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Original Article: Soil weed seedbank response to tillage types and crop residue mulches in different cropping patterns

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ABSTRACT

The composition of weed species and the distribution of weed seeds in the soil profile vary significantly and closely correlated to the previous cropping system. Information on the effect of tillage types, crop residue mulching and crop rotation on the soil weed seedbank is a useful tool for sustainable weed management in conservation agriculture (CA). With the view to studying the trend of weed seedbank in CA, a net-house experiment was conducted at the Department of Agronomy, Bangladesh Agricultural University during January - December, 2016. Soil samplings were done at 0 - 15 cm depth from four different sites after the end of CA trials at Mymensingh and Baliaknadi during 2012 - 2015 and Durgapur and Godagari in 2010-2015, in Bangladesh. At Mymensingh, conventional tillage (CT) and strip tillage (ST), while at Durgapur and Godagari, additional bed planting (BP) were practiced. On the other hand, at Baliakandi additional Zero tillage (ZT) was included. At all sites 20% and 40 - 50% of standing mulches of previous crops were applied. A total of 290 samples replicated four times were placed in individual trays following a completely randomized design. The year-round headcount of emerged weed revealed that the smallest size of weed seedbank in terms of weed species composition and weed density was found in ST followed by CT, BP, and ZT with 40 - 50% crop mulch than 20% mulch. The ST, BP, and ZT produced a higher number of perennials weeds than annual weeds, but opposite in CT. Based on the results, it could be concluded that the continuous practice of ST with 40 - 50% residue mulch declined the size of weed seedbank with the proliferation of perennial weeds. Weed seedbank size in ST is even smaller than BP and ZT.

Introduction

Conservation agriculture (CA) is the practice of any tillage sequence that minimizes soil disturbances with at least 30% soil cover by crop residue mulches utilizing the intensive crop rotation involving at least three different crops as defined by the United Nations' Food and Agriculture Organization (Kassam et al. 2019). CA is being promoted globally for improving soil health; sustainably increase the overall economic productivity of mechanized agriculture (Sanyal et al. 2008). In addition to agronomic benefits, CA also has a major influence on the relative abundance of weed species (Fonteyne et al. 2020), and weed control is perceived as one of the most challenging issues due to a reduction in tillage operations. The composition and dynamics of weeds in the soil weed seedbank under minimum tillage was found to be changed compared to conventional tillage (Pittelkow et al. 2015). Literatures reported that minimum tillage favors the infestation of perennial weeds like *Cyperus rotundus* L., *Saccharum spontaneum* L., *Sorghum halepense* L. than annual weeds, which are generally reproduced from tubers and rhizomes and have not buried them or by failed to uproot and killed them as by conventional tillage. According to Woźniak (2018), populations of annual grass increase in no-tillage systems concurrent with a decrease in populations of dicotyledonous weeds. Again, Fonteyne et al. (2020) observed annual and perennial grasses, and perennial dicot species would increase, and annual dicot species would decrease in reduced tillage. Moreover, Moonen and Barberi (2004) recorded fivefold higher seedbank density in reduced tillage systems compared to full tillage systems. Barberi and Lo Cascio (2001) discovered *Amaranthus* spp. seedling density was much higher in no-till environments than tilled environments.

Despite the widespread promotion, in Bangladesh the practice of CA began in 2005 (Hossain et al. 2015) to validate its' principles for small farm hold. But adequate information on weed species composition in the soil seedbank under CA is not available which is expected to be a problem after several years. Reduced tillage practice with the residue mulching of previous crops in different cropping patterns changes weed seed density in the soil by affecting the soil weed seedbank and the efficacy of weed control practices. Such knowledge on the soil weed seedbank might be a useful tool for sustainable weed management in CA. Hence, this study was undertaken to assess the trend the soil weed seedbank in 3-5 years long trials of CA in Bangladesh context. By necessity, it was hoped that understanding gained about weed seedbanks could be used to fill the gaps in weed seedbank information and the best managing of weeds to trigger the widespread adoption of CA.

Materials and Methods

Experimental site

The net-house experiment was conducted at the Department of Agronomy, Bangladesh Agricultural University (BAU), located geographically at 24.75° N and 90.50° E at an average altitude of 18 m above the mean sea level.

Edaphic and climatic environments

The experiment field was located at a flood-free medium-high land on the Old Brahmaputra Floodplain of predominantly dark grey non-calcareous alluvium soils under the *Sonatala* series (Brammer, 1996). The pH of sandy clay loam (50% sand, 23% silt, and 27% clay) soil was 7.2. The research site was characterized by high temperature, high humidity, and heavy monsoon rainfall with occasional gusty wind during April-September and low precipitation with moderately low temperature during October - March (Figure 1). The maximum temperature varies from 32.3 - 33.5℃ during April - June while January was the coldest month. About 95% rainfall and relative humidity was received during April - September. The rest of rainfall was very unevenly distributed and mostly uncertain. Sunshine hours differed much in during the months of rainfall due the cloudy weather.

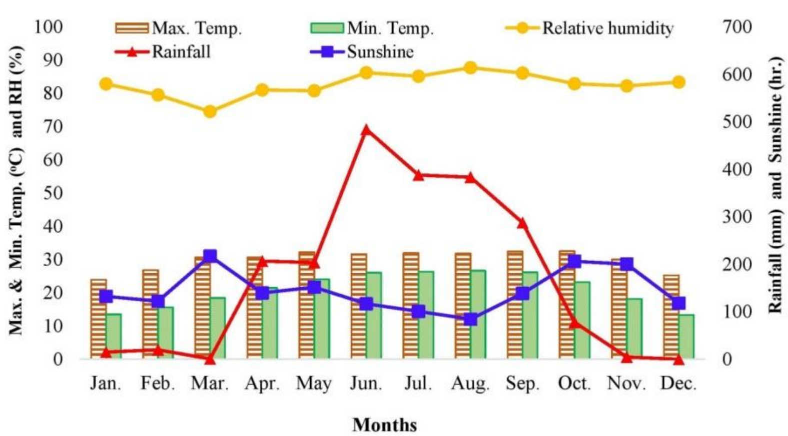

Figure 1. Monthly temperature and rainfall distribution pattern in 2016.

Sites of long-term CA trials

CA trials were conducted at four locations. At Mymensingh, trials were conducted at the Soil Science Field Laboratory of the BAU campus at Sadar sub-district of Mymensingh district. In this site, six experiments on CA trials under T. aman rice-wheat-mungbean cropping pattern was studied during 2012 - 2015. Durgapur and Godagari sub-districts situated under the Rajshahi district, geographically at 24°22′ N and 88°36′ E in 2010 - 2015. There were, 12 trials following T. aman rice-mustard-Boro rice, T. aman rice-mungbean-lentil, and lentil-jute-T. aman rice patterns at Durgapur while T. aman rice-wheat-mungbean, T. aman rice-wheat-jute, and T. aman rice-chickpea-jute cropping patterns. Baliakandi (at 23°39'45" N and 89°29'39" E) sub-district was located at the Rajbari district where, CA trials conducted during 2012 - 2015. At this site, six trials were performed under T. aman rice-wheat-jute system. The treatments imposed in these four locations have been presented in Table 1.

Table 1. Treatments details at four locations of long-term CA trial.

Locations	Treatments		No. of replication
	Tillage types	Residue mulching (%)	
Mymensingh	i. Conventional tillage (CT) ii. Strip tillage (ST)	i. 20 ii. 40	3
Durgapur and Godagari	i. CT ii. ST iii. Bed planting (BP)	i. 20 ii. 50	4
Baliakandi	i. CT ii. ST iii. BP iv. Zero tillage (ZT)	i. 20 ii. 50	4

Weed control strategies of long-term CA trials

In CT, weeds were controlled by hand weeding in all crops. In ST, BP, and ZT weeds were controlled using different herbicides for different crops, as stated in Table 2. Similar herbicides were used at all locations.

Table 2. Weeding regimes of long-term CA trials at four locations.

Tillage types	Weeding regimes in different crops*
CT	▪ Three hand weeding (HW) at 25, 45 and 65 DAT/S in rice and wheat. ▪ Two HW at 25 and 45 DAS in mustard, jute, mungbean, lentil, chickpea.
ST BP ZT	▪ Glyphosate @ 3.7 L at 3 DBT for all crops. ▪ Pendimethalin at @ 2.7 L 3 DAT/S in rice and wheat while at IAS in mustard, jute, lentil, mungbean, and chickpea. ▪ Isoproturon @ 2.5 L at 15 DAS in mustard. ▪ Ethoxysulfuron-ethyl @ 100 g at 25 DAT in rice. ▪ Carfentrazon-ethyl + isoproturon @ 1.25 kg at 25 DAS in wheat. ▪ Fenoxaprop-p-ethyl @ 650 ml at 25 DAS in jute, mungbean, lentil, chickpea.

CT= Conventional tillage, ST= Strip tillage, BP= Bed planting, ZT= Zero tillage, DAT= Days after transplanting, DAS= Days after sowing, @= at the rate of, DBT= Days before tillage, IAS= Immediately after sowing, *Dose of product ha^{-1}.

Tillage practices followed in long-term CA trials

The CT was done by a two-wheel tractor (2WT) by four plowings and cross plowing followed by sun-drying for two days (in non-rice crops), finally by inundation and laddering (in rice). The ST was done by a versatile multi-crop planter (VMP) in a single pass operation. Strips were prepared for four rows, each of six cm wide and five cm deep made at a time. In BP, raised beds (15 cm high and 90 cm wide with 60 cm tops and 30 cm furrows) were made with a bed planting machine. In ZT, the land remained untilled. Initially, at Mymensingh, the effect of ST was tested at limited areas university field laboratory.

With the view to achieving more justified results, additionally, BP was included in the farmer's field of Durgapur and Godagari. In contrast, ZT was included along with these three tillage types at Baliakandi. That is why tillage types were not uniform across the experimental sites.

Crop residue mulching in the long-term CA trials

Two levels of crop residue mulching (height basis) were used across the experimental sites. There were 20% mulch in all locations, while 40% mulch in Mymensingh and 50% mulch in other areas. In ST operation, tines of VMP were clogged by standing 50% mulch. To avoid this interruption, this was reduced to 40% at Mymensingh.

Soil sampling procedure

The soil was collected from the field of all locations from 0-15 cm soil depth. Five samples from each plot; hence 290 samples were collected using a stainless-steel pipe of five cm diameter following the "*W*" shape pattern described by Chancellor (1966). After sampling, pieces were tagged and appropriately bagged for transportation to the net-house.

Experimental set-up

Sub-samples from each plot were combined, and approximately one-kilogram soil was placed immediately in an individual round-shaped plastic tray of 33 cm in diameter. Total 290 trays were arranged following a completely randomized design. The study period was January 02-December 29, 2016.

Weed seed emergence and data collection in net-house

Emerged seedlings were identified, counted, and removed at 30 days intervals using the seedling keys of Chancellor (1966). Unnamed seedlings were transferred to another pot and grown until maturity to facilitate identification. After the removal of each batch of seedlings, soils were air-dried, thoroughly mixed, and re-wetted to permit further emergence. The number of seedlings emerged converted to the numbers m^{-2} using the formula, Area = πr^2 (r = radius of the tray= 33 cm).

Results and Discussion

Effect of tillage and mulches on weed species compositions

At Mymensingh, CT with 20% mulch produced 28 weed species consisting of 18 broadleaves, five of grass and five sedges (Table 3). Among them, 24 weeds were annuals, and four perennials. There were three less broadleaf and one less grass weed in 40% mulch than 20% mulch. In ST with 20% mulch, 25 species were found consisting of 15 broadleaf and five grass and five sedges. Among them, 18 were annuals, and seven were perennials. But in ST with 40% mulch, five less broadleaf, one grass, and one sedge were found than 20% mulch.

At Durgapur, CT with 20% mulch, produced 29 species consisting of 19 broadleaf, five grass, and sedges each, of which 25 were annuals and four perennials (Table 4). Retention of 50% mulch generated 21 annuals and four perennials. ST with 20% mulch produced 23 species, including 14 broadleaf, four grass, and five sedges. Annuals were outnumbered than perennials. In ST with 50% mulch, 18 species found having ten broadleaf, four grass, and sedges each, of which 13 annuals and five perennials. BP, with 20% mulch, made 25 species consisting of 15 broadleaf, four grass, and six sedges where 20 were annuals and five perennials. The BP with 50% mulch, had 23 species with 19 annuals and four perennials. Results reflect that the lowest number of weed species was found in ST, followed by BP and CT. Retention of 50% mulch produced lower weeds than 20% mulch. At Godagari, almost all types of weeds were found with similar trend of response to that of Durgapur (Table 5).

At Baliakandi, CT with 20% mulch produced 14 species (eight broadleaf, three grasses, and sedges each) consisting of 10 annuals and four perennials (Table 6). But at 50% mulch, 12 species found having eight broadleaf, two grass, and sedge each, including nine annuals and three perennials. The ST with 20% mulch produced ten species consisting of seven broadleaf, two grasses, and one sedge having four annuals and six perennials. But nine species were having an almost similar number of all types of weed except one with 50% mulch. In BP with 20% mulch, 17 species were found, including ten broadleaf, three grass, and four sedges. There were 16 annuals and one perennial. In 50% mulch, 15 species were found with a similar amount of grass and sedge and fewer annual broadleaf. The ZT with 20% mulch produced 19 weed species belonged to 11 broadleaf and four grass and four sedges, having 15 annuals and four perennials. But in ZT with 50% mulch, 16 species were found to have less number broadleaf grass and sedges.

Table 3. Composition of weed species in different tillage types and residue mulches at Mymensingh.

Weed types and species			Conventional tillage		Strip tillage	
			M_{20}	M_{40}	M_{20}	M_{40}
Broadleaf	*Alternanthera sessilis* L.	Perennial	P	P	P	P
	Amaranthus viridis L.	Annual	P	P	P	P
	A. spinosus L.	Annual	P	P	P	P
	Chenopodium album L.	Annual	P	A	P	A
	Commelina benghalensis L.	Annual	P	P	P	A
	Cyanotis axillaris Roem.	Annual	P	P	P	P
	Dentella repens L.	Perennial	P	P	P	A
	Eclipta alba L.	Annual	P	P	A	P
	Euphorbia parviflora L.	Annual	P	P	A	P
	E. hirta L.	Annual	P	A	P	P
	Hedyotis corymbosa Lamk.	Annual	P	P	P	A
	Jussia deccurence Walt.	Perennial	A	A	P	P
	Lindernia hyssopifolia L.	Annual	P	P	P	A
	L. antipoda Alston.	Annual	P	P	P	A
	Monochoria hastata L.	Annual	P	P	A	A
	Physalis minima L.	Annual	P	P	A	A
	Rotala ramosior (L.) Koehne.	Annual	P	A	P	P
	Solanum torvum Sw.	Perennial	A	A	P	A
	Sphenoclea zeylanica Gaertn.	Annual	P	P	P	A
	Spilanthes acmella Murr.	Annual	P	P	P	P
Sub-total			18	15	15	10
Grass	*Digitaria sanguinalis* L.	Annual	P	P	P	P
	Echinochloa colonum L.	Annual	P	P	P	P
	E. crusgalli L.	Annual	P	A	P	P
	Eleusine indica L.	Annual	P	P	P	P
	Leersia hexandra L.	Perennial	P	P	P	A
Sub-total			5	4	5	4
Sedges	*Cyperus difformis* L.	Annual	P	P	P	A
	C. iria L.	Annual	P	P	P	A
	C. rotundus L.	Perennial	A	A	P	P
	Eleocharisatro purpurea Retz.	Annual	P	P	P	P
	Fimbristylis miliacea L.	Annual	P	P	A	P
	Scripus supinus L.	Perennial	P	P	P	P
Sub-total			5	5	5	4
Grand-Total			28	24	25	18

M_{20} = 20% mulch, M_{40} = 40% mulch, P = Present, A = Absent

Effect of tillage types and mulch levels on density (plants m-^{2}) of different weed types

Data presented in Table 7 reflect that at Mymensingh, ST created 777 less number of weeds than CT, and 40% mulch produced 288 less number of weed m^{-2} than 20% mulch (Table 7). Broadleaf weeds were most dominant over sedges and grasses in CT but dominant over grasses and sedges in ST. Annuals led over perennials in CT, but perennials led over annuals in ST (Table 8).

Table 4. Composition of weed species in different tillage types and residue levels at Durgapur.

Weed types and species		Lifecycle	Conventional tillage		Strip tillage		Bed planting	
			M_{20}	M_{50}	M_{20}	M_{50}	M_{20}	M_{50}
Broad leaf	*Alternanther asessilis* L.	Perennial	P	P	P	P	P	P
	Amaranthus viridis L.	Annual	P	P	P	P	P	P
	A. spinosus L.	Annual	P	P	P	P	P	P
	Chenopodium album L.	Annual	P	A	P	A	P	A
	Commelina benghalensis L.	Annual	P	P	P	A	P	A
	Cyanotis axillaris Roem.	Annual	P	P	A	P	A	P
	Dentella repens L.	Annual	P	P	P	A	P	P
	Eclipta alba L.	Annual	P	P	A	P	A	P
	Euphorbia parviflora L.	Annual	P	P	A	A	A	P
	E. hirta L.	Annual	P	A	P	P	P	P
	Hedyotis corymbosa Lamk.	Annual	P	P	P	A	P	P
	Jussia deccurence Walt.	Perennial	P	A	P	P	P	P
	Lindernia hyssopifolia L.	Annual	P	P	P	A	P	P
	L. antipoda Alston.	Annual	P	P	P	A	P	A
	Monochoria hastata L.	Annual	A	P	P	P	P	P
	M. vaginalis Burm.	Annual	P	P	A	A	A	P
	Physalis minima L.	Annual	P	P	A	A	A	A
	Rotala ramosior (L.) Koehne.	Annual	P	A	P	P	P	P
	Solanum torvum Sw.	Perennial	A	P	P	P	A	A
	Sphenoclea zeylanica Gaertn.	Annual	P	P	A	A	P	A
	Spilanthes acmella Murr.	Annual	P	P	A	A	P	P
Sub-Total			19	17	14	10	15	15
Grass	*Digitaria sanguinalis* L.	Annual	P	P	A	P	A	P
	Echinochloa colonum L.	Annual	P	A	P	P	P	P
	E. crusgalli L.	Annual	P	A	P	P	P	P
	Eleusine indica L.	Annual	P	P	P	P	P	P
	Leersia hexandra L.	Perennial	P	P	P	A	P	A
Sub-Total			5	3	4	4	4	4
Sedges	*Cyperus difformis* L.	Annual	P	P	P	A	P	A
	C. iria L.	Annual	P	P	A	A	P	A
	C. rotundus L.	Perennial	A	A	P	P	P	P
	Eleocharisatro purpurea Re.	Annual	P	P	P	P	P	P
	Fimbristylis miliacea L.	Annual	P	P	P	P	P	P
	Scripus supinus L.	Perennial	P	P	P	P	P	P
Sub-Total			5	5	5	4	6	4
Grand-Total			29	25	23	18	25	23

M_{20} = 20% mulch, M_{50} = 50% mulch, P = Present, A = Absent

At Durgapur and Godagari, BP generated the highest weed density followed by CT and ST (Table 7). Compared to CT (1738 at Durgapur and 2079 at Godagari), ST had 172 and 237 fewer weeds, but BP had 717 and 776 more number of weeds at two locations, respectively. Retention of 50% mulch produced 442 and 610 fewer numbers of weeds than 20% mulch at two locations, respectively. Broadleaf weeds were the most dominant in all types of tillage at both locations, while grasses dominated over sedges in ST at Durgapur and BP at Godagari but opposite in BP at Durgapur and ST at Godagari. Perennials led over annuals both in ST and BP but reverse in CT at both locations (Table 8).

Table 5. Composition of weed species in different tillage types and residue levels at Godagari.

Weed types and species		Lifecycle	Conventional tillage		Strip tillage		Bed planting	
			M_{20}	M_{50}	M_{20}	M_{50}	M_{20}	M_{50}
Broad leaf	*Alternanther asessilis* L.	Perennial	P	P	P	P	P	A
	Amaranthus viridis L.	Annual	P	P	P	P	P	P
	A. spinosus L.	Annual	P	P	P	P	P	P
	Chenopodium album L.	Annual	P	A	P	A	P	A
	Commelina benghalensis L.	Annual	P	P	A	A	P	A
	Cyanotis axillaris Roem.	Annual	P	P	A	P	A	P
	Dentella repens L.	Annual	P	P	A	A	P	P
	Eclipta alba L.	Annual	P	P	A	P	A	P
	Euphorbia parviflora L.	Annual	P	P	A	P	A	P
	E. hirta L.	Annual	P	A	P	P	P	P
	Hedyotis corymbosa Lamk.	Annual	P	P	A	A	P	P
	Jussia deccurence Walt.	Perennial	P	P	P	P	P	P
	Lindernia hyssopifolia L.	Annual	P	P	A	A	P	P
	L. antipoda Alston.	Annual	P	P	P	A	P	A
	Monochoria hastata L.	Annual	P	P	P	A	P	P
	M. vaginalis Burm.	Annual	P	P	A	P	A	P
	Physalis minima L.	Annual	P	P	A	A	A	A
	Rotala ramosior (L.) Koehne.	Annual	P	P	P	P	P	P
	Solanum torvum Sw.	Perennial	P	P	P	A	A	A
	Sphenoclea zeylanica Gaertn.	Annual	P	P	A	A	P	A
	Spilanthes acmella Murr.	Annual	P	P	A	A	P	P
Sub-Total			21	19	10	10	15	14
Grass	*Digitaria sanguinalis* L.	Annual	P	P	A	P	A	P
	Echinochloa colonum L.	Annual	P	A	P	P	P	P
	E. crusgalli L.	Annual	P	P	P	P	P	P
	Eleusine indica L.	Annual	P	P	P	P	P	P
	Leersia hexandra L.	Perennial	P	P	P	A	P	A
Sub-Total			5	4	4	4	4	4
Sedges	*Cyperus difformis* L.	Annual	P	P	P	A	P	A
	C. iria L.	Annual	P	P	P	A	P	A
	C. rotundus L.	Perennial	A	A	P	P	A	P
	Eleocharisatro purpurea Re.	Annual	P	P	P	P	P	P
	Fimbristylis miliacea L.	Annual	P	P	P	P	P	P
	Scripus supinus L.	Perennial	P	P	P	A	P	P
Sub-Total			5	6	6	3	6	4
Grand-Total			31	29	20	17	25	22

M_{20} = 20% mulch, M_{50} = 50% mulch, P = Present, A = Absent

At Baliakandi, the trend of weed density m^{-2} was ZT > BP > CT > ST. Compared to CT (1668), ST has 560 fewer weeds, but 386 and 2639 more weeds in BP and ZT, respectively. On the other hand, 50% of mulch produced 608 fewer weeds than 20% mulch (Table 7). In all types of tillage and mulch levels, broadleaf led over sedges and grasses. Annuals were dominant over perennials in CT, but perennials led over annuals in ST, BP, and ZT (Table 8).

In this study, the higher number of weeds composting broadleaf, grass, and sedge types was found in CT than ST. This phenomenon might be attributed to the emergence of more weed species in CT over ST. Mohler (2001) quoted dormant seeds in CT become viable to germinate by scarification, ambient CO_2 concentrations, and higher nitrate concentrations, which may lead to producing higher weed emergence of new weed species in CT.

Table 6. Composition of weed species in different tillage types and residue mulches at Baliakandi.

Weed types and species		Lifecycle	CT		ST		BP		ZT	
			M_{20}	M_{50}	M_{20}	M_{50}	M_{20}	M_{50}	M_{20}	M_{50}
Broad leaf	*Alternanthera sessilis* L.	Perennial	A	A	P	P	A	A	P	P
	Amaranthus viridis L.	Annual	P	P	A	A	P	A	P	A
	Commelina benghalensis L.	Annual	A	P	A	A	P	P	A	A
	Cyanotis axillaris Roem.	Annual	A	A	A	A	P	P	P	A
	Dentella repens L.	Perennial	P	P	P	P	A	A	P	P
	Eclipta alba L.	Annual	P	P	A	A	P	P	P	P
	Euphorbia parviflora L.	Annual	A	A	A	A	P	P	A	P
	Hedyotis corymbosa (L.) Lamk.	Annual	A	A	P	P	P	P	P	P
	Jussia deccurence Walt.	Perennial	P	P	P	P	A	A	P	P
	Lindernia hyssopifolia L.	Annual	P	P	P	P	P	P	P	P
	Lindenia antipoda Alston.	Annual	P	P	P	P	P	P	P	P
	Monochoria hastata L.	Annual	P	P	A	A	P	P	A	A
	Rotala ramosior (L.) Koehne.	Annual	A	A	A	A	A	A	P	P
	Solanum torvum Sw.	Perennial	P	A	P	P	A	A	A	A
	Spilanthes acmella Murr.	Annual	A	A	A	A	P	A	P	A
Sub-total			8	8	7	7	10	8	11	9
Grass	*Digitaria sanguinalis* L.	Annual	P	P	A	A	P	P	P	P
	Echinochloa colonum L.	Annual	P	P	P	P	P	P	P	P
	Echinochloa crusgalli L.	Annual	A	A	A	A	A	A	P	A
	Eleusine indica L.	Annual	A	A	A	A	P	P	P	P
	Leersia hexandra L.	Perennial	P	A	P	A	A	A	A	A
Sub-total			3	2	2	1	3	3	4	3
Sedges	*Cyperus difformis* L.	Annual	P	A	A	A	P	P	P	P
	C. iria L.	Annual	P	A	A	A	P	P	P	P
	C. rotundus L.	Perennial	A	A	P	P	P	P	P	P
	Fimbristylis miliacea L.	Annual	P	P	A	A	P	P	P	P
Sub-total			3	1	1	1	4	4	4	4
Grand-total			14	11	10	9	17	15	19	16

CT= Conventional tillage, ST= Strip tillage, BP= Bed planting, ZT= Zero tillage, M_{20} = 20% mulch, M_{50} =50% mulch, P= Present, A= Absent.

Table 7. Effect of tillage types and mulch levels on the density (plants m^{-2}) of different weed types at different locations.

Locations	Tillage / Mulch	Broadleaf			Grass			Sedges		
		M_{20}	$M_{40/50}$	$\bar{X}$	M_{20}	$M_{40/50}$	$\bar{X}$	M_{20}	$M_{40/50}$	$\bar{X}$
Mymensingh	CT	2616	2402	2509	643	764	703	765	838	801
	ST	2249	1775	2012	703	601	652	562	583	572
	$\bar{X}$	2433	2089	-	673	682	-	663	710	-
Durgapur	CT	1900	1575	1738	760	630	695	506	422	464
	ST	1805	1421	1613	779	456	617	528	459	493
	BP	2243	2359	2301	615	426	520	760	823	791
	$\bar{X}$	1983	1785	-	718	504	-	598	568	-
Godagari	CT	2261	1897	2079	895	542	718	613	556	584
	ST	2067	1704	1885	617	561	589	943	398	670
	BP	2635	2714	2674	897	864	880	672	535	603
	$\bar{X}$	2321	2105	-	803	656	-	743	496	-
Baliakandi	CT	2019	1317	1668	650	497	573	446	671	558
	ST	1405	1272	1339	619	417	518	468	298	383
	BP	1989	1613	1801	768	720	744	733	547	640
	ZT	2891	2854	2873	1908	1376	1642	983	866	924
	$\bar{X}$	2076	1764	-	986	752	-	657	595	-

CT = Conventional tillage, ST = Strip tillage, BP = Bed planting, ZT = Zero tillage, M_{20} = 20% mulch, M_{40} = 40% mulch, M_{50} = 50% mulch, $\bar{X}$ = Mean.

Table 8. Effect of tillage types and mulch levels on the density (plants m^{-2}) of annual and perennial weeds at different locations.

Locations	Tillage / Mulch	Annual weeds			Perennial weeds		
		M_{20}	$M_{40/50}$	$\bar{X}$	M_{20}	$M_{40/50}$	$\bar{X}$
Mymensingh	CT	2683	2397	2540	1341	1607	1474
	ST	1663	1281	1472	1851	1678	1765
	$\bar{X}$	2173	1839	-	1596	1643	-
Durgapur	CT	1631	1429	1530	1535	1198	1366
	ST	1462	864	1163	1650	1472	1561
	BP	1681	1739	1710	1937	1869	1903
	$\bar{X}$	1592	1344	-	1707	1513	-
Godagari	CT	1926	1689	1807	1843	1306	1575
	ST	1674	1077	1375	1953	1586	1770
	BP	1811	1954	1882	2393	2159	2276
	$\bar{X}$	1803	1573	-	2063	1683	-
Baliakandi	CT	2407	1863	2135	708	621	664
	ST	1112	833	972	1380	1154	1267
	BP	1651	1307	1479	1839	1573	1706
	ZT	2378	1889	2134	3403	3207	3305
	$\bar{X}$	1887	1473	-	1832	1638	-

CT = Conventional tillage, ST = Strip tillage, BP = Bed planting, ZT = Zero tillage, M_{20} = 20% mulch, M_{40} = 40% mulch, M_{50} = 50% mulch, $\bar{X}$ = Mean.

The research finding of Cardina et al. (2002) also revealed the increase of weed species composition in CT offered from the higher rate of seed viability occurred from weed seed burial in the soil profile. Such a higher rate of weed seed survivability might lead to an increase in weed composition in CT. Gallandt et al. (2004) found germination stimulus is generally higher near the soil surface and decreases with depth. In the reduced tillage system of ST, seedbanks are concentrated in the top layer of the soil; thus, a higher proportion of reduced tilled seedbanks will germinate compared with CT, which led to reduce seedbank size in ST than CT. The reduction of weed species in ST might also be due to minimizing the weed seedbank status in the soil by increasing non-viable or dormant weed seeds in the seedbank. Due to minimal soil disturbance (only 20%) at the upper soil layer in ST, most of the weed seeds remain on the soil surface. They can lose viability due to desiccation and adverse climate, as reported by Nichols et al. (2015). Losing of seed viability in ST may also be attributed to increased seed dormancy at an undisturbed deeper soil layer. Seeds remain dormant at a deeper layer suffer from suffocation for less oxygen pressure and darkness for feeble light, as weed seeds required oxygen and light for maximum germination (Oziegbe et al. 2010).

Surface accumulation of weed seeds in ST would increase predator like ants, insects, rodents, and birds (Blubaugh and Kaplan, 2015) access to weed seeds and could increase their removal rates. For example, common ground beetles or crickets can reduce weed seed emergence by 5 to 15% (White et al. 2007). Overall, the adoption of ST may encourage seed losses via predation by increasing the availability of seeds to predators, and by minimizing mortality and forced relocation of predators, therefore, represent a potentially valuable tool for reducing weed seedbank size in ST. Higher dispersal of weed seeds may also lead to an increase in the seedbank in CT over ST. Barroso et al. (2006) found the weed seeds traveled 2–3 m in the direction of full tillage, while in reduced tillage soils, the distance is negligible. Reducing tillage in ST, therefore, reduced the spread of weed seed both within and across fields and reduced seedbank size in this study. The reduced weed seedbank in ST may also have occurred from more lavish weed seed burial as strips were made in the same location over the years because the field layout and all the treatments were the same in the field study.

Furthermore, the application of different herbicides might lead to having less amount of weed in ST, BP, and ZT. We used glyphosate and pendimethalin herbicide in all crops. Besides, we used ethoxysulfuron-ethyl in rice; oxadiazon in mustard; Carfentrazon-ethyl + isoproturon in wheat while fenoxaprop-p-ethyl in jute, lentil, mungbean, and chickpea. These herbicides are previously reported to reduce seed viability or induced seed dormancy in weed, which might have led to reducing weed pressure in ST than CT. It was reported that a range of herbicides could reduce seed production and germination by several folds depending on the biotypes. Glyphosate is registered to affected pollen and seed production almost 100% in *Ambrosia artemisiifolia* L. (Gauvrit and Chauvel, 2010) and *Bromus japonicus* Thunb. (Rinella et al., 2010) while and 69.8% in *Conyza bonariensis* L. (Wu et al. 2007). Findings of previous studies reported that herbicides could reduce the germination of weeds seeds. Tanveer et al. (2009) found pendimethalin herbicide exerted only 30.57% seed germination of *Chenopodium album* L., while ethoxysulfuron-ethyl killed 98-100% seeds of *Echinochloa glabrescens* L. (Opeña et al. 2014). Moreover, oxadiazon waived 85.81% seeds of *Fimbristylis cymosa* R.Br. Furthermore, carfentrazon-ethyl + isoproturon damaged 100% seeds of *Emex spinosa* L. (Javaid et al. 2012) and fenoxaprop-p-ethyl wrecked 96.78% seeds of *Phalaris minor* L. (Singh et al. 2017).

The results of these studies agree the findings of the present study demonstrated that herbicides could potentially reduce seed production and viability of weeds, thereby reducing seedbank size in ST than CT, followed by BP and ZT. On the other hand, herbicide induced seed dormancy could contribute to the altered seed dormancy found in *Hordeum murinum* L., *Bromus diandrus* Roth., and *Lolium rigidum* Gaud., in intensive cropping systems that relied heavily on herbicidal weed control reported by Kleemann and Gurjeet (2013) and Owen et al. (2015). The above-discussed reasons might lead to a decline in the size of the weed seedbank in ST in a trend of weed species composition following ST < CT at Mymensingh, ST < CT < BP at Durgapur and Godagari, and ST < CT < BP < ZT at Baliakandi. Bàrberi and Cascio (2001) agree with the findings of the present study as stated the higher weed density at ZT, followed by reduced tillage because of taller weeds seedlings recruitment from the topsoil in ZT. In the present study, annual weeds led over perennials in CT, but perennial weeds led over annuals in ST, BP, and ZT. Boscutti et al. (2015) agree this finding in support with Erenstein and Laxmi (2008) concluded that altering the tillage regimes changes the disturbance frequency of the field, which results in shifts in weed vegetation of that field. Many studies support our survey with the reports; CT systems favor annuals, while reduced tillage systems favor perennial weeds (Tuesca et al. 2001). Ecological succession theory (Aweto, 2013) also agrees with our research finding suggesting the dominancy of perennials weeds in less disturbed systems. Because CT kills most of the underground vegetative reproduction structures (rhizomes, tubers, bulbs, runner, and stolons) of perennials weeds, hence, reserves only annuals weeds which reproduce mostly by seeds (matured ovules). On the other hand, the vice-versa phenomenon generally occurs in tillage was minimized in ST and BP while absent in ZT, which favored perennial weeds here in the soil weed seedbank. In this study, retention of 40 or 50% crop mulch had fewer above ground weed taxa than 20% mulch. This phenomenon might be due to the drastic effect of suppressing weed seed germination caused by a physical barrier, lowering soil temperatures and allelochemicals released from decaying plant tissues, as suggested by Curran (2016). Moreover, reduced light penetration stating cooler average soil temperatures could reduce weed seed germination or causing delay germination, damage of weed seeds upon predation and decomposition by macro and microbial populations (Conklin et al., 2002) and massive moisture conservation (Manici et al. 2004); delay the emergence of etiolated plants producing lower seeds as stated earlier (Begum et al. 2006) might have reduced weed seedbank size in 40/50% mulch over 20% mulch.

Conclusion

Based on the study, it might be concluded that long-term strip tillage of 3-5 years with 40-50% crop mulch under conservation agriculture practice reduced weed seedbanks in terms of weed species composition and density, and this reduction is much higher than bed planting and zero tillage. Strip tillage, bed planting and zero tillage also increased perennial weeds in the weed seedbank while conventional tillage increased annual weeds.

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Conflicts of Interest

The authors have declared no conflicts of interest.

References

Aweto A.O. 2013. Ecological succession theory and models. in: Aweto A.O. (Ed), Shifting Cultivation and Secondary Succession in the Tropics. CABI Publications, Oxfordshire, UK. pp. 116-130. [Crossref], [Google scholar], [Publisher]

Barberi P, Lo Cascio B. 2001. Long-term tillage and crop rotation effects on weed seedbank size and composition. *Weed Res*. 41: 325–340. [Crossref], [Google scholar], [Publisher]

Barroso J, Navarrete L, Sánchez del Arco M, Fernandez-Qunitanilla C, Lutman P, Perry N, Hull R. 2006. Dispersal of *Avena fatua* and *A. sterilis* patches by natural dissemination, soil tillage and combine harvesters. *Weed Res*. 46: 118-128. [Crossref], [Google scholar], [Publisher]

Begum M, Juraimi A.S, Rastan S.O.B.S, Rajan A, Man A.B. 2006. Seedbank and seedling emergence characteristics of weeds in rice field soils of the muda granary area in north-west peninsular Malaysia. *Biotrop*. 13(1): 11-21. [Google scholar], [Publisher]

Bell R, Haque M, Jahiruddin M, Rahman M, Begum M, Miah M, Islam M, Hossen M, Salahin N, Zahan T, Hossain M, Alam M, Mahmud M. 2018. Conservation agriculture for rice-based intensive cropping by smallholders in the Eastern Gangetic Plain. *Agric*. 9(1): 5-22. [Crossref], [Google scholar], [Publisher]

Blubaugh C.K, Kaplan I. 2015. Tillage compromises weed seed predator activity across developmental stages. *Biol Control*. 81: 76-82. [Crossref], [Google scholar], [Publisher]

Boscutti F, Sigura M, Gambon N, Lagazio C, Krüsi B.O, Bonfanti P. 2015. Conservation tillage affects species composition but not species diversity. *J Environ Manage*. 55: 443-452. [Crossref], [Google scholar], [Publisher]

Brammer H. 1996. The Geography of the Soils of Bangladesh, First ed. Dhaka, Bangladesh. [Publisher]

Cardina J, Herms C.P, Doohan D.J. 2002. Crop rotation and tillage systems effects on weed seedbank. *Weed Sci*. 50: 448-460. [Crossref], [Google scholar], [Publisher]

Chancellor R.J. 1966. The Identification of weed seedlings of farm and garden, first ed. Oxford, England. [Crossref], [Google scholar], [Publisher]

Conklin A.E, Erich M.S, Liebman M, Lambert D, Gallandt E.R, Halteman W.A. 2002. Effects of red clover green manure and compost soil amendments on wild mustard growth and incidence of disease. *Plant Soil*. 238: 245-256. [Crossref], [Google scholar], [Publisher]

Curran W.S. 2016. Persistence of herbicides in soil. *Crops Soils*. 49(5): 16–21. [Crossref], [Google scholar], [Publisher]

Erenstein O, Laxmi V. 2008. Zero tillage impacts in India's rice-wheat systems: a review. *Soil Tillage Res*. 100: 1-14. [Crossref], [Google scholar], [Publisher]

Fonteyne S, Singh R.G, Govaerts B, Verhulst N. 2020. Rotation, mulch and zero tillage reduce weeds in a long-term conservation agriculture trial. *Agron*. 10(7): 962-978. [Crossref], [Google scholar], [Publisher]

Gallandt E.R, Fuerst E.P, Kennedy A.C. 2004. Effect of tillage, fungicide seed treatment and soil fumigation on seedbank dynamics of wild oat (*Avena fatua*). *Weed Sci*. 52: 597-604. [Crossref], [Google scholar], [Publisher]

Gauvrit C, Chauvel B. 2010. Sensitivity of *Ambrosia artemisiifolia* to glufosinate and glyphosate at various development stages. *Weed Res*. 50: 503-510. [Crossref], [Google scholar], [Publisher]

Hossain M.I, Sarker M.J.U, Haque M.A. 2015. Status of conservation agriculture-based tillage technology for crop production in Bangladesh. *Bangladesh J Agric Res*. 40(2): 235-248. [Crossref], [Google scholar], [Publisher]

Javaid M.M, Tanveer A, Ahmad R, Yaseen M, Khaliq A. 2012. Optimizing activity of herbicides at reduced rate on Emex spinosa with adjuvants. *Planta Daninha*. 30(2): 425-435. [Crossref], [Google scholar], [Publisher]

Kassam A, Friedrich T, Derpsch R. 2019. Global spread of conservation agriculture. *Int J Environ Stud*. 76(1): 29–51. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Kleemann S.G, Gurjeet G. 2013. Seed dormancy and seedling emergence in ripgut brome (*Bromus diandrus*) populations in Southern Australia. *Weed Sci*. 61: 22-29. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Manici L.M, Caputo F, Babini V. 2004. Effect of green manure on Pythium spp. population and microbial communities in intensive cropping systems. *Plant Soil*. 263: 133-142. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Mohler C.L. 2001. Ecological Management of Agricultural Weeds. Cambridge, UK. **[Google scholar]**, **[Publisher]**

Moonen A.C, Barberi P. 2004. Size and composition of the weed seedbank after 7 years of different cover crops-maize management systems. *Weed Res*. 44: 163–177. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Nichols V, Verhulst N, Cox R, Govaerts B. 2015. Weed dynamics and conservation agriculture principles: A review. *Field Crops Res*. 183: 56-68. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Opeña J.L, Chauhan B.S, Baltazar A.M. 2014. Seed germination ecology of *Echinochloa glabrescens* and its implication for management in rice (*Oryza sativa* L.). *PLoS One*. 9(3): 1-13. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Owen M.J, Goggin D.E, Powles S.B. 2015. Intensive cropping systems select for greater seed dormancy and increased herbicide resistance levels in *Lolium rigidum*. *Pest Manag Sci*. 71: 966-971. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Oziegbe M, Faluyi J.O, Oluwaranti A. 2010. Effect of seed age and soil texture on the germination of some *Ludwigia* species (Onagraceae) in Nigeria. *J Univ Zagreb*. 69(2): 249-257. **[Google scholar]**, **[Publisher]**

Pittelkow C.M, Liang X, Linquist B.A, Van Groenigen K.J, Lee J, Lundy M.E, van Gestel N, Six J, Venterea R.T, van Kessel C. 2015. Productivity limits and potentials of the principles of conservation agriculture. *Nature*. 517: 365-368. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Rinella M.J, Hagerkamp M.R, Masters R.A, Muscha J.M, Bellows S.E, Vermeire L.T. 2010. Growth regulator herbicides prevent invasive annual grass seed production. *Invasive Plant Sci Manag*. 3: 12-16. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Sanyal D, Bhowmik P.C, Anderson R.L, Shrestha A. 2008. Revisiting the perspective and progress of integrated weed management. *Weed Sci*. 56: 161-167. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Singh R, Pramanick B, Singh A.P, Neelam, Kumar S, Kumar A, Singh G. 2017. Bio-efficacy of fenoxaprop-p-ethyl for grassy weed control in onion and its residual effect on succeeding maize crop. *India J Weed Sci*. 49(1): 63-66. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Taa A, Tanner D, Bennie A.T. 2004. Effects of stubble management, tillage and cropping sequence on wheat production in the south-eastern highlands of Ethiopia. *Soil Tillage Res*. 76: 69-82. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Tanveer A, Nadeem M.A, Ali A, Tahir M, Zamir M.S.I. 2009. Germination behavior of seeds from herbicide treated plants of *Chenopodium album* L. *Ann Brazilian Aca Sci*. 81(4): 873-879. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Tuesca D, Puricelli E, Papa J. 2001. A long-term study of weed flora shifts in different tillage systems. *Weed Res*. 41: 369-382. **[Crossref]**, **[Google scholar]**, **[Publisher]**

White S.S, Renner K.A, Menalled F.D, Landis D.A. 2007. Feeding preferences of weed seed predators and effect on weed emergence. *Weed Sci*. 55: 606-612. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Woźniak A. 2018. Effect of tillage system on the structure of weed infestation of winter wheat. Span J Agric Res. 16(4): 1-7. **[Crossref]**, **[Google scholar]**, **[Publisher]**

Wu H, Walker S, Rollin M.J, Tan D.K.Y, Robinson G, Werth J. 2007. Germination, persistence, and emergence of flaxleaf fleabane (*Conyza bonariensis* (L.) Cronquist). Weed Biol Manag. 7: 192-199. **[Crossref]**, **[Google scholar]**, **[Publisher]**