R-2401
[1-6]

REVIEW ARTICLE Agricultural Reviews, Volume Issue : ()

Understanding and Managing Weed Seed Banks: A Review

Sarwan Kumar, S.S. Rana, Gaytri Hetta, Navjot Rana

10.18805/ag.R-2401

ABSTRACT

The seed bank is an important part of the weed life cycle since it is where weed seeds rest. Seed banks are the only source of future weed populations for those annual and perennial weed species that reproduce only through seeds. As a result, understanding the fate of seeds in the seed bank may be crucial for overall weed management. When weed seeds reach the seed bank, a number of factors determine how long they may stay viable. Seeds in the seed bank can sense their surroundings and use these stimuli to go dormant or commence germination. Soil and crop management strategies can have a direct impact on the environment of seeds in the soil weed seed bank, allowing them to be utilised to manage weed seed longevity and germination.

Key words: Management, Weed, Weed Seed Bank.

The weed seed bank is the reserve of viable weed seeds present and scattered throughout the soil profile (Begum *et al.,* 2006; Singh *et al.,* 2012). The weed seed bank in the area of the soil where the viable weed seeds are stored. It consists of both new weed seeds recently shed and older seeds that have persisted in the soil from previous years. The soil's weed seed bank also includes the tubers, bulbs, rhizomes and other vegetative structures through which the perennial weeds propagate themselves. The bank also includes the plants that produce the seeds. Agricultural soils can contain thousands of weed seeds and a dozen or more vegetative propagules per square foot (Menalled, 2013). A comprehensive study of weed seed bank in soil system can reveal the past crops and cropping history of a given field and help to forestall and effective management of the given weed. Soil is considered an inexhaustible source of crop and weed seeds, it only depends upon our management practices how we smartly and efficiently manage it. Weed seed banks are very critical in farming systems. Cultivation is used as a major weed management method. A high starting population will result in a high density of weeds surviving cultivation and competing with the crop because a cultivation pass normally kills a fixed proportion of weeds. Initial weed population is directly related to the density of seeds in the seed bank (Brainard *et al.,* 2008; Teasdale *et al.,* 2004); thus, effective cultivation-based weed control requires a low seed bank density (Forcella *et al.,* 2003). The weed seed bank is a collection of viable weed seeds found on the soil surface and in the soil profile. The weed seed bank serves as a physical history of the past successes and failures of cropping systems and knowledge of its content (size and species composition) can help producers both anticipate and ameliorate potential impacts of crop weed competition on crop yield and quality. Eliminating "deposits" to the weed seed bank also called seed rain-is the best approach to ease future weed management (Menalled, 2008).

Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, Himachal Pradesh, India.

Corresponding Author: Sarwan Kumar, Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur-176 062, Himachal Pradesh, India. Email: Sarwanmehar024@gmail.com

How to cite this article: Kumar, S., Rana, S.S., Hetta, G. and Rana, N. (2022). Understanding and Managing Weed Seed Banks: A Review. Agricultural Reviews. DOI: 10.18805/ag.R-2401.

Submitted: 08-10-2021 **Accepted:** 01-02-2022 **Online:** 26-03-2022

Types of seed bank

Aerial seed bank

Aerial seed banks are seed banks in which the seeds remain attached to the mother plant after maturation for a period of time and then allowed for more dispersal techniques. Some of these strategies include dispersal of weed seeds clinging to animals' fur (*e.g. Biden pilosa*, *Achyranthes aspera* and *Hackelia uncinata*), relying on passage through the digestive tract (as many fruit-bearing shrubs and trees or shaking off the mother plant as it is blown away from its point of origin by wind, *e.g. Kochia scoparia* L.. In grassland, orchard, or natural settings, aerial seed banks are more important than in agricultural fields.

Soil seed bank

Soil seed banks are often defined by their lifetime, which is assessed by how long an individual seed may survive in a viable state within them. The lifetime of plants is mostly determined by their species. Transient seed banks, such as *Kochia scoparia* L. and Taraxacum officinale weber, are ones where seeds only survive for a few years in the seed bank. Seed banks of these species require virtually annual renewal, but seed banks of other species, such as *Amaranthus retroflexus* L. and *Chenopodium album* L., are managed in a consistent manner.

Purpose of seed bank

Weed seeds are important aspect of the wildlife cycle because they are the source of future populations. This is especially true for annual and simple perennial species like *Taraxacum officinale* Weber, which reproduce only through seeds (Gulden and Shirtliffe 2009) Perennial plants, on the whole, rely on seeds to create new colonies far distant from the mother plant. Colony expansion occurs as a result of vegetative reproduction around the mother plant. Annual weeds, for example, may withstand the rigid winter temperatures. They help a species survive by protecting it from harsh climatic circumstances or extremely effective control tactics and allowing it to germinate over a long period of time. This feature slows the genetic shift of a weed population under high selection pressures by ensuring that seedlings hatch from different genetic backgrounds each year (Gulden and Shirtliffe, 2009).

Fate of weed seeds in the seed bank

After being distributed onto a field, weed seeds might take a variety of paths (Fig 1). Only a small percentage of the seeds in the seed bank will germinate and generate a plant. Before growing, most seeds will perish, degrade, or be eaten. Some of those that do germinate will die before producing a full plant (Menalled, 2013). When weed seeds stay on the surface and there is enough residual cover for predators, seed predation is usually at its peak (*i.e.* no-till). Weed seed emergence can be reduced by 5 to 15% using generalist predators like common ground beetles or crickets (White *et al.*, 2007). Weed seeds can be consumed in large quantities by larger animals such as rats and birds.

Seed dormancy

Seed dormancy hinders germination even when the conditions are optimal for it. The majority of weed seeds are dormant when they reach maturity, which is known as primary dormancy. Seeds, on the other hand, can cycle in and out of dormancy as a result of environmental factors. This is known as secondary dormancy and it controls weed seed germination seasonally (Baskin and Baskin, 1998). Secondary seed dormancy restricts germination at a time of year when a plant's life cycle cannot be completed, ensuring that summer annuals germinate largely in the spring and winter annual weeds primarily in the fall. Seasonal fluctuations in soil temperature control this process. The cold of winter will break the dormancy of most summer annual weeds that germinate in the spring. Winter annual weeds like stinkweed (*Thlaspi arvense*) and shepherd's purse (*Capsella bursa-pastoris*), on the other hand, need the heat of summer to break dormancy. This enables them to germinate in the early fall and build a rosette before the arrival of winter.

Types of seed dormancy

Several systems are in charge of good seed dormancy. Germination will be impossible if the embryo is underdeveloped at the moment of seed maturation. This is a type of primary dormancy that affects *Avena fatua* (Gulden and Shirtliffe, 2009). Before seeds can germinate, they must go through a 'after ripening' stage.

Physical dormancy**,** in which a hard seed coat limits water uptake, is another mechanism for seed dormancy. This is a crucial mechanism for the soil seed bank's long term persistence. The pea family, such as *Abutilon thoephrasti* L. and members of the goosefoot family, such as *Chenopodium album* L., have high numbers of seeds with impermeable coatings. Seeds from these species can easily persist in the soil seed bank for decades (Radosevich *et al.*, 1997). Finally, physiological changes may cause seed dormancy. This is the process that controls secondary or cyclical seed dormancy and it is influenced by a variety of circumstances (Baskin and Baskin, 1998). Temperature, light, oxygen and specific biochemicals all play a role in secondary seed dormancy. Secondary seed dormancy can be induced and broken by light and temperature (Gulden *et al.*, 2003). The presence of other plants and the burying depth of weed seeds can also be determined by light quality and temperature. Because the seed is close to the surface in small seeded species like *Amaranthus retroflexus*, a flash of white light (as dim as full moonlight) is often enough to break seed dormancy. This is one of the ways that daytime

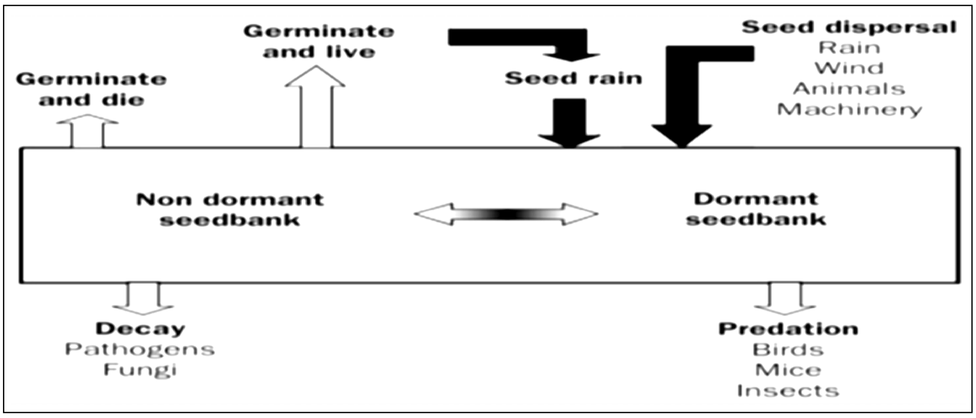

Fig 1: Fate of weed seeds (Inputs to the seed bank are shown with black arrows and losses with white arrows) Source: Menalled (2013).

cultivation boosts seed germination. High quantities of white light, for example, inhibit germination in other species like *Avena fatua*, indicating that the seed is not buried deeply enough for optimal seedling development. Only a few light reach the soil profile. The changes in daily temperature that decrease throughout the soil profile provide an indication of burial depth in some small seeded species. Small seeded weeds that can only emerge successfully from shallow depths rely heavily on temperature changes. In many species, low oxygen concentration indicates burial depth and causes seed dormancy.

There are also a number of substances that can be used to break seed dormancy. In particular, nitrate nitrogen and a few compounds are found in smoke. These chemical cues show niche availability when they are released by dead vegetation or following a fire. In the 1960s, scientists experimented with using nitrate-nitrogen to control germination in the wild. The concept was that adding nitrate-nitrogen in the soil would enable wild oat seeds to germinate, which could then be eliminated by ploughing (Sexsmith and Piman, 1967). Because of the high amount of nitrate-nitrogen required and the variability of the effect, this strategy ultimately failed. Gibberellic acid, a plant hormone that removes seed dormancy, has been used to induce germination in dormant volunteer canola (*Brassica napus* L.) seed in the soil in the greenhouse with some success (Thornton *et al*., 1998); however, the high cost of producing this compound makes this method impractical in field situations. Dormancy is an intricate system that regulates when a seed germinates. Seed dormancy traits and seed bank persistence (Table 1) on the other hand, are not necessarily connected (Thompson *et al*., 2003). One reason for this is that seed dormancy can only control germination when all of the germination criteria are met. However, in many circumstances, optimal conditions do not exist and non-dormant seeds cannot germinate. Despite the fact that seed dormancy is a key strategy for most weed species, some major weed species, such as Kochia and Dandelion, have no seed dormancy at all.

Table 1: Longevity of different weed species in the seed bank (Source: Conn *et al.,* 2006).

Weed species	Maximum longevity (years)
Calamagrostis canadensis (Michx.) Beauv.	8-14
Hordeum jubatum L.	7-8
Elytrigia repens (L.) Nevski	4-6
Avena fatua L.	4-6
Dracocephalum parviflorum Nutt.	>20*
Stellaria media (L.) Vill.	>20
Galeopsis tetrahit L	2-3
Chenopodium album L.	>20
Spergula arvensis L.	18-20
Descurainiasophia (L.) Webb ex Prantl.	16
Polygonum pensylvanicum L.	14-18
P. aviculare L.	10-14
P. convolvulus L.	6-8
Matricaria matricarioides (Less.) C.L. Porter	>20
Potentilla norvegica L.	12-14
Capsella bursa-pastoris (L.) Medicus	>20

N.B. * about 60% of the seed were still viable after 20 years.

Seed longevity (Table 1) in the soil is determined by a complex interaction of factors, including seed population intrinsic dormancy, seed burial depth, disturbance frequency, environmental conditions (light, moisture, temperature) and biological processes such as predation, allelopathy and microbial attack (Davis *et al*., 2005; Liebman *et al.,* 2001). Understanding how management strategies and soil conditions affect the residence length of viable seeds can help producers avoid weed problems in the future. Seeds of 20 weed species put into the top 6 inches of soil, for example, lasted longer in untilled soil than in soil tilled four times annually (Mohler, 2001a) indicating that the disturbed treatment had more germination losses.

Practices to exhaust weed seed bank

Soil and crop management

The most obvious strategy to diminish the weed seed bank is to reduce seed input into the seed bank. Any strategy that minimizes the size and number of weeds that produce seed reduces the number of seeds that are “deposited” in the seed bank. Of course, various ways can be used to manage the weed seed bank, such as increasing seed death or encouraging germination, which allows the weeds to be readily handled. Only a few important ways directly affect weed seed input, seed bank persistence and germination from the seed bank, despite the fact that most agronomic operations have an indirect effect on the weed seed bank.

Stale seed bank

Before crop planting, nondormant weeds in the germination zone (shallow soil layers from which weeds can arise) are killed in a stale seedbed. A novel approach of exhausting weed seed bank before the crop emergence by stale seed bed approach was standardized for *Bt* cotton based intercropping system. Among the treatments, Stale Seed Bed Technique (SSBT) using a mixture of pendimethalin 1.0 kg+ glyphosate 1.0 kg one week after pre-sowing irrigation (one week before sowing) recorded the highest weed control efficiency of 85.2 per cent on 35- 40 DAS (Nalavini and Suveetha 2016).

Microwave radiation/ Thermal weed control

Interest in controlling weed plants using radio frequency or microwave energy has been growing in recent years because of the growing concerns about herbicide resistance and chemical residues in the environment. Most research have concentrated on applying microwave energy across a large region, which takes around 10 times the energy that is inherent in conventional chemical treatments to accomplish effective weed control (Brodie *et al.,* 2019).

Thermal runaway, according to a closer examination of the microwave heating process, can cut microwave weed treatment time by at least one order of magnitude. If thermal runaway in weed plants can be caused, the energy costs of microwave weed control will be comparable to chemical weed control.

Summer ploughing or soil solarization

Tillage in the off-season improves the water content of soils and lowers runoff. It also helps to keep pests and weeds at bay. The quantity and depth of ploughing depends on the amount of weeds present. Prior to the arrival of the monsoon, at most two summer ploughings are done at a 15-20-day interval. By mulching the soil and covering it with a tarp, usually a translucent polyethylene cover to capture solar radiation, soil solarization weakens and kills fungi, bacteria, nematodes, insect and mite pests, as well as weeds. Time, temperature and soil moisture all play a role in soil solarization.

Herbicides

Herbicides are particularly successful at reducing weed populations and the number of seeds added to the soil seed bank at the same time (Hossain *et al.,* 2014e). Weed seed bank densities are generally higher in organic management systems than in herbicide-based systems, while this is not always the case because other factors such as crop rotation also have a significant impact on weed seed output.

Seed bank densities in production methods that rely heavily on herbicides to control weeds are typically between 1000 and 4000 seeds per square metre (Blackshaw *et al*., 2004a; Clements *et al.,* 1996). Weed seed banks will be near the low end of this range when herbicide tolerant crops are widely employed in cropping systems, yet despite decreased weed seed bank densities in these systems, weed seedling emergence remains considerable in subsequent years. Glyphosate pre-harvest treatments can reduce seed output and seed viability in late blooming weeds. However, because glyphosate has a gradual action, weeds must be controlled well before the plant sheds its seed near maturity.

Crop rotation

Crop rotation is also a good way to keep the weed seed bank under control. When perennial crops are introduced into annual cropping systems, the soil seed bank of annual species is depleted over time.

This approach is more effective on weeds with a short lifespan, such as kochia and many grassy weeds such as wild oat and green foxtail. Crop competition is also crucial for reducing the number of weed seeds recruited to the seed bank. Seed bank populations were found highest in summer fallow (approximately 1600 seeds m^{-2}) against wheat stubble (about 500 viable seeds m^{-2}) in studies done near Saskatoon, SK in the late 1970s (Archibold, 1981). Due to insufficient weed control by tillage and the lack of a competitive crop, weed seed bank additions are significant on fallow areas (Archibold and Hume 1983).

Chaff collection

Chaff collection is an efficient way to reduce weed seed bank input. Because weed seeds are lighter than crop seeds, they wind up in the chaff percentage, which is scattered equally across the field. Even for large weed seeds like wild oat, chaff collection can prevent up to 90% of weed seed counts from being transferred to the seed bank during harvest (Shirtliffe and Entz, 2005).

Tillage

Prior to the introduction of herbicides, tillage was the primary method of weed control. The vertical distribution of weed seeds in the soil seed bank was greatly influenced by the degree of soil inversion and the depth of tillage. Under no-till conditions, 37 per cent of the viable weed seed bank was detected in the top 5 cm of the soil profile when using a moldboard plough and 74 per cent when using a no tillage (Clements *et al.,* 1996). Using a chisel plough, 61% of the seed was found at the soil surface. Deeply buried seeds that are not disturbed can last for decades in the soil seed bank because they escape some of the seed viability risks mentioned above.

As a result, tillage slows the seed bank's turnover rate. In practice this could have an impact on the rate at which herbicide – resistant weed populations evolve, with a slower shift in conventional tillage circumstances than in no till situations. However, there is no experimental proof for this. During the no-till seeding technique, some soil inversion and weed seed burying occurs. Because disc openers cause less soil disturbance than hoe openers, seed burial should be reduced. However, a study done in Saskatchewan discovered that after three years, the seed bank persistence of volunteer canola was identical under conventional and no-till conditions (Gulden *et al.,* 2004). Because buried canola seed only lasts three years (Liebman *et al.,* 2001), these findings shows that even a single pass with a low disturbance disc opener resulted in some seed burial, even in the no till regime. Only a few research have compared the degree of seed bank burial using various seed openers. The average seedling emergence of all weed species investigated was from a greater depth in conventional-till management than in no-till management, according to a Manitoba study (Fenner and Thompson, 2005). Farmers who practise no till farming in western Canada reported fewer weed populations, which is indicative of lower weed seed banks (Blackshaw *et al.,* 2008)

In Ontario, weed seed banks were nearly twice as large under chisel plough management as they were under no-till management (Croix *et al*., 2000). Tillage can help weed seeds germinate through a variety of ways. Tillage disturbs the soil, exposing weed seeds to a burst of light, causing them to awaken from their slumber. Furthermore, tillage disturbs the soil, resulting in nitrogen mineralization, which can aid seed germination in some cases. Because of the presence of high nitrate levels, this method is dependent on the exact location of the seed after ploughing, as well as other factors such as nitrogen mineralization, which can increase germination independent of light (Mickelson and Grey, 2006).

Mulching

In no till systems, the mulch of dead plant debris on the soil surface has an impact on the seed bank. Crop residues produce micro-environments in which animals that eat them can hide. Furthermore, residues reduce temperature changes in the soil, which can affect seed dormancy in many smaller seeded broadleaf weeds that use daily temperature swings to determine burial depth. Allelopathic compounds hinder seed germination in plant residues such as rye (*Secale cereale* L.), clover (*Trifolium spp.* L.) and canola (Moyer *et al*., 2000; Vera *et al*., 1987). Allelopathic compounds lose their potency over time when they are leached from crop residue and disintegrate owing to soil moisture, light and microbial activity. Weeds with large seeds are less vulnerable to allelopathic substances than those with small seeds. It's unclear if this is related to the larger seeds' lower surface area to volume ratio or to lower allelo-chemical concentrations at the deeper depths where large seeded weed species tend to develop.

Fertilization

Weeds, like crops, respond favourably to inorganic fertiliser application (Blackshaw *et al.,* 2003; 2004a) Many species' weed seed banks can be decreased by up to 50% over time by using the right timing and application of nitrogen fertiliser, with spring bands during planting being the most effective. Surprisingly, nitrogen fertiliser bands significantly reduced green foxtail and stinkweed populations, particularly in no-tillage cropping systems (Donovan *et al*., 1997). Weeds competitive ability is enhanced by fall applied nitrogen that is distributed over the surface, allowing more access to the fertiliser, which increases weed populations and the weed seed bank. Weed seed viability is reduced by composting manures before application, resulting in fewer weed seed inputs into the seed bank (Menalled, 2008).

Challenge of weed seed bank diversity

Keep in mind that none of these tactics will completely eliminate the weed seed bank and you may need to adjust your seed bank management plan as the seed bank evolves. The weed seed bank is challenging to manage since it contains not only a large number of seeds, but also a variety of seeds, with a single field generally containing 20 to 50 different weed species. To put it another way, the grower may have to cope with anything from 20 to 50 distinct plant survival tactics! As a result, whatever combination of seed bank management tactics the farmer employs, some weeds will nearly always tolerate, if not thrive, on it. Some weed species, but not all, have light- responsive seeds and dark cultivation inhibits emergence only in those that respond to light. Similarly, careful nitrogen (N) management can lessen nitrate responder problems while having no effect on nonresponders and may even benefit a weed that is well adapted to low soluble N levels. The ideal way to manage weed seed banks is to plan your strategy around the four or five most troublesome weeds in the area, then track changes in the weed flora over time, noting which new plant species develop as the original target weed species diminish.Then make the necessary adjustments to your seed bank management approach. Plan on making similar changes every few years and try to maintain a feeling of wonder and humour about the weeds.

CONCLUSION

Reduce the quality of weed seeds present in the field to restrict prospective weed populations during crop production is one of the most critical, yet often overlooked, weed management tactics. This can be done by keeping track of the weed seed bank. The weed seed bank is home to a variety of fates and processes, many of which are poorly understood. Weed experts have been unable to fully comprehend the weed seed bank due to the sheer difficulties of monitoring a process that takes place largely underground. Despite this, current knowledge of weed seed banks has shown several management alternatives. Reducing seed bank inputs is an important part of seed bank management, but other methods, such as employing a no-till farming system, can have a direct impact on weed seed germination, persistence and death. Managing weed seed banks would be a crucial part of integrated weed control.

Conflict of interest: None.

REFERENCES

Archibold, O.W. (1981). Buried viable propagules in native prairie and adjacent agricultural sites in central Saskatchewan. Canadian Journal of Botany. 59: 701-706.

Archibold, O.W. and Hume, L. (1983). A preliminary survey of weed input into fallow fields in Saskatchewan. Canadian Journal of Botany. 61: 1216-1221.

Amartalingam, R. and Man, A.B. (2006). Seedbank and seedling emergence characteristics of weeds in rice field soils of the muda granary area in north-west peninsular Malaysia. Biotropia. 13(1): 11-21.

Baraibar, B., Westerman, P.R., Carrion, E. and Recasens, J. (2009). Effects of tillage and irrigation in cereal fields on weed seed removal by seed predators. Journal of Applied Ecology. 460: 380-387.

Baskin, C.C. and Baskin, J.M. (1998). Seeds: Ecology, biogeography and evolution of dormancy and germination. San Diego: Academic Press. 666p.

Begum, M., Juraimi, A.S., Rastan, Blackshaw, R.E., Brandt, R.N., Janzen, H.H., Entz, T., Grant, C. and Derksen, D.A. (2003). Differential response of weed species to added nitrogen. Weed Science. 51: 532-539.

Blackshaw, R.E., Brandt, R.N/, Janzen, H.H. and Entz, T. (2004a). Weed species response to phosphorous fertilization. Weed Science. 52: 406-412.

Blackshaw, R.E., Harker, K.N., Donovan, J.T., Beckie, H.J. and Smith, E.G. (2008). Ongoing development of integrated weed management systems on the Canadian Prairies. Weed Science. 56: 146-150.

Blackshaw, R.E., Molnar, L.J. and Janzen, H.H. (2004b). Nitrogen fertilizer timing and application method affect weed growth and competition. Weed Science. 52: 614-622.

Blubaugh, C.K. and Kaplan, I. (2015). Tillage compromises weed seed predator activity across developmental stages. Biological Control. 81: 76-82.

Brainard, D.C., Bellinder, R.R., Hahn, R.R. and Shah, D.A. (2008). Crop rotation, cover crop and weed management effects on weed seedbanks and yields in snap bean, sweet corn and cabbage. Weed Science. 56: 434-441.

Brodie, G., Ryan, C., Lancaster, C. and Cousens, R. (2019). Understanding the Energy Requirements for Microwave Weed and Soil Treatment. Global Journal of Agricultural Innovation, Research and Development. (2019). 6: 11-24.

Clements, D.R., Benoit, D.L., Murphy, S.D. and Swanton, C.J. (1996). Tillage effects on weed seed return and seedbank composition. Weed Science. 44: 314-322.

Conn, J.S., Beattie, K.L. and Blanchard, A. (2006). Seed viability and dormancy of 17 weed species after 19.7 years of burial in Alaska. Weed Science. 54: 464-470.

Cousens, R. and Moss, S.R. (1990). A model of the effects of cultivations on the vertical distribution of weed seeds within the soil. Weed Research. 30: 61-70.

Croix, D., Sissons, M.J., van Acker, R.C., Derksenm, D.A. and Thomas, A.G. (2000). Depth of seedling recruitment of five weed species measured in situ in conventional- and zero-tillage fields. Weed Science. 48: 327-332.

Davis, A.S. (2004). Managing weed seedbanks throughout the growing season [Online]. New Agriculture Network. Vol. (1): 2.

Davis, A.S., Renner, K.A. and Gross, K.L. (2005). Weed seedbank and community shifts in a long-term cropping systems experiment. Weed Science. 53: 296-306.

Donovan, O., McAndrew, D.W. and Thomas, A.G. (1997). Tillage and nitrogen influence weed population dynamics in barley (*Hordeumvulgare* L.). Weed Technology. 11: 502-509.

Fenner, M. and Thompson, K. (2005). The ecology of seeds. Cambridge, UK: Cambridge University Press. 250 p .

Forcella, F. (2003). Debiting the seedbank: Priorities and predictions. p. 151-162. *In* Bekker *et al.* (eds.) Seedbanks: Determination, dynamics and management. Aspects of Applied Biology 69. Association of Applied Biologists, Welles Bourne. UK.

Gulden, R.H, Thomas, A.G. and Shirtliffe, S.J. (2004). Secondary dormancy, temperature and seed burial depth regulate seedbank dynamics in Brassica napus. Weed Science. 52: 382-388.

Gulden, R.H. and Shirtliffe, S.J. (2009). Weed Seed Banks: Biology and Management. Prairie Soils and Crops. 2: 46-52.

Gulden, R.H., Thomas, A.G. and Shirtliffe, S.J. (2003). Secondary seed dormancy prolongs persistence of volunteer canola (*Brassica napus*) in western Canada. Weed Science. 51: 904-913.

Hossain, M.M., Begum, M., Hashem, A., Rahman, M.M., Bell, R.W., Haque, M.E. (2014e). Yield response of mustard as influenced by weed management practice under conservation agriculture system. Bangladesh Journal of Weed Science. 4 and 5: 87-92.

Liebman, M., Mohler, C.L. and Staver, C.P. (2001). Ecological management of agricultural weeds. Cambridge, UK: Cambridge University Press. 532 p.

Menalled, F.D. (2008). Weed Seedbank Dynamics and Integrated Management of Agricultural Weeds. Agriculture and Natural Resources (Weeds). 200-708 SA.

Menalled, F.D. (2013). Manage the Weed Seed Bank- Minimize “Deposits” and Maximize “Withdrawals”. Available at: extension.org http://www.extension.org/pages/18527/manage-the-weed-seed bank minimize-deposits-and maximize-withdrawals#. VkG6 Xl53C1t.

Mickelson, J.A. and Grey, W.E. (2006). Effect of soil water content on wild oat (*Avena fatua* L.) seed mortality and seedling emergence. Weed Science. 54: 255-262.

Mohler, C.L. (2001a). Weed life history: identifying vulnerabilities. Cambridge University Press, New York. p. 40-98.

Moyer, J.R., Blackshaw, R.E., Smith, E.G. and McGinn, S.M. (2000). Cereal cover crops for weed suppression in a summer fallow-wheat cropping sequence. Canadian Journal of Plant Science. 80: 441-449.

Nalavini, P. and Suveetha, M. (2016). Exhausting weed seed bank before sowing through stale seedbed technique for managing weeds in winter irrigated *Bt* cotton (*Gossypium hirsutum*) based intercropping system. Journal of Cotton Research and Development. 30 (1): 49-53.

Radosevich, S., Holt, J. and Ghersa, C. (1997). Weed ecology: Implications for management. New York: John Wiley and Sons, Inc. 589p.

Sexsmith, J.T. and Piman, V.J. (1967). Effect of nitrogen fertilization on germination and stand of wild oats. Weed Research. 11: 99-101.

Shearin, A., Reberg-Horton, S. and Gallandt, E. (2007). Direct effects of tillage on the activity and density of ground beetle (Coleoptera: Carabidae) weed seed predators. Environment Entomology. 36: 1140-1146.

Shirtliffe, S.J. and Entz, M.H. (2005). Chaff collection reduces seed dispersal of wild oat (Avenafatua) by a combine harvester. Weed Science. 53: 465-470.

Singh, A., Kaur, R., Kang, J.S. and Singh, G. (2012). Weed dynamics in rice-wheat cropping system. Global Journal of Biology, Agriculture and Health Sciences. 1(1): 7-16.

Teasdale, J.R., Magnum, R.W., Radhakrishnan, J. and Cavigelli, M.A. (2004). Weed seedbank dynamics in three organic farming crop rotations. Agronomy. 96: 1429-1435.

Thomas, A.G., Banting, J.D. and Bowes, G. (1986). Longevity of green foxtail seeds in a Canadian prairie soil. Canadian Journal of Plant Science. 66: 189-192.

Thompson, K., Ceriani, R.M., Bakker, J.P. and Bekker, R.M. (2003). Are seed dormancy and persistence in soil related. Seed Science Research. 13: 97-100.

Thornton, M.A., Peters, N.B.C., West, T.M. and Thomas, T.H. (1998). A novel way to control volunteer oilseed rape (*Brassica napus*). Aspects of Applied Biology. 51: 191-196.

Vera, C.L., McGregor, D.I. and Downey, R.K. (1987). Detrimental effects of volunteer Brassica on production of certain cereal and oilseed crops. Canadian Journal of Plant Science. 67: 983-995.

White, S.S., Renner, K.A., Menalled, F.D. and Landis, D.A. (2007). Feeding preferences of weed seed predators and effect on weed emergence. Weed Science. 55: 606-612.