Weed Seed Bank Density in Seven-Year-Old Conservation in No-Till System

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Abstract

Weed management remains a challenge when introducing new cropping systems. In Lebanon, farmers are increasingly adopting conservation agriculture (No-till) because it saves energy and reduces water and nutrient erosion. However, introducing a new system will cause a significant shift in production and management practices and is expected to produce novel weed management challenges. Thus, knowledge of soil seed banks of weeds in such systems is vital in designing effective weed management strategies. The objective of this research was to assess the size of the weed seed bank in seven-year-old conservation no-till fields. Soil samples were collected from established till and no-till fields at a depth of 0-5 cm. Transient and persistent weed seeds banks were evaluated. Results provide tangible evidence that the weed seed bank at a depth between 0-5cm in no-till system is greater than in till system. The no-till fields contained almost seven times the density of monocot and dicot weed seeds than in the conventional tilled fields. Ongoing work that builds on present results will help gain knowledge pertaining to weed seed bank dynamics in no-till system compared with conventionally tilled system.

Keywords: conservation agriculture, no-till, transient and persistent weed seed bank

1. Introduction

Conservation agriculture (CA) is a new system that was introduced to Lebanon around 12 years ago. This system is becoming common in a few countries in the MENA region due to the economics of crop production and the improvement of water conservation and soil health (Tubbs & Gallaher, 2005; Saini *et al.*, 2006). However, weed management in this system remains a challenge because it influences weed populations differently than conventional systems. Studies show that perennial weeds could become a problem in CA due to the lack of tillage (Chauhan *et al.*, 2012; Peigne *et al.*, 2007), and most of the soil-applied herbicides are either not incorporated or could be intercepted by crop residues, and may result in lower herbicide efficacy (Chauhan *et al.*, 2012; Hartzler & Owen, 1997). Thus, the only possible way to manage weeds is by using an integrated weed management strategy; a strategy that combines pre-and post-emergence herbicides, use of cover crops, crop rotations, and mulching (Chauhan *et al.*, 2012; Kelton *et al.*, 2011; Hossain *et al.*, 2014; Reeves *et al.*, 2005). Weed research in Lebanon or in the MENA region is limited to weed management in conventional systems. There are almost no studies of weed seed banks in both systems in this region. Thus, there is a need for local research to understand weed composition and sources of weeds in this system.

Various studies show that weed seed banks is a major and primary source of weed infestation in various agricultural systems. Cardina et al., 2002, found that weed seed bank was generally greater under no-till than under till system. Seed bank in CA system is concentrated on the upper soil surface (Chauhan et al., 2012; Conn, 2006). By discovering and understanding the weed seed bank and the fate of weed seeds, we can implement a variety of management methods that can be used to prevent, maintain, and manage weeds. The objective of this study was to estimate the size of the transient and persistent weed seed bank in the upper soil layer (0-5cm) after 7 years of no-tillage farming in Barley/Vetch cropping systems compared with conventional tilled systems.

2. Materials and Methods

2.1 Site Information

Seeds were collected from a 4 ha till and no-till fields at the Advanced Research Enabling Communities Centre (33º 56’ N, 36º 05’ E, 995 m a.s.l.) of the American University of Beirut in the semi-arid northern Beq’aa valley of Lebanon, which has a relatively cool Mediterranean climate. The soil is an alkaline (pH 8.0), clayey, Vertic Xerochrept formed from fine-textured alluvium derived from limestone. Barley and vetch were used in the rotation because of their adaptation to the dry conditions of this region. 2,4-D + MCPA (Broadleaf killers) in barley and Cycloxydim (Grass killer) in vetch were used in both till and no-till fields for the last 7 years.

Wet soil samples were collected randomly along a 100-m transect across the middle of the field in late November. At that time, most weeds had matured and shed their seeds. At each location, one soil sample was collected by using a thread auger 10 cm in diameter and 5 cm long. Analysis of seeds was limited to this depth because the majority of seeds are at this depth (Clements *et al.*, 1996; Hoffman *et al.*, 1998; Yenish *et al.*, 1992). Eight fields: 4 till (0.5ha/each) and 4 no-till (0.5ha/each), 10 samples or cores/field were randomly collected in a zig-zag shape (total of 80 samples). Samples were placed in plastic bags and immediately stored at 5°C for 2 weeks (Chilling) to break the dormancy of seeds that may be present in the soil. At the end of this period, samples were sieved through mesh with an opening of 5mm. Each soil sample was divided into three parts with known weight to measure: transient seed bank (TSB) and persistent seed bank (PSB). TSB and PSB were measured according to Gonzalez & Ghermandi, 2012; Roberts, 1981; Tsuyuzaki, 1984).

2.2 TSB

To measure the TSB or the total quantity of non-dormant seeds (emerged seedlings) per ha cm of soil, the known weight of soil samples (1.8 kg/sample) were placed in plastic trays (20x40x6cm) and left in the greenhouse area (15:9 h day: night photoperiod and a 20–25° C (Temperature range) for 40 days. The 80 trays or replicates (40 till and 40 no-till) were irrigated every three days with 1mm GA to enhance seed germination. Emerged seedlings were counted and removed every 10 days and the soil in each tray was stirred to stimulate germination (Santin-Montanya *et al.*, 2016). Seedlings were identified at the family level. The following formula was used to calculate the quantity of viable seeds per ha cm of soil:

Soil weight per hectare at 16cm depth is equal to 2,200,000kg soil (Zimdahl, 1988). Thus, weed seeds per hectare: 1ha, 5cm deep is equal to 687,500kg soil

$$\frac{\text{No. of viable seeds counted}}{\text{Av. Weight of soil in tray (1.8kg)}} = \frac{\text{No. of viable seeds (unknown)}}{\text{687,500kg}}$$

$$\frac{\text{Viable seeds}}{\text{5 cm}} = \text{Viable seeds per hectare cm (n= 40)}$$

2.3 PSB

To determine the total quantity of seeds (Viable and nonviable seeds) per ha cm of soil, two extraction methods were used.

2.3.1 Sieving

One hundred grams soil sub-samples of soil were air-dried for 3 days, and the seeds were physically extracted by washing them from soil samples as described by Mesgaran et al., 2007. Briefly, each 100g of soil was placed in a small 10x15cm netted polyethylene bag (Pore diameter of 0.2mm) and washed gently with running tap water to remove all silt, clay, and sand. Bags (40 till and 40 no-till) were left in the lab for 24hrs to dry out.

2.3.2 Floating

Seeds from 100g of dried sub-samples of soil were extracted by using high-density chemical as described by Zimdahl, 1988, Mesgaran et al., 2007 and Tsuyuzaki, 1994. Briefly, each soil sample was placed in a 500ml beaker containing 150g of potassium carbonate dissolved with 300 ml of water. The mixture (soil+ solution) was stirred by a stirrer for 15 minutes and then left to rest for 20 minutes. Nearly all weed seeds and light organic matter floated on the top of the solution while soil particles and heavy materials settled at the bottom. Supernatants were filtered through a small-netted polyethylene bag (Pore diameter of 0.2mm) and washed gently with running tap water to remove all dirt and potassium carbonate. Bags (40 till and 40 no-till) were left in the lab for 24hrs to dry out.

Dry residues from each method were placed in plastic dishes and weed seeds were counted by using a binocular stereoscope with variable magnification. Undamaged firm seeds were assumed to be viable (Santin-Montanya et al., 2016). None of the separation methods damaged seeds. A seed reference collection was used to identify the seeds after counting. The following formula was used to calculate the number of seeds per ha cm of soil (Zimdahl, 1988):

Soil weight per hectare at 16cm depth is equal to 2,200,000kg of soil

Weed Seeds per hectare: 1ha, 5cm deep is equal to 687,500kg of soil

$$\frac{\text{No. of seeds in mesh bag counted}}{\text{Weight of soil (0.1kg)}} = \frac{\text{No. of seeds unknown}}{\text{687,500 kg}}$$

Data are the average of 40 bags, trays, or replicates and standard errors.

3. Results and Discussion

3.1 TSB

Transient weed seed bank analysis indicated that there were significant differences between till and no-till fields (Figure 1). The mean TSB for the no-till plots was 901,979 seeds/ha and 508,809 seeds/ha for the till plots, showing the tendency of higher weed seeds in no-till system. These findings agree with various studies that demonstrated higher weed seed density in no-till system than in the till system (Cardina *et al.*, 1991; Hoffman, 1998; Yenish, 1992). This study agrees with the results of Cardina *et al.*, 2002, and Buhler, 1995 in that, a large number of germinating seeds and seedlings are expected in no-till system. Accordingly, we decided to proceed and measure the persistent weed seed bank in the till and no-till systems.

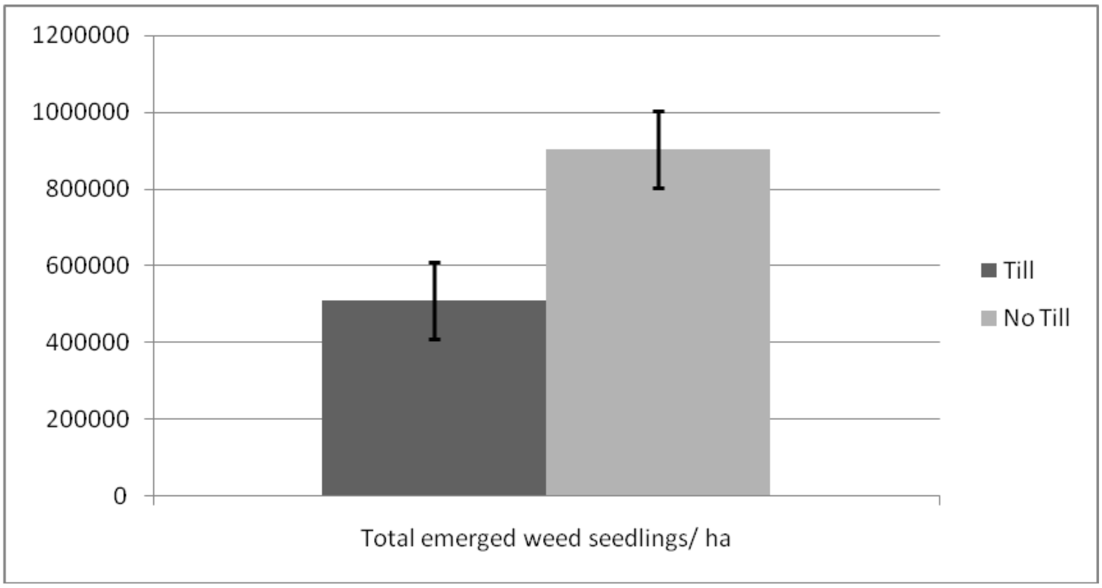

Figure 1. Average emerged seedlings/ ha of tilled vs no-tilled fields. Data represent the average of 40 soil samples ± SE

3.2 PSB

Both sieving and floating techniques detected a greater amount of seeds in comparison to the seedling emergence technique. According to Price et al,. 2010, the seed extraction methods detected greater seed densities in comparison to the seedling emergence method. The seed bank estimated by sieving method was four times higher than that estimated by the seedling emergence (Tray) method (Gonzalez & Ghermandi, 2012).

Results also show that there are a greater amount of weed seeds in the no-till system than in the till system (Figure 2 & 3). This study agrees with the results of Cardina et al., 2002 and Conn, 2006, in that, the weed seed bank is greater under no-till than under till system. However, we observed that there was some difference between the sizes of the seed bank in both methods. The floating technique shows that the density of weed seeds in the no-till fields was almost seven times that in conventional tilled fields (Figure 3). While it was three times that in conventional tilled fields in the sieving technique (Figure 2). Accordingly, we concluded that the floating method is more accurate than the sieving technique in extracting weed seeds from the soil. According to Tsuyuzaki, 1994, the floating technique is more common than the sieving technique. The majority of the weed seeds could be extracted due to the presence of K2CO3 that neutralized the seeds in the solution. The sieving method involves only water and mesh decantation, which entails that a great proportion of small seeds could be lost in the solution by leaching down the mesh and therefore won’t be trapped. Therefore, this experiment reveals that in seed bank evaluation, it is advisable to use the floating techniques rather than using sieving technique. However, both techniques are more accurate than the seedlings emergence method (Tray) in estimating the weed seed banks in soil. Both extraction techniques, in particular the floating technique is easy to use with simple and inexpensive equipment.

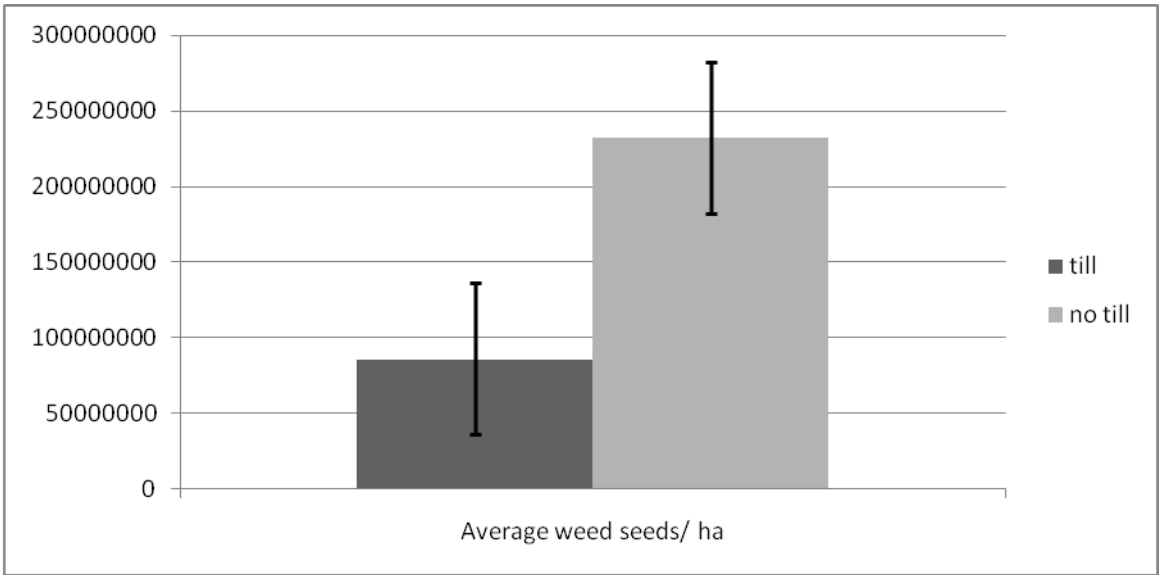

Figure 2. Average weed seed bank/ha of tilled vs no-tilled fields using sieving extraction method. Data represent the average of 40 soil samples ± SE

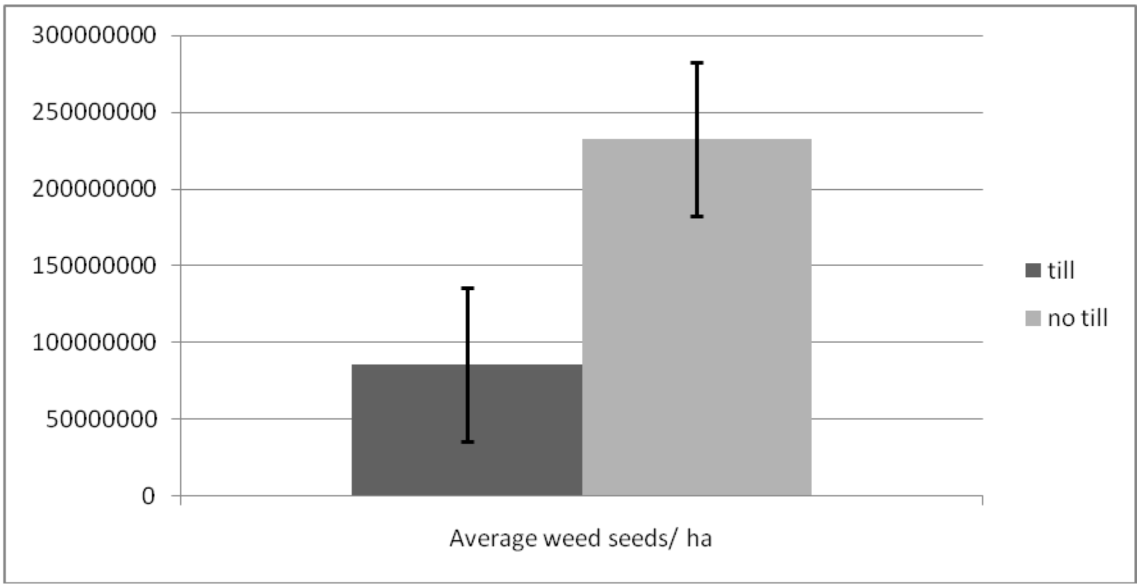

Figure 3. Average weed seed bank/ha of tilled vs no-tilled fields using floating extraction method. Data represent the average of 40 soil samples ± SE

3.3 Implications for Weed Management

Results indicated that unlike the till system, weed seeds remain in the upper soil surface. Thus, farmers have to develop weed management strategies to reduce the number of the weed seed bank in the field, and thus reduce potential weeds in the crop growing season. This could be done by managing the weed seed bank in the upper soil surface. Reducing seed rain is an important component of weed seed management, while other strategies like using PRE herbicides could be used to reduce weed seed germination or emergence, thus enhancing the mortality of weeds. Furthermore, the application of foliar applied herbicides against weeds during the growing season is a must to reduce seed rain. Reducing weed seed bank is an essential component of an integrated weed management system.

3.4 Ecological Significance

Our observation also shows that the no-till system enhanced the level of weed infestation in comparison to the till or conventional system. Although the no-till system reduced few common weeds of arable lands in Lebanon such as *Anthemis hyalina* and *Fumaria* spp., it enhanced noncommon weeds such as *Adonis* spp., *Cardaria draba*, and *Erodium romanum*. Such weeds are usually found in undisturbed or rarely disturbed habitats such as pastures, roadsides, waste places, and neglected sites. The no-till system caused a shift in weed population from common to non-common weeds of the Beqaa valley of Lebanon. It reduced *Anthemis* spp., which is considered the most common weed in cereals, but enhanced *Adonis* spp., *Erodium* spp., and *Cardaria* spp., which are not common weeds in the conventional system of Lebanon. We believe that the adoption of the no-till system may increase the selection pressure on the weed community and may cause weed shifts; an ecological change in the Lebanese agro-system.

4. Conclusion

Results suggest that the TSB and PSB at a depth of 0-5 cm in no-till fields are larger than in conventional tilled fields. The no-till fields contained almost seven times of weed seeds than that in conventional tilled fields.

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