from the preferences. Quality of grasses declines with increasing sward height (Summers and Critchley 1990, Hassall et al. 2001, Durant et al. 2004, Bos et al. 2005). Maturing white clover also increases in fiber content (Nielsen and Søegaard 2000) and leaves and petioles decrease in protein content, which occurs particularly during flowering (Søegaard 1994, Ayres et al. 1998). Increase in height may, therefore, result in reduced attractiveness. Nevertheless, height cannot be the main cause for the observed preferences; grass in the pasture around test plots was about the same height as clover in autumn 2004, but dropping density in clover was 5 times higher. Moreover, greylag geese compensate for reduced forage qualities with high intake rates and even prefer grass heights up to 12 cm compared to shorter grass (Durant et al. 2003, 2004), potentially resulting in grazed and shorter blades with high numbers of droppings. The negative correlation between density of droppings and vegetation height seems, therefore, to result from the observed preferences, although we cannot conclusively determine this.

If preference for grass depends on cyclic grazing that maintains grass at an attractive height and quality (Drent and Van der Wal 1999; Lang and Black 2001; Van der Graaf et al. 2002, 2006), then its attractiveness for geese may deteriorate with a disturbance of that cyclic pattern. Thus, attracting geese to a highly attractive alternative field with white clover might allow nearby grass fields to reach heights that are unattractive to geese. Alternative fields of white clover can be instrumental in attracting geese for successive years, because white clover plots in our study recovered during spring, despite that in winter they faced persistent pressure from geese and were 37–47% barren.

Treatment of grass with activated charcoal did not affect consumption by greylag geese, which was unexpected, because we applied 6 times more activated charcoal than Mason and Clark (1995). Moreover, we estimated that 3 times the amount used by Mason and Clark (1995) remained on our plots after 1 week and still twice the amount they used remained after 2 weeks. We found these amounts even after more rain and wind than in autumn 2004 when we sprayed test plots. Trampling by 2 geese in the 4-m^2 cages could have rubbed off or transposed the activated charcoal in the deterrent experiment. However, we would still have expected some effect of activated charcoal on consumption, because the cages were twice daily moved to fresh strips of treated and untreated grass.

The most likely explanation for the lack of an effect of activated charcoal on geese consumption is the small particle size of our activated charcoal. Mason and Clark (1994, 1995) used 106-μm Anjan-activaid activated charcoal, which is a blend of carbonaceous powders and fibers. We used Norit SA4, which was granular, and median particle size was 30 μm. Geese can differentiate leaf texture and reject leaves covered with hairs (Williams and Forbes 1980) and coarse or tough blades (Lieff et al. 1970, Conover 1991). Therefore, deterring effects of texture warrant further exploration.

MANAGEMENT IMPLICATIONS

Attractive white clover potentially distracts geese from fertilized perennial ryegrass, allowing grass to grow to such lengths that its forage quality declines for geese and to heights required in normal farming for cutting and silaging. We advise to provide for alternative fields of white clover only in fallow areas, but sufficient to support the local population of greylag geese, in order to reduce geese damage in nearby pastures of grass, particularly during the most sensitive period for farmers (i.e., spring). By the same reasoning, we do not advise planting white clover in agricultural fields frequently visited by geese. Such plantings would potentially increase loss of crops to geese. We suggest that methods continuously reducing attractiveness of areas under cultivation reinforce geese to consistently choose for white clover in fallow areas, but we could not demonstrate a geese-deterring effect of activated charcoal. We, therefore, cannot recommend activated charcoal as a means to make areas under cultivation less attractive to geese.

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