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Kutikuppala Hemalatha
Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh India

Yashwant Singh
Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh India

Correspondence
Kutikuppala Hemalatha
Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh India

Effect of leaf colour chart based nitrogen and weed management on yield and economics of direct seeded rice

Kutikuppala Hemalatha and Yashwant Singh

Abstract
A field experiment was conducted during *Kharif*, 2016 and 2017 in sandy clay loam soils of experimental field at Banaras Hindu University, Varanasi, Uttar Pradesh to find out the effect of leaf colour chart based nitrogen and weed management practices on yield attributes, yield and economics of direct seeded rice. The experiment was laid out in split plot design with four main plot treatments and five sub plot treatments which were replicated thrice. It was found that superior performance of rice in terms of yield attributes and yield was observed with application of nitrogen @ LCC $\leq$ 5 (N_4). Among weed management practices, maximum Weed control efficiency, yield, gross returns, net returns and B: C ratio was recorded with application of pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (W_4) which was comparable with two hand weedings at 20 and 40 DAS (W_1) while weedy check (W_0) recorded lowest weed control efficiency, yield and yield attributes and economics.

Keywords: Economics, B: C ratio, LCC, Nitrogen, herbicides, weed management

Introduction
Rice is the staple food for more than half of the population of the world, is an important target to provide food security and livelihoods for millions. Imminent water crisis, water-demanding nature of traditionally cultivated rice and climbing labour costs ramble the search for alternative management methods to increase water productivity, system sustainability and profitability. Direct seeded rice technique because of its low-input demanding nature is becoming popular nowadays. In direct seeded rice, weed and nematode infestation are major problems, which cause enormous yield losses. Other associated problems with DSR are increased incidences of blast disease crop lodging impaired kernel quality, increased panicle sterility and stagnant yields across the years (Ekta *et al*., 2013) [2]. Direct seeding of rice refers to the process of establishing the crop from seeds sown in the field rather than by transplanting seedlings from the nursery (Farooq *et al*., 2011) [3].

Nitrogen (N) consumption has increased substantially in the past decades since it is the most widely used fertilizer nutrient in rice. The quantity of rice grain produced per unit of applied N fertilizer (partial factor productivity) has continuously decreased to very low values (Dobermann *et al*. 2002) [1]. Unbalanced and extreme use of N-fertilizers causes environmental pollution, lodging of plants and increased pest outbreak, in addition to increased cost to farmers from excessively applied fertilizers and pesticides. Hence, International Rice Research Institute and the Philippine Rice Research Institute developed a leaf color chart (LCC) to guide need based N applications that helps farmers for real-time nitrogen management in rice farming. Adoption of direct-seeded rice has resulted in a change in the relative abundance of weed species in rice crop. The shift from transplanted to direct-seeded rice results in more aggressive weed flora and increased reliance on herbicides, owing to increasing labour problems and time consuming, cumbersome and less effective nature of cultural and mechanical methods of weed control. To avoid undesirable weed shift and herbicide resistance in weeds, the continuous use of herbicides with similar mode of action has to be restricted.

Material and Methods
A field experiment was conducted during rainy (*Kharif*) season of 2016 and 2017 at Agricultural Research Farm, Department of Agronomy, Institute of Agricultural sciences,

Banaras Hindu University, Varanasi, Uttar Pradesh. The soil was Gangetic alluvial having Sandy clay loam in texture with pH 7.80. The experiment was laid out in split-plot design with three replications. The nitrogen management subjected to main plots while weed management in sub plots. A combination of 20 treatments consisting of 4 nitrogen management, viz., N_1: RDN (120 kg N ha^{-1}), N_2: LCC $\leq$ 3, N_3: LCC $\leq$ 4, N_4: LCC $\leq$ 5 and 5 weed management treatments viz., W_0: Weedy check, W_1: Two hand weedings at 20 and 40 DAS, W_2: Pendimethalin @ 1 kg a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS, W_3: Flufenacet @ 120 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS, W_4: Pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS. Recommended dose of N, P and K were applied at 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}. Zn@ 5 kg ha^{-1} was applied basal. Full dose of phosphorus and potash were applied as basal application and nitrogen was applied as treatment wise. Dry seed of 'HUR 105' variety of rice at 30 kg ha^{-1} was used for seeding of rice. Rice variety 'HUR 105' @ 30 kg ha^{-1} was sown manually with the help of spade at a spacing of row 20 cm. The herbicides were applied as per treatment using spray volume of 500 litres of water ha^{-1} with the help of knap sack sprayer fitted with flat fan nozzle. The data on weeds were subjected to square-root transformation ($\sqrt{x+0.5}$) to normalize their distribution. The density and dry weight of weeds were taken at different growth stages in each plot using a quadrate of 0.25m^2. Weed species in each quadrate were separated and dried in shade initially and later oven dried till the constant weight was recorded. The data on density and dry weight of weeds were subjected to square-root transformation. The net return was worked out by using following formula:

Net return (Rs ha^{-1}) = Gross return (Rs ha^{-1}) – Cost of cultivation (Rs ha^{-1})

Whereas, benefit cost ratio (B: C ratio) was worked out on the basis of gross return (Rs ha^{-1}) and cost of cultivation (Rs ha^{-1}).

$$\text{B: C ratio} = \frac{\text{Gross returns (Rs ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

The data obtained by various observations during the course of investigation were subjected to statistical analysis for determining the significance of difference as described by Snedecor and Cochran (1968).

Results and Discussion

Weed Flora

Major weed flora species infesting in the direct seeded rice as observed in weedy check plots were, grasses, sedges and broad-leaved weeds. The critical analysis of data on relative composition of weed species indicated that *Echinochloa colona*, *Echinochloa crussgalli* and *Cyanodon dactylon* among grasses, *Cyperus rotundus* and *Cyperus iria* among sedges and *Eclipta alba* and *Caesulia auxillaris* among broad leaved weed were dominant throughout the crop growth period.

Effect on Weeds

Weed Density

Statistically detectable disparities were noticed with respect to total weed density (Table 1) due to various nitrogen and weed control practices. Among nitrogen management treatments, LCC $\leq$ 5 (N_4) was effective in controlling broad spectrum of weeds *i.e.*, grasses, sedges and broad leaved weeds at harvest and significantly lower weed population was found which was comparable with LCC $\leq$ 4 (N_3). Maximum weed population was found in case of N_1-RDN (120 kg N ha^{-1}) during both the years of study. This might be due to the fact that in all LCC treatments equal and liberal amounts of nitrogen were applied with more number of splits at critical growth stages and made timely availability of nitrogen as per need of the plant. These results are in conformity with the findings of Sen *et al*., (2011) [8].

All the weed management practices showed significant effect on weeds and had less weed infestation as compared to weedy check (W_0) which recorded maximum weed population. The lowest weed density among the herbicide treatments was registered with two hand weedings at 20 and 40 DAS (W_1) and application of pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (W_4) and significantly superior to rest of the herbicide treatments and weedy check (T_1). Better performance exhibited by W_4 in reducing the total number of grasses, broad leaved weeds and sedges might be due to the reason that it was able to control all the weeds effectively at all growth stages. These results are corroborating with the study of Upasani and Barla (2014).

Table 1: Effect of Leaf colour chart based nitrogen and weed management on density of weeds, dry weight and WCE at harvest of direct seeded rice

Treatments	Grasses (No. m-2)		Sedges (No. m-2)		Broad leaved weeds (No. m-2)		Weed dry weight (g m-2)		WCE (%)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Nitrogen management										
N_1: RDN (120 kg N ha^{-1})	11.63 (138.54)	12.91 (168.98)	7.44 (56.04)	8.35 (70.24)	6.03 (37.67)	6.67 (45.54)	10.25 (105.77)	10.98 (123.67)	23.62	25.39
N_2: LCC $\leq$ 3	10.47 (113.77)	12.10 (148.57)	7.60 (57.97)	8.45 (71.79)	5.83 (35.14)	6.52 (43.65)	9.80 (96.26)	10.77 (116.87)	30.48	29.49
N_3: LCC $\leq$ 4	10.10 (103.54)	11.64 (136.25)	6.87 (48.73)	7.82 (62.89)	5.59 (31.87)	6.37 (41.24)	9.49 (91.85)	10.47 (110.00)	33.67	33.63
N_4: LCC $\leq$ 5	9.18 (85.98)	10.68 (115.71)	6.60 (45.44)	7.57 (58.57)	5.46 (30.84)	5.96 (36.73)	9.21 (89.17)	10.21 (106.93)	35.60	35.49
SEm $\pm$	0.16	0.21	0.35	0.17	0.11	0.14	0.15	0.14	--	--
CD (P=0.05)	0.55	0.71	0.54	0.58	0.38	0.48	0.51	0.49	--	--
Weed management practices										
W_0: Weedy check	12.71 (166.43)	13.86 (193.48)	8.87 (78.42)	9.85 (96.75)	7.47 (56.17)	8.10 (65.50)	11.77 (138.47)	12.83 (165.75)	0.00	0.00
W_1: Two hand weedings at 20 and 40 DAS	8.49 (72.60)	10.06 (101.66)	5.93 (35.38)	6.70 (44.96)	4.24 (17.63)	4.83 (23.17)	8.57 (74.38)	9.34 (86.75)	46.28	47.66
W_2: Pendimethalin @ 1 kg a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	10.26 (104.92)	11.92 (141.99)	7.01 (48.88)	7.98 (63.30)	6.09 (36.83)	6.80 (46.06)	9.49 (90.17)	10.54 (111.25)	34.88	32.88

W_3: Flufenacet @ 120 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	11.05 (122.24)	12.70 (161.49)	7.28 (52.75)	8.28 (68.20)	5.64 (31.53)	6.27 (39.26)	9.77 (95.57)	10.85 (117.66)	30.98	29.01
W_4: Pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	9.23 (86.09)	10.63 (113.25)	6.55 (44.79)	7.44 (56.16)	5.20 (27.23)	5.91 (34.97)	8.83 (80.23)	9.49 (90.42)	42.06	45.45
SEm ±	0.13	0.14	0.31	0.26	0.20	0.23	0.10	0.13	--	--
CD (P=0.05)	0.36	0.40	0.90	0.76	0.58	0.65	0.29	0.39	--	--

Weed Dry Weight

Total weed dry weight was significantly influenced by different nitrogen and weed management practices. Application of nitrogen @ LCC ≤ 5 (N_4) recorded minimum weed dry weight which was comparable with application of nitrogen @ LCC ≤ 4 (N_3) and the maximum weed dry weight was recorded with the application of N_1-RDN (120 kg N ha^{-1}) at harvest during both the years of study. This might be due to the increased availability of nitrogen in the soil at higher doses and timely availability of nitrogen as per requirement of the plant. These results are in agreement with those of Singh and Tripathi (2007) [9].

Among weed management practices, significantly lower total dry weight of weeds at harvest was noticed with two hand weedings at 20 and 40 DAS (W_1) which was on a par with application of pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (W_4). Maximum weed dry weight was found with weedy check (W_0).Superior performance of herbicides in reducing the weed dry weight might be due to tank mix application for controlling diverse group of weeds at a time in direct seeded condition. The tank mix application of such suitable herbicides performed better against diverse weed flora as compared to application of a single herbicide has also been reported by Narolia *et al*. (2014) [6].

Weed Control Efficiency

Under different nitrogen treatments, application of nitrogen @ LCC ≤ 5 (N_4) recorded highest weed control efficiency (35.60 and 35.49, respectively) due to lower dry matter accumulation of weeds at all the stages of crop growth at harvest during both the years of study (Table 1). Application of N_1-RDN (120 kg N ha^{-1}) had minimum weed control efficiency (23.62 and 25.39, respectively) than other nitrogen treatments due to higher dry weight of weeds.

Among different weed management practices, two hand weedings at 20 and 40 DAS (46.28 and 47.66, respectively) recorded higher weed control efficiency followed by pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (42.06 and 45.45, respectively) which might be due to the fact that the successive application of two herbicides at an interval of 20 days created an adverse reduction in total weed dry matter. The results of the present investigation was in conformity with those reported by Narolia *et al*. (2014) [6] who also obtained significant increase in weed control efficiency with sequential application of herbicides.

Effect on yield attributes and yield

Nitrogen and weed management practices were found to influence the yield attributing characters markedly. Among nitrogen management practices, application of nitrogen @ LCC ≤ 5 (N_4) produced significantly higher number of spikelets panicle^{-1} (Table 2) which was comparable with application of nitrogen @ LCC ≤ 4 (N_3). More number of early formed tillers under favorable N nutrition tends to bear more number of panicles. It might be due to higher availability and uptake of N which is a substrate for synthesis of organic compounds, which constitute protoplasm and chlorophyll (Sen *et al*., 2011) [8].

Under weed management treatments, two hand weedings at 20 and 40 DAS (W_1) and pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (W_4) recorded more number of spikelets panicle^{-1} and was followed by Pendimethalin @ 1 kg a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (W_2). Minimum number of spikelets panicle^{-1} were observed with weedy check (W_0). Effective suppression of weed growth throughout the critical period of crop-weed competition might have enabled direct seeded rice to bear promising architecture for yield attributes. Fertility percentage and test weight of direct seeded rice did not alter significantly (Table 2) due to nitrogen levels and weed management practices during both the years of study.

Grain yield is an ultimate result of yield attributes *viz*. total number of spikelets panicle^{-1}, fertility percentage and 1000 grain weight. The various nitrogen treatments and weed management practices were significantly affected grain and straw yield of crop during both the years of experimentation. Application of LCC ≤ 5 (N_4) was recorded maximum grain and straw yield than other nitrogen treatments (Table 2). The increased yield was perhaps as a result of higher quantity of nitrogen applied in more number of splits compared to other levels. These results are also in close conformity with the findings of Maiti and Das (2006) [5] who reported higher grain yield with LCC based nitrogen management. The minimum grain and straw yield was recorded under nitrogen application of N_1-RDN (120 kg N ha^{-1}).

Amongst various weed management treatments, hand weeding twice at 20 and 40 DAS resulted in significantly higher grain and straw yield and was comparable with application of pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (Table 2) than other weed management treatments. It might be due to the reason that the sequential application of two herbicides having distinct mode of actions created a rather weed free environment by effectively suppressing a broad-spectrum of weed population and consequently weed dry matter. Similar views were also expressed by Narolia *et al*. (2014) [6].

Table 2: Effect of Leaf colour chart based nitrogen and weed management on yield and yield attributes of direct seeded rice

Treatments	No. of spikelets panicle^{-1}		Fertility percentage (%)		Test weight (g)		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Nitrogen management										
N_1: RDN (120 kg N ha^{-1})	102.60	98.67	79.36	76.84	21.61	20.96	3515.15	3122.91	5471.86	5350.65
N_2: LCC ≤ 3	110.75	106.60	85.10	78.05	21.35	21.41	3688.31	3316.02	5645.02	5428.57
N_3: LCC ≤ 4	116.42	114.60	83.45	81.10	22.21	21.87	3826.84	3696.97	5437.23	5423.84

N_4: LCC ≤ 5	123.25	118.67	84.68	81.97	22.62	22.42	4277.78	4025.97	6025.97	5922.08
SEm ±	2.62	1.44	1.50	1.38	0.77	0.81	97.91	59.70	70.21	63.26
CD (P=0.05)	9.08	4.98	NS	NS	NS	NS	338.82	206.59	242.95	218.90
Weed management practices										
W_0: Weedy check	97.78	94.25	76.72	80.17	20.63	20.28	2532.47	2186.15	4956.71	4745.17
W_1: Two hand weedings at 20 and 40 DAS	124.07	123.25	83.01	80.11	23.11	22.62	4827.75	4574.63	6093.07	6006.49
W_2: Pendimethalin @ 1 kg a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	113.73	108.75	84.91	78.82	21.83	21.59	3733.77	3463.20	5692.64	5562.77
W_3: Flufenacet @ 120 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	107.33	100.50	87.20	78.55	21.42	21.28	3387.45	3084.42	5422.08	5357.14
W_4: Pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	123.38	121.42	83.89	79.79	22.73	22.57	4653.68	4393.94	6060.61	5984.85
SEm ±	1.22	1.33	1.33	1.32	0.62	0.60	76.89	70.45	68.19	54.23
CD (P=0.05)	3.52	3.83	NS	NS	NS	NS	221.49	202.94	196.42	156.22

Effect on Economics

The economics of different nitrogen treatments revealed that the maximum gross return (₹ 65468.61 and 61740.26 ha^{-1}), net returns (₹ 28758.43 and 25030.08 ha^{-1}) and B: C ratio (1.76 and 1.69) were recorded with application of nitrogen through LCC ≤ 5 (Table 3) during both the years of experimentation. This might be due to steady supply of nitrogen which synchronized with the peak period of nitrogen requirement that had produced higher yield (Gupta *et al*., 2011) [4].

In case of weed management treatments, hand weeding twice at 20 and 40 DAS (W_1) resulted in significantly higher gross returns (₹ 73531.65 and 69792.84 ha^{-1}) which was followed by application of pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (Table 3). Pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (W_4) resulted in higher net returns (₹ 36510.09 and 25030.08ha^{-1}) and B: C ratio (2.06 and 1.96). While, significantly lower values for gross (₹ 39452.38 and 34290.33 ha^{-1}), net returns (₹ 8594.45 and 3432.40ha^{-1}) and B: C ratio (1.28 and 1.12) was observed in weedy check (W_0). It might be due to higher grain yield, barring labour costs and effective working of pyrazosulfuron *fb* bispyribac compared to other treatments. The lower B: C ratio with weedy check might due to higher labour cost involved in hand weeding and the higher cost involved in manual weeding was not compensated by the additional grain yield obtained in hand weeding twice at 20 and 40 DAS (W_1) resulting in lower benefit cost ratio (BCR). Similar results were given by Saravanane *et al.* (2016) [7].

Table 3: Effect of Leaf colour chart based nitrogen and weed management on economics of direct seeded rice

Treatments	Gross returns (₹ ha^{-1})		Net returns (₹ ha^{-1})		B:C ratio	
	2016	2017	2016	2017	2016	2017
Nitrogen management						
N_1: RDN (120 kg N ha^{-1})	54057.14	48269.77	18438.75	12651.38	1.52	1.34
N_2: LCC ≤ 3	56671.85	51128.14	21647.67	16103.96	1.62	1.46
N_3: LCC ≤ 4	58590.48	56687.68	22442.30	20539.50	1.60	1.58
N_4: LCC ≤ 5	65468.61	61740.26	28758.43	25030.08	1.76	1.69
Weed management practices						
W_0: Weedy check	39452.38	34290.33	8594.45	3432.40	1.28	1.12
W_1: Two hand weedings at 20 and 40 DAS	73531.65	69792.84	29443.72	25704.91	1.66	1.59
W_2: Pendimethalin @ 1 kg a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	57359.31	53344.16	21896.87	17881.72	1.62	1.52
W_3: Flufenacet @ 120 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	52167.75	47711.04	17663.82	13207.11	1.51	1.39
W_4:Pyrazosulfuron @ 20 g a.i ha^{-1}(PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS	70974.03	67143.94	36510.09	32680.01	2.06	1.96

Conclusion

Thus, it can be concluded that, application of nitrogen through LCC ≤ 5 was found most economical in DSR as it resulted in higher gross, net returns and B: C ratio. Among weed management treatments sequential application of pyrazosulfuron @ 20 g a.i ha^{-1} (PE) *fb* bispyribac @ 25 g a.i ha^{-1} at 15-20 DAS (W_4) was found to be the most effective weed management practice to achieve broad spectrum weed control and to realize higher yield attributes, grain yield as well as economic returns from *Kharif* sown direct seeded rice compared to hand weeding.

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