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DEVELOPMENT AND APPRAISAL OF MECHANICAL WEED MANAGEMENT STRATEGIES IN DIRECT SEEDED AEROBIC RICE (*Oryza sativa* L.)

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Water scarcity is an annihilating threat to sustainability of transplanted rice. Weeds are notorious competitor of rice and major constraint in adaptation of direct seeding. Although a number of mechanisms have been introduced for weed control but still a huge gap is present for a solid innovation and its practical implementation. A two years study was conducted to develop sustainable mechanical methods for managing weeds in aerobic rice grown by dry direct-seeding at Students' Farm, Department of Agronomy, University of Agriculture, Faisalabad, during 2008 and 2009. Experiment was laid out in RCBD with split plot arrangement (inter row cultivation implements in main plots and inter row cultivation frequencies in sub plots). Experiment was replicated thrice for both years with net plot size 3.0 m x 6.0 m. The results revealed that Tine Cultivator significantly reduced the weed dry weight consistently for all inter row frequencies whereas Spike Hoe and Plug Weeder provided minimum weed control. Inter row cultivation frequencies statistically had no differences at 15 days after sowing (DAS) for weed dry weight while at 45 DAS F_4 (15, 25, 35 and 45 DAS) and F_3 (15, 25 and 35 DAS) significantly reduced the weeds dry weight when combined with Tine Cultivator. Tine Cultivator significantly increased the plant height, number of productive tillers, panicle length, number of kernels per panicle, 1000-grain weight and paddy yield for both growing seasons. Similar increases in above yield components were also observed in F_4 inter row cultivation frequency. Tine Cultivator combined with F_4 was proved to be the best interaction and that was followed by Tine Cultivator and F_3 frequency. Weed control by Tine Cultivator proved to be the most viable and economical method.
Keywords: Direct seeded rice, inter row cultivation, paddy yield, tine cultivator, weeds.

INTRODUCTION

Rice (*Oryza sativa* L.) is a most widely consumed high energy grain, staple food for large part of human population especially in Asia and Latin America (Chauhan and Johnson, 2011). Traditionally it is being cultivated as transplanted flooded rice (Ehsanullah *et al*., 2007) while currently some advances; alternate wetting and drying, raised bed sowing and aerobic rice have been made for rice cultivation.

Decline in crop production worldwide is driven by water scarcity and concerns about its future are consistently increasing (Rijsberman, 2006). Agriculture covers 70% of the world's water consumption (IWMI, 2007) which is increasing every moment to feed the growing population. Tuong and Bouman (2003) have predicted that 20% of the Asian transplanted rice will experience severe water shortage up to 2025. Conventional transplanting method in rice requires a lot of water and labor for field puddling before transplantation (Bhushan *et al*., 2007).

Low water availability, late sowing, imbalance crop nutrition, sub-optimum plant population, high weed infestation and labor shortage in transplanted rice are responsible factors for consistently stagnant/declining paddy yield in Pakistan (Mann and Ashraf, 2001). Rapid economic development, industrialization and high pricing have promoted the migration of labor to urban areas from countryside for higher income and living standard which greatly enhanced the agricultural labor shortage in rural areas (Habito and Briones, 2005). Technological innovations and implementation is necessitated to reduce labor requirement for rice production. Agricultural mechanization would be a potential tool towards labor saving. Partial shift from traditional transplanting to alternate wetting and drying, raised bed sowing and aerobic rice is an alternate option to save water and labor (Weerakoon *et al*., 2011).

Direct seeded rice (Aerobic Rice) is now being practiced in various South Asian countries, due to which in many regions of Asia, direct seeding of rice is replacing transplantation (Chauhan *et al*., 2006). About 35-57% water (Bhushan *et al*., 2007) and 66% labor (Ho and Romli, 2000) saving has been reported in DSR. Weeds infestation is a serious threat to aerobic rice as they compete for nutrients, light, space and moisture contents. It can cause up to 74% paddy yield reduction in DSR (Ramzan, 2004) and may result in complete failure of crop if weeding is delayed. During early establishment, weeds make 20-30 % of their growth while the crop makes only 2-3% (Moody, 1990). The optimum time at which crop must be free of the adverse effect of weeds is referred to as the critical period of weed competition. Almost all the annual crops are susceptible to weed competition during the early stage of development, particularly within the first one-third to one-half of the crop life cycle (Mercado, 1979). Chauhan and Johnson (2011) concluded that the critical period for controlling of rice weeds in DSR was between 14-41 days after sowing.

High weeds intensity in DSR can be controlled in various ways summarized as: manual or hand weeding, herbicides and mechanical weed controller. Hand weeding is although an effective but not an efficient method as it needs more manpower and time (Singh *et al*., 2005). Chemical herbicidal use is much effective as pre/post emergence but weed specific herbicides are not available in Pakistan or unaffordable by farmers (Rao *et al.,* 2007). Weed resistance to certain chemicals is another debatable issue. Manual or mechanically operated implements e.g. inter row implements, could possibly control the weeds more efficiently (Islam *et al*., 2004). Remington and Posner (2000) demonstrated effective weed control in DSR using a mechanical weeder whereas Fazlolallh *et al.* (2001) compared two mechanical weeders with and without engine power in rice; both have been found efficient. Keeping in view the above mentioned facts, present study was designed to develop an effective, economical, efficient and time specific mechanical weed control strategy which may increase the sustainable DSR productivity.

MATERIALS AND METHODS

A two year field experiment was conducted at Students' Farm, Department of Agronomy University of Agriculture, Faisalabad, Pakistan (31°-25‘N, 73°-09‘E, 150 m altitude, canal irrigated) during 2008 and 2009. Crop was cultivated in summer season having high mean temperature and adequate rainfall (Fig. 1 and 2). Soil sampling was done for 15-30 cm depth and analyzed for physical and chemical properties according to the methods described by Cottenei *et al*. (1982) and But (2004) whereas soil organic matter was determined following Walkly-Black method (Nelson and Sommers, 1982) for both years (Table 1).

Experiment was designed with three replications under Split Plot arrangement as described by Gomez and Gomez (1984); randomizing inter culture implements (Tine Cultivator, Spike Hoe, Plug Weeder) in main plot while inter culture frequencies (i- 15 DAS, ii- 15 and 25 DAS, iii- 15, 25 and 35 DAS, iv- 15, 25, 35 and 45 DAS) as sub-plot treatment. Under rice wheat cropping system, field was ploughed followed by planking by tractor drawn implements to achieve the required tilth for DSR.

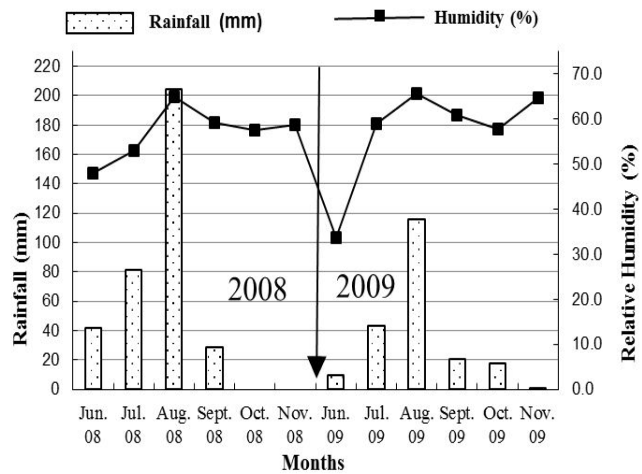


Figure 1. Rainfall and humidity 2008-2009

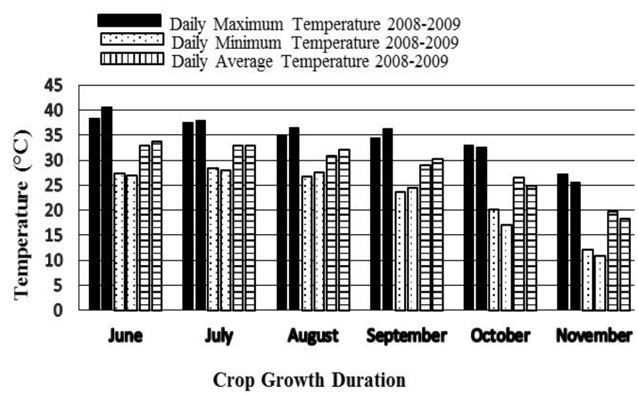


Figure 2. Daily temperature changes during crop growth period

Source: Agricultural Meteorology Cell, Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan

Super Basmati cultivar was sown by a cereal drill (22.5cm line to line distance) on 20th and 28th June in 2008 and 2009 respectively. Seed rate was 75 kg ha^{-1} and fertilizers (150 kg N, 85 kg P and 67 kg K ha^{-1}) were applied as Urea, DAP and

Table 1. Soil physical and chemical properties.

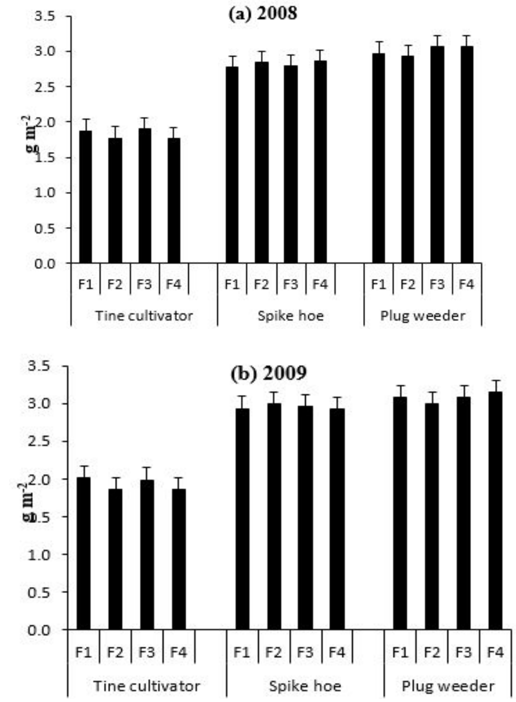
Year/ Character	Sand (%)	Silt (%)	Clay (%)	Texture Class	pH	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)	TSS (%)
2008	52.0	22.2	26.9	Sandy Clay Loam	8.0	0.73	0.052	6.5	186	0.21
2009	52.0	21.8	26.8	Sandy Clay Loam	7.9	0.74	0.053	6.2	185	0.22

Potassium Sulphate. Half of N and whole of the P and K were applied at sowing; while remaining nitrogen was broad casted in two equal splits, at tillering and panicle initiation stage of the crop. Mature crop was harvested at 15th and 21st November in 2008 and 2009 respectively. All three weed control implements were manually operated for all frequency treatments according to the experimental design. Weed dry weight was recorded thrice; 15, 30 and 45 days after sowing. Weeds collected from 1 m^2 area were washed and oven dried at 70°C until the constant weight was obtained. Major weed flora observed consistently in both years consisted of Nut Sedge (*Cyperus rotundus*), Jungle Rice (*Echinochloa colona*), Barnyard Grass (*Echinochloa crusgalli*), Egyptian Crowfoot Grass (*Dactyloctenium aegyptium*), Desert Horse Purslane (*Trianthum portulacastrum*), False Daisy (*Eclipt alba*) and Spurge (*Euphorbia granulata*). Weeds were collected manually from 100 x 100 cm quadrate within each plot at 45 DAS, uprooted, washed with water, separated into sedges and broad leaved weeds, oven-dried at 70°C for 72 hours and then weighed. At maturity, the crop was harvested and the number of fertile tillers, the number of grains per panicle, the thousand grain weight and grain yield (at 14% moisture content) were measured. Means differing from one another by one or more $LSD_{0.05}$ were considered to be significantly different (Steel *et al*., 1997).

RESULTS

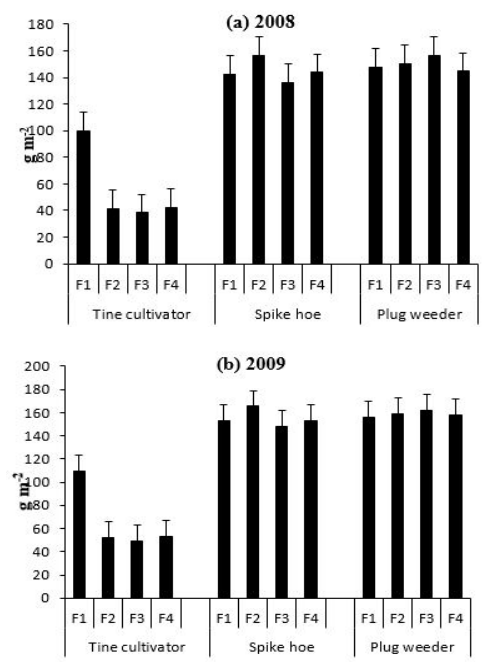
Weed dry weight for all four frequencies within each inter row cultivation implement was not significantly affected at 15 days after sowing (Fig. 3) for both consecutive years (2008 and 2009). Tine Cultivator consistently reduced the weed weight dry significantly more than Spike Hoe and Plug Weeder during the year 2008. The similar trends were observed in 2009. After 30 days of sowing (Fig. 4) weed dry weight significantly differed for different intercultural frequencies but this trend was observed only in Tine Cultivator. Tine Cultivator resulted in minimum weed dry weight whereas weed dry weight in F_3 (39.52 g m^{-2}) was minimum followed by F_2 (41.98 g m^{-2}) and F_4 (43.44.46 g m^{-2}) during the year 2008, similar trend was found during the crop growth season of 2009. Weed dry weight outcome at 45 DAS is clearly indicating (Fig. 5) the significant differences for frequencies, implements as well as their interactions consistently for both the years 2008 and 2009. Minimum weed dry weight was recorded under Tine Cultivator in F_4 which was statistically at par with F_3 followed by F_2.

Plant height, number of productive tillers, panicle length, number of kernels per panicle, 1000-kernel weight and paddy yield have been found significant for inter row cultivation implements (S), inter row cultivation frequency (F) as well as for interaction (S x F) in both years 2008-2009 (Table 2).



(F_1= Inter row cultivation at 15 DAS F_2=Inter row cultivation at 15 and 25 DAS F_3= Inter row cultivation at 15, 25 and 35 DAS F_4=Inter row cultivation at 15, 25, 35 and 45 DAS)

Figure 3. Effect of different weed control implements on total weed dry weight (15 DAS) in rice.



(F_1= Inter row cultivation at 15 DAS F_2=Inter crow cultivation at 15 and 25 DAS F_3= Inter row cultivation at 15, 25 and 35 DAS F_4=Inter row cultivation at 15, 25, 35 and 45 DAS)

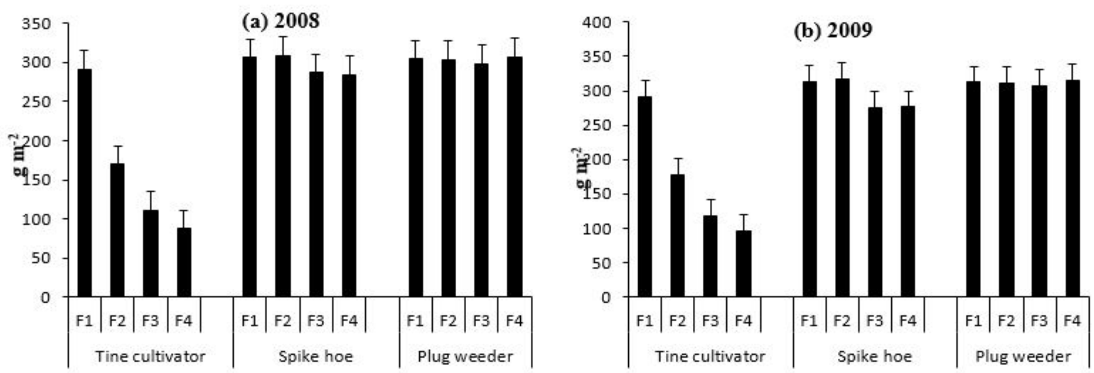
Figure 4. Effect of different weed control implements on total weed dry weight (30 DAS) in rice.

Table 2. Analysis of variance summery for inter row cultivation implements, frequencies and their interaction on various yield component characters of rice.

Source of variation	Degree of Freedom	Plant Height	Productive Tiller	Panicle Length	Kernels panicle^{-1}	1000 grain weight (g)	Paddy Yield
				2008			
S	2	74.41**	1512.20**	147.20**	13.68*	18.39**	143.40**
F	3	90.34**	155.16**	93.06**	5.71**	6.25*	91.26**
S x F	6	36.12**	69.53**	40.81**	7.77**	2.88*	39.92**
E(R x S x F)	18						
				2009			
S	2	73.09**	651.83**	75.22**	37.68**	47.35**	525.75**
F	3	84.06**	1127.10**	67.71**	59.30**	35.05**	54.35**
S x F	6	43.15**	148.53**	14.71**	11.35**	7.05**	40.35*
E(R x S x F)	18						

Table 3. Effect of inter row cultivation implements and frequency interaction on plant height, number of productive tillers and panicle length in direct seeded rice.

Treatments		Plant height (cm)		Productive tillers m^{-2}		Panicle length (cm)	
Weeder	**Frequency**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Tine Cultivator	F_1	70.33 C	65.66 CD	205.77 D	199.60 E	17.52 D	16.65 D
	F_2	70.00 C	64.46 D	237.65 A	251.95 C	19.08 BC	18.10 BC
	F_3	94.66 A	89.93 A	339.97 A	328.50 B	23.01 A	22.03 A
	F_4	95.66 A	91.26 A	349.26 A	337.62 A	23.89 A	22.91 A
Spike Hoe	F_1	70.00 C	65.46 CD	185.95 E	189.07 F	17.01 D	16.03 D
	F_2	71.00 C	66.20 CD	194.22 DE	190.59 F	16.92 D	15.94 D
	F_3	81.00 B	76.40 B	224.33 BC	216.35 D	19.21 BC	18.23 BC
	F_4	78.66 B	74.06 B	237.33 BC	220.26 D	19.96 B	18.99 B
Plug Weeder	F_1	72.00 C	67.26 CD	187.11 E	193.60 EF	18.01 D	17.03 CD
	F_2	72.33 C	68.06 C	191.08 E	186.47 F	17.27 D	16.29 D
	F_3	72.33 C	67.53 CD	185.73 E	188.97 F	17.26 D	16.27 D
	F_4	72.66 C	67.86 C	189.50 E	187.43 F	17.00 D	15.99 D
LSD		3.92	3.42	13.21	7.91	1.45	1.22



(F_1= Inter row cultivation at 15 DAS F_2=Inter row cultivation at 15 and 25 DAS F_3= Inter row cultivation at 15, 25 and 35 DAS F_4=Inter row cultivation at 15, 25, 35 and 45 DAS)

Figure 5. Effect of different weed control implements on total weed dry weight (45 DAS) in rice.

Tine Cultivator produced maximum plant height of 95.66 cm and 91.26 cm (Table 3) in F_4 during 2008 and 2009, respectively. Number of productive tillers and panicle length were found more when Tine Cultivator was used at F_4 and F_3 during the years 2008 and 2009, respectively (Table 3). Kernels per panicle, 1000-kernel weight and paddy yield (3.93 t ha^{-1} and 3.79 t ha^{-1}) were also found higher when

Table 4. Effect of inter row cultivation implements and frequency interaction on kernels per panicle, 1000-grain weight and paddy yield in direct seeded rice.

Treatments		Kernels per panicle		1000-grain weight (g)		Paddy yield (t ha^{-1})	
Weeder	Frequency	2008	2009	2008	2009	2008	2009
Tine	F_1	62.40 B	61.62 CDE	15.68 D	15.68 D	1.52 D	1.47 DE
Cultivator	F_2	65.14 B	63.88 C	16.69 BCD	16.69 BCD	2.22 BC	2.36 B
	F_3	74.46 A	70.21 B	18.67 AB	15.76 CD	3.71 A	3.55 A
	F_4	76.33 A	73.12 A	19.56 A	18.67 AB	3.93 A	3.79 A
Spike Hoe	F_1	63.92 B	61.01 DE	15.69 CD	19.56 A	1.47 D	1.46 E
	F_2	63.79 B	60.23 E	15.82 CD	15.82 CD	1.48 D	1.57 CDE
	F_3	62.37 B	63.19 CD	17.10 BCD	17.10 BCD	1.96 C	1.74 CD
	F_4	65.55 B	61.91 CDE	17.71 ABD	17.72 ABC	2.26 B	1.84 C
Plug Weeder	F_1	65.99 B	60.93 DE	15.75 CD	15.69 CD	1.53 D	1.44 E
	F_2	62.33 B	61.47 CDE	16.08 CD	16.08 CD	1.51 D	1.51 DE
	F_3	63.67 B	60.90 DE	16.49 CD	16.48 CD	1.54 D	1.41 E
	F_4	62.67 B	60.81 DE	16.73 BCD	16.73 CD	1.57 D	1.34 E
LSD		4.61	2.65	2.18	2.18	0.32	0.27

Tine cultivator was used at F_4 and F_3 during the years 2008 and 2009, respectively (Table 4).

DISCUSSION

Seed of variety Super Basmati with good vigor and germination percentage was dry direct seeded using automatic drill (seed-cum-fertilizer drill) after land preparation. It allowed line sowing maintaining 22.5 cm row to row distance and facilitated manual and mechanical weeding. Kumar and Ladha (2011) reported that drill sowing facilitated weed control between rows, saved seed and placed the fertilizer at proper depth. High quality seed was used because larger seeds with greater carbohydrate reserves have increased ability to emerge even from greater burial depths also found by Baskin and Baskin (1998). Within rows distance was maintained at 22.5 cm because studies of Chauhan and Johnson (2010a) revealed that in this range growth and seed production of various weeds in aerobic conditions was less as compared to wider (30 cm) rows. Similarly Weerakoon *et al*. (2011) reported that row spacing (15-45 cm) in direct-seeded rice had little effect on the paddy yield of the crop in the absence of weeds but in competition with weeds the wider spacing resulted in significantly lower grain yield.

Weeds are one of the major biological constraints to direct seeded rice production and are notorious yield reducers, in many situations economically more important than insects, fungi or other pest organisms (Chauhan *et al.,* 2006). Weed dry weight differed significantly in all weed control implements at various frequencies. Lower weed dry weight was observed when tine cultivator was used at F_4 and F_3, possibly because it uprooted early flushes of weeds. Fazlollaalh *et al*. (2011) also reported that appropriate control has an important effect on yield. Second reason of less weed dry weight might be beushaning which killed the weeds with single stem. This was also reported by Rao *et al*. (2007) and Sharma (1997). Inter row cultivation with tine cultivator at F_2 resulted in more weed dry weight than the two earlier ones. Increased weed dry weight might have been due to increased critical period of weed infestation. This prolonged competition period possibly provided a considerable opportunity for weeds to emerge subsequently and produce seeds. Studies by Chauhan and Johnson (2011) revealed that in direct seeded rice weed competition period was beyond 40 DAS. Lower weed dry weight was recorded when spike hoe was operated at F_4 and F_3. This might be due to beushaning which killed the weeds with single stem. This was also reported by Rao *et al*. (2007) and Sharma (1997).

Variation in productive tillers among different treatments was observed in current studies. More productive tillers were observes when tine cultivator was used at F_4 and F_3. This increase in productive tillers might have been due to less early competition of crop with weeds and more availability of moisture and nutrients. Increase in productive tillers with decreased weed dry weight was also observed by Phoung *et al*. (2005). Ekleme *et al.* (2009), Mann *et al.* (2007), Singh *et al.* (2007) and Fischer *et al*. (2001) also reported that as number of fertile tillers of rice increased, dry weight of weeds decreased significantly.

Paddy yield with tine cultivator used at F_4 and F_3 was observed more than two other frequencies. This increase in yield might be due to minimum presence of weeds during critical competition period. Studies of Haefele *et al*. (2000) suggested that there was a considerable scope to increase yield with improved weed control in direct seeded rice. Proper availability of nutrients, space and moisture resulted in more productive tillers, more kernels per panicle and heavier 1000-kernel weight providing high returns in the form of paddy yield (Phoung *et al.,* 2005). Paddy yield recorded in weed control by Spike hoe at F_4 and F_3 was observed more than two other frequencies. One reason of this increase in yield might be low weed dry weight and second reason might be beushaning effect resulting in more tillers and more yield. Sharma (1997) also observed that integrated weed management strategy involving summer ploughing, thiobencarb application and inter-crop cultivation is essential for effective weed control in direct-sown, flood-prone, lowland rice, in order to ensure higher N-use efficiency and crop productivity. Paddy yield was not affected by any inter row cultivation of plug weeder. Low yield might have been due to several reasons. First reason might be; emerging direct seeded rice seedlings were less competitive with concurrently emerging weeds resulting in low paddy yield (Kumar *et al*., 2008a). Second reason of low paddy yield might be competitive advantage of C4 weeds which increased their efficiency to use crop nutrients more than rice. Similarly, Ekleme *et al.* (2009), Hussain *et al.* (2008), Singh *et al*. (2008), Mann *et al.* (2007) and Singh *et al.* (2007) also reported that grain yield of rice significantly reduced due the presence of C4 weeds than that of others. This is why, better performance of C4 weeds under biotic as well as abiotic stress than rice plant.

***Conclusion*:** Among inter row mechanical cultivators Tine Cultivator controlled the weed infestation and reduced the weed dry weight when frequently used (F_3= Inter row cultivation at 15, 25 and 35 DAS F_4=Inter row cultivation at 15, 25, 35 and 45 DAS), whereas inter row cultivation frequencies F_4 resulted highly efficient for weed control followed by F_3 Inter row cultivation. Implements and frequencies as well as their interactions have significantly affected the weed intensity and yield component characters in direct seeded rice. Maximum plant height, number of productive tillers, panicle length, number of kernels per panicle, 1000-grain weight and paddy yield were recorded when Tine Cultivation was used at F_4 (15, 25, 35 and 45 DAS).

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