Colouration and flavouring of sunflower seeds affect feeding behaviour in urban Carrion crows (Corvus corone): A preliminary study

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Abstract

The damage caused to crops by wildlife, particularly birds, represent a major challenge for farmers. This study aimed to preliminarily assess feeding behaviour of Carrion crows (*Corvus corone*) on sunflower seeds in field conditions. The crows' preferences were tested along a visual cue (seed colour: blue vs. uncoloured) and a taste cue (pepper coating vs. unflavoured). The experiments were carried out in two sessions interspersed by several weeks. For each session, the influence of seed colours on birds' preferences (n=200 uncoloured, n=200 blue) was assessed on day 1, and the influence of seed pepper coating (n=200 pepper coated, n=200 unflavoured seeds) was assessed on days 2 and 3. Every day, the remaining seeds within each furrow were counted at 4 after the start of the assay. Throughout the experiments, the only wild birds seen consuming seeds were Carrion crows (*Corvus corone*). In each session, the

birds consumed significantly less blue seeds than controls ($p < 0.05$). However, blue seed intake significantly increased between the 2 sessions. The birds thus appear to rely on sight to select sunflower seeds. Otherwise, a significant effect of pepper coating arose in session 2, with birds consuming less pepper-coated seeds than unflavoured seeds ($p < 0.0001$). This intake of pepper seeds was significantly higher in session 1 than in session 2. Therefore, coating the seeds with a pungent irritant may induce reluctance. These assays confirm that Carrion crows are sensitive to the colour and flavour of sunflower seeds, rapidly learn and get used to visual and chemosensory novelty.

Keywords*:* Corvids; *Corvus corone*; Bird repellents; Avoidance learning; Colour preferences; chemosensory preferences.

Highlights

- Crows rely on sight to select seeds, but seed colouring is insufficient to prevent intake in the long-term.
- Crows rapidly learn the safe character of a food made visually unfamiliar.
- Crows appear not very sensitive to capsaicin.
- Multisensory repellence methods should be favoured against birds.

1. Introduction

The damage caused to crops by wildlife, particularly birds, represents a major challenge for farmers (Linz et al., 2015; Sausse et al., 2021). Birds feed on a wide range of crops, but sunflower crops are especially appetent to them (Linz et al., 2011; Sausse et al., 2021). Sunflower seeds contain essential proteins and lipids, they are a very attractive nutritional

resource to birds. Hence, birds are considered as key pests on sunflower farms in America, Europe and Asia (Peer et al., 2003; Khaleghizadeh, 2011; Sausse et al., 2021).

In America, birds feed on sunflower heads with little evidence of emergent saplings intake (Klosterman et al., 2013). In fact, the development of sunflower seeds coincides with the post-reproduction and pre-migration periods of birds, during which nutritional requirements are high. For example, North-American sunflower producers expect crop losses during August and September when large numbers of Blackbirds (*Icterinae*) congregate prior to migration (Peer et al., 2003). For sunflower producers in North Dakota, Blackbird damage is a chronic problem costing millions of dollars annually (Klosterman et al., 2013). Bird damage rate to sunflower crops has also been estimated at about 15-25% overall, based on individual estimates in Manitoba (Canada), Punjab (India), Bangalore (India), Turkey, and Khoy (Iran) (Khaleghizadeh, 2011). Using bioenergetic and economic modelling to estimate the potential impact of birds on production yields of sunflower in the northern Great Plains of North America, Peer et al. (2003) concluded "the solution to the conflict appears to be one that focuses not on eliminating all damage, but on preventing it from exceeding 5% per field".

In Europe, although damage from *Passerines* on flower heads exists since the introduction of sunflowers (ACTA, 1967), damage from *Columbidae* and *Corvidae* at the seed then at the emergence has been the subject of increasing concern over the last 15 years. A survey on oilseeds and pulses conducted by Terres Inovia (a French institute devoted to vegetable oils and proteins production) since 2016 shows that sunflower is the first crop affected (80%) by bird damage and that damage at maturity only constitutes 3% of declaration. Wood pigeon (*Columba palumbus*) is the main species declared, followed by the Carrion crow (*Corvus corone*) and the Rook (*Corvus frugilegus*) (Sausse et al., 2021). Accordingly, many farmers hesitate to grow sunflowers, a useful alternative crop offering environmental and agricultural

benefits as it is a honey crop and a favourable precedent for weed management in rotation with winter crops (de la Fuente et al., 2014).

Over the past century, various methods of bird control have been tested to protect sunflowers, including lethal control and acoustic harassment (Linz et al., 2011). For example, in 1989, experiments on aerial avicide sprays in the USA were conducted on a roost of 330.000 Blackbirds and European starlings (*Sturnus vulgaris L.*). The population of birds decreased to 70.000, 5 days after the spray of avicide and the roost was abandoned 13 days after it (Heisterberg et al., 1990). However, lethal management of granivorous bird populations has several drawbacks, such as public disapproval, low cost-effectiveness, difficult logistics and environmental risks especially to non-target birds and biodiversity at large (e.g., Linz et al., 2015). Thus, non-lethal alternatives are needed to manage bird feeding on sunflower crops. Among these non-lethal management options, a number of studies have explored the sensory keenness and cognitive biases of birds, in manipulating the pre-ingestive effects of visual, acoustic or chemosensory cues associated with the crops or the seeds. For example, Delwiche et al. (2007) were successful in broadcasting distress calls to reduce feeding of crows in almond orchards. Wang et al. (2019) tested a drone system incorporating bird psychology for efficient bird damage control in vineyards. Their drone broadcasting bird distress calls could deter large birds (Ravens (*Corvus*) and Cockatoos (*Psittacidae*)). Other strategies used secondary repellence, i.e. the effects of stimuli affecting the birds after they have ingested a target crop or seed. For example, Werner et al. (2011) tested an anthraquinone-based bird repellent on captive Ring-necked Pheasants (*Phasianus colchicus*) and Common Grackles (*Quiscalus quiscula*), which induced post-ingestive illness and long-term avoidance of visual or chemosensory cues associated with the seeds. These birds discriminated between untreated sunflower seeds and seeds treated with 1300-ppm anthraquinone. Moreover, a field efficacy study (Linz et al., 2011) found less bird damage on ripening sunflowers in anthraquinone-

98 treated enclosures than in untreated enclosures. Even if such strategies were used for high-
99 value crops and on limited areas, the concept of exploiting the animals' foraging behaviour
100 and cognition of foods has largely improved the methods of bird control for other crops
101 (Beauchamp, 1995; Clark, 1997; Avery, 2003).
102 The present study aimed to better understand the birds' foraging behaviour and preference for
103 sunflower seeds in an area of intensive agriculture situated in Burgundy, France. Locally,
104 Corvidae (especially, *Corvus Frugilegus* and *Corvus Corone*) predominate in the avifauna of
105 this open field landscape (Frochot, 2016). Here, two sensory cues were considered to assess
106 the alteration of the birds' preference for sunflower seeds when these are artificially coloured
107 or flavoured through pepper coating. Several preliminary assays were conducted in open
108 fields to reproduce the local conditions of sunflower production, but without systematically
109 controlling variations in meteorology.
110
111 **2. Materials and methods**
112 ***2.1. Study site and animals***
113 The study was conducted between November and December 2018 in the experimental field
114 belonging to Institut Agro Dijon, an Agricultural Engineering School located at the periphery
115 of Dijon, France (47°18'34.0"N, 5°04'00.9"E). The experimental plots devoted to this
116 research (Figure 1) are situated in a urban wooded environment, measured 5 x 10 m and have
117 had no pesticide treatment. A little group of 6 adult carrion crows were known to live in the
118 area of these plots.
119 ***2.2.Experimental design***
120 The experiments were carried out over two 3-day sessions from 19 to 21 November (session
121 1), then from 17 to 19 December 2018 (session 2). For each session, day 1 was dedicated to
122 measuring the influence of seed colours, whereas days 2 and 3 were allocated to measure the

influence of seed pepper coating on birds' feeding behaviour. We organized the experiment in this way to prevent rejection of seeds by birds first trying pepper-coated seeds. For each assay, 200 sunflower seeds were placed in 10 furrows (10-m long; 3-cm deep) spaced 10 cm apart.

2.3. Assessing the influence of seed colours on birds' intake

On day 1, two colour modalities were assayed: uncoloured sunflower seeds (control) and blue sunflower seeds, coloured with food colouring [composed of Blue 1 (CAS: 3844-45-9, E133); citric acid; and potassium sorbate (CAS: 24634-61-5, E202), purchased from Vahiné® Avignon, France)]. We used black and white striated aviary sunflower seeds (Confection non-oilseeds, Hamiform©). Following certain authors (Pegram and Rutowski, 2014), we considered blue coloration as a potential warning colour for birds . On each day, twenty seeds of each colour modality were alternately placed 25 cm apart in each furrow on the surface of the soil and left for 4 hours from 9 am. Each furrow began with a blue seed then a control seed, then a blue seed and so on. The operation was repeated within the ten furrows (n_{total}=20 seeds x 2 colours x 10 furrows= 400 seeds; 200 seeds by colour). Four hours after placing the seeds, the remaining seeds within each furrow were counted.

The bird species seen on the plot and their numbers were identified with a panoramic videorecorder (Moultrie P-180i, PRADCO Outdoor Brands, Birmingham, USA) equipped with motion detection. When the camera detected a motion, one picture (Figure 2) and one short video (10 sec) were recorded. The minimum duration between two motion detections was 1 min. The behaviour of the bird was analysed along following behavioural categories: feeding (head movements downwards with beak directed to or in contact with the ground), moving (bird walking or hopping on the ground) and flying (bird positioned over the experimental ground without contact, wings spread). To accustom the birds to the video-camera, it was positioned 2 days prior to the start of the session.

2.4. Assessing the influence of pepper coating seeds on birds' intake

A pepper coating (PNF19, Bio Natural Protect, Roissy, France) composed of a mixture of spices (chili peppers and pepper) and an odour agent (geraniol) suspended in water and oil, was assayed on the same striated sunflower seeds. To prevent a possible generalization of avoidance of all seeds in birds who would have first tried the pepper-coated seeds, we delayed the presentation of the different types of seeds. Thus, twenty uncoated seeds (control) were placed in each of the 10 furrows on day 2 for 4 hours from 9 am as control. Then, after removing the uncoated seeds, twenty pepper-coated seeds (Pepper Seeds) were placed in the same 10 furrows on day 3 for 4 hours from 9 am (n_{total}=20 seeds x 2 modalities (control *vs.* pepper) x 10 furrows= 400 seeds; 200 seeds by modality). The remaining seeds within each furrow were counted 4 hours after the start of each assay.

To ensure that only birds consumed the seeds in both sessions (4 hours after the start of each assay), an experimenter systematically checked the pictures-recordings, directly in the experimental field. Then, the exact number and behavior of birds cannot be analyzed due to technical problem with the storage of pictures and videos.

2.5. Data Handling and Statistical Analyses

From the number of seeds remaining in the furrows, we calculated the bird's intake of each kind of seed (Colours: control vs. blue seeds; Pepper-Coating: control vs. pepper seeds) 4 hours after the start of an assay.

The intake of birds was tested for normal distribution of the error residuals and homogeneity of variance (Shapiro-Wilk test). Parametrical tests were used if the conditions of normality were verified and non-parametrical tests if not. A mixed procedure with "Colour", "Session" and "Colour*Session" as fixed effects and "Furrow" as random effect was used for testing the

influence of sunflower seed colour. When there was a significant interaction between the factors, the Bonferroni correction was applied to pair comparisons. A Kruskall-Wallis test with "Coating*Session" as factor was used for assaying the pepper effect. Then a multiple comparison by pairs with the Dunn procedure was used. The significance threshold was set at p= 0.05. Statistical analysis relied on the XLSTAT software (version 2016.03.35937, Addinsoft, Paris, France).

3. Results

3.1. Species attracted to the experimental plots

Only Carrion crows (Corvus corone) were detected in both sessions from the video recordings on the experimental plot during the 4 h-observations from assay onset. Depending on the period, one to 3 individual crows landed on the furrows at the same time (Figure 2).

3.2. Influence of seed colour on bird's intake

Birds' general behaviour are described in Figure 3. They spent 91% of time feeding and 9% of time moving (on 44 pictures of bird taken between 9h00 and 13h00) during session 1; 81% of time feeding, 15% of time moving and 4% of time flying (on 54 pictures of bird taken between 9h00 and 13h00) during session 2 (Figure 3).

Table 1 describes the number of seeds consumed by session and colour modality. In session 1, after 4-h testing, the total intake consisted of 85.5% of control seeds and 14.5% of blue seeds (Table 1) (i.e., 74% of total control seeds and 12.5% of total blue seeds were consumed). In session 2, after 4-h testing, the total intake consisted of 57.1% of control seeds and 42.9% of blue seeds (Table 1) (i.e., 62% of total control seeds and 46.5% of total blue seeds were consumed).

The birds' intake of sunflower seeds was significantly affected by the colouring, as attested by the main effects of Session ($F=4.7$; $P=0.04$) and Colour factors ($F=62.1$; $P<0.0001$), and the Session x Colour interaction ($F=23.8$; $P<0.0001$). For both sessions, blue seeds were significantly less consumed than control seeds at 4 after the assay onset (Figure 4). The blue seeds were significantly less consumed in session 1 than in session 2 (Figure 4).

3.3. Influence of seed pepper coating on bird's intake

Table 2 describes the number of seeds consumed by session, and coating. In session 1, after 4 h testing, the total intake consisted of 51% of control seeds and 49% of pepper seeds (Table 2) consumed (i.e., 100% of total control seeds and 96% of total pepper seeds were consumed). In session 2, after 4h testing, the total intake consisted of 62% of control seeds and 38% of pepper seeds (Table 2) consumed (i.e., 100% of total control seeds and 60.5% of total pepper seeds were consumed).

Pepper coating affected significantly the birds' intake of sunflower seeds (Kruskal Wallis test, $K=30.4$; $P<0.0001$; Figure 5). In session 2, the pepper coating induced a significant effect on ingestion, the birds consuming less pepper seeds than control seeds. However, this difference was not significant in session 1 (Figure 5). Birds consumed significantly less pepper seeds in session 2 than in session 1 (Figure 5).

4. Discussion

This study assessed whether and how birds react when naturally attractive sunflower seeds are altered visually or chemosensorily. In the present conditions, the video-recordings of assays lasting 4 h showed that only birds consumed the seeds. Specifically, only Carrion crows (*Corvus corone*) landed on the experimental plots to consume sunflower seeds.

Crows' reaction to the visual alteration of seeds

The colouring of the sunflower seeds in blue hue influenced significantly the birds' selection. Against non-coloured seeds, blue colouring reduced indeed seed intake. Corvids (crows and ravens) are able to discriminate between colours, and appear especially reactive to blue [e.g., blue plastic tubes (Range et al., 2008), eggs (Götmark, 1992) or images (Nieder, 2017)]. In our study, the crows appeared clearly reluctant to ingest blue-coloured seeds. These results ascertain first that they rely at least in part on sight to detect the seeds, and secondly that the blue hue is used selectively before food intake. Here, crows appear to perceive blue as a negative clue. This might represent a case of neophobia, a stable behavioural trait in corvid species (Miller et al., 2021). The crows' reluctance to blue seeds decreased indeed between sessions, as they consumed significantly more of them during session 2 than during session 1. Neophobia in corvids is modified by socio-ecological factors: it decreases when the observed corvid species dwell in urban habitats (as in the present study), and forage in larger flocks and family groups (Miller et al., 2021). Thus, several hours might be enough to attenuate their assumed neophobia in familiarizing them with seeds newly coloured in blue. This rapid change from selective to non-selective intake behaviour suggests that the crows quickly learn the visually safe character of this novel food, probably in testing the absence of negative post-ingestive consequences of its intake. Carrion crows, as other corvid species, show indeed great behavioural plasticity to environmental challenges due to their high cognitive abilities (Emery and Clayton, 2004; Nieder, 2017). After a first episode of rejection of visual novelty conveyed by foodstuffs, they can rapidly adopt novel foods (Chiarati et al., 2012). This fast habituation is probably boosted by the social group, as an individual bird's feeding behaviour depends on the food choices of co-occurring conspecifics (and even heterospecifics, as carrion crows often flock with other corvid species) (Reidinger and Mason, 1983). Here, the lower intake of blue seeds by birds may not be linked to a true avoidance or lower detectability of

247 the coloured seeds, but only to some delay in learning that this colour is not detrimental. To
248 sum up, it appears that only altering the colour of sunflower seeds is transitorily effective to
249 prevent carrion crows from eating them, but it is clearly not an operative way in the long run.
250
251 **Crows' reaction to the chemosensory alteration of the seeds**
252 It may be noted that the method used to colour the sunflower seeds in blue was confounded
253 with an exposure to flavourants (citric acid and potassium sorbate). Thus, the reluctance to
254 consume the blue seeds may be additionally explained in part by the effect of chemosensory
255 novelty at the pre-ingestive and oral phases of ingestion, respectively. In the second
256 experiment, we assessed whether altering only the chemosensory features of the seeds
257 impacted their intake by the crows. We opted to treat the seeds with a commercial mixture of
258 compounds, dominated by pepper and geraniol, activating simultaneously all types of oro-
259 nasal chemoreceptors of birds (olfaction, taste, trigeminal chemesthesis). It turns out that the
260 pepper coating induced a reluctance relative to the control seeds in the second session only
261 (i.e., 3 weeks after the session 1). This result suggests that the birds may sense and remember
262 adverse interoceptive effects of the flavoured seeds. Indeed, crows can learn and memorize
263 negative events associated with feeding as, for example, the presence of dead conspecifics (in
264 wild American crows (Corvus brachyrhynchos) : Swift and Marzluff, 2015) or taste-aversion
265 conditioning (in wild American crows (Corvus brachyrhynchos) : Nicolaus et al., 1983; in
266 hooded crows (Corvus cornix) : Bogliani and Bellinato, 1998).
267 Earlier studies (Mason et al., 1991; Werner et al., 2010) showed that birds are not exceedingly
268 sensitive to capsaicin, the active compound of pepper, and that therefore pepper-coating does
269 not suffice to induce long-term deterrence. Whereas capsaicin is a useful deterrent for
270 mammals (e.g., horses: (Aley et al., 2015); flying squirrels: (Meyer and Cox, 2019)), the
271 Flock Buster®, a repellent in the USA which contains pepper among other substances, is

insufficiently effective to reduce bird damage on sunflower crops (Werner et al., 2010). Moreover, the 'Blue1' used here as the colouring agent also contains citric acid, which has a sour taste. Hence, it may be hypothesized that the addition of sourness alone has no strong, long-term repellent effect on Carrion crows. Some authors suggest even that capsaicin and acid taste are effective in repelling mammalian predators from birds' nests, considering that birds are relatively insensitive to them (Baylis et al., 2012). It would be interesting to study in an experimental population the flavours that birds prefer.

In fact, other chemical treatments used on crops, in particular bitter tastants, appeared to be more efficient repellents for birds. For example, the bitter/astringent taste of anthraquinone reduced corn pulling by birds and increased plant populations (Curtis et al. (2019). Considering the present and earlier investigations (Werner et al., 2007), approaches targeting the bitter taste, such as black soap or caffeine, should be favoured. However, relying on monomodal cues (only visual or only chemosensory) to alter the sensory properties of the seeds appears moderately effective or ineffective to prevent carrion crows from eating sunflower seeds. Experiments associating multiple cues should be conducted, for example, associating visual and olfactory at pre-ingestive phase, taste and olfactory cues at the ingestive phase, and adverse interoceptive cues favouring the engagement of aversive conditioning at the post-ingestive phase.

Limitations and perspectives

This study is exploratory in nature, and, hence, has several limitations. First, the sensory alterations of the seeds relied on single sensory cues, visual or chemosensory (although the visual cues were confounded with chemosensory cues). We suggest, in line with other studies (e.g., Japperton et al., 2012; Sausse & Levy, 2021), that associating visual plus chemosensory

primary repellents into a multisensory effect may bear more efficiency in the interaction between carrion crows and sunflower seeds.

Secondly, multiple factors linked with the presentation of the seeds should be explored more thoroughly. For example, the depth of burying (making or not the seeds visible), the visual contrast effect of seeds on the soil background, and the timing of seedling or the visibility of furrows might be investigated. Here, the study was conducted in autumn, which is not the usual sowing season for sunflowers in France, but which corresponds to the birds' maximal anabolic needs before winter. The bird's cognitive abilities (Dufour et al., 2020) may have let them anticipate an easy-to-get energy food source. Moreover, here the seeds were left in the furrows uncovered whereas the seeds for the regular practice of sowing are covered with dirt. It would be interesting to study the behaviour of birds with covered seeds.

Thirdly, issues can be raised about the generalisation of the present results with Carrion crows living in different landscape ecologies. Here, the crows most probably belong to an urban population as they were assessed in a built area interspersed with numerous wooded parks. Birds habituated to anthropic environments may behave differently from those living in rural or wild habitats (Miller et al., 2021). Indeed, urban birds may adjust to the multiplicity and variety of foraging and shelter conditions typical of cities (Sol et al., 2013). Accordingly, it is reasonable to consider that urban Carrion crows are more exposed to artificially coloured and spicy leftovers from human consumption goods. This could attenuate visually- and chemosensorily-based neophobia and partially explain why the birds consumed the sunflower seeds within a day in the experimental plot. Thus, this investigation should be pursued on larger samples of individuals and groups of multiple species, including Rooks (*Corvus frugilegus*) and Jackdaws (*Corvus monedula*) as they often occur in the field.

Fourthly, although difficult in wild birds, it would be useful to recognize the birds individually, at least some of them that could be used as markers of social groups recurring on

the feeding grounds. In the present conditions, it is indeed probable that the same birds flew to the experimental field, explaining their rapid habituation to the visual and chemosensory treatments applied on the seeds, especially between the two sessions. We assumed the birds that visited the experimental furrows in sessions 1 and 2 were the same, but cannot be fully certain as the individuals were not recognizable.

Finally, both above experiments underline the learning competence of Carrion crows. It is indeed well known that these birds easily get used to common scarecrows (Marsh et al., 1992) and rapidly adapt to human activities (Lee et al., 2011). Accordingly, any method aiming to manipulate their behaviour should rely on these cognitive abilities to shape their interactions with the crops, in turning these interactions into long-standing avoidance. Werner and Provenza (2011) showed that Red-winged blackbirds (*Agelaius phoeniceus*) associate visual and gustatory experience with post-ingestive consequences to avoid alimentary toxicants. In addition to social facilitation and long-term memory, such a multisensory paradigm is promising with crows. Multiple ways of sensory manipulation are available for these birds, relying on auditory, chemosensory, tactile, interoceptive, visual, physiological, pyrotechnic or physical means and their combination (Mason and Clark, 1992; Clapperton et al., 2012). Thus, we encourage the implementation of sustainable control studies, based on the associative learning of the target bird species and keeping in mind the use of natural products applicable to organic farming, such as plant secondary metabolites. Moreover, in a context of societal valuation of animal welfare, especially in agriculture, it is important to seek sustainable alternatives to the lethal methods often implied in the management of crops.

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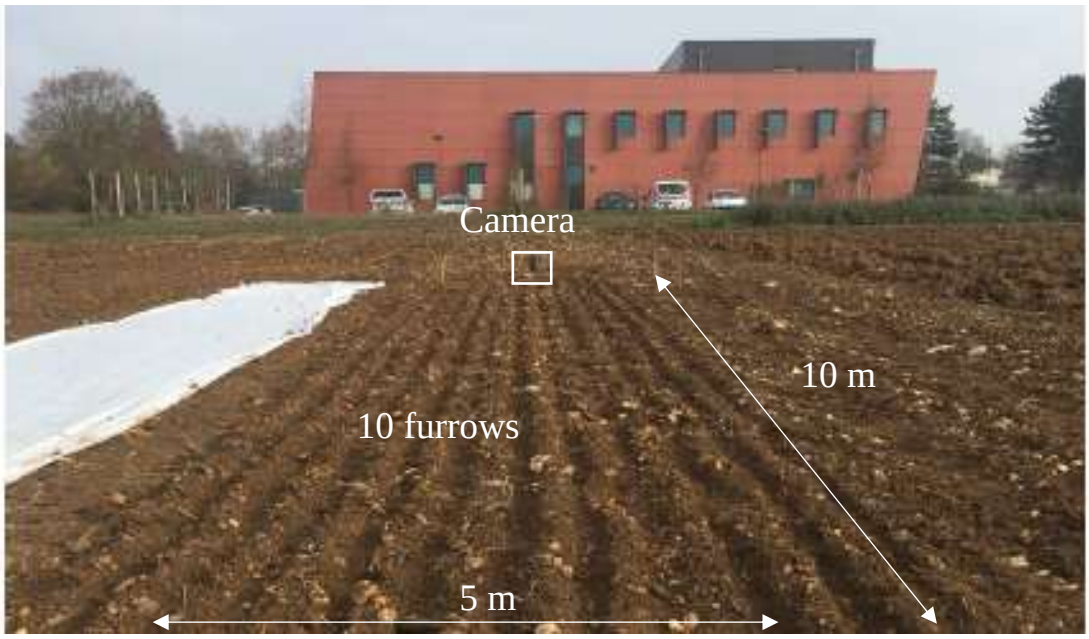

Figure 1. Experimental design

Figure 2. Example of a picture from the camera: three individual carrion crows (Corvus corone) detected, n°1 is moving, n°2 and n°3 are feeding

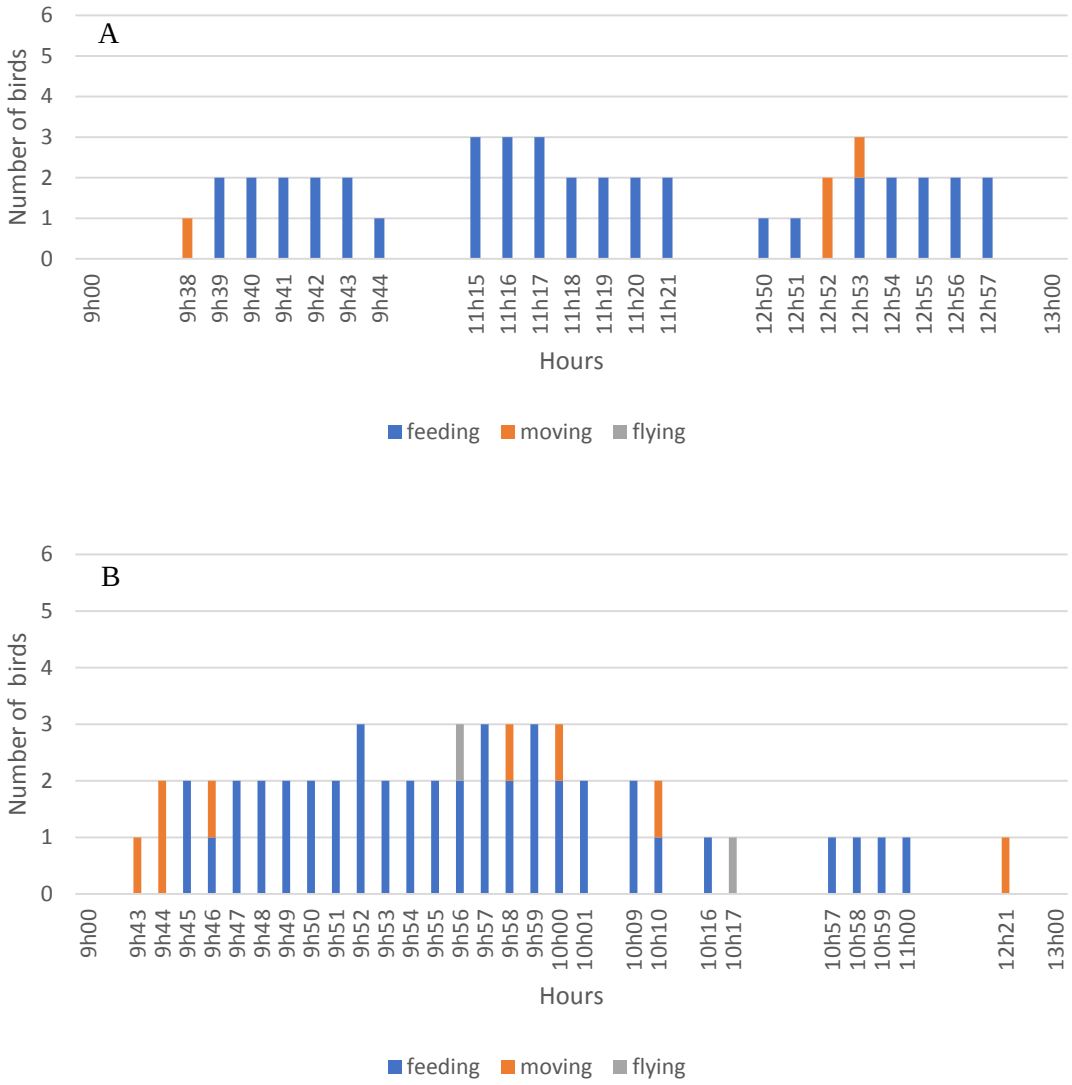

Figure 3. Number of carrion crows and their behavior during the assay assessing the influence of seed colour on birds' intake A. Session 1; B. Session 2

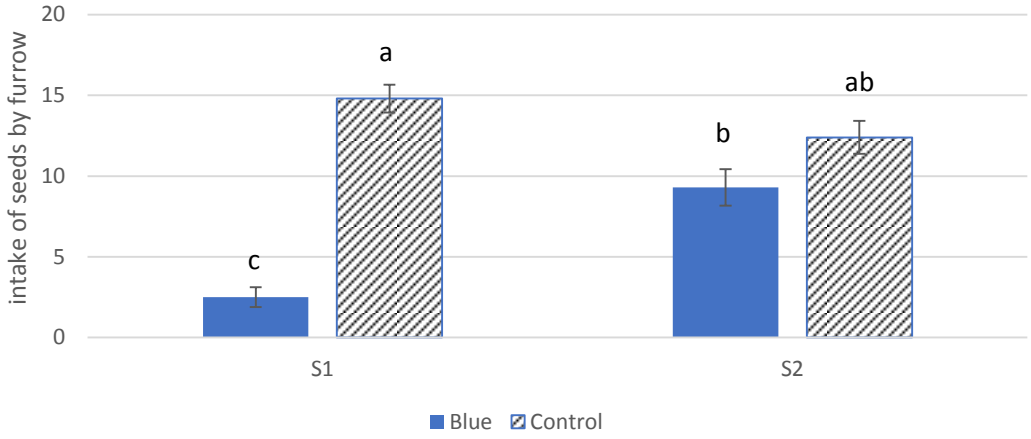

Figure 4. Average intake of seeds by furrow (n=10) depending on coloration (Blue and Control seeds). Results are presented for session 1 (S1) and session 2 (S2) after 4h testing. Data are means ± SEM. Different letters indicate statistically significant differences with P <0.05 (Bonferroni's correction).

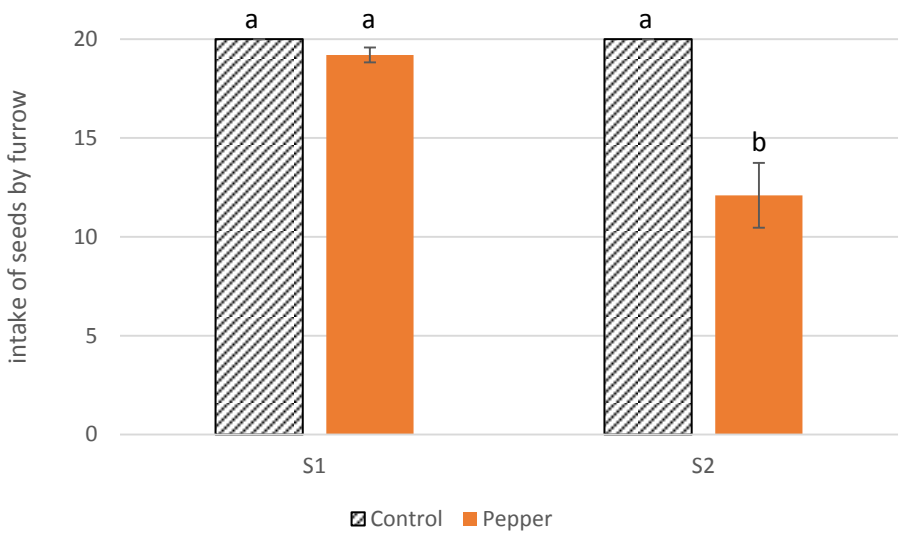

Figure 5. Average intake of seeds by furrow (n=10) depending on pepper coating (Control and Pepper seeds). Results are presented for session 1 (S1) and session 2 (S2) after 4h testing. Data are means ± SEM. Different letters indicate statistically significant differences with P <0.05 (Dunn procedure).

Table 1. Number of seeds consumed by session, hour of test and colour

Session	Hour	Total seeds consumed	Blue seeds consumed	Control seeds consumed
1	4h	173	25	148
2	4h	217	93	124

Table 2. Number of seeds consumed by session, hour of test and coating

Session	Hour	Total seeds consumed	Pepper seeds consumed	Control seeds consumed
1	4h	392	192	200
2	4h	321	121	200