Journal of Pure and Applied Agriculture (2018) 3(1): 13-32

RESEARCH PAPER

Assessment of different tillage systems on the soil weed seed bank in rainfed wheat (*Triticum aestivum* L.) in arid zone of Pakistan

Tauqir Ahmad[1]*, Safdar Ali[1] and Adnan Noor Shah[2]

[1]Department of Agronomy, Faculty of Crop and Food Sciences, Pir Mehr Ali Shah, Arid Agriculture University Rawalpindi, Pakistan
[2]Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan 29050, KPK, Pakistan

***Corresponding author email: tauqir172@gmail.com**

Key Message: This study reveals that tillage systems affect the soil weed seed bank that is a potential threat for potential yield of rainfed wheat. This study will provide the clear picture of the weeds for their sustainable management.

ABSTRACT: Weeds reduce the potential yield of many crops as they are the host of many pests and diseases that ultimately deteriorate the quality and quantity of the produce. Therefore, this study was conducted to determine the weed seed bank in arid zone area of Pakistan. This study reports the results of a 2 years experiment that was carried out at University Research Farm, Chakwal Road, Rawalpindi to assess weed seed bank response against different tillage systems in rain fed wheat. Experiment was arranged in Randomized Complete Block Design (RCBD) with four tillage treatments repeated thrice. These tillage treatments i.e. T_1 = conventional tillage (farmer's practice), T_2 = zero tillage, T_3 = disk harrowing + glyphosate + direct seeding and T_4 = chiseling + glyphosate + direct seeding were applied in kharif season, 2013 (Kharif crops are those crops which are grown on the onset of monsoon season i.e. from July to October each year) just after harvesting of wheat crop of previous rabi season, 2012-13 (Rabi cropping season is from October to March each year). Soil samples for weed seed bank analysis were collected periodically from three soil depths i.e. 0-10 cm, 11-20 cm and 21-30 cm at three stages i.e. pre cultivation, pre sowing and post harvesting stages. The results demonstrated that higher seed species density, weed species diversity, species frequency, dominant weed seed species, relative density, relative frequency, relative importance of species, temporal distribution of species were reported at post harvesting stage as compared to pre-cultivation and pre-sowing stages. This study would enable us to find the clear picture of the weed seed bank present in these soils to design future weed management strategies.

Keywords: Chiseling, Conventional tillage, Glyphosate, Weeds growth, Wheat, Zero tillage

How to cite this article:

Ahmad, T., Ali, S., & Shah, A. N. (2018). Assessment of different tillage systems on the soil weed seed bank in rainfed wheat (*Triticum aestivum* L.) in arid zone of Pakistan. *Journal of Pure and Applied Agriculture*, *3*(1), 13-32.

INTRODUCTION

Agriculture plays a major role in the economy of Pakistan as it contributes 21.8% to GDP of Pakistan (Khan et al., 2011). About 27% of total area of country is being used for agricultural production in Pakistan, in which 30% area is under rainfed and 70% area is irrigated. The 19% area of province Punjab lies in the rainfed region of Pothwar (Agency for Barani Areas Development [ABAD], 1996). Rainfed agriculture is substantial part of the economy of Pakistan and it includes 17% of the total area cropped in the country (Adnan et al., 2009). Wheat, being a staple diet of the country, is considered as the most important cereal crop. In Punjab, wheat is grown on the estimated area of 6.69 million hectares with 19.04 million tons production with average yield of 2737 kg/ha. Whereas in barani tract (Areas where the growing of crops totally depends on rainfall with no irrigation system), wheat covered an area of 549.1 thousand hectares with 431.3 thousand tons production having 1005 kg/ha average yields in the province (Government of Pakistan [GOP], 2011). It is the most value added crop in the barani areas of Pakistan (Hayat & Ali, 2010). According to Ashraf et al. (2007), wheat can yield more than 2964 kg/ha in rainfed areas. But in these areas, average per acre yield remains extremely low due to scarce soil moisture, low soil fertility and dense weed infestation (Razzaq et al., 2002; Naz et al., 2010; Ahmad et al., 2012). But weed infestation is one of the most considerable factors in reducing the yield potential of wheat (Vasileiadis, 2007; Khan et al., 2012). Ahmed and Sheikh (2003) reported that in barani areas the wheat yield decreases 20-40% of the total wheat produced under rainfed conditions due to weeds competition. Weeds are considered to be the biggest competitor of the domesticated crops as they compete for light, moisture, space, nutrients and solar radiations (Kadioglue et al., 2005).

Weeds act in several ways to reduce the potential yield of many crops as they are the host of many pests and diseases that ultimately deteriorate the quality and quantity of the produce (Lehoczky & Reisinger, 2003). They impede cultural operations and hinder harvesting of crops. Some weeds release toxic chemicals (allelochemicals) which hamper growth and development of crop plants (Weston & Duke, 2003; Belz, 2007). Weeds survival mechanism make them special component in the ecosystem because they have adopted special features to survive and reproduce such as higher germination rates, dormancy, quick establishment, large number of seed production, adoption to the unfavorable surroundings and hard nature of the plants. These features have enabled the weeds as highly diversified and the biggest competitor of the domesticated plants (Wijdeven & Kuzee, 2000). Weeds compete with the standing crops for all resources which are required by the plants, at the same time they act as an alternative host for many pests and diseases. So, in the barani tract, the weeds are the most limiting factor of the potential yield after moisture deficiency aspect. One of the other factors which distinguishes the weeds from other vegetation on the planet earth is their difficulty of eradication, as they are very resistant to the applied herbicides (Dhawan et al., 2008). The other considerable factors in weeds eradication are the unavailability of cheap labor and mechanical instruments that may be difficult at certain stages of the crops that are termed as the critical stages of the crops.

Soil seed bank is the ultimate store house for both the weeds and crops, as the seed which are in dormant conditions are stored in soil seed bank. Therefore, it is important to understand the nature and pattern of the soil seed bank of different soils keeping in mind the economical and ecofriendly strategies to control the weeds at regular intervals (Forcella et al., 2004). The understanding of the soil seed bank is also necessary for the prediction of potential weeds emergence, estimating of the weed crop competition, forecasting the weed flora in future and designing better approach to control weeds. Proper management of weed seed bank resulting in the control of weed infestation is an important option for weed management (Sago, 2000). The main source of the weed seed bank establishment is setting of the seeds from locally matured weeds species which set their seeds under field conditions and disseminate the seeds on the soil surface, ultimately establish the weed seed bank. Weeds seeds have different destinies after their dispersal as some of the seed will germinate, grow further, will be eaten by the birds, animals, decayed in weathering process and other will remain dormant until favorable environment reaches (Menalled, 2008).

Tillage is considered as the basic tool in agricultural operations for all preparatory steps including seed bed preparation, conserving moisture, controlling weeds and improving the infiltration rate along with better soil physical properties. These characteristics have direct impact on the productivity of crop (David et al., 2006). Weed control was lately shifted to the chemical control methods instead of tillage in most of the conventional farming systems (Saini et al., 2006). This shift was due to a number of problems caused by the extensive use of tillage as the implements used during tillage deteriorate the quality and physical conditions of the soil during weed control programs. So it is advised that soil should be covered with the leftover of previous crop in order to conserve the soil from physical distraction (Aykas et al., 2004). Intensity and method of tillage change the vertical distribution of soil seed bank and most importantly the weeds that emerge from the nearby seeds present in the soil surface (Swanton et al., 2012). Soil seed bank may be affected by the type and process of the tillage (Vanasse & Leroux, 2000; Reuss et al., 2001; Lutman et al., 2002), weed biotype and seed size (Reuss et al., 2001; Grundy et al., 2003), crop rotation (Cardina et al., 2002), weed management practices (Cardina et al., 2002; Ranjit et al., 2007) herbicide use (Hyvonen & Salonen, 2002) and tillage practices. Recent researches have shown that in no tillage system there is greater proliferation of weeds as the weed density and diversity is more, when compared other tillage systems (Menalled et al., 2001; Cardina et al., 2002; Torresen & Skuterud, 2002). Zero tillage and minimum tillage left the weed seed bank near or on the surface of the soil (Chauhan et al., 2006) and it usually appeared that due to less tillage operations, the weeds emerge vigorously and have higher population rates as compared to those where extensive tillage systems are practiced (Chauhan & Johnson, 2009).

To the best of our knowledge, this is the first report about the determination of the weed seed bank under different sort of tillage systems in the arid zone of Pakistan. This study would enable us to find the clear picture of the weed seed bank present in these soils in order to manage the weeds problem relying on the available sources while practicing appropriate tillage systems. This study was aimed to find the effect of different tillage systems in order to determine the density and composition of weed seed bank present in the soils of arid zone of Pakistan. It was also aimed to find out the effect of different tillage systems on the vertical as well as temporal distribution of soil weed seed bank.

MATERIALS AND METHODS

The present study was conducted during the years 2012 to 2014 at PMAS, Arid Agriculture University Research Farm, Chakwal Road, Rawalpindi, Pakistan. In this study, the crop was sown on October every year and harvested on April every year. Four tillage treatments (Table 1) before sowing of wheat crop was applied in the field from where soil samples were collected periodically from different depths and stages for comparison of soil weed seed bank. The sampling was done on three stages namely pre-cultivation stage (S_1), pre-sowing stage (S_2) and post-harvesting stage (S_3) at three sampling depths i.e. D_1 = 0-10 cm, D_2 = 11-20 cm and D_3 = 21-30 cm. The field experiment was conducted in the field using randomized complete block design (RCBD) having three replications. Each plot size of the tillage system was 13 m x 9 m. The wheat cultivar Chakwal 50 was sown @ 100 kg/ha in 25 cm apart rows. The NPK fertilizer was applied @ 90-60-60 kg/ha in the form of urea, diammonium phosphate and potassium sulphate, respectively. Half dose of nitrogen and full dose of PK was applied at the sowing time and remaining half dose of nitrogen was applied at booting stage. In plots of zero tillage and reduced tillage, sowing of wheat was done with no-till sowing drill but in case of conventional tillage, sowing of wheat was done using tractor drawn seed cum fertilizer drill. In reduced tillage, a non-selective herbicide (Glyphosate) was sprayed when needed at the recommended dose to control the weeds during fallow period. Conventional tillage was done according to the farmer's practice during the fallow period. This was involved once deep tillage with moldboard plow on the onset of monsoon followed by one shallow cultivation with cultivator after each heavy rainfall with a total of 8 cultivations including seed bed preparation. While in zero tillage system no any tillage practice was done before sowing of crop but the weeds during fallow period was controlled with a non-selective herbicide (Glyphosate) as and when required. The sowing of crop was done by using no till drill. In third treatment, disc-harrowing was done at the 1st flush of weeds after monsoon rains, while during fallow period weeds was controlled by using Glyphosate as per requirement. The winter wheat was seeded with no-till drill. In fourth treatment, chisel plow was used before the onset of monsoon and then fallow period weeds were controlled with Glyphosate as per need and direct sowing was done with no-till drill.

Table 1 Four tillage systems that were applied before the sowing of wheat crop

Treatment name	Tillage system
T_1	Conventional tillage system (Farmer's Practice)
T_2	Zero tillage
T_3	Disc harrowing + Glyphosate + Direct seeding
T_4	Chiseling + Glyphosate + Direct seeding

Soil sampling

Five soil samples was collected through W arrangement for making a representative working sample from three soil depths i.e. (0-10), (11-20), (21-30) by using steel probe having 2.5 cm diameter from each plot at three stages i.e. (pre-cultivation), (pre-sowing), (post-harvesting). Samples were stored at room temperature in the dark until processing.

Sieving method

Seeds were extracted from soil by sieving of soil sample through various sieves with different mesh sizes following the method devised by Konstantinovic et al. (2011).

Parameters studied

Seed density (m^{-2})

The total number of viable seeds in each working sample was counted and converted into number of seeds m^{-2}.

Species absolute frequency (AF)

Weed frequency (the number of samples in which a weed species occurs relative to the total sample studied) was recorded by the following formula.

$$AF = \frac{\text{Number of samples with individual weeds spp}}{\text{Total number of samples}}$$

Relative density of species (RD)

Relative density was calculated from the density data for each species by the following formula.

$$RD = \frac{\text{Density of weed species in questions}}{\text{Total weed desnity}}$$

Relative frequency of species (RF)

Relative frequency was calculated by taking absolute frequency of each species individually and by aggregation.

$$RF = \frac{\text{Absolute frequency of weed seed species}}{\text{Total absolute frequency of all weeds seeds}}$$

Where
Total absolute frequency of all weed seeds = the sum of all the individual species absolute frequencies.

Relative importance of species (RI)

The relative importance (RI) index was calculated according to Cardina et al. (2002).

$$RI = \frac{RD + RF}{2}$$

Where
RD = Relative density
RF = Relative frequency

Species vertical distribution

Vertical species distribution was calculated through the density and frequency data recorded from different depths of soil.

Species temporal distribution

Species temporal distribution was calculated by the data of three stages. Statistical analysis was not applied on data due to large differences in coefficient of variations.

RESULTS

Weed seed density (m^{-2}) in soil weed seed bank under different sampling stages

More weed seeds were extracted at post-harvesting stage S_3 (41048 seeds m^{-2}) followed by pre-cultivation stage S_1 (39261 seeds m^{-2}) and the lowest seed density was recorded at pre-sowing stage S_2 (37007) from the soil samples at the upper 0-10 cm soil depth (Table 2). Results at the pre-cultivation stage (S_1) showed that seeds of weed species *Chenopodium album*, *Fumaria indica*, *Asphodelus tenuifolius* and *Convolvulus arvensis* were dominant with the densities of 16508, 7786.7, 3230.6 and 3110, respectively. The data recorded at stage (S_3) showed the highest value of 19287 observed by *Chenopodium album* followed by *Fumaria indica*, *Asphodelus tenuifolius Melilotus indica* and *Euphorbia helioscopia* with the seed density of 8327.2, 3215, 2862.8 and 2595.6 respectively whereas the least value recorded was *Vicia sativa* (40.56). Comparison of weed seed density m^{-2} among different sampling stages at the depth of 11-20 cm indicated that higher weed seed density m^{-2} at post harvesting stage S_3 (24723.1) was extracted than other two stages S_2 (23575.2) and S_1 (21432.6) respectively. At stage S_1, the seeds of *Chenopodium album*, *Fumaria indica*, *Asphodelus tenuifolius* and *Convolvulus arvensis* were found to be dominant with the densities of 8482, 4456.7, 2102.8 and 1893.1 seeds m^{-2}, respectively. The *Chenopodium album* showed the highest seeds density with value of 11213 which was followed by *Fumaria indica*, *Melilotus indica*, *Asphodelus tenuifolius* and *Convolvulus arvensis* with the densities of 5615.8, 1953.6, 1940.8 and 1654.7, respectively. Data regarding weed seed density m^{-2} in weed seed bank at study area at the depth of 21-30 cm indicated that higher weed seeds m^{-2} was observed at third stage S_3 (16249.5) the seed density recorded at stage S_2 (14140.9) and the least one value was recorded at stage S_1 (12077.3). Seeds of *Chenopodium album* (5560.6), *Fumaria indica* (2008.3), *Asphodelus tenuifolius* (1244.4) and *Euphorbia helioscopia* (758.3) were found to be higher as compared to other weed species at S_1. At second stage (S_2), higher densities were observed for *Chenopodium album* (6257.2), *Fumaria indica* (2977.8), *Asphodelus tenuifolius* (1325.6) and *Euphorbia helioscopia* (991.39), while least density was recorded by *Vicia sativa* (39.17) in lower layer at S_2. The results of seed densities at third stage (S_3) showed the highest density by *Chenopodium album* (7670.2) which was followed by *Fumaria indica*, *Asphodelus tenuifolius*, *Euphorbia helioscopia* and *Melilotus indica* with densities of 3414.9, 1433.5, 1121.1 and 1069.7 respectively, the least density m^{-2} recorded for *Lathyrus aphaca* (78.33).

Weed seed density (m^{-2}) in soil weed seed bank affected by different tillage systems

Total seed density m^{-2} at the depth of 0-10 cm under different tillage systems varied from 35816 seeds m^{-2} in conventional tillage system (T_1) to 44382.7 seeds m^{-2} in zero tillage system (Table 3). Among different weed species, *Chenopodium album* had the highest seed density in all tillage systems i.e. T_1 (17763), T_2 (18565), T_3 (15847) and T_4 (15892) showing the most abundant species following *Fumaria indica* with the densities of 7782.6, 8760.7, 7713.3 and 6614.4 in all tillage systems respectively. In T_1, other weed species *Melilotus indica*, *Asphodelus tenuifolius* and *Euphorbia helioscopia* with seed density of 2360, 2275.2 and 2039.3 (m^{-2}), respectively were densely populated whereas *Euphorbia dracunculoide* had minimum seed density (98.89). In T_1, the two species *Avena fatua* and *Vicia sativa* were not found. In T_2, after *Chenopodium album* and *Fumaria indica*, the highest seed of *Asphodelus tenuifolius* (4136.7) *and Convolvulus arvensis* (3341.9) were found, while the lowest seed density m^{-2} was observed for *Euphorbia dracunculoide* (56.3), species *Vicia sativa* was absent in this tillage system. In T_3, weeds seeds of *Chenopodium album* (15847) followed by *Fumaria indica*, *Asphodelus tenuifolius* and *Convolvulus arvensis* with density of 7713.3, 3621.1 and 3355.9 respectively were densely populated in the weed seed bank of T_3 while minimum density was recorded of *Euphorbia dracunculoide* (95.56). In T_4, higher numbers of weed seeds were observed of *Fumaria indica*, *Asphodelus tenuifolius* and *Melilotus indica* with the densities of 6614.2, 3773.7 and 3042.6 respectively after *Chenopodium album* whereas the least weed seeds were recorded for *Euphorbia dracunculoide* (155.93), seeds of two weed species *Anagallis arvensis* and *Lathyrus aphaca* were not observed in T_4. Weed seed density m^{-2} as affected by different tillage systems at the depth of 11-20 cm showed that maximum weed seed density was observed in T_4 (26367) followed by T_3 (25477.4), T_1 (22884.6) and T_2 (18245.2). Species wise seed density m^{-2} demonstrated that in T_1 *Chenopdium album* attained highest seed density of 9189 which was followed by *Fumaria indica* (4884.1), *Asphodelus tenuifolius* (2263.3) and *Convolvulus arvensis* (2006.3) whereas the lowest seed density was recorded for *Euphorbia dracunculoide* (97.778). For T_2, besides *Chenopodium album* (8440), seeds of *Fumaria indica* (4286), *Convolvulus arvensis*(1397) and *Melilotus indica* (1249.9) were densely populated in weed seed bank, while minimum seed density was observed for *Euphorbia dracunculoide* (49.63) and three species were absent in this tillage system i.e. *Avena fatua, Carthamus oxyacantha* and *Vicia sativa*. For T_3, the highest weed seeds density m^{-2} of *Chenopodium album* (10493) was observed which was followed by *Fumaria indica* (5695.9), *Asphodelus tenuifolius* (2516.3) and *Convolvulus arvensis* (1751.5) respectively, and the least value was showed by *Lathyrus aphaca* (228.15). In T_4, maximum density of weed seeds was recorded for *Chenopodium album* (10664). This was followed by *Fumaria indica* (6447.8), *Asphodelus tenuifolius* (2380.4) and *Melilotus indica* (2203.3). Minimum seed density was observed *Vicia* sativa (55.185). Seed density m^{-2} under different tillage systems at the depth of 21-30 cm revealed that the highest total seed density m^{-2} (15365.9) was recorded in the T_3, while the lowest seed density was attained in the T_1 (10675.9). Species wise density showed that the highest weed seeds were recorded for *Chenopodim album* (5552.6) followed by *Fumaria indica* (2128.9), *Asphodelus tenuifolius* (1047.4) and *Euphorbia helioscopia* (522.2), while the lowest seed density was observed for *Euphorbia dracunculoide* (4.261) in T_1. In T_2 maximum seed density (5355.2) was recorded for *Chenopodium album* followed by *Fumaria indica* (2801.9), *Asphodelus tenuifolius* (1294.8) and *Convolvulus arvensis* (966.7), while minimum density (50.37) was observed for *Euphorbia dracunculoide*. For T_3 maximum density (6745.6) was examined for *Chenopodim album* which was followed by *Fumaria indica* (3109.6), *Asphodelus tenuifolius* (1570.7) and *Euphorbia helioscopia* (1061.5). In T_4, it was observed that maximum weed seed density m^{-2} was presented by *Chenopodium album* (8330.7) followed by *Asphodelus tenuifolius, Melilotus indica* and *Euphorbia helioscopia* with values of 1425, 1294 and 1292.2, respectively. The least value was observed for *Euphorbia dracunculoide* (45.333).

Absolute frequency of weed species under different sampling stages

The data regarding absolute frequency of weed seed presented in Table 4 showed that there was differential effect of tillage systems on weed seed bank at different sampling stages of the study area. Absolute frequency of weed species was recorded through sieving extraction method from the obtained soil samples from different soil layers. Data given in Table 4 at the depth of 0-10 cm demonstrated that at all the three sampling stages, *Chenopodium album* was the most frequently weed species followed by *Fumaria indica* and *Asphodelus tenuifolius* with the frequency of 1, 1.00 and 0.86 in S_1 while 1.00, 0.97 and 0.50 respectively in S_2. The data regarding absolute frequency of weeds seed in the middle layer at different sampling stages showed that the highest frequency values for *Chenopodium album* in three stages i.e. S_1, S_2 and S_3 had frequency of 1.00, 1.00 and 0.97, respectively. Other frequently occurred weeds seeds were *Fumaria indica* and *Asphodellis tenuifolius* in S_1 and *Fumaria indica, Asphodellis tenuifolius* and *Convolvulus arvensis* in S_2. Whereas, the least frequently distributed species in S_3 was *Lathyrus aphaca* with absolute frequency of 0.06. At the depth of 21-30 cm it was observed that *Chenopodium album* with the absolute frequency of 0.64, 0.58 and 0.63 in S_1, S_2 and S_3, respectively, was the most dominating species. In S_1, other frequently occurred species were *Fumaria indica*, *Asphodelus tenuifolius* and *Convolvulus arvensis* with the frequencies of 0.39, 0.39 and 0.42, respectively. While in S_2, *Fumaria indica* (0.47), *Convolvulus arvensis* (0.42) and *Melilotus indica* (0.33) were frequently occurred. The lowest absolute frequency was observed for *Lathyrus aphaca* (0.05) in S_3.

Absolute frequency of weed species affected by different tillage systems

Tillage systems affected on species absolute frequency demonstrating that maximum absolute frequency was observed for *Chenopodium album* in all tillage systems having absolute frequency of 1.00 in T_2, T_3, T_4 and 0.96 in T_1 (Table 5). In T_1, other than *Chenopodium album, Fumaria indica, Asphodelus tenuifolius*, and *Convolvulus arvensis* were observed more frequent with absolute frequencies of 0.96, 0.89 and 0.74, respectively, while less absolute frequency of 0.06 for *Lathyrus aphaca* was recorded at 0-10 cm depth. In T_2, *Chenopodium album*, *Asphodelus tenuifolius* and *Fummaria indica* showed absolute frequency values of 1.00, 0.85 and 0.85, respectively. In T_3, after *Chenopodium album*, *Fumaria indica* (0.89), *Convolvulus arvensis* (0.70), *Asphodelus tenuifolius* (0.70) *and Euphorbia helioscopia* (0.70) were frequently occurred in study area. In T_4, the highest frequency of 1.00 was noted for *Chenopodium album* and *Fumaria indica* was (0.89) and these were followed by *Asphodelus tenuifolius* (0.85) and *Fumaria indica* (0.81). Data pertaining to absolute frequency under different tillage systems at 11-20 cm depth illustrated that in T_1 more frequently weed species were *Chenopodium album* (0.96), *Fumaria indica* (0.89), *Asphodelus tenuifolius* (0.74) and *Convolvulus arvensis* (0.67), while minimum absolute frequency with value of 0.04 was recorded for *Euphorbia dracunculoide* at 11-20 cm depth. In T_2, the most frequently occurred species was *Chenopodium album* (1.00) followed by *Fumaria indica*, *Asphodelus tenuifolius*, *Convolvulus arvensis* with the absolute frequencies of 0.81, 0.59 and 0.48, respectively. In T_3, maximum absolute frequency (1.00) was observed for *Chenopodium album* which was followed by *Fumaria indica* (0.81), *Asphodelus tenuifolius* (0.59) and *Convolvulus arvensis* (0.48). *Chenopodium album* was the most frequently occurred with absolute frequency of 1.00 followed by *Fumaria indica* (0.96), *Melilotus indica* (0.48) and *Asphodelus tenuifolius* (0.44) in T_4. At 21-30 cm depth tillage systems, the seed of *Chenopodium album* (0.74) was found to be frequent in T_1 which was followed by *Fumaria indica* (0.56), *Asphodelus tenuifolius* (0.37) and *Convolvulus arvensis* (0.33). *Lathyrus aphaca* (0.04) was the least frequently observed at this depth. In T_2, the species more frequently occurred were *Chenopodium album* (0.74), *Fumaria indica* (0.48), *Euphorbia helioscopia* (0.44) and *Asphodelus tenuifolius* (0.41), while the lowest absolute frequency was recorded for *Anagallis arvensis* (0.07). In T_3, the highest absolute frequency was examined for *Chenopodium album* (0.52) which was followed by *Convolvulus arvensis, Fumaria indica* and *Asphodelus tenuifolius* with the absolute frequencies of 0.44, 0.41 and 0.30, respectively. The lowest absolute frequency was observed for *Avena fatua* (0.04). In T_4, after *Chenopodium album* (0.47), *Convolvulus arvensis* (0.43), *Asphodelus tenuifolius* (0.40) and *Fumaria indica* (0.39) were more frequently found in the soil weed seed bank.

Species relative density under different sampling stages

Table 6 showed the relative density regarding to the weed species which were present in soil weed seed bank at different soil depths i.e. 0-10 cm, 11-20 cm and 21-30 cm at three different stages S_1, S_2 and S_3. It indicated that at 0-10 cm depth, *Chenopodium album*, *Fumaria indica*, *Euphorbia helioscopia*, *Melilotus indica* and *Asphodelus tenuifolius* gave higher value of 50.54, 23.80, 6.10, 5.98 relative density than that of rest of species in S_1. While in S_2, *Chenopodium album*, *Fumaria indica*, *Asphodelus tenuifolius* and *Melilotus indica* gave density values of 43.14, 20.57, 9.13 and 6.86, respectively. In S_3, the relative density of seeds of species *Chenopodium album*, *Fumaria indica*, *Melilotus indica* with relative density of 42.84, 19.18 and 8.32, respectively were recorded. The data relating to species relative density at 11-20 cm depth revealed that in S_1, maximum relative density of 53.48 was observed for *Chenopodium album* which heavily infested the weed seed bank. It was followed by *Asphodelus tenuifolius* (19.81) and *Fumaria indica* (8.19), respectively. In S_2, the highest relative density was recorded for *Fumaria indica* (40.48) followed by *Chenopodium album* (40.06), *Asphodelus tenuifolius* (4.90) and *Melilotus indica* (3.64). In S_3, the highest relative density was recorded for *Chenopodium album* (48.62) followed by *Fumaria indica* (27.66), *Melilotus indica* (5.62). Data regarding relative density at lower soil depth (21-30 cm) under different stages showed that in S_1, the highest relative density was observed for *Chenopodium album* (42.62) which was followed by *Convolvulus arvensis*, *Fumaria indica* and *Euphorbia helioscopia* with the relative densities of 16.81, 12.38 and 10.62, respectively. In S_2, maximum relative density (25.50) was examined for *Fumaria indica* followed by *Chenopodium album* (25.13), *Convolvulus arvensis* (19.03) and *Asphodelus tenuifolius* (17.76). In S_3, *Fumaria indica* (30.41) showed the highest relative density which was followed by *Convolvulus arvensis*, *Asphodelus tenuifolius, Chenopodium album* and *Euphorbia helioscopia* with values of 20.87, 20.33, 17.94 and 10.06.

Species relative density affected by different tillage systems

The data regarding relative densities in different tillage systems at 0-10 cm depth revealed that *Chenopodium album* represented maximum relative density of 48.7 compared to the other species in T_1 followed by *Fumaria indica* (19.84), *Melilotus indica* (7.03), *Asphodelus tenuifolius* (6.28) and *Convolvulus arvensis* (5.82) (Table 7). For T_2, the highest relative density (38.33) was recorded for *Chenopodium album* followed by *Fumaria indica* (21.78), *Asphodelus tenuifolius* (9.76) and *Melilotus indica* (8.19). In T_3, *Chenopodium album* was the most dominating species with relative density of 45.19. For T_4, maximum relative density of 49.80 was observed for *Chenopodium album* followed by *Fumaria indica* (20.71), *Asphodelus tenuifolius* (6.88) and *Euphorbia helioscopia* (6.57). *Euphorbia dracunculoide* showed the lowest relative density of 0.13. Data related to relative density under different tillage systems at 11-20 cm depth demonstrated that in T_1, *Chenopodium album* (47.45), *Fumaria indica* (22.59), *Asphodelus tenuifolius* (13.21) and *Euphorbia helioscopia* (4.93) showed higher values of relative density than that of other species (Table 7). For T_2, maximum relative density of 53.52 and 17.25 was recorded for *Chenopodium album* and *Fumaria indica* followed by *Asphodelus tenuifolius* (11.06) and *Melilotus indica* (4.56), while minimum relative density (0.33) was observed for *Euphorbia dracunculoide*. In T_3, the highest relative density of 41.78 was examined for *Chenopodium album* whereas other species like *Fumaria indica*, *Asphodelus tenuifolius*, *Melilotus indica* and *Convolvulus arvensis* showed relative densities of 30.71, 10.70, 7.28 and 5.97. For T_4, *Chenopodium album* and *Fumaria indica* were the most dominant species with relative density values of 46.82 and 31.24. At 21-30 cm soil depth, in T_1 tillage system, more abundantly weed species were *Chenopodium album*, *Fumaria indica*, *Convolvulus arvensis* and *Asphodelus tenuifolius* with the relative densities of 36.95, 20.76, 20.15 and 14.95, respectively. The highest relative density was recorded for *Chenopodim album* (27.68) followed by *Fumaria indica* (26.94), *Asphodelus tenuifolius* (19.38) and *Convolvulus arvensis* (18.79) in T_2. For T_3, maximum relative density of weed seeds was recorded for *Chenopodium album* (24.15). This was followed by *Euphorbia helioscopia* (22.52), *Fumaria indica* (19.43) and *Convolvulus arvensis* (16.91). In T_4, *Chenopodium album* had the highest relative density of 25.45 which was followed by *Fumaria indica*, *Convolvulus arvensis* and *Asphodelus tenuifolius* with the relative densities of 23.90, 19.75 and 17.26, respectively, while least relative density was observed for *Anagallis arvensis* (0.52).

Weed seed relative frequency under different sampling stages

Relative frequency at different sampling stages showed that at 0-10 cm depth, maximum relative frequency was observed in *Fumaria indica* (22.16) and *Chenopodium album* (18.97) (Table 8). These were followed by *Asphodelus tenuifolius* (13.72), *Euphorbia helioscopia* (12.98) and *Convolvulus arvensis* (12.03). In S_2, after *Chenopodium album* and *Fumaria indica* (14.87 for each), *Asphodelus tenuifolius* (13.92), *Melilotus indica* (11.94) and

Convolvulus arvensis (11.76) were more frequently occurred in weed seed bank. In S_3 the maximum value was recorded for *Fumaria indica* (15.32) and *Chenopodium album* (14.52). The data about relative frequency of species at 11-20 cm depth indicated that in S_1, the highest relative frequency values ranged from 27.22 and 21.18 recorded for *Chenopodium album* and *Asphodelus tenuifolius*. In S_2, after *Chenopodium album* (25.04), *Fumaria indica* (24.35), *Asphodelus tenuifolius* (11.14) and *Convolvulus arvensis* (11.13) were more frequently found in the soil weed seed bank. In S_3, the highest value was recorded for *Chenopodium album* (23.63) followed by *Fumaria indica*, *Melilotus indica*, *Anagallis arvensis and Convolvulus arvensis* having relative frequency values of 22.63, 13.18, 11.08 and 10.31, respectively. The data pertaining to species relative frequency at 21-30 cm depth is given in Table 8 showed that *Chenopodium album* occurred frequently with relative frequency of 22.66, while *Euphorbia helioscopia*, *Convolvulus arvensis*, *Fumaria indica* and *Asphodelus tenuifolius* showed relative frequencies of 18.98, 16.96, 14.35 and 12.40, respectively in S_1. For S_2, *Chenopodium album* (21.46), *Convolvulus arvensis* (20.22), *Fumaria indica* (15.68) and *Euphorbia helioscopia* (15.33) showed higher values of relative frequency whereas the lowest relative frequency was observed for the *Avena fatua* (0.97). For S_3, *Asphodelus tenuifolius* recorded maximum relative frequency of 25.76 followed by *Euphorbia helioscopia*, *Chenopodium album*, *Fumaria indica* and *Convolvulus arvensis* showed 22.56, 20.93, 16.38 and 12.96 relative frequencies, respectively.

Weed seed relative frequency affected by different tillage systems

Results regarding relative frequency at the depth of 0-10 cm showed that *Chenopodium album* was the most frequent weed seed in the study area with 17.63 relative frequency in T_1 (Table 9). Relative frequency of 17.63 was recorded for *Fumaria indica* and 13.59, 11.57 and 11.10 for *Asphodelus tenuifolius*, *Convolvulus arvensis* and *Melilotus indica* (Table 9). For T_2, *Fumaria indica* was found to be frequent with relative frequency of 16.60, while *Chenopodium album*, *Asphodelus tenuifolius*, *Convolvulus arvensis*, and *Melilotus indica* showed relative frequency of 15.53, 13.58, 13.26 and 11.36, respectively. In T_3, relative frequency of 18.79 and 16.01 was observed for both *Fumaria indica* and *Euphorbia helioscopia*.. In T_4, the highest relative frequency of 16.78 was observed for *Chenopodium album* followed by *Fumaria indica* (18.53), *Euphorbia helioscopia* (13.49) and *Asphodelus tenuifolius* (13.14). Tillage effects shown in Table 9 at the depth of 11-20 cm indicated that *Chenopodium album* and *Asphodelus tenuifolius* were the most frequent weed seed in T_1 with relative frequencies of 28.43 and 22.42. For T_2, *Chenopodium album* had found with relative frequency of 22.25 while, *Fumaria indica*, *Asphodelus tenuifolius* *Convolvulus arvensis* and *Anagallis arvensis* showed relative frequencies of 20.21, 14.03, 14.04 and 9.73, respectively. In T_3, maximum relative frequencies of 26.26 and 25.48 were presented by *Fumaria indica* and *Chenopodium album* followed by *Euphorbia helioscopia*, *Asphodelus tenuifolius* and *Convolvulus arvensis* with relative frequencies of 11.13, 10.29 and 9.45, respectively. The highest relative frequency (25.03) was observed for the most frequently occurring *Chenopodium album* and least relative frequency of 1.35 was observed for *Lathyrus aphaca* in T_4. Data presented in Table 9 for the depth of 21-30 cm regarding relative frequency under different tillage systems showed that *Chenopodium album* was the most frequent species found in T_1 and T_2 tillage systems. It presented the maximum relative frequency of 32.29 in T_1 and T_2, respectively. For T_2, the higher relative frequencies of 26.04, 22.83, 17.53 and 14.34 were found for *Chenopodium album*, *Convolvulus arvensis*, *Fumaria indica* and *Euphorbia helioscopia*, respectively. In T_3, after *Asphodelus tenuifolius* (26.75), *Convolvulus arvensis* with the relative frequency of 16.93 was the most frequently occurring species. For T_4, more frequently occurring species were *Euphorbia helioscopia*, *Chenopodium album* and *Asphodelus tenuifolius* with relative frequencies of 30.09, 20.03 and 17.98, respectively.

Relative importance value under different sampling stages

The relative importance (RI) of species presented in Table 10 at 0-10 cm soil depth indicated that *Chenopodium album* was the most dominant species with 32.73, 27.36 and 33.40 RI value in S_1, S_2 and S_3 respectively followed by *Fumaria indica* at S_1 (20.04), S_2 (18.67) and S_3 (18.31). Next dominant species was *Asphodelus tenuifolius* at S_1 (10.04) and S_2 (11.44), and *Euphorbia helioscopia* (10.55) at S_3. Data regarding relative importance value examined at 11-20 cm soil depth showed that *Chenopodium album* depicted the maximum RI value (40.35) at S_1 which was followed by *Asphodelus tenuifolius* (21.33), *Fumaria indica* (12.85), *Convolvulus arvensis* (9.07) and *Melilotus indica* (7.11). At S_2, *Chenopodium album* was the most dominating species with the RI value of 32.56 and other dominating species were *Fumaria indica*, *Asphodelus tenuifolius*, *Convolvulus arvensis* and *Euphorbia helioscopia* with RI values of 32.42, 8.03, 7.29 and 5.37, respectively. At S_3, *Chenopodium album* was recorded as most dominated species having RI value of 36.13 which was followed by *Fumaria indica*, *Melilotus indica*, *Anagallis arvensis* and *Convolvulus arvensis* 25.06, 9.41, 7.54 and 7.27, respectively. Relative importance values at different sampling stages at 21-30 soil depth indicated that at S_1, *Chenopodium album* (32.64), *Convolvulus arvensis* (16.89), *Euphorbia helioscopia* (14.78) and *Fumaria indica* (13.37) were the dominant species than that of other species. For S_2, after *Chenopodium album* (23.48), *Convolvulus arvensis* (20.79), *Fumaria indica* (20.66) and *Asphodelus tenuifolius* (14.88) were the dominant species. At S_3, the most dominated species observed was *Fumaria indica* (23.40) which was followed by *Asphodelus tenuifolius, Chenopodium album and Convolvulus arvensis* with RI values of 23.04, 19.44 and 16.91, respectively.

Relative importance value affected by different tillage systems

Relative importance (RI) for the depth of 0-10 cm affected by tillage revealed that RI value of *Chenopodium album* (32.88) was the highest value followed by *Fumaria indica* (18.45), *Asphodelus tenuifolius* (9.74) and *Melilotus indica* (9.58) in T_1 tillage system (Table 11). In T_2, *Chenopodium album* was found to be the most frequently occurring with RI value of 27.19 which was followed by *Fumaria indica* (18.91), *Asphodelus tenuifolius* (11.46), *Convolvulus arvensis* (10.27) and *Melilotus indica* (9.57). In T_3, it was observed that maximum relative importance value was presented by *Chenopodium album* (31.29) followed by *Fumaria indica*, *Euphorbia helioscopia Asphodelus tenuifolius* and *Melilotus indica* with values of 19.90, 11.51, 10.54 and 8.88, respectively. In T4, *Chenopodium album* (33.29), *Fumaria indica* (18.74), *Euphorbia helioscopia* (10.04), *Asphodelus tenuifolius* (10.01) and *Melilotus indica* (8.72) were dominant species. Whereas**,** under different tillage systems at 11-20 cm soil depth, the relative importance of species varied in the study area. In T_1, it was observed that higher relative importance values were presented by *Chenopodium album*, *Fumaria indica*, *Asphodelus tenuifolius, Euphorbia helioscopia* and *Convolvulus arvensis* having 34.28, 20.84, 14.27, 8.59 and 7.71 values, respectively. While *Chenopodium album*, *Fumaria indica, Asphodelus tenuifolius Convolvulus arvensis* and *Melilotus indica* were the dominant species in the no till system (T_2) with the RI values of 39.98, 18.59, 13.19, 7.82 and 6.39, respectively. In T_3, the highest relative importance value was observed for *Chenopodium album* (35.00) followed by *Fumaria indica* (26.59), *Asphodelus tenuifolius* (13.50), *Melilotus indica* (9.40) and *Convolvulus arvensis* (7.88). Data of RI values regarding T_4 showed that *Chenopodium album* with RI value of 36.11 was the most dominant species than that of other weed species. The RI values of 27.76, 8.10, 7.35 and 7.11 were recorded for *Fumaria indica*, *Convolvulus arvensis*, *Asphodelus tenuifolius* and *Melilotus indica*, respectively. For 21-30 cm soil depth, data regarding relative importance under tillage systems indicated that in T_1, *Chenopodium album* (33.02), *Fumaria indica* (20.21), *Asphodelus tenuifolius* (18.40), *Convolvulus arvensis* (16.93) and *Melilotus indica* (5.28) reflected more dominance with higher RI values. For T_2, after *Chenopodium album* (27.00), *Fumaria indica* (21.32), *Asphodelus tenuifolius* (16.91), *Convolvulus arvensis* (15.69) and *Euphorbia helioscopia* (11.76) were the dominant species. In T_3, maximum RI value was recorded for *Euphorbia helioscopia* (25.90) followed by *Chenopodium album* (20.49), *Convolvulus arvensis* (17.83) and *Fumaria indica* (15.98). For T_4, *Convolvulus arvensis* was found to be the most dominant occurring species with RI value of 22.35 which was followed by *Chenopodium album, Fumaria indica* and *Asphodelus tenuifolius* with 20.24, 19.06 and 17.36 RI values, respectively.

Species vertical distribution

Data presented in the Table 12 showed that tillage affected vertical distribution of weed seed bank. In conventional tillage (T_1), the highest seed density (34016) was perceived in the upper most soil layer (0-10 cm), after that the seed density (25246) recorded at soil depth (11-20) and minimum (18676) in the deepest layer (21-30 cm). Proportion of total seed density among the soil layers i.e. upper (0-10 cm), middle (11-20 cm), and lower layer (21-30 cm) being 43.64%, 32.39%, and 23.96 %, respectively. In no till system (T_2), the vertical distribution of weed seeds showed that the highest weed seed density was recorded in the upper layer (44043), exceeding from the middle (18885) and deeper layer (9283). The distribution proportion of weed seeds in no till system was 60.99% in upper, 26.15% in middle, and 12.86 % in the deepest layer. Weed seeds in T_3 were observed as uniformly distributed among different soil layers showing 55.38%, 25.49 % and 19.12% weed seed in upper, middle and the deepest layer. The highest seed density (44495) in 0-10 cm soil layer and the lowest seed density (15366) was recorded in 21-30 cm soil layer. Maximum seed density of 38869 m^{-2} was examined in 0-10 cm depth, while minimum seed density was recorded in 21-30 cm soil layer with density of 16157 in T_4 tillage system. This system distributed 48.96 % weeds seeds in 0-10 cm, 30.69% in 11-20 cm and 20.35 % in 21-30 cm soil depths.

Table 2 Weed seed density (m^{-2}) under different sampling stages

Weed species	Sampling stages (at 0-10 cm depth)			Sampling stages (at 11-20 cm depth)			Sampling stages (at 21-30 cm depth)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Anagallis arvensis	704.44	850.28	540.56	545.83	451.94	275.56	120.28	124.17	121.67
Asphodelus tenuifolius	3230.6	3909.4	3215	2102.8	2086.7	1940.8	1244.4	1325.6	1433.5
Avena fatua	1026.4	718.6	273.1	434.17	279.17	117.78	209.44	328.61	118.36
Carthamus oxyacantha	420.83	84.44	544.17	122.5	43.33	372.5	194.72	0	253.36
Chenopodium album	16508	15255	19287	8482	9395	11213	5560.6	6257.2	7670.2
Convolvulus arvensis	3110	3030	2591.4	1893.1	1872.8	1654.7	723.33	941.39	968.47
Euphorbia dracunculoide	113.89	40.56	150.56	146.67	0	37.222	163.33	0	0
Euphorbia helioscopia	2801.7	2792.5	2595.6	1432.5	1469.4	1384.4	758.3	991.4	1121.1
Fumaria indica	7786.7	7039.4	8327.2	4456.7	5913.1	5615.8	2008.3	2977.8	3414.9
Melilotus indica	2939.2	2966.7	2862.8	1534.2	1691.9	1953.6	738.3	909.2	1069.7
Lathyrus aphaca	228.61	320.56	660.83	199.44	251.94	157.78	205.28	246.39	78.33
Vicia sativa	39261	37007	41048	82.778	120	0	151.11	39.17	0
Mean	**78131.37**	**74014.44**	**82096.22**	**21432.69**	**23575.28**	**24723.14**	**12077.39**	**14140.93**	**16249.59**

∴ S_1 = Pre-cultivation stage; S_2 = Pre-sowing stage; S_3 = Post-harvesting stage

Table 3 Weed seed density (m^{-2}) as affected by different tillage systems

Weed species	Tillage systems (at 0-10 cm depth)				Tillage systems (at 11-20 cm depth)				Tillage systems (at 21-30 cm depth)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
Anagallis arvensis	550.74	1500.7	742.22	0	484.44	455.56	757.78	0	55.926	214.44	217.78	0
Asphodelus tenuifolius	2275.2	4136.7	3621.1	3773.7	2263.3	1013.7	2516.3	2380.4	1047.4	1294.8	1570.7	1425
Avena fatua	0	923.33	573.7	1193.7	259.26	0	327.04	521.85	0	215.19	339.26	320.78
Carthamus oxyacantha	532.22	660	0	207.04	0	0	449.26	268.52	254.07	0	228.89	173
Chenopodium album	17763	18565	15847	15892	9189	8440	10493	10664	5552.6	5355.2	6745.6	8330.7
Convolvulus arvensis	1962.6	3341.9	3355.9	2981.5	2006.3	1397	1751.5	2072.6	492.2	966.7	842.6	1209.4
Euphorbia dracunculoide	98.89	56.3	95.56	155.93	97.778	49.63	0	97.778	0	50.37	117.04	45.333
Euphorbia helioscopia	2039.3	3079.6	2997	2803.7	1371.5	1148.5	1539.6	1655.6	522.2	951.9	1061.5	1292.2
Fumaria indica	7782.6	8760.7	7713.3	6614.4	4884.1	4286.3	5695.9	6447.8	2128.9	2801.9	3109.6	0
Melilotus indica	2360	2973.3	3115.6	3042.6	1734.8	1249.3	1718.9	2203.3	505.6	807.4	1015.9	1294
Lathyrus aphaca	451.48	385.19	776.67	0	378.89	205.19	228.15	0	117.04	472.59	117.04	0
Vicia sativa	0	0	0	209.3	215.19	0	0	55.185	0	152.96	0	90.667
Mean	**35816**	**44382.7**	**38838.1**	**36873.8**	**22884.6**	**18245.2**	**25477.4**	**26367**	**10675.9**	**13283.45**	**15365.9**	**14181.1**

∴ T_1 = Conventional tillage system (Farmer's Practice); T_2 = Zero tillage; T_3 = Disc harrowing + Glyphosate + Direct seeding; T_4 = Chiseling + Glyphosate + Direct seeding

Table 4 Species absolute frequency under different sampling stages

Weed species	Sampling stages (at 0-10 cm depth)			Sampling stages (at 11-20 cm depth)			Sampling stages (at 21-30 cm depth)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Anagallis arvensis	0.33	0.5	0.14	0.25	0.25	0.47	0.06	0.00	0.06
Asphodelus tenuifolius	0.7	0.89	0.89	0.86	0.5	0.42	0.39	0.28	0.44
Avena fatua	0.36	0.47	0.28	0.00	0.03	0.00	0.00	0.03	0.00
Carthamus oxyacantha	0.28	0.22	0.06	0.00	0.03	0.08	0.00	0.00	0.00
Chenopodium album	1.0	1.0	1.0	1.00	1.00	0.97	0.64	0.58	0.63
Convolvulus arvensis	0.7	0.81	0.81	0.56	0.5	0.44	0.42	0.42	0.27
Euphorbia dracunculoide	0.17	0.00	0.3	0.00	0.14	0.00	0.00	0.00	0.00
Euphorbia helioscopia	0.67	0.75	0.78	0.19	0.42	0.39	0.31	0.00	0.27
Fumaria indica	0.78	0.81	0.89	0.69	0.97	0.94	0.39	0.47	0.51
Melilotus indica	0.61	0.67	0.69	0.5	0.33	0.58	0.31	0.33	0.00
Lathyrus aphaca	0.22	0.08	0.47	0.14	0.03	0.06	0.11	0.00	0.05
Vicia sativa	0.11	0.08	0.17	0.11	0.06	0.00	0.00	0.00	0.00

∴ S_1 = Pre-cultivation stage; S_2 = Pre-sowing stage; S_3 = Post-harvesting stage

Table 5 Species absolute frequency as affected by different tillage systems

Weed species	Tillage systems (at 0-10 cm depth)				Tillage systems (at 11-20 cm depth)				Tillage systems (at 21-30 cm depth)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
Anagallis arvensis	0.41	0.3	0.26	0.33	0.41	0.33	0.19	0.37	0.04	0.07	0.00	0.04
Asphodelus tenuifolius	0.89	0.85	0.7	0.85	0.74	0.59	0.59	0.44	0.37	0.41	0.3	0.4
Avena fatua	0.52	0.33	0.33	0.3	0.00	0.04	0.00	0.00	0.00	0.00	0.04	0.00
Carthamus oxyacantha	0.15	0.19	0.19	0.22	0.00	0.04	0.00	0.11	0.00	0.00	0.00	0.00
Chenopodium album	1.0	1.0	1.0	1.0	0.96	1.0	1.0	1.0	0.74	0.74	0.52	0.47
Convolvulus arvensis	0.7	0.78	0.7	0.89	0.67	0.48	0.48	0.37	0.33	0.26	0.44	0.43
Euphorbia dracunculoide	0.18	0.15	0.11	0.18	0.04	0.04	0.04	0.07	0.00	0.00	0.00	0.00
Euphorbia helioscopia	0.81	0.67	0.7	0.74	0.56	0.41	0.26	0.11	0.19	0.44	0.00	0.32
Fumaria indica	0.74	0.85	0.89	0.81	0.89	0.81	0.81	0.96	0.56	0.48	0.41	0.39
Melilotus indica	0.82	0.63	0.41	0.78	0.56	0.44	0.41	0.48	0.19	0.19	0.3	0.17
Lathyrus aphaca	0.3	0.41	0.15	0.18	0.11	0.04	0.04	0.11	0.04	0.07	0.00	0.1
Vicia sativa	0.07	0.22	0.04	0.15	0.07	0.07	0.07	0.00	0.00	0.00	0.00	0.00

∴ T_1 = Conventional tillage system (Farmer's Practice); T_2 = Zero tillage; T_3 = Disc harrowing + Glyphosate + Direct seeding; T_4 = Chiseling + Glyphosate + Direct seeding

Table 6 Species relative density (%) under different sampling stages

Weed species	Sampling stages (at 0-10 cm depth)			Sampling stages (at 11-20 cm depth)			Sampling stages (at 21-30 cm depth)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Anagallis arvensis	0.44	2.43	0.93	1.59	3.37	3.99	2.14	0.2	0.4
Asphodelus tenuifolius	5.98	9.13	8.22	19.81	4.91	5.5	10.57	17.76	20.33
Avena fatua	0.63	2.39	2.11	0.00	0.25	0.00	0.00	0.17	0.00
Carthamus oxyacantha	1.15	2.01	2.72	0.00	0.25	0.37	0.00	0.00	0.00
Chenopodium album	50.54	43.14	42.84	53.48	40.07	48.62	42.62	25.13	17.94
Convolvulus arvensis	4.51	6.57	7.09	6.09	3.44	4.22	16.81	19.03	20.87
Euphorbia dracunculoide	0.52	0.00	0.1	0.00	1.58	0.00	0.00	0.00	0.00
Euphorbia helioscopia	6.1	5.47	6.63	2.66	1.51	3.56	10.62	1.11	10.06
Fumaria indica	23.8	20.57	19.18	8.19	40.49	27.67	12.38	25.5	30.41
Melilotus indica	4.77	6.86	8.32	6.37	3.65	5.63	4.86	11.11	0.00
Lathyrus aphaca	1.12	1.44	1.85	0.96	0.21	0.44	0.00	0.00	0.00
Vicia sativa	0.45	0.00	0.00	0.85	0.29	0.00	0.00	0.00	0.00

∴ S_1 = Pre-cultivation stage; S_2 = Pre-sowing stage; S_3 = Post-harvesting stage

Table 7 Species relative density (%) as affected by different tillage systems

Weed species	Tillage systems (at 0-10 cm depth)				Tillage systems (at 11-20 cm depth)				Tillage systems (at 21-30 cm depth)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
Anagallis arvensis	0.68	0.97	1.41	2.0	3.04	4.08	1.39	3.43	1.92	1.2	0.00	0.53
Asphodelus tenuifolius	6.28	9.76	8.19	6.88	13.21	11.06	10.7	5.32	14.96	19.38	13.28	17.27
Avena fatua	2.14	1.92	1.57	1.2	0.00	0.33	0.00	0.00	0.00	0.00	0.23	0.00
Carthamus oxyacantha	2.51	3.42	0.6	1.32	0.00	0.33	0.00	0.49	0.00	0.00	0.00	0.00
Chenopodium album	48.7	38.33	45.19	49.8	47.45	53.52	41.78	46.82	36.96	27.69	24.16	25.46
Convolvulus arvensis	5.82	7.83	5.82	4.76	2.77	4.27	5.97	5.34	20.15	18.79	16.91	19.75
Euphorbia dracunculoide	0.00	0.45	0.26	0.13	0.48	0.33	0.19	1.11	0.00	0.00	0.00	0.00
Euphorbia helioscopia	5.11	4.93	7.65	6.57	4.93	3.02	1.31	1.05	1.87	2.91	22.52	1.74
Fumaria indica	19.84	21.78	22.42	20.71	22.59	17.25	30.71	31.24	20.76	26.95	19.44	23.9
Melilotus indica	7.03	8.19	6.27	5.11	4.36	4.56	7.28	4.65	3.39	3.08	3.47	11.35
Lathyrus aphaca	1.9	1.83	0.62	1.52	0.73	0.58	0.29	0.54	0.00	0.00	0.00	0.00
Vicia sativa	0.00	0.59	0.00	0.00	0.44	0.69	0.38	0.00	0.00	0.00	0.00	0.00

∴ T_1 = Conventional tillage system (Farmer's Practice); T_2 = Zero tillage; T_3 = Disc harrowing + Glyphosate + Direct seeding; T_4 = Chiseling + Glyphosate + Direct seeding

Table 8 Species relative frequency (%) under different sampling stages

Weed species	Sampling stages (at 0-10 cm depth)			Sampling stages (at 11-20 cm depth)			Sampling stages (at 21-30 cm depth)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Anagallis arvensis	1.58	6.13	1.82	5.46	6.14	11.08	2.57	0.00	1.39
Asphodelus tenuifolius	13.72	13.92	12.97	21.19	11.14	8.27	12.41	12.66	25.76
Avena fatua	1.59	6.31	5.2	0.00	0.49	0.00	0.00	0.97	0.00
Carthamus oxyacantha	2.57	4.81	6.26	0.00	0.49	1.51	0.00	0.00	0.00
Chenopodium album	18.97	14.88	14.53	27.22	25.05	23.63	22.66	21.47	20.93
Convolvulus arvensis	12.04	11.77	12.19	10.32	11.14	10.32	16.97	20.22	12.96
Euphorbia dracunculoide	1.22	0.00	0.38	0.00	3.34	0.00	0.00	0.00	0.00
Euphorbia helioscopia	12.98	11.55	13.07	3.32	9.23	8.4	18.95	15.34	22.57
Fumaria indica	22.16	14.88	15.32	16.12	24.35	22.46	14.35	15.68	16.39
Melilotus indica	9.56	11.95	13.28	10.53	6.98	13.19	12.09	13.66	0.00
Lathyrus aphaca	2.8	3.81	4.97	3.37	0.46	1.15	0.00	0.00	0.00
Vicia sativa	0.79	0.00	0.00	2.48	1.19	0.00	0.00	0.00	0.00

∴ S_1 = Pre-cultivation stage; S_2 = Pre-sowing stage; S_3 = Post-harvesting stage

Table 9 Species relative frequency (%) as affected by different tillage systems

Weed species	Tillage systems (at 0-10 cm depth)				Tillage systems (at 11-20 cm depth)				Tillage systems (at 21-30 cm depth)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
Anagallis arvensis	2.14	2.13	4.03	4.4	3.13	9.73	6.43	10.95	3.43	0.00	0.00	1.85
Asphodelus tenuifolius	13.59	13.58	13.83	13.15	22.42	14.04	10.3	7.37	12.87	10.17	26.75	17.99
Avena fatua	4.78	4.93	4.47	3.3	0.00	0.65	0.00	0.00	0.00	0.00	1.29	0.00
Carthamus oxyacantha	5.44	7.26	1.62	3.88	0.00	0.65	0.00	2.01	0.00	0.00	0.00	0.00
Chenopodium album	17.64	15.54	14.54	16.78	28.44	22.25	25.48	25.03	25.18	26.04	15.5	20.04
Convolvulus arvensis	11.58	13.27	11.02	11.14	7.93	14.04	9.46	10.93	12.28	22.83	16.94	14.81
Euphorbia dracunculoide	0.00	0.53	1.12	0.48	0.00	1.58	2.87	0.00	0.00	0.00	0.00	0.00
Euphorbia helioscopia	10.65	9.98	16.01	13.5	4.43	6.64	11.13	5.74	19.67	14.35	11.7	30.09
Fumaria indica	17.64	16.6	18.79	16.78	14.75	20.21	26.27	22.69	13.03	17.54	16.12	15.21
Melilotus indica	11.11	11.36	11.6	12.32	12.29	8.42	6.47	13.75	13.55	9.07	11.7	0.00
Lathyrus aphaca	5.44	3.78	1.96	4.27	3.31	1.79	0.00	1.53	0.00	0.00	0.00	0.00
Vicia sativa	0.00	1.06	0.00	0.00	3.3	0.00	1.59	0.00	0.00	0.00	0.00	0.00

∴ T_1 = Conventional tillage system (Farmer's Practice); T_2 = Zero tillage; T_3 = Disc harrowing + Glyphosate + Direct seeding; T_4 = Chiseling + Glyphosate + Direct seeding

Table 10 Species relative importance values (%) under different sampling stages

Weed species	Sampling stages (at 0-10 cm depth)			Sampling stages (at 11-20 cm depth)			Sampling stages (at 21-30 cm depth)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Anagallis arvensis	0.99	3.17	2.4	2.97	4.76	7.54	2.35	0.35	0.89
Asphodelus tenuifolius	10.04	11.44	9.84	21.33	8.03	0.88	11.49	14.88	23.04
Avena fatua	3.04	3.68	2.56	0.00	0.37	0.00	0.00	0.33	0.00
Carthamus oxyacantha	4.15	3.35	2.73	0.00	0.37	0.94	0.00	0.00	0.00
Chenopodium album	32.73	27.36	33.4	40.35	32.56	36.13	32.64	23.48	19.44
Convolvulus arvensis	8.33	10.16	8.01	9.07	7.29	7.27	16.89	20.79	16.91
Euphorbia dracunculoide	0.61	0.24	0.47	0.00	2.46	0.00	0.00	0.00	0.00
Euphorbia helioscopia	7.42	9.64	10.55	3.5	5.37	5.98	14.78	7.87	16.31
Fumaria indica	20.04	18.67	18.31	12.85	32.42	25.06	13.37	20.66	23.4
Melilotus indica	3.22	2.14	2.9	7.11	5.31	9.41	8.47	11.65	0.00
Lathyrus aphaca	8.57	10.15	8.83	1.48	0.34	0.8	0.00	0.00	0.00
Vicia sativa	0.86	0.00	0.00	1.34	0.74	0.00	0.00	0.00	0.00

∴ S_1 = Pre-cultivation stage; S_2 = Pre-sowing stage; S_3 = Post-harvesting stage

Table 11 Species relative importance values (%) as affected by different tillage systems

Weed species	Tillage systems (at 0-10 cm depth)				Tillage systems (at 11-20 cm depth)				Tillage systems (at 21-30 cm depth)			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
Anagallis arvensis	1.32	1.55	2.68	3.2	4.95	5.89	3.29	6.22	2.06	1.67	0.00	1.06
Asphodelus tenuifolius	9.74	11.46	10.54	10.01	14.27	13.19	13.5	7.35	18.4	16.91	13.22	17.36
Avena fatua	3.71	3.38	3.02	2.25	0.00	0.49	0.00	0.00	0.00	0.00	0.44	0.00
Carthamus oxyacantha	4.39	5.29	1.33	2.6	0.00	0.49	0.00	1.25	0.00	0.00	0.00	0.00
Chenopodium album	32.88	27.19	31.29	33.29	34.28	39.98	35.0	36.11	33.02	27.0	20.49	20.24
Convolvulus arvensis	8.51	10.27	8.6	7.95	7.71	7.82	7.88	8.1	16.93	15.69	17.83	22.35
Euphorbia dracunculoide	0.00	0.82	0.64	0.3	0.7	0.49	0.6	1.49	0.00	0.00	0.00	0.00
Euphorbia helioscopia	7.94	7.34	11.51	10.04	8.59	5.61	2.17	3.42	4.1	11.76	25.9	10.19
Fumaria indica	18.45	18.91	19.9	18.74	20.84	18.59	26.59	27.76	20.21	21.32	15.98	19.06
Melilotus indica	9.58	9.57	8.88	8.72	6.22	6.39	9.4	7.11	5.28	5.66	6.15	9.73
Lathyrus aphaca	3.48	3.08	1.56	2.9	1.42	0.29	0.57	1.2	0.00	0.00	0.00	0.00
Vicia sativa	0.00	1.15	0.00	0.00	1.02	0.77	0.98	0.00	0.00	0.00	0.00	0.00

∴ T_1 = Conventional tillage system (Farmer's Practice); T_2 = Zero tillage; T_3 = Disc harrowing + Glyphosate + Direct seeding; T_4 = Chiseling + Glyphosate + Direct seeding

Table 12 Vertical distribution under tillage systems at various soil depths

Sampling depths	Tillage systems			
	T_1	T_2	T_3	T_4
0-10 cm	34016 (43.64%)	44043 (60.99%)	44495 (55.38%)	38869 (48.96%)
11-20 cm	25246 (32.39%)	18885 (26.15%)	20477 (25.49%)	24367 (30.69%)
21-30 cm	18676 (23.96%)	9283 (12.86%)	15366 (19.12%)	16157 (20.35%)

∴ T_1 = Conventional tillage system (Farmer's Practice); T_2 = Zero tillage; T_3 = Disc harrowing + Glyphosate + Direct seeding; T_4 = Chiseling + Glyphosate + Direct seeding

Table 13 Temporal distribution under various tillage systems and sampling stages at different soil depths

0-10 cm				
	Tillage systems			
Sampling stages	T_1	T_2	T_3	T_4
Pre-cultivation (S_1)	35899	47430	36804	34847
Pre-sowing (S_2)	31771	44197	35278	33550
Post-harvesting (S_3)	39650	49251	41160	39430
11-20 cm				
	Tillage systems			
Sampling stages	T_1	T_2	T_3	T_4
Pre-cultivation (S_1)	16332	24998	20690	23712
Pre-sowing (S_2)	19503	17798	29707	27292
Post-harvesting (S_3)	18901	25859	26036	28098
21-30 cm				
	Tillage systems			
Sampling stages	T_1	T_2	T_3	T_4
Pre-cultivation (S_1)	9210	13102	13679	12319
Pre-sowing (S_2)	12620	10843	17063	21787
Post-harvesting (S_3)	10198	9904	15356	17920

∴ T_1 = Conventional tillage system (Farmer's Practice); T_2 = Zero tillage; T_3 = Disc harrowing + Glyphosate + Direct seeding; T_4 = Chiseling + Glyphosate + Direct seeding

Table 14 Cost of soil sampling and soil weed seed bank determination techniques

Particulars	Unit	Rate per unit (Rs.)	Rate for total samples (360 samples)	Cost (Rs.)
Soil weed seed bank sampling				
Sampling bags	1 Bag	Rs. 5/ bag	Rs. 1800/360 bags	1800
Labor	3 Persons per day	Rs. 400/person	Rs. 2400/6 person for 2 days	2400
Steel king tubes set	2 Tubes	Rs. 3000/tube	Rs. 6000/2 steel king tubes	6000
Wooden hammer	2 Hammers	Rs. 700	Rs. 1400/2 hammers	1400
Permanent marker	4 Markers	Rs. 30	Rs. 120/2 hammers	120
Clipboard	2 Clipboards	Rs. 50	Rs. 100/2 clipboards	100
Measuring tape	2 Measuring tapes	Rs. 30	Rs. 60/2 measuring tapes	60
Samples carrying bags	6 bags	Rs. 100	Rs. 600/6bags	600
Total sampling cost (Rs.)				12480
Sieves	6 Sieves	Rs. 800/sieve	Rs. 4800/6 sieves	4800
Petridishes	360 Petridishes	Rs. 30/petridish	Rs. 10800	10800
Sodium hexametaphosphate	1 kg	Rs. 800/kg	Rs. 800	800
Watering bottles	2 Bottles	Rs. 100/bottle	Rs. 200	200
Labor cost for sieving	1 Person/day	Rs. 400/person/day	Rs. 4800	4800

Species temporal distribution

The data presented in Table 13 showed that the temporal distribution of weed seed bank was affected by different tillage systems. The maximum seed density was noticed at post-harvest stage (S_3) followed by pre- cultivation (S_1) and pre-sowing (S_2). In first tillage system (0-10 cm soil depth), conventional tillage (T_1) and at post harvesting stage (S_3), the maximum seed density m^{-2} (39650) was recorded, while the lowest seed density m^{-2} (31771) was recorded at pre-sowing stage in upper soil layer (0-10 cm). The same trend was recorded in zero tillage (T_2) i.e. the maximum seed density m^{-2} (49251) was recorded at stage S_3 and in T_2. In tillage system T_3, the maximum seed density m^{-2} (41160) was noticed at stage S_3 followed by S_1 (36804) and S_2 (35278). In tillage system T_4, the highest density m^{-2} (39430) was recorded at S_3 followed by S_1 and S_2 with 34847 and 33550 densities, respectively. The temporal distribution of seed at middle soil layer (11-20 cm) presented in Table 13 showed that tillage differed the seed density m^{-2} at different sampling stages. In tillage system T_1, the maximum seed density (19503) was recorded at S_2 followed by S_3 (18901) and S_1 (16332), respectively. In tillage system T_2, the maximum seed density m^{-2} (25859) was recorded at S_3 and the least seed density m^{-2} (17798) was recorded at S_2. In tillage system T_3, the temporal distribution of seed density was recorded in different trend i.e. S_2, S_3 and S_1 with the value of 29707, 26036 and 20690, respectively. In tillage system T_4, the maximum seed density m^{-2} (28098) was recorded at S_3, followed S_2 (27292), while the lowest seed density value (23712) was recorded at S_1. The data given in Table 13 in deeper soil layer (21-30 cm) indicated that different tillage system has influence on the temporal distribution of weed seeds. In tillage system T_1, the maximum seed density was recorded at stage S_2 (12620) followed by stage S_3 (10198), and the least density was recorded at stage S_1 (9210). In tillage system T_2, the seed densities recorded at stages S_1, S_2 and S_3 were 13102, 10843 and 9904, respectively. In T_3, maximum seed density was recorded at pre-sowing stage (17063) followed by density recorded at stage S_3 (15356), and the minimum density was recorded at S_1 (13679). In tillage system T_4, the temporal seed distribution trend was similar as T_1 i.e. S_2, S_3 and S_1 with values 21787, 17920 and 12319, respectively.

Cost comparison of weed seed bank extraction techniques

The data regarding economic analysis of both soil weed seed bank extraction techniques are presented in Table 14. The total cost for each method was calculated including soil sampling cost, equipments cost for each method and labor cost. An amount of Rs. 26,480 was spent in case of sieving method for extraction of weeds seeds from 360 soil samples. These results showed that sieving method is more cost effective.

DISCUSSION

One of the dominant yield limiting factors in barani areas of Pakistan is weed management. Weeds infestation to the domesticated crops severely affects the crop productivity due to traditional cultural practices and mono cropping systems. Weeds have immense power to prevalence their seeds which ultimately form the weed seed bank above and under the soil surface and reduce the wheat yield substantially. The present study was carried out at PMAS, Arid Agriculture University Research Farm, Chakwal Road, Rawalpindi, Pakistan to investigate the effect of different tillage systems on soil weed seed bank in order to manage weeds issues which have greater impact in limiting wheat yield under rainfed conditions of Potohar, Pakistan.

A similar type study was carried out in the Midwest USA and the mean objective of the study was to assed emergence pattern and to evaluate the use of primary tillage and chemical weed control can affect the seeds buried in the different layers of the soil, weed flora density in weeds control practices (Forcella, 1992). Mansor et al. (2012) carried out an experiment at the rice fields of Muda area of Peninsular Malaysia during four consecutive seasons from February 2004 to September 2006 to study the size and weed species of soil seed bank. Species composition with their dominance ranking and similarity between the species was recorded. Eight weed species namely *Fimbristylis miliacea, Ludwigia hyssopifolia, Oryza sativa* complex (weedy rice), *Scirpus grossus, Echinochloa crusgalli, Sagittaria guyanensis, Scirpus juncoides* and *Ischaemum rugosum* were found to emerge from the seed bank. The species *F. miliacea, L. Hyssopifolia* and *O. sativa* contributed more than 80% of the total weed population.

Consistent to our findings, Juroszek and Gehards (2004) performed an experiment and reported that tillage operation at night time has more efficiency than that of day time practices, by this 80% weed seeds emerged and 97.5% weed cover reduced, this range largely influenced by the type of implement used, type of tillage operation, the soil water content, dormancy pattern of weed seeds and by the light sensitivity of weeds. To determine the population of weeds and also for establishing weed control programmed the knowledge of weed seed bank in the soil has a prime importance. Seed bank and above ground levels both affected the composition of weed seeds and their density. An experiment was conducted on weed seed bank response to soil depth, tillage and weed management in the mid hill ecology and they concluded that the agronomic practices such as management of weed, nutrients, tillage and crop rotation are the major phenomenon which influences the soil weed seed bank (Ranjit et al., 2007). An experiment was designed by Kashe et al. (2010) at research station of University of New England in Armidale, Australia. No tillage, chisel plough and mouldboard plough were used as tillage treatments. Tillage had significant effect on both weed seed bank and seedling emergence. Chisel plough and mouldboard plough resulted in maximum seedling emergence; whereas, less seed were emerged under no till system.

During our study it was found that tillage systems more influenced the soil weed seed bank at different soil depths. These results also correlated with the studies conducted by Zanin et al. (1997) who showed that different tillage systems greatly affect the soil weed seed bank. During year 1997-98, the response of weed seed banks of five weed species to tillage and crop rotations were studied in semi-arid area of northern Jordan. Tillage practices of mouldboard- chisel-plowing and cropping patterns of barley (*Hordeum vulgare*) planting - fallow were evaluated on permanently established subplots. Soil samples were collected from the upper 10 cm for three consecutive years. Soil seed banks of the five dominant weed species i.e. *Anthemis palestina*, *Diplotaxis erucoides*, *Hordeum marinum*, *Rhagadiolus stellatus,* and *Trigonella caelesyriaca* were estimated using greenhouse and laboratory procedures. At initiation, more viable seeds were present in soil subjected to mouldboard plowing than chisels plowing. In the following two sampling seasons, significant rotation by tillage interaction affected the seedbank of each species. Generally, mouldboard plowing increased weed seedbanks when combined with frequent fallowing. Conversely, chisel plowing combined with barley cropping generally reduced weed seedbank sizes. Results emphasized the importance of managing weeds during fallow to avoid the buildup of *H. marinum*, a serious grass weed in semi-arid environments (Ghosheh & Hajaj, 2004).

During the present study, it was confirmed that the highest density of weeds were noticed during zero tillage. These results are in accordance with the findings of Cardina et al. (2002) who reported that maximum density was observed in no till system as compared to tilled system. More weed seeds in upper layer may be due to the fact that seeds of different weeds species may take time to infiltrate in the lower soil depths. These results are in agreement with findings of Gulshan et al. (2013) who observed maximum density at upper layer compared to the deeper layers. The species which were more commonly observed in the soil weed seed bank such as *Chenopodium album*, *Convolvulus arvensis, Fumaria indica, Asphodellis tenuifolius, Melilotus indica, Euphorbia helioscopia*, *Anagallis arvensis,* and *Lathyrus aphaca,* these species also noticed more repeatedly above ground flora at study research farm. The results obtained during study are correlated with the results of Qureshi et al. (2011) who stated that these species were present in large amount at the study area (University Research Farm, Chakwal Road, Rawalpindi). It was also observed that species relative density of weed seed bank was influenced by tillage systems. These results are in agreement with the findings of Javadzadeh and Fallah (2011), who reported the highest relatively density of *Chenopodium album* as an above ground flora in the wheat field which ultimately produced relatively more number of weed seeds than other weed species.

In a previous research study, Conn (2006) evaluated the effect of different tillage systems on weed seed bank during year 1985 at Alaska. Tillage treatments included no-till, disked once, disked twice, and chisels plough. Results showed significant relationship between weed seed bank and tillage. Weed seeds were maximum at top surface of soil as compared to sub surface. Maximum weed diversity was observed under no till system, followed by chisel plough treatment. Minimum weed seeds were found in disked twice treatment. Hossain and Begum (2015) studied on weed seed bank dynamics and composition and showed that the weed situation in a specific area determined by amount of weed seeds in soil seed bank and also by the quality of those seeds, Seed bank serve as the reservoir of alive weed seeds which are present on the surface of soil and as well as in the soil profiles. Weed seed bank can also be considered as a place where seeds of weeds remain buried before their germination; actually the soil weed seed bank is the single source for the further propagation of weeds.

Our findings are supported by the earlier research report by Swanton et al. (2012) who reported that the tillage type, its depth and type of the soil affects the vertically distribution of soil weed seed bank, they also observed that the different types of tillage operations changes the size of weed seed bank in no till systems, mostly weeds emerge from the weed seed bank present near to the soil surface and the higher proportion of seeds bank located in the more deeper layers of the soil. Bhatt and Singh (2007) conducted a study in upland and low land paddy cultivation areas of western Nepal. The soil samples from the upland and lowland sites were collected with the 8 cm diameter and 10 cm depth. Germination method was followed to estimate seed bank, 46 weed species, with 18 families and 34 genera, in upland site and 43 weed species, belonging to 32 genera and 17 families, were observed. Menallad (2008) reported that weeds seed dispersed in the soil profile by the movement of seeds on soil surface horizontally. Many factors are responsible for the horizontally distribution of soil weed seed bank like direction of crop rows and types of tillage practices determine the distribution of soil weed seed bank.

CONCLUSION

During this study the comparative analysis of sampling stages revealed higher weed seeds density, weed frequency with more diversity of weed species at post-harvest stage in comparison to other two stages i.e. pre-cultivation and pre-sowing stages. The research study also revealed little difference in various weed parameters including seed density m^{-2}, frequency, relative density, relative frequency, relative importance value, dominance and diversity in soil weed seed bank in different soil layers under conventional tillage, zero tillage, disk harrowing and chisel ploughing tillage systems. Generally, weed seed density was found maximum in zero tillage systems. The vertical distribution of weed seeds was such that maximum weeds seeds were observed in at upper soil layer (0-10 cm), with minimum weed seed number in the lower soil layer (21-30 cm). The prevalence of higher weed seed density under zero tillage systems and in upper soil layers implicates that efficient weed control strategies need to be devised under zero tillage to promote adoption of the resource conservation technology in drought hit areas of Pothwar.

Author Contribution Statement: Safdar Ali generated the idea, supervised the research. Tauqir Ahmad conducted the research project. Adnan Noor Shah wrote and edited the manuscript. All the authors read and approved the manuscript to be published.

Conflict of Interest: The authors declare that they have no conflict of interest.

Acknowledgements: The authors are thankful to the department of Agronomy, PMAS, Arid Agriculture University, Rawalpindi for providing platform for this research.

REFERENCES

Adnan, S., Ahmood R. M., & Khan, A. H. (2009). Water balance conditions in rainfed areas of Potohar and Balochistan plateau during 1931-08. *World Applied Sciences Journal*, *7*(2), 162-169.

Agency for Barani Areas Development [ABAD]. (1996). Punjab barani tract in figure. Agency for Barani Areas Development (ABAD), Planning & Development Department, Government of Punjab, Rawalpindi, Pakistan.

Ahmad, R., & Sheikh, A. S. (2003). Common weeds of wheat and their control. *Pakistan Journal of Water Resources*, *7*(1), 71-73.

Ahmad, M., Hassan, F. U., Aslam, M., & Aslam, M. A. (2012). Physiological attributes based resilience of wheat to climate change. *International Journal of Agriculture and Biology*, *14*, 407–412.

Ashraf, M., Kahlown, M. A., & Ashfaq, A. (2007). Impact of small dams on agriculture and groundwater development: a case study from Pakistan. *Agricultural Water Management*, *92*(1-2), 90-98.

Aykas, E., Cakir, E., & Gulsolu, E. (2004). The effects of tillage parameters on the performance of the heavy duty offset disk harrow. *Asian Journal of Plant Sciences*, *3*(4), 425-428.

Belz, R.G. (2007). Allelopathy in crop/weed interactions–an update. *Pest Management Science*, *63*, 308-326.

Bhatt, M. D., & Singh, S. P. (2007). Soil seed bank dynamics of weed flora in upland and lowland paddy cultivation areas of Far Western Nepal. *Scientific World*, *5*(5), 54-59.

Cardina, J., Herms, C. P., & Doohan, D. J. (2002). Crop rotation and tillage system effects on weed seedbanks. *Weed Science*, *50*, 448–460.

Chauhan, B. S., Gill, G. S., & Preston, C. (2006). Seedling recruitment pattern and depth of recruitment of 10 weed species in minimum tillage and no-till seeding systems. *Weed Science*, *54*, 658-668.

Chauhan, B. S., & Johnson, D. E. (2009). Influence of tillage systems on weed seedling emergence pattern in rainfed rice. *Soil & Tillage Research*, *106*, 15-21.

Conn, J. S. (2006). Weed seed bank affected by tillage intensity for barley in Alaska. *Soil & Tillage Research*, *90*, 156–161.

David, A. L., Edward, H., Donald, C., & Reicosky. (2006). Importance of information on tillage practices in the modeling of environmental processes and in the use of environmental indicators. *Journal of Environmental Management*, *82*, 377-387.

Dhawan, R. S., Singh, R., Punia, S. S., Dhawan, A. K., & Dudeja, S. S. (2008). Molecular diversity of little seed canary grass (*Phalaris minor* Retz.) populations from wheat growing belts of India. *Indian Journal of Weed Science*, *40*(3-4), 101-108.

Forcella, F. (1992). Prediction of weed seedling densities from buried seed reserves. *Weed Research*, *32*, 29-38.

Forcella, F., Webster, T., & Cardina, J. (2004). Protocols for the determination of weed seed banks in agrosystems. In R. Labrada (Ed.), *Weed Management for Developing Countries* (pp. 3-22). Roma, Italia: Addendum 1, FAO.
Ghosheh, H. Z., & Al-Hajaj, N. A. (2004). Impact of soil tillage and crop rotation on barley (*Hordeum valgare*) and weeds in a semi-arid environment. *Journal of Agronomy and Crop Science*, *190*, 374-381.
Government of Pakistan [GOP]. (2011). Economic Survey Government of Pakistan 2010-2011. Finance Division, Economic Advisory Wing, Islamabad, Pakistan.
Grundy, A. C., Mead, A., & Burston, S. (2003). Modelling the emergence response of weed seeds to burial depth: Interactions with seed density, weight and shape. *Journal of Applied Ecology*, *40*, 757–770.
Gulshan, A. B., Dasti, A. A., Mahmood, S., Hussain, S., & Atta, I. (2013). Role of soil seed bank in pattern of species distribution along the aridity gradient by using the technique of multivariate analysis. *ARPN Journal of Agricultural and Biological Science*, *8*(1), 13-23.
Hayat, R., & Ali, S. (2010). Contribution of water use efficiency of summer legumes for the production of rainfed wheat. *International Journal of Agriculture and Biology*, *12*, 655–660.
Hossain, M. M., & Begum, M. (2015). Soil weed seed bank: Importance and management for sustainable crop production- A review. *Journal of the Bangladesh Agricultural University*, *13*(2), 221–228.
Hyvonen, T., & Salonen, J. (2002). Weed species diversity and community composition in cropping practices at two intensity levels-a six-year experiment. *Plant Ecology*, *159*, 73-81.
Javadzadeh, S. M., & Fallah, S. R. (2011). Spatial and density of weeds and appointment important and dominant species in Ghayenat region (Iran). *International Journal of Agriculture: Research and Review*, *1*(3), 97-102.
Juroszek, P., & Gerhards, R. (2004). Photocontrol of weeds. *Journal of Agro Crop Science*, *190*, 402-415.
Kadioglue, I., Yanar, Y., & Asav, U. (2005). Allelopathic effects of weed leachates against seed germination of some plants. *Journal of Environmental Biology*, *26*, 169-173.
Kashe, K., Sindel, B., Kristiansen, P., & Jessop, R. (2010). Effect of tillage on weed seed bank and weed flora in maize (*Zea mays*). *Seventeenth Australasian Weeds Conference*, 67-70.
Khan, I., Jan, A. U., Gull, F., Ali, K., Ali, G., Ahmed, S., & Ahmad, N. (2011). Weeds as a major constraint in wheat production in district Peshawar. *Pakistan Journal of Weed Science Research*, *17*(4), 381-386.
Khan, M. Z., Haq, Z. U., Khan, N. U., Pervez, U., & Khan. M. A. (2011). Training needs of Agricultural extension agents in Khyber Pakhtunkhwa. *Sarhad Journal of Agriculture*, *27*(1), 133-137.
Khan, R., Khan, M. A., Waqas, M., Haroon, M., Hussain, Z., Khan, N., Ullah, I., Ramzan, M., & Bashir, S. (2012). Bioherbicidal activity of some winter weeds against some crops. *Pakistan Journal of Weed Science Research*, *18*(4), 561-569.
Konstantinovic, B., Meseldzija, M., Korac, M., & Konstantinovic, B. (2011). Study of weed seedbank in soybean crop. *African Journal of Agricultural Research*, *6*(10), 2316-2320.
Lehoczky, E., & Reisinger, P. (2003). Study on the weed-crop competition for nutrients in maize. *Communications in Agricultural and Applied Biological Sciences*, *68*(4), 373-380.
Lutman, P. J. W., Cussans, G. W., Wright, K. J., Wilson, B. J., Wright, G. Mc. N., & Lawson, H. M. (2002). The persistence of seeds of 16 weed species over six years in two arable fields. *Weed Research*, *42*, 231–241.
Mansor, M., Karim, S. M. R., & Hamid, Z. A. A. (2012). Seasonal variation in weed seed bank in the rice field soils of Muda area, Peninsular Malaysia. *World Applied Sciences Journal*, *20*(8), 1086-1091.
Menalled, F. (2008). *Weed seedbank dynamics & integrated management of agricultural weeds*. Retrieved from http://www.msuextension.org/publications/AgandNaturalResources/MT200808AG.pdf) (verified 11 March 2010).
Menalled, F., Gross, K., & Hammond, M. (2001). Weed above ground and seed bank community responses to agricultural management systems. *Ecological Applications*, *11*, 1586-2160.
Naz, N., Hameed, M., Ahmad, M. S. A., Ashraf, M., & Arshad, M. (2010). Is soil salinity one of the major determinants of community structure under arid environments? *Community Ecology*, *11*(1), 84-90.
Qureshi, R., Bhatti, G. R., & Shabbir, G. (2011). Floristic inventory of Pir Mehr Ali Shah Arid Agriculture University Research Farm at Koont and its surrounding areas. *Pakistan Journal of Botany*, *43*(3), 1679-1684.
Ranjit, J. D., Suwanketnikom, R., Chinawong, S., Suprakarn, S., Sooksathan, I., & Juntakool, S. (2007). Weed seed bank response to soil depth, Tillage and Weed Management in the Mid Hill Ecology. *Journal of Natural Sciences*, *41*, 17-33.
Razzaq, A., Munir, M., Hashmi, N. I., Hobbs, P. R., & Majid, A. (2002). Current management practices for wheat production in a rainfed agro-ecological zone in northern Punjab. *Pakistan Journal of Agricultural Research*, *17*(3), 201-205.
Reuss, S. A., Buhler, D. D., & Gunsolus, J. L. (2001). Effects of soil depth and aggregate size on weed seed distribution and viability in a silt loam soil. *Applied Soil Ecology*, *16*, 209–217.

Sago, R. (2000). Weed seed bank response to herbicide use in rice paddy fields. *Journal of Weed Science and Technology*, *45*, 88-95.

Saini, M., Price, A., & Santen, E. V. (2006). Cover crop residue effects on early-season weed establishment in a conservation-tillage corn-cotton rotation. *Southern Conservation Systems Conference*, *Amarillo TX*, *June 26-28*, 175-181.

Swanton, C. J., Shrestha, A., Knezevic, S. Z., Roy, R. C., & Coelho, B. R. (2012). Influence of tillage type on vertical weed seed bank distribution in a sandy soil. *Canadian Journal of Plant Science*, *80*, 455-457.

Torrensen, K. S., & Skuterud, R. (2002). Plant protection in spring cereal production with reduced tillage. IV. Changes in weed flora and weed seed bank. *Crop Protection*, *21*, 179–193.

Vanasse, A. & Leroux, G. D. (2000). Floristic diversity, size and vertical distribution of the weed seed bank in ridge and conventional tillage systems. *Weed Science*, *48*, 548-560.

Vasileiadis, V. P., Froud-Williams, R. J., & Eleftherohorinos, I. G. (2007). Vertical distribution, size and composition of the weed seed bank under various tillage and herbicide treatments in a sequence of industrial crops. *Weed Research*, *47*, 222-230.

Weston, L. A., & Duke, S. O. (2003). Weed and crop allelopathy. *Critical Reviews in Plant Sciences*, *22*, 367-389.

Wijdeven, S. M. J., & Kuzee, M. E. (2000). Seed availability as a 1imiting factor in forest recovery processes in Costa Rica. *Restoration Ecology*, *8*, 414-424.

Zanin, G. (1997). Ecological interpretation of weed flora dynamics under different tillage systems. *Agriculture, Ecosystems & Environment*, *66*, 177-188.