Org. Agr.
DOI 10.1007/s13165-012-0029-4

Protection strategies for farmland birds in legume–grass leys as trade-offs between nature conservation and farmers' needs

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Received: 16 September 2010 / Accepted: 12 August 2012

Abstract The study shows organic legume–grass leys to be highly attractive for skylark (*Alauda arvensis*), corn bunting (*Emberiza calandra*), yellow wagtail (*Motacilla flava*) and whinchat (*Saxicola rubreta*). But due to harvesting three to four times per year, legume–grass leys can become an 'ecological trap'. Therefore, the aim was to analyse the effects of optimized harvesting measures on territory densities and the breeding success of farmland birds and, concomitantly, on forage yield and quality of dairy farms: (1) later first cut, (2) later second cut, (3) high first cut and (4) unmown strips. Measures (1) and (2) improve productivity for breeding skylark but result in a sharp decline in the nutritional quality and net energy lactation yield (NEL) in the conserved forage. Measure (3) causes a yield reduction of about 5 GJ NEL ha^{-1} with no effect on quality. Due to the higher cut, grass regrowth is accelerated, and this could lead to earlier nest initiation for skylark, rendering a delay in the second cut unnecessary. Direct nest losses are reduced for all species. Measure (4) might allow whinchat and yellow wagtail to maintain territories after mowing and may increase the reproductive success of all species, with yield reductions similar to measure (3). For the first time, this study demonstrates, under large-scale practical conditions (1,200 ha), measurable benefits for farmland birds in legume–grass leys by integrating modified harvesting measures. The effectiveness and the feasibility are highly dependent on individual farm conditions; we therefore recommend the adoption of all measures into agri-environmental schemes.

Keywords Biodiversity · Organic farming · Agri-environmental measures · Arable land · Farmland birds · Breeding success · Nature conservation · Nutritional fodder quality · Yield effect

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Introduction

Over the last 30 years, many investigations have shown that organic agriculture makes a significant contribution to environmental protection (e.g. SRU 2003; Hole et al. 2005; Bengtsson et al. 2005), and the extension of organic agriculture is recommended by policy makers (Stern 2003). Organic farming has increased rapidly in nearly all European countries since 1990 (SÖL 2008). In Germany, 6.1 % of the agricultural land is currently managed organically according to EU Regulation 834/2007 (BÖLW 2012). With 10.2 % or approximately 135,100 ha, the federal state of Brandenburg has the highest percentage of organically managed land in Germany (Agrarbericht 2009), mainly because of the high proportion within its large protected areas. For example, within the Schorfheide-Chorin Biosphere Reserve,

Published online: 15 September 2012

29 % of the agricultural land (equivalent to almost 13,000 ha) was already managed organically in 2008 (MLUV 2008). These large, organically managed areas, which are associated with relatively low soil fertility, a high proportion of natural and seminatural landscape elements, and a rich wildlife population in major parts of northeast Germany, offer a high potential for integrating nature conservation aims into agricultural practice (Flade et al. 2006; Schwarz and Flade 2007; Stein-Bachinger et al. 2010).

Legume–grass leys play a crucial role in organic farming systems, mainly for the maintenance of soil fertility and nitrogen supply within the rotation (Köpke 1996): 30 to 40 % of the organic land is cultivated with this crop. On organic dairy farms in regions with little permanent grassland, legume–grass leys provide the main fodder base for the cattle as an energy and protein source. In addition, several studies have shown that a wide range of farmland wildlife benefits from organic farming (Evans et al. 1995; Christensen et al. 1996; Wilson et al. 1997; Kelemen-Finan and Frühauf 2005; Fuchs and Saacke 2006a, b). Organic legume–grass or lucerne leys have been shown to be a preferred breeding habitat for ground breeding birds such as the skylark, corn bunting, whinchat and quail (Wilson et al. 1997; Fuchs and Saacke 2006a; Kragten et al. 2008). However, the necessity of frequent harvesting to produce high-quality forage can turn these crops into 'ecological traps' where high bird densities are reached but successful reproduction is inhibited by routine farming operations (Jenny 1990). Most farmland birds in Germany and (Western) Europe are actually under pressure as they have undergone severe declines as a result of the intensification of agricultural land use (Tucker and Evans 1997; BirdLife International 2004; NABU 2006). The populations e.g. of skylark, whinchat and corn bunting in Europe decreased by 43, 52 and 62 %, respectively, between 1980 and 2002 (Gregory et al. 2005; EBCC 2006).

Considering the high attractiveness of organic legume–grass leys for farmland birds and the high proportion of them in northeast Germany, their relevance for the protection of farmland birds in this region is apparent. However, although the agri-environmental schemes in Germany offer various nature conservation measures on arable fields (Hartmann et al. 2006), no special importance has been attached to legume–grass leys, and very little research relating to nature conservation issues has so far been carried out on this crop. In contrast, a lot of research has been conducted on grassland (i.a. Mährlein 1993; Briemle 1997; Briemle et al. 1999; Elsäßer 2000; Oppermann and Gujer 2003; Nocera et al. 2005; Rühs 2006; Bullock et al. 2007; Berg and Gustafson 2007), and a wide range of management measures for pastures and meadows with regard to different types of vegetation and site conditions have been an inherent part of agri-environmental schemes since 1992.

The successful integration of nature conservation goals into agricultural practice requires, first and foremost, measures which have been proven and are well described, with fully quantified consequences for farmers from an agronomic, economic and ecological point of view. Secondly, financial incentives are important in order to increase acceptance by farmers because the protection of natural species generally incurs additional economic costs. Although the need for agri-environmental measures in Europe is increasing (Firbank 2005; Matzdorf et al. 2008), a decrease in public funding following EU enlargement has to be accommodated. For example, Germany will spend approximately 12 % less money for rural development measures in the second pillar between 2007 and 2013, compared to the previous period (Matzdorf and Lorenz 2010). Therefore, there is a strong need to improve the effectiveness and efficiency of agri-environmental measures (Kleijn and Sutherland 2003; Taylor and Morecroft 2009). Moreover, new investigations document that the cross-compliance regulations are inadequate for maintaining biodiversity in Germany's agricultural countryside and, as a consequence, the implementation of adequate farm management measures must be supported by corresponding funding (Oppermann 2009).

The purposes of this study were to evaluate the habitat quality of legume–grass leys for farmland birds under organic farming conditions on a dairy farm in northeast Germany and to outline different ways to integrate nature conservation measures into the management of organic legume–grass leys, based on the interdisciplinary 'Nature Conservation Farm Brodowin' project (Stein-Bachinger et al. 2010). For the first time in Germany, there was an opportunity to perform extensive interdisciplinary investigations within a large-scale implementation on an entire farm of about 1,240 ha over 8 years working in a fruitful cooperation with the farmer and his staff. The farm put up to 90 % of its arable land

(900 ha) at the project's disposal thereby giving researchers the opportunity to obtain their results under real working and marketing conditions, an opportunity for research that was new on this scale.

The objective of this study is the assessment of standard and modified crop production activities on the territory densities of skylark, corn bunting, whinchat and yellow wagtail as well as on the breeding success of the skylark. At the same time, the effects on fodder production (yield and quality) were examined. In addition, compromises between nature conservation goals and the basic principles of organic farming were elaborated within the context of whole farm management and its economic viability.

Methods

Study sites and common farming practices

The investigations were conducted between 1998 and 2005 at two locations in Brandenburg, Germany: at the Demeter farm 'Ökodorf Brodowin GmbH and Co. KG' in the Schorfheide-Chorin Biosphere Reserve, 60 km northeast of Berlin (=Brodowin), and at the organic model farm at the experimental station of the Leibniz Centre for Agricultural Landscape Research in Müncheberg, 60 km east of Berlin (=Müncheberg). The farms are located in moraine landscapes, characterised by sandy to loamy soils from glacial deposits with a high small-scale heterogeneity and a mean German soil rating index (SRI) of 33 (18 to 58). The SRI indicates the soil quality by the so-called Ackerzahl, a dimensionless value that ranges between 7 (=lowest quality) and 100 (=best quality), mainly based on different soil types and soil texture. The SRI is the only nationwide soil data available at field level. The average annual precipitation amounts to 540 mm. The Brodowin farm with 1,240 ha of farmland keeps about 280 dairy cows and 250 young cattle. Permanent grassland occupies 100 ha. Of 1,100 ha of arable land, up to 30 % is cultivated with legume–grass mixtures, 40–50 % with winter cereals, about 10 % with spring cereals, 10–15 % with grain legumes, silage maize and oil seeds. A five and six-field crop rotation, adapted to the site conditions, is used.

The legume–grass mixtures include alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), perennial ryegrass (*Lolium perenne*), Wiesenschweidel (*Festulolium* crossbreed of *Lolium multiflorum* × *Festuca pratensis*), timothy grass (*Phleum pratense*) with a small portion of white clover (*Trifolium repens*) and cocksfoot (*Dactylis glomerata*). The mixtures are undersown in spring in winter rye or oats. In autumn, after cereal harvesting, the sward is cut once or grazed by sheep. The following 2 years are the main production years, with about three cuts per year (50 % silage and 50 % hay). To meet the nutritional requirements of a dairy farm, the first cut is made preferably by the middle of May, the second cut approximately 5 to 6 weeks later and the third cut in August. The farming operations in Brodowin are similiar to Müncheberg.

On the Brodowin farm, the harvesting period of the legume–grass leys lasted an average of 3 days from the start of mowing until the removal of the cut material from the field, including all other farming operations such as turning or swathing. Subsequently, these procedures are referred to as harvesting operations.

Modified cutting measures

In 1998 and 1999, the Biosphere Reserve administration financed pilot investigations into the influence of different forage harvesting techniques on farmland birds. Following on from this, different cutting and harvesting measures were tested within the 'Nature Conservation Farm Brodowin' project from 2001 to 2005: (1) later first cut, (2) later second cut, (3) high first cut and (4) unmown bird strips (Table 1). Further modifications to the customary measures were driven by difficult weather conditions such as rainfall and extreme spring or summer droughts and by technical problems with the machinery. The second cut took place 6 to 9 weeks after the first cut. Due to a severe summer drought in 1999, the second cut had to be cancelled on several fields, and in 2001 and 2003, the first cut was delayed by 2 weeks. The normal cutting height is 5 to 7 cm. A higher first cut (12–14 cm) was tested on two selected fields in 2001 and 2002, but this was abandoned in the following years when a water deficit prevented legume–grass from attaining this height. In 2004 and 2005, a cutting height of 10 cm was implemented on all legume–grass fields to counteract the effects of summer drought. Unmown strips were retained in all study years except 2003.

The investigations and field experiments at Brodowin were mainly performed at field level. Additional investigations into yield and fodder quality were carried out each year from 2001 to 2004 at the model

Table 1 Optimisation strategies in legume–grass leys

Modified production measures		Description	Expected effects on farmland birds
I	Later first cut	1 or 2 weeks later	Provide a period without disturbance for at least one brood
II	Later second cut	7 or 8 weeks after the first cut or no second cut	
III	High cut (first cut)	Up to 14 cm cutting height	Reduce direct losses of broods; quicker reestablishment of habitat conditions for breeding
IV	Unmown strips (bird strips)	Retention of unmown strips (≥10 m width, 10 % of the field) during the third cut, maintenance until autumn of the following year	Preserve or improve habitat conditions (nesting sites, food sources, cover and shelter during and after harvesting)

farm in Müncheberg, using plot experiments with a randomised block design.

Monitoring territory densities and breeding success of farmland birds

Data collection

To assess the (potential) habitat quality of the organically farmed legume–grass leys and to study the harvesting effects, we monitored the population densities of four regular ground breeding bird species: skylark (*Alauda arvensis*), corn bunting (*Miliaria calandra*), yellow wagtail (*Motacilla flava*) and whinchat (*Saxicola rubetra*) in Brodowin. Territory mapping was carried out between April and July on legume–grass leys covering a total of 200 ha in each study year. The number of fields studied in each year ranged from 5 to 21. Every field was visited at least three times a year (up to 20). To assess the impact of the first cut and the effects of unmown strips on the stability of the territories, fields were visited shortly before and after the first cut. Song, display postures, the presence of a pair and other observations indicating territories were recorded on 1:5,000 topographical maps to assess the number of breeding territories, their distribution and stability over the whole breeding season.

Breeding phenology and success of the skylark were monitored at Brodowin. Nest searching took place from mid-April to mid-July in every study year except 2005. The work was carried out several times per week by observing the adults from a car or hide. Nests were marked inconspicuously, and the clutch size or number and age of nestlings were recorded based on the date of hatching or on chick development (according to Pätzold 1983). The nests were visited every 2 to 4 days, and the status was recorded (incubated, nestlings present, failed due to predation, farming operation or other reasons, successful). A nest was defined as successful when at least one chick was proven to be alive after leaving the nest, e.g. by adults carrying food or giving alarm calls nearby (=nest leaver). To monitor the nest survival during harvest, affected nests were investigated shortly before and after every harvesting operation. Nests were defined as failed due to harvesting if they were destroyed, abandoned (=not found any more by the adults) or predated during mowing or within the 3 days following mowing, when the remaining harvesting operations took place (referred to here as the harvesting phase).

Data analysis

The field maps were analysed separately as the species studied do not live in stable, clearly distinguished, non-overlapping territories and therefore do not fulfil all of the basic requirements necessary to form paper territories (compare Bibby et al. 1995). Thus, each observation of a displaying bird or pair marked a territory. Marginal territories and territories that also used adjacent fields were counted as 0.5 territories.

Seasonal maximum counts of territories were used to quantify abundance. Average territory densities were calculated across the entire mapped area as described in Flade (1994). But as the species studied avoid vertical structures such as forest edges, the area suitable for breeding is often smaller than the whole area mapped (see Jeromin 2002). In order to better assess the relationship between the abundances and the investigated crops (rather than e.g. landscape structure), the territory sums were therefore related to the total 'suitable field area', defined as the part of the fields with a minimum distance of 58 m (for skylark and corn bunting) or 76 m (for yellow wagtail and whinchat) from the forest edges, as determined on the basis of real minimum nest site distances from forest edges by Fuchs (in: Stein-Bachinger et al. 2010). For the skylark, we additionally calculated the yearly field-level median abundance based on territories within single fields (only for fields holding at least three territories, see Flade 1994).

For all breeding records, the dates of nest building, first egg laying, breeding, hatching or nest leaving were calculated from nest observations according to Pätzold (1983). The breeding success was calculated according to Mayfield (1975, 1961). In this context, harvesting was defined as a 'human disturbance judged serious enough to affect the outcome' (Mayfield 1975) so daily survival rate estimates were based on egg or chick exposure of affected broods up to the mowing date. We calculated the daily survival rates (dsr) during the incubation period and during the nestling period, and the hatching rates, using the formulas

$$\mathrm{dsr_{eggs}} = 1 - \text{nest losses}_{\mathrm{eggs}} / \text{exposure} - \text{days}_{\mathrm{eggs}}$$

$$\mathrm{dsr_{nestlings}} = 1 - \text{nest losses}_{\mathrm{nestlings}} / \text{exposure} - \text{days}_{\mathrm{nestlings}}$$

$$\text{hatching rate} = \text{nestlings present after hatching} / \text{eggs present before hatching.}$$

The breeding success, being the probability that eggs at the start of incubation will produce nest leavers, if only natural losses through predation or abandonment were concerned, was calculated with the following formula: Breeding success $= \mathrm{dsr_{eggs}}^{11} \times \text{hatchingrate} \times$ $ds\mathrm{r_{nestlings}}^{7}$. This is the estimated breeding success for nest attempts that started early enough to reach completion before the field was mown. Note that the formulae below give the correct value for nests that started too late to finish before mowing, even if they failed naturally before mowing.

To obtain the estimated number of nest leavers per nest, the breeding success was multiplied with the recorded clutch sizes. Survival during harvesting was calculated separately and defined as 'harvesting rate' within the harvesting phase, being the probability that eggs/nestlings present just before harvesting will still be present after the harvesting phase. The harvesting phase was the number of days from mowing until the fodder was removed from the field, which was 3 days in average at the Brodowin farm (n=26 harvesting phases). The harvesting rate was determined for all nests affected by mowing using the formula: Harvesting rate = eggs or nestlings present before mowing/eggs or nestlings present after the harvesting phase. To finally assess the total breeding success for the broods affected by harvesting (i.e. all nests where the period between nest initiation and the expected fledging date included a harvesting period), we calculated the following: Breeding success = $\mathrm{dsr_{eggs}}^{8} \times \text{harvesting rate} \times \text{hatching rate} \times \mathrm{dsr_{nestlings}}^{7}$ (for nests affected during incubation) or Breeding success = $\mathrm{dsr_{eggs}}^{11} \times \text{hatching rate} \times \text{harvesting rate} \times$ $ds\mathrm{r_{nestlings}}^{4}$(for nests affected during nestling period). This approach explicitly assumes that daily survival rates were the same before and after the harvesting period.

The skylark's productivity (estimated nest leavers per pair) depending on the date of the first and second cut was calculated on the basis of our recorded field data (territory density, number of breeding attempts and nest initiation dates) and the mean survival probabilities and numbers of nest leavers per nest as described later in the results. We used the recorded nest initiation dates for estimating the share of broods finished before or affected by harvesting, depending on different cutting dates and intervals.

To investigate the relationship between bird densities and field size and the effects of unmown strips, and to compare the clutch size of first and second broods of the skylark, we used Mann–Whitney U tests and one-way ANOVA. To detect differences between several years (for skylark abundances, clutch sizes), we used the median test.

Agricultural investigations and data analysis

During 2001–2004, the effects of the modified cutting measures on vegetation structure (height, density and development stage) (Klapp 1971; BBA 2001), forage yield and nutritional quality were investigated in large-scale on-farm experiments in Brodowin. The effects of a higher first cut were investigated on two fields in 2002, while unmown 'bird strips' were examined from

2003 to 2005. To investigate all of the modified measures (1), (2) and (3) (Table 1) simultaneously, plot experiments comprising four replicates with a plot size of 4×9 m were conducted at the experimental station in Müncheberg from 2001 to 2004.

The vegetation height and coverage were measured weekly from April to June. Yield and quality samples were taken at each of the three main harvesting dates during the year (see "Study sites and common farming practices" section). Depending on the different cutting regimes, sample harvests were taken weekly, from the beginning of May until the first cut, and from 5 to 8 weeks after the first cut, in order to investigate the dynamics of forage yield and quality (crude protein, crude fibre, energy content (NEL) (VDLUFA 2004). In addition to the standard assessment method based on crude nutrients, the enzyme-insoluble organic matter (EULOS) was ascertained by near infrared spectroscopy (Hertwig 2004), so as to avoid an overestimation of the energy content through delayed cutting, an effect well known from grassland experiments (Hertwig 1999; Mährlein 1993) and also found in our own analyses.

Statistical analyses were performed with SAS 9.1 standard programmes. The experimental design was kept unmodified during the whole study. On the Brodowin farm, plots were placed in pairs by dividing fields (20–30 ha: without/with modifications) that were comparable in terms of soil parameters, topography and coverage (12 replications, hand harvesting on 1 m^2), using the T- and Wilcoxon test. At the organic model farm in Müncheberg, investigations were conducted using a randomised block design (four replications) and mechanical harvesting (20 m^2 in each plot). After the analysis of variance and F test, the Tukey HSD test was used.

Results

Territory densities and breeding success of farmland birds

We found above average territory densities in all investigated species (Table 2). The skylark densities were 5.4± 2.5 pairs per 10 ha in average (across entire mapped area). In 2002 and 2003, the densities were comparatively low, while in 2004 and 2005, the skylark number was much higher than the average (Table 2 and Fig. 1). But the differences between years showed not to be significant (Fig. 1; median test, p=0.056). Skylark and corn bunting occurred on the investigated legume–grass fields with high frequencies of 89 and 61 %, while yellow wagtail and whinchat settled on less than 50 % (Table 3). Fields without territories were smaller than settled fields. For the skylark, yellow wagtail and whinchat, this field size effect was highly significant (Table 3).

The territories of skylark and corn bunting remained relatively constant throughout the breeding season. Around 30 % of the territories were moved to adjacent fields after mowing, but in most cases only for 1 to 3 weeks. In contrast, in the absence of unmown strips, more than 70 % of the breeding pairs of yellow wagtail and more than 80 % of whinchat abandoned their territories with the first cut in May (Fig. 2). However, on fields with 'bird strips', fewer territories were abandoned (Fig. 2), although the differences were not significant (whinchat, p=0.07; wagtail, p=0.13) probably because of the small samples. Most of the remaining territories were associated with one or several strips. The birds used the strips as singing and hunting posts and as foraging and breeding habitat. However, skylark and corn bunting either did not or only exceptionally used the strips for nesting. Individual birds were observed searching for food adjacent to the strips and, during or following the cuts, leading their young into the strips which were the only structures providing cover, shelter and insect food. Additionally, in some cases the strips helped the adults to relocate their nests after mowing (own observations).

In total, 195 skylark nests or chicks that had just left the nest were recorded during the study period. All nests were situated well within the fields, usually under red clover, alfalfa or dicotyledoneous weeds. A total of 157 nests were not affected by harvesting operations or failed before harvesting operation began, while 38 nests were affected (first or second cut). Of the 157 non-affected broods, 89 were successful, 57 predated, 4 abandoned and the outcome of 7 nests remained unknown. The distribution over the breeding season of the nest initiation dates showed two peaks, indicating double broods as well as replacement broods after the nest building peaks (Fig. 3). First broods were started in April with a peak in the second 10-day period. The second broods' peak was at the end of May/beginning of June. The mean initiation date of the second broods was 18 days after the first cut (n=77 initiation dates), probably because immediately after the first cut, the vegetation cover was too poor for nesting. The mean vegetation height (across all fields) 18 days after cutting was 20 cm (Fig. 4).

Table 2 Mean total area abundances of four farmland bird species on legume–grass fields at the Brodowin farm, based on the total territory sums and the total area mapped per year, and expressed as breeding pairs per 10 ha suitable field area

	1998	1999	2001	2002	2003	2004	2005	Mean (1998–2005)
Number of fields mapped	18	9	5	7	21	16	7	
Total area mapped (ha)	298	226	124	110	217	250	164	
Skylark	5.0	5.5	5.0	2.9	2.9	6.3	10.2	5.4±2.5
Corn bunting	0.3	0.2	0.4	0.9	1.1	2.3	1.8	1.0±0.8
Yellow wagtail	0.2	0.6	0.3	0.1	1.1	1.0	1.4	0.7±0.5
Whinchat	0.4	1.3	0.2	0.4	0.4	0.2	1.1	0.6±0.4

The clutch size varied between two and six eggs with a mean clutch size of 3.8±0.18 eggs per nest (1998–2004, n=177). For the single years, the values were 4.1±0.75 (1998; n=22), 3.8±0.83 (1999; n=51), 3.7±0.46 (2001; n=25), 3.8±0.70 (2002; n=14), 3.5±0.75 (2003; n=11) and 3.8±0.61 (2004; n=54), but the differences between the years were not significant (p=0.07). Second clutches were significantly bigger than first clutches ($p<0.001$).

The skylark's breeding success [expressed as the probability that eggs at the start of incubation will produce nest leavers, according to Mayfield (1961, 1975)] was 35.4±0.11 % in average for all study years, only natural causes of loss such as predation and abandonment being considered (Table 4). The mean daily survival rates for eggs (0.95±0.03) and nestlings (0.94±0.03) were "similar" (Table 4). Based on the clutch sizes and the breeding success found, each skylark breeding pair was expected to produce 1.3±0.47 nest leavers on average per nest (Table 4). In 1998, 1999 and 2004, a higher breeding success was found, while from 2001 to 2003, the breeding success was significantly lower (Table 4), probably due to higher predation ($p<0.05$).

Apart from natural causes (in Brodowin mainly predation), the hay or silage harvesting was the second most important reason for nest failure. In our study, harvesting reduced the breeding success, but did not lead to a total loss of all broods: of 38 nests affected by harvesting, 15 were not harmed during the 3-day harvesting phase, while 8 nests were directly destroyed by mowing or subsequent harvest measures, 7 were abandoned (presumably lost) by the adults, 6 were predated during the harvesting phase and the result of 2 nests was unknown.

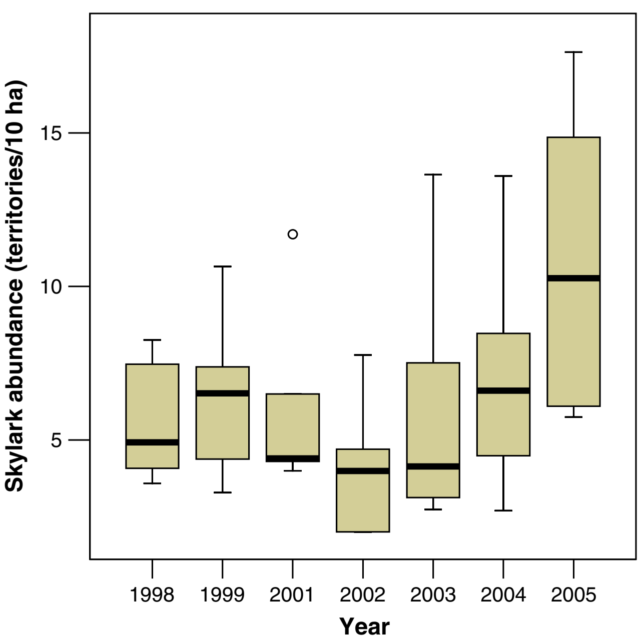

Fig. 1 Median abundances of skylark on legume–grass fields at the Brodowin farm, based on the abundances of single fields and expressed as breeding pairs per 10 ha suitable field area. Only fields with at least three territories were considered (n=58 fields). Boxplot: median, 1. and 3. quartile (*box*), outlier (*circle*). Median test non-significant

Table 3 Territorial presence of four farmland bird species on legume–grass fields at Brodowin farm, showing percentage occupied along with mean areas (hectares; 1998–2004)

	Number of fields		% fields occupied	Size of fields		*P*
	With territories	Without territories		With territories	Without territories	
Skylark	72	9	89	15.3±10.3	4.8±2.0	**
Corn bunting	51	32	61	15.4±10.3	11.3±9.9	*
Yellow wagtail	30	51	37	19.0±10.2	9.7±8.1	**
Whinchat	22	59	27	19.4±10.3	10.8±8.8	**

**P*>0.05 (non-significant); ***P*<0.01, level of significance between the size of fields without territories and fields with territories

We found a mean harvesting rate of 0.46±0.25 (Table 5); that is, 54 % of the eggs or nestlings present at the time of harvesting were killed directly or indirectly during the 3-day harvesting period. Consequently, the breeding success of nests affected by harvesting was only 19.27± 16.47 % (Table 5; as opposed to 35.4±0.11 % for non-affected nests, compare Table 4). The total average number of expected nest leavers decreased to 0.7±0.27 per affected nest.

Our calculations showed that the date of the first cut or the length of the interval between the first and second cuts had a strong influence on the expected number of nest leavers produced (Table 6). Generally, we found similar increases in nest leaver numbers with the delay of the first or second cut. Delays of 5 to 7 days resulted in increases of 21 to 34 %, and delays of 2 weeks or more led to very strong increases of more than 50 % (Table 6).

Forage yield and nutritional quality

The investigations at Müncheberg showed that a first cut, carried out before middle of May, guaranteed high forage quality (Table 7). Acceptable energy contents for lactating cows should be above 6.0 MJ NEL kg^{-1} DM (NEL=net energy content for lactation), crude fibre should be below 25 % (Wolf and Briemle 1989; Borstel et al. 1994). These values were not reached by later cuts on 22 May and 15 May, respectively (Table 7). Naturally, delaying the first cut caused

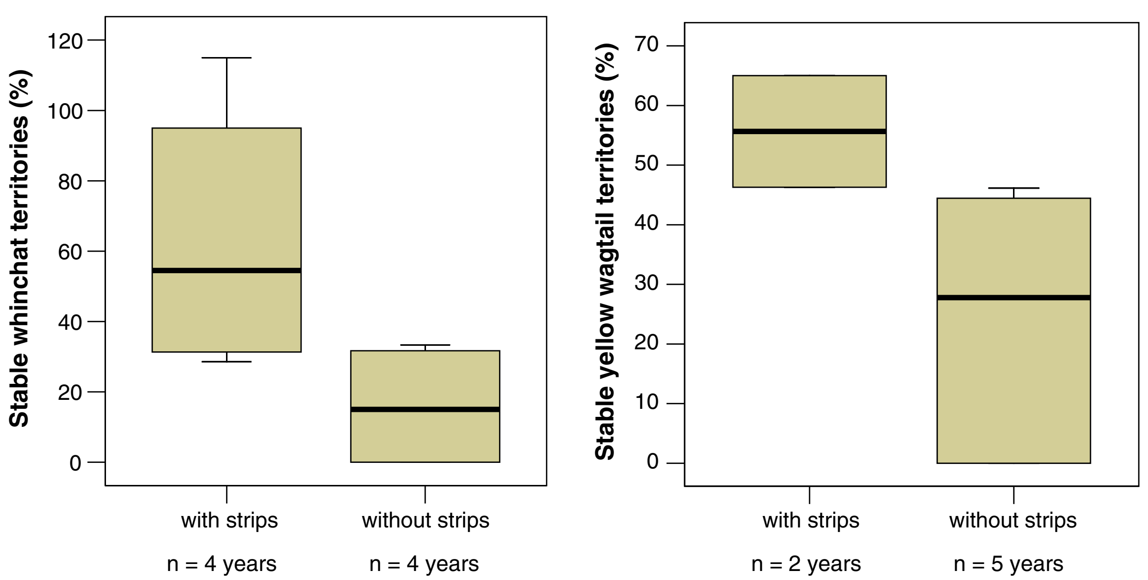

Fig. 2 Impact of unmown strips in legume–grass leys on the stability of territories of whinchat (*left*) and yellow wagtail (*right*) at the Brodowin farm (1998–2005). Mean percentage (median) of whinchat or yellow wagtail territories still present after the first cut with and without unmown strips, based on total area abundances per year. Boxplot: median, 1. and 3. quartile (*box*). One-way ANOVA non-significant

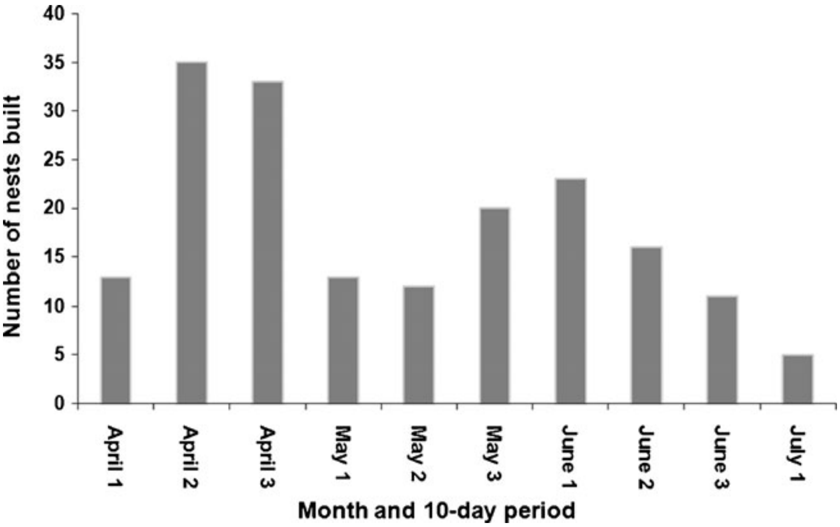

Fig. 3 Distribution of skylark nests built over the breeding period in legume–grass leys at the Brodowin farm (1998–2005, n=181 initiation dates); 10-day period per month

higher yields, but the nutritional quality declined below the requirements for dairy cows. Due to the fact that most grasses had completed heading and the legumes were in flower at this time, the energy content showed a significant reduction, while crude fibre increased significantly above 29 %.

In order to guarantee a reasonable yield, the second cut is normally carried out in the study region after 5 to 6 weeks. Table 8 shows that after an interval of 6 weeks, second cuts could not match the quality of a first cut performed before mid-May (Table 7). Longer delays of 7 or 8 weeks after the first cut caused further declines in fodder quality. On average, crude fibre concentration increased by 7 % and exceeded 32 % in all cases at the eighth week, while the energy content declined drastically below 5.5 MJ NEL kg DM^{-1}. The decrease of the crude protein concentration averaged at 3 % with the lowest content of 11.9 % in 2004 in the eighth week. The delay resulted in a sharp decline in the nutritional quality under the level required for dairy cows and a reduction in the annual yield of net energy lactation up to 25 GJ NEL ha^{-1}. It has to be noticed that for all of the

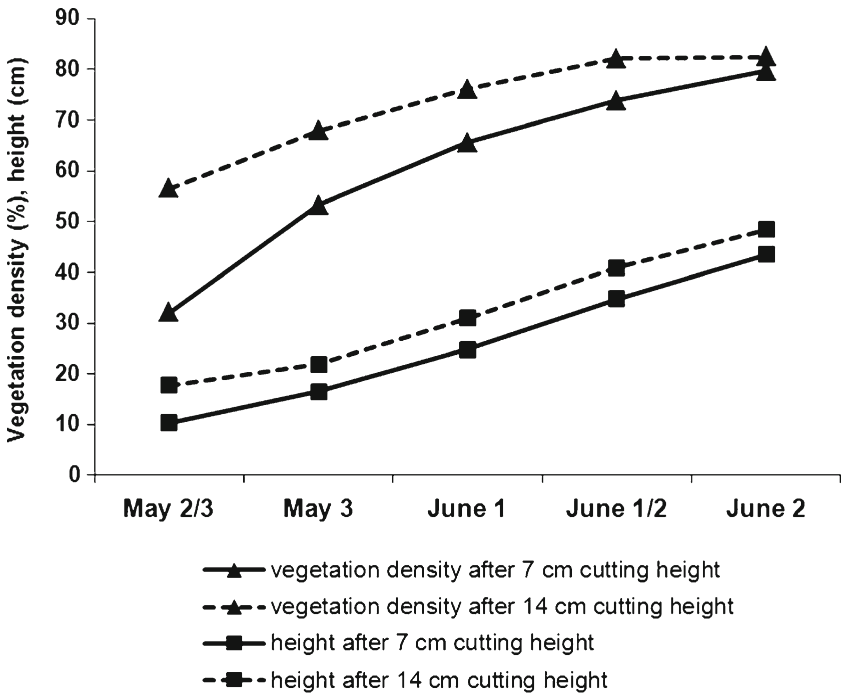

Fig. 4 Vegetation density (percentage) and height (centimetres) of legume–grass leys at a cutting height of 7 and 14 cm (2002–2004); 10-day period per month

Table 4 Daily survival rates, breeding success and estimated number of nest leavers for skylark on legume–grass fields at the Brodowin farm (n=177 breeding records) considering only natural causes of loss (predation and abandonment)

	1998	1999	2001	2002	2003	2004	Mean
Number of nests	22	55	26	15	9	50	
Number of nest losses	7	18	15	5	3	11	
Nest days observed (eggs)	65	208	53	28	25	110	
Nest days observed (chicks)	82	200	111	44	26	175	
dsr[a] eggs	1.00	0.94	0.94	0.93	0.96	0.96	0.95±0.03
Hatching rate	0.94	0.95	0.94	1.00	0.92	0.95	0.96±0.04
dsr[a] chicks	0.91	0.97	0.89	0.93	0.92	0.96	0.94±0.03
Breeding success[b] (%)	47.2	40.0	20.5	26.8	31.8	48.2	35.4±0.11
Nest leavers per nest	1.9	1.5	0.8	1.0	1.1	1.8	1.3±0.47

[a] Daily survival rate

[b] Probability that eggs at the start of incubation will produce nest leavers

years, the main significant effects occurred between the sixth and the seventh week (Table 8), which implies that the vegetation will become increasingly fibrous and indigestible after the sixth week. Moreover, an interval of 8 weeks or more between the first and second cut would increase the loss for the farmer at the third cut, unless a delay of the third cut is also implemented. The comparison between a delayed first and second cut showed that the daily reduction of crude protein and energy content was nearly twice as high.

The third optimized harvesting option was a first cut with an increased cutting height of 14 cm. This measure enhanced the vegetation cover and height in all years (Fig. 4). After cutting at 14 cm, the regrowth reached a height of 20 cm 7 days earlier than after a cut at 7 cm (11 vs. 18 days). At the same time, the vegetation density was 20 % higher. In all field trials, the increased cutting height of 14 cm resulted in a significant yield reduction of the first cut of up to 30 % and an increase in nutritional quality, with increased protein and energy content, accompanied by a decrease in crude fibre content (Table 9). However, the forage quality of subsequent cuts was lower if a higher cutting height was used for the preceding cut: on average, crude protein decreased by 1 %, energy content by 0.5 MJ NEL ha^{-1}, while crude fibre increased by 1 %, due to the presence of more stalk material. Therefore, the weighted mean forage quality across the whole year remained unmodified, while the total annual dry matter yield was reduced by 10 to 15 % (Stein-Bachinger et al. 2010). In plots subject to delayed cuts, the calculated annual energy yield showed a loss of up to 5 GJ NEL ha^{-1}. The fourth optimized harvesting option (the unmown bird strips on 10 % of the field area) caused a total forage loss similar to the higher first cut (4 to 5 GJ NEL ha^{-1}), but required extra mulching or harvesting operations in autumn.

Table 5 Harvesting rates, breeding success and estimated numbers of nest leavers of skylark nests affected by harvesting (n=38 breeding records)

	1998	1999	2001	2002	2003	2004	2005	Mean
Number of nests affected by harvesting	4	7	2	2	4	18	1	
Eggs/chicks present before harvesting	15	19	7	9	14	68	3	
Eggs/chicks present three days after mowing	4	9	3	2	6	35	3	
Harvesting rate[a]	0.27	0.47	0.43	0.22	0.43	0.51	1.00	0.46±0.25
Breeding success[b] (%) of nests affected by harvesting	14.4	21.3	11.7	7.5	16.5	27.4	–	19.3±16.47
Nest leavers per nest affected by harvesting	0.6	0.8	0.4	0.3	0.6	1.1	–	0.7±0.27

[a] Probability that eggs/chicks present just before harvesting will still be present after the 3-day harvesting phase

[b] Probability that eggs at the start of incubation will produce nest leavers

Table 6 Mean skylark's estimated productivity on legume–grass fields depending on the date of the first and second cut

Date of first cut	10.05.	15.05.	22.05.	30.05.
Nest leavers per pair (first brood)	1.04	1.26	1.59	1.72
Increase (%)		21	53	66
Interval between first and second cut	6 weeks	7 weeks	8 weeks	no second cut
Nest leavers per pair (second brood)	1.04	1.39	1.61	2.20
Increase (%)		34	55	113
Nest leavers per pair and year (total)	2.07	2.65	3.20	3.93

Calculations are based on our recorded field data (1998–2004). The increase (percentage) always refers to the productivity with the earliest (normal) cutting date (10.05. or 6-week interval). The calculations are based on the following assumptions: two breeding attempts per pair plus replacement broods of first broods depending on the date of the first cut (10 May: 30 % replacement broods; 15 May: 40 % replacement broods; 22 May: 50 % replacement broods; 30 May: 60 % replacement broods) and replacement broods of the second broods depending on the length of the mowing interval (6 weeks, 20 % replacement broods; 7 weeks, 40 % replacement broods; 8 weeks, 50 % replacement broods; no second cut, 70 % replacement broods); mean survival probabilities and numbers of nest leavers per nest as described in this article; nesting period of 30 days until the chicks leave the nest; nest initiation dates recorded in the field

Discussion

The challenge of our study was to find and evaluate compromises between the breeding habitat requirements of farmland birds and the forage demands of an organically managed dairy farm based on legume–grass leys. Several success-oriented harvesting measures were investigated. Similar to investigations in grassland (Mährlein 1993; Nocera et al. 2005), changes of the cutting regime had negative influences on forage quality. In particular, the adherence to the harvesting date to find the optimal trade-off between yield and nutritional quality is crucial from the farmers' perspective, especially because the feed supply for ruminants in organic production systems has to be organic (EU regulations have been updated since 1999).

From the nature conservation point of view, legume–grass leys represent a highly attractive and important breeding habitat for the investigated species: The territory densities were found to be well above the averages for arable land and grassland in central and northern Germany (Flade 1994; Schwarz and Flade 2007). A strong preference in the skylark for e.g. lucerne leys was also found by Wilson et al. (1997) and Kragten et al. (2008). For the whinchat, approximately 50 % of the total farm's population settled in legume–grass leys (Fuchs in: Stein-Bachinger et al. 2010), which underlines the importance of this crop for this species in northeast Germany. Only the yellow wagtail achieved higher densities in some cereal crops and grain legumes.

The skylark's breeding success of 35.4 % was in the upper part of the range of comparable results from other studies (overview in Jeromin 2002). The estimated productivity of 1.3 nest leavers per nest at the Brodowin farm was comparatively high (overview in Jeromin 2002: six of nine studies examined reported skylark productivities below 0.9 nest leavers). At the

Table 7 Yield and nutritional quality of legume–grass leys at different first cut dates, with a cutting height of 7 cm (values per line followed by the same letter do not differ significantly at the 5 % level, Tukey test, organic farm Müncheberg 2002)

Date of first cut	Trial I			Trial II	
	08.05.	15.05.	22.05.	08.05.	15.05.
Dry matter yield (t ha^{-1})	3.01 a	3.65 b	5.03 c	3.41 a	4.75 b
Crude fibre (%)	22.60 a	26.20 b	31.40 c	23.50 a	29.10 b
Crude protein (%)	20.60 a	16.10 b	14.80 b	20.30 a	16.70 a
Energy content (MJ NEL kg DM^{-1})	6.95 a	6.35 b	5.66 c	6.23 a	5.78 b

Table 8 Yield and nutritional quality of legume–grass leys with varying cutting delays after the first cut, cutting height 7 cm (values per line followed by the same letter do not differ significantly at the 5 % level, Tukey test, organic farm Müncheberg, 2001–2004)

Year	Weeks after the first cut			Weeks after the first cut			Weeks after the first cut			Weeks after the first cut		
	6	7	8	6	7	8	6	7	8	6	7	8
	Dry matter yield (t ha^{-1})			Crude fibre (%)			Crude protein (%)			Energy content (MJ NEL kg DM^{-1})		
2001	2.09 a	2.90 b	3.11 b	24.7 a	30.9 a	32.9 b	19.5 a	15.8 b	15.1 b	5.95 a	5.54 b	5.08 b
2002	4.01 a	4.86 b	5.54 c	30.3 a	30.7 a	35.7 b	16.9 a	15.7 b	14.6 b	5.60 a	5.48 a	5.20 b
2003	2.69 a	3.25 a	3.31 a	24.4 a	28.9 b	32.2 b	16.6 a	14.7 b	13.4 b	6.14 a	5.78 b	5.43 b
2004	2.70 a	3.57 b	3.63 b	26.4 a	28.9 a	31.9 b	14.9 a	13.1 b	11.9 c	6.01 a	5.30 b	5.08 b

Brodowin farm, the main causes of failure were predation and farming operations; no nests failed due to starvation or poor weather conditions. The reason might have been a sufficient availability of nestling food and nest cover on the organic leys (Odderskaer et al. (1997); Boatman et al. (2004)).

During the study, relatively few skylark broods were affected by harvesting because of the modified harvesting measures practised in Brodowin during the study ("Modified cutting measures" section). Based on our field data and published data from literature (see Delius 1965; Jenny 1990; Schläpfer 1988; Daunicht 1998), we calculated that, at the Brodowin farm, 2.41 nest leavers per pair and year must be realised in order to replace 30 % of the adults and thus to maintain a constant population (Fuchs in: Stein-Bachinger et al. 2010). The survival rate of nest leavers until they are totally fledged was not quantified in this paper, but we assume that an estimated mortality rate of 75 % for nest leavers until the next breeding season (on which the replacement rate of 30 % was based) might be realistic. This threshold of 2.41 nest leavers was reached in most study years and was largely surpassed in 1998 and 1999, when harvesting was performed as described in the "Modified cutting measures" section (see also Table 6). We therefore assume that the total skylarks' success was high enough to keep the Brodowin legume–grass population stable or even growing and that this was largely due to the modified production measures implemented. If a harvesting regime had been implemented that was optimal from the farm's point of view (e.g. first cut on 10 May and second cut after 6 weeks), skylarks' productivity would have decreased below the 2.41 nest leavers needed (Table 6). Thus, in spite of being a potentially excellent habitat, legume–grass leys can also act as sink habitats. Breeding success can be low despite high densities if high brood losses occur due to the farm's harvesting methods.

Delaying the first or second cut produced a positive effect on skylark reproductive success, but the magnitude of the effect depended on the length of the delay. Delays of 5 to 7 days resulted in estimated increases of 21 to 34 %, which may be not enough, particularly in years with low breeding success. In contrast, delays of 2 weeks or more led to strong expected increases of more than 50 %, producing a surplus of nest leavers.

Table 9 Yield and nutritional quality of legume–grass leys at different cutting heights at the first cut (values per line followed by the same letter do not differ significantly at the 5 % level, Tukey test (*M* organic farm Müncheberg), T- and Wilcoxon test (*B* Brodowin farm)

Year	Cutting height		Cutting height		Cutting height		Cutting height	
	7 cm	14 cm	7 cm	14 cm	7 cm	14 cm	7 cm	14 cm
	Dry matter yield (t ha^{-1})		Crude fibre (%)		Crude protein (%)		Energy content (MJ NEL kg DM^{-1})	
2002_B1	3.16 a	2.12 b	29.0 a	24.8 b	15.6 a	20.7 b	6.08 a	6.77 b
2002_B2	3.58 a	2.40 b	26.7 a	25.4 a	15.3 a	17.5 b	6.12 a	6.42 b
2002_M	4.77 a	3.44 b	27.1 a	25.9 b	18.7 a	19.4 b	6.30 a	6.40 a
2003_M	3.67 a	2.23 b	21.5 a	20.3 b	19.4 a	21.5 b	6.52 a	6.66 b
2004_M	3.86 a	2.35 b	24.6 a	20.9 b	17.4 a	20.8 b	6.48 a	6.88 b

Second clutches were bigger than first clutches, a fact that has been found also in earlier studies (e.g. Delius 1965; Schläpfer 1988; Jenny 1990). Moreover, according to Weibel (1999) and Jeromin (2002), later broods grow faster than earlier broods. There is no information on whether post-fledging survival is higher for chicks from second broods, but faster growing and thus heavier chicks may be better prepared to survive after fledging. Thus, the delay of the second cut may maximize the benefit of the measure for the skylark.

The accuracy and generality of our productivity estimates might be limited as they rely on a number of implicit assumptions: In our approach, we assumed that the DSR before and after the harvesting period are the same, which might not be accurate as nests get more exposed after mowing. This could lead to an increased mortality by predation or extreme weather. On the other hand, the adults can approach their nests much more inconspicuously than in high or dense vegetation, a fact that should lower the predation risk. Second, we did not quantify the harvesting survival rates depending on the stage in the nesting cycle (because of the relative small sample of affected nests). But our data and observations indicate that nestlings survived better than eggs, as the nestlings were vocal for parents to find them even if covered, while clutches were abandoned (=not found) after mowing more often. Therefore, any cutting delay might result in higher survival rates than calculated here. Third, it was assumed that first egg dates are independent of mowing, allowing us to calculate the proportion of nests affected by harvesting under different management regimes. This empirical approach may have been subject to unknown bias introduced e.g. by the ease or difficulty of finding individual nests or if nest initiation varies with different cutting heights.

It should be noted that a later cut may not have similar effects on all of the species studied. The yellow wagtail and the whinchat only start breeding in May, and the young fledge in June or even July. The corn bunting starts breeding even later (Wagner 2006). In Brodowin, only 27 % of all nest-building dates of corn buntings in legume–grass leys (n=36 nests) were in May (thus mainly breeding in June; Fuchs in: Stein-Bachinger et al. 2010). Therefore, a later first cut would probably still not allow any of the three species to improve their breeding success sufficiently. Most of the whinchats and yellow wagtails abandoned their territories after the first cut, so they could not have benefited from measures affecting the second cuts either. Corn buntings at Brodowin did not resume breeding until 28 days after the first cut on average, which meant that an extended mowing delay of more than 9 weeks would be optimal for this species (Fuchs in: Stein-Bachinger et al. 2010).

Regarding the agricultural demands, any delay of the cutting date would lead to a deterioration of nutritional quality and delays to further growth, both resulting in reduced yields of high-quality forage. For dairy cows, the cutting date should be at specific growth stages: for grass, between the end of the flush till the middle of heading and before the bud stage for legumes (Wolf and Briemle 1989; Hertwig 2004). Investigations on grassland showed that the amount of crude fibre can increase by 3 to 5 g kg DM^{-1} per day depending on the weather conditions (Hertwig 2004), results that were confirmed for legume–grass leys in our investigations as well in previous investigations (Stein-Bachinger et al. 2001). We also found that the forage quality levels for dairy cows could be achieved more easily with the first cut than with the second, and that the daily reduction of crude protein and energy content caused by a later first cut was nearly twice as high as that caused by delays to the second cut. The option to use the low-quality fodder for young cattle, dry or late-lactation cows still means that the farmer has to find an alternative for feeding the dairy cows. Shortage of high-quality fodder generally limits production on dairy farms (mainly because of difficult weather conditions), so the farmer has to either compensate for losses with fodder production from other fields within the crop rotation or purchase additional fodder from outside. The standards of organic farming only permit organically grown fodder for ruminants, which is rather expensive. Reductions in high-quality fodder therefore necessitate high compensation payments for dairy farmers if using strategy (1) and (2) (Stein-Bachinger et al. 2005, 2010).

As an alternative, strategy (3) with a cutting height of 14 cm at the first cut would minimise the losses and allow the forage requirements of dairy cows to be met (Table 9). The results also showed a better forage quality with a doubled cutting height due to the lower proportion of stalks. This advantage was, however, counterbalanced by a lower forage quality of the following cuts caused by more stalk material, so that the annual mean nutrient contents were not affected (Stein-Bachinger et al. 2010). For the dairy farmer, a higher first cut would therefore only cause a reduction in forage amount, and compensation payments could be considerably lower than with a delayed cut (Stein-Bachinger et al. 2010).

After the first cut, most skylarks resumed nest building around the date when mean vegetation heights had reached 20 cm. While this study did not directly measure the existence of threshold sward heights for nest initiation, a vegetation height for nest building of 20–50 cm has been found by Kragten et al. (2008). In the legume–grass leys studied, the minimum vegetation height of 20 cm was reached again on average 18 days after the first cut and coincided with the mean nest initiation date of the skylark. After a cut at 14 cm, a vegetation height of 20 cm was attained 1 week earlier. Therefore, we would predict that nest initiation would be earlier following a raised cut and that a higher first cut could allow a majority of the skylarks to finish their broods before the normal second cut.

Additional benefits of increased cutting height are likely for extant nests and unfledged chicks as the cutting machinery is likely to pass over many nests. The broods of the corn bunting and yellow wagtail in particular as well as nest leavers (of all species) are subject to a high risk of being destroyed with cutting heights below 10 cm (Fuchs in: Stein-Bachinger et al. 2010). In contrast to the shallow scrapes of skylark and whinchat, the nests of these species have a rim of up to 8 cm above ground level. One caveat has to be made: the mower must guarantee at least 8 cm net free space beneath the cutting tools, which was only achieved with an average cutting height of 14 cm in our study.

For whinchat, the presence of old vegetation from the previous year is an important habitat component, and they have been shown to use them as nest sites (Fuchs in: Stein-Bachinger et al. 2010). Where nests are sited within strips, they are safe from harvesting operations, and the strips have also been shown to provide a haven for arthropods (food items) which are reduced by 70 % on harvested areas. From an agricultural point of view, bird strips are comparatively easy to establish as 90 % of the field can still be managed for production, and the losses for the farmer are similar to a higher first cut. The harvested material from the strips could be used as litter or hay for horses, or if weed content is low the strips could be used for harvesting seeds.

While further research is required to establish the full benefits of unharvested strips and altered cutting regimes, this study shows that legume–grass leys represent an important breeding habitat for declining farmland birds which can be improved further by manipulations that have quantifiable effects on agronomic performance (Table 10).

To guarantee the optimal performance and success of the recommended measures, it is crucial to carefully select suitable fields or sites, taking both agricultural needs and habitat demands of the birds into consideration. The establishment of bird strips could allow increases of thistles (*Cirsium arvense*) and couch grass (*Agropyron repens*) on parts of some fields in subsequent years. That problem can be avoided by a careful choice of fields with low weed infestation risks (Bachinger and Zander 2007). Also, from the nature conservation point of view, a careful positioning of measures is crucial: The highest abundances of the target species occurred on field sizes ≥5 ha with no forest-like vertical structures nearby. Fuchs (in: Stein-Bachinger et al. 2010) found a mean distance of 239 m of skylark nest sites from forest edges (n=207 nest sites). Elle (2005) found that skylark preferred fields with a slope ≤5°. The highest densities of whinchat were found on set-asides or fields with non-cropped set-aside-like structures. Additionally, the territories of corn bunting, whinchat or yellow wagtail are usually clustered on single fields or discrete areas (Fischer 2006). Thus, the specific site preferences of farmland birds might only be satisfied on parts of a farm or even only on individual fields or parts of fields. Therefore, we propose that a reasonable trade-off between nature conservation and farmer's needs would be that 10 to 30 % of the arable land of a farm should be targeted for nature conservation purposes, providing a flexible choice of result-oriented agri-environmental measures for the farmer (compare Fuchs and Stein-Bachinger 2008) and concentrating measures on suitable areas with respect to the species' habitat requirements and preferences.

Conclusions

Legume–grass leys offer a high potential for the protection of farmland birds if modified production measures are implemented. Their acceptance will increase if the farmer (1) can choose between different effective measures, (2) can assess their economic effects and (3) receives adequate remuneration. Moreover, their effectiveness and their feasibility may depend on soil quality and weather conditions, necessitating flexibility of choice and appropriate financial incentives. Therefore,

Table 10 Optimisation strategies in legume–grass leys for the protection of farmland birds

Modified production measures	Variant	Effects on farmland birds	Effects on dairy farms
Later first cut	1 week later	Increase (21 %) in breeding success of skylarks' first broods	Decrease in nutritional quality (up to 0.6 MJ NEL kg DM^{-1}) possibly below requirements for dairy cows; potential use for young cattle
	2 weeks or more later	Strong increase (53–66 %) in breeding success of skylarks' first broods	Significant decrease in nutritional quality below requirements for dairy cows; energy loss up to 25 GJ NEL ha^{-1}. Separate harvesting; potential use as litter or hay for horses
Later second cut	7 weeks after the first cut	Increase (34 %) in breeding success of the skylarks' second broods	Decrease in nutritional quality (up to 12 % in energy content) below requirements for dairy cows; potential use for young cattle
	8 weeks after the first cut	Strong increase (55 %) in breeding success of the skylarks' second broods	Significant decrease in nutritional quality; energy loss up to 20 GJ NEL ha^{-1}; separate harvesting or mulching; potential use as litter or hay for horses. Delay of the third cut and extra harvesting necessary
	No second cut	Very strong increase (113 %) in breeding success of the skylarks' second broods No agricultural disturbance of nests and young in all investigated bird species in June/July	Additionally to above variant: Separate harvesting or mulching after 9–10 weeks requires a lengthy delay of the third cut and extra harvesting
High cut (first cut)	14 cm	Less direct nest and young losses during the cut in all studied bird species Vegetation cover and height suitable for breeding one week sooner following the first cut	No negative effect on nutritional quality per year, slight increase in nutritional quality at the first cut; 10 % decline in yield, energy loss up to 5 GJ NEL ha^{-1}.
Unmown bird strips		Territories less abandoned after the first cut by whinchat (14 %) and yellow wagtail (22 %) Improved survival in all studied species during and after harvesting (strips serve as nest sites, landscape marks, food source, shelter and cover)	With 10 % bird strips, total energy loss up to 5 GJ NEL ha^{-1}. Potential use as litter, hay for horses or seed harvesting if weed content is low

we recommend the adoption of all the tested production measures for legume–grass leys into agri-envrionmental schemes for (organic) arable farming systems in northeast Germany. Further investigation will be necessary to give recommendations for individual regions with, for example, different site conditions or target species. For this reason, the German Federal Agency for Nature Conservation has supported a similar project since 2006, conducted by the University of Kassel in Hesse (www.uni-kassel.de/Frankenhausen).

Acknowledgments We thank the German Federal Agency for Nature Conservation (BfN) for the basic funding, the Ökodorf Brodowin e.V. for their assistance in overseeing the project and the Brandenburg State Office of Nature Protection for their support of the research activities. We are particularly grateful to the farmer and his staff who agreed to let us do this study on the whole farm. We also thank the Swiss Ornithological Institute (Sempach) for its financial support to investigate the status of the whinchat at the Brodowin farm and study the effects of the bird strips in 2004 and 2005. We warmly thank Andreas and Adele Matthews, Jörg Wagner, Sebastian Koerner and several others for their incredible ability and commitment in searching nests and mapping territories. Many thanks to Gerlinde Stange, Anke Schnabel, Heike Schobert and the staff of the experimental station Müncheberg for their reliable help with the field trials, and to Johann Bachinger and Eva Reining for improving the manuscript. Moreover, we thank David Buckingham for his constructive help in particular to improve the farmland birds' calculations. We also thank Dave Berry-Lichtenberg for correcting the English version. Thanks to two anonymous referees for their helpful comments.

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