



Herbicide combinations and nitrogen scheduling for weed management and yield improvement in transplanted rice

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ABSTRACT

Field experiment was conducted during rainy seasons of 2018 and 2019 to evaluate the efficacy of herbicide mixtures and nitrogen application scheduling to control grasses, sedges and broad-leaved weeds in transplanted rice. Post-emergence application of triafamone 20% + ethoxysulfuron 10% (ready-mix) 67.5 g/ha at 20 days after transplanting (DAT) was found comparable with two rounds of hand weeding at 20 and 40 DAT in controlling all categories of weeds. Among different nitrogen application schedules, application of 25% N at 10 DAT + 50% N at active tillering (AT) + 25% N at panicle initiation (PI) recorded higher weed control efficiency (73.4%) and grain yield (6.3 t/ha) of rice as compared to the recommended schedule of 25% N as basal + 50% N at AT + 25% N at PI (WCE of 66.9% and grain yield of 5.7 t/ha). Triafamone 20% + ethoxysulfuron 10% (ready-mix) 67.5 g/ha at 20 DAT recorded 81.7% WCE, improved crop growth and yield attributes and consequently increased grain yield (6.0 t/ha) as well as net return (69360 ₹/ha) as compared to fenoxaprop-p-ethyl 9 EC 56.2 g/ha + ethoxysulfuron 15 WDG 18.7 g/ha (tank-mix) at 20 DAT. Tank-mix application of fenoxaprop-p-ethyl + ethoxysulfuron caused yellowing of rice leaves although it disappeared within 20 days after application, whereas no such phytotoxicity was recorded under ready-mix application of triafamone + ethoxysulfuron.

INTRODUCTION

Rice (*Oryza sativa* L.) occupies prime position among food crops in India. It is cultivated in an area of 43.79 million hectares with production of 112.91 million tonnes (mt) and productivity of 2.58 t/ha in 2017-18 (Agristat 2018). Weeds are the major pests that affect the rice yields up to 57% in puddled transplanted rice and 82% in direct-seeded rice (Mahajan *et al.* 2009). Transplanted rice is infested with both grassy and broad-leaved weeds at initial stages of crop growth. Fenoxaprop-p-ethyl is most widely used herbicide for management of grassy weeds although ineffective against broad-leaved weeds in rice. Exclusive reliance on herbicides with single mode of action is not advisable as they contribute to rapid evolution of multiple herbicide resistance, which is again becoming a threat to weed control in rice. Metsulfuron-methyl + chlorimuron-ethyl and penoxsulam + cyhalofop-butyl are certain ready-mix combinations introduced as post-emergence application against complex weed flora in transplanted rice (Tripathy and Mohapatra 2017). Likewise, tank-mix application of azimsulfuron 27.5

g/ha + metsulfuron-methyl 2.0 g/ha was also found effective to control grassy and broad-leaved weeds in transplanted rice (Jayadev *et al.* 2010). Still there is a need to identify suitable herbicide combinations for improving weed control efficiency without any adverse effect on crop.

Nutrient management is an important component of integrated weed management systems that influences crop yield and reduces weed infestation over time (Blackshaw *et al.* 2004). Soil nutrients, especially nitrogen, are known to promote seed germination in some weed species (Hendrics and Taylorson 1972). Selective placement or delayed application of nitrogen may avoid flushes of weeds to come up at initial period of crop growth (Tripathy and Mohapatra 2007). There is often a significant interaction between herbicide and nitrogen, where increased level of nitrogen is found to enhance the performance of herbicide as well as nitrogen. Scheduling of nitrogen application not only influences the crop growth, but also affects the weed growth at large (Kim *et al.* 2006). However, precise information in this regard is meagre under rice-rice cropping

system in Hirakud command areas of West Central Table Land Zone of Odisha. Hence, an attempt was made to study the effect of newer herbicide combinations and nitrogen application scheduling on weeds and yield of transplanted rice.

MATERIALS AND METHODS

A field experiment was conducted at Regional Research and Technology Transfer Station, Chiplima, Odisha during rainy seasons of 2018 and 2019. The soil of the experimental field was sandy clay loam with pH 6.6 and fertility status with low in organic carbon (0.43%), low (268 kg/ha) in available N (KMnO₄ method), medium (13.4 kg/ha) in available P (Olsen's method) and medium (132 kg/ha) in available K (NH₄OHC method). The experiment was laid out in a split plot design with three replications. The treatments included four weed management methods, viz. triafamone 20% + ethoxysulfuron 10% (ready-mix) 30 WG 67.5 g/ha at 20 days after transplanting (DAT), fenoxaprop-p-ethyl 9 EC 56.2 g/ha + ethoxysulfuron 15 WDG 18.7 g/ha (tank-mix) at 20 DAT, hand weeding at 20 and 40 DAT and weedy in main plots and three different schedules of nitrogen application, viz. 25% at 10 DAT + 50% at active tillering (AT) + 25% at panicle initiation (PI), 25% as basal + 50% at AT + 25% at PI and 50% as basal + 25% at AT + 25% at PI in sub-plots. The field was prepared with two ploughings, each followed by planking with the help of a tractor-drawn cultivator. The puddling was done at the time of transplanting. The crop variety 'MTU 1001' was transplanted in July and harvested in November during both the years. A common fertilizer dose of 80-40-40 kg N-P-K/ha was applied, giving full doses of P and K as basal and N fertilizers as per treatment schedule. Two rice seedlings per hill were transplanted at 20 × 15 cm spacing in experimental field. Plant protection measures and irrigation were provided as and when required. The required quantity of herbicides was applied with manually operated knapsack sprayer fitted with flood jet nozzle, using a spray volume of 500 L of water/ha. A thin film of water was maintained in the field at the time of herbicide application.

Weed count (no./m²) and weed dry weight (g/m²) were recorded after random sampling at two spots with the help of 0.25 m² quadrat at 50 DAT. For the assessment of weed dry weight, weed samples were kept at 85°C in hot air oven for 16 h (Klingman 1971). Weeds were separated into three broad categories (grass, sedge and broad-leaved) before drying. Weed data were analysed after subjecting

them to square root transformation. Phytotoxicity of herbicides at different nitrogen application scheduling were recorded at 5 and 20 days after application (DAA) of herbicides using visual scoring scale of 0 to 10, where 0: no injury and 10: complete mortality (Rao 2001). Data were recorded on crop growth (plant height at harvest, number of tillers/hill at 50 DAT and leaf area index at flowering), whereas yield attributes (panicle length, number of filled grains/panicle and test weight) along with yields (grain and straw) were recorded at crop harvest. Weed control efficiency (%) was also calculated on the basis of dry matter production of weeds.

$$\text{Weed control efficiency (WCE)} = \frac{(\text{WDc} - \text{WDt})}{\text{WDc}} \times 100$$

Where, WDc was the weed dry weight in weedy check plots and WDt was the weed dry weight in treated plots.

Economics were computed using the prevailing market price of inputs and outputs such as rice grain (₹ 17.5 × 10³/t), rice straw (₹ 0.7 × 10³/t) and manual labour (₹ 0.28 × 10³/day). All data were subjected to analysis of variance as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on weeds

The major weed flora in the experimental field comprised of grasses, viz. *Digitaria sanguinalis* L. Scop., *Echinochloa crus-galli* L., *Echinochloa colona* L. Link, *Panicum repens* L.; sedges, viz. *Cyperus difformis* L., *Cyperus iria* L., *Fimbristylis miliacea* L. Vahal; and broad-leaved weeds (BLW) viz. *Ammania baccifera* L., *Ludwigia parviflora* L., *Eclipta prostrata* L., *Eclipta alba* L., *Lippia nodiflora* Nich, *Marsilea quadrifolia* L., *Sphenoclea zeylanica* Gaertn., *Commelina benghalensis* L., and *Leptochloa chinensis* L.. Similar weed flora was reported earlier by Mohapatra *et al.* (2017). The proportionate composition of grasses, sedges and broad-leaved weeds in weedy check plots was 45.4, 29.1 and 25.4%, respectively. Emergence of grasses was noticed earlier as compared to broad-leaved weeds.

Hand weeding twice manually resulted in 100% weed control. But among the herbicides, triafamone 20% + ethoxysulfuron 10% (ready-mix) 67.5 g/ha proved to be the most effective herbicide against grasses and broad-leaved weeds, and recorded significantly lower density (4.2, 6.5) and biomass (1.8, 5.3 g/m²) of these weeds than the tank-mixed

application of fenoxaprop-p-ethyl 9 EC 56.2 g/ha + ethoxysulfuron 15 WDG at 18.7 g/ha (Table 2). Weed density and biomass of grass, sedge and broad-leaved weeds were made in the year 2018 as compared to 2019 in weedy check plot (Table 1). The highest weed control efficiency (81.7%) was recorded under triafamone 20% + ethoxysulfuron 10% (ready-mix) 67.5 g/ha than tank-mixed application of fenoxaprop-p-ethyl 9 EC 56.2 g/ha + ethoxysulfuron 15 WDG at 18.7 g/ha. Compared with fenoxaprop-p-ethyl 9 EC 56.2 g/ha + ethoxysulfuron 15 WDG 18.7 g/ha, higher efficacy of triafamone 20% + ethoxysulfuron 10% (ready-mix) 67.5 g/ha was attributed to complete control of grassy and broad-leaved weeds throughout the crop growth period. Again tank-mix application of fenoxaprop-p-ethyl + ethoxysulfuron caused yellowing of rice leaves which disappeared within 20 days after application, whereas no such phytotoxicity was found under ready-mix application of triafamone + ethoxysulfuron.

Split application of nitrogen as 25% at 10 DAT + 50% at AT + 25% at PI showed lower density and biomass of weeds, being at par with 25% N as basal + 50% N at AT + 25% N at PI, but it was significantly superior to 50% N as basal + 25% N at AT + 25% N at PI. This might be due to improved crop growth, which caused a smothering effect on weed growth. These findings were in conformity with those of Sahu *et al.* (2015).

Crop phytotoxicity

Crop phytotoxicity (injury) was observed with application of fenoxaprop-p-ethyl 9 EC 56.2 g/ha + ethoxysulfuron 15 WDG (tank-mix) 18.7 g/ha at 5 days after application (DAA) of herbicide (Table 3). Such phytotoxicity was primarily expressed as yellowing of flag leaves and reduced plant growth although it was automatically reversed at 20 DAA. The crop recovered quickly from the herbicidal phytotoxicity with the application of 25% N at 10 DAT + 50% N at AT + 25% N at PI than that of 50% N as basal + 25% N at AT + 25% N at PI.

Table 1. Effect of herbicides and time of nitrogen application on weed density and biomass of rice at 50 DAT

Treatment	Weed density (no./m ²)						Weed biomass (g/m ²)					
	Grass		Sedge		Broad-leaved		Grass		Sedge		Broad-leaved	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
<i>Weed management</i>												
Fenoxaprop-p-ethyl + ethoxysulfuron	2.9(10)	3.2(10)	3.3(10)	3.2(9)	4.4(19)	3.9(15)	2.1(4)	2.3(4)	3.0(8)	2.9(8)	4.1(16)	4.3(19)
Triafamone 20% + ethoxysulfuron 10%	2.2(5)	2.7(7)	2.2(4)	2.9(6)	2.9(8)	3.1(9)	1.7(2)	2.0(3)	2.1(3)	2.6(6)	3.2(9)	3.4(11)
Two hand weeding	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)
Weedy	8.9(8)	6.8(5)	5.3(3)	4.4(2)	7.5(6)	5.9(35)	6.0(38)	4.6(21)	4.6(20)	3.8(14)	5.9(34)	6.9(49)
LSD(p=0.05)	0.12	0.26	0.20	0.27	0.29	0.34	0.09	0.11	0.10	0.08	0.08	0.06
<i>Nitrogen application schedule</i>												
25% N at 10 DAT + 50% N at AT + 25% N at PI	2.7(12)	2.8 (9)	2.9(10)	2.7(8)	3.5(16)	3.2(12)	2.0(5)	2.1(4)	2.7(8)	2.6(7)	3.5(14)	3.6(16)
25% N at basal + 50% N at AT + 25% N at PI	3.0(15)	3.1(12)	2.9(10)	2.8(8)	3.3(13)	3.1(11)	2.2(7)	2.2(5)	2.5(7)	2.5(6)	3.5(14)	3.3(12)
50% N at basal + 25% N at AT + 25% N at PI	5.6(48)	4.4(27)	3.0(11)	2.9(9)	5.1(36)	4.2(22)	3.8(21)	3.1(12)	2.8(9)	2.6(7)	3.6(16)	4.9(31)
LSD (p=0.05)	0.10	0.22	0.17	NS	0.25	0.29	0.09	0.09	0.08	0.07	0.07	0.05

Figures within parentheses were original values, and those without parentheses were values transformed to square root of ($\sqrt{x+1}$) before statistical analyses; DAT: Days after transplanting; AT: Active tillering; PI: Particle initiation

Table 2. Effect of herbicides and time of nitrogen application on weed density, biomass and weed control efficiency of rice at 50 DAT (pooled data of 2 years)

Treatment	Weed density (no./m ²)				Weed biomass (g/m ²)				WCE (%)
	Grasses	Sedges	Broad-leaved	Total	Grasses	Sedges	Broad-leaved	Total	
<i>Weed management</i>									
Fenoxaprop-p-ethyl + ethoxysulfuron	2.6(6)	2.7(6)	3.4(11)	4.9(24)	1.8(3)	2.5(5)	3.1(9)	4.1(17)	68.5
Triafamone 20% + ethoxysulfuron 10%	2.1(4)	2.1(4)	2.6(6)	3.8(14)	1.6(2)	1.9(3)	2.4(5)	3.2(10)	81.7
Two hand weeding	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	100
Weedy	6.5(44)	3.9(15)	5.5(31)	9.2(91)	4.4(20)	3.5(11)	4.9(24)	7.3(55)	0
LSD (p=0.05)	1.84	0.05	0.53	2.2	1.18	0.11	1.09	1.4	
<i>Nitrogen application schedule</i>									
25% N at 10 DAT + 50% N at AT + 25% N at PI	2.8(12)	2.0(4)	2.7(10)	3.9(19)	2.1(5)	1.8(3)	2.5(8)	3.4(15)	73.4
25% N at basal + 50% N at AT + 25% N at PI	2.8(13)	2.5(6)	3.1(12)	5.0(27)	2.1(6)	2.2(5)	2.8(9)	3.6(18)	66.9
50% N at basal + 25% N at AT + 25% N at PI	3.5(16)	2.8(9)	3.5(15)	5.2(41)	2.4(7)	2.6(7)	3.2(12)	4.6(29)	47.3
LSD (p=0.05)	0.21	0.04	0.45	1.03	0.11	0.01	0.06	0.6	-

Figures within parentheses were original values, and those without parentheses were values transformed to square root of ($\sqrt{x+1}$) before statistical analyses; DAT: Days after transplanting; WCE: Weed control efficiency

Effect on crop

Higher leaf area index (4.1) at flowering was found in the ready-mix application of triafamone 20% + ethoxysulfuron 10% at 67.5 g/ha, followed by tank-mix application of fenoxaprop-p-ethyl 9 EC 56.2 g/ha + ethoxysulfuron 15 WDG 18.7 g/ha as compared to weedy check (**Table 3**). This might be due to effective control of weeds which, in turn, significantly increased the number of tillers/hill (9.1), number of grains/panicle (163) and 1,000-grain weight (20.6 g), thereby improving grain and straw yield. Control of grass, sedge and broad-leaved weeds by ready-mix application of triafamone 20% + ethoxysulfuron 10% at 67.5 g/ha resulted in lower competition for growth resources throughout the crop growth period and influenced the crop plants to grow and develop in a better way as evidenced from higher values of yield attributes. Similar findings were also observed by Ramachandra *et al.* (2012).

Application of nitrogen as 25% at 10 DAT + 50% at AT + 25% at PI registered significantly higher LAI (4.7), plant height (114.9 cm), panicle length (24.8 cm) and 1,000-grain weight (21.2 g) (**Table 3**). Initial reduction in dose and delayed application of nitrogen resulted in significant improvement in panicle length, grains/panicle and grain yield in comparison to conventional scheduling of recommended nitrogen application. Higher values of yield attributes and grain yield were ascribed to more utilization and uptake of nitrogen at active growth stages, *viz.* AT and PI. Similar findings were also reported by Gill and Walia (2013).

The grain (6.8 t/ha) and straw (8.4 t/ha) yields were the highest in the weed free plot and the lowest (4.7 t/ha) in weedy plot (**Table 4**). The reduction in grain and straw yield in weedy plot were 30.9 and

30.5%, respectively due to weeds. Triafamone 20% + ethoxysulfuron 10% (ready-mix) at 67.5 g/ha recorded higher grain and straw yield (6.0 and 7.7 t/ha) than fenoxaprop-p-ethyl 9 EC 56.2 g/ha + ethoxysulfuron 15 WDG 18.7 g/ha. (tank-mix). Similar findings on rice grain yield by application of triafamone + ethoxysulfuron was also reported by Hossain and Mallik (2017).

Nitrogen scheduling as 25% at 10 DAT + 50% at AT + 25% at PI recorded higher grain (6.3 t/ha) and straw (8.0 t/ha) yield followed by 25% at basal + 50% at AT + 25% at PI. The traditional practice of higher basal dose of N (50-25-25% split) recorded the lowest grain (5.5 t/ha) and straw (6.8 t/ha) yield. The scheduling of N with split amounts increased the grain and straw yield by 12.7% and 15%, respectively over traditional approach.

Economics

The cost of cultivation was lower in all the treatments involving herbicide use. It was the lowest with ready-mix combination of triafamone 20% + ethoxysulfuron 10% (₹ 35.64 x 10³/ha), closely followed by fenoxaprop-p-ethyl + ethoxysulfuron (₹ 35.71 x 10³/ha). Although two hand weeding at 20 and 40 DAT resulted in the highest yield (6.8 t/ha), it involved the highest cost of cultivation (₹ 55.71 x 10³/ha), resulting in less net return (₹ 64.46 x 10³/ha) and reduced return per rupee invested (1.2) as compared to chemical weed management (1.8-1.9). As reported by Warde *et al.* (2006), manual hand weeding was very effective in controlling weeds although it was cumbersome, labour-intensive, cost-prohibitive and time-consuming. B:C ratio was the highest (1.9) with application of triafamone 20% + ethoxysulfuron 10%, fetching higher economic return.

Table 3. Growth and yield parameters of rice as influenced by herbicides and time of nitrogen application (pooled data of 2 years)

Treatment	Plant height (cm)	tillers/hill	LAI at flowering	Panicle length (cm)	Filled grains/panicle	1000 grain weight (g)	Crop phytotoxicity Initial (5 DAA)	20 DAA of herbicide
<i>Weed management</i>								
Fenoxaprop-p-ethyl + ethoxysulfuron	111.7	9.0	3.9	23.9	160.0	20.2	4.0	1.4
Triafamone 20% + ethoxysulfuron 10%	114.4	9.1	4.1	24.4	163.0	20.6	1.0	1.0
Two hand weeding	115.7	11.0	4.7	25.2	164.0	21.5	1.0	1.0
Weedy	102.5	7.0	3.8	22.6	141.0	18.9	1.0	1.0
LSD (p=0.05)	2.97	1.29	0.33	0.89	3.02	0.92	-	-
<i>Nitrogen fertilizer schedule</i>								
25% N at 10 DAT + 50% N at AT + 25% N at PI	114.9	10.0	4.7	24.8	161.0	21.2	1.8	1.0
25% N at basal + 50% N at AT + 25% N at PI	110.6	9.0	3.8	23.8	157.0	20.1	1.8	1.1
50% N at basal + 25% N at AT + 25% N at PI	107.7	9.0	3.9	23.4	153.0	19.6	1.8	1.2
LSD (p=0.05)	2.56	NS	0.27	0.77	2.61	0.79	-	-

DAT: Days after transplanting; DAA: Days after application; NS: Not significant

Table 4. Yield and economics of rice as influenced by herbicide mixture and nitrogen application (pooled data of 2 years)

Treatment	Grain yield (t/ha)			Straw yield (t/ha)			Cost of cultivation (x10 ³ ₹/ha)	Net returns (x10 ³ ₹/ha)	B:C ratio
	2018	2019	Pooled	2018	2019	Pooled			
<i>Weed management</i>									
Fenoxaprop-p-ethyl + ethoxysulfuron	6.2	5.5	5.8	7.6	6.9	7.2	35.71	66.92	1.8
Triafamone 20% + ethoxysulfuron 10%	6.0	6.1	6.0	7.8	7.6	7.7	35.64	69.36	1.9
Two hand weeding	7.2	6.7	6.8	8.9	8.2	8.5	55.71	64.46	1.2
Weedy	4.6	4.7	4.7	6.0	5.8	5.9	34.03	47.83	1.4
LSD (p=0.05)	0.28	0.01	0.59	0.47	0.03	0.22	-	10.4	0.29
<i>Nitrogen fertilizer schedule</i>									
25% N at 10 DAT + 50% N at AT + 25% N at PI	6.6	6.2	6.3	8.2	7.8	8.0	39.27	71.07	1.8
25% N at basal + 50% N at AT + 25% N at PI	5.8	5.7	5.7	7.4	7.1	7.2	39.27	59.62	1.5
50% N at basal + 25% N at AT + 25% N at PI	5.6	5.4	5.5	7.1	6.7	6.8	39.27	55.73	1.4
LSD (p=0.05)	0.25	0.01	0.52	0.40	0.02	0.19	-	9.03	0.25

DAT: Days after transplanting; AT: Active tillering; PI: Particle initiation

Among the treatments of nitrogen scheduling, split application of nitrogen as 25% at 10 DAT + 50% at AT + 25% at PI recorded significantly the highest net return (₹ 71.07 x10³/ha) and B: C ratio (1.8) over the others.

It was concluded that application of triafamone 20% + ethoxysulfuron 10% (ready-mix) 67.5 g/ha at 20 DAT along with scheduling of nitrogen as 25% at 10 DAT + 50% at AT + 25% at PI would be an effective recommendation for ensuring cost-effective weed management as well as higher productivity in transplanted rice.

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