Progressive Agriculture 27: 39-47, 2016 ISSN: 1017 - 8139

Progressive Agriculture
Journal homepage:http://www.banglajol.info/index.php/PA

Diversities of soil weed seed bank and rice yield performance in response to tillage method and weeding regime

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Abstract

Rice field was infested with eight weed species. Among the species found in conventionally tilled plots, the five dominant species ranked in order of importance value were *Cynodon dactylon* (L.), *Paspalum distichum* (L.), *Cyperus rotundus* (L.), *Azolla pinnata* (L.) and *Cyanotis axillaris* (L.) while in stale seedbed the rank was *Paspalum distichum* (L.), *Cynodon dactylon* (L.), *Cyanotis axillaris* (L.), *Leersia hexandra* (L.) and *Cyperus rotundus* (L.). There were 15 weed species found in the soil weed seed bank studied at the net house. Among them five species were common of rice field. Ten new species were found in the seed bank. *Azolla pinnata* (L.), *Cyperus difformis* (L.) and *Paspalum commersonii* (L.) of field rice were not found in net house seed bank. In the field, *Cynodon dactylon* (L.) was the dominant over *Paspalum distichum* (L.) but at the net house *Paspalum distichum* (L.) was dominant over *Cynodon dactylon* (L.). In seed bank under conventional tillage, 11 species were found consisting of 3559 heads count and in stale seedbed 12 species consisting 3826 heads were counted. Among the identified species, nine were common in both tillage practice. *Parapholis strigose* (Dumort.) and *Phyllanthus niruri* (L.) were present in the soil of conventional tillage but not in stale bed while *Echinochloa colonum* (L.), *Fimbristylis miliaceae* (L.) and *Eragrotis gangetica* (Roxb.) were found in stale bed but not in conventional tillage. At the rice field grass weeds were dominant over sedges and broad leaf under the both types of tillage. At the seed bank of net house, grass weeds were dominant over sedges and broadleaf under conventional tillage while under stale seedbed, sedges were dominant over broad leaf and grass. Around 7% higher grain was recorded from stale seedbed compared to conventional tillage which attributed from higher number of effective tillers hill^{-1}, higher number of fertile grains panicle^{-1}, and lower number of sterile grains panicle^{-1}. Weed free condition yield the highest grains followed by the combination of pre and post-emergence herbicides and unweeded control yielded the lowest. Stale seedbed kept weed free yielded the highest followed by stale seedbed sprayed the two herbicides. Conventional tillage remained unweeded yielded the lowest grain.

Key words: Weed seed bank, conventional tillage, stale seedbed, herbicides, yield

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Introduction

Weed is the competitive nutrient absorbing destructive pest of crops (Laxminarayan and Mishra 2001). Among the factors responsible for low crop production, weeds are considered as the major limiting factors (Kalyanasundaram *et al.* 2006). In Bangladesh, weed infestation reduces the grain yield by 70-80% in *aus* rice (early summer), 30-40% for transplanted *aman* rice (late summer) and 22-36% for modern *boro* rice cultivars (winter rice) (BRRI, 2006; Khan and Ashraf, 2006; Sarker, 1996). Subsistence farmers of the tropics spend more time, energy and money on weed control than on any other aspects of crop production (Kassasian, 1971). Poor weed control is the major factors responsible for reduction in yield (Amarjit *et al.,* 1994). Therefore, weed control with minimum cost and less adverse effect on environment is of prime importance.

Farmers' in the tropics and subtropics of Asian continent are used to cultivating rice through seedlings transplanting in puddled soil (Singh *et al*., 2014) usually for easy crop establishment and weed control (Zahan *et al.,* 2014). In Bangladesh puddling is achieved by 3-4 ploughing and cross ploughing done by power tiller or two wheeler tractor (Haque *et al.,* 2008). This traditional method is very labor and capital intensive. About 30 man days and 20-40% water of total crop production requires for puddling one hector land (Singh *et al.,* 2014). But the world is suffering from severe labor crisis with higher wage rate. Not only that, puddling is detrimental to soil health through formation of hard pan (Sharma *et al.,* 1995), destroying soil aggregates breaking, capillary pores, increasing bulk density, reducing soil organic carbon and decreasingsoil fertility (Gupta *et al.,* 2003). So, it is the high time finding out an alternative of puddling and reduced tillage might be one option. There are different forms of reduced tillage. Stale seedbed technique is one them which very in Bangladesh. But reduced tillage is characterized by a large weed species and changes in tillage practices from conventional to reduce can lead to shifts in weed composition in agricultural farming system (Ball and Miller, 1993). Heavy weed pressure in reduced tillage triggers to find appropriate weed control practice for successful crop production. Manual Weed control is very costly in terms of huge labor demand and weed control using herbicides is a smart tool. But other methods need to be integrated with herbicides to avoid the bad effect of chemicals. Managing of soil weed seed bank might be an effective and sustainable approach for controlling weeds in reduced tillage system.

The weed seed bank is the reserve of viable weed seeds present on the soil surface and scattered throughout the soil profile. It consists of both new weed seeds recently shed, and older seeds that have persisted in the soil from previous years. In practice, the soil's weed seed bank also includes the tubers, bulbs, rhizomes, and other vegetative structures through which most serious perennial weeds propagate themselves. The weed seed bank serves as a physical history of the past successes and failures of cropping systems, and knowledge of its content (size and species composition) can help producers both anticipate and ameliorate potential impacts of crop weed competition on crop yield and quality. One of the most important, yet often neglected, weed management strategies is to reduce the number of weed seeds present in the field. This reduction can be accomplished by managing the soil weed seed bank. Considering the above facts, the present study was undertaken investigate the diversities of weeds in the soil weed seed bank in respect of the effect of tillage and weed management practice on the yield performance of rice.

Materials and Methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from June to December 2012. Binadhan-7 was transplanted with two tillage methods *viz.,* (i) Conventional tillage and (ii) Stale seedbed; andnine weeding regimes*viz.,* (i) Unweeded (UW), (ii) Hand weeding (HW) at 20 days after transplanting (DAT) and 40 DAT, (iii) HW at 40 DAT and 70 DAT, (iv) Pre-emergence herbicide, (v) Pre-emergence herbicide + HW at 40 DAT, (vi) Post-emergence herbicide, (vii) Post-emergence herbicide + HW at 70 DAT, (viii) Pre-emergence herbicide followed by post emergence herbicide, and (ix) Weed free (WF). Butachlor @ 25kg ha^{-1} was used as pre-emergence and Pyrazosolfuran-Ethyl @ 1.12 L ha^{-1} was used as post-emergence herbicide. The design was split plot with three replications. Tillage was assigned in the main plot while the weeding regimes were on the sub plots. The land was well prepared and balanced fertilized as per the recommendations of BINA (2011).

For weed seed bank study, soils were collected from five spots of each plot with auger to a depth of 15 cm following W-shape patterns. Approximately one-kilogram soil from each plot was placed in plastic trays. The soils were kept moist sprinkling water daily. Emerged weed seedlings were identified using the seedling keys of Chancellor (1966). Heads were counted, and removed at fifteen days' interval throughout the cropping season. Seedlings of questionable identity were transferred to another pots and grown until maturity. After the removal of each batch of seedlings, soils were air dried, thoroughly mixed, and rewetted to permit further emergence. This process was repeated until the emergence was stopped. In the field, the density of infesting weed species was recorded with a quadrate of 1 m × 1 mand theimportance value (IV) for each weed species was calculated using the equation as follows:

$$IV (\%) = \frac{\text{Number of each species in a community}}{\text{Total number of all species in a community}} \times 100$$

All the yield contributing characters and yield were recorded. Data were subjected to ANOVA using Duncan's Multiple Range Test.

Results and Discussion

Weed infestation in the rice field

The experimental plots were infested with eight weed species belonging to four families (Table 1). Four weed species were of the family Poaceae, two of the family Cyperaceae, and one each of the family Commelinaceae and Azollaceae. Based on the importance value, perennial weeds constituted 62.5 % and annual weed constituted37.5% of the weed population.

Table1. Weed species identified in the experimental plots

Local name	English name	Scientific name	Family	Weed type	Life cycle
1. Khude pana	Azolla	*Azolla pinnata* (L.)	Azollaceae	Broadleaf	Annual
2. Kanai nala	Spreading day flower	*Cyanotis axillaris* (L.)	Commelinaceae	Broadleaf	Annual
3. Sabuj nakful	Small flowered umbrella	*Cyperus difformis* (L.)	Cyperaceae	Sedge	Annual
4. Mutha	Purple nutsedge	*C. rotundus* (L.)	Cyperaceae	Sedge	Perennial
5. Angta	Joint grass	*Paspalum distichum* (L.)	Poaceae	Grass	Perennial
6. Gaicha	Paspalum grass	*P. commersonii* (Lamk.)	Poaceae	Grass	Perennial
7. Arail	Swamp rice	*Leersia hexandra* (Sw.)	Poaceae	Grass	Perennial
8. Durba	Bermuda grass	*Cynodon dactylon* (L).	Poaceae	Grass	Perennial

In conventional tillage method, among the infesting weed species the five most dominant weeds based on importance value were *Cynodon dactylon>Paspalum distichum>Cyperus rotundus>Azolla pinnata> Cyanotis axillaris* and rest of the three weed species represented 1.95% (Figure 1). Grasses were dominant over broadleaf and sedges (Figure 2). In stale seedbed method, among the infested weed species five most dominant weed species based on importance value were *Paspalum distichum> Cynodon dactylon >Cyanotis axillaris> Leersia hexandra>Cyperus rotundus* and rest of the three weed species represented around 10% of total (Figure 3). Grasses were dominant over broadleaf and sedges (Figure 4).

Weed species found in soil weed seed bank at the net house

There were 15 weed species identified in soil weed seed bank (Table 2). Six species belonged to the family Poaceae, three to Cyperaceae, two to each of Commelinaceae and Euphorbiaceae and one each of the family Najadaceae, and Sphenocleaceae. Based on the importance value, annual weeds constituted 60% and perennial constituted 40% of the total weed population.

In the seed bank of conventionally tilled plots, eleven weed species were found (Table 3). Among them the five most dominant weeds based on importance value were *Cynodon dactylon>Paspalum distichum> Cyperus rotundus>Leersia hexandra>Commelina benghalensis* and rest of the six weed species represent around 6% of total importance value (Figure 5). Grasses were dominant over broadleaf and sedges (Figure 6).

In stale seedbed method, twelve weed species were observed in the soil seed bank (Table 4). Among them the five most dominant weeds based on importance value were *Cynodon dactylon>Cyperus rotundus>Commelina benghalensis>Paspalum distichum>Leersia hexandra* and rest of the weed species represent around 3% of whole weed population (Figure 7). Sedges were dominant over broadleaf and grasses (Figure 8).

Diversities in the weed species composition was observed in soil weed seed bank than the above ground weed flora of rice field. In the experiment plots, eight weed species were found but in the seed bank studied at the net house, 15 species were identified.

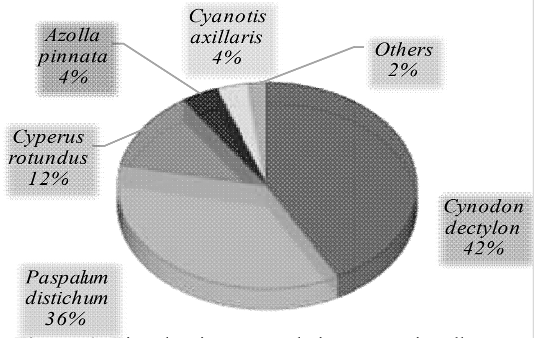

Figure 1: Five dominant weeds in conventionally tilled plots

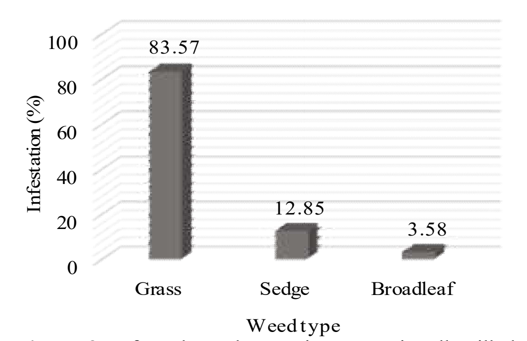

Figure 2. Infested weed types in conventionally tilled plots

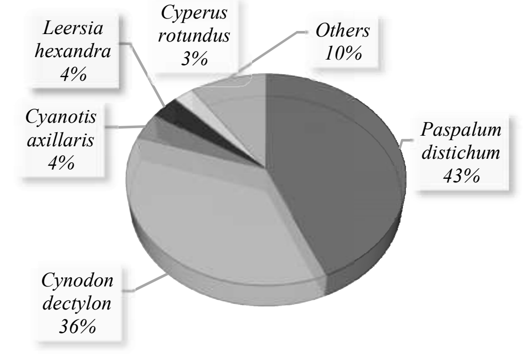

Figure 3. Five dominant weeds in stale seedbed

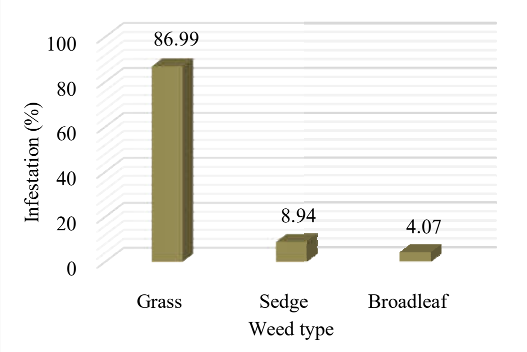

Figure 4. Infested weed types in stale seedbed

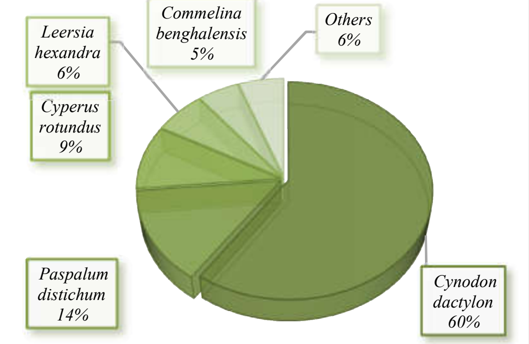

Figure 5. Five dominant weeds in the seed bank of conventionally tilled plot

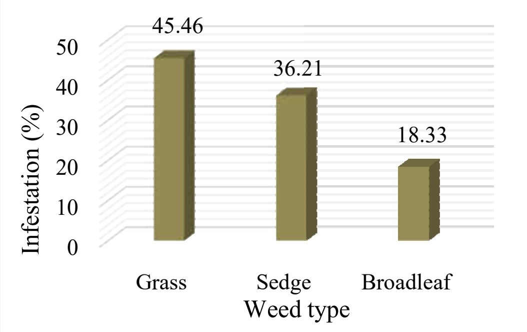

Figure 6. Infested weed types in the seed bank of

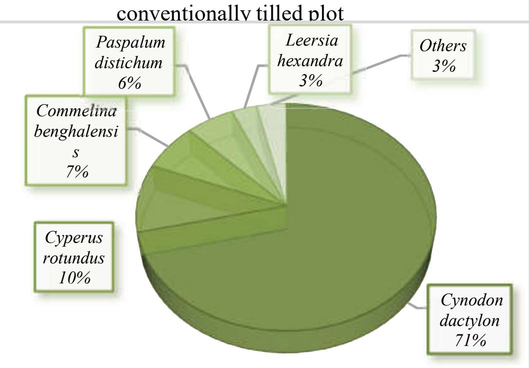

Figure 7. Five dominant weeds in the seed bank of stale seedbed

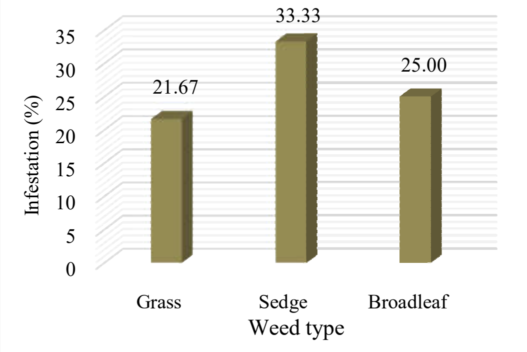

Figure 8. Infested weed types in the seed bank of stale seedbed

Table 2. Weed species identified in the soil seed bank

Local name	English name	Scientific name	Family name	Weed type	Life cycle
1. Arail	Swamp rice	*Leersia hexandra* (Sw.)	Gramineae	Grass	Perennial
2. Angta	Joint grass	*Paspalum distichum* (L.)	Gramineae	Grass	Perennial
3. Durba	Bermuda grass	*Cynodon dactylon* (L.)	Gramineae	Grass	Perennial
4. Chira ghas	Slim flower grass	*Eragrotis gangetica* (Roxb.)	Gramineae	Grass	Annual
5. Khude shama	Jungle rice	*Echinochloa colonum* (L.)	Gramineae	Grass	Annual
6. Chela	Hard grass	*Parapholis strigose* (Dumort.)	Poaceae	Grass	Annual
7. Boro chocha	Umbrella sedge	*Cyperus irria* (L.)	Cyperaceae	Sedge	Annual
8. Mutha	Purple nut sedge	*C. rotundus* (L.)	Cyperaceae	Sedge	Perennial
9. Joina	Grass like fimbry	*Fimbristylis miliaceae* (L.)	Cyperaceae	Sedge	Perennial
10. Pani shapla	Water nymph	*Najas graminea* (Del.)	Najadaceae	Broadleaf	Perennial
11. Bon morich	Croton plant	*Croton sparsiflorus* (L.)	Euphorbiaceae	Broadleaf	Annual
12. Hazar dana	Corn spurge	*Phyllanthus niruri* (L.)	Euphorbiaceae	Broadleaf	Annual
13. Kanai nala	Spreading day flower	*Cyanotis axillaris* (L.)	Commelinaceae	Broadleaf	Annual
14. Kanai bashi	Spider wort	*Commelina benghalensis* (L.)	Commelinaceae	Broadleaf	Annual
15. Jheel morich	Chicken spike	*Sphenoclea zeylanica* (Gaertner.)	Sphenocleaceae	Broadleaf	Annual

Seven new species found in soil weed seed bank compared to the rice field among them five were similar in both conventional tillage and stale seedbed (Table 1 and Table 2). On the other hand, *Azolla pinnata* (L.), *Cyperus difformis* (L.) and *Paspalum commersonii* (L.) were found in rice field as above ground flora but not found in soil seed bank in both tillage system (Table 1 and Table 2). At the rice field, *Cynodon dactylon* was the dominant followed by *Paspalum distichum* (L.) but at the net house the reverse scenario was observed i.e. *P. distichum* (L.) was the dominant over *C. dactylon* (L.) (Figure 1 and Figure 3). Such type of diversities might be due to the different environmental condition affecting the germination pattern of weeds which influencing the altercation of species composition.

Table 3. Weed species found in the soil weed seed bank of conventionally tilled plots

Weed species	Head count (no.)	Importance value (%)
1. *Cynodon dactylon* (L.)	2185	59.67
2. *Paspalum distichum* (L.)	508	13.87
3. *Cyperus rotundus* (L.)	346	9.45
4. *Leersia hexandra* (L.)	232	6.34
5. *Commelina benghalensis* (L.)	186	5.08
6. *Cyperus irria* (L.)	22	2.89
7. *Najas graminea* (Del.)	20	0.75
8. *Parapholis strigose* (Dumort.)	19	0.62
9. *Croton sparsiflorus* (L.)	17	0.56
10. *Sphenoclea zeylanica* (Gaertner.)	16	0.45
11. *Phyllanthus niruri* (L.)	8	0.32
Total	**3559**	**100**

Table 4. Weed species and density found in the soil weed seed bankof stale seedbed plots

Weed species	Head count (no.)	Importance value (%)
1. *Cynodon dactylon* (L.)	2719	71.29
2. *Cyperus rotundus* (L.)	371	9.73
3. *Commelina benghalensis* (L.)	258	6.76
4. *Paspalum distichum* (L.)	219	5.74
5. *Leersia hexandra* (Sw.)	114	2.99
6. *Cyperus irria* (L.)	48	1.25
7. *Sphenoclea zeylanica* (Gaertner.)	33	0.76
8. *Echinochloa colonum* (L.)	27	0.61
9. *Najas graminea* (Del.)	17	0.35
10. *Croton sparsiflorus* (L.)	8	0.21
11. *Fimbristylis miliaceae* (L.)	8	0.21
12. *Eragrotis gangetica* (Roxb.)	4	0.10
Total	**3826**	**100**

In the soil seed bank study, under conventional tillage 11 species were found consisting of 3559 heads and in stale seedbed 12 species consisting 3826 heads were found ((Table 3 and Table 4). Among them, nine species were common in both tillage systems. But, two species *viz., Parapholis strigosa* (Dumort.) and *Phyllanthus niruri* (L.) were present in conventional tillage system and absent in stale seedbed. There were three species *viz., Echinochloa colonum* (L.)*, Fimbristylis miliaceae* (L.) and *Eragrotis gangetica* (Roxb.) were found in stale bed but not found in conventional tillage. Such type of altercation in seed bank might be due to differences in tillage systems. About 267 more weeds were presented in stale bed might be due to the higher dormancy of seeds in stale bed by the minimal disturbance of soils. Reduced number of weeds in the conventional tillage occurred might be by the heavy pulverization that lowered the weed seed bank composition in the soil. This finding is the line of Andrew and Kelton (2011) concluding reduced tillage triggers the higher weeds pressure compared to conventional tillage and hence their management is a great challenge. However, the five most dominant weed species were similar between conventional tillage and stale seedbed but they differed in respect of their importance value from each other (Figure 5 and Figure 7), consequently, the rank of order was different between these two tillage methods. Therefore, rice cultivation adopting stale bed practice necessitates proper weed control practice and understanding the diversities in seed bank may help to investigate the effective weed control strategy (s).

Effect of tillage methods on yield attributes and yields of rice

Tillage method exerted significant effect on all the plant characters of rice except the number of sterile grains per panicle, 1000 grain weight, straw yield and biological yield (Table 5). The taller plant (86.95 cm) was obtained from stale seedbed method and shorter plant (82.19 cm) obtained from conventional tillage. The higher number of tillers hill^{-1} (86.95) was recorded from stale seedbed and the lower number of tillers hill^{-1} (82.19) was from conventional tillage. Stale seedbed produced the higher number of effective tillers hill^{-1} (9.54) and the lower number of effective tillers (8.65) was obtained from conventional tillage. The highest number of non-effective tillers hill^{-1} (2.42) was obtained from conventional tillage while the stale seedbed produced the lower number of non-effective tillers hill^{-1} (1.63). The higher number of fertile grains panicale^{-1} (87.69) was recorded from stale seedbed and the lower number of fertile grains panicale^{-1}(80.69) was obtained from conventional tillage. Stale seedbed yielded the highest grain (4.50 tha^{-1}) while the lower (4.39 tha^{-1}) was recorded from conventional tillage. The higher harvest index (45.41) was recorded from stale seedbed which might be resulted from the higher grain yield. The lower harvest index (44.36) was calculated from conventional tillage.

Effect of weeding regimes on yield attributes and yield of rice

All the plant characters of rice except plant height, number of non- effective tillers plant^{-1}, 1000 grain weight, and harvest index were influenced significantly by the weeding regimes (Table 6). The plant height is the varietal character was not influenced by the weeding regimes. The highest number of tillers (13.82) was produced from weed free treatment which was identical to pre-emergence herbicide followed by the post-emergence herbicide (13.31). Control treatment produced the lowest number of tillers (8.09). Weed free treatment produced the highest number of effective tillers (11.85) while the combination of pre and post-emergence herbicide produced the second highest value (9.89). Unweeded treatment produced the lowest number of effective tillers (5.99). The highest number of fertile grains panicle^{-1} (98.96) was recorded from weed free treatment which was identical to pre-emergence herbicide followed by post-emergence herbicide (98.88). Control treatment produced the lowest number fertile grains (55.99). Control treatment produced the highest sterile grains (22.21) and the lowest sterile grains were found in the weed free treatment (9.04) followed by the combination of pre and post emergence herbicide. Weed free treatment yielded the highest grains (5.92 t ha^{-1}) and the combination of pre emergence and post emergence herbicide yielded the second highest grains (5.72 t ha^{-1}). Bhowmick *et al*. (2001) found similar finding who concluded application of a pre emergence herbicide followed by a post emergence control weeds more effectively and increase the crop yield. The lowest grain (4.27 t ha^{-1}) was recorded from the control. The lowest straw yield was recorded from the control (3.00 t ha^{-1}) and the highest (5.89 t ha^{-1}) was found in weed free treatment which was identical to pre emergence herbicide followed by post emergence herbicide (5.24 t ha^{-1}). The highest biological yield (11.16 t ha^{-1}) was calculated from weed free treatment which was identical to combination of pre and post emergence herbicide (11.06t ha^{-1}). Unweeded control earned the lowest biological yield (7.28 t ha^{-1}).

Interaction effect of tillage methods and weeding regimes on yield attributes and yields of rice

Treatment interaction was significant on the number of effective tillers hill^{-1}, number of fertile grains panicle^{-1}, number of sterile grains panicle^{-1}, and grain yield of rice while rest of all the parameters were not affected (Table 7). Stale seedbed kept weed free produced the highest number of effective tillers hill^{-1} (12.25) which was identical to the stale bed sprayed the combination of pre and post emergence herbicides (11.85). Conventional tillage remained unweeded produced the lowest number of effective tillers hill^{-1} (5.76) followed by stale bed unweeded (6.22).The highest number of fertile grains panicle^{-1} was recorded from stale seedbed kept weed free (103.73) followed by stale bed sprayed the combination of pre and post emergence herbicide (97.99).conventional tillage kept unweeded produced the lowest fertile grains (47.01) followed by stale bed remained unweeded (64.78).

Table 5. Effect of tillage methods on yield attributes and yields of rice

Tillage method	Plant height (cm)	Total tiller hll^{-1} (no.)	Effective tiller hll^{-1} (no.)	Non-effective tiller hll^{-1} (no.)	Fertile grains panicle^{-1} (no.)	Sterile grains panicle^{-1} (no.)	1000 grain weight (gm)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
CT	82.19b	10.27b	8.65b	2.42a	80.69b	19.93	21.97	4.19b	5.46	9.85	44.36b
SS	86.95a	11.96a	10.54a	1.63b	87.69a	13.49	21.96	4.50a	5.36	9.86	45.41a
CV (%)	3.80	7.13	6.01	19.41	5.10	14.55	3.45	5.39	3.66	3.85	3.61
LS	*	**	*	**	*	NS	NS	**	NS	NS	**

CT= Conventional tillage, SS= Stale seedbed, *= Significant at 5% level of probability, **= Significant at 1% level of probability, NS = Non-significant. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly

Table 6: Effect of weeding regimes on yield attributes and yield of rice

Weeding regimes	Plant height (cm)	Total tiller hll^{-1} (no.)	Effective tiller hll^{-1} (no.)	Non-effective tiller hll^{-1} (no.)	Fertile grains panicle^{-1} (no.)	Sterile grains panicle^{-1} (no.)	1000 grain weight (gm)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
UW	80.47	8.09f	5.99e	2.30	55.99e	22.21a	21.64	4.27g	3.00g	7.28f	41.27
W$_1$	82.42	9.58e	7.42d	2.16	75.17d	12.15def	21.84	4.97f	3.83f	8.81e	43.50
W$_2$	83.50	9.94de	7.88d	2.06	78.77d	12.97cde	21.72	5.22e	4.22d	9.43d	44.70
W$_3$	85.88	11.10c	8.89c	2.21	84.97c	15.09bc	22.21	5.61cd	4.30d	9.91c	43.40
W$_4$	86.01	11.10c	11.85a	2.10	89.90bc	14.38bcd	21.81	5.17e	4.62c	10.35c	46.93
W$_5$	84.37	12.35b	10.29b	2.06	92.60b	11.51efg	22.21	5.41d	4.97bc	10.37bc	47.87
W$_6$	84.37	12.19b	8.89c	2.21	84.97c	15.09bc	22.07	5.61cd	4.30d	9.91c	43.40
W$_7$	86.09	13.31a	9.89b	1.97	98.88a	10.40fg	22.26	5.72b	5.24ab	11.06a	46.77
WF	83.90	13.82a	11.44a	1.88	98.96a	9.04g	22.26	5.92a	5.89a	11.16a	44.61
CV (%)	3.80	7.13	6.01	19.41	5.10	14.55	3.45	3.66	5.39	3.85	3.61
LS	NS	**	**	NS	**	**	NS	**	**	**	NS

UW: Unweeded, W$_1$: hand weeding at 20 DAT and 40 DAT, W$_2$: hand weeding at 40 DAT and 70 DAT, W$_3$: Pre-emergence herbicide, W$_4$: Pre-emergence herbicide + Hand weeding at 70 DAT, W$_5$: Post emergence herbicide, W$_6$: Post-emergence herbicide + Hand weeding at 40 DAT (W6), W$_7$: Pre-emergence herbicide followed by post emergence herbicide, WF: Weed free *= Significant at 5% level of probability, **= Significant at 1% level of probability, NS = Non significant, In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly

Conventional tillage or stale bed remained unweeded produced the highest sterile grains panicle^{-1}. Stale bed kept weed free produced the lowest sterile grains (8.96) which was identical to stale bed sprayed the combination of pre and post emergence herbicide (9.75).Stale bed kept weed free yielded the highest grain (5.28 tha^{-1}) which was identical to stale bed sprayed the combination of pre or post emergence herbicide (5.22 tha^{-1}). The second highest grain (5.07tha^{-1}) was yielded from conventionally tilled plots kept weed free. Unweeded plots under conventional tillage yielded the lowest grain (5.28 tha^{-1}) followed by stale bed remained unweeded (3.05 tha^{-1}).

Results reveal that, soil weed seed bank status shows diversity in the composition of weed speciesin respect to tillage system. Seed bank of stale bed was richer than conventional practice. This scenario triggers to find out effective weed control method(s) for stale seedbed technique. Spraying a pre-emergence herbicide followed by a post-emergence herbicide might an options for controlling weeds and obtaining higher outcome. Although, weed free gave the highest benefit, it is not possible for the farmers keeping fields weed free. Land preparation conventionally by 3 to 4 ploughing require is very costly in terms of higher labor with higher wage as the world is facing severe labor shortage. Considering this fact and yield performance of stale bed, it might be concluded that, rice cultivation following stale seedbed and managing weeds by spraying the combination of pre and post emergence herbicide is more beneficial over the conventional practice of rice cultivation.

Table 7. Interaction effect of tillage methods and weeding regimes on yield attributes and yield of rice

Treatment Combina-tion	Plant height (cm)	Total tiller hll^{-1} (no.)	Effective tiller hll^{-1} (no.)	Non-effective tiller hll^{-1} (no.)	Fertile grains $panicle^{-1}$ (no.)	Sterile grains $panicle^{-1}$ (no.)	1000 grain weight (gm)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biologic-al yield (tha^{-1})	Harvest index (%)
CT UW	81.20	7.64	5.76j	1.85	47.01j	23.72a	21.75	2.16kl	7.11	9.27	40.55
CT W_1	82.07	8.22	6.8hi	1.40	75.66h	12.55h	20.25	2.25k	6.90	9.15	44.32
CT W_2	80.25	8.86	7.55g	1.01	74.36h	12.69h	10.99	2.95jk	6.18	9.13	44.25
CT W_3	86.31	13.02	7.50g	1.51	77.02hi	10.21gh	21.55	4.06gh	5.84	9.90	42.15
CT W_4	80.99	10.25	7.48g	2.37	77.98hi	11.85fgh	21.25	4.25g	5.25	9.75	46.25
CT W_5	79.68	11.62	9.66de	1.68	81.40gh	13.58d-f	22.27	4.25g	5.84	10.09	42.58
CT W_6	86.31	8.55	6.83hi	4.28	87.25ef	12.26h	21.25	4.50def	5.66	10.15	46.25
CT W_7	84.10	12.25	6.55g	1.69	86.23ef	11.07gh	21.99	4.58de	5.58	10.16	43.50
CT WF	78.61	10.68	8.58fg	2.40	82.77gh	16.36h	22.23	5.07bc	5.77	10.84	41.99
SS UW	79.69	8.25	6.22i	2.36	64.78i	20.70ab	21.56	3.05j	6.22	9.27	41.69
SS W_1	82.25	10.36	6.22i	2.36	74.25h	11.72fgh	21.74	3.58hi	6.22	9.90	42.25
SS W_2	86.25	10.32	7.56g	3.02	85.25fgh	14.2c-f	21.22	3.22i	6.00	9.22	47.12
SS W_3	90.77	14.62	11.22bc	2.43	82.25fghj	14.97c-f	21.55	4.13fg	5.83	9.96	42.32
SS W_4	90.77	12.13	10.08de	2.06	89.645def	15.95abc	22.17	4.23e	5.26	9.49	44.56
SS W_5	89.36	13.08	10.65cd	2.43	93.81bcd	22.14	21.07	4.71cd	5.25	9.96	48.77
SS W_6	90.69	11.13	9.43ef	1.70	92.13bcd	15.12c-f	22.10	4.45de	5.13	9.58	45.72
SS W_7	88.07	14.29	11.82ab	2.47	97.99bc	9.75h	22.08	5.22a	5.83	11.05	47.51
SS WF	89.19	13.42	12.25a	2.20	103.73a	8.96h	22.19	5.28a	5.58	10.86	45.97
CV (%)	3.80	7.13	6.01	19.06	5.10	14.55	3.45	5.39	3.66	3.85	3.61
LS	NS	NS	**	NS	*	**	NS	*	NS	NS	NS

CT= Conventional tillage, SS= Stale seedbed, UW: Unweeded, W_1: hand weeding at 20 DAT and 40 DAT, W_2: hand weeding at 40 DAT and 70 DAT, W_3: Pre-emergence herbicide W_4: Pre-emergence herbicide + Hand weeding at 70 DAT, W_5: Post emergence herbicide, W_6: Post-emergence herbicide + Hand weeding at 40 DAT (W6), W_7: Pre-emergence herbicide followed by post emergence herbicide, WF: Weed free*= Significant at 5% level of probability, **= Significant at 1% level of probability, NS = Non significant, In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly

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