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PERSISTENCE OF SOME WEED SPECIES FROM WHEAT (*TRITICUM AESTIVUM* L.) MONOCULTURE VIA SOIL SEED RESERVES

SEEMA MAHMOOD*, ASMA HUSSAIN AND SAEED AHMAD MALIK

Institute of Pure and Applied Biology, Bahaudin Zakariya University, Multan
**Corresponding author's e-mail: drseemapk@gmail.com*

Abstract

The relationship between soil seed reserves and degree of infestation by common weed species (*Avena fatua* L., *Convolvulus arvensis* L., *Cyperus rotundus* Pers., *Fumaria parviflora* Lamk., *Phalaris minor* Ritz. and *Solanum nigrum* L.) was assessed for from five wheat fields. Soil sampling was carried out before sowing season in fields where wheat crop was grown. Soil from two profiles (0-8 and 8-15cm) was taken from five sites within each field and seed bank size was estimated via seedling emergence. A considerable number of viable weed seeds of the species were quantified from both soil profiles. More viable seeds were found in the lower soil profile than the surface layer. *C. rotundus* had the greatest seed bank size followed by *C. arvensis, F. parviflora* and *A. fatua*, respectively. *S. nigrum* had the lowest values for the attribute. The study indicated that seed reserves of these species can be a major source of weed infestation in wheat fields. It is likely that seeds are transferred to the surface layer by tillage and give rise new weed population that cause infestation. Moreover, seed population seems to be demographically well adapted through fecundity, seed size and longer viability. The study suggested an integrated approach for weed management and control to minimize yield losses particularly in situations where weed species persist through soil seed reserves.

Introduction

The concept of weeds probably originated with the start of agriculture (Marwat *et al*., 2010). Weeds are unwanted guests in agricultural fields invited by management decisions that defy nature's principles (Lemerle *et al*., 1995; Cousens, 1996; Hartzler, 2003). Weeds are evidence of nature struggling to bring about ecological succession as modern crop agriculture is characterized by large acreages of a single plant type accompanied by a high percentage of bare ground- an ideal environment for annual weeds to prosper in the first stage of succession (Christensen & Heisel, 1998; Hartzler, 2003). Furthermore, stirring soil with tillage creates conditions encouraging for weed germination and survival (Hartzler, 2004; Gul *et al*., 2011). As a consequence, weeds negatively affect crop production efficiency in several ways including reduced yields, harvest efficiency and contributing to future problems through weed seed production (Smith & Levick, 1974; Cousens, 1996; Lemerle *et al*., 2001).

Weed seed banks are reserves of viable seeds present in the soil. These consist of new seeds recently shed by a weed plant as well as older seeds that have persisted in soil for several years (Mahmood *et al.,* 2005). The seed bank is an indicator of past and present weed populations. It has been estimated that only 1-9% of the viable seeds produced in a given year develop into seedlings; the rest remain viable and dormant that may germinate in the subsequent years depending on the depth of burial. As a result, weed seed banks prove to be main source of weeds in agricultural fields. Weeds that escape weed control practice produce thousands of seeds, depending upon species, and these seeds are returned to the soil seed bank and become the source of future weed population. Annual weeds exhibit prodigious seed potential thus produce small superabundant seeds (Sullivan, 2001; Marwat *et al.,* 2010).

Weed seeds are distributed both horizontally and vertically in the soil profiles. Seed rain through various dispersal mechanisms is the main source of seed bank input. Similarly, germination and emergence, physiological death, physical damage by implements as well as predation are various causes of seed losses from soil reserve. However, survival and germination of weed seeds in the soil depends on the weed species, depth of burial, soil type and tillage. Seeds at or near the soil surface can easily be eaten by insect, rodents and birds. They may also rot or germinate. On the other hand, buried seeds are more protected from seed eating animals and are also buffered from extremes of temperature and moisture (Sullivan, 2001).

The weed seed bank in an agricultural field is made up of many species but in a given year, the infestation is typically dominated by a few species. The species that dominate the infestation are those best adapted to current management practices and have several characteristics that assure their survival. Variability of dispersal mechanisms, dormancy during unfavorable conditions and viability even after long time burial allow weeds to withstand unpredictable disturbances and harsh climatic conditions (Hartzler & Buhler, 2000).

Wheat is one of the major crops that have a significant economic and social impact (Hall *et al*., 1992; de la Fuente *et al.*, 2003). Being an agricultural country with major arable land cultivated for this crop, Pakistan still has to spend a considerable amount for wheat import (Bakhsh *et al.*, 2006). The reason is mainly attributable to competition from weeds, which seems to be one of the major factors reducing crop yield and farmers' income (Crammer, 1967). *Avena fatua* L., *Convolvulus arvensis* L., *Cyperus rotundus* Pers., *Fumaria parviflora* Lamk., *Phalaris minor* Ritz. and *Solanum nigrum* L. are among noxious weeds affecting wheat fields every year despite of management practices (Bakhsh *et al.*, 2006). In developing countries, such as Pakistan, despite the availability of high-tech solutions (e.g. selective herbicides and genetically-modified herbicide-resistant crops), the share of crop yield loss to weeds seemed not to be reduced significantly over time (Cousens & Mortimer, 1995). Moreover, herbicides are rarely accessible at a reasonable cost; hence farmers often need to rely on alternative methods for weed management.

Without the proper knowledge and technical assistance, the strategies they use have the least effect thus, weeds remain the major cause of yield impediments. In order to meet the needs of growing population, the country requires almost triple yield from existing farmland. For achieving this goal, we need to avoid those aspects that result in yield loss particularly weeds. Therefore, the current study was conducted to investigate seed banks of these weeds from different soil profiles. The aim of this study was to establish the role of soil seed reserves as a source of weed population and to suggest appropriate weed management and control strategies to minimize yield losses due to soil seed reserves of the weed species.

Materials and Methods

Sampling was done at the start of the wheat crop growing season when previous crop was removed and there had been no tillage practice. The sampling sites were chosen in District Vehari, Punjab, (30^0 N, 72^0 E) because of the fact that wheat is one the main crops grown there in rotation with cotton. Moreover, this pattern of wheat cultivation was being followed at least for last 5 years at the study sites. Five wheat fields, each having an area of one acre, were selected for sampling. Each of the fields was divided into 5 equal plots and 2 soil samples were taken from each of these 5 different plots following Mahmood *et al.*, (2005). Using a sharp knife, an area of 12x12 cm was marked and 15 cm deep cut was given in the soil. Then a thin section of metal was slipped under the marked square and soil block was removed. Thus, a total of 50 samples were collected from 5 fields. Sampled soil core was divided into upper (0-8 cm) and lower (8-15 cm) profiles and then transferred to labeled paper bags.

Germination experiment was carried out in plastic trays (6x12 cm) for 6 weeks under laboratory conditions (21^0C ±3) and watered as and when necessary. The number of viable seeds was quantified via seedling emergence from both soil depths. The seed bank size (number of seeds/ cm^2) was estimated for each species following Mahmood *et al.*, (2005). ANOVA (General Linear Model) was applied to the data to reveal variability among fields, soil depths and species using MINITAB version 14. Fisher's LSD (Least Significant Difference) multiple comparison test (Little & Jackson, 1978) was used to elucidate significant differences for means values at $p<0.05$.

Results and Discussion

A significant number of seeds of the species were quantified from both soil profiles (Fig. 1). All 5 sites were well differentiated for seed banks. Moreover, a differential distribution of weed seeds between the 2 soil profiles also became evident from the statistical analysis (Table 1). More seedlings emerged from the deeper soil profile than from the surface. Thus, it became clear that the lower soil profile contained greater number of buried viable seeds of the weeds.

Highest values for seedling emergence were observed for *C. rotundus* from both the soil profiles and more seedlings emerged from the deeper soil layer than the surface layer (Fig. 1). It is evident from the data that *C. rotundus* had the greatest overall seed bank size (number of seeds/ cm^2) that was significantly different from rest of the weeds ($p< 0.05$) (Fig. 2). Moreover, the size of seed bank was greater (4.65 seeds/cm^2) in the deeper soil profile (8-15cm) than in the surface layer (3.25 seeds/cm^2). *C. arvensis* had the second highest value for same attribute followed by *F. parviflora* and *A. fatua* respectively (Fig. 2). However, these species did not differ significantly from each other in seed bank size. No marked contrast was observed between *P. minor* and *S. nigrum* as both exhibited the lowest seed bank size for 2 soil profiles (Fig. 2A). Though more seed reserves for *C. arvensis* is surprising because of lower fecundity and larger seed size of the species but still it seems that selection has favoured the superior seed progeny by restricting their dispersal as compared to lighter seeds. Moreover, chances of seed loses of larger seeds due to predation are fairly lesser as smaller seeds which are preferential particularly for ants.

A greater number of seed bank from deeper soil layer (Figs. 2B & C) can be attributed to many reasons. Firstly, the sampling was carried out prior to soil preparation (ploughing or tillage) before wheat sowing thus buried seeds were not exposed to the soil surface. Secondly, seeds that survived in deeper profiles are added to them over a number of years thus the seed bank represent weed population for the past years. Since tillage practices before sowing result reshuffling of soil then weed seeds get a fair chance of germination and emergence thus causing weed problem (Clements *et al*., 1996). These findings are in line with Sullivan (2001) who experimentally demonstrated that seed burial of barnyard grass and green foxtail was up to ten inches but the species had shown 34-38% seed germination followed by digging and spreading of soil. On contrary, only 1-5% seed germination was recorded for seeds that were buried even up to an inch (2.5cm). Another study (Harrison *et al.*, 2007) also depicted a consistent relationship between seed bank size and depth of burial and regarded it as a successful survival strategy because seeds near the surface are prone to more losses while, deep burial provide more protection but buried seeds only germinate when they get exposed to soil surface by any means.

Another important aspect of weed survival is genetic variability because seed banks always tend to be a potential mixture of many genotypes and this store of hidden genetic variation provide raw material for selection. As a result, weeds become well adapted and compete with crop plants. Furthermore, it is a hard fact that weed seeds are present all the times in soil as seed banks. These can be controlled by limiting those conditions that favor seed germination and development of weed seedling cohort. Since seed bank exhibit time course changes, reflects the past, present and future weed populations thus it also becomes important to limit ever increasing contributions of the weed seeds in the form of soil bank for effective weed management. Thus, preventing seed set may not only benefit the current crop but also have long term advantages. In addition, an integrated management approach can work best to improve the situation where conventional farming practices are carried out. Weed biology along with demographic approach can certainly provide more efficient weed management strategies prior to weed seed dispersal. Thus an integrated approach must be emphasized to reduce seed banks (Layon, & David, 1995). In this regard, an integrated knowledge of fertilizer use, timing and frequency of pre-sowing treatments and herbicide application is very important and proved to be useful (Marwat *et al.,* 2011). Application of fertilizers affect weed growth because the entire weed community is fertilized along with the crop under such situations fertilizer banded in rows will be available to crop as proposed by Swanton & Shrestha (2001). Studies from Nebraska (Wilson, 1996) suggested that by reducing weed seeds from the soil can cause a 25% decline in weed population just in a single year. Also, the rotation of crops and herbicides can also cause a shift in weed species and knowledge of these shifts can help in changing the composition of the seed banks from undesirable to desirable species (Wilson & Furrer, 1996). Pre-irrigation can stimulate the seeds in the shallow zone to germinate; the emerged seedlings can be controlled and prevented from completing their life cycle and producing more seeds (Swanton & Shrestha, 2001).

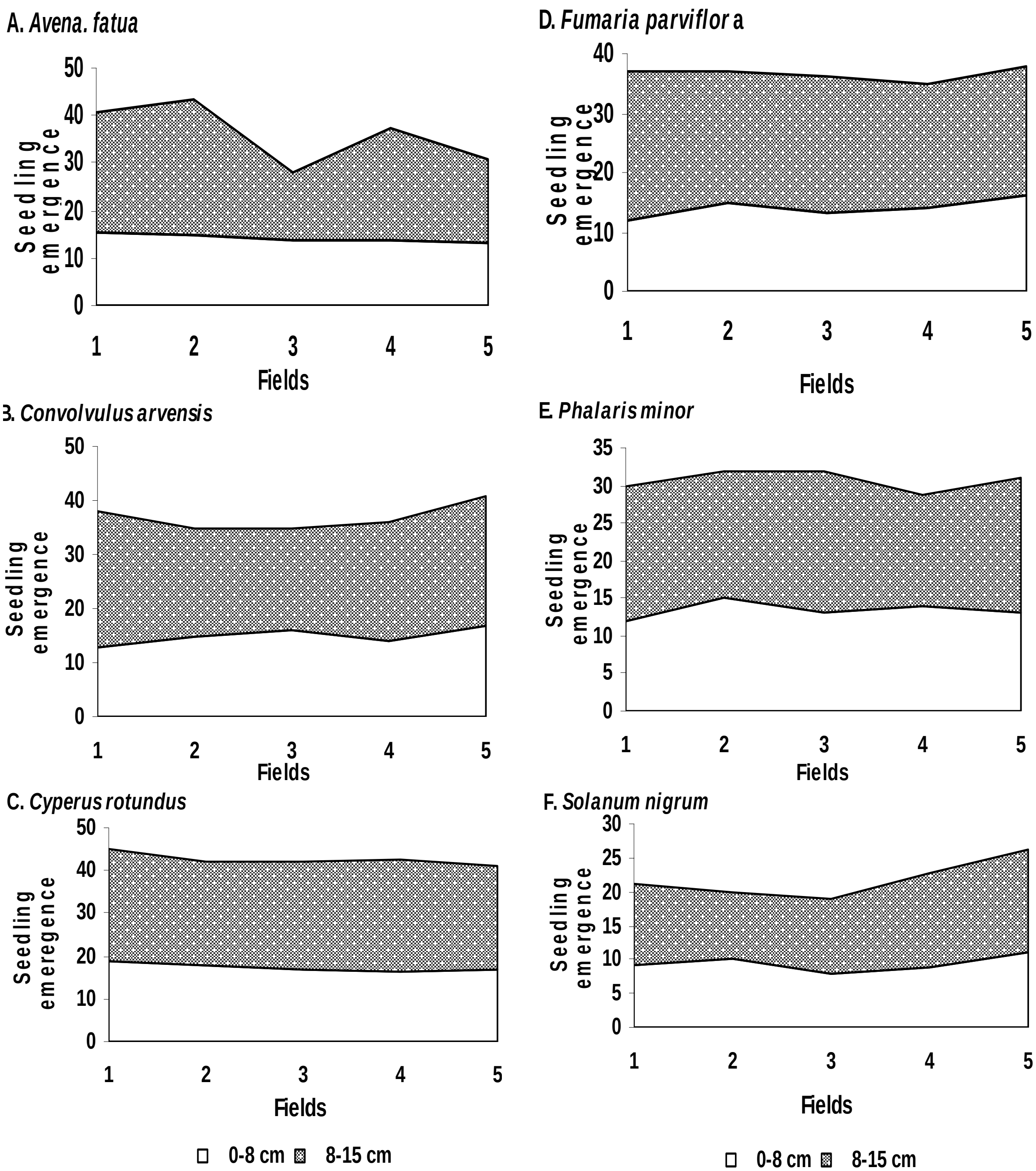
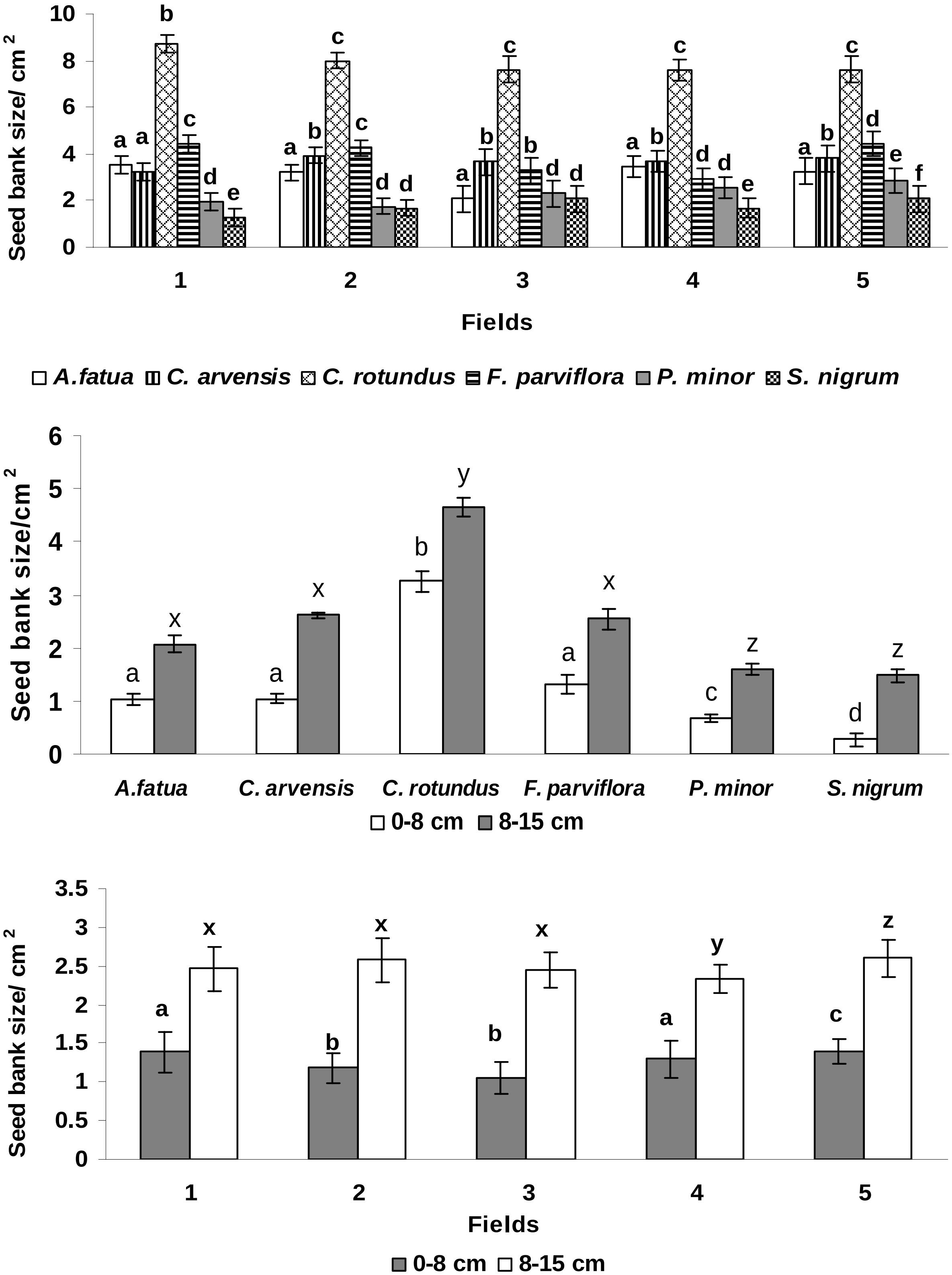


Fig. 1. (A-F): Distribution of seed reserves of six weed species (0.6m^2) estimated via seedling emergence from two soil depths from five different wheat fields (30^{0}N, 72^{0}E).



Mean values in each figure sharing the same letters do not differ significantly by Fisher's multiple comparison test at 0.05% probability level

Fig. 2. (A-C): Interactive seed bank size (number of seeds/cm^2): species x fields across two soil depths (A), species x depths across five fields (B), fields x depths across six species (C).

Table 1. Analysis of variance for soil seed bank of six weeds estimated via seedling emergence from two soil depths from five different wheat fields (30°N, 72°E).

Sources of variation	*df*	Sum of squares	Mean squares	F
Species	5	29.5193	5.9039	***
Fields	4	1.9565	0.4891	*
Depths	1	23.9781	23.9871	***
Species x Fields	20	15.4697	0.7735	**
Species x Depths	5	0.9726	0.1945	**
Fields x Depths	4	0.2798	0.0700	*
Species x Fields x Depths	20	1.2274	0.0614	**

*,**,*** significant at 0.05, 0.01and 0.001probability levels

Conclusions

This study revealed that the soil seed reserves are one of the main sources of weed infestation in wheat fields. The seeds can survive in the deep soil profile and contribute considerable viable reserves of the weed. Soil preparation before cultivation brings about seed transfer to the surface and cause considerable weed germination and growth. Our study suggests that various farming and management practices should be synchronized to limit soil reserves of weed species for effective weed control.

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