

Effect of weed patch size on seed removal by harvester ants

Einfluss der Unkrautnestgröße auf die Samenprädation durch Ernteameisen

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Abstract

In dryland cereals in North-eastern Spain, the harvester ant, *Messor barbarus* L., is responsible for removal of a large proportion of the newly produced weed seeds (40-100%). The probability that seeds will be found by the ants may be influenced by weed patch size. To investigate this source of variability, 30 seed patches were created in each of three, 50 × 50 m, blocks in a cereal field after harvest, by sequentially seeding (10, 16 and 17 August 2010) with 2000 seeds m⁻² of *Avena sativa* L.. Patch size varied from 0.25 to 9 m². Twenty four hours after seeding, the remaining seeds were collected and seed removal rates estimated.

Average seed removal rate was lowest in the smallest (78-94%) and highest in the largest patches (99-100%). Differences were mainly caused by the fact that some of the smaller patches (9.7%) were not found. However, when patches were found, they were exploited at equal rates (98-100%).

As predicted, the probability of finding a patch increased slightly, but significantly, with increasing patch size. When a patch was found, it was almost always fully exploited, resulting in very high seed removal rates, irrespective of patch size. These results indicate that the size of the seed patch is only a minor source of variation influencing this form of biological control of weeds.

Keywords: Biological control, encounter rate, granivory, harvester ants, patch size, seed predation

Zusammenfassung

Im Getreideanbau der trockenen Regionen im Nordosten von Spanien sind die Ernteameisen (*Messor barbarus* L.) für den Fraß einer großen Menge der neu produzierten Unkrautsamen verantwortlich (40 – 100 %). Die Wahrscheinlichkeit, dass Samen durch die Ameisen gefunden werden, könnte durch die Größe der Unkrautnester beeinflusst sein. Um diese Möglichkeit zu untersuchen, wurden nach der Getreideernte in drei 50 x 50 m Blöcken 30 Samennester geschaffen und darauf am 10., 16. und 17. August 2010 jeweils 2000 Samen m⁻² von *Avena sativa* L. ausgebracht. Die Nestgröße variierte zwischen 0,25 und 9 m². 24 Stunden nach dem Ausbringen der Samen wurden die übrig gebliebenen Samen wieder eingesammelt und die Rate der Samenprädation bestimmt.

Die durchschnittliche Rate der Samenprädation war am niedrigsten bei den kleinen (78 - 94 %) und am höchsten bei den großen Nestern (99 - 100 %). Diese Unterschiede wurden hauptsächlich dadurch verursacht, dass die kleineren Nester (9,7 %) durch die Ameisen nicht gefunden wurden. Wenn die Nester jedoch entdeckt wurden, wurden auch sie mit vergleichbarer Rate gefressen (98 - 100 %).

Wie angenommen, erhöht sich die Wahrscheinlichkeit ein Samennest zu finden geringfügig, aber signifikant mit zunehmender Größe des Nestes. Wurde ein Nest entdeckt, wurde es aufgrund des sehr hohen Samenfraßes unabhängig von seiner Größe fast vollständig geleert. Diese Ergebnisse deuten darauf hin, dass die Samennestgröße von untergeordneter Bedeutung für diese Form der biologischen Unkrautbekämpfung ist.

Stichwörter: Biologische Bekämpfung, Ernteameisen, Granivoren, Nestgröße, Samenprädation, Trefferrate

Introduction

Seed mortality by granivores, such as birds, rodents, crickets, carabids and harvester ants may limit the population growth of weeds in arable fields. In dryland cereal fields in North-eastern Spain, the harvester ant *Messor barbarus* L. is an important seed predator. It is usually present at high densities (BARAIBAR *et al.*, 2011a) and can cause up to 46-100% seed losses, depending on the weed species (WESTERMAN *et al.*, 2012).

Weeds tend to have a patchy spatial distribution, with some areas that are densely populated and other areas that are void of weeds (e.g., Johnson *et al.*, 1996). Various factors are known to influence weed patch dynamics, such as seed dispersal, seed persistence, crop-weed and weed-weed competition, soil conditions and herbicide treatment (e.g., JOHNSON *et al.*, 1996; WEBSTER *et al.*, 2000; BLANCO-MORENO *et al.*, 2004; SHIRTLIFFE *et al.*, 2002; HEIJTING *et al.*, 2007). Seed mortality due to granivory may be another factor influencing patch dynamics. The use of patchy resources consists of two components, namely the patch encounter rate and patch exploitation rate (BARAIBAR *et al.*, 2011 b).

Patch encounter rate is influenced by the action radius of the ant colony. *Messor barbarus* is a central place forager, i.e. its workers return to the nest after a successful encounter with a food item. It forms stable trunk trails up to 30 m around the nest entrance (AZCÁRATE and PECO, 2003). In addition, it may form temporary trails in response to temporary patchy resources. Recruitment of workers to trails is controlled by pheromones (PLOWES *et al.*, 2013). Superimposed on colony behaviour is the spatial arrangement of nests and patches. *Messor barbarus* colonies tend to be regularly distributed at the small scale (≤ 10 m), but can occur clustered at larger scales. It is likely that weed patches located in areas that are heavily occupied by ant nests will have a higher probability of being discovered than patches located in an area relatively void of nests.

In this study, we investigated whether weed patch size influenced patch encounter rate. We hypothesized that smaller patches would have a lower probability of being found and exploited than larger patches, forming an escape mechanism by which weed may persist. By creating seed patches of different size but similar seed density, we eliminated the effect of exploitation rate.

Material and Methods

In a commercial, no-till cereal field in North-eastern Spain in 2010, an experimental area (150×50 m) was divided into three blocks (A, B and C) of 50×50 m each, one month after crop harvest. Thirty patches were created by removing the straw and manually scattering oats (*Avena sativa* L.), as a model species, at a rate of 2000 seeds m^{-2} , as determined by weight, during the early morning hours (7:00 - 7:30 h). Patches varied in size (Tab. 1), and were randomly located within a block, at a minimum distance of 1 m from each other and block edge. Twenty four hours after seeding, the remaining seeds were retrieved using a D-Vac (Vortis; Burkard manufacturing Co. Ltd., Rickmansworth, UK), operated for approx. two minutes per m^2 . In the case of patch sizes 1 and 2, the entire area was vacuum-cleaned; for size 3, two, 1 m^2 sub-areas were sampled; for size 4, three, 1 m^2 sub-areas were sampled. Samples were dried, sieved, cleaned from straw and weighed to estimate seeds retrieved. The experiment was initiated sequentially: block A on 10 August, B on 16 August, and C on 17 August.

Per block, five additional 1 m^2 patches (controls) were sampled one day prior to seed application to assess background seed densities. Furthermore, three additional 1 m^2 patches per block were used to test the efficiency of the D-vac, by retrieving seeds immediately after application. The average sampling efficiency, E , was calculated as the ratio between the weights of the seeds recovered (S_r) and seed applied (S_i). The seed removal rate, R , was estimated as the difference between initial, S_i , and recovered seed weight, S_r , corrected for the average sampling efficiency, E , and relative to the initial seed weight (S_i); $R = (S_i - S_r / E) / S_i * 100\%$. Ant nest density was determined by counting all nests per block.

A linear mixed regression model (Binomial distribution, logit link function, Genstat 11) was used to explain the effect of the factors block, patch within block and patch size on the proportion of seeds removed. Patches were included as a random factor and block and patch size as fixed factors. Because the factor block was significant, subsequent analyses were performed for each block separately.

Tab. 1 Patch characteristics for patch sizes 1, 2, 3 and 4.**Tab. 1** Nestmerkmale für die Nestgrößen 1, 2, 3 und 4.

Patch size class	Number of patches per block	Length = width [m]	Surface area [m ²]
1	16	0.5	0.25
2	8	1	1
3	4	1.73	3
4	2	3	9

Results

No seeds were found on the soil surface prior to seeding, except for some barley seeds (30, 22, and 85 seeds m⁻² for blocks A, B, and C, respectively). Given these low numbers, pre-existing seeds are not likely to have influenced seed removal rates. Ant nest density was similar in all blocks (416, 436 and 428 nests ha⁻¹ in blocks A, B and C, respectively) and, therefore, not likely to have affected seed removal rates. The average temperature during the sequential exposure periods was 25.3 °C in block A, 20.4 °C in block B and 24.1 °C block C. The average sampling efficiency, *E*, was 93.8%. The lowest efficiency found in a patch (91.3%) was used to derive the threshold value (8.7%) below which patches were assumed not to have been found and exploited by ants.

Tab. 2 Average seed removal rate, *R* (based on weight), and the number of patches not found ($R < 8.7\%$), partially exploited ($8.7\% \leq R < 98\%$) and fully exploited ($R \geq 98\%$) in blocks A, B and C.

Tab. 2 Mittlere Rate der Samenpräädation, *R* (basierend auf Gewicht) und die Anzahl der Nester, die in den Blöcken A, B und C nicht gefunden ($R < 8.7\%$), teilweise gefressen ($8.7\% \leq R < 98\%$) und vollständig gefressen ($R \geq 98\%$) wurden.

Block	Patch size class	N	Average R [%]	Number of patches with			% patches found
				$R < 8.7^*$	$8.7 \leq R < 98$	$R \geq 98$	
A	1	16	88	2	0	14	87.5
	2	8	100	0	0	8	100
	3	4	100	0	0	4	100
	4	2	100	0	0	2	100
B	1	16	78	3	2	11	81.25
	2	8	82	1	1	6	87.5
	3	4	100	0	0	4	100
	4	2	86	0	1	1	100
C	1	16	94	1	0	15	93.75
	2	8	100	0	0	8	100
	3	4	100	0	0	4	100
	4	2	100	0	0	2	100

* patches considered not found

Average seed removal rate was lowest in small (78-94%) and highest in medium and large patches (86-100%; Tab. 2). Patch size significantly influenced average seed removal rate in blocks A ($P < 0.001$) and C ($P = 0.002$), but not in block B ($P = 0.063$). Differences in average seed removal rate were mainly caused by the encounter rate and less so by the exploitation rate. Six out of 48

patches of size 1 and 1 out of 24 patches of size 2 had not been discovered by harvester ants ($R < 8.7\%$) and only four patches of different sizes, but all located in block 2, had been partially exploited ($8.7\% \leq R < 98\%$). All other patches had been (almost) fully exploited ($98\% \leq R \leq 100\%$) (Tab. 2).

Discussion

The probability of finding a patch increased slightly, but significantly, with increasing patch size. When a patch was found, it was almost always fully exploited, resulting in very high seed removal rates, irrespective of patch size.

A 24h exposure period had been chosen deliberately. Prior experience with these harvester ants had indicated that prolonged exposure could result in extremely high encounter and exploitation rates (BARAIBAR *et al.*, 2011 b), which would have masked any (temporary) differences caused by patch size. However, under normal field conditions, exposure can last several weeks, which should suffice to annihilate any patch of any size. Consequently, small patch size is not a very likely mechanism by which weed seeds can avoid predation despite strong predation pressure. If weeds have no other mechanisms by which they can safely enter the seed bank in fields occupied by harvester ants, the seed bank should gradually exhaust (FORCELLA, 2003) and the weed population could perish.

Assuming a regular distribution of nests in space and an action radius of 25 m around the nest entrance (AZCÁRATE and PECO, 2003), a density of 16 nests ha^{-1} should suffice to fully cover a field. Here, nest densities had been 26 times higher, although absolutely normal for the region (range 140–1168 nests ha^{-1} ; BARAIBAR *et al.*, 2011a). Results may have been different if nest density had been (much) lower.

Results in block B differed from those in the other blocks; more patches remained undiscovered and only this block harboured partially exploited patches. The average temperature during the period of seed exposure in block B had been 4 - 5 °C lower than in the other two blocks. It is likely that this was responsible for the deviating results, as *M. barbarus* is known to respond strongly to temperature, affecting foraging activity (AZCÁRATE *et al.*, 2007). We noticed that some patches were discovered late, such that only part of the seeds had been harvested by the time of the evaluation.

Two other mechanisms may have been involved in the partially exploited or undiscovered patches. Three of the undiscovered small patches were located next to large patches, which may appear more attractive, luring the ants away from the neighbouring smaller patches (LÓPEZ *et al.*, 1993). As soon as the larger patches have been exploited, the ants may have focused their attention on smaller patches. As anticipated, seed patches could (temporary) escape harvesting if located in an area that is relatively void of nests. This was the case for the size-4 patch in block B that had been partially exploited. Only one small nest was present in a radius of 10m around the patch.

In the normal range of nest densities found in the area, small patch size *per se* is not a very likely mechanism by which weed seeds can avoid predation. The size of a seed patch is only a minor source of variation influencing this form of biological control of weeds. Harvester ants appear to be highly effective seed predators, more so than most other seed predators in most other agroecosystems (compare DAVIS *et al.*, 2011).

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