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Weed abundance and soil weed seed bank response to varied tillage, weed and nutrient management practices in green manure-maize-pulse cropping system

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Abstract
The field and pot culture experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai during 2016-2018 and laid out in a split-split plot and completely randomized block design replicated thrice. Predominant weed species observed in the field included grasses like *Chloris barbata*, *Cynodon dactylon*, *Dactyloctenium aegyptium* and *Echinochola crusgalli*; *Cyperus rotundus* and *Cyperus iria* under sedges and broad-leaved weeds like *Acalypha indica*, *Amaranthus viridis, Boerhavia diffusa*, *Commelina benghalensis, Cleome viscosa*, *Convolvulus arvensis*, *Eclipta alba*, *Euphorbia hirta*, *Portulaca oleracea*, *Phyllanthus niruri* and *Trianthema portulacastrum*. During both the years of experiments, the results revealed that minimum tillage with 30% daincha residue and PE application of atrazine followed by one hand weeding at 30 DAS along with 75% RDF (NPK) + vermicompost + azhophos recorded significantly lesser grasses, sedges and broad leaved weeds density, dry weight and higher weed control efficiency (WCE) in maize. In case of black gram, conventional tillage with PE application of Pendimethalin followed by one hand weeding at 20 DAS and 75% RDF (NPK) + vermicompost + rhizobium attained the lowest weed density, dry weight and higher WCE. Soil weed seed bank studies showed that, conservation tillage with 30% crop residue retention and PE application of herbicides influenced different weed flora occurrence in the maize based conservation agriculture system.

Keywords: conservation tillage, green manure, maize, pulses, weed control efficiency

Introduction
Conservation tillage suggests upkeep of plant residues on the soil surface helps to maintains soil structure by eliminating tillage for seed bed preparation and weed control. However, different tillage practices significantly influence weed population. Irrespective of the weed species, conventional tillage significantly reduces the population of weeds as compared to zero tillage and minimum tillage practices. The inversion of soil by following conventional tillage resulted in deeper placement of weed seeds which could not emerge out, causing a significant reduction in the population of weeds (Chahal *et al*. 2003) [3].

Soil surface residues influence soil temperature and moisture which may affect weed seed germination and emergence patterns. Incorporated crop residues inhibit weeds, but not crop establishment through seed size-dependent effects on germination and emergence. (Murphy *et al*. 2006; Swanton *et al*. 2008) [8, 12]. Three key ethics of conservation tillage have been identified viz., continuous minimum soil disturbance, permanent soil organic cover, crop diversification/ rotation which is crucial to its success (Hobbs *et al*. 2008) [6]. Inclusion of leguminous crop (green manure and pulses) for weed and nutrient management is considered to the fourth ethics that is vital for success implementation of Conservation Agriculture.

Considering the advantage of conservation tillage and integrated crop management practices, the present study was undertaken to standardize and workout the feasible and profitable conservation management techniques for farmers with the following objective: To study the weed abundance and soil weed bank responses to varied agronomic practices in maize based conservation agriculture system.

Materials and Methods

The experiments were conducted at Agricultural College and Research Institute, TNAU, Madurai during 2016-2018. The experimental site was located in the southern zone of Tamil Nadu at 9º54' Nlatitude and 78º54' E longitude with an altitude of 147mabove mean sea level. The annual rainfall of experimental site was 501mm in 2016-17 and 332mm in 2017-18 with the maximum and minimum temperature ranging from 21.8 to 35.9 ºC in 2016-17 and 22.6 to 31.5 ºC in 2017-18. The soil of the experimental field was red sandy clay loam belonging to *Madukkur* series. Conventional tillage (T_1) and minimum/ zero tillage (T_2) were allotted in the main plots. Whereas weed management practices viz., crop residue mulch (W_1), pre emergence application of herbicide followed by one hand weeding (W_2) and twin wheel hoe weeding twice (W_3) were assigned to sub plots. Nutrient management practices i.e., 100% RDF (NPK) (N_1), 75% RDF (NPK) + vermicompost + bio-fertilizer (N_2) and 50% RDF (NPK) + vermicompost + bio-fertilizer (N_3) were allocated to sub sub plots.

The conventional tillage included one disc ploughing, two cultivators and then one rotovater to obtain a pulverized soil. The field operations for minimum tillage comprised of single disc harrow with one cultivator. The disc harrow was used for partial residue retention on soil surface. The field operations for zero tillage consisted of no tillage and 30 per cent residue maintenance of previous crop on soil surface for succeeding crops. Glyphosate was sprayed in no tillage treatment for controlling existing weeds so as to facilitate to take up sowing of pulse crops. Daincha was raised up to 40 days and 30 per cent biomass was retained as residue in minimum tillage plots. A seed rate of 20kg/ ha was used for both maize (CO MH6) and black gram (VBN (Bg) 8) as succeeding crop.

Sugarcane trash was used as crop residue mulch (5.0t/ha) for *Rabi* maize 2016 and 2017 at 10 DAS. Thereafter maize residues were used as residue mulch for summer black gram 2017 and 2018 at 10DAS. Pre-emergence herbicides (Atrazine 0.25 kg a.i./ha in maize and Pendimethalin 1.0 kg a.i./ha in black gram) were applied to the respective treatment plots at 3 DAS under adequate soil moisture condition. PE herbicide followed by one hand weeding was given at 30 DAS in maize and 20 DAS in black gram. Twin wheel hoe weeding was done at 20 and 40 DAS for maize crop and 15 and 30 DAS for black gram in single direction (between the rows) of both crops. The un-weeded control was kept outside the treatment plot, which was undisturbed for the entire cropping period.

Recommended dose of N, P, and K fertilizers for maize (250:62.5:50) and black gram (25:50:25) were applied as per treatment schedule. Vermicompost at the rate of 2.5t/ha was uniformly incorporated, levelled and applied as basal. Azophos seed treatment at the rate of 600g/ha seed and soil application at the rate of 2.0kg/ha in maize mixed with vermicompost and broad casted. Rhizobium seed treatment was given at the rate of 600g/ha to black gram. The control (without fertilizer) plot was kept outside the treatment plots. Other cultural operations were followed as per TNAU crop production guide 2012.

Weed seed bank studies in soil

To compare the critical period of weed seed germination, the experiments were conducted under both pot and field conditions. The soil sample of 1 kg was taken using a 15 cm diameter metal core, carefully excavated from two soil depths of 0-15 and 15-30 cm from each treatment plots after harvest of maize and black gram and they were bulked to give a composite soil. Bulked soil samples were partially air dried, well labeled and spread on 30x30x10cm plastic tray separately to get homogeneous and uniform layer. The plastic trays were marked for each treatment separately. Under field condition, one square meter land area of soil was marked at 0-15cm and 15-30cm depth. The above ground portions of the weeds were removed from each plot. Later, regular watering was done with the help of water cane uniformly in all plastic trays and field plot. The number of germinated weed seedlings were counted under each treatment up to 45th day's germination. Finally, weed seed counts of soil was worked out for each treatment.

The data on various characters studied during the course of investigation were statistically analyzed as suggested by Gomez and Gomez (2010) [5]. Data on weed density showed high variation and hence they were subjected to square root transformation ($\sqrt{X+0.5}$) and analyzed statistically. Wherever statistical significances were observed, least square difference (LSD) at 0.05 level of probability was worked out for comparison. Non–significant comparison was indicated as 'NS'.

Results and Discussion

Weed flora of experimental site

General weed flora of the experimental fields was observed in un-weeded check (absolute control) at 60 DAS during *Rabi* maize and summer black gram.

Maize

The predominant grass weeds noticed were *Brachiaria reptans, Chloris barbata, Cynodon dactylon, Dactyloctenium aegyptium* and *Echinochloa Crus Galli*. Among the BLWs *Acalypha indica, Amaranthus viridis, Boerhavia diffusa, Cleome viscosa, Commelina benghalensis, Convolvulus arvensis, Parthenium hysterophorus* and *Trianthema portulacastrum* were the dominant ones. *Cyperus rotundus* was the only sedge existed in the field

Black gram

Among grass weeds, *Chloris barbata, Cynodon dactylon, Dactyloctenium aegyptium* and *Echinochloa Crus Galli* were predominantly seen. *Cyperus rotundus* and *Cyperus iria* were the sedges observed in the field. In case of BLWs *Amaranthus viridis, Boerhavia diffusa, Commelina benghalensis, Convolvulus arvensis, Eclipta alba, Parthenium hysterophorus, Phyllanthus niruri* and *Trianthema portulacastrum* were the dominant ones.

Weed density and Dry weight

The grass, sedge, and BLW density and dry weight were significantly influenced by varied tillage, weed and nutrient management practices at 45 DAS in maize and black gram.

Maize

Minimum tillage with 30% daincha residue recorded significantly lower grass, sedge and BLW density and dry weight as compared to conventional tillagein both the years of experiment (Table 1). The reduction in weed density occurs by physical impedance caused by partial retention of daincha on soil surface as well as continued leaching of allelo chemical in to the soil. These findings confirmed with Weston (1996) [14]. Similarly Singh *et al*. (2007) [11] reported that incorporation of daincha at 30 days was found to effective in controlling weeds in rice.

PE application of atrazine followed by one hand weeding at 30 DAS recorded the lowest grass, sedges and BLW density and dry weight as compared to twin wheel hoe weeding twice at 20 and 40 DAS in both year of experiments (Table 1). This is might be due to most of grass, BLW and few sedge weeds were completely destroyed by broad spectrum selectivity of atrazine followed by manual weeding at later stage. These findings were in line with Kamble *et al*. (2015) [7] who reported that lower density and dry weight of weeds were recorded with atrazine and subsequent hand weeding suppressed the weed growth up to critical stages of crop-weed competition in maize.

Among nutrient management practices, 75% RDF (NPK) + vermicompost + azhophos (N_2) recorded significantly lesser grass, sedge and BLW density and dry weight than 100% NPK alone (Table 1). This might be due to application of inorganic fertilizer with organic sources viz., vermicompost and bio fertilizer favors the crop growth and suppressed the weeds by producing lower weed density and dry weight. These findings coincides with results of Vijay mahantesh *et al.* (2016) [13] who reported application of inorganic N application alone encourages the weed population in finger millet.

Table 1: Effect of tillage, weed and nutrient management practices on weed density (No/m^2) and dry weight (g/m^2) at 45 DAS in maize

Treatments	***Rabi*maize 2016**						***Rabi* maize 2017**					
	Weed density			**Weed dry weight**			**Weed density**			**Weed dry weight**		
	Grass	**Sedge**	**BLW**	**Grass**	**Sedge**	**BLW**	**Grass**	**Sedge**	**BLW**	**Grass**	**Sedge**	**BLW**
Tillage												
T_1	7.01 (50.4)	4.12 (17.3)	9.05 (84.2)	5.08 (28.9)	3.29 (10.3)	6.49 (41.6)	6.31 (46.1)	4.68 (22.2)	9.06 (84.4)	5.12 (26.1)	3.02 (8.63)	6.27 (38.8)
T_2	5.02 (30.9)	3.44 (11.5)	8.06 (64.6)	3.99 (17.9)	2.60 (6.27)	5.11 (25.6)	4.99 (29.1)	3.42 (11.9)	7.62 (59.9)	3.57 (14.5)	2.41 (5.33)	5.55 (30.3)
LSD (P=0.05)	0.29	0.26	0.38	0.22	0.13	0.29	0.27	0.26	0.05	0.26	0.13	0.19
Weed management												
W_1	9.15 (84.5)	4.30 (18.4)	9.99 (102)	6.37 (41.0)	3.51 (11.8)	7.22 (51.6)	8.73 (76.6)	4.76 (22.7)	9.25 (87.2)	6.10 (37.6)	3.03 (8.67)	6.82 (46.0)
W_2	2.44 (5.58)	2.29 (5.57)	4.51 (20.3)	2.33 (5.24)	1.98 (3.44)	4.68 (21.4)	3.06 (9.17)	3.06 (9.53)	4.04 (16.4)	2.14 (4.37)	2.06 (3.73)	4.18 (17.0)
W_3	5.61 (31.9)	3.96 (15.6)	8.93 (80.3)	4.92 (23.8)	3.22 (9.88)	5.32 (27.8)	5.17 (27.1)	4.33 (18.9)	10.6 (113)	4.35 (18.9)	3.00 (8.53)	6.41 (40.6)
LSD (P=0.05)	0.37	0.13	0.32	0.23	0.09	0.15	0.31	0.10	0.05	0.22	0.07	0.17
Nutrient management												
N_1	5.94 (43.1)	3.68 (14.0)	8.07 (71.1)	4.70 (24.6)	3.10 (9.08)	7.22 (51.6)	5.76 (40.8)	4.32 (18.8)	8.23 (75.3)	4.38 (21.8)	2.83 (7.49)	5.87 (34.0)
N_2	5.20 (33.8)	3.04 (9.88)	7.24 (58.6)	4.17 (20.0)	2.62 (6.37)	4.68 (21.4)	5.05 (30.7)	3.45 (12.7)	7.44 (64.9)	3.76 (16.4)	2.38 (5.17)	5.15 (26.0)
N_3	6.04 (45.1)	3.84 (15.7)	8.12 (72.7)	4.75 (25.4)	3.19 (9.70)	5.32 (27.8)	5.95 (41.3)	4.38 (19.6)	8.26 (76.2)	4.44 (22.6)	2.96 (8.28)	6.64 (43.6)
LSD (P=0.05)	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03	0.06	0.02	0.02	0.06

T_1- Conventional tillage, **T_2**- Minimum tillage with 30% crop residue, **W_1**- Sugarcane trash mulching (5.0t/ha) at 10 DAS, **W_2**- PE Atrazine (0.25 kg/ha) followed by one hand weeding at 30 DAS, **W_3**- Twin wheel hoe weeding twice at 20 and 40 DAS, **N_1**-100% Recommended dose of fertilizer (NPK), **N_2**-75% RDF (NPK) + Vermicompost (2.5t/ha) + Azhophos (20kg/ha), **N_3**-50% RDF (NPK) + Vermicompost (2.5t/ha) + Azhophos (20kg/ha)

Black gram

Highest grass, sedge, BLW density and dry weight were noticed in zero tillage (ZT) with 30% maize residue (Table 2). Conventional tillage (CT) registered the lowest grass, sedge and BLW density and dry weight as compared to zero tillage with 30% maize residue. The reason could be due to conventional tillage causes inversion of soil resulting in deeper placement of weed seeds and causing a significant reduction in the population of weeds due to decay of weed seeds. Similar findings were also reported by Chahal *et al.* (2003) [3].

Among weed management practices, PE application of pendimethalin followed by one HW at 20 DAS recorded significantly the lowest grasses, sedge and BLW density and dry weight (Table 2). Season long herbicide efficacy and subsequent hand weeding during crop growth resulted in lowest weed density and dry weight. These results were confirmed with Sanbagavalli (2001) [9].

Among nutrient management practices, 75% RDF (NPK) + vermicompost + rhizobium registered significantly produced lesser grass, sedge and BLW population and dry weight (Table 2). However, 100% RDF (NPK) alone registered significantly higher weed density and dry weight. Similar findings were also reported and confirmed by Vijaymahantesh *et al.* 2016 [13].

Table 2: Effect of tillage weed and nutrient management practices on weeddensity (No/m²) and dry weight (g/m²) at 45 DAS in black gram

Treatments	Summer black gram 2017						Summer black gram 2018					
	Weed density			Weed dry weight			Weed density			Weed dry weight		
	Grass	Sedge	BLW	Grass	Sedge	BLW	Grass	Sedge	BLW	Grass	Sedge	BLW
Tillage												
T_1	8.46 (71.0)	5.69 (31.9)	8.25 (67.6)	5.50 (29.7)	3.80 (14.0)	6.71 (44.5)	7.48 (55.5)	4.92 (23.7)	7.72 (59.1)	4.79 (22.4)	3.63 (12.7)	6.17 (37.6)
T_2	8.76 (76.3)	5.90 (34.1)	5.68 (31.8)	5.84 (33.6)	4.02 (15.6)	7.22 (51.6)	7.67 (58.4)	4.97 (24.2)	7.87 (61.4)	4.80 (22.5)	3.71 (13.3)	6.50 (41.8)
LSD (P=0.05)	0.07	0.07	0.10	0.07	0.06	0.11	0.06	0.04	0.12	0.02	0.01	0.03
Weed management												
W_1	12.8 (164)	7.92 (62.2)	13.0 (168)	8.02 (63.9)	5.06 (25.1)	10.3 (105)	11.8 (138)	6.96 (47.9)	12.5 (156)	7.23 (51.8)	4.65 (21.1)	10.0 (100)
W_2	3.75 (13.6)	3.19 (9.67)	3.85 (14.3)	3.09 (9.06)	2.61 (6.31)	3.61 (12.5)	2.87 (7.72)	2.48 (5.67)	2.79 (7.28)	2.14 (4.06)	2.61 (6.29)	2.34 (4.98)
W_3	6.66 (43.9)	4.23 (17.4)	5.47 (29.4)	4.73 (21.9)	3.15 (9.41)	5.19 (26.4)	5.12 (25.7)	4.34 (18.3)	4.20 (17.1)	3.48 (11.6)	3.49 (11.7)	3.81 (14.0)
LSD (P=0.05)	0.50	0.27	0.53	0.27	0.14	0.38	0.51	0.25	0.57	0.29	0.11	0.22
Nutrient management												
N_1	8.79 (76.8)	5.82 (33.4)	8.63 (73.9)	5.79 (33.0)	3.94 (15.0)	7.12 (50.2)	7.82 (60.6)	5.17 (26.2)	7.94 (62.5)	4.95 (24.0)	3.82 (14.1)	6.47 (41.3)
N_2	8.32 (68.7)	4.84 (22.9)	7.92 (62.2)	5.48 (29.5)	3.38 (10.9)	6.58 (42.8)	7.09 (49.7)	4.58 (20.5)	7.29 (52.7)	4.47 (19.5)	3.51 (11.8)	5.93 (34.7)
N_3	8.72 (75.6)	5.78 (32.9)	8.73 (75.7)	5.74 (32.4)	3.91 (14.8)	7.18 (51.1)	7.82 (60.6)	5.07 (25.2)	8.13 (65.6)	4.94 (23.9)	3.70 (13.2)	6.60 (43.1)
LSD (P=0.05)	0.02	0.03	0.03	0.01	0.02	0.02	0.03	0.02	0.03	0.02	0.01	0.02

T_1- Conventional tillage, **T_2**- Zero tillage with 30% crop residue, **W_1**- Maize residue mulching (5.0t/ha) at 10 DAS, **W_2**- PE pendimethalin (1.0 kg/ha) followed by one hand weeding at 20 DAS, **W_3**- Twin wheel hoe weeding twice at 15 and 30 DAS, **N_1**-100% Recommended dose of fertilizer (NPK), **N_2**-75% RDF (NPK) + Vermicompost (2.5t/ha) + Rhizobium (20kg/ha), **N_3**-50% RDF (NPK) + Vermicompost (2.5t/ha) + Rhizobium (20kg/ha)

Weed control efficiency

Weed control efficiency indicated the extent of effectiveness of weed dry weight reduction by weed control treatments over unweeded control (Absolute control). Different tillage, weed and nutrient management treatments significantly influenced the weed control efficiency at 45 DAS in maize and black gram (Fig.1). Interaction effect between minimum tillage with 30% daincha residue and PE application of atrazine followed by one hand weeding at 30 DAS along with 75% RDF (NPK) + vermicompost + ahophosrecorded the highest WCE in maize. This might be due to higher suppression in weed growth by reducing the weed density. These finding are in accordance with the results of Kamble *et al.* (2015) [7]. Similarly in black gram, highest WCE was recorded in conventional tillage and PE application of pendimethalin followed by one hand weeding at 20 DAS along with 75% RDF (NPK) + vermicompost + rhizobium. The reason for higher WCE might be due to lower weed density and dry weight in respective treatments. It is in conformity with the results of Sangeetha *et al*. (2012) [10].

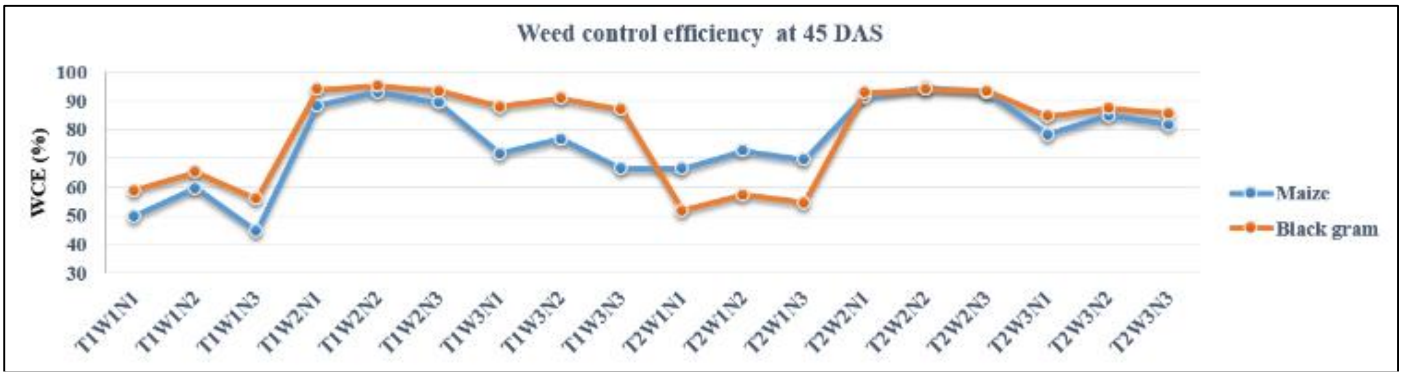

Fig 1: Effect of tillage, weed and nutrient management practices on weed control efficiency at 45 DAS in maize and black gram

Weed seed bank study

Tillage and weed management practices had significantly influenced the soil weed seed bank and weed dynamics. In case of nutrient management practices, no significant differences were shown on soil weed seed dynamics.

Pot culture

Grass weeds *viz., Chloris barbata, Cynodon dactylon, Dactyloctenium aegyptium* and *Echinochloa crus Galli,* sedges viz., *Cyperus rotundus* and *Trianthema portulacastrum* among BLWs were germinated under pot condition (Table 3).

Table 3: Post-harvest analysis of grass, sedge and BLW seed population on 45th day of germination under pot condition at 0-15cm and 15-30cm depth.

Treatments	0-15cm					15-30cm				
	CB	CD	EC	CR	TP	CB	CD	EC	CR	TP
T_1W_1	1.90 (3.10)	2.10 (3.89)	3.09 (9.06)	2.56 (6.03)	2.34 (4.97)	2.60 (6.25)	3.52 (11.9)	1.34 (1.30)	2.76 (7.10)	4.01 (15.6)
T_1W_2	1.43 (1.54)	2.52 (5.84)	2.57 (6.11)	3.23 (9.91)	1.81 (2.77)	2.32 (4.87)	2.70 (7.28)	1.11 (0.74)	3.02 (8.62)	3.48 (11.6)
T_1W_3	2.28 (4.70)	3.10 (9.14)	3.51 (11.8)	3.48 (11.6)	2.91 (7.97)	2.61 (6.33)	3.32 (10.5)	1.65 (2.22)	3.07 (8.90)	4.22 (17.3)
T_2W_1	3.07 (8.94)	3.48 (11.6)	2.49 (5.72)	3.59 (12.4)	2.05 (3.72)	2.35 (5.00)	2.00 (3.52)	1.04 (0.58)	1.61 (2.08)	2.66 (6.56)
T_2W_2	1.84 (2.88)	2.13 (4.05)	3.20 (9.73)	2.89 (7.87)	1.78 (2.66)	1.46 (1.63)	1.84 (2.88)	1.26 (1.10)	1.82 (2.81)	2.61 (6.30)
T_2W_3	2.68 (6.67)	3.51 (11.8)	3.09 (9.05)	3.45 (11.4)	2.86 (7.67)	1.89 (3.08)	1.97 (3.40)	1.35 (1.33)	1.83 (2.84)	2.80 (7.35)
LSD (P=0.05)	NS	NS	0.76	0.16	0.39	0.54	NS	NS	NS	NS

0-15cm depth

Among grass weeds, *Echinochloa Crus Galli* population was significantly lowest in conservation tillage with 30% crop residue and crop residue mulching (5.0t/ha) at 10 DAS (T_2W_1). However, there was no significant difference noticed in *Chloris barbata* and *Cynodon dactylon* population within tillage and weed management practices. *Cyperus rotundus* the only sedge population was significantly lowest in conventional tillage with crop residue mulching (5.0 t/ha) at 10 DAS (T_1W_1). Among BLWs, *Trianthema portulacastrum* population was significantly lower in conservation tillage (minimum/zero) with 30% crop residue and PE application of herbicide followed by one hand weeding (T_2W_2).The reason could be due to lower weed density, dry weight and higher weed control efficiency in the order of T_2W_2, T_2W_1 and T_1W_1 led to lower weed seed population in soil.

15-30cm depth

Chloris barbata a grass weed alone germinated and significantly reduced lower population in conservation tillage (minimum-zero) with 30% crop residue and PE application of herbicide followed by one hand weeding (T_2W_2). This might be due to allelopathic effect of crop residue retention in conservation tillage and prolonged efficacy of herbicides reduced the weed density, weed dry weight and higher weed control efficiency which ultimately caused lower weed seed population in soil. These findings are in line with Singh *et al.* (2007) [11] and Buhler *et al.* (1997) [2]. However, rest of weed flora viz., *Cynodon dactylon, Echinochloa Crus Galli, Cyperus rotundus* and *Trianthema portulacastrum* had not shown any significant differences at 15-30cm soil depth under pot condition.

Field studies

The grass weeds germinated in pot condition were also seen under field condition. Similarly, *Amaranthus viridis, Cleome viscosa, Parthenium hysterophorus* and *Trianthema portulacastrum* among BLWs and *Cyperus rotundus* among sedges were germinated under field condition. (Table 4 and 5). These findings concurred with Buhler *et al.* (1997) [2].

Table 4: Post-harvest analysis of grass, sedge and BLW seed population on 45th day of germination in field condition at 0-15cm depth.

Treatments	Grass				Sedge	BLW			
	CB	CD	DE	EC	CR	AV	CV	PH	TP
T_1W_1	3.33 (10.6)	2.90 (7.91)	2.50 (5.76)	2.28 (4.72)	3.30 (10.4)	4.07 (16.1)	3.36 (10.8)	4.11 (16.4)	4.01 (15.6)
T_1W_2	2.27 (4.64)	2.09 (3.86)	2.88 (7.81)	3.19 (9.68)	3.30 (10.4)	3.32 (10.6)	2.94 (8.17)	4.52 (19.9)	3.48 (11.6)
T_1W_3	3.67 (13.0)	3.42 (11.2)	1.89 (3.06)	3.70 (13.2)	3.83 (14.2)	4.40 (18.9)	4.04 (15.8)	4.48 (19.6)	4.22 (17.3)
T_2W_1	3.92 (14.9)	2.65 (6.51)	2.90 (7.93)	3.82 (14.1)	3.62 (12.6)	3.79 (13.9)	2.33 (4.93)	3.39 (11.0)	2.66 (6.56)
T_2W_2	3.55 (12.1)	3.33 (10.6)	2.14 (4.07)	3.52 (11.9)	3.95 (15.1)	3.22 (9.89)	2.17 (4.21)	4.11 (16.4)	2.61 (6.30)
T_2W_3	4.20 (17.1)	3.35 (10.7)	3.04 (8.73)	4.18 (17.0)	4.17 (16.9)	4.35 (18.4)	2.36 (5.08)	4.47 (19.5)	2.80 (7.35)
LSD (P=0.05)	0.17	0.13	0.13	NS	0.09	0.12	0.18	NS	NS

CB- *Chloris barbata,* **CD-** *Cynodon dactylon,* **EC-** *Echinochloa Crus Galli,* **CR-** *Cyperus rotundus,* **AV**-*Amaranthus viridis,* **CV-** *Cleome viscosa,* **PH-** *Parthenium hysterophorus,* **TP-** *Trianthema portulacastrum*

Table 5: Post-harvest analysis of grass, sedge and BLW seed population on 45th day of germination in field condition at 15-30cm depth

Treatments	Grass				Sedge	BLW			
	CB	CD	DE	EC	CR	AV	CV	PH	TP
T_1W_1	2.78 (7.23)	2.88 (7.78)	4.55 (20.2)	1.88 (3.02)	2.88 (7.77)	4.24 (17.5)	3.92 (14.9)	2.95 (8.23)	4.21 (17.2)
T_1W_2	1.78 (2.68)	2.19 (4.30)	4.04 (15.8)	2.87 (7.75)	2.48 (5.67)	3.54 (12.0)	4.06 (16.0)	4.34 (18.3)	5.11 (25.6)
T_1W_3	3.22 (9.86)	3.26 (10.1)	4.97 (24.2)	3.05 (8.83)	3.13 (9.32)	4.66 (21.2)	4.59 (20.6)	4.77 (22.3)	4.73 (21.9)
T_2W_1	3.09 (9.04)	2.06 (3.76)	2.51 (5.88)	1.94 (3.26)	2.26 (4.62)	2.19 (4.28)	2.25 (4.56)	2.17 (4.21)	3.04 (8.72)
T_2W_2	2.96 (8.23)	2.34 (4.97)	2.58 (6.16)	2.30 (4.77)	1.98 (3.43)	2.38 (5.18)	2.41 (5.32)	2.66 (6.57)	3.19 (9.65)
T_2W_3	3.26 (10.1)	1.85 (2.93)	2.18 (4.26)	1.79 (2.71)	1.98 (3.43)	2.31 (4.84)	2.45 (5.51)	3.79 (13.9)	2.68 (6.67)
LSD (P=0.05%)	0.14	NS	0.33	0.12	0.10	0.27	0.25	0.25	0.27

CB- *Chloris barbata,* **CD-** *Cynodon dactylon,* **EC-** *Echinochloa Crus Galli,* **CR-** *Cyperus rotundus,* **AV**-*Amaranthus viridis,* **CV-** *Cleome viscosa,* **PH-** *Parthenium hysterophorus,* **TP-** *Trianthema portulacastrum*

0-15cm depth

Conventional tillage with PE application of herbicide followed by one hand weeding (T_1W_2) recorded significantly the lowest grass weed population viz., *Chloris barbata* and *Cynodon dactylon*. The reduction of weed seed population in conventional tillage could be due to greater inversion of soil and thus led to occurrence of more weed seeds in deeper layer. These are confirmed with findings of Buhler *et al.* (1997) [2]. However, significantly lower *Dactyloctenium aegyptium* population was noticed in conventional tillage + twin wheel hoe weeding twice (T_1W_3). Similar results were observed by Yenish *et al.* (1992) [15]. Whereas, *Echinochloa Crus Galli* had no significant difference within tillage and weed management interaction. Lowest population of *Cyperus* *rotundus* was recorded in conventional tillage + crop residue mulching (5.0t/ha) at 10 DAS (T_1W_1) and conventional tillage + PE application of herbicide followed by one hand weeding (T_1W_2).

Among BLWs, *Amaranthus viridis and Cleome viscose* germination were lowest under conservation tillage with 30% crop residue with PE application of herbicide followed by one hand weeding (T_2W_2). However, no significant difference was noticed in *T. portulacastrum* and *P. hysterophorus* among tillage and weed management treatments. The weed seed reduction in soil could be due to allelopathy effect of crop residue retention and prolonged efficacy of herbicides along with subsequent hand weed weeding operation suppressed the weed seed germination. These findings are in line with Singh *et al*. (2007) [11] and Buhler *et al.* (1997) [2].

15-30cm depth

Conventional tillage with PE application of herbicide followed by one hand weeding (T_1W_2) recorded the lowest *Chloris barbata* seed population. The reason could be due to greater inversion of soil thus led to occurrence of weed seeds in deeper layer. These are confirmed with findings of Buhler *et al.* 1999. Whereas, conservation (minimum-zero) tillage with 30% crop residue and twin wheel hoe weeding twice (T_2W_3) recorded the lowest *Dactyloctenium aegyptium* and *Echinochloa Crus Galli* seed population at 15-30cm soil depth. Similar results were also observed by Yenish *et al.* (1992) [15]. Lower population of *Cyperus rotundus* was seen in conservation tillage (minimum-zero) with 30% crop residue and twin wheel hoe weeding twice (T_2W_3) and it was on par with conservation tillage (minimum-zero) with 30% crop residue retention with PE application of herbicide followed by one hand weeding twice (T_2W_2). However, no significant differences were observed in *Cynodon dactylon* population with respect to tillage and weed management interaction effects.

Among BLWs, *Amaranthus viridis, Cleome viscose* and *Parthenium hysterophorus* population were lower under conservation tillage (minimum-zero) with 30% crop residue and crop residue mulching at 10 DAS (T_2W_1). This might be due to season long residual effect of crop residue cover which suppressed the weed seed germination by continuous releasing of allelochemicals into soil. These findings are in line with Singh *et al*. (2007) [11]. However, *Trianthema portulacastrum* population was significantly lower in conservation tillage with 30% crop residue and twin wheel hoe weeding twice (T_2W_3). This is in accordance with findings of Yenish *et al.* (1992) [15].

Hence from the present investigation, conservation tillage (minimum/zero) with 30% crop residue and PE application of herbicide application followed by one hand weeding along with 75% recommended dose of NPK + vermicompost + bio-fertilizer effectively controlled weeds and recorded higher weed control efficiency and reduced the lower weed seeds in soil under maize based conservation agriculture system.

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