Medicon Agriculture & Environmental Sciences
Volume 5 Issue 5 December 2023
Article Type: Research Article
ISSN: 2972-2691

Integrated Weed Management Approach for The Mitigation of Complex Weed Flora in Transplanted Rice Systems

Lakshmanakumar Periyannan[1]*, Sreegayathri Elango[2] and Saran Rajan[3]

[1]*Associate Professor (Agronomy), Department of Agronomy, Adhiyamaan College of Agriculture and Research, Athimugam, Krishnagiri, Tamil Nadu, India*

[2]*Ph.D scholar, Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore, Tamilnadu, India*

[3]*Associate Manager, Sumitamo chemicals (i) Pvt. Ltd., Bangalore, India*

***Corresponding Author:** Lakshmanakumar Periyannan, Associate Professor (Agronomy), Department of Agronomy, Adhiyamaan College of Agriculture and Research, Athimugam, Krishnagiri, Tamil Nadu, India.

Received: October 28, 2023; **Published:** November 14, 2023

DOI: 10.55162/MCAES.05.145

Abstract

Rice (*Oryza sativa* L.) is a staple food crop popularly grown in more than 100 countries with 90% of the total global production from Asia. Major constraint in paddy cultivation is heavy weed infestation which causes 50-90 % yield reduction. Weeds causes adverse effects to crops in many ways and this arise due to the unusual adaptation characteristics of the weeds and their regeneration ability. To achieve timely and effective weed control, broad-spectrum herbicide based integrated weed management may offer a pathway for simultaneously reducing costs and markedly increasing productivity. A field experiment was conducted during the Navarai (Late *Rabi*) Season of 2023 to investigate the efficacy of new herbicide combinations for the management of weed flora in transplanted paddy at Field No. A18, ACAR Farm, Adhiyamaan College of Agriculture and Research, Krishnagiri district situated at North western zone of Tamil Nadu. The experiment was conducted with nine treatments where six treatments are combination of herbicides, two cultural operations and one untreated check. The field experiment was designed using randomized block designs with three replications. The experiment results revealed that the post emergence application of Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl) 250+20 ml ha^{-1} followed by Cono weeding twice on 15 and 30 DAT enhanced the growth and yield of transplanted paddy with decreased weed growth, reduction in nutrient depletion by weeds and enhanced nutrient uptake by the crop. The treatment positively influenced growth and physiological parameters like plant height, number of tillers, leaf area index and also recorded distinctly higher grain yield (6.5 tonnes ha^{-1}), net return (Indian Rupees 114923.2 ha^{-1}) and benefit cost ratio (3:10). Combination of herbicides along with cono weeding increased cropping system sustainability and reduced selection pressure for weed resistance to herbicides.

Keywords: Transplanted paddy; Bispyribac sodium; Cono weeding; Weed control efficiency; Yield

Introduction

Rice (*Oryza sativa* L.) is predominantly cultivated in Asia and it is included among top cereals of the world that contributes significantly to global food security. Rice is the foremost and most substantially consumed staple food grain for more than two - third of the world's population (Abbade, 2021). The world's total area under rice cultivation is 165.25 Mha with total production of about 503.27 MT along with the productivity of 3.05 t ha^{-1} (Statista, 2023). India has the largest area of land (46.28 Mha) under rice cultivation and second largest rice producing country (124,000,000 MT) in the world with an annual production of 129.47 MT and average productivity is 4.06 t ha^{-1} (Statista, 2023). India contributes to 21 per cent of global rice production with about 25 per cent of world's rice is grown in India (FAO, 2018). With the increasing food demand by the growing population, rice will continue to be the primary source of food therefore, national food security system largely depends on productivity of rice ecosystems. A recent survey by the International Food Policy Research Institute indicates rice production will need to be increased by 38 per cent in 2030 to feed the world's growing population, to meet global rice demand and achieving self-sufficiency. The challenge to rice cultivation has increased many folds with shrinking land mass and climate change. This poses an additional challenge to meet future rice demand with lower environmental footprint (using less water, labor, agro-chemicals) to ensure food security and environmental sustainability.

Rice is grown in both kharif and Rabi seasons under diverse ecological and climatic conditions in India. In crop production, number of factors acts as serious production constraints namely abiotic stress i.e., water and nutrient stress and biotic stress i.e., weed infestations, pests and diseases (Kaur et al., 2018). Weeds are inevitable and intrinsic factors of the rice ecosystems and the losses caused by weeds to rice usually surpass those caused by insect pests and diseases (Jabran et al., 2019). Weeds grow profusely in rice fields and prime yield limiting factors when grown in early stages of crop growth than at later stages. Under transplanted paddy cultivation, diverse weed flora is seen throughout the cropping season which consists of grasses, sedges and broad-leaved weeds causing yield reduction due to crop weed competition (Shipra Yadav et al., 2020). Under certain cases, weeds have been reported to cause a major loss in rice productivity or a total crop failure (23-100%) (Jabran and Chauhan, 2015). It is estimated that annual economic losses caused due to weeds in rice cultivation is around 4420 million USD in India (Gharde et al., 2018).

Crop weed competition starts around 20 days after transplanting (DAT) paddy seedlings (Mukherjee et al., 2005). Hence, farmers follow frequent weeding but these measures are not effective to control weeds in the field due to great difficulty in differentiating rice and *Echinochloa colona* seedlings in early growth stage and labour intensive too. The chemical weed control method has become standard production practice among the farmers because it is the most efficient means to reduce weeds competition with minimum labor cost. But over reliance on chemical control measures and indiscriminate use of very limited number of herbicides raise serious concerns like environmental and economic risks that includes evolution of herbicide resistance, shifts in weed flora, herbicide residues in food chain and disintegration of soil biological health (Kumar et al., 2012).

In this context, there is an urgent need to come up with potential and promising novel weed management strategies with broad spectrum post emergence herbicides to control dynamic nature of weeds and to increase the yield. Effective weed control at the early stages of this crop's development (0-40 DAT) can significantly improve its productivity. However, despite the fact that several researchers have evaluated the effectiveness of different herbicides in terms of weed control and grain yield, very few studies have assessed the effectiveness of herbicide combination-based integrated weed management options that maintain weed densities at manageable levels and also place crops at competitive advantage over weeds with increased yields. The aim of the current study is to evaluate the biological efficacy of new herbicide combinations on weed flora of transplanted Paddy and compare it with traditional practices on weed flora of transplanted Paddy and yield, weed control cost, net income, and labour use.

Materials and Methods

Experimental site

The experiment was laid out in ACAR Farm field number, A18 at North western zone of Tamil Nadu during the Navarai (late *Rabi*) Season of 2023. The experimental field is situated at 12.7°N latitude and 77.9° E longitude and at an altitude of 802 m above the mean sea level. The mean annual rainfall of the location is 842 mm distributed in 59 rainy days, mostly received during North East monsoon. The maximum temperature ranges from 33 to 36°C and minimum temperature from 12 to 22°C. Initially, soil samples were collected and analyzed from the experimental field. The soil contains 25.2% clay, 6.8% silt, 31.5% coarse sand, 26.8% fine sand and the soil in the experimental field was red sandy clay loam in texture with pH 8.3 and electrical conductivity 0.05 ds m^{-1} (Datta et al., 1997). Initial properties of a composite soil sample collected at the beginning of the experiment were 318 kg ha^{-1} available Nitrogen (Subbiah and Asija, 1956), 6.0 kg ha^{-1} available Phosphorus (Olsen and Sommers, 1982), and 246 kg ha^{-1} available Potassium (Warncke and Brown, 1998). The nitrogen and potassium contents in the soil were relatively medium but the available phosphorus in the soil is very low. The pH of the irrigation water is 8.19.

Crop management and weed control treatments

The experiment was laid out with the rice variety ADT 53, a short duration variety (110 - 115 days) using a seed rate of 40 kg ha^{-1}. Puddling was done earlier to transplanting with the help of a rotavator. Seeds were treated with Bavistin, a broad-spectrum systemic fungicide at 2 g/kg prior to sowing in the seedbed. Two rice seedlings (15 to 20 days old) were transplanted manually in each plot at a spacing of 25 cm x 25 cm with a depth of 2-3 cm. Fertilizers were applied as per soil test-based recommendations. Basal application of nitrogen (N) at 60 kg ha^{-1}, phosphorus (P_2O_5) at 50kg ha^{-1}, potassium (K_2O) at 50 kg ha^{-1} and zinc sulphate at 25 kg ha^{-1} was applied using urea, single super phosphate (SSP), and muriate of potash (MOP). Flooding up to 2-5 cm was maintained in the field from transplanting to physiological maturity. The field study was conducted with six weed control treatments, one cultural operation with cono weeder, a weed free check (achieved with manual weeding) and a weedy check were laid out in randomized block design with three replications. The observations in each treatment were recorded at different intervals. All herbicides are recommended for post-emergence application. The observed data on weeds and crops were statistically analyzed based on the procedure given by Gomez and Gomez (1984) to find out the treatment differences.

Treatment no.	*Treatment details*	*Rate of herbicides applied per treatment*	*Time of application*
1	Hand weeding twice	-	15 and 30 DAT
2	Cono weeding twice	-	15 and 30 DAT
3	Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl)	250 + 20 ml ha^{-1}	4-5 Leaf stage
4	Triafamone20%+ Ethoxysulfuron 10% WG	225 ml ha^{-1}	2 Leaf stage
5	Penoxsulam1%+ Pendimethalin24% SC	2.5 lit ha^{-1}	2 Leaf stage
6	Bensulfuron 0.6% + Pretilachlor 6%	10 kg ha^{-1}	3 DAT
7	Pretilachlor 6%+ Pyrazosulfuron 0.15% Gr	10 kg ha^{-1}	3 DAT
8	Bispyribac sodium 20%+ Pyrazosulfuron 15% WDG @	100 ml ha^{1}	1-3 Leaf stage (10-14DAT)
9	Untreated check	-	-

Table 1: Treatment details, rate of herbicides applied per treatment, amount of active ingredient in each herbicide, time of application of herbicides applied to wet transplanted rice in the year 2023.

Results and Discussion

Field experiment was conducted at ACAR farm, Adhiyamaan College of Agriculture and Research, Athimugam, Krishnagiri district in Tamil Nadu during the Navarai (Late *Rabi*) season (Jan 2023 - April 2023), to evolve an efficient integrated management method for weeds in transplanted paddy.

General weed spectrum and weed density

The weed flora in the experiment field consisted of four grassy weeds *Echinochloa colona*, *E. crussgalli*, *Cynodon dactylon*, *Dactyloctenium aegyptiacum*, two sedges *Cyprus rotundus*, *C. difformis* and two broad leaved weeds *Eclipta alba and Sphaeranthus indicus*. The absolute density and relative density of the weed species were calculated at 20 and 40 DAT. *E. colona* was the most predominant weed with absolute density of 5.80 and 8.50 No. m^{-2} and relative density of 21.32 and 21.04 per cent at 20 and 40 DAT respectively, among the total weeds observed in the field (Figure 1). Relative composition of different weed species in weedy check revealed that the composition of *E. colona* was high and occupied the experimental field to large extent. A recent study by Shipra Yadav et al. (2020) concluded that *E. colona* prefers paddy crops. This corroborates with the findings of Singh et al., (2016) who also reported that the dominance of grassy weeds over other weed species. Cyprus rotundus recorded high relative density of 23.90 per cent at 20 DAT but relatively lower relative density of 18.32 per cent at 40 DAT when compared to *E. colona*. Other broad-leaved weeds, sedges, and grasses were of lower densities leaving maximum share to *E. colona* throughout crop growth period except early part of crop establishment (Figure 1). *E. colona*, *Cynodon dactylon* and *C. iria* weeds were dominant in the trails conducted to evaluate of efficacy of herbicides in rice fields (Verma et al., 2023). Tian et al., (2020) reported that *E. crusgalli and C. difformis* coexisted in the rice fields during early stages of paddy cultivation and increased coexistence decreased rice yield. The predominant occurrence of all types of weed species in rice fields could probably be attributed to the ecological adaption and dominance of the weeds in Red sandy clay loam of North western zone of Tamil Nadu. Chemical and cultural methods of weed control significantly reduced the weed density over unweeded check.

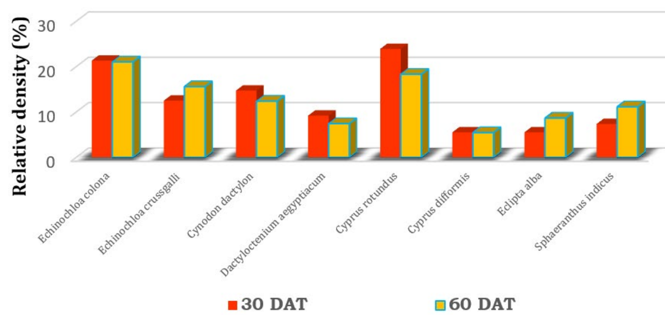

Figure 1. Relative density (%) of predominant weeds in Tranplanted paddy

Effect of different treatments on weed control efficiency

All the herbicide treatments significantly reduced the weeds when compared to untreated check (Figure 2). Weed control practices influence weed control efficiency (WCE). WCE with respect to grasses, sedges and broad-leaved weeds showed distinct reduction of total weed density by post emergence application of Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl) @ 250 +20 ml ha^{-1} at 60 & 90 DAT followed by cono-weeding twice at 15 days interval. Comparable effect on weed control efficiency was observed in cono weeding twice at 15 days interval (15 and 20 DAT) followed by hand weeding twice (15 and 20 DAT). Post emergence application of Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl) @ 250 +20 ml ha^{-1} at 60 DAT had WCE of about 82.56 per cent followed by cono weeding alone (81.23 per cent). Higher WCE was observed at 90 DAT with 83.42 per cent for the same treatment but cono weeding alone showed 85.25 per cent efficiency with lowest weed density concluding it to be the most efficient weed management strategy than treatments. The better performance of this treatment followed by conoweeding could be attributed to the reduced weed competition and suppression of late emerged weeds. The results are in conformity with the findings of Kabdal et al., (2014) who observed highest weed control efficiency with post-emergence application of bispyribac sodium at 25 g ha^{-1} + ethoxysulfuron at 18.75 g ha^{-1}. Bispyribac-sodium was the most effective treatment in reducing weed pressure over the weedy control. Only bispyribac sodium was effective in controlling *C. iria*, showing 74% WCE and it was more effective in controlling BLWs also (Biswas et al., 2020). Effective control of weeds in the interspace due to Bispyribac sodium 10% SC + (Metsulfuron-methyl + Chlorimuron ethyl) @ 250 +20 ml ha^{-1} in rice was reported by many workers (Das et al., 2017; Devi and Singh, 2018). Bispyribac sodium is an effective, selective, systemic herbicide derived from the pyrimidinylcarboxy group that is absorbed by the roots and foliage of the plants, when applied. It effectively suppresses various weeds by interfering with production of acetohydroxyacid synthase (AHAS) enzyme in branched chain amino acid synthesis responsible for growth, thus controlling weed growth (Bhattacharya et al., 2022).

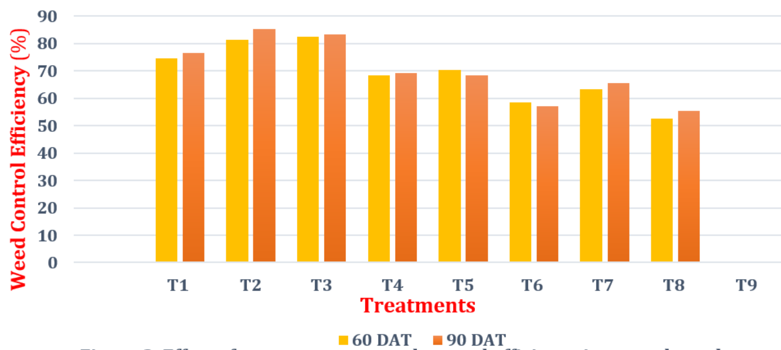

Figure 2. Effect of treatments on weed control efficiency in transplanted paddy

Effect of different treatments on growth attributes

The growth attributes *viz*., plant height, number of tillers, leaf area index was significantly influenced by crop improvement methods and weed management practices (Figure 3). Weed control treatments showed remarkable effect on number of tillers at all the stages of crop growth. Cono weeding twice at 15 and 30 DAT registered higher number of tillers as compared to other treatments observed at 60, 90 DAT and at harvest. This might be due to the weed free environment which favored better utilization of moisture and nutrient resulting in a greater number of tillers. Significantly, variations on leaf area index (LAI) were observed after 30 DAT. Post emergence application of Bispyribac sodium 10% SC + (Metsulfuron-methyl + Chlorimuron ethyl) @ 250 +20 ml ha^{-1} recorded higher leaf area index followed by cono weeding twice at 15 and 30 DAT. The reason could be attributed to favorable weed free environment for the higher nutrient uptake by the crop which might lead to higher LAI and better source sink relationship for the higher growth rate. In a study by Kumar et al., (2012), bispyribac sodium 30 g ha^{-1} significantly increased the height of transplanted rice plants compared to other herbicides treatments. Ali et al., (2018) reported that there was a significant difference in crop growth rate, dry matter accumulation and LAI with the application of bispyribac sodium 25 g ha^{-1} compared with butachlor, as well as mechanical and hand weeding throughout the crop season.

Effect of different treatments on rice grain yield

Yield and related attributes were also significantly influenced by herbicide treatments. Yield components like number of tillers and 1000 grain weight were positively influenced by the weed control treatments. Steady correlation was exhibited rice grain yield under various weed management practices. The highest yield was recorded in Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl) @ 250 +20 ml ha^{-1} at the rate of 6529.2 kg ha^{-1} and it was statistically comparable with Cono weeding twice (15 and 30 DAT) that had yield of 6470.8 kg ha^{-1}. In the study, weeds in the weed plots reduced grain yield by 55 per cent, when compared with application of Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl) @ 250 +20 ml ha^{-1}. The maximum 1000 grain weight was observed in weed free check (13.4 g) followed by treatment with Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl) @ 250 +20 ml ha^{-1} (13.2 g). The data pertaining to the best performance of bispyribac sodium corroborated with the findings of Chauhan et al., (2012) and Choudhary and Dixit (2018). Biswas et al. (2020) also found similar trends in the growth and yield attributes and their results showed weed free check followed by Bispyribac sodium treatments had the longest panicles, the highest number of grains per panicle, and the maximum 1000-grain weight. Straw yield was not significantly influenced under weed control treatments but the higher straw yield was recorded at POE Bispyribac sodium 20% + Pyrazosulfuron 15% WDG @ 100 ml ha^{-1} followed by PE Pretilachlor 6% + Pyrazosulfuron 0.15% Gr 10 kg ha^{-1}. It might be due to increase in number of unproductive tillers. Increase in the yield and yield attributes might be due to reduced state of crop-weed competition during critical growth stages. The plant did not suffer from nutrient or moisture deficiencies caused by a heavy weed infestation and was weed-free during its main vegetative and developmental phase. Consequently, they received adequate sunlight to produce carbohydrates, resulting in better growth of the plant, increased leaf area index, longer ear heads, more effective tillers, more filled grains/spikes, and higher test weights. These ultimately led to a higher grain yield of rice (Singh and Pandey, 2019).

Effect of herbicides on economics of rice

Chemical weed control always cost effective than other method of weed controls this might be due to less cost involved in chemical treatment per unit of yield obtained. It was observed that the yield, net returns, gross returns and B: C ratio was significantly influenced with the treatment of Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl) @ 250 +20 ml ha^{-1}. This treatment registered Rs. 169759.2 ha^{-1} gross returns, Rs. 114923.2 ha^{-1} net returns and B:C ratio of 3.10. Das et al., (2017) concluded that the post-emergence application of bispyribac sodium 25 g ha^{-1} at 25 DAT proved economical herbicide for transplanted rice as compared to hand weeding twice and also other herbicides and weedy check. The also find support with the works of Kumaran et al., (2015) that adoption of different weed management practices significantly influenced the gross returns, net returns and B:C ratio. The treatment consisting of bispyribac sodium 10% SC 40 g ha^{-1} registered Rs. 60,698 ha^{-1} as gross income next to weed free check Rs. 63,217 ha^{-1} with a net return of Rs. 38,970 ha^{-1} and a B:C ratio 2.79.

Conclusion

Weeds are the major hindrance in rice production that has several direct and indirect ill effects. Direct losses in crop yield are caused by competition and indirectly the weed control measures that contribute to increased cost of production and also contribute to increasing economic loss due to weeds. Herbicides are being predominantly used by farmers in last decades. At the same time, herbicides are able to control the weeds up to certain time but further flushes of weeds pose new challenges to the farmers during cropping season. Hence, integrated strategies will be the best option for the management of diverse weed flora. The present study revealed the potential for greater adoption of combination of broad-spectrum post-emergence herbicides with mechanical weeding in rice than manual weeding with increased WCE and higher rice yield. *Echinochloa colona* is a predominant weed in transplanted paddy under red sandy clay loam soils of Western Zone of Tamil Nadu. Productivity and profitability of paddy, reduction of weed density, leaf area index and 1000 grain weight of weeds with best control efficiency could be achieved with post emergency application of Bispyribac sodium 10% SC + (Metsulfuron-methyl+ Chlorimuron ethyl) @ 250 +20 ml ha^{-1} and Cono weeding twice on 15 and 30 DAT. Combination of cono weeding and chemical control may result in economical and efficient weed control in paddy fields. In the future, cost effective combination of different molecules of herbicides can be checked for their efficacy in controlling diverse weed flora in accordance with changing climate change scenario.

Acknowledgement

We are grateful to Adhiyamaan College of Agriculture and Research, Krishnagiri district of Tamil Nadu for providing field to conduct the trail. We extend our thanks to Sumitamo chemicals (i) Pvt. Ltd., Bangalore, India for supplying us with herbicides used in the trail.

References

1. Abbade EB. "Estimating the potential for nutrition and energy production derived from maize (Zea mays l.) and rice (*Oryza sativa* l.) losses in Brazil." Waste Management 134 (2021): 170-176.

2. Ali MN., et al. "Influence of herbicides on growth and profitability of transplanted rice (*Oryza sativa* L.) in Jharkhand". Journal of Pharmacognosy and Phytochemistry. SP1 (2018): 401-404.
3. Bhattacharya., et al. "Response of rice (*Oryza sativa* L.) to weed management methods in the lower Gangetic Plain Zone". Indian Journal of Agricultural Research (2022).
4. Biswas., et al. "Weed control in transplanted rice with post emergence herbicides and their effects on subsequent rapeseed in Eastern India". International Journal of Pest Management (2020).
5. Bonu Rama Devi and Yashwant Singh. "Influence of Nitrogen and Weed Management Practices on Growth and Yield of Direct Seeded Rice (*Oryza sativa* L.)". Int.J.Curr.Microbiol.App.Sci 7.01 (2018): 2566-2574.
6. Chauhan., et al. "Ecology and management of weeds under conservation agriculture: A review". Crop Prot 38 (2012): 57-65.
7. Choudhary VK and Dixit A. "Herbicide weed management on weed dynamics, crop growth and yield in direct-seeded rice". Indian Journal of Weed Science 50.1 (2018): 6-12.
8. Das R., et al. "Weed management in transplanted rice through bispyribac-sodium 10% SC and its effect on soil microflora and succeeding crop blackgram". International Journal of Current Microbiology and Applied Sciences 4.6 (2017): 681-688.
9. Datta SP., et al. "Effect of electrolytes coupled with variable stirring on soil pH". J. Indian Soc. Soil Sci 45 (1997): 185-187.
10. FAO, 2018. FAOSTAT Database. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.
11. Gharde Y., et al. "Assessment of yield amd economic losses in agriculture due to weeds in India". Crop Prot 107 (2018).
12. Gomez KA and AA Gomez. "Statistical procedures for agricultural research". (2nd ed) Intl. Rice Res. Inst., P.B.Box. Manil, Philippines and John Wiley and Sons, New York, USA (1984): 680.
13. Jabran K., et al. "Sustainable weed control in rice". Weed control: sustainability, hazards and risks in cropping systems worldwide edited by Korres, NE., et al. CRC Press, Taylor & Francis group (2019): 276-287.
14. Kabdal P., et al. "Control of complex weed flora in transplanted rice with herbicide mixture". Indian Journal of weed science 46.1 (2014): 377-379.
15. Kaur S., et al. "Understanding crop-weed-fertilizer-water interactions and their implications for weed management in agricultural systems." Crop Prot 103 (2018): 65-72.
16. Khawar Jabran and Bhagirath Singh Chauhan. "Weed management in aerobic rice systems". Crop Prot 78 (2015): 151-163.
17. Kumar J., et al. "Sowing time and weed management practices to enhance yield of direct-seeded rice". Indian Journal of Weed Science 44.4 (2012): 207-209.
18. Kumaran ST., et al. "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". Journal of Applied and Natural Sciences 7.1 (2015): 279-285.
19. Mukherjee D and Singh RP. "Effect of micro-herbicides on weed dynamics, yield and economics of transplanted rice". Indian Journal of Agronomy 50.40 (2005): 292-295.
20. Olsen SR and Sommers LE. "Methods of soil analysis, part 2, chemical and microbiological properties". Madison, Wisconsin USA, American Society of Agronomy, Soil Science Society of America (1982): 403-430.
21. Shipra Yadav RB., et al. "Efficacy of different herbicides and its combination against the weed flora of transplanted rice: A review". Int.J.Curr.Microbiol.App.Sci 9.08 (2020): 2057-2068.
22. Singh R., et al. "Weed management in dryland agriculture in India for enhanced resource use efficiency and livelihood security". Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci 88 (2016): 1309-1322.
23. Singh A and Pandey IB. "Effect of crop establishment methods, nutrient levels and weed management on yield attributing characters of hybrid rice". International journal of chemical studies 7.3 (2019): 5153-5157.
24. Statista, Department of Agriculture and farmers welfare, Ministry of Agriculture and farmers welfare, Government of India, Krishi Bhawan, New Delhi. www.agricoop.nic.in
25. Subbiah BV and Asija GL. "A rapid procedure for the determination of available nitrogen in soils". Curr. Sci 25 (1956): 259-260.
26. Tian Z., et al. "Effects of Echinochloa crusgalli and Cyperus difformis on yield and eco-economic thresholds of rice" J.clean.Prod

259 (2020): 120807.

27. Verma., et al. “Weed management in direct-seeded rice (Oryza sativa) in central India”. Indian Journal of Agronomy 68.2 (2023): 211-214.
28. Warncke D and Brown JR. “Potassium and other basic cations”. In (Ed.), Recommended chemical soil test procedures for the north central region (North Central Region edited by Brown, J Missouri Agricultural Experiment Station, University of Missouri.USA. North Central Regional Research Publication 221 (1998): 36-38.

Volume 5 Issue 5 December 2023