

Original Research Article

Evaluation of new generation herbicide-based weed management strategies on direct sown rice production in Cauvery deltaic zone

Abstract

Field assay was conducted during “Navarai” season, 2019 at Chidambaram region of Cauvery delta to find out the influence of new generation herbicide-based weed management in direct sown rice production. The Experiment was laid out in randomized block design with three replications using rice cultivar CO-51. The treatments include T₁- Un-weeded check, T₂- Twice hand weeding at 15 and 30 DAS T₃- Pre-emergence application of pyrazosulfuron-ethyl 10% WP at 200g ha⁻¹ at 7 DAS + one Hand weeding at 30 DAS T₄- Pre-emergence application of metsulfuran-methyl 10% + chlorimuron-methyl 10% WP at 20g ha⁻¹ at 7 DAS + one Hand weeding at 30 DAS T₅-Pre-emergence application of Pretilachlor 50% EC at 1250 ml ha⁻¹ at 7 DAS + one Hand weeding at 30 DAS T₆- Early post-emergence application of pretilachlor 6% + pyrazosulfuron-ethyl 0.15% G at 615g ha⁻¹ at 15 DAS. T₇- Early post-emergence application of bispyribac-sodium 10% SC at 300 ml ha⁻¹ 15 DAS T₈- Early post-emergence application of pretilachlor 6% + pyrazosulfuron-ethyl 0.15% G at 615g ha⁻¹ at 15 DAS + one Hand weeding at 30 DAS T₉- Early post-emergence application of bispyribac-sodium 10% SC at 300 ml ha⁻¹ at 15 DAS+ one Hand weeding at 30 DAS. On analysing the experimental results, it is revealed that all the imputed treatments have affected weed flora, crop growth, yield attributes and economics of direct sown rice cultivation. Furthermore, application of bispyribac-sodium 10% SC at 300 ml ha⁻¹ at 15 DAS + one hand weeding at 30 DAS provided superior results amid all the treatments. The absence of weed management practices (i.e) T₁- Un-weeded check has negatively affected the crop production to a greater extent by registering poor crop growth and yield parameters.

Key words: Crop yield, Direct Sown Rice, New-generation herbicides and Integrated Weed management

Introduction

Cauvery delta zone is a highly fertile rice growing area lies in the eastern part of Tamil Nadu in which the cropping systems are majorly based on rice. The farmers in this zone are specialized in wetland rice cultivation since time immemorial. Globally, weeds are the main biotic factor limiting rice productivity. Approximately 60% of the weeds in transplanted rice appear one week to one month after transplanting. At the effective tillering

stage, these emerging weeds are competing with rice, and a decrease in panicle quantity results in a lower grain yield³³. One of the most common weeds *Cyperus rotundus*, makes it difficult to prepare land for rice farming. Additionally, during the early stages of rice growth, weed infestation and *Cyperus* rhizome regeneration occur due to improper land levelling and an alternating wet and dry irrigation pattern¹⁷. As transplanted paddy is most common practice among this area, due to resource constraint situations direct sown rice cultivation is opted by rice farmers among this agro-ecological zone³⁵. While undergoing conversion from transplanted rice production to directly sown rice results in more weed flora competition, requiring revised weed management approaches to effectively control the complex weed biota²¹. Farmers frequently use hand weeding as a method of controlling weeds, but it takes a lot of time, is labor-intensive, and is waged highly. The most practical, affordable, and efficient method of controlling weeds is through the use of herbicides³⁷. But old generation herbicides requires bulk application and formation of toxic residues in environment, modern new generation low dose herbicides offers a feasible management practice in crop production without affecting the environment^{4,40,41,42}. Although butachlor, a renowned rice herbicide, when applied in field conditions may cause ecological consequences like alteration of the metamorphosis cum growth of the alpine cricket frog (*Fejervaryalimnocharis*)¹⁴, causing DNA damage on the erythrocytes of freshwater catfish (*Clarias batrachus*)², and has been affirmed as a B2, L2, and C class of carcinogen by various environmental agencies¹⁹. Recently, pendimethalin has been banned by the government of Kerala because of its harmful side effects on humans and aquatic animals. New generation herbicides like bispyribac sodium and pyrazosulfuron-ethyl are relatively much safer when applied appropriately (i.e., bispyribac sodium improved the AMF colonisation, sporulation, and other microbial properties in an aerobic rice system²⁴, and application of pyrazosulfuron ethyl at 25 g ha⁻¹ to manage annual and perennial weeds in rice field, did not cause any environmental hazard³¹). Considering the above information in view, a field investigation has been carried out to study the efficacy of new generation herbicide-based weed management strategies on weed population dynamics, crop growth and development, crop yield, and economics in direct-sown rice and to find a suitable weed management strategy for this locality.

Materials and methods

Field assessment was conducted during Navarai rice growing season, 2019 at Agronomy Department Experimental Farm, Annamalai University to observe the influence of certain new generation herbicide-based weed management practices in direct-sown rice production. The soil of the experimental field was clay loam in texture and the physico-

chemical properties of the experimental field soil is presented in Table 1. The treatments assigned in this field assessment were tabulated in Supplementary Table 1. Before sowing, the test crop CO51 rice variety seeds were treated with *Pseudomonas fluorescens* for preventing fungal infection at early growth stages and sown at a spacing of 15 x 10 cm in the main field. The experiment was carried out in a randomized block design (RBD) with three replications. All the pre-emergence herbicides (pyrazosulfuron-ethyl 10%, pretilachlor 50% EC, metsulfuron-methyl 10%, and chlormuron-ethyl 10% @ 20 g ha⁻¹) were sprayed on 7 DAS, and early post-emergence herbicides (pretilachlor 6%, pyrazosulfuron-ethyl 0.15% G, and bispyribac-sodium 10%) were applied on 15 DAS with a flat fan nozzle attachment of knapsack sprayer. As per the recommendations issued by Tamil Nadu Agriculture University, the blanket fertiliser recommendation of 120:40:40 kg NPK ha⁻¹ was followed by applying entire quantity of phosphorus as basal dose whereas Nitrogen cum potassium fertilisers were given in 3 splits during basal, tillering, and panicle initiation stages of the crop. Observations, viz., weed parameters (weed population, weed Dry Matter Production (DMP)), crop growth parameters (plant height, Leaf area Index (LAI), number of tillers clump⁻¹, and Dry Matter Production (DMP)), yield parameters (number of panicles m⁻², number of filled grains in panicle⁻¹, 1000 grain weight, grain yield, and straw yield), and economics (cost of cultivation, gross income, net income, and benefit cost ratio (BCR)) were recorded and furnished in tables 2, 3, 4, 5 and 6. The experimental data were statistically analysed and significance of the difference between the means of the treatments, the critical difference (CD) was calculated at the 5% probability level.

Result

Effect of weed control measures on weed attributes

The most important weed flora detected in the experimental field are *Echinochloa colonum*, *Echinochloa crus-galli*, *Leptochloa chinensis*, *Cyperus rotundus*, *Cyperus difformis*, *Marsilea quadrifolia*, and *Eclipta alba*. Sedges are the dominant weed biota in rice production, our experimental setup has also shown a severe infestation of sedges. All the given treatments have a substantial influence on the weed population, DMP and Weed Control Index (WCI). Among them, T₇- early post-emergence application of bispyribac-sodium 10% SC at 15 DAS + one Hand weeding at 30 DAS produced superior results by recording the lowest weed population of 6.77 and 8.83 on 30 and 60 DAS, the lowest DMP of 17.23 and 24.87 on 30 and 60 DAS, and the highest WCI of 92.40% on 60 DAS.

Effect of weed control measures on Crop growth attributes

All the imposed weed control treatments has shown momentous effects on the crop growth. Among them, T₇- early post-emergence application of bispyribac-sodium 10% SC at 15 DAS + one Hand weeding at 30 DAS gives superior results, viz., plant height (75.56 cm on 60 DAS), number of tillers clump⁻¹ (26.21 on 60 DAS), LAI (6.74), and DMP (10.43 t ha⁻¹ on 60 DAS).

Effect of weed control measures on Yield parameters

The results showed that the assigned treatments impacted yield parameters viz., number of panicles, number of filled grains, grain yield and straw yield. The rice yield is mainly governed by the efficiency of the weed control practices involved in cultivation¹. 415.42 number of panicles m⁻², 113.56 number of filled grains panicle⁻¹, 5675 kg ha⁻¹ grain yield and 7865 kg ha⁻¹ straw yield are recorded in our trial with application of bispyribac-sodium 10% SC on 15 DAS + one Hand weeding at 30 DAS which is the best among given treatments.

Effect of weed control measures on economics

Higher crop productivity with lesser cost of cultivation could result in better economic parameters like higher net returns and B:C ratio. The treatment, Bispyribac-sodium 10% SC @ 15 DAS + one hand weeding on 30 DAS (T₉) registered the highest net income of Rs.49260.89 ha⁻¹ and return rupee⁻¹ invested of rupee 2.07. Unweeded control (T₁) recorded the least net income of Rs.-1264.13 ha⁻¹ and return rupee⁻¹ invested of 0.96.

Discussion

Effect of weed control measures on weed attributes

Bispyribac sodium + hand weeding recorded lowest weed density and highest weed control index. This result is attributed to the weed-control potential of systemic herbicide bispyribac-sodium (2,6-bis [(4,6 dimethoxypyrimidin-2-yl) oxy] benzoate), which moves inside plant tissues and interferes with the production of acetolactate synthase (ALS), which plays a pivotal role in the branched chain amino acids (i.e.) leucine, isoleucine, and valine production⁷. Except for BCAA starvation, other hypotheses about the secondary effects of ALS inhibition, such as accumulation of pyruvate and 2-aminobutyrate, inhibition of DNA synthesis, disruption of photo-assimilate translocation, and anaerobic respiration, have also been implicated in the mechanism of plant death caused by ALS-inhibiting herbicides^{15,39}. The affected weeds show stunted growth, reddening at plant tips, and further end up in plant

death. As this treatment is given along with hand weeding at 30 DAS, which removes the new weeds, it provides a weed-free environment in the crop vicinity, favouring crop growth to its maximum potential without any competition from weeds in the critical period of crop weed competition. The major advantage of following Integrated Weed Management (IWM) is that it prevents the formation of herbicidal resistance among weed flora and the accumulation of toxic herbicidal residues in the ecosystem. These findings agree with^{9,13,32}.

Effect of weed control measures on growth attributes

Researchers³⁶, reported the growth improvement by bispyribac-sodium 10% SC+ hand weeding^{3,29} stimulated growth attributes by herbicide cum hand weeding practise in direct sown rice. In this line, the selection of bispyribac-sodium 10% SC at 15 DAS + one hand weeding at 30 DAS for weed control in direct-sown rice has modified the agro-ecosystem for rice crop production by eliminating the competitive heterogeneous allelopathic weed flora present in the crop land during the active crop growth stages and making sure that the crop plant receives maximum light, space, nutrient, and moisture¹². As weed plants harbours harmful pests and diseases, its removal ensures safer and competition free environment to the crop plants and resulted in improved growth of rice plants¹⁷.

Effect of weed control measures on Yield parameters

Yield parameters also bispyribac-sodium 10% SC+ hand weeding combination was best this is because of the right selection and adoption of integrated weed management strategy rather than using chemical methods of weed management alone, it was similar with the findings of²⁶. This new generation herbicide based integrated weed management practise improved availability of natural resources and critical inputs for establishment of rice crop and endangering the survival of weed biota in the field²⁷. As direct sown rice is highly succumbed to weed competition, the effectiveness of this treatment removes the weed competition and facilitated higher yield in rice. This report is synchronous with the reports of^{10,25}. Yield reduction in rice cultivation is attributed to the increased weed infestation and weed interference throughout the crop period⁶. Due to heavy competition offered by weeds in unweeded control plot, poor crop performance was obtained⁵.

Effect of weed control measures on economics

The efficacy of any production system is ultimately evaluated on the basis of its economics. Effective weed control without increasing the cost of cultivation is highly preferable among the farming community^{16,30}. As traditional weed management needs high

labour charges, this integrated approach produced good results with lesser expenses²⁰. This hypothesis is supported by the highest B:C ratio (2.07) in the given treatment bispyribac sodium 10% SC & 15 DAS followed by one hand weeding on 30 DAS. This finding is congruent with the results of^{11,28}.

Conclusion

Our experimental results revealed that the use of this integrated approach to weed management in direct-sown rice production has controlled the weed biota, enhanced crop growth, and produced a higher yield at a lower expense. As this method requires less labour and provides good control over heterogeneous weeds without building up toxic residues in the environment, it can be easily adapted in resource-constrained situations. Hence, the recommendation of bispyribac sodium 10% SC @15 DAS followed by one hand weeding on 30 DAS is advisable among the direct sown rice farming community for effective weed management in this Cauvery Deltaic Zone. As our studies are conducted from an agronomical perspective, much research is needed to find out about the various factors hindering the adoption of this practise in this region for achieving sustained rice production and food security.

Conflict of Interest

The author has no conflict of interest with the other authors and academic institution

Acknowledgement

The authors wish to express their gratitude to Department of Agronomy, Faculty of Agriculture, Annamalai University, for supporting the research work on “A comparative study on the effect of new generation herbicide based weed management strategies on weed population dynamics, Crop growth, yield& economics on direct sown rice cultivation in Cauvery deltaic zone”.

Table 1 Soil Physico-chemical properties of the experimental field

Parameters	Values	Remark	Methods adopted
pH	7.5	Neutral	Jackson, 1973
Organic carbon (%)	0.70	Medium	Walkley and Black, 1934
Available N (kg ha ⁻¹) 1)	232.5	Low	Subbiah and Asija, 1956
Available P (kg ha ⁻¹)	19.2	Medium	Olsen <i>et al.</i> , 1954
Available K (kg ha ⁻¹) 1)	324.6	High	Jackson, 1973

Supplementary Table 1- Treatment details

T₁	Un-weeded check
T₂	Twice hand weeding @ 15 and 30 DAS
T₃	Pre-emergence application of Pyrazosulfuron-ethyl 10% WP @ 200g ha ⁻¹ @ 7 DAS + one Hand weeding @ 30 DAS
T₄	Pre-emergence application of Metsulfuran-methyl 10% + Chlorimuron-methyl 10% WP @ 20g ha ⁻¹ @ 7 DAS + one Hand weeding @ 30 DAS
T₅	Pre-emergence application of Pretilachlor 50% EC @ 1250 ml ha ⁻¹ @ 7 DAS + one Hand weeding @ 30 DAS
T₆	Early post-emergence application of Pretilachlor 6% + Pyrazosulfuran-ethyl 0.15% G @ 15 DAS.
T₇	Early post-emergence application of Bispyribac-sodium 10% SC @ 300 ml ha ⁻¹ 15 DAS
T₈	Early post-emergence application of Pretilachlor 6% + Pyrazosulfuran-ethyl 0.15% G @ 15 DAS + one Hand weeding @ 30 DAS
T₉	Early post-emergence application of Bispyribac-sodium 10% SC @ 300 ml ha ⁻¹ @ 15 DAS+ one Hand weeding @ 30 DAS

Table.2. Effect of weed control treatments on individual weed population (m⁻²) on 30 DAS

Treatments	<i>Echinochloa lonum</i>	<i>Echinochloa crus-galli</i>	<i>Leptochloa chinensis</i>	<i>Cyperus rotundus</i>	<i>Cyperus difformis</i>	<i>Marsilea quadrifolia</i>	<i>Eclipta alba</i>
T ₁	12.5 (3.60)	10.2 (3.27)	11.3 (3.43)	41.02 (6.44)	19.26 (4.44)	8.6 (3.01)	3.2 (1.92)
T ₂	1.84 (1.52)	3.6 (2.02)	-	4.3 (2.19)	3.25 (1.93)	-	-
T ₃	6.03 (2.55)	7.2 (2.77)	4.2 (2.16)	12.1 (3.54)	8.14 (2.93)	5.1 (2.36)	1.9 (1.54)
T ₄	5.1 (2.36)	6.2 (2.58)	3.4 (1.97)	11.2 (3.42)	7.4 (2.81)	4.5 (2.23)	1.3 (1.34)
T ₅	5.9 (2.52)	6.8 (2.70)	3.9 (2.09)	11.8 (3.50)	7.8 (2.88)	4.8 (2.30)	1.7 (1.48)
T ₆	8.58 (3.01)	8.1 (2.93)	5.3 (2.40)	16.4 (4.11)	12.83 (3.65)	6.4 (2.62)	2.21 (1.64)
T ₇	9.57 (3.17)	8.8 (3.04)	6.40 (2.62)	25.2 (5.01)	14.75 (3.90)	7.3 (2.79)	2.8 (1.81)
T ₈	3.8 (2.07)	4.9 (2.32)	2.38 (1.69)	7.6 (2.84)	5.41 (2.43)	-	-
T ₉	1.04 (1.24)	1.73 (1.49)	-	2.16 (1.63)	1.84 (1.52)	-	-
S.Ed	0.11	0.09	NS	0.26	0.15	NS	NS
				0.54			

CD (p=0.05)	0.23	0.2			0.31		
-------------	------	-----	--	--	------	--	--

Figures in paranthesis are original values, values are square root transformed ($\sqrt{x + 0.5}$)

Table.3. Effect of weed control treatments on individual weed population (m⁻²) on 60 DAS

Treatments	<i>Echinochloa colonum</i>	<i>Echinochloa crus-galli</i>	<i>Leptochloa chinensis</i>	<i>Cyperus rotundus</i>	<i>Cyperus difformis</i>	<i>Marsilea quadrifolia</i>	<i>Eclipta alba</i>
T ₁	23.36 (4.88)	16.91 (4.17)	11.6 (3.47)	47.34 (6.91)	27.91 (5.33)	12.41 (3.59)	3.96 (2.11)
T ₂	5.36 (2.42)	2.05 (1.59)	-	6.65 (2.67)	3.68 (2.04)	-	-
T ₃	12.86 (3.65)	7.42 (2.81)	4.21 (2.17)	17.67 (4.26)	12.73 (3.63)	3.13 (1.90)	1.43 (1.38)
T ₄	11.74 (3.49)	6.21 (2.59)	3.16 (1.91)	16.63 (4.13)	11.92 (3.52)	2.24 (1.65)	1.13 (1.26)
T ₅	12.15 (3.55)	6.84 (2.70)	3.81 (2.07)	17.12 (4.19)	12.17 (3.55)	2.72 (1.79)	1.20 (1.30)
T ₆	17.72 (4.26)	13.11 (3.68)	7.45 (2.81)	22.91 (4.83)	17.82 (4.28)	6.21 (2.59)	3.14 (1.90)
T ₇	18.53 (4.36)	13.54 (3.74)	8.34 (2.97)	23.82 (4.93)	18.51 (4.36)	7.35 (2.80)	3.61 (2.02)
T ₈	8.25 (2.95)	3.81 (2.07)	-	10.37 (3.29)	7.86 (2.89)	-	-
T ₉	2.79 (1.81)	1.01 (1.22)	-	3.61 (2.02)	1.42 (1.38)	-	-
	0.21	0.20		0.28	0.31		

S.Ed			NS			NS	NS
Treatments	Weed population on 30 DAS	Weed population on 60 DAS	Weed DMP 30 DAS	Weed DMP 60 DAS	Weed Control Index (WCI)		

CD (p=0.05)	0.42	0.41		0.56	0.62		
-------------	------	------	--	------	------	--	--

Figures in paranthesis are original values, values are square root transformed ($\sqrt{x + 0.5}$)

Treatments	Plant height (cm) on 60 DAS	LAI 60 DAS	No. of tillers clump ⁻¹ 60 DAS	DMP 60 DAS	Number of panicles (m ⁻²)	Number of filled grains panicle ⁻¹	1000 grain weight	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
T ₁	106.08 (10.29)		145.29 (11.99) ₁		210.84		327.38		
T ₂	12.99 (3.60)		17.71 (4.27)		28.30 ₂		37.53	88.53	
T ₃	44.67 (6.68)		59.45 (7.74)		63.89		114.26	65.09	
T ₄	39.10 (6.25)		53.03 (7.31)		59.31		109.43	66.57	
T ₅	42.70 (6.53)		56.01 (7.51)		61.46		112.11	65.75	
T ₆	59.81 (7.73)		88.36 (9.42)		144.68		157.54	52.53	
T ₇	74.82 (8.64)		93.67 (9.70)		148.52		155.39	51.87	
T ₈	24.09 (4.91)		30.29 (5.54)		37.74		46.72	85.72	
T ₉	6.77 (2.60)		8.83 (3.05)		17.23		24.87	92.40	
S.Ed	0.47		0.59		2.67		3.27		
CD (p=0.05)	0.97		1.21		5.43		6.65		

Table.4. Effect of weed control treatments on total weed population, weed dry matter production (kg ha⁻¹) and WCI

Figures in paranthesis are original values, values are square root transformed ($\sqrt{x + 0.5}$)

T ₁	55.06	2.43	13.16	5.36	216.90	48.93	16.41	2290	4721
T ₂	72.06	5.72	23.36	9.26	403.79	104.70	16.69	5287	7546
T ₃	63.90	3.94	18.34	7.26	385.64	88.76	16.51	4655	6795
T ₄	65.33	4.16	19.27	7.60	352.38	90.79	16.58	4784	6986
T ₅	64.73	4.07	18.81	7.43	346.09	89.06	16.53	4701	6832
T ₆	60.10	3.37	16.53	6.46	318.53	80.32	16.48	3805	6437
T ₇	59.33	3.23	15.82	6.33	312.34	79.33	16.46	3634	6211
T ₈	68.83	4.88	21.15	8.46	385.64	98.25	16.60	5046	7307
T ₉	75.56	6.74	26.21	10.43	415.42	113.56	16.72	5675	7865
S.Ed	1.09	0.13	0.61	0.21	6.64	1.55	NS	91	112
CD (p=0.05)	2.23	0.27	1.24	0.43	13.49	3.16		184	227

Table.5. Effect of weed control treatments on Crop growth and yield attributes

Table.

Treatments	Cost of cultivation (Rs.)	Grossincome (Rs.)	Netincome (Rs.)	BCR
T ₁	41500.38	40236.25	-1264.13	0.96
T ₂	46745.54	88737.5	41991.96	1.89
T ₃	46019.27	77165	31145.73	1.67
T ₄	45563.78	79055	33491.22	1.73
T ₅	45745.43	78168.75	32423.32	1.70
T ₆	43575.62	65121.27	21545.65	1.49
T ₇	43695.38	62273.75	18578.37	1.42
T ₈	46975.15	84823	37847.85	1.80
T ₉	45695.36	94956.25	49260.89	2.07

6.Economic analysis ofweed control treatments on direct sown rice

UNDER PEER REVIEW

Reference

1. Arivelarasan T., Manivasagam V.S., Geethalakshmi, V., Bhuvanewari K., Natarajan, K., Balasubramanian, M. and Muthurajan R., How Far Will Climate Change Affect Future Food Security? An Inquiry into the Irrigated Rice System of Peninsular India, *Agriculture*, **13**(3), 551(2023)
2. Ateeq B., Farah M.A. and Ahmad W., Detection of DNA damage by alkaline single cell gel electrophoresis in 2, 4-dichlorophenoxyacetic-acid- and butachlor exposed erythrocytes of *Clarias batrachus*, *Ecotoxicol. Environ. Saf.*, **62**, 348-354(2015)
3. Chakraborti M., Duary B. and Datta M., Effect of Weed Management Practices on Nutrient Uptake by Direct Seeded Upland Rice under Tripura Condition, *Int.J.Curr.Microbiol.App.Sci.*, **6**(12), 66-72(2017)
4. Cheng F. and Cheng Z., Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy, *Frontiers in plant sci.*, **6**, 1020(2015)
5. Das R., Bera S., Pathak A. and Mandal M.K., Weed management in transplanted rice through bispyribac-sodium 10% SC and its effect on soil microflora and succeeding crop-Blackgram. *Int. J. Cur. Micro App. Sci.*, **4**(6), 681-688(2015)
6. Dass A., Shekhawat K., Choudhary A.K., Sepat S., Rathore S.S., Mahajan G. and Chauhan B.S., Weed management in rice using crop competition-a review. *Crop protection*, **95**, 45-52(2017)
7. Gu T., Wang Y., Cao J., Zhang Z., Li G., Shen W. and Wang H., Hydrogen-Rich Water Pre-treatment Alleviates the Phytotoxicity of Bispyribac-Sodium to Rice by Increasing the Activity of Antioxidant Enzymes and Enhancing Herbicide Degradation, *Agronomy*, **12**(11), 2821(2022)
8. Jackson M.L., Soil chemical analysis, Prentice Hall of India Pvt. Ltd., New Delhi. IInd Indian Reprint, 1-498 (1973)
9. Kaur S. and Singh S., Bio-efficacy of different herbicides for weed control in direct-seeded rice, *I. J. Weed. Sci.*, **47**(2), 106-109(2015)
10. Khaliq A., Matloob A., Ihsan M.Z., Abbas R.N., Aslam Z. and Rasool F. Supplementing herbicides with manual weeding improves weed control efficiency, growth and yield of direct seeded rice, *Int. J. Agric. Biol.*, **15**: 191-199(2013)
11. Kumar S., Rana S.S., Chander N. and Ramesh, Mixed weed flora management by Bispyribac-sodium in transplanted rice, *I. J. Weed. Sci.*, **45**(3), 151-155(2013)

12. Kumaran S.T., Kathiresan G., Arthanari P.M., Chinnusamy C. and Sanjivkumar V., Efficacy of new herbicide (bispyribac sodium 10% SC) against different weed flora, nutrient uptake in rice and their residual effects on succeeding crop of green gram under zero tillage, *J. Appli. Nat. Sci.*, **7**(1), 279-285(2015)
13. Lamichhane J.R., Devos Y., Beckie H.J., Owen M.D., Tillie P., Messéan A. and Kudsk P., Integrated weed management systems with herbicide-tolerant crops in the European Union: lessons learnt from home and abroad, *Critical reviews in biotechnology*, **37**(4), 459-475(2017)
14. Liu W.Y., Wang C.Y., Wang T.S., Fellers G.M., Lai B.C. and Kam Y.C., Impacts of the herbicide butachlor on the larvae of a paddy field breeding frog (*Fejervaryalimnocharis*) in subtropical Taiwan, *Eco.*, **20**, 377-384(2011)
15. Liu X.Q., Yu C.Y., Dong J.G., Hu S.W. and Xu A.X., Acetolactate synthase-inhibiting gametocide amidosulfuron causes chloroplast destruction, tissue autophagy, and elevation of ethylene release in rapeseed. *Frontiers in Plant Science*, **8**, 1625(2017)
16. MacLaren, C., Storkey J., Menegat A., Metcalfe H. and Dehnen-Schmutz K., An ecological future for weed science to sustain crop production and the environment. A review. *Agronomy for Sustainable Development*, **40**, 1-29 (2020)
17. Manisankar G., Ramesh T., and Rathika S., Weed management in Transplanted Rice through pre plant application of herbicide: A Review, *International Journal of Current Microbiology and Applied Science.*, **9**(5), 684-692 (2020)
18. Manisankar G., Ghosh P., Malik G.C. and Banerjee M., Recent trends in chemical weed management: A review, *The Pharma Innovation*, **11**(4), 745-753(2022)
19. Mohanty S.S. and Jena H.M., A systemic assessment of the environmental impacts and remediation strategies for chloroacetanilide herbicides, *J. Water Process Engi.*, **31**, 100860(2019)
20. Monteiro A. and Santos S., Sustainable approach to weed management: The role of precision weed management, *Agronomy*, **12**(1), 118 (2022)
21. Nazir A., Bhat M.A., Bhat T.A., Fayaz S., Mir M.S., Basu U. and El Sabagh A., Comparative analysis of rice and weeds and their nutrient partitioning under various establishment methods and weed management practices in temperate environment, *Agronomy*, **12**(4), 816(2022)
22. Olsen S.R., Cole C.V., Watanabe F.S. and Dean D.A., Estimation of available phosphorus in soil by the extraction with sodium bicarbonate, USDA (1954)

23. Pandey D., Singh G., Kumar R., Rao A., Kumar M. and Kumar A., Effect of weed management practices on growth and yield of Indian mustard. *J. Pharm. Phyto-chem.*, **8(4)**, 3379-3383(2019)
24. Panneerselvam, Periyasamy S., Saha A., Senapati A.K., Nayak U., Kumar and Mitra, D., New generation post-emergence herbicides and their impact on arbuscular mycorrhizae fungal association in rice, *Cur. Res. Micro. Sci.*, **2**: 100067(2021)
25. Parthipan T., Ravi V., Subramanian E. and Ramesh T., Integrated weed management on growth and yield of transplanted rice and its residual effect on succeeding black gram, *J. Agron.*, **12(2)**, 99-103(2013)
26. Pawar S.B., Mahadkar U.V., Jagtap D.N. and Jadhav M.S., Effect of different planting techniques and inputs on yield attributes and yield of rice (*Oryza sativa* L.) during kharif season, *Fmg. & Mngmt*, **2 (1)**, 16-21 (2017)
27. Peerzada A.M., Bukhari S.A.H., Dawood M., Nawaz A., Ahmad S. and Adkins S., Weed management for healthy crop production, *Agronomic Crops: Volume 2: Management Practices*, 225-256(2019)
28. Priya R.S., Chinnusamy C., Arthanari P.M. and Janaki P., Bio-efficacy of new herbicide combination (Bispyribac sodium 4% + Metamifop 10% SE) on weeded control, economics and profitability of direct seeded rice, *Intl. J. Chem Stud.*, **5(4)**: 2349-8528(2017)
29. Satapathy B.S., Duary B., Saha S., Pun K.B. and Singh T. Effect of weed management practices on yield and yield attributes of wet direct seeded rice under lowland ecosystem of Assam, *ORYZA-An Intl. J. Rice*, **54(1)**, 29-36(2017)
30. Scavo A. and Mauromicale G., Integrated weed management in herbaceous field crops, *Agronomy*, **10(4)**, 466(2020)
31. Shobha S. and Waseem U., Residue dynamics and degradation behaviour of pyrazosulfuron-ethyl in the rice field environment, *I. J. Weed Sci.*, **52(4)**: 362-365(2020)
32. Singh R.S., Singh R.P., Singh R.K., Pathak M., Kumar and Pandey D., Effect of weed management practices on weed flora, growth attributes and yield of direct seeded rice (*Oryza sativa* L.), *I. J. Agron.*, **1(1)**, 27-34(2014)
33. Soe thura., 2010. Evaluation of Weed Management practices in the System of Rice Intensification (SRI). M.Sc. (Ag.) Thesis, Department of Agronomy, Yezin Agricultural University, Yezin, Nay Pyi Taw

34. Subbiah B.V. and Asija G.L., A rapid procedure for the estimation of available nitrogen in soils, *Curr. Sci.*, **25**, 259-260 (1956)
35. Surendran U., Raja P., Jayakumar M. and Subramoniam S.R., Use of efficient water saving techniques for production of rice in India under climate change scenario: A critical review, *Journal of Cleaner Production*, **309**, 127272 (2021)
36. Toppo O. and Kewat M.L., Impact of sowing time and weed management practices on yield of direct-seeded rice, *The Pharma Innovation Journal*, **12**(2): 3475-3478 (2023)
37. Verma B., Bhan M., Jha, A.K., Khatoon S., Raghuwanshi, M., Bhayal L., Sahu M.P., Patel R. and Singh V., Weeds of direct seeded rice influenced by herbicide mixture, *The Pharma Innovation Journal*, **11**(2), 1080-1082 (2021)
38. Walkley A. and Black C.A., An examination of digestion method for determining soil organic matter and proposed modification of the chromic acid titration method, *Soil Sci.*, 37, 28-29 (1934)
39. Zhou Q., Liu W., Zhang Y. and Liu K.K., *Pesticide Biochemistry and Physiology*, **89**, 89-96 (2007)
40. Kalyani, M. S. R., Ameena, M., Srinivas, Y., Shanavas, S., Susha, V. S., & Sethulakshmi, V. S. (2024). Bio-Efficacy of New Herbicide Molecules for Weed Management in Grain Legumes. *Journal of Advances in Biology & Biotechnology*, 27(1), 191–204. <https://doi.org/10.9734/jabb/2024/v27i1691>
41. Bhadoria, P. B. S. (2010). Allelopathy: A Natural Way towards Weed Management. *Journal of Experimental Agriculture International*, 1(1), 7–20. <https://doi.org/10.9734/AJEA/2011/002>
42. Lodovichi MV, Blanco AM, Chantre GR, Bandoni JA, Sabbatini MR, Vigna M, López R, Gigón R. Operational planning of herbicide-based weed management. *Agricultural Systems*. 2013 Oct 1;121:117-29.