Evaluation of alternate tillage and weed management options on production potential and weed incidences for dry seeded rice

ABSTRACTS

The study which aims at the evaluation of conservation tillage and to identify appropriate management options for dry seeded rice (DSR) under conservation tillage system was carried out at the Bangladesh Rice Research Institute (BRRI), regional station, Rajshahi during wet season of 2010-11 and 2011-12. The experiment was laid out in split plot design with three replications. The main plot treatments were Zero tillage (ZT), Strip tillage (ST) using power tiller operated seeder (PTOS), Minimum tillage using PTOS (MT), Permanent bed (PB) using bed planter, Fresh bed (FB) using bed planter and Conventional tillage (CT). Except conventional tillage, other alternate tillage treatments considerad as conservation tillage treatments. The subplot treatments were Weed free (W_1); Post emergence herbicide + 1 hand weeding (W_2), Pre-emergence herbicide + post-emergence herbicide (W_3), Post emergence herbicide (W_4) and Weedy control (W_5). Among the tillage treatments, conventional tillage (CT) registered the comparatively lower population as well weeds biomass. Alternate tillage treatments showed about similar result in terms of weed incidences. Again, crop weed competition almost remained same among the weed free and herbicide applied treatments. Although the number of panicle m^{-2} was comparatively lower, the higher panicle length associated with higher grains $panicle^{-1}$ was achieved in fresh bed and permanent bed treatments. The grain yield of rice was also comparable among the conventional tillage, bed planting system and also the zero or strip tillage treatments. On the other-hand, the post emergence herbicide (Bispyribac Na^+) was found more effective in controlling weeds where weed free treatment and Nominee gold + 1 hand weeding (HW) treatment showed identical effect in relation to weed intensity and grain and straw yield of rice.

Keywords: Alternate tillage, Nominee gold, weed incidences, dry seeded rice, weed free condition

INTRODUCTION

Rice, a cereal crop plays a vital role in global food security and acts as a main source of nutrition for the millions of farm families living in Asia especially in Bangladesh**.** Puddling associated with conventional excessive alternate tillage consumes a high proportion (30-35%) of the total operational energy for rice production. At present, conventional tillage pose some serious concerns e.g. high fuel, time and labour requirement, soil compaction and deterioration in soil structure (Mitchell *et al.,* 2009). Intensive tillage practices may also result in increased greenhouse gas emissions and energy requirements (Gathala *et al*., 2011b). It also caused long-term sustainability of intensive cultivation systems in South Asia (Joshi *et al*., 2005; Timsina *et al*., 2011). Now the challenges of crop production are to produce more food at less cost and to improve water, labor and land productivity. One of the strategies is to grow crop with the introduction of alternate tillage systems with use of direct drill seeder. Alternate tillage options reduce the production costs; time and labor. With the advent of effective herbicides and rising concern over natural resource degradation, conservation tillage systems have gained more attention in recent years. Moreover, the application of machineries in conservation agricultural system reduces drudgery of farm work and sustain crop production at more economic levels (Osunbitana *et al.*, 2005). The zero or strip tillage, reduced or minimum tillage and raised bed practices are to be considered as conservation tillage. Compared with conventional, conservation agriculture (CA) has been found to maintain or increase crop yields, improve soil fertility and reduce soil erosion (Hobbs *et al*., 2008; Kassam *et al.*, 2009).

Conservation tillage can improve soil physical, chemical and biological properties (Rice and Smith, 1984; Franzluebbers *et al.*, 1994) and decrease input costs for labor, tractor and other equipment's. Benefits from conservation tillage, include improvement of soil properties e.g. soil water content (Moreno *et al*., 1997) and aggregate stability and soil aggregation (McQuaid and Olsen, 1998), savings of time and energy and water and wind erosion control. Growers can save 30-40% of time, labor, and fossil fuels through CA as mechanized compared to conventional cropping (Hobbs and Gupta, 2004).

Conservation tillage practices, such as zero tillage and permanent raised beds combined with straw mulching, may offset the production costs and other constraints associated with land preparation (Hobbs, 2001). In zero tillage, the soil is left undisturbed except for seed or nutrient placement. The minimal soil disturbance is achieved with special equipment like tine openers, litho or coulters etc. Zero tillage has been evaluated in rice in the United States (Watkins *et al.*, 2004, Linquist *et al.*, 2008) and in the Philippines (Mabbayad and Buensosa, 1967) and the authors reported similar yield in some seasons but not in others between zero and conventional tillage. Strip tillage decreases both the volume of soil disturbance and reduces fuel, labor and equipment costs when compared with traditional broadcast tillage (Johansen *et al.*, 2012). Strip tillage is practiced in irrigated row crop production systems in Colorado and Western Nebraska (Smith and Pearson, 2004). Bed planting is a technique of conservation tillage for improving resource use efficiency and increasing the yield. Growing wheat on raised beds in the Indo-Gangetic Plains (IGP) started few years ago. The practice of planting rice, the major water using crop in the rice-wheat cropping system, on narrow raised bed was introduced very recently in South Asia (Connor *et al.*, 2003). Permanent raised beds were introduced as a resource conservation technology to address the economic, water and soil constraints of conventional flat sowing. Potential benefits of raised bed for production of upland crop after rice in the IGP have been reported in terms of yield and water productivity (Yadvinder-Singh *et al.*, 2008).

The direct dry seeded rice (DSR) is a resource conservation technology as it incurs low labor expenses and is conducive to mechanization (Bhuiyan *et al.*, 1995; Mahajan *et al.*, 2012a,b; Singh *et al.*, 2006; Jeghangir *et al.*, 2005). Farooq *et al.* (2011) summarized the benefits of DSR i.e. substantially reduce crop water requirements, soil organic matter turn over and reduce greenhouse gas emissions because of its low-input demand. Earlier planted DSR matures 1-2 weeks before TPR, thus reducing the risk of terminal drought and allowing earlier planting of a following non-rice crop (Saleh *et al.*, 2000). Aerobic rice systems can reduce water application by 44% relative to conventionally transplanted systems by reducing percolation, seepage and evaporative loses, while maintaining yield at an acceptance level (Bouman *et al.*, 2005). Typically, DSR is established earlier than TPR; which hastens physiological maturity and reduces vulnerability to late season drought (Tuong *et al.*, 2005). Fujisaka *et al.* (1993) reported that Asian rice farmers are shifting from transplanting to direct seeding rice culture to reduce cost of labor, input, water use, time and cultivation cost. The increased availability of chemical weed control methods encouraged many farmers in the Philippines, Malaysia, Thailand and India to switch from transplanted to DSR culture. DSR occupies 26 percent of the total rice in South Asia and 23% globally (Rao *et al.*, 2007).

But the traditional agronomic management practices for DSR, confronts the farmers with several problems such as poor establishment, higher seed rate, high early seedling mortality during a rainfall event, weed infestation. High weed infestation is the major bottleneck in DSR especially in dry field conditions (Harda and Sibyamal, 1996; Rao *et al.*, 2007; Tomita *et al.*, 2003). Estimated losses from weeds in rice are around 10% of total production grain yield; however, such losses may be up to 53% for DSR (Ramzan, 2003). DSR is subjected to more severe weed infestation than TPR because, in dry seeded rice, weeds germinate simultaneously with rice, and there is no water layer to suppress the weed growth (Fukai, 2002). Transplanted seedlings have a competitive advantage over newly emerged weeds compared with emerging DSR seedlings. In addition, early weeds in TPR are controlled by flooding, unlike in DSR

(Rao *et al.,* 2007).

Successful rice cropping by dry DSR is critically dependent on weed control (Mahajan *et al.,* 2011). Since hand weeding is becoming expensive due to shortage of labor, use of herbicides can be a better cost-effective alternative to control weeds. Any single method of weed control may not provide season long and effective weed control. Several pre or post emergence herbicides or supplemented with hand weeding may act as good weed control in DSR (Singh *et al.,* 2005b). Therefore, a combination of different weed management strategies should be evaluated for sustainable crop production. DSR was not expanded earlier due to lack of appropriate machinery (Gupta *et al.,* 2002). Now, mechanized direct seeding opens the window for expanding of DSR in the Globe. Machine sowing permits crops to take advantage of residual moisture and reduces labor requirements to establish DSR. In unfavorable rainfed environments, mechanical seeding reduces drought stress of seedlings by providing better seed covering after seeding (Bakker *et al.,* 2000). Moreau *et al.* (1998) concluded that mechanical row seeding led to better emergence, more uniform plant stand, faster and more efficient weeding between rows. DSR and adoption of alternat tillage-based practices together with utilization mechanical seeder for crop production can be evolved as sustainable technology with low cost in this region.

Materials and methods

The experiment was carried out at the Bangladesh Rice Research Institute (BRRI), Regional station, Rajshahi (24°69´latitude N, 88°30 longitude E) in the wet season of 201-11 and 2012-13 under Maize-Mungbean-Aman (wet season) rice cropping pattern. The experiment was laid out in split plot design with three replications. The main plot treatments were Zero tillage (ZT), Strip tillage (ST) using power tiller operated seeder (PTOS), Minimum tillage using PTOS (MT), Permanent bed (PB) using bed planter, Fresh bed (FB) using bed planter and Conventional tillage (CT). Except conventional tillage, other alternate tillage treatments considerad as conservation tillage treatments. The subplot treatments were Weed free (W_1); Post emergence herbicide + 1 hand weeding (W_2), Pre-emergence herbicide + post-emergence herbicide (W_3), Post emergence herbicide (W_4) and Weedy control (W_5). Pendimethalin and Nominee gold (bispyribac Na+), respectively were used as pre and post emergence herbicide. The soil of the experimental plot was low in organic matter (1.35%), very low in available N (0.07%) and low in P, K, S and Zn and having soil reaction in slightly alkaline range (8.3). Except CT, rice was established in dry direct seeding in all five conservation tillage treatments.

Power tiller operated seeder (PTOS): The PTOS is a single-pass shallow-tillage seed and fertilizer drill which is attached in 2-wheel tractor (2WT) and it is 120-cm wide, allowing six rows of rice at 20-cm spacing. Operating capacity is typically 0.14–0.20 ha/hr (Hossain *et al.,* 2004). This seeder accomplishes three operations in a single pass, including tillage (up to 5cm), placement of seed and fertilizer in a furrow, and seed covering by a post-furrow opener roller bar. Compared with traditional broadcast sowing 2-wheel tractor (WT) full tillage, the PTOS requires less than half the time and fuel for sowing cereals, and is sometimes referred to as "reduced tillage" because of shallow seeding and the reduction in number of passes, though the 400–480 rotor RPM speed results in considerable soil surface disturbance (Wohab *et al.,* 2007).

Bed planter: Bed planter is a single 2WT attachable unit that tills the soil, places seed and fertilizer by inclined plates and finally shapes beds by a trapezoidal shaped. Once beds are established, the seasonal reshaping of beds involves only reshaping of beds with minimal soil disturbance. A 2 WT operated bed planter, developed jointly by BARI, Cornell University, and CIMMYT in Bangladesh, and based on CIMMYT models developed in Mexico, can make and shape beds and place seed and fertilizer in furrows on the bed in one pass (Hossain *et al.,* 2004; Krupnik *et al.,* 2013; Wohab *et al.,* 2009). Beds of 54-cm furrow to furrow (30-35 cm top of bed width) distance are produced which can accommodate two rows of rice with about 25 cm distance

Description of tillage treatments and establishment of crops: In CT, conventionally transplanted rice was grown on puddled soil. In such case, the land was cultivated with power tiller 3 times followed by consecutive irrigation and laddering. As a result, puddled condition was prevailed in soil. In case of all five conservation tillage treatments, glyphosate (Roundup) was applied in untilled soil @ 1.0 kg a.i. ha^{-1} using 500 L water 5 days before sowing of seeds. In case of ZT, little slits apart from 20 cm distance rows were made in untilled soil by hook like iron made structure locally called lithao. Then rice seeds were sown on manually with discontinuous seeding. Strip tillage was made by removing 2/3rd tines from PTOS and then strips were made in untilled soil though one pass of PTOS. During ST, seeds and fertilizers were dropped in furrow of strips with 20 cm row to row distance where 3 rows of seeds were sown in one pass of PTOS. Minimum tillage was done through one pass with PTOS where seeds and fertilizers were also placed. Fresh beds were prepared by a bed planter in untilled soil. Permanent beds and fresh beds were remained same for the first crop; the next crops were grown in PB with only renovating the beds. Except CT and ZT, seeds of all crops were sown on during tillage operation either by power tiller operated seeder (PTOS) or by bed planter.

Crop management practices: A medium-duration variety BRRI dhan 39 maturing at 118 days was used in Aman season. All DSR plots were sown at the of 25–30 kg seeds ha^{-1} after initial precipitation (between 10 and 15 June) in each year. Seeds for all transplanted rice (TPR) plots were sown on seedbeds at the same time. Twenty-five days old seedlings were transplanted between 05 and 10 July. Nitrogen, P, K, S, Zn, and B fertilizers rates for rice in the elemental forms were 76, 12.5, 25, 8 and 7.5 kg ha^{-1}, respectively, applied as per the recommendation of the Bangladesh Rice Research Institute (BRRI). In DSR, N was broadcast as urea in 3 equal splits (10 days after seeding (DAS), 25–30 DAS, and 45–50 DAS). In TPR, urea was broadcast at basal, at 15–20 days after transplanting (DAT) and 35–40 DAT. Required gap filling was done after 10-15 days of seeding/transplanting. Thinning of all crops was also done whenever needed.

Soil Analysis: The initial nine soil sub-samples were collected from the experimental field and mixed in a composite sample and then the soil sample was analyzed for determining the initial properties of soil. Analysis of variance (ANOVA) for different parameters of the treatments was also done by software package CROP STAT version 7.2 developed by International Rice Research Institute (IRRI).

Data collection and Statistical Analysis: Weed data were computed in population and dry matter basis at first weeding (21 DAT /28 DAS), at 2nd weeding (42 DAT/56 DAS) and at maturity stage of crop. Six m^2 areas in each plot were harvested to record grain yield. Grain yield was adjusted with the moisture content of 14% for rice. The data were analyzed statistically through computer based statistical program package software package CROP STAT version 7.2 developed by International Rice Research Institute (IRRI).

RESULTS

Effect of tillage on weed density and dry biomass before 1st hand weeding

The broadleaf weeds population before first hand weeding responded significantly due to tillage options in both the years **(Table 1**). The maximum broadleaf weeds population m^{-2} was found in MT (55.02 and 36.67 in 2010 and 2011, respectively) in both the years. The lowest broadleaf weeds population in first year was recorded in ZT which was statistically identical with all other treatments except MT. In 2nd year, broadleaf weed density was found lower in CT followed by ZT. It was also noticed that all the alternate tillage treatments gave statistically similar number of broadleaf weeds population during 2nd year. Unlike population, the biomass of broadleaf was not influenced due to tillage options across the years. Sedge weeds population as well as dry biomass was not affected by the tillage options in both the years **(Table 1).** The density and dry biomass of grass weeds before 1st hand weeding in 2010 were not influenced significantly by the tillage options **(Table 1)** although it caused significant variation during 2011. In 2011, the lower number of weeds m^{-2} was observed in FB followed by CT and MT treatments. The maximum number of weeds m^{-2} during 2011 was found in ZT which was statistically resembled with ST and PB treatments. The lowest dry mass of grass weeds in 2011 was found in CT (6.54 g m^{-2}) which was statistically comparable with rest of the treatments except ZT and ST while the highest biomass was recorded in ST (16.10 g m^{-2}) followed by ZT and PB. It was also notice that MT, PB and FB gave the similar dry biomass of grass weeds wt. during 2nd year.

Effect of weed management options on weed density and dry biomass before 1st hand weeding

There was a wide variation among the weed management options on weed density and dry biomass of every category of weeds for all the years **(Table 2**). For each category of weed at first hand weeding, the lowest and the highest weed density and dry biomass were recorded in W_3 (Panida + Nominee Gold) and W_5 (Weedy) treatments, respectively in all the years. It was also noticed that all herbicide treated treatments (W_2, $W_3$and W_4) gave statistically lower weed density and biomass over non treated treatments across the years. Among those herbicides treated treatments, W_3 performed better than W_2 and W_4 in all the years although this difference was insignificant. Besides these, W_1 and W_5 had dissimilar effect on broadleaf weeds population although those treatments showed identical effect on broadleaf weeds biomass in all the years. The sedge weeds population and dry matter were remained unchanged between W_1 and W_5 in all the years. The W1 and W_5 treatments showed significant variation on grass weed density in both the years while grass weed biomass remained same during 2010 and those treatments gave identical effect during 2011.

Table 1: Population and dry matter of weeds as affected by tillage options before first hand weeding in Aman rice, 2010-11

Tillage	Broadleaf (No. m^{-2})	Broadleaf wt. (g m^{-2})	Sedge (No. m^{-2})	Sedge wt. (g m^{-2})	Grass weed (No. m^{-2})	Grass weed wt. (g m^{-2})
			2010-11			
ZT	32.93	8.11	40.44	8.70	35.83	23.22
ST	50.44	14.68	32.53	6.43	35.42	23.57
MT	55.02	13.99	35.44	9.01	30.83	20.07
PB	43.76	11.09	27.53	7.34	30.00	17.23
FB	49.19	14.06	34.61	9.48	31.67	13.84
CT	37.53	10.10	26.69	5.09	28.33	10.10
LSD (0.05)	20.62	NS	NS	NS	NS	NS
CV (%)	47.5	64.3	67.1	89.7	50.6	48.3
			2011-12			
ZT	31.67	6.44	20.83	3.52	27.92	13.29
ST	34.58	7.98	17.50	4.57	27.90	16.10
MT	36.67	6.85	18.33	3.71	16.67	9.63
PB	35.24	7.45	16.67	3.15	22.50	11.69
FB	34.17	8.55	20.85	3.85	14.58	7.49
CT	25.00	5.23	17.08	3.59	15.42	6.54
LSD (0.05)	15.29	NS	NS	NS	7.64	9.46
CV (%)	43.10	62.40	70.10	96.60	52.90	72.30

NS=Not significant, ZT=Zero tillage, ST=Strip tillage, MT=Minimum tillage, PB=Permanent bed, FB=Fresh bed, CT=Conventional tillage

Table 2: Population and dry matter of weeds as affected weed management options before first hand weeding in Aman rice

Tillage	Broadleaf (No. m^{-2})	Broadleaf wt. (g m^{-2})	Sedge (No. m^{-2})	Sedge wt. (g m^{-2})	Grass weed (No. m^{-2})	Grass weed wt. (g m^{-2})
			2010-11			
W_1	64.93	19.21	59.72	14.05	46.88	31.03

W_2	27.43	7.09	12.50	2.04	21.53	10.64
W_3	14.93	3.15	7.99	1.17	13.89	6.33
W_4	19.79	5.65	13.89	2.18	17.36	8.27
W_5	96.88	24.88	70.14	18.92	60.42	33.74
LSD (0.05)	17.13	6.99	11.75	3.82	10.37	7.23
CV (%)	47.5	64.3	67.1	89.7	50.6	48.3
			2011-12			
W_1	51.39	11.44	32.3	7.31	30.21	17.93
W_2	19.44	4.43	9.72	1.61	9.36	3.38
W_3	10.76	2.12	5.90	0.95	8.33	3.20
W_4	14.24	3.03	9.38	1.28	10.24	5.19
W_5	68.60	14.40	35.4	7.51	45.83	24.29
LSD (0.05)	10.63	3.77	5.97	4.69	9.02	4.19
CV (%)	43.10	62.40	70.10	96.60	52.90	72.30

NS=Not significant, W_1=Weed free (2 Hand weeding), W_2=Bispyribac Na^+ + 1HW, W_3=Pandimenthylin + Bispyric $Na^{+,}$ W_4=Bispyribac $Na^{+,}$ W_5= Weedy (Control)

Effect of tillage on weeds density and dry biomass before second hand weeding

Table 3 shows the density and dry matter of weeds in different years. In 2010, the main effect of tillage did not cause significant effect on population and dry matter of broadleaf weeds before 2nd hand weeding but it did little influence on broadleaf weeds biomass in 2011. The maximum broadleaf population m^{-2} was found in ZT (37.08 and 32.9, respectively in 2010 and 2011) in both the years while the highest biomass was recorded in MT (6.42 g m^{-2}) and ZT (6.31 g m^{-2}), respectively during 2010 and 2011. Though FB recorded (25.0 and 23.3, respectively in 2010 and 2011) minimum number of broadleaf weeds m^{-2} but CT (4.19 and 3.68 g m^{-2}, respectively in 2010 and 2011) obtained the lowest biomass in all the years. Before 2nd hand weeding, sedge density and biomass were influenced significantly due to main effect of tillage options in 2010. The highest number of sedge weeds m^{-2} in 2010 was found in FB (65.0) which was statistically comparable with other alternate tillage treatments where weeds population was significantly lower in CT (38.33) treatment. In 2010, FB (18.93 g m^{-2}) obtained the highest sedge biomass yield where all the alternate tillage treatments affected identically. The lowest sedge biomass in 2010 was found in CT which was also statistically resembled with other tillage treatments except FB. In 2011, the density of sedge weeds was not influenced although its biomass was affected due to tillage options. The maximum sedge weeds biomass in 2011 was also found in FB (9.8 g m^{-2}) followed by MT, CT and PB treatments while the lowest biomass was obtained in ST which was statistically similar with all other treatments except MT and FB. The population and dry biomass of grass weeds before 2nd hand weeding were affected significantly by the tillage options over the years. In 2010, the maximum grass weeds population m^{-2} was found in ST (37.08) which was statistically resembled with other alternate tillage treatments (except CT). On the other-hand the highest biomass of grass weed in 2010 was observed in MT (28.07 g m^{-2}), differed with only CT. In 2011, the population and biomass of grass weed were the highest in PB (20.42, 16.88 g m^{-2}) which was also statistically alike with other treatments except CT. The lowest grass weed density and biomass were found in CT (21.3, 8.75 g m^{-2} in 2010 and 10.0, 6.8 g m^{-2} in 2011) in all the years.

Table 3: Population and dry matter of weeds as affected by tillage options before 2nd hand weeding in Aman rice

Tillage	Broadleaf (No. m^{-2})	Broadleaf wt. (g m^{-2})	Sedge (No. m^{-2})	Sedge wt. (g m^{-2})	Grass weed (No. m^{-2})	Grass weed wt. (g m^{-2})
			2010-11			
CT	37.08	6.26	64.58	9.75	32.50	26.75

ZT	33.33	5.21	59.58	9.72	37.08	20.30
ST	36.67	6.42	62.50	16.40	31.67	28.07
MT	28.75	4.63	47.92	13.68	26.67	17.48
FB	25.00	4.51	65.00	18.93	30.83	24.70
PB	32.08	4.19	38.33	7.42	21.25	8.75
LSD (0.05)	NS	3.96	23.56	10.36	13.50	18.30
CV (%)	59.80	90.90	57.00	111.5	67.10	122.8
			2011-12			
ZT	32.92	6.31	35.42	5.28	21.67	15.98
ST	25.83	4.80	33.75	5.19	18.75	12.34
MT	25.83	5.74	48.75	9.00	16.25	15.88
PB	25.42	4.92	40.42	7.59	20.42	16.88
FB	23.33	4.38	49.17	9.80	13.75	16.36
CT	27.50	3.68	47.50	8.11	10.00	6.83
LSD (0.05)	10.57	1.73	19.60	3.28	9.54	7.10
CV (%)	39.80	43.56	35.08	42.21	48.41	51.80

NS=Not significant, ZT=Zero tillage, ST=Strip tillage, MT=Minimum tillage, PB=Permanent bed, FB=Fresh bed, CT=Conventional tillage

Effect of weed management options on weeds density and dry biomass before second hand weeding

Irrespective of tillage options, there was a wide variation among the weed management treatments on population as well as dry biomass for all categories of weeds in both the years. **(Fig. 1 and Fig. 2).** It was found that the density and dry matter of all categories of weeds were top ranked in W_5 which was statistically differed with rest of the treatments in each year. The population and biomass of broadleaf were lower in W_1 (10.07, 1.22 g m^{-2} in 2010 and 10.42, 0.86 g m^{-2} in 20110) in both the years. The density of broadleaf weeds was remained same among W_1, W_2 and W_3 treatments in both the years. Next to control treatment (W_5), the significantly superior broadleaf weeds population was found in W_4over W_1, W_2 and W_3 treatments in all the years. The broadleaf biomass was lower in W_1 followed by W_2 during 2010 where W_2 and W_3 treatments also affected identically. It was also noticed that the W_3 and W_4 did similar effect on broadleaf weeds biomass in 2010. On the other-hand, all the treatments except W_4 and W_5 produced similar broadleaf weed biomass in 2011where W_2, W_3 and W_4 gave similar result.

The population of sedge weeds was the lowest in W_1 (17.01) followed by W_2 in 2010 whereas its biomass yield was lower in W_2 (2.51) which was statistically similar with other treatments except W_5. The W_2 and W_3 did similar effect on sedge weeds population in 2010. The data also revealed that the sedge weeds density in first year was remained same between W_3 and W_4 treatments. In 2011, sedge weeds population as well biomass was the lowest in W_1which was statistically alike with W_2 and W_3 treatments. The W_4 showed statistical variation from the other treatments in relation to sedge weeds population in 2011 where the W_3 and W_4 gave similar result on sedge biomass yield. In 2010, the W_2 registered the lowest grass weed population followed by W_1 and W_3 treatments. The W_3 and W_4 treatments gave similar result in respect to grass weed population in 2010. The lowest biomass yield of grass weed during 2010 was also found in W_2 which was statistically comparable with rest of the treatments except W_5. Like 2010, the lowest grass weed population was obtained in W_2 which was statistically similar with rest of the treatments except W_5. The lower biomass yield of grass weeds was also found in W_2 followed by W_1 and W_3 during 2011 where W_3 and W_4 also showed the similar result.

Fig. 1: Effect of weed management on weeds density and dry biomass of Aman rice before 2nd hand

weeding, 2010-11

Fig. 2: Effect of weed management on weeds density and dry biomas of Aman rice before 2nd hand weeding, 2011-12

W_1=Weed free (2 Hand weeding), W_2=Bispyribac Na^+ + 1HW, W_3=Pandimenthylin + Bispyric $Na^{+,}$ W_4 =Bispyribac $Na^{+,}$ W_5= Weedy (Control)

Effect on yield components

Panicle m^{-2}

The tillage, weed management options and tillage x weed management interactions showed significant effect on number of panicles across the years **(Table 4).** The number of panicles m^{-2} remained maximum in ST and that was the minimum in FB in both the years where FB and PB showed the identical effect. Irrespective of tillage options, the W_1 recorded the maximum and W_5 obtained the significantly lower number of panicle m^{-2} in both the years. It was also noticed that the W_2, $W_{3,}$ W_4 responded alike in terms of number of panicle m^{-2} during 2010. The interaction result showed that the highest number of panicle m^{-2} was recorded ST with W_1 which was statistically similar with all other weed free and Post-emergence + 1 HW weeding plots in both the years. It was noticed that the weedy (control) plots showed the comparatively lower number of panicle m^{-2} over the years.

Table 4: Yield components of Aman rice as affected by tillage and weed management options, 2010

	ZT	ST	MT	PB	FB	CT	Mean
Panicles m^{-2} (No.)							
W_1	252	260	249	241	239	252	249
W_2	236	232	226	205	206	248	226
W_3	236	243	235	209	216	228	228
W_4	218	226	214	223	216	227	221
W_5	194	195	208	187	180	196	193
Mean	227	231	226	213	211	230	
LSD (0.05)	T = 10.9	W = 12.4		T x W = 30.3			
Panicle length (cm)							
W_1	24.3	23.6	23.4	25.0	24.5	24.0	24.1
W_2	23.6	24.0	23.3	23.7	25.1	24.0	24.0
W_3	23.8	23.4	23.6	24.1	25.3	23.9	24.1
W_4	23.5	22.6	23.5	24.2	23.4	23.6	23.5
W_5	21.8	21.9	22.9	24.1	24.3	21.4	22.7
Mean	23.4	23.1	23.3	24.2	24.5	23.4	
LSD (0.05)	T = 0.93	W = 0.70		T x W = 1.73			
Grains $panicle^{-1}$ (No.)							
W_1	124	127	117	137	140	131	129
W_2	124	125	119	141	146	135	131
W_3	115	117	113	148	148	135	129
W_4	125	123	120	139	142	128	130
W_5	116	114	120	116	123	119	118
Mean	121	121	118	136	140	129	
LSD (0.05)	T = 11.7	W = 7.0		T x W = 14.2			

ZT=Zero tillage, ST=Strip tillage, MT=Minimum tillage, PB=Permanent bed, FB=Fresh bed, CT=Conventional tillage

W_1=Weed free (2 Hand weeding), W_2=Bispyribac Na^+ + 1HW, W_3=Pandimenthylin + Bispyric $Na^{+,}$ W_4

=Bispyribac Na+, W_5= Weedy (Control

Panicle length

It was noticed that the inverse relation was prevailed between the number of panicle m^{-2} and the panicle length **(Table 5).** The larger panicle length was obtained in FB followed by PB in both the years whereas the shorter panicle length was obtained in ZT and MT, respectively during 2010 and 2011. The panicle length of rice was remained same in W_1, W_2, and W_3 and those treatments were significantly superior over control (W_5) in both the years. The tillage and weed management showed positive interaction, the longer panicle length was found in FB with W_3 and that was the shorter in CT with W_5 in both the years. The results also revealed that the weedy plots showed inferiority in decreasing panicle length compared with the other plots across the years.

Table 5: Yield components of Aman rice as affected by tillage and weed management options, 2011

	ZT	ST	MT	PB	FB	CT	Mean
Panicles m^{-2} (No.)							
W_1	246	271	264	237	226	257	250
W_2	260	254	244	244	204	258	244
W_3	254	267	246	230	244	223	244
W_4	241	238	222	237	244	251	239
W_5	194	214	204	193	174	220	200
Mean	239	249	236	228	218	242	
LSD (0.0%)	T = 18.0	W = 16.7		T x W = 28.1			
Panicle length (cm)							
W_1	24.3	23.6	23.4	24.6	24.2	23.9	24.0
W_2	23.7	24.2	23.6	23.2	25.1	24.0	23.9
W_3	23.8	23.4	23.3	23.8	25.3	23.8	23.9
W_4	23.5	22.6	23.5	24.2	23.4	23.5	23.4
W_5	21.4	22.3	22.1	24.0	23.8	21.5	22.5
Mean	23.3	23.2	23.2	24.0	24.3	23.3	
LSD (0.05)	T = 1.11	W = 0.73		T x W = 1.50			
Grains $panicle^{-1}$ (No.)							
W_1	143	152	120	147	159	156	146
W_2	131	140	137	141	161	141	142
W_3	113	127	120	152	157	143	135
W_4	124	130	110	154	149	135	134
W_5	121	123	130	132	136	121	128
Mean	127	134	124	145	153	139	
LSD (0.05)	T = 23.3	W = 10.7		T x W = 31.0			

ZT=Zero tillage, ST=Strip tillage, MT=Minimum tillage, PB=Permanent bed, FB=Fresh bed, CT=Conventional tillage

W_1=Weed free (2 Hand weeding), W_2=Bispyribac Na+ + 1HW, W_3=Pandimenthylin + Bispyric Na+, W_4 =Bispyribac Na+, W_5= Weedy (Control

Grains $panicle^{-1}$

Like panicle length, the higher number of filled grains $panicle^{-1}$ was recorded in FB followed by PB in both the years (Table 6). The MT obtained lower number of filled grains $panicle^{-2}$ over the years. Irrespective of tillage options, the maximum number of filled grains $panicle^{-1}$ was found in W_2 and W_1, respectively during 2010 and 2011. The lowest number of panicle m^{-2} was obtained in W_5 which was statistically differed from rest of the treatments in both the years. The number of filled grains $panicle^{-1}$ also remained unchanged among weed free and herbicide applied plots.

Effect on grain and straw yield

Grain yield

The grain yield of rice was little affected by the tillage options in both the years (Table 7). The CT (4.28 and 4.37 t ha^{-1}, respectively in 2010 and 2011) obtained the highest and the MT (3.64 and 3.71 t ha^{-1}, respectively in 2010 and 2011) recorded the lowest grain yield in both the years where identical effect had been remained among CT, FB and PB and ZT in first year and among CT, ZT, FB and PB in the succeeding year. It was also notice that he MT, ZT and ST also gave comparable grain yield of rice in both the years. A remarkable effect was observed in grain yield of rice by the weed management options across the years (Table 7). In both years, the superior grain yield of rice was found in W_1 closely followed by W_2 while the significantly lower grain yield was recorded in W_5. Among herbicide applied treatments, grain yield of rice was significantly superior in W_2 over W_3 and W_4 in both the years. The tillage and weed management options showed a highly significant interaction on grain yield of rice. All the weedy plots proved inferior causing significantly lower grain yield compared with other plots in all the years. The grain yield was found higher in CT plus W_1 followed by FBxW_1 in 2010 while it remained maximum in PB plus W1 in 2011. The tillage options did not produce significant effect in first year while it had done slight effect year on straw yield of rice in succeeding year (Table 7). Straw yield ranges from 5.44 t ha^{-1} in ST to 5.83 t ha^{-1} in FB in 2010. In following year, the highest straw yield was found in PB treatment which is statistically identical with all other treatments except MT.

Weed management options produced significant influence on straw yield of rice in both the years. Like grain yield, the highest straw yield of rice during 2010 was found in W_1 followed by W_2. The straw yield of rice was statistically similar between W_2 and W_3 in 2010. In 2011, W_1 and W_3 recorded the highest straw yield of rice and those treatments were statistically identical with W_2. The straw yield of rice was significantly lower in W_5 than other treatments in both the years. The highest straw yield (6.86 t ha^{-1}) was achieved in ST with W_1 during 2010. In 2011, the highest straw yield of rice was found in STxW_3 which was statistically identical with all of weed free and herbicide applied plots with little exception. The ZT plus W_5 (4.30 t ha^{-1}) and MT plus W_5 (4.45 t ha^{-1}) recorded the lowest straw yield of rice during 2010 and 2011, respectively.

Table 6: Grain and straw yield of Aman rice as affected by tillage and weed management options, 2010 and 2011

	ZT	ST	MT	PB	FB	CT	Mean
2011							
Grain yield (t ha^{-1})							
W_1	4.56	4.54	4.04	4.89	4.89	4.99	4.65
W_2	4.47	4.50	4.34	4.76	4.75	4.71	4.59
W_3	4.21	3.88	3.81	4.61	4.54	4.46	4.25
W_4	3.81	3.71	3.12	4.16	4.17	4.12	3.85
W_5	2.72	2.85	3.33	2.69	2.70	3.13	2.90
Mean	3.95	3.89	3.73	4.22	4.21	4.28	
LSD (0.05)	T = 0.37	W = 0.59		T x W = 0.73			
Straw yield (t ha^{-1})							
W_1	6.28	6.86	6.23	6.21	6.46	6.01	6.34
W_2	6.47	5.78	5.80	6.30	5.81	6.34	6.08
W_3	4.80	5.04	5.06	5.74	6.56	6.11	5.55
W_4	5.69	5.10	5.14	6.00	5.66	5.48	5.51
W_5	4.30	4.41	5.46	4.46	4.65	5.14	4.74
Mean	5.51	5.44	5.54	5.74	5.83	5.82	

LSD (0.05)	T = 0.31 W = 0.56 T x W = 1.33						
2011							
Grain yield (t ha^{-1})							
W_1	4.99	4.87	3.85	5.11	5.01	5.12	4.82
W_2	4.50	4.64	4.54	4.87	5.01	5.00	4.76
W_3	3.79	4.11	4.04	4.49	4.44	4.35	4.20
W_4	3.40	3.55	3.76	4.37	4.07	4.27	3.90
W_5	2.95	3.08	2.36	2.82	2.36	3.13	2.78
Mean	3.93	4.05	3.71	4.33	4.18	4.37	
LSD (0.05)	T = 0.39 W = 0.60 T x W = 0.81						
Straw yield (t ha^{-1})							
W_1	6.84	6.74	5.86	6.25	6.13	6.63	6.41
W_2	6.10	6.08	6.22	6.48	6.13	5.99	6.17
W_3	6.00	6.92	5.50	6.60	6.89	6.55	6.41
W_4	5.64	5.68	6.08	6.75	5.66	5.80	5.94
W_5	5.34	4.80	4.45	5.27	5.07	5.48	5.07
Mean	5.99	6.04	5.62	6.27	5.98	6.09	
LSD (0.05)	T = 0.34 W = 0.47 T x W = 1.22						

DISCUSSION

Effect of tillage on weed incidences

The density of broadleaf weeds at first weeding affected significantly due to tillage options and the weeds population remained higher in MT during both the years while it was the lowest in ZT and CT, respectively during 2010 and 2011. In some cases, abundance of weeds especially broadleaf weeds was comparatively lower in zero tillage or some other alternate tillage treatments. Fewer annual broadleaf weeds in zero tillage fields than CT were reported by Singh, 2007; Malik *et al.* 2002. Similarly, Swanton *et al.* (1999) reported that the conventional tillage system was associated with some broadleaf weeds. Cussans (1976) found the higher broadleaf weeds with increase in tillage intensity. The number of broadleaf weeds at 2nd weeding was remained higher in ZT in both the years while the highest biomass was recorded in MT and ZT, respectively during 2010 and 2011. Although FB recorded lower numbers of broadleaf weeds but CT obtained the lowest biomass at 2nd weeding in both the years. Therefore, contrasting results was found regarding broadleaf weeds abundance. Some cases CT and zero or strip tilled plots showed a small difference in weeds intensity which was supported by Derksen *et al.* (1993) and Wrucke and Arnold (1985). The sedge weeds abundance was at 2nd weeding was also found lower in CT where all conservation tillage obtained higher weeds compared with CT. Similarly, the density and biomass of grassy weeds at 1st weeding remained lower in CT. Similar trend of grassy weeds intensity remained at 2nd weeding. The lower density and dry matter of grassy weeds in CT were in same line with the findings of Ozpinar, 2006; Gill and Arshad, 1995; Froud-Williams *et al*. 1981; Moody and Mian 1979. Majid *et al.* (1998) and Das and Choudhury (1985) reported that tillage is one of most practical methods for perennial weed control. Compared with CT, the density and dry mass of grassy weeds were remained higher in all alternate conservation tillage treatments. Many researchers stated that reduced or no-till system increased perennial grass weeds densities and diversity (Chokkor *et al.,* 2007; Swanton *et al.,* 1999; Moody, 1992; Gill and Arsad, 1995; Moyer *et al.,* 1994; Nyarko and De Datta, 1991; Feldman *et al.,* 1997).

Effect of weed management options on weed incidences

There was a wide variation among the weed management options on density and dry biomass of weeds at first and 2nd weeding. The crop weed competition at 28 DAS in all the years was markedly reduced by two herbicide (W_3) applied treatment. It was noticed that all of the herbicide treated treatments (W_2, W_3 and W_4) recorded statistically lower weed density and biomass over non treated treatments at 1st weeding across years. Herbicide use can markedly affect crop-weed competition was reported by Chauhan *et al.,* 2012, 2006; Rao *et al.,* 2007; Catheart *et al.,* 2004. Weed management using herbicide has become an integral part of modern agriculture was also reported by Maity and Mukherjee, 2008; Rao *et al.*, 2007. Although the weed control at 1st weeding was found better in W_3 than W_2 and W_4 in both the years but this difference was insignificant indicated that the pre-emergence herbicide (pendimethalin) did least effect on weed suppression. Poor weed control due to pre-emergence herbicide (such as pendimethalin) under CA system was also reported by Chauhan *et al.,* 2012; Mahajan and Timsina, 2011; Walker and Bond 1977; Savage and Barrentine, 1969. In CA systems, effectiveness of pre-emergence herbicides was found lower (Hartzler and Owen, 1997). Similarly, Chauhan *et al.,* (2006) reported that within CA systems of low soil disturbance, the pre-emergence herbicide on soil surface was susceptible to loss through volatilization and photodecomposition. In contrast, Jayadeva and Bhairappanavar (2002) and Singh *et al.* (2006) reported that the pendimethalin as pre-emergence herbicide was quite effective for weeds suppression.

More weeds suppression at 1st weeding by W_3 might be due the more suppression of weeds by post emergence-Bispyribac Na^+. Moreover, abundance of weeds at 2nd weeding and maturity stage of the crop remained similar between W_3 and W_4 during both the years. This happened due to more suppression of weeds by Bispyribac Na^+. The effective weeds suppression by Bispyribac Na^+ were also reported by Mahajan and Timsina, 2011; Mahahjan *et al.,* 2009: Rici *et al.,* 2004, Schmidt *et al.,* 1990. At 1st, and 2nd weeding, the population and dry biomass of weeds were found lower in W_1 decreasingly followed by W_2 over the years. The longer weed free period obviously recorded the lower weeds density as well as dry biomass supported by the findings of Sanjay *et al.* (2008). The W_2 also performed better in regards to weeds suppression than other herbicide applied treatments at 2nd weeding. Integration of recommended herbicide with one hand weeding significantly reduced the weeds density and dry matter compared to application of one or more herbicide which was supported by and Mahajan *et al.* (2009). Bispyribac Na^+ supplemented with one hand weeding has been found very effective against most of the weeds (Misra and Singh, 2012; Rao *et al.* 2007). Similar findings were also reported by Mahajan and Timsina (2011) and Risi *et al.,* (2004).

Effect on yield and yield components

The number of panicle m^{-2} remained lower in FB in both the years while there was inverse relation was prevailed between the number of panicle m^{-2} and the panicle. The shorter panicle length was obtained in ZT and MT, respectively during 2010 and 2011. The larger panicle length was obtained in FB followed by PB in both the years. Connor *et al*. (2003) reported that panicle length of rice was found to be longer in transplanted rice on beds (23.4 cm) than conventional tillage (21.5cm). length. Like panicle length, the higher number of filled grains panicle^{-1} was recorded in FB followed by PB in both the years. The MT obtained lower number of filled grains panicle^{-2} over the years. The results also indicated that the raised bed plots (either fresh bed or permanent bed) gave comparatively higher number of filled grains panicle in both the years. Connor *et al*. (2003) also reported that numbers of grains panicle^{-1} was higher on beds (173) than conventional tillage (163). The grain yield of rice was little affected by the tillage options in both the years (Table 6). The CT and MT, respectively recorded the highest and the lowest grain yield in both the years where identical effect had been remained among CT, FB and PB and ZT in first year and among CT, ZT, FB and PB in the succeeding year. Cavalaris and Gemtos (2004) showed that the reduced tillage gave similar yield with the conventional tillage presented a lower energy productivity indicating that it was the most possible method to substitute the plough and obtain significant benefits. Fahong *et al*. (2003) and Grover *et al.* (2004) also reported that bed planting technology increased the yield and net returns to the farmers.

Irrespective of tillage options, the maximum number of filled grains panicle^{-1} was found in W_2 and W_1, respectively during 2010 and 2011. The lowest number of panicle m^{-2} was obtained in W_5 which was statistically differed from rest of the treatments in both the years. The number of filled grains panicle^{-1} was also remained unchanged among weed free and herbicide applied plots.

The interaction result showed that the highest number of panicle m^{-2} was recorded ST with W_1 which was statistically similar with all other weed free and Post-emergence + 1 HW weeding plots in both the years. It was noticed that the weedy (control) plots showed the comparatively lower number of panicle m^{-2} over the years. The panicle length of rice was remained same in W_1, W_2, and W_3 and those treatments were significantly superior over control (W_5) in both the years. The tillage and weed management showed positive interaction, the longer panicle length was found in FB with W_3 and that was the shorter in CT with W_5 in both the years. The results also revealed that the weedy plots showed inferiority in decreasing panicle length compared with the other plots across the years. Irrespective of tillage treatments, the superior grain yield of rice was found in W_1 closely followed by W_2 across the years while the significantly lower grain yield was recorded in $W_{5.}$ Among herbicide applied treatments, grain yield of rice was significantly superior in W_2 over W_3 indicated that post-emergence herbicide supplemented with one hand weeding is necessary to obtain better grain yield. Similar result was also reported by Singh *et al*. (2005). The interactions result also indicated that almost all the weed free and Post-emergence + 1 hand weeding plots showed identical effect in relation to grain yield of rice.

Conclusion

The CT obtained the comparatively lower weeds population as well weeds biomass across the years where alternate tillage treatments showed about similar result. Some cases weed intensity was also less in ZT and FB treatments. Again, crop weed competition was almost remained same among the weed free and herbicide applied treatments. Although the number panicle m^{-2} was comparatively lower, the higher panicle length associated with higher grains panicle^{-1} was achieved in fresh bed or permanent bed. The grain yield of rice was also comparable among the conventional tillage, bed planting system and also the zero or strip tillage treatments. On the other-hand, the post emergence herbicide (Bispyribac Na^+) was more effective in controlling weeds where weed free (W_1) and W_2 (Nominee gold + 1 HW) treatments showed identical effect in relation to weed intensity and grain and straw yield of rice. Among herbicide applied treatments, grain yield of rice was significantly superior in W_2 (Nominee gold + 1 HW) over W_3 indicated that post-emergence herbicide supplemented with one hand weeding is necessary to obtain better grain yield.

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