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Review paper

EFFECT OF PREDATORS ON WEED SEED PRODUCTION AND SOIL SEED BANKS

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Predation is one of the crucial sources of seed mortality, or damage and loss of their germinative capacity, which is important for plant population dynamic and consequently the biological studies of weed species. The main factors affecting the level of predation of seeds prior to their dispersal (pre-dispersal predation) and after dispersal (post-dispersal predation) are reviewed. Attention is especially focused on effects of agricultural soil cultivation, the development and apprearance of predators' weed hosts, timing of seed shed and timing of seed burial. The most frequent groups of predators and their participation in weed seed predation are discussed.

Key words: predation, weed seeds, pre-dispersal predation, post-dispersal predation, mice, ground beetles, birds

INTRODUCTION

Reproduction of weeds, germination of their seeds and soil seed banks, as well as their population dynamic and competition within agro-ecosystem are gaining in importance in modern agriculture (KOVAČEVIĆ AND MOMIROVIĆ, 2000), especially as part of the development of organic and sustainable agriculture.

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Conventional weed control methods aim either at preventing or delaying their germination (agricultural soil cultivation methods), or at treating seedlings in different stages of development (mechanical control or herbicides application). However, at least 95% of plant mortality takes place at the seed stage, which makes the period between zygote formation and seed germination the riskiest stage in the life of a weed plant (FENNER, 1985). Besides other factors that may result in the death or damage and loss of germinative capacity, predation is another major source of seed mortality in plant population dynamic.

Seed predation occurs prior to dispersal (pre-dispersal predation) or after dispersal (post-dispersal). Most pre-dispersal seed predators are insects specializing in one plant species, genus or family (CRAWLEY, 1992). Conversely, post-dispersal predators are mostly larger, more mobile and less specialised organisms (rodents, birds, ants and beetles), which feed on seeds of different plant species (CRAWLEY, 1992).

PRE-DISPERSAL PREDATION

A number of predators, mostly insects, destroy seeds while they are still immature and developing, before being dispersed from mother plant. Pre-dispersal seed predation leads to reduced formation of seedlings in the ecosystems of both temperate and tropical regions (HAWTHORN AND HAYNE, 1978; LOUDA, 1982; CALVO-IRABIÉN AND ISLAS-LUNA, 1999). Ants and larvae of other insects cause pre-dispersion damage of over 70% of the seeds on plants in understorey rain forests (CALVO-IRABIÉN AND ISLAS-LUNA, 1999). Similarly, LOUDA (1982) found in ecosystems of temperate regions that the degree of pre-dispersal seed predation of the species *Haplopappus squarrosus* Hook. and Arn. ranged between 44% and 73%. Both studies have led to conclusion that pre-dispersal seed predation limited the population size of the relevant plant species.

Pre-dispersal seed predation is a factor crucially affecting population dynamic of individual weed species, which has been researched particularly so as to be able to implement the results in biological weed control. Pre-dispersal predation of seeds of the species *Cirsium arvense* (L.) Scop. by midge *Orellia ruficauda* Fab., for example, has been recorded on 20-85% of inflorescences in Canada, and 20-80% seeds (FORSYTHE AND WATSON, 1985). HARRIS (1989) found 99.5% seeds of the weed species *Centaurea miculosa* Lamarck in Canada to be destroyed by two fly species, two wasps and one moth that attack its generative organs. The weed species *Carduus nutans* L. is being biologically controlled in the USA, Canada and New Zealand by weevil *Rhinocyllus concinus* Prelich (*Coleoptera: Curculionidae*), which destroys seeds in their development. This weevil species has been found to destroy 63% of the seeds of some biannual and 90 % of annual plants (SHEPPARD *et al.*, 1989).

This country has a long and extensive tradition of research of biological methods of weed control (PETANOVIĆ *et al.*, 2000a, 2000b). The list of predators includes organisms that attack generative organs of weed plants (MANOJLOVIĆ *et al.*, 1989; TALOŠIĆ *et al.*, 1989; MANOJLOVIĆ AND TOŠEVSKI, 1990; MANOJLOVIĆ AND SIVČEV, 1996; SIMOVA-TOŠIĆ *et al.*, 1998; SPASIĆ AND SMILJANIĆ, 1998). The monofagous species *Gymnophytomyza heteroneura* Hendel (*Diptera, Agromyzidae*), for example, has been reared on *Gallium aparine* L. seeds (SIMOVA-TOŠIĆ, 1998), while *Melanogromyza cuscutae* Her. develops on stems and seeds of parasite flowering plants belonging to the *Cuscuta* genus (SPASIĆ AND SMILJANIĆ, 1998).

Effects of pre-dispersal seed predation on weeds in annual crops have not been thoroughly studied. Annual crops are unique by the high-frequency and high-intensity of mechanical and chemical treatments that are required for their cultivation. It is therefore not possible to evaluate seed predation in annual systems on the basis of data collected for perennial ones.

The most common pre-dispersal damage caused to seeds by a single predator is around 10%, rarely over 20% (HAWTHORN AND HAYNE, 1978; SHEPPARD *et al.*, 1994; DESOUSA *et al.*, 2003; NURSE *et al.*, 2003). SHEPPARD *et al.* (1994) reported that the larva of *Lepidoptera* was responsible for pre-dispersal predation of *Carduus nutans* L. seeds at 0-11% level. DESOUSA *et al.* (2003) estimated seed loss of *Amaranthus retroflexus* L. in maize fields, caused by *Coleophora lineapuvella* Chambers (*Lepidoptera: Coleophoridae*) at around 4-11%. NURSE *et al.* (2003) tested two plant species over a period of two years and found a pre-dispersal predation mean ranging from below 1% to 26% in 1998, and from 1% to 9% in 1999 for the species *Amaranthus retroflexus* L., and between 2% and 4% for *Chenopodium album* L.

Higher rates of pre-dispersal seed predation were reported in researches where more than one species of insect larvae were responsible for predation (LAMP AND MCCARTY, 1982; ANDERSEN, 1989; MOLAU *et al.*, 1989). LOUDA (1982) for example found that pre-dispersal seed predation by a combination of larvae of different taxa caused damage to seeds of the species *Haplopappus squarrosus* Hook and Arn. at a level that exceeded 90% in some cases.

Soil cultivation methods and technology may influence the level of predation. Tillage methods and crop row width can affect soil moisture, as well as the quality and quantity of light reaching soil surface. Besides, HOUSE *and al.* (1981) and READER (1991) have shown that plant debris on the soil surface, such as that left after reduced tillage, provide a micro-habitat that can improve insect survival. A higher level of seed predation may therefore be expected with such agricultural practices that favour survival and reproduction of seed predators. NURSE *et al.* (2003) started from the hypothesis that reduced cultivation (no-tillage) and narrow-row width would create microclimatic conditions inside soybean (*Glycine max.* Merr.) fields that would favour insect populations feeding on seeds of the species *Amaranthus retroflexus* L. and *Chenopodium album* L. However, they found that pre-dispersal predation of *Amaranthus retroflexus* L. seeds in the presence of soybean was highest in tilled fields with narrow-row width. The mean of pre-dispersal predation was lower in treatments with a cultivated crop (soybean) than in crop-free control. The percentage of predation in soybean fields did not exceed 5% either in tilled or untilled fields, while it was as high as 26% in fields with no (soybean) crop. Pre-dispersal predation of *Amaranthus retroflexus* L. was in 1998 higher on untilled than on tilled soil both in crop-free fields and in those with soybean sown in wide-row width. For *Chenopodium album* L., however, the level of pre-dispersal predation was 4 % or lower both in fields with cultivated crop and those without any crops. On the other hand, DESOUSA *et al.* (2003) found a low level of pre-dispersal seed predation of *Amaranthus retroflexus* L. growing in maize (*Zea mays* L.), the predation degree being 4-11% and unaffected by row width or density of maize sowing. Besides, they observed no effect of tillage method on the level of predation, nor any differences in treatments with and without cultivated crops in the field.

Pre-dispersal seed predation is normally highly variable in space and time (EHRLÉN, 1996), and often greater variation occurs between individuals within a population than between populations tested in different experiments. NURSE *et al.* (2003) reported that variation in pre-dispersal seed predation rates for individual plants was 0-80% in both investigated plant species, *Amaranthus retroflexus* L. and *Chenopodium album* L., although predation rate for most individuals was below 10%. Statistical analysis showed pre-dispersal predation to be positively correlated with weed height, number of seeds and mass of terminal inflorescence in both species, and directly correlated with the length of terminal inflorescence only in *Chenopodium album* L. Many insects were found to be attracted to plants with multiple flowers, larger inflorescences, great density or biomass. FENNER *et al.* (2002) found that larval presence on plants of the family *Asteraceae* increased with capitulum size and that this occurred between and within species. Similarly, individual plants of *Lathyrus vernus* (L.) Bernh. (*Fabaceae*) with larger inflorescences sustained higher rate of seed predation (EHRLÉN, 1996). SHEPPARD *et al.* (1994) showed that moth egg laying on inflorescences of *Carduus nutans* L. increased with their size.

Evidently the criteria for insects' choice of a host-plant are its properties that secure better survival and greater reproduction rates of the insect. Inflorescence architecture is a crucial characteristic in making this choice. Inflorescences with abundant branching and many closely packed flowers provide space and resources for survival and overwintering of great many larvae. Dense inflorescence structure enables larvae to stick undetected by its enemies and thus overwinter on the plant. Besides, if a large number of seeds are present, they will provide a source of food for the larvae forming overwintering chrysalis. An interesting implication has thus been observed that herbicide-resistant weeds are more attractive to insect predators because resistant plants are larger in size than more susceptible ones. Consequently, it is possible that weeds resistant to herbicides sustain greater predation rates (NURSE *et al.*, 2003).

Pre-dispersal predation in its own right may not be the most important cause of seed mortality. In order to be biologically significant, seed loss needs to be sufficiently extensive so as to reduce the high reproductive potential of weed species, which often produce thousands of seeds per plant and maintain successful strategies of seed dormancy. Consequently, a high loss by pre-dispersal predation would have to be combined with post-dispersal predation and other forms of seed mortality to be biologically significant.

POST-DISPERSAL PREDATION

In natural ecosystems, animals may consume over 70 % of produced seeds (CRAWLEY, 1992). Although agrarian ecosystems have conditions different from natural ones, seed predators may be expected to have a considerable share in regulating population dynamics of plant species. A total of 70-99 % of weed seeds produced in cereal crops annually is eliminated, i.e. their germination and development into seedlings never occurs (CARDINA and NORQUAY, 1997). Predation may be responsible for most of those losses (BRUST and HOUSE, 1988; READER, 1991; POVEY *et al.*, 1993; CARDINA *et al.*, 1996; ANDERSSON, 1998; CROMAR *et al.*, 1999; TOOLEY *et al.*, 1999; MENALLED *et al.*, 2000; Westerman *et al.*, 2003a, 2003b). The data recorded, however, has been difficult to compare because of the different lengths of measurement times and conditions during measurements (i.e. different parts of the vegetation season, application of different agricultural practices, different crops in fields under investigation, etc.) (Table 1).

Table 1. - Examples of weed seed predation levels (percentage of consumed seeds per exposure time) on arable land

Predation level	Crop	Period	Reference
20-90 % per 3 weeks	oat, grass -clover	July-August	ANDERSSON (1998)
3-62 % per 7 days	soybean	October-November	BRUST AND HOUSE (1988)
14-99 % per 14 days	maize	January-December	CARDINA *et al.* (1996)
49-84 % per 7 days	maize	September	MENALLED *et al.* (2000)
5-35 % per 3-4 days	field margins around cereals	September-October	POVEY *et al.* (1993)
24-90 % per 2 weeks	cereals	June-August	TOOLEY *et al.* (1999)
32-70 % per 1 year	cereals	May-September	WESTERMAN *et al.* (2003b)

Estimates of predation-caused weed seed losses that are available in literature suggest that this type of mortality may be considerable, but there is significant variation over different years or even during one particular year (WILLSON AND WHELAN, 1990; CARDINA *et al.*, 1996; TOOLEY *et al.*, 1999) as well as between different fields (HULME, 1994; MENALLED *et al.*, 2000).

CARDINA *et al.* (1996) found that post-dispersal seed predation in maize fields may reduce as much as 11% of available seeds per day, while CROMAR *et al.* (1999) measured a mere 3% daily reduction in maize fields.

Soil cultivation method most directly affects the degree of seed predation. BRUST AND HOUSE (1988) showed that around 69% of weed seeds were used by predators in a system of soybean cultivation without tillage, compared with 27% under conventional cultivation. The difference in percentages comes mostly from seeds that get buried deeper into the soil during conventional tillage, which expands the existing soil seed bank and increases the number of weed plants that may potentially germinate and thus threaten agricultural production.

LANDIS AND MARINO (1999) assumed that post-dispersal seed predation would be greater in areas with higher abundance of non-crop habitats as they can supply richer and more multifarious fauna of predators. However, although WESTERMAN *et al.* (2003b) included such fields in their research and despite considerable differences between the tested fields, e.g. regarding seed production level, composition of weed species, crop types, date and density of sowing, field size, soil type, spacing of sown seeds and type of margin vegetation, none of these factors has brought about a tangible change in the existing trend or level of seed predation. The authors assumed that populations of seed predators had reached their maximum in the areas of investigation and become powerful enough to be relatively indifferent to changes in soil cultivation practices and other changes in the fields and surrounding areas.

Annual seed losses due to post-dispersal predation is generally determined by the duration of exposure times of seeds, i.e. the time during which seeds are available to predators, and the degree of predation during that period. WESTERMAN *et al.* (2003b) reported a calculated annual weed seed loss caused to cereal crops by predation of 32% to 70% per tested agricultural farm under presumed continuing exposure of seeds to predators. When they limited the period of seed exposure in the calculation to 4 or 2 weeks after dispersal, the degree of predation was found to be 28-67% per farm within four weeks, and 18-57% within 2 weeks.

The exposure period starts with seed shed, although some predators consume mature seeds while they are still on plants (KJELLSSON, 1985). The timing of seed shed depends on the plant species, crop and climatic conditions, and is generally known for most weed species (LEGUIZAMÓN AND ROBERTS, 1982; JANJIĆ AND KOJIĆ, 2000). Exposure terminates with seed burial in the soil (HULME, 1994) or with seed germination. Germination of newly-produced seeds in the field prior to harvest is limited by the reduced intensity and quality of light under dense plant cover and unfavourable conditions for germination on soil surface over the summer season, as well as by the primary dormancy of seeds of many weed species. Consequently, the exposure and susceptibility of weed seeds to predation are mostly conditioned by the variation in the time of shed and burial in soil.

Burial of seeds in soil is mostly achieved by tillage. However, natural seed burial also occurs during the vegetation season. The depth of seed burial seems to depend mostly on weather conditions, soil type and seed characteristics. Preliminary experiments in The Netherlands show that 50% of small-size seeds of *Chenopodium album* L. disappear from the soil surface within about two weeks (WESTEMAN *et al.*, 2003b). The degree of burial for species with large-size seeds, such as *Avena fatua* L. and *Polygonum convolvulus* L., was found to be significantly lower.

Environmental conditions and agricultural practices, which speed up weed phenology and cause early shed of seeds and delayed burial into the substrate, will lead to large-scale seed losses in cereal fields. Species that mature earlier, e.g. *Capsella bursa-pastoris* (L.) Medic. or species that bear fruit during longer periods of time such as *Stellaria media* (L.) Vill., *Viola arvensis* Murr. or *Chenopodium album* L., sustain more considerable seed losses to predation. On the other hand, many weed species with large-size seeds, such as *Polygonum convolvulus* L. and *Vicia cracca* L., are late-maturing species which disperse seeds in late summer or in autumn, when predator pressure is at its lowest. Large-size seed production in late season could be a form of plant adaptation aimed to avoid predators (BROWN and VENABLE, 1991).

The differences observed in predators' preference of seeds of particular weed species (BORCHERT AND JAIN, 1978) may be attributed to different timing of seed shed and duration of seed exposure to predators, although they may also be the result of differences in seed attractiveness to predators caused by, for example, their physical properties, tastefulness and nutritive value (BORCHERT AND JAIN, 1978).

The composition of weed vegetation affects the timing of seed shed as only one or two species are normally responsible for the production of the main mass of seeds on a farm. Of 35 weed species that MOORCROFT *et al.* (2002) found on stubble fields under observation, merely 16 species had over 1% coverage in one or more types of stubble.

MICE AND GROUND BEETLES

The composition of predator populations also affects the level of seed consumption. Various groups of animals feed on seeds, including some vertebrates (i.e. birds and rodents) and invertebrates (snails, ants, ground beetles, crickets, etc.) (BRUST AND HOUSE, 1988; CARDINA *et al.*, 1996; CROMAR *et al.*, 1999). Birds are the most important predators in fields over the winter period, while they are normally rare on tilled fields during the vegetation season (WESTERMAN *et al.*, 2003a). Mice, ants and ground beetles are the most frequent main groups of organisms responsible for the epigeaic loss of weed seeds on tilled fields over the season (CARDINA *et al.*, 1996; CROMAR *et al.*, 1999). They differ in mobility, food and habitat affinities and population dynamics, and can consequently respond differently to any particular type of agricultural practice. Mice, in general, prefer larger seeds, while ground beetles and some other insects are inclined to seeds of smaller size (HULME, 1994). However, needs and affinities of predators may change over time (TEW *et al.*, 2000). Vertebrates and invertebrates often compete over the same seeds. In spring, for example, when food is in short supply, seed predators may not be too fastidious. In late summer, when food is abundant, consuming of particular seeds will depend on the seed taste, its nutritive value and availability compared with other seeds (WESTERMAN *et al.*, 2003a). Vertebrates move much faster and have excellent sense of smell, which enables them to locate seeds at some distance (JENNINGS, 1976). The speed of consumption is also greater with vertebrates. Furthermore, invertebrates may themselves be the food of vertebrates, e.g. wood mouse.

In using natural enemies within biological pest control, a gradient has frequently been observed both for the density of predator individuals and the activity shown from the margin area towards the central part of a particular crop field. Some investigations suggest that a similar regularity exists regarding seed predation, and that mice prefer feeding closer to the field margin, while invertebrates, e.g. insects, take their food in its middle (TOOLEY *et al.*, 1999). In some other researches, however, seed predation by vertebrates and invertebrates has been found spatially variable, without any evidence of pattern relating to field borders (WESTERMAN *et al.*, 2003a).

Seed predation has also proved variable in time, i.e. both predation by invertebrates (WILLSON AND WHELAN, 1990; MENALLED *et al.*, 2000; WESTERMAN *et al.*, 2003a) and by vertebrates (HULME, 1994; CARDINA *et al.*, 1996; TOOLEY *et al.*, 1999; WESTERMAN *et al.*, 2003a). Data on the proportions of seed consumption by vertebrates or invertebrates are scarce. Mice are evidently affecting seed survival over longer time periods as they are active nearly all year round and capable of reproduction almost throughout that time, while ground beetles recover from hibernation in the spring, breed a single generation of adults during June-July (spring breeders) or July-August (autumn breeders), and then again go into hibernation late in autumn and winter. Mice may survive both harvest and tillage (LOMAN, 1991). Most invertebrates leave the field in autumn or winter, the reason being either their natural life cycle or a lack of sufficient food and loss of shelter. Mice have a high degree of dispersion, which enables them to quickly colonise cultivated fields (HARRIS AND WOOLLARD, 1990) and seek new areas with high food density or with a more suitable food source (TEW *et al.*, 2000). Ground beetles and other soil invertebrates have a significantly lower level of dispersion than rodents. However, OUIN *et al.* (2000) have described the decreasing density of wood mouse *Apodemus sylvaticusi* L. population on cultivated fields in May-August due to migration. Mice show no tendency to migrate from fields unless there are alternative habitats for them, such as hedges or woodlots (HARRIS AND WOOLARD, 1990). CARDINA *et al.* (1996) reported a gradual increase in seed demand in maize fields over the vegetation season, but this could not be clearly attributed to either vertebrates or invertebrates. WESTERMAN *et al.* (2003a) reported a low level seed predation by vertebrates early in the season, increasing towards mid-June, and then decreasing. As no adequate alternative habitat for migration was available to mice in the vicinity of investigated fields, it is possible that the number of rodents did not vary, but food availability grew during the summer, causing a satiation of predators and lower seed demand. The authors concluded that, although invertebrates were principal seed predators in only one of eight cases, early high demand for seeds among mice (May-June) would cause lower total seed loss and have less effect on the weed life cycle than a later seed demand during the season by invertebrates, and that consequently it had a potential for greater control of weed populations than predation by vertebrates.

BIRDS

Birds are important seed predators all year round, but their participation and role in weed seed elimination is especially prominent over the winter period. Passerines are the most frequent species in fields during the winter season. As stubble fields have greater relative density of seeds than other field types (ROBINSON and SUTHERLAND, 2000) many grain-eating species of the *Passeriformes* order choose almost exclusively stubble fields for their feeding ground (BUCKINGHAM *et al.*, 1999).

Seed predation by birds depends on the amount and density of seeds existing in a field and on their availability. Linnet (*Carduelis cannabina* L.) and reed bunting (*Emberiza schoeniclus* L.) were rarely found in stubble fields with densities of weed seeds of their choice below 250 seeds/m^2, although fields with seed densities above this threshold may be unpopulated during bird individual visits (MOORCROFT *et al.*, 2002). Besides, linnets have been found to feed on field parts which had an average seed density of 300 seeds/ m^2 or more. In that research, the density of seeds consumed by linnet and reed bunting dropped by March below 250 seeds/m^2 in around half of the sampling fields (down to 12 for linnet and 14 for reed bunting of a total of 23 fields monitored). At the beginning of monitoring, in October, the number of fields with densities below this rate was mere 22% for linnet and 37% for reed bunting.

Food availability in organic and conventional stubbles varies. Linnet distribution between and within intensively cultivated (conventional) stubbles is highly correlated with food resources, but a clear correlation cannot be determined in undersown (organic) stubble fields (MOORCROFT *et al.*, 2002). The lack of any significant correlation within undersown fields probably reflects a difference between source abundance and food availability. Undersowing greatly increases coverage and decreases the occurrence of weed plants, probably by limiting opportunities for germination. Although organic stubble fields contain equal or greater seed densities than conventional stubbles (ALBRECHT AND FORSTER, 1996), food availability to birds could be significantly lower than in open conditions.

Seed availability to predators may be greater in areas of bare ground in stubble fields. A number of authors have observed a positive correlation between the percentage of bare ground in stubble fields and the use of stubbles by birds feeding on seeds (GRZYBOWSKI, 1983; MOORCROFT *et al.*, 2002). For species such as linnet (*Carduelis cannabina* L.), yellowhammer (*Emberiza citrinella* L.), reed bunting (*Emberiza schoeniclus* L.) and corn bunting (*Miliaria calandra* L.), which feed exclusively on seeds during winter time, rather than vegetation, more accessible bare ground may increase the efficiency of feeding by reducing physiological detriment caused by feeding in thick vegetation, which is more humid and makes movement more difficult. Bare ground also increases possibilities for finding seeds (WHITEHEAD *et al.*, 1995) and allows greater efficacy in observing predators (GRZYBOWSKI, 1983). Although the existence of a correlation between food source and number of granivorous animals has been shown, this relationship has not been reported for all tested species. For example, yellowhammer (*Emberiza citrinella* L.) showed a significant correlation with grain resources at the beginning, but not at the end of winter (MOORCROFT *et al.*, 2002). Explanation for this may be the fact that yellowhammer is significantly less successful in finding grains buried in the soil than those remaining on the surface.

The occurrence of woodpigeon (*Columba palambus* L.), however, decreases with an increase of bare ground, most probably because it feeds on developing vegetation in winter, especially on clover *Trifolium repens* L. (MURTON *et al.*, 1966) and oil seed rape (*Brassica napus* L. var. *oleifera*) (INGLIS *et al.*, 1997), the former being a possible explanation for its visits to stubbles.

Lacking correlation between the habitation of skylark (*Alauda arvensis* L.) and percentage of bare ground in stubbles is a possible explanation of its multifarious nutrition, which includes leaf material, grains and weed seeds (WILSON *et al*, 1999).

CLOSING REMARKS

How important is seed predation in regulating plant populations and could it be used for weed control?

The annual level of predation is decisive for stabilizing or at lease reducing the formation of soil seed banks. Seed mortality is crucial for the population dynamic of weed plants as their annual loss of 25-50% could be sufficient for a significant reduction of weed populations (FIRBANK AND WATKINSON, 1986). Available data show that pre-dispersal seed predation is around 10%, while post-dispersal predation may exceed 70% of all seeds produced.

Epigeaic predation of seeds over long periods is essential for weed suppression in agricultural fields (CARDINA AND NORQUAY, 1997; CROMAR *et al.*, 1999). In fact, it seems that seed predation may be a more significant factor concerning seed banks than seed mortality caused by physiological senescence and activity of microorganisms (ROBERTS AND FEAST, 1972). Considering the aspect of population dynamic, seed predation is effective in weed control as much as mechanical methods (WILSON *et al.*, 1993). A combination of external conditions (warm and dry weather) and agricultural practices (early sowing of crops) may speed up weed phenology, delay seed burial into the substrate and thus increase the proportion of weed seed losses in crops by predation.

These figures promote seed predation into a crucial factor of weed control and an important natural supplement to weed control that requires serious approach, utilization and advancement. All things considered, pre- and post-dispersal predation may be an important factor in eliminating weed seeds from agricultural systems. The main drawback, however, both of pre-dispersal and post-dispersal seed predation is that it is variable in space and time. Differences between individuals, and those within a field can be greater than differences between various experimental instances. It is therefore important to detect patterns and reveal the causes of variability so as to be able to understand seed predation and utilize it as a form of biological weed control.

Animals feeding on seeds have been traditionally considered pests as they also feed on agricultural crop seeds. Various measures employed to control such organisms, as well as the development and modernisation of modern agricultural production, have resulted over the past several decades in a decrease in population sizes of many taxa visiting agricultural fields across Europe (e.g. plants: RICH AND WOODRUFF, 1996; invertebrates: WILSON *et al.*, 1999; birds: PAIN AND PIENKOWSKI, 1997; mammels: FLOWERDEW, 1997). Perhaps this is the right moment to raise the question of the limit line below which control of seed predators in fields is no longer desirable and becomes harmful rather than useful to us.

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UTICAJ PREDATORA NA PRODUKCIJU I REZERVE SEMENA KOROVSKIH BILJAKA U ZEMLJIŠTU

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Izvod

Predatori semena, pored raznih drugih uzroka koji mogu dovesti do propadanja semena ili oštećenja i gubitka sposobnosti klijanja, predstavljaju važan faktor u održavanju semena, značajan u populacionoj dinamici biljaka, a time i u proučavanju biologije korovskih vrsta.

Predatorstvo semena se može dešavati pre rasejavanja (predisperziono predatorstvo) i posle rasejavanja semena (postdisperziono predatorstvo).

Predatorstvo semena pre rasejavanja se javlja kao faktor koji bitno utiče na populacionu dinamiku pojedinih vrsta korovskih biljaka, što je posebno izučavano radi korišćenja u biološkoj kontroli korova. U pojedinim primerima korišćeni predisperzioni predatori semena su bili sposobni da unište preko 90 % semena određenih korova. U uobičajenim uslovima na poljoprivrednim površinama je evidentiran stepen predisperzionog predatorstva oko 10-20%.

Postdisperziono predatorstvo može eliminisati i do 70% produkovanih semena korova. Izgleda da na stepen predatorstva semena posle rasejavanja najvećeg uticaja ima način obrade zemljišta i vreme izloženosti semena predatorima, odnosno vreme kada se rasejavanje najve?eg dela semena dešava i vreme potrebno da seme dospe u zemljište.

Većina predatora semena pre rasejavanja su visoko specijalizovani insekti, dok su postdisperzioni predatori obično veći, mobilniji i manje specijalizovani organizmi (glodari, ptice, mravi i bube) koji mogu da se hrane semenima različitih biljnih vrsta. Ptice su najvažniji predatori na poljoprivrednim površinama tokom zime, dok se tokom sezone obično ređe viđaju na oranicama. Miševi, mravi i trčuljci su najčešće glavne grupe organizama odgovorne za epigeični gubitak semena korova na oranicama tokom sezone.

Osnovna osobina predatorstva semena, kako predisperzionog tako i postdisperzionog, je varijabilnost u prostoru i vremenu. Razlike između jedinki i razlike unutar jednog polja mogu biti veće nego razlike između različitih eksperimentalnih slučajeva. Zato je važno da se detektuju obrasci i rasvetle uzroci varijabilnosti da bi se predatorstvo semena bolje upoznalo i iskoristilo u kontroli korova.

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