Indian Journal of Agronomy **68** (2): 140–146 (June 2023)

Research Paper

Effect of integrated weed-management practices in direct-seeded autumn rice (*Oryza sativa*) on growth, yield and soil microflora

BONTI GOGOI [1] AND JAYANTA DEKA[2]

College of Agriculture, Assam Agricultural University, Jorhat, Assam 785 013

Received: April 2021; Revised accepted: April 2023

ABSTRACT

A study was carried out during the rainy (*kharif*) season of 2015 and 2016 at Assam Agricultural University, Jorhat, to evaluate the effect of 6 weed-management practices on growth, yield and soil microflora with 3 different direct-seeded upland rice (*Oryza sativa* L.) varieties. The percentage of grasses was higher, followed by broad leaf weeds in variety 'Maizubiron' followed by 'Guni' during the critical crop growth period. The lowest weed density as well as dry weight at 20, 40 and 60 days after sowing (DAS) was recorded in rice variety 'Inglongkiri' under integrated weed management of pretilachlor 1.5 kg/ha and mechanical weeding which resulted in higher weed-control efficiency (36.29 and 37.62%, respectively) at 20 DAS. The light transmission ratio was the lowest in 'Inglongkiri' followed by 'Guni'. The fungal and bacterial populations were reduced at 25 days after herbicide application which gradually increased up to 50 days. Higher grain yield and harvest index among rice varieties were recorded in 'Inglongkiri' (1.98 t/ha and 43.09, respectively.) and application of pretilachlor 0.75 or 1.5 kg/ha combined with mechanical weeding 30 DAS resulted in the higher grain yield (1.95 t/ha) and harvest index (39.33%) over 2 years.

Key words: Integrated weed-management, Light transmission ratio, Leaf angle oxadiargyl, Pretilachlor, Soil microflora

Rice (*Oryza sativa* L.) is one of the most important cereal crops in the world, and 90% of worldwide rice cultivation takes place in Asia (Lei and Yuan, 2019). In India, it is the most important staple food crop and in Assam the upland rice occupies an area of 0.7 million ha, with the production and productivity of 1.913 million tonnes and 1,242 kg/ha, respectively (Saud, 2018). The autumn rice along with a part of summer rice is grown as a direct-seeded crop but it's yield is poor due to nutrient and weed problem. The average annual loss in rice yield attributable to weeds is estimated to be 10%, amounting to about US $30 billion (Singh *et al.,* 2016). Weed management is a major challenge towards the success of upland direct-seeded rice (DSR), as weeds are comparatively denser in this system than in transplanted situation, because of simultaneous emergence of rice and weeds and the absence of standing water at the early stage of rice growth (Rao, 2011; Chauhan, 2012). The DSR in India is grown totally as a rainfed crop and weed menace is more critical than in wet direct-seeded and transplanted cultures primarily due to differences in land preparation. The use of pre-emergence herbicides is a good option to achieve effective weed control and higher yield in DSR (Chauhan and Mahajan, 2016).

The varietal characteristics of rice and pre-emergence application of herbicides are responsible for lower weed density. The variation in varieties has a subtle effect on effective weed management due to their genetic characters, environmental effect and also the growing season (Sultana *et al.,* 2012). The tall varieties of rice can help in managing the growth of weeds. Hoque *et al.,* (2003), found that, the taller paddy variety could suppress the weed growth as compared to dwarf variety.

Pre-emergence herbicide alone, cannot give a competition-free environment during the critical growth period of upland DSR. Therefore, integrated weed-management combining herbicide and other means is essential for effective weed-management. Therefore, supplementary means like selection of a cultivar with weed-smothering ability has been considered as a suitable option under upland direct-seeded situation. A better weed-control efficiency in upland DSR by coupling application of a pre-emergence herbicide with a follow-up mechanical or manual weeding has been reported (Singh *et al.,* 2016) but still a definite solution to a weed problem eludes the scientists of the

[1]**Corresponding author's Email:** bonti_gogoi@hotmail.com
[1]Subject Matter Specialist (Agronomy), Krishi Vigyan Kendra, Nagaon, Assam Agricultural University, Nagaon, Assam 782 002; [2]Dean, College of Agriculture, Assam Agricultural University, Jorhat, Assam 782 002

regions where this rice culture is practiced.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*kharif*) seasons of 2015 and 2016 at the Instructional-cum Research Farm of Assam Agricultural University, Jorhat, Assam, India which is situated at 26°47' N and 94°12' E and 86.6 m above the mean sea-level. The meteorological data revealed that during the crop growth period (April–August), considerable fluctuation was observed in weather parameters during both the years. The experiment was set up in factorial randomized block design with 3 replications and 18 treatments with a plot area of 12 m^2. The experiment was undertaken in a well-drained medium land. Before the experiment was laid out, representative soil sample from the depth of 15 cm was collected at random for studying the physico-chemical properties. The surface soil of the experimental site was sandy loam in texture, acidic in reaction (5.6), medium in organic carbon (0.57%), medium in available nitrogen (297.87 kg/ha), low in available phosphorus (23.28 kg/ha) and potassium (101.71 kg/ha).

The treatments consisted of 3 different autumn DSR varieties, viz. 'Guni', 'Inglongkiri' and 'Maizubiron' and 6 different integrated weed-management practices, i.e. pretilachlor 0.75 kg/ha + mechanical weeding at 30 days after sowing (DAS), pretilachlor 1.5 kg/ha + mechanical weeding at 30 DAS, oxadiargyl 0.1 kg/ha + mechanical weeding at 30 DAS, oxadiargyl 0.2 kg /ha + mechanical weeding at 30 DAS, mechanical weeding at 15 and 45 DAS and weedy check. The experimental plot consisted of 14 rows, with a spacing of 20 cm between each row. 'Guni' is a traditional direct seeded upland rice variety, popular in Assam because of its slender and medium-bold grain but the variety has thin stalk with less lodging resistance. It matures in 85 to 90 days, with an average yield of 2.0 t/ha. 'Inglongkiri' variety, developed by the Assam Agricultural University, is a medium-tall and recommended for direct-seeded, rainfed upland situations. It has good tillering ability, broad droopy leaves, desired plant height and good early vigour with good weed-suppressing ability and ability to withstand water-stress condition. It is a short-duration variety (100 to 110 days) with potential yield of 2.5 t/ha. 'Maizubiron' is a semi-dwarf variety with erect leaves, result in to the least weed-suppressing ability. It is a short-duration variety (100 to 110 days), with an average yield of 2.2 t/ha. It is moderately resistant to blast and bacterial leaf blight (BLB) and durable field resistance to stem-borer and leaf folder, with medium slender grains. The fertilizers were applied at a recommended dose of 40 : 20 : 20 of N: P_2O_5 : K_2O kg/ha with split application of nitrogenous fertilizer. Weed population study was done by collecting weeds at different intervals from an area of 1 m^2. Yield and other associated yield parameters were determined from 10 m^2 area in each plot. The data collected from the experiment at different growth stages were subjected to statistical analysis. While the method of critical difference test at 5% probability was used to check the differences among various treatment means as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Weed distribution

Altogether, 18 species comprising sedges, broad-leaf weeds and grasses were found and they consisted of *Cynodon dactylon, Digitaria setigera, Panicum repens, Eleusine indica, Phyllanthus erineria, Chenopodium album, Ageratum conyzoides*, *Leersia hexandra, Gnaphalium polycaulom, Commelina diffusa, Scroparia dulcis, Mimosa pudica, Borreria articularis*, *Mimosa pudica, Cyperus pilosus, Cyperus iria*, *Cyperus rotundus,* and *Fimbristylis littoralis*. Among all the weed species, the most dominant weed species among sedges were *Cyperus rotundus* and *Cyperus iria*, *Cynodon dactylon* among the grass and *Ageratum conyzoides* among the broad-leaf weeds. Dominance of these weed species in upland direct seeded rice were also reported by Acharya *et al.* (2007). It might be due to favourable climatic conditions like high rainfall and high temperature at the different crop-growth stages, presence of vegetative propagules of *Cynodon dactylon* and *Cyperus rotundus* and rich soil seed bank of the other dominant weeds in soil that could help in early establishment and abundance of these weed species. (Dangol *et al.,* 2020)

Weed density and dry weight

A significantly lower weed density and dry weight at early crop growth stage was recorded due to application of pretilachlor 0.75 kg/ha (Table 1), followed by mechanical weeding and pretilachlor 1.5 kg/ha, followed by mechanical weeding. However, at later stages of crop growth, oxadiargyl 0.1 kg/ha, followed by mechanical weeding and oxadiargyl 0.2 kg/ha, followed by mechanical weeding were able to suppress weeds better. This could be owing to better weed-controlling ability of pretilachlor during the early stages over oxadiargyl; the later however, exhibited its prolonged effect. Duary *et al.,* (2009) also recorded the lowest weed density and weed dry weight in DSR by pre-emergence application of pretilachlor and hand-weeding. Pre-emergence application of pretilachlor reduced the weed density as well as weed dry weight and resulted in higher returns in rice (DWR, 2013). The % yield loss due to weed infestation was 64.89 in 2015 and 79.83 in 2016 as compared to pretilachlor 0.75 kg/ha followed by

Table 1. Effect of variety and integrated weed management on weed density and weed dry weight at different days after sowing of rice

Treatment	Weed density (no./m^2)* (2015)			Weed density (no./m^2)* (2016)			Weed dry weight (g/m^2)* (2015)			Weed dry weight (g/m^2)* (2016		
Variety	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
'Guni'	5.94	6.32	6.90	5.23	7.04	7.28	1.05	1.16	1.53	1.23	1.26	1.71
	(36.33)	(41.06)	(47.40)	(24.22)	(50.80)	(53.00)	(0.89)	(0.94)	(2.12)	(13.08)	(4.86)	(2.49)
'Inglongkiri'	5.80	5.50	6.41	4.95	7.53	6.69	0.98	1.08	1.56	1.16	1.23	1.77
	(34.89)	(32.05)	(41.31)	(24.17)	(57.11)	(45.00)	(0.52)	(0.72)	(2.23)	(13.05)	(3.28)	(2.51)
'Maizubiron'	6.71	5.81	6.88	5.57	7.33	6.58	1.14	1.20	1.55	1.35	1.36	1.92
	(46.00)	(37.39)	(48.45)	(30.22)	(55.09)	(43.61)	(0.64)	(1.12)	(2.24)	(16.32)	(5.22)	(2.48)
SEm±	0.20	0.25	0.30	0.41	0.45	0.36	0.05	0.07	0.06	0.06	0.07	0.15
CD (P=0.05)	0.56	0.70	0.86	1.17	NS	1.03	0.14	0.21	0.18	0.17	0.20	0.44
Integrated weed management												
Pretilachlor 0.75 kg/ha +	5.11	4.73	6.84	5.06	6.43	6.94	0.94	0.97	1.43	1.18	1.14	1.55
mechanical weeding at 30 DAS	(25.78)	(22.13)	(46.51)	(24.33)	(41.57)	(47.89)	(0.39)	(0.45)	(1.54)	(13.14)	(1.85)	(2.36)
Pretilachlor 1.5 kg/ha +	5.04	5.12	6.56	4.73	6.55	6.84	0.93	0.98	1.40	1.11	1.09	1.39
mechanical weeding at 30 DAS	(25.00)	(26.22)	(42.73)	(23.44)	(43.04)	(46.67)	(0.37)	(0.48)	(1.47)	(12.66)	(2.28)	(2.35)
Oxadiargyl 0.1 kg/ha +	5.53	4.70	6.19	4.91	6.94	6.50	0.99	0.96	1.22	1.17	1.08	1.48
mechanical weeding at 30 DAS	(30.67)	(22.08)	(38.67	(25.00)	(48.62)	(42.67)	(0.50)	(0.42)	(1.02)	(13.50)	(2.92)	(2.18)
Oxadiargyl 0.2 kg/ha +	5.72	4.59	6.21	4.88	6.95	6.53	0.90	0.94	1.21	1.08	1.03	1.23
mechanical weeding at 30 DAS	(32.89)	(21.00)	(38.33)	(25.33)	(48.72)	(42.56)	(0.30)	(0.39)	(0.97)	(13.68)	(3.94)	(2.16)
Mechanical weeding at	5.42	7.87	6.43	3.67	8.34	6.62	0.97	1.23	1.29	1.15	1.32	1.32
15 and 45 DAS	(54.89)	(61.44)	(41.00)	(12.44)	(70.31)	(43.67)	(0.45)	(1.02)	(1.19)	(6.72)	(6.19)	(2.25)
Weedy check	8.10	8.24	8.14	8.25	8.60	7.69	1.61	1.79	2.71	1.79	2.03	3.81
	(65.22)	(68.11)	(67.07)	(46.67)	(73.66)	(59.78)	(2.09)	(2.79)	(7.01)	(25.20)	(9.54)	(3.67)
SEm±	0.33	0.32	0.42	0.48	0.46	0.64	0.06	0.05	0.19	0.07	0.11	0.32
CD (P=0.05)	0.94	0.92	1.21	1.38	1.32	NS	0.17	0.14	0.54	0.21	0.33	0.91
Interaction (V × IWM)												
SEm±	0.09	0.11	0.13	0.18	0.20	0.16	0.02	0.03	0.03	0.03	0.03	0.05
CD (P=0.05)	0.25	0.32	0.38	0.52	0.58	0.46	NS	0.10	0.08	NS	0.09	NS

DAS: Days after sowing, *square-root transformed data; figures in the parentheses are original data; NS, non-significant mechanical weeding at 30 DAS. Various reports also explained that the yield loss in rice due to weeds varied from 15 to 20%; but in severe cases the yield loss may exceed 50% (Hasanuzzaman *et al.,* 2009) or even 100% (Jayadeva *et al*., 2011).

Weed-control efficiency (%)

The weed-control efficiency varied with the varieties (Table 2). Among the varieties, 'Inglongkiri' showed the highest weed-control efficiency at all growth stages over 2 years. Higher weed-control efficiency was observed with the application of pretilachlor followed by mechanical weeding at early stages during both the years and oxadiargyl followed by mechanical weeding during the later growth stages of rice in the first year (Hashim *et al*., 2022).

Light transmission ratio

The light transmission ratio (%) is an important parameter for crop as well as weed suppression (Table 2). The highest light interception at upper to middle zone and upper to lower crop zone was observed in 'Maizubiron' rice (51.82%), followed by 'Guni' (40.96%) and lowest in 'Inglongkiri' (25.57%). This also determines the competitive ability of a particular variety to overcome the stress due to low light intensity at different stages of crop growth. The variety with higher light interception can easily provide the required sunlight and space for the growth of weeds increasing the competition for other available resources with the crop. The light interception ratio from middle to lower part was the highest in 'Inglongkiri' which signified that, there was sufficient light for the lower leaves of the crop which might have resulted in production of more photosynthates, resulting in more yield. There are also reports that cultivars with tall stature intercepted a greater proportion of PAR which helps in effective suppervision of weed growth than short cultivars with low light interception capabilities (Dingkuhn *et al.,* 1999).

Leaf angle

Canopy structure of crop directly influences the fractional interception of solar energy which ultimately affects the photosynthesis and the crop yield. The variety 'Guni' possessed wider leaf angle (52.33° and 55.28°), while 'Maizubiron' has erect leaf arrangement (25.28° and 25.11°) permitting more light transmission to the ground which might have resulted in higher weed growth. Intermediate leaf angle was observed in 'Inglongkiri' with a leaf angle of 45.61° and 45.17° during 2015 and 2016, respectively. The leaf angle is an important morphological trait of rice which affects the efficiency of light interception and nitrogen reservoirs (Zhang *et al.,* 2017). It also helps in determining the efficient interception of transmitted light from the upper canopy and thus helps in proper utilization of available resources (Zhang *et al.,* 2013). The more inclined leaf indicated the droopiness character of the variety which could help in better weed suppression; but at the same time less light transmission to the lower leaves which might help in reducing yield.

Soil microflora

The rice varieties could not bring about significant difference in bacterial as well as fungal population at all the 3 stages, i.e. initial, 25 DAS and 50 DAS (Table 3). There was a gradual decrease in fungal and bacterial population with the application of herbicides. Microflora recorded 25 days after herbicide application was found non-significant due to either varieties or weed-management practices. The bacterial and fungal population gradually increases and almost reached the initial level at 50 days after herbicide application. The application of herbicides was found lethal for the microbial population around the vicinity of the crop.

Table 2. Effect of variety and integrated weed management on weed-control efficiency and light transmission ratio at different days after sowing of rice

Treatment	Weed-control efficiency (%)						Light transmission ratio (%)		
	2015			2016					
Variety	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	U-M*	M-L**	U-L***
'Guni'	34.39	15	39.26	21.22	14.75	33.7	40.96	21.81	7.78
'Inglongkiri'	36.29	28.25	42	37.62	29.41	33.5	25.57	40.25	15.21
'Maizubiron'	31.82	24.78	40.65	34.21	23.02	32.86	51.82	33.26	17.83
Integrated weed management									
Pretilachlor 0.75 kg/ha + mechanical weeding at 30 DAS	41.38	31.75	44.95	41.38	31.12	41.75	41.2	36.78	17.19
Pretilachlor 1.5 kg/ha + mechanical weeding at 30 DAS	44.05	32.55	45.12	44.05	31.01	41.22	40.4	35.19	15.08
Oxadiargyl 0.1 kg/ha + mechanical weeding at 30 DAS	38.19	31.78	52.04	38.19	30.9	41.13	40.3	35.69	16.62
Oxadiargyl 0.2 kg/ha + mechanical weeding at 30 DAS	42.08	29.18	52.63	42.08	31.76	40.28	39.6	34.74	14.67
Mechanical weeding at 15 and 45 DAS	39.3	10.78	49.09	39.3	9.57	35.74	39.1	30.66	12.57
Weedy check	-	-	-	-	-	-	36.1	17.58	5.51

*U-M, Upper to middle crop zone; **M-L, middle to lower crop zone; ***U-L, upper to lower crop zone

Table 3. Effect of variety and integrated weed management on bacterial population in rice rhizosphere before and after herbicide application

Treatment	Bacterial count (×10⁻⁶cfu/g soil)						Fungal count (×10⁻⁶ cfu/g soil)					
	2015			2016			2015			2016		
Variety	Before application	25 DAS	50 DAS	Before application	25 DAS	50 DAS	Before application	25 DAS	50 DAS	Before application	25 DAS	50 DAS
'Guni'	23.12	13.81	19.54	24.14	13.92	20.41	13.08	9.55	11.55	12.97	9.3	11.91
'Inglongkiri'	23.27	13.49	19.58	24.02	13.76	20.12	13.16	9.4	11.61	13.14	9.32	10.81
'Maizubiron'	23.23	13.68	19.47	24.83	13.73	20.25	13.27	9.31	11.23	13.22	9.73	11.66
SEm±	1	0.54	0.98	1.22	0.64	1.16	0.39	0.4	0.35	0.35	0.37	1
CD (P=0.05)	NS	NS	NS	1.73	NS	NS	NS	NS	NS	NS	1.06	NS
Integrated weed management												
Pretilachlor 0.75 kg/ha + Mechanical weeding at 30 DAS	23.17	13.99	18.94	24.3	14.16	19.29	13.1	9.01	12.02	13.04	8.83	12.02
Pretilachlor 1.5 kg/ha + Mechanical weeding at 30 DAS	23.52	10.92	16.62	24.6	11.46	16.96	12.89	7.15	10.5	12.92	8.9	10.68
Oxadiargyl 0.1 kg/ha + Mechanical weeding at 30 DAS	22.43	13.72	18.97	24.12	13.97	19.98	13.66	9.76	11.57	13.08	9.42	11.44
Oxadiargyl 0.2 kg/ha + Mechanical weeding at 30 DAS	22.22	10.73	16.2	24.22	11.44	16.51	13.3	7.56	10.04	13.54	8.76	10.57
Mechanical weeding at 15 and 45 DAS	23.48	15.96	22.73	24.28	15.49	23.99	12.86	11.8	12.43	13.28	10.27	11.06
Weedy check	24.47	16.63	23.73	24.47	16.3	24.82	13.22	11.74	12.94	12.8	10.53	12.97
SEm±	0.97	0.79	0.22	1.69	0.95	0.87	0.28	0.22	0.12	0.32	0.34	1.41
CD (P=0.05)	NS	2.27	0.63	NS	2.72	2.5	NS	0.62	0.34	NS	0.99	NS

DAS, Days after sowing; NS, non-significant

The application of herbicides initially reduces the inherent population of bacteria and fungi, but at later stages there was buildup of microbial population towards the harvesting of crop. Similar findings were also reported by Andrea *et al.,* (2004). A decrease in bacterial and fungal population was also observed in the treatments without herbicide application (Annon, 2016). These may be caused due to disturbance to soil during land preparation and also application of fertilizers. The equivalent acidity of urea in soil leads to more variation in the bacterial population than fungal population by changing the soil *p*H.

Flag-leaf area (cm²)

There was significant difference among the varieties in respect of flag-leaf area, 'Inglongkiri' showing higher flag-leaf area of 35.12 and 34.75 cm² in 2015 and 2016, respectively which was closely followed by 'Guni' (Table 4). The crop leaf arrangement in 'Inglongkiri' and 'Guni' was significantly superior to that of 'Maizubiron'. Since from biology of a crop like flag-leaf characteristic which is basically a genetically controlled character which reflected in the results obtained for the varieties.

Panicles

Among all the varieties in this study 'Inglongkiri' rice had significantly higher number of panicles (48.10 and 47.68) in both the years as compared to that in 'Guni' and 'Maizubiron' (Table 4). This might be owing to higher number of tillers recorded in 'Inglongkiri'. The highest number of panicles was recorded from 'Inglongkiri' variety with combination of use of pretilachlor 0.75 kg/ha + mechanical weeding at 30 DAS. Grovois and Helms, 1992 reported that number of panicles attributes about 89% of yield changes.

Grain yield (t/ha)

Of the 3 rice varieties, 'Inglongkiri' gave highest grain yield of 2.02 t/ha in 2015 and 1.92 t/ha in 2016 (Table 4), being significantly higher over than 'Guni' and 'Maizubiron'. Pretilachlor 0.75 kg/ha followed by mechanical weeding at 30 DAS resulted in the highest grain yield in both the years, and the pooled data showed its significant superiority to mechanical weeding twice. The yield of 'Inglongkiri' was 30.96 and 35.50% higher than 'Guni' and 'Maizubiron', respectively (Table 4). This could be evinced from the data on leaf angle as well as other plant growth characters of this variety. This might be owing differences in the varietal characteristics. The crop structure and canopy arrangement have a very imperious effect on the vegetation growing near the crop zone. The type of leaf arrangement decides the dissipation of sunlight and hence the proper partitioning of photosynthates which can help in higher yield. Among the 3 varieties, 'Inglongkiri' has shown a smothering effect on weeds over the other 2 varieties which might be due to the canopy arrangement and plant architecture.

Straw yield (t/ha)

'Inglongkiri' rice gave significantly higher straw yield (4.70 and 5.38 t/ha) in both the years than 'Guni' and 'Maizubiron'. Results also indicated significant variation among integrated weed-management practices where the highest straw yield of 4.31 and 4.94 t/ha during 2015 and 2016, respectively, was recorded with the application of pretilachlor 0.75 kg/ha followed by mechanical weeding at 30 DAS. However, it was found to be at par with the remaining treatments except mechanical weeding at 15 and 45 DAS and weedy check in both the years. The higher straw yield in 'Inglongkiri' might be owing to better vegetative growth as explained earlier which resulted in high straw yield and dry-matter production. Similar results confirm the finding of Desai *et al.,* (2011).

Harvest index

The harvest index (HI) of rice varieties differed in both the years and the variety 'Inglongkiri' registered the highest HI (43.09 and 35.29% in 2015

Table 4. Effect of variety and integrated weed management on yield and yield-attributing characters of rice

Treatment	Leaf angle (°) (50 DAS)		Flag leaf area (cm^2) (60 DAS)		Panicles/running meter		Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Variety												
'Guni'	34.8	34.36	39.72	39.4	20.72	20.34	1.34	1.38	3.12	3.36	42.48	34.77
'Inglongkiri'	35.12	34.75	48.1	47.68	20.48	20.11	2.03	1.92	4.70	5.38	43.09	35.29
'Maizubiron'	26.14	26.2	38.26	37.57	20.17	19.79	1.29	1.25	2.68	3.29	42.71	34.82
SEm±	0.98	0.92	1.44	1.11	1.1	1.1	1.07	0.8	2.04	2.19	-	-
CD (P=0.05)	2.82	2.62	4.14	3.18	NS	NS	3.07	2.31	5.84	6.83	-	-
Integrated weed management												
Pretilachlor 0.75 kg/ha + mechanical weeding at 30 DAS	33.64	33.33	46.86	46.32	21.05	20.68	1.91	1.98	4.31	4.94	43.14	35.51
Pretilachlor 1.5 kg/ha + mechanical weeding at 30 DAS	33.01	32.03	46.61	45.79	20.8	20.42	1.89	1.9	4.18	4.74	43.23	35.54
Oxadiargyl 0.1 kg/ha + mechanical weeding at 30 DAS	32.29	31.68	46.07	45.33	20.82	20.44	1.76	1.83	4.15	4.68	43	35.46
Oxadiargyl 0.2 kg/ha + mechanical weeding at 30 DAS	31.59	31.89	45.04	44.83	20.89	20.51	1.72	1.67	4.11	4.71	42.96	35.48
Mechanical weeding at 15 and 45 DAS	30.9	31.55	39.87	40.41	19.8	19.42	1.39	1.32	3.13	3.85	42.73	35.46
Weedy check	30.7	30.14	27.71	26.61	19.39	19.01	0.67	0.4	1.12	1.13	41.49	32.32
SEm±	0.91	0.83	1.58	1.04	0.96	0.96	1.12	0.89	2.83	2.62	-	-
CD (P=0.05)	NS	NS	4.54	2.99	NS	NS	3.22	2.53	8.14	7.53	-	-
Interaction (V × IWM)												
SEm±	0.44	0.41	0.64	0.5	0.49	0.49	0.48	0.36	0.91	0.98	-	-
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.37	1.03	2.61	2.81	-	-

DAS, Days after sowing; NS, non-significant and 2016, respectively), followed by 'Guni' and 'Maizubiron' in descending order (Table 4). However, the values in the second year were lower than the respective values of the first year mainly due to higher rainfall in the second year, resulting higher dry-matter accumulation but limited partitioning ability of the varieties. Application of pretilachlor followed by mechanical weeding at 30 DAS resulted in higher harvest index in both the years. It followed the pattern of the dry matter production, grain and straw yields of these treatments. It is notable that, plant species growing under stress conditions always strives for efficient partitioning of the dry matter accumulated to the reproductive parts, i.e. grains in cereal, in an attempt to continue the survival of the species (Patel, 2009). Donald and Hamblin (1976) also reported that, harvest index varied greatly with cultivars, locations, seasons, and ecosystem and it is related to biological yield and grain harvest index. Snyder and Carlson (1984) reviewed harvest index for selected annual crops and noted variation of 23 to 50% for rice.

Thus, the combination of upland rice variety 'Inglongkiri' receiving of pretilachlor 0.75 kg/ha followed by mechanical weeding at 30 DAS was proven the best for effective weed control, soil health, crop growth, yield and economic profit.

REFERENCES

Acharya, L.P., Chaudhary, N.K., Mishra, K. and Amagain, L.P. 2007. Effect of nitrogen and weed management on yield of rainfed rice *Oryza sativa* L. var. *indica*. (In): Thapa, R.B. and Sharma, M.D. (Eds.) *IAAS Research Advances* **1**: 23–29.

Andrea, S., Frank, H. and Eder, K. 2004. Thermally oxidized dietary fat upregulates the expression of target genes of PPARá in rat liver. *Journal of Nutrition* **1,346**: 1,375–1,383.

DWR. 2016–17. *Annual Report* 2016–17 of the All India Co-Ordinated Research Project on Weed Control. Directorate of Weed Research Centre, Jorhat, p. 5,74,75.

Chauhan, B.S. and Mahajan, G. 2016. Research needs for improving weed-management in rice. *Indian Journal of Weed Science* **46**(1): 1–13.

Chauhan, B.S. 2012. Weed ecology and weed management strategies for dry-seeded rice in Asia. *Weed Technology* **26**: 1–13.

Dangol, R., Pandey, S.R., Shrestha, B., Bishal, Maga, D.B., and Bhattarai, N. 2020. Effects of different weed management practices on growth and yield of direct-seeded spring rice in Jhapa, Nepal. *Cogent Food and Agriculture* **6**(1): 1–18.

Desai, V.B.K., Vishwanatha, S., Kumar, A.S.N., Rao, S. and Halepyati, A.S. 2011. Growth and yield of rice (*Oryza sativa* L.) varieties as influenced by different methods of planting under aerobic method of cultivation. *Research Journal of Agricultural Sciences* **22**: 298–300.

Dingkuhn, M., Johnson. D.E., Sow, A. and Audebert, A.Y. 1999. Relationship between upland rice canopy characteristics and weed competitiveness. *Field Crops Research* **61**: 79–95.

Donald, C.M. and Hamblin, J. 1976. The biological yields and harvest index of cereals as agronomic and plant breeding criteria. *Advances in Agronomy* **28**: 361–405.

Duary, B., Roychowdhury, S. and Mukherjee, A. 2009. Effect of sole and sequential application of herbicides on weed growth and productivity of transplanted *kharif* rice in the lateritic belt of West Bengal, p. 28. (In) *Abstracts of National Symposium on Weed Threat to Environment, Biodiversity and Agricultural Productivity*, held during 2–3 August, 2009 at Tamil Nadu Agricultural University, organized by ISWS, Jabalpur.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedure for Agricultural Research*. An International Rice Research Institute Book. A Wiley- Inter-science Publication, John Wiley & Sons, Inc. New York.

Grovois, K.A. and Helms, R.S. 1992. Path analysis of rice yield and yield components as affected by seeding rate. *Agronomy Journal* **84**: 1–4.

Hasanuzzaman, M., Ali, M.H., Akther, M. and Alam, K.F. 2009. Evaluation of pre-emergence herbicide and hand weeding on the weed control efficiency and performance of transplanted Australian rice. *American-Eurasian Journal of Agronomy* **23**: 138–143.

Hashim, M., Singh, V.K., Singh, K.K. and Dhar, S. 2022. Herbicidal weed-management options for dry direct-seeded rice (*Oryza sativa*) in North-Eastern Plains of India. *Indian Journal of Agronomy* **67**(4): 337–342.

Hoque, M., Hossain, M., Khan, R.H., Khalequzzaman, K.M. and Karim, S.M.R. 2003. Effect of varieties of rice and weeding on weed growth and yield of transplant aman rice. *Asian Journal of Plant Sciences* **2**(13): 993–998.

Jayadeva, H.M., Bhairappanavar, S.T., Hugar, A.Y., Rangaswamy, B.R., Mallikarjun, G.B., Malleshappa, C. and Naik, D.C. 2011. Integrated weed management in aerobic rice (*Oryza sativa* L.). *Agriculture Science Digest* **311**: 58–61.

Lei, S. and Yuan, L. 2019. *Rice Bran Usage in Diarrhea* (In) *Dietary Interventions in Gastrointestinal Diseases*. (In) book Foods, Nutrients, and Dietary Supplements, Pp 257–263, Publised by Academic press

Pandey, S. 2009. Effect of weed control methods on rice cultivars under the system of rice intensification SRI. M.Sc. thesis Agronomy, Tribhuvan University Institute of Agriculture and Animal Science Rampur, Chitwan, Nepal.

Saud, H.K. 2018. Agricultural production in Assam in the Recent decades: An empirical Study of select crops in 2 districts of western Assam. In Ph.D. thesis submitted to IIT Guwahati, pp 2–5.

Singh, V., Mangi, L.J., Zahoor, A.G., Bhagirath C.S. and Raj, K.G. 2016. Herbicide options for effective weed management in dry directed seeded rice under scented rice–wheat rotation of western Indo Gangetic plains. *Crop Protection* **81**: 168–176.

Snyder, F.W. and Carlson, G.E. 1984. Selection for partitioning of photosynthetic products in crops. *Advances in Agronomy* **37**: 47–72.

Sultana, M.R., Alim, M.A., Hossain, M.B., Karmaker, S. and Islam, M.S. 2012. Effect of variety and weed management practices on yield and yield attributes of wheat. *Journal of Environmental Science and Natural Resources* **5**(2): 91–96.

Zhang, X., Chuan, L., Ning, H., Yao, K., Zhang, Q. and Dai, Q. 2013. Simulation of canopy leaf inclination angle in rice. *Rice Science* **206**: 434–441.

Zhang, Y., Tang, L., Liu, X., Liu, L., Cao, W. and Zhu, Y. 2017.Modelling the leaf angle dynamics in rice plant. *PLoS ONE* **122**: 1–13.