Effect of herbicidal weed management on crop growth, weed density, weed biomass, yield and economics of direct seeded rice (*Oryza sativa* L.): A review

Abstract

This review examines the impact of herbicidal weed management on crop growth, weed density, weed biomass, yield, and the economic aspects of direct-seeded rice (*Oryza sativa* L.) cultivation. Effective weed control is critical for maximizing rice yields and promoting sustainable agricultural practices. The application of herbicides has been shown to significantly reduce weed density and biomass, which in turn enhances crop growth and increases yield potential. Moreover, herbicide use can decrease labor costs associated with manual weeding, contributing to overall economic efficiency in rice production. Economic analyses indicate that while herbicide costs can be substantial, the benefits in yield and reduced labor can result in favorable economic outcomes. This review highlights the necessity of balancing the benefits of herbicidal weed management. Future research should focus on optimizing herbicide application techniques and exploring alternative weed management practices to enhance the sustainability of rice production systems. Key results indicate that timely and appropriate herbicide application not only minimizes weed biomass but also enhances rice growth metrics, such as plant height, tiller number, and grain yield. The findings highlight the critical role of herbicidal weed management in mitigating weed-related challenges in direct-seeded rice systems.

Keywords: herbicidal weed management, direct-seeded rice, crop growth, weed density, economic viability.

Introduction:

"Weed management in direct-seeded rice (*Oryza sativa* L.) is a critical factor influencing crop growth, yield, and overall agricultural sustainability.). India is one of the largest exporter of rice to the world, exporting nearly 10 million tonnes every year. Chhattisgarh, known as the Rice bowl of central India" (Mooventhan*et al.*, 2015), accounts for 3.82 Mha area with a production of 7.82 MT and productivity of 2.04 t ha^{-1} in the state. (Anon., 2023). "The direct seeding of rice results in the increased efficiency of time, energy, water, and labor costs" (Rao *et al.*, 2007).This review paper aims to synthesize current research on the effects of herbicidal weed management in direct-seeded rice systems. “We will examine how various herbicide treatments impact weed density and biomass, explore their consequences for crop growth and yield, and analyze the economic implications for farmers. The yield losses due to weeds vary from 40-100 per cent in direct seeded rice” (Choubey*et al.*, 2001). Unchecked growth of weeds in DSR reduced crop yield by 82% (Dass*et al*., 2017). “Herbicide based weed management is becoming the popular method of weed control in rice, because of lower costs involved” (Singh *et al*., 2012). “Along with pre-emergence herbicides, the application of post-emergence herbicides found to be affective to combat with use as to increase yield”(Jayadeva*et al*.,2011). “ Ready mix herbicides demonstrate effectiveness in controlling weeds as compared to single herbicides. Specifically, a mixture that includes metsulfuron has shown significant benefits in managing broadleaf weed populations compared to other single herbicides” (Meena., 2019). “Weed management by hand weeding is very easy and environment-friendly” (Sharma *et al.*, 2020).“Rice is the most significant and extensively cultivated food crop grown extensively in tropical and subtropical regions, which provides half of the daily food for one of every three persons on the earth. About 70% of the global population consumes rice as an essential food while more than two billion people in Asia alone, obtain 60- 70% of their energy intake from rice and its products” (Kumar *et al.,* 2023). “Weed competition reduced multiple rice yield components, and weed biomass in wet-seeded rice was six-fold greater that in rice transplanted into puddled soil and twice as much again in dry-seeded rice sown either after dry tillage or without tillage” (Singh et al. 2011). “Chemical control, on the contrary, is the most effective, economic and practical way of weed management” (Hussain et al. 2008, Anwar et al. 2012a). In addition to higher economic returns, DSR crops are faster and easier to plant, having shorter duration, less labour intensive, consume less water (Bhushan *et al.* 2007).

Major weed flora in DSR:

“In general, transplanted rice is mostly grown all over India. But now days farmer shifted towards direct seeded rice (DSR) because of less water use. When we change our crop there is also change in the weed flora. Same in case of DSR. When we shift from transplanted rice to direct seeded rice there is also change or shift in the Weed flora” (Singh *et al.,* 2008). “As compare to the transplanting rice in the DSR weed is more and it get difficult to control many times quoted by the Kumar and Ladha, 2011) Weed infestation is one of the major biotic constraints in rice production. “Rice community is infested with diverse type of weed flora colonized by aquatic, semi-aquatic and terrestrial weeds, grown under diverse agro-climatic conditions, different cropping sequence, tillage and irrigation regimes. About 350 species have been reported as weeds of rice, of which grasses are ranked as first posing serious problem followed by sedges and broad-leaf weeds causing major losses to rice production worldwide. The weed flora in the rice field were *Echinochloacolona, Echinochloaglabrescens, Leptochloachinensis, Dactylocteniumaegyptium, Cyperusiria, Cyperusdifformis, Fimbristylismiliacea, Eclipta alba, Ammaniabaccifera, Digera arvensis, Lindernia crustacean* and *Mazus pumilus* in direct seeded rice” (Ganie*et al.* 2014). In dry direct-seeded rice at Varanasi, India during rainy season in 2008 and 2009. The experimental field was infested with grassy *Echinochloacolona*, *Echinochloacrusgalli*, *Paspalum* spp., *Cynodondactylon*; among sedges *Cyperusrotundus* and *Cyperusiria*, and among broad-leaved weeds *Caexuliaauxillaries*. They found among the weed flora the maximum relative percentage was of *Echinochloacolona* (23.8, 24.5 and 23.4%), *Echinochloacrusgalli* (23.4, 24.0 and 22.9%), *Cyperusrotundus* (16.1, 15.7 and 16.2%) and *Caesulia axillaries* (7.8, 6.8 and 8.2%) in zero-till DSR, zero-till DSR with anchored residue and reduced till, respectively (Singh and Singh 2014).“*Echinochloacolona* and *Echinochloacrusgalli* are the most serious weeds affecting DSR. The density of these weeds in DSR depends upon moisture condition in the field. *Echinochloacolona* requires less water, so it is more abundant in DSR. *Cyperusrotundus* and *Cynodondactylon* may be major problems in poorly managed fields or where un-decomposed farm yard manure has been applied. Noticed the major weed flora in aerobic rice during a experimental trail during summer of 2013. The weeds were *Cyperusrotundus*, *Cyperusiria*, *Trianthemaportulacastrum*, *Echinochloacolona*, *Dactylocteniumaegyptium*, *Elusineindica*, and *Echinochloacrusgalli”* (Ali *et al.* 2019). The efficacy of pendimethalin and cyhalofop-butyl + penoxsulam against major grass weeds *viz.Echinochloaglabrescens, Leptochloachinensis, Eragrostis japonica and Dactylocteniumaegyptium* of direct seeded rice under the screen house conditions at CCS Haryana Agricultural University, Hisar. They found that at 2 and 4 weeks after treatment (WAT) at any of the application rate, *Dactylocteniumaegyptium* was not effectively controlled by cyhalofop-butyl + penoxsulam as there was only 20% control at 4 WAT when applied at 270 g ha^{-1} (Singh *et al.* 2019). The major weed flora in dry direct-seeded rice during *Kharif* were *Echinochloacolona* (45.09%), *Echinochloacrussgalli* (48.14%) and *Cyanodondactylon* (39.25%)

among grasses; *Cyperusrotundus* (62.92%) and *Cyperusiria* (58.22%) among sedges and *Eclipta alba* (45.02%) and *Caesuliaauxillaris* (54.98%) among broad-leaved weeds at Varanasi, Uttar Pradesh, India (Hemalatha *et al.* 2020).The grass weeds were the most dominant weed species followed by broad-leaf weeds and sedges in an experiment in wet-seeded rice during*Kharif* of 2018 and 2019. The grass weeds were comprised of *Leptochloachinensis, Echinochloacolona*and*Isachnemiliacea*. The major broad-leaf weeds were *Sphenocleaazeylanica, Bergiacapensis, Monochoria vaginalis, Limnocharis flava, Ludwigia perennis, Alternnatheraphiloxeroides*and*Lindernia parviflora*. The sedges present were *Cyperusiria, Cyperusdifformis* and *Fimbristylismiliacea* (Sekhar *et al.* 2020). The weed flora observed in the experimental field of direct seeded rice during *Kharif* of 2010 to 2015 at I.G.K.V., Raipur, Chhattisgarh were *Echinochloacolona*, *Ischeamumrugosum* among grasses; *Alternanthera triandra*, *Commelinabenghalensis*, *Cyanotisaxillaris*, *Croton bonplandianus*, *Spilanthusacmella* and *Ludwigiaparviflora* among broad-leaved and *Cyperusiria* among sedges. However, the field was dominated by *Echinochloacolona*, *Ischeamumrugosum, Alternanthera triandra*, *Cyanotisaxillaris* and *Cyperusiria* weed species (Tiwari *et al.* 2020). The major weed flora and their degree of infestation in direct-seeded rice under different nutrient and weed management practices during *Kharif* of 2018 and 2019. The experimental field was infested with *Fimbristylismiliacea* (L.) (29.59%), *Aeschynomeneindica* (L.) (17.05%), *Echinochloa crus-galli* (L.) P Beauv. (14.79%), *Cyperusiria* (L.) (11.06%), *Eleusineindica*Gaerts. (9.27%), *Commelinabenghalensis* (L.) (7.47%), *Ageratum conyzoides* (L.) (4.78%), *Cynotisaxillaris* (L.) D.Don (2.85%), *Cynodondactylon* (L.) (1.65%) and *Dactylocteniumaegyptium* (L.) (1.49%) (Barla *et al.* 2021).

Table 1 :Weed flora in direct seeded rice composition of experimental field during *Kharif* 2020 and 2021

No.	Scientific Name	Common Name	Local Name	Family	Growth habit *
A.	**Grasses**				
1	*Echinochloacolona* (L.) Link	Jungle rice	Sawa	Poaceae	Annual, Monocot
2	*Ischaemumrugosum*Salisb.	Wrinkle duck-beak	Badauri	Poaceae	Annual,Monocot
3	*Dactylocteniumaegyptium* (L.) Willd	Crowfoot grass	Makadaghass	Poaceae	Annual,Monocot
4	*Cynodondactylon* (L.) Pers.	Bermuda grass	Dhoobi	Poaceae	Perennial,Monocot
5	*Digitariasanguinalis* L. (Scop.)	Large crabgrass	GhudDoob	Poaceae	Annual,Monocot
B.	**Sedges**				
1	*Cyperusiria* L.	Ricefieldflatsedge	Motha	Cyperaceae	Annual,Monocot
2	*Cyperusdifformis*L.	One arm sedge	Button motha	Cyperaceae	Annual, Monocot
3	*Fimbristylismiliacea* (L.) Vahl.	Grass-like fimbry	Bandar puchhia	Cyperaceae	Annual,Monocot
C.	**Broad-leaved weeds (BLW)**				
1	*Abutilon indicum*	Country mallow	Raksi	Malvaceae	Annual, Dicot
2	*Alternanthera sessilis*(L.) DC.	Sessile joyweed	Resham kata	Amaranthaceae	Perennial,Dicot
3	*Cassia tora* (L.) Roxb.	Sickle pod	Charota	Fabaceae	Annual,Dicot
4	*Commelinadiffusa* L.	Climbing dayflower	Kawakeni	Commelinaceae	Annual,Dicot
5	*Cyanotisaxillaris* L.	Spreading dayflower	Badhanula/ Pondi	Commelinaceae	Annual,Dicot
6	*Eclipta alba*	Country mallow	Bhrangraj	Malvaceae	Annual,Dicot
7	*Ludwigiaparviflora*Roxb.	Water primerose	Laungghass	Onagraceae	Perennial,Dicot
8	*Phyllanthus niruri* L.	Stonebreaker/ Gripeweed	Hajardana	Euphorbiaceae	Annual,Dicot
9	*Physalis minima* L.	Sunberry/ Hogweed	Chirpoti	Solanaceae	Annual,Dicot

(Satyaraj Guru, 2022)

Critical period of crop weed competition:

"One of the important thing in today's farming is yield & income from that but now a days productivity is going down because of the several factor that these factor may be biotic or abiotic. One of the major yield limiting factor is weed. It compete for other essential factor water, light & nutrients etc. Weeds problem is more in the direct seeded rice rather than in transplanted rice" (Rathika*et al*., 2020)."Main reason for the decrease in yield in direct seeded rice is competition from weed in the initial stage. But in the later stage decrease in the yield not happen because there maximum damage is already happened" (Johnson, 1996)."Weed free situation for first 60 or 70 DAS produced yield comparable with weed free situation until harvesting. The competition in DSR beyond 15 days after seeding may cause significant reduction in grain yield"(Singh2008). "Critical period crop-weed competition was 7-53 DAS to achieve 95% of weed-free yield, and 21-43 DAS to achieve 90% of weed-free yield in direct seeded rice under trial conducted at Malaysia" (Anwar *et al.* 2012). "First 40 days after sowing was the most critical period for crop-weed competition. The weed free condition ensures a higher number of panicles m^{-2} and number of grains $panicle^{-1}$ along with yield assurance of 2.93 t ha^{-1} in case of DSR" (Singh *et al.* 2012). "To reduce the loss in the grain yield of rice by more than 10% and higher economic return, it is important to keep the crop weed-free between 30 to 70 days after crop emergence"(Mekonnen*et al*. 2017). Field experiment to find out the critical period of crop-weed competition in aerobic rice. Weed competition beyond 15 DAS caused drastic reduction in rice grain as well as straw yield, while weed-free until 45 DAS (5.4 t ha^{-1}) resulted in the yield which was statistically at par with weedy unti1l 15 DAS (5.6 t ha^{-1}) and weed free 60 (5.5 t ha^{-1}), 75 days (5.6 t ha^{-1}) and up to harvesting stage (5.5 t ha^{-1})Singh *et al.* (2018).

Effect of weed management practices on weeds:

This review synthesizes current literature on weed management strategies and their effects on weed dynamics. "Almost all growth parameters, yield attributes and grain yield, and the lower weed density were noted under post emergence application of almix (chlorimuron ethyl+ metsulfuron methyl) 4 g ha^{-1} at 20, 40, 70 and 90 DAS"(Kaushik*et al*. 2012). Among all the herbicidal treatments, the lowest weed density (7.0 m^{-2}) was observed under bispyribac - sodium 80 g/ha at 15 DAS, followed by bispyribac-sodium 40 g ha^{-1} (Rawat *et al*. 2012).Pre emergence application of pendimethalin 0.75 kg ha^{-1} with post emergence application of bispyribac sodium 25 g ha^{-1}, in direct seeded rice resulted in significant reduction in dry matter of weeds and increased grain yield (Walia*et al*.2012).“Post emergence mixture of fenoxaprop + (Chlorimuron +metsulfuron) on 30 DAS provided broad spectrum weed control by significantly reducing weed desity and dry weight at 60 DAS and higher weed control efficiency and lower depletion of nutrients by weeds”(Ramachandiran*et al*., 2012).Penoxsulam 35 g ha^{-1} at 10 DAS *fb* 1 hand weeding at 35 DAS had lesser weed dry weight in comparison to rest of the treatments except hand weeding(Brar and Bhullar 2013).The efficacy of some promising herbicides found that different yield attributes i.e no of effective tillers $hill^{-1}$, filled grains were recorded highest with application of metsulfuron methyl 10% + chlorimuron ethyl 10% resulting in higher grain yield 68.98 q ha^{-1} increasing 20.29% over control plot of rice under rainfed conditions, (Heisnam*et al.* 2015).Sole application of chlorimuron ethyl+ metsulfuron methyl @ 4 g ha^{-1} ,ethoxysulfuron @18 g ha^{-1} and 2,4-D ethylester @ 400 g ha^{-1} showed selectivity towards broad leaved weeds whereas fenoxa prop -p-ethyl towards grasses. Tank mix application of chlorimuron ethyl + metsulfuron methyl with fenoxa prop-p-ethyl (4+60 g ha^{-1}) proved to be most effective in minimizing density (10.57 m^{-1}), biomass 4.07g m^{-1} of weeds and enhancing weed control efficiency (95.7%), grain yield (5.68 t ha-1), net returns (Rs30,439 ha^{-1}), benefit cost ratio (0.61) (Tripathy*et al.* 2016).Metsulfuron methyl + chlorimuron ethyl 4g ha^{-1} was effective in suppressing broadleaved weeds and preemergence application of pendimethalin 0.75 kg ha^{-1} at 3-5 DAS *fb*metsulfuron methyl + chlorimuron ethyl 4g ha^{-1} as post emergence at 20-25 DAS recorded higher grain yield (Hemalatha*et al*. 2017).Bispyribac-sodium 12.5 g ha^{-1} + (chlorimuron -ethyl + metsulfuron-methyl) 2 g ha^{-1} at 10 DAS *fb* 1 hand weeding at 35 DAS had higher plant height, number of tillers m^{-2} , dry matter accumulation (g m^{-1}), leaf area index and chlorophyll content as compared to bispyribac sodium 12.5 g ha^{-1} + (chlorimuron-ethyl + metsulfuronmethyl) 2 g ha^{-1} at 20 DAS *fb* 1 hand weeding at 35 DAS and bispyribac-Na 12.5g ha^{-1} + azimsulfuron 15 g ha-1 at 10 DAS *fb* 1 hand weeding at 35 DAS and all these treatments were statistically similar to each other (Sanodiya*et al.,* 2017).Among all herbicidal treatment, sequential application of pendimethalin 1000 g ha^{-1}*fb*bispyribac sodium 25 g ha^{-1} and metsulfuron methyl + chlorimuron ethyl 4 g ha^{-1} had highest number of effective tillers m^{-2} (209.3), filled grains $panicle^{-1}$ (83.7) and grain yield (3.97 t ha^{-1}) which was at par with weed free treatment (Singh*et al.* 2017).Among all the integrated weed management practices, weed free treatment i.e. hand weeding at 20, 40 and 60 DAS recorded highest weed control efficiency (WCE) of 77.54% (Bhargav*et al.* 2018).

Effect of weed management practices on rice growth and development:

"Weeds compete with rice for light, nutrients, and water, leading to reduced growth rates and lower yields. Studies indicate that high weed densities can decrease rice yield by up to 50%" (Roberts, 2019). Different combination of pre emergence and post emergence herbicides and observed that the herbicidal weed management practices *viz.*pyrazosulfuron @ 25 g ha^{-1} at 3 DAS (PE), cyhalofop butyl @ 90 ml ha^{-1} at 25 DAS (PoE), fenoxaprop @ 60 ml ha^{-1} at 30 DAS (PoE), cyhalofop butyl + (chlorimuron + metsulfuron) @ 90 ml + 20 g ha^{-1} at 30 DAS (PoE), the post-emergence mixture application of fenoxaprop + ethoxysulfuron @ 60 ml + 15 g ha^{-1} at 30 DAS recorded significantly taller plants (103 cm) with maximum leaf area index (6.67), SPAD value (43) and more number of tillers (520 m^{-2}), which ultimately resulted in the accumulation of greater dry matter production (16084 kg ha^{-1}) over all treatments including farmers practice (Ramachandiran and Balasubramanian 2012). The application of pyrazosulfuron-ethyl 10% WP @ 20 g ha^{-1} at 3 DAS *fb*cono-weeding on 25 DAS recorded the taller plant height of 48.8 to 92.2 cm during 2014 and 2015, respectively. This was followed by cono-weeding at 10 and 25 DAS, it recorded the plant height of 48.4 to 91.9 cm during 2014 and 2015, respectively. The lower plant heights of 46.7 to 87.7 cm were recorded in weedy check in a field experiment in direct-seeded rice (Sivakumar *et al.* 2020). The influence of different nine weed management practices and found that the pendimethalin @ 1000 g ha^{-1} at 3 DAS *fb*bispyribac-sodium @ 25 g ha^{-1} at 20 DAS *fb* manual weeding at 40 DAS treatment recorded highest plant height (114.8 cm) and no. of tillers m^{-2} (464.6). However, lowest plant height (88.4 cm) and no. of tillers m^{-2} (251.5) were noticed under the unweeded control during 2015-16 and 2016-17 (Saravanane 2020).

Effect of weed management practices on yield and yield attributes ofrice:

"Proper timing of herbicide applications is crucial; pre-emergence treatments can effectively prevent early weed competition and improve yield" (Thompson *et al.,* 2023).The efficacy of pre- and post-emergence herbicides and their combinations and recorded *viz.*pyrazosulfuron 25 g ha^{-1}, pretilachlor 750 g ha^{-1}, cyhalofop-butyl 90 g ha^{-1}, fenoxaprop 60 g ha^{-1}, cyhalofop-butyl + ready mix of chlorimuron + metsulfuron 90 +20 g ha^{-1}, fenoxaprop + ready mix of chlorimuron + metsulfuron 60 + 20 g ha^{-1}, azimsulfuron 35 g ha^{-1}, bispyribac sodium 25 g ha^{-1}, tank mix of fenoxaprop + ethoxysulfuron 60 + 15 g ha^{-1}, oxyflurofen + 2,4-D 300 + 500 gha^{-1}, twice hand weeding at 20 and 40 DAS and weedy check in weed control in dry-DSR, the highest grain yield (3.50 t ha^{-1}) was recorded with hand weeding twice at 20 and 40 DAS which was statistically at par with fenoxaprop + ethoxysulfuron 60 + 15 g ha^{-1} (3.48 t ha^{-1}) and bispyribac-sodium 25 g ha^{-1} (3.13 t ha^{-1}). Uncontrolled weeds in weedy check plots caused an average reduction in yield to the extent of 89.9% in 2010 and 88.8% 2011 when compared with fenoxaprop + ethoxysulfuron 60 + 15 g ha^{-1} and bispyribac-sodium 25 g ha^{-1} a mainly due to highest weed density and biomass in weedy check plots. The lowest yield (0.35 t ha^{-1}) was recorded in weedy check (Pratap *et al.* 2016).The influence of seven weed management practices in direct-seeded aromatic rice and reported that the application of bispyribac sodium @ 30 g ha^{-1} at 30 DAS (PoE) recorded significantly the highest number of panicles m^{-2} (147.8 in 2012 and 148.6 in 2013), number of grains panicle^{-1} (76.6 and 78.7), grain (2.33 and 2.39 t ha^{-1}) and straw yield (4.20 and 4.40 t ha^{-1}) which was statistically at par with application of cyhalofop butyl @ 90 g ha^{-1} + 2,4-D @ 500 g ha^{-1} (PoE) at 30 DAS and anilophos @ 375 g ha^{-1} + ethoxysulfuron @ 15 g ha^{-1} at 15 DAS (PoE) (Sharma *et al.* 2016).The effect of row spacing and weed management practices on the performance of aerobic rice and found the maximum number of productive tillers per m^{2} (346), no. of kernels per panicle (87.33), biological yield (17.8 t ha^{-1}) and grain yield (4.12 t ha^{-1}) in weed free treatment followed by sequential application of pendimethalin @ 900 g ha^{-1} (PE) *fb*bispyribac sodium @ 30 g ha^{-1} at 15 DAS(Ali *et al.* 2019).The efficacy of herbicide mixtures *viz.*triafamone 20% + ethoxysulfuron 10% (pre-mix) 67.5 g ha^{-1} @ 12 DAS, cyhalofop-butyl+ penoxsulam 6% OD (pre-mix) 150 g ha^{-1} @ 20 DAS, and fenoxaprop-p-ethyl 6.9 EC 60 g ha^{-1} + ethoxysulfuron 15 WDG (tank mix) 15 g ha^{-1} @ 20 DAS with the bispyribac-sodium 25 g ha^{-1} at 20 DAS, hand weeding (20 and 40 DAS) and unweeded control in wet-seeded rice. All herbicide treatments were at par with the hand weeding (20 and 40 DAS) for yield attributing parameters and grain yield except tank mix application of fenoxaprop-p-ethyl 6.9 EC 60 g ha^{-1} + ethoxysulfuron 15 WDG 15 g ha^{-1} @ 20 DAS (Menon 2019). The influence of different weed management treatments *viz.*need based two hand weedings at 20/30 and 40/60 DAS/DAT, oxadiargyl 80 WP @100 g ha^{-1} (PE) + one hand weeding at 20/30 DAS/DAT, oxadiargyl 80 WP @100 g ha^{-1} (PE) + one hand weeding at 40/60 DAS/DAT, oxadiargyl 80 WP @100 g ha^{-1} (PE) + almix 20 WP @ 4 g ha^{-1} (PoE) and unweeded control at Dapoli, during *Kharif*seasons of 2016 and 2017. Among weed management practices, two hand weedings at

20/30 and 40/60 DAS/DAT significantly increased the number of panicle (284.13 and 283.60 no. m^{-2}), panicle length (23.68 and 23.65 cm), panicle weight (3.63 and 3.52 g) and yield (4.29 and 4.20 t ha^{-1}) of rice as compared to integration of oxadiargyl 80 WP @100 g ha^{-1} (PE) with one HW either at 20/30 DAS/DAT or 40/60 DAS/DAT during both the years. Unweeded control recorded significantly lowest value of yield and yield attributing characters of rice as compared to other weed management practices during 2016 and 2017, respectively (Shendage *et al.* 2019).The effect of bispyribac sodium (25 g ha^{-1}), penoxusulam (25 g ha^{-1}), azimsulfuron (35 g ha^{-1}), pretilachlor + pyrazosulfuron- ethyl (600 + 15 g ha^{-1}), pyrazosulfuron-ethyl (20 g ha^{-1}), 2,4-D sodium salt (1000 g ha^{-1}), hand weeding at 20 and 40 DAS and weedy check in increasing grain yield in dry direct-seeded rice. "During both the seasons, twice hand weeding at 20 and 40 days after sowing recorded significantly higher rice grain yield (5.89 and 5.92 t ha^{-1} in *Kharif*2016 and 2017, respectively) and which was at par with pre-emergence application of pretilachlor + pyrazosulfuron-ethyl (600 + 15 g ha^{-1}) (5.78 and 5.84 t ha^{-1} in *Kharif* 2016 and 2017, respectively)" (Ramesha *et al.* 2019).

Effect of weed management practices on weed density, biomass:

"The herbicide treatments *viz.* butachlor @ 0.3 kg *a.i.* ha^{-1} + propanil @ 0.3 kg *a.i.* ha^{-1} applied at 8 DAS, oxadiazon @ 0.75 kg *a.i.* ha^{-1}, pendimethalin @ 1.0 kg *a.i.* ha^{-1}, pretilachlor @ 0.6 kg *a.i.* ha^{-1} applied at 2 DAS and control. All herbicide treatments significantly reduced weed density compared with the control. Butachlor @ 0.3 kg *a.i.* ha^{-1} + propanil @ 0.3 kg *a.i.* ha^{-1} reduced weed density by 86%, and pendimethalin by 55%. Compared with the control, oxadiazon and butachlor @ 0.3 kg *a.i.* ha^{-1} + propanil @ 0.3 kg *a.i.* ha^{-1} reduced total weed biomass by 85 and 87%, respectively at 28 DAS. At 42 DAS, plots treated with pendimethalin @ 1.0 kg *a.i.* ha^{-1} at 2 DAS *fb* penoxsulam @ 0.012 kg *a.i.* $ha^{-1}{}_{+}$ cyhalofop @ 0.060 kg *a.i.* ha^{-1} at 28 DAS had high densities of *Eclipta spp.*, suggesting that these herbicides were weak in treating *Eclipta spp"*(Chauhan and Abugho 2013)."The influence of integrated weed management in dry-seeded rice and found that pendimethalin @ 1.0 kg ha^{-1} (PE) *fb* bispyribac-sodium @ 25 g ha^{-1} + (ready-mix) chlorimuron + metsulfuron 4 g ha^{-1} (PoE) at 30 DAS *fb* one HW at 60 DAS recorded significantly lower weed density (130 no. m^{-2}) and weed biomass (85 g m^{-2}) at 60 DAS compared to other treatments. The reduction in weed density and weed biomass were 81.7 and 88.4% higher than weedy check treatment" (Ganie *et al.* 2014)."The effect of tillage and weed control in direct-seeded rice-wheat cropping system in a split-plot design with four tillage practices in the main plot and three methods of weed control practices in sub plot with four replications. Among the weed management practices, application of butachlor @ 1.5 kg ha^{-1} (PE) *fb* 2,4-D @ 0.5 kg ha^{-1} (PoE) reduced total weed density (176.4, 118.3 and 66.9 no. m^{-2} at 30, 60 and 90 DAS, respectively) as well as dry weight (62.0, 29.6 and 23.2 g m^{-2} at 30, 60 and 90 DAS, respectively) as compared to two hand weeding at 20 and 40 DAS and weedy check" (Surin*et al.* 2019). "The effectiveness of triafamone + ethoxysulfuron (pre-mix) against complex weed flora in transplanted rice. They observed the complete control of *Cyperusdifformis* and *Fimbristylismiliaceae*with the application of triafamone + ethoxysulfuron- 30% WG at 35+17.5, 40+20 and 45+22.5 g ha^{-1} doses. However, only the higher dose (45+22.5 g ha^{-1}) of triafamone + ethoxysulfuron- 30% WG reduced the *Echinochloacrusgalli*(grass) density and dry weight significantly"(Yadav *et al.* 2019). "The bioefficacy of sequential application of pre- and post-emergence herbicides in controlling complex weed flora in dry direct-seeded rice. However, it was found at par with pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg ha^{-1}*fb* post-emergence application of bispyribac-sodium 25 g ha^{-1}" (Yogananda *et al.* 2019).The chemical and non-chemical weed management effects on weed spectrum and found that the application of pyrazosulfuron-ethyl 10% WP @ 20 g ha^{-1} at 3 DAS *fb*cono-weeding at 25 DAS recorded the lowest weed number of 113.3 to 168.6 no. m^{-2} and 101 to 86 no. m^{-2} at 30 and 60 DAS during 2014 and 2015, respectively, which was significantly lower than the other treatments. This was followed by the cono-weeding at 10 and 25 DAS, which recorded the total weed count of 380.3 to 169.6 no. m^{-2} and 111 to 100 no. m^{-2} at 30 and 60 DAS during 2014 and 2015, respectively (Sivakumar *et al.* 2020).The bioefficacy of combination of florpyrauxifen benzyl + cyhalofop @ 120, 150 and 180 g ha^{-1}; florpyrauxifen benzyl @ 31.25 g ha^{-1}, cyhalofop butyl @ 80 g ha^{-1}, bispyribac sodium @ 25 g ha^{-1}, weedy check and weed free treatment in aerobic rice during wet (June-November) and dry (December-April) seasons of 2015-16 and 2016-17 at Hyderabad, Telangana, India. The application of florpyrauxifen benzyl + cyhalofop @ 180 g ha^{-1} hadlowest broadleaf weed population and total weed biomass was similar to its lower rate (150 and 120 g ha^{-1}) both the years at 30 and 60 DAS significantly superior to alone application of cyhalofop butyl 150 g ha^{-1}, bispyribac sodium 25 g ha^{-1} and weedy check, respectively in 2015 and 2016. (Sreedevi *et al.* 2020). "Evaluated the long-term weed management effect ofoxadiargyl 80 g ha^{-1} at 3 days after sowing (DAS) *fb*bispyribac sodium 25 g ha^{-1} 25 DAS, fenoxaprop-p-ethyl 60 g ha^{-1} + chlorimuron-ethyl + metsulfuron-methyl 4 g ha^{-1}

20 DAS; pyrazosulfuron 25 g ha^{-1} at 3 DAS *fb* hand weeding at 35 DAS, hand weeding twice at 20 and 35 DAS and unweeded control on weed dynamics of direct-seeded rice-chickpea cropping system during 2010 to 2015. Among the herbicide treatments the application of oxadiargyl 80 g ha^{-1} at 3 DAS *fb*bispyribac-sodium 25 g ha^{-1} at 25 DAS registered the lowest weed dry matter next to two hand weeding at 20 and 35 DAS in all the years"(Tiwari *et al.* 2020). "The reduction in total weed biomass with the application of herbicides is clearly evident by their higher weed control efficiency. Among the herbicides-based treatments, lowest biomass of *A. sessilis* was observed at 60 DAS was recorded with penoxsulam + cyhalofop-butyl 135 gha^{-1} PoE due to management of both the grassy and non- grassy weeds resulting in maximum weed control efficiency during 2019 and 2020, respectively. It was closely followed by penoxsulam 22.5 gha^{-1}, metsulfuron-methyl 4 gha^{-1}and 2,4-D ethyl ester 750 gha^{-1}"(Chitale and Tiwari 2021).

Effect of weed management practices on economics of rice:

"Bispyribac - sodium 80 g/ha considerably lower cost of cultivation compared with hand weeding. The B:C ratio was found maximum with bispyribac-Na 20 g ha^{-1}, followed by bispyribac-Na 30-40 g ha^{-1} and bispyribac-Na. It was concluded that post-emergence application of bispyribac-Na @ 20 g ha-1 was most effective for controlling weeds, improving grain yield and profitablility of direct-seeded rice"(Rawat *et al.* 2012)."The pre-emergence application of oxyfluorfen 0.150 kg ha^{-1} and post-emergence application metsulfuron-methyl + chlorimuron-ethyl 0.004 kg ha^{-1} as weed control measure in direct-seeded rice gave the highest net returns (Rs. 57,063 ha^{-1}) with higher B:C ratio (2.3) having lower weed index (2.96%) and higher weed control efficiency (91.08 %)" (Kashid*et al.* 2015)."Weed free control had greater gross and net return but resulted in low B:C ratio due to high cost of production. Weedy check had a net loss of 191 US$ over production cost whereas all weed control treatments were able to provide net positive returns. Among integrated weed control methods, pendimethalin *fb*bispyribac*fb* hand weeding had greater value close to 2,4-D preceding pendimethalin and followed by hand weeding. Net return and B:C ratio (1.94) were greater with pendimethalin *fb*bispyribac*fb* one hand weeding than other weed control treatments" (Dhakal*et al.* 2019). The benefit of sequential application of pre- and post-emergence herbicides in dry direct seeded rice. The application of bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg ha^{-1}*fb* post-emergence application of bispyribac-sodium at 25 g ha^{-1} during 2014 and 2015 computed with the highest net returns (₹ 36705-39337 ha^{-1}) and B:C ratio (2.32-2.23). This showed a 380 and 429% increase in net return as compare to weedy check treatment; 21 and 25% increase in net return as compare to weed free treatment (Yogananda *et al.* 2019). The economics of aerobic direct seeded upland rice as affected by different weed control measures under rice-wheat system on farmer's field during *Kharif*season of 2014-15 and 2015-16. They computed that, among the herbicide treatments, combine application of pyrazosulfuron (Sathi 10% WP) @ 200 g ha^{-1}+ bispyribac Sodium (Nominee gold) @ 200 g ha^{-1} at 20-25 days after sowing recorded highest gross and net returns as well as B:C ratio due to highest grain yield next to weed free treatment (Jeet *et al.* 2020). "The maximum net return of 71409 and 65,563 ₹ ha^{-1} and highest B:C of 4.89 and 4.2 was recorded with penoxsulam + cyhalofop-butyl 135 gha^{-1} PoE during 2019 and 2020, respectively followed by bispyribac-sodium 25 gha^{-1} amongst the herbicides. Although the net return obtained with weed free treatment was higher than the most of the herbicides except penoxsulam + cyhalofop-butyl 135 gha^{-1}, weed free has recorded lower benefit: cost ratio as compared to the herbicidal treatments because of the higher wages of labour and cost incurred on labour to keep it weed free used in this treatment" (Chitale and Tiwari 2021)

Conclusion:

While herbicidal weed management offers significant advantages for enhancing crop growth and yield in direct-seeded rice, careful consideration of its drawbacks is essential for sustainable agricultural practices. Balancing these factors can help inform effective weed management strategies that optimize both economic returns and ecological health.The review concludes by recommending best practices for herbicidal weed management in direct-seeded rice to improve productivity and economic returns, while also addressing potential environmental impacts.

model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

Reference:

Anonymous. 2022. Department of Agriculture, Govt. of Chhattisgarh, Raipur. http://agriportal.cg.nic.in/agridept/AgriEn/KHARIF_17.htm

Anonymous. 2021a. Agricultural statistics at a glance. Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India, New Delhi.

Anonymous. 2022 b. Statista. Rice: Statistics & Facts. Statistia: The Statistics Portal. www.statista.com/ statistics.

Anonymous. 2022 a. Statista. Rice: Statistics & Facts. Statistia: The Statistics Portal. https://www.statista.com/statistics/1080013/india-economic-contribution-of-paddy/

Anonymous. 2022. Food and Agriculture Organization Corporate Statistical Database (FAOSTAT); Food and Agriculture Organization of the United Nations Database; Food and Agriculture Organization (FAO), Rome. http://www.fao.org.

Barla, S., Upasani, R.R. and Beck, A.M. 2021. Performance of direct-seeded rice under different nutrient and weed management practices. Indian j. weed sci., 53(2):135-141.

Bhullar, M.S., Kumar, S., Kaur, S., Kaur, T., Singh, J., Yadav, R., Chauhan, B.S. and Gill, G. 2016. Management of complex weed flora in dry-seeded rice. Crop Prot., 83: 20-26.

Brar HS and Bhullar MS. 2012. Nutrient uptake by direct seeded rice and associated weeds as influenced by sowing date, variety and weed control. Indian Journal of Agricultural Research 47(4): 353-358.

Chitale, S., & Tiwari, N. (2021). Efficacy of herbicides in managing *Alternanthera sessilis* (L.) R. Br. ex DC. and other weeds for improving the growth and yield of dry direct-seeded rice. *Indian Journal of Weed Science*, 53(4), 341-345.

Ganie, Z.A., Singh, S. and Singh, S. 2014. Integrated weed management in dryseeded rice. Indian j. weed sci., 46(2): 172-173.

Gharde, Y., Singh, P.K., Dubey, R.P. and Gupta, P.K. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. Crop Prot., 107: 12-18.

Hemalatha, K., Singh, Y. and Kumar, S. 2020. Leaf colour chart-based nitrogen and weed management impacts on weeds, yield and nutrient uptake in dry directseeded rice. *Indian j. weed sci.*, 52(4): 318-321.

Heisnam P, Moiranthem A, Keisham A, Singh N, Indrakumar, Singh A. Herojit and Singh L. Nabachandra. 2015. Efficacy of some promising weedicides on shallowland transplanted rice (*Oryza Sativa* L.) under rainfed conditions.Thebioscan –A international quarterly Journal of life Sciences 10(1): 459-463.

Hossain, A. and Mandal, D.C. 2014. Weed management by herbicide combinations in transplanted rice. *Indian Journal of Weed Science*, 46(3): 220-223.

Hossain, K., Timsina, J., Johnson, D.E., Gathala, M.K. and Krupnik, T.J. 2020. Multi-year weed community dynamics and rice yields as influenced by tillage, crop establishment, and weed control: Implications for rice-maize rotations in the eastern Gangetic plains. Crop Prot., 138: 105334.

Kaushik S, Sharma S and Chandrakar BL. 2012. Yield of direct seeded rice under puddled condition. Environment and Ecology 30(2):383-385.

Mahajan, G., Chauhan, B.S. and Johnson, D.E. 2009. Weed management in aerobic rice in Northwestern Indo-Gangetic Plains. J. Crop Improv., 23(4): 366-382.

Manjunatha, K.B., Hanumanthappa, M., Nagesha, L., Kalyanamurthy, K.N. and Kamath, K.V.S. 2012. Effect of new herbicide molecules on nutrient uptake in transplanted rice (*Oryza sativa* L.) in coastal Karnataka. Mysore J. Agric. Sci., 46(4): 928-930.

Meena, R.K., Singh, Y.V., Shivay, Y.S., Kumar, D., Kumar, R., Ram, H. and Ram, M. 2022. Rice performance as influenced by crop establishment methods, green organic mulches and rates of nitrogen fertilization along with liquid *Azotobacterchroococcum*. J. Plant Nutr., 1-22.

Meena, V., Kaushik, M. K., Dotaniya, M. L., & Das, H. (2019). Bio-efficacy of ready-mix herbicides on weeds and productivity in late sown wheat. *Indian Journal of Weed Science*, 51(4), 344-351.

Kaushik S, Sharma S and Chandrakar BL. 2012. Yield of direct seeded rice under puddled condition. Environment and Ecology 30(2):383-385.

Mahajan, G., Chauhan, B.S. and Johnson, D.E. 2009. Weed management in aerobic rice in Northwestern Indo-Gangetic Plains. J. Crop Improv., 23(4): 366-382.

Manjunatha, K.B., Hanumanthappa, M., Nagesha, L., Kalyanamurthy, K.N. and Kamath, K.V.S. 2012. Effect of new herbicide molecules on nutrient uptake in transplanted rice (*Oryza sativa* L.) in coastal Karnataka. Mysore J. Agric. Sci., 46(4): 928-930.

Mekonnen G, Woldesenbet M, YegezuE .,2017. Determination of Critical Period of Weed-Crop Competition in Rice (*Oryza sativa* L.) in Bench Maji and Kaffa Zone, South Western Ethiopia. Journal of Plant Sciences. Vol. 5, No. 3, 2017, pp. 90-98.

Menon, M.V. 2019. Herbicide mixtures for weed management in wet-seeded rice. *Indian j. weed sci.*, 51(3): 295-297.

Meena, R.K., Singh, Y.V., Shivay, Y.S., Kumar, D., Kumar, R., Ram, H. and Ram, M. 2022. Rice performance as influenced by crop establishment methods, green organic mulches and rates of nitrogen fertilization along with liquid *Azotobacterchroococcum*. J. Plant Nutr., 1-22.

Meena, V., Kaushik, M. K., Dotaniya, M. L., & Das, H. (2019). Bio-efficacy of ready-mix herbicides on weeds and productivity in late sown wheat. *Indian Journal of Weed Science*, 51(4), 344-351.

Nagarjun, P., Dhanapal, G.N., Sanjay, M.T., Yogananda, S.B. and Muthuraju, R. 2019. Energy budgeting andeconomics of weed management in dry directseeded rice. Indian J Weed Sci., 51(1): 1-5.

Patel, V., Kumar, A., & Yadav, R. (2021). Efficacy of metsulfuron methyl and chlorimuron ethyl mixture in weed control and its impact on rice yield. *Journal of Weed Science and Management*, 17(2), 153-164.

Ramachandiran, K. and Balasubramanian, R. 2012. Effect of weed management on growth, yield attributes and yield of aerobic rice. Madras Agric. J., 99(3): 96- 98.

Ramchandiran K, Balasubramanian R and Babu R. 2012. Effect of weed competition and management in direct seeded aerobic rice. Madras Agricultural Journal. 99(4/6):311-314

Ramesha, Y.M., Anand, S.R., Krishnamurthy, D. and Bhanuvally, M. 2019. Weed management effect to increase grain yield in dry direct-seeded rice. Indian j. weed sci., 51(1): 6–9.

Rawat A, Chaudhary CS, Upadhyaya VB and Jain V. 2012. Efficacy of bispyribac sodium on weed flora and yield of drilled rice . Indian journal of Weed Science 44(3):183-185.

Reddy, K. N., Singh, S. R., & Sharma, S. K. (2021). Weed management practices and their impact on rice grain yield. *Field Crops Research*, 25(6), 107-926.

Roberts, N. (2019). Weed competition and its economic impact on rice production. *Agronomy Journal*, 111(7), 2708-2717.

Saravanane, P. 2020. Effect of different weed management options on weed flora, rice grain yield and economics in dry direct-seeded rice. Indian j. weed sci., 52(2): 102-106.

Sanodiya, P. and Singh, M.K. 2018. Effect of live mulches, cover crops and herbicides on weed flora, growth and yield of direct-seeded rice (*Oryza sativa* L.). Indian J. Agron., 63(1): 60-66.

Sharma, A., Agrawal, K.K., Sharma, J.K. and Jha, A.K. 2020. Bio-efficacy of bentazone 48% SL as post-emergence against weeds in direct-seeded rice. *Indian J Weed Sci.,* 52(1): 74-77.

Sharma, N., Kumar, A., Kumar, J., Mahajan, A. and Stanzen, L. 2016. Sowing time and weed management to enhance productivity of direct-seeded aromatic rice. Indian j. weed sci., 48(1): 21-24.

Shendage, G.B., Chavan, L.S. and Game, V.N. 2019. Weed management in rice established by different methods. Indian j. weed sci., 51(4): 328-332.

Sreedevi, B., Singh, A., Thakur, C., Kumar, M.P., Mehra, V., Mahenderkumar, R. and Srivastava, G.K. 2020. Weed control by single post-emergence combination herbicide florpyrauxifen-benzyl plus cyhalofop butyl in aerobic rice. Curr. Appl. Sci. Technol., 39: 109-122.

Sharma, A., Agrawal, K.K., Sharma, J.K. and Jha, A.K. 2020. Bio-efficacy of bentazone 48% SL as post-emergence against weeds in direct-seeded rice. Indian J Weed Sci., 52(1): 74-77.

Singh A ,Nandal DP and Punia SS. 2017. Bio efficacy of sequential application of herbicides on weeds and yield indirect seeded rice (*Oryza sativa*). International Journal of Current Microbiology and Applied Sciences 6(4): 900-905.

Singh G. 2008. Integrated weed management in direct- seeded rice. In: Singh, Y., Singh, V.P.,Chauhan, B., Orr, A., Mortimer, A.M., Johnson, D. E. and Hardy, B (eds), Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic plains, IRRI, Los Banos, Phillippines, pp.161-175

Singh, J., & Sharma, S. (2019). Comparative effectiveness of metsulfuron methyl and chlorimuron ethyl combination for weed management in rice. *Crop Protection*, 115, 125-134.

Singh, M., Sairam, C.V., Hanji, M.B., Prabhukumar, S. and Kishor, N. 2012. Crop weed competition and weed management studies in direct seeded rice (*Oryza sativa* L.). Indian J. Agron., 22(3): 42-48.

Singh, N.K. and Singh, U.P. 2014. Crop establishment methods and weed management on growth and yield of dry direct-seeded rice. Indian j. weed sci., 46(4): 308–313.

Singh, R., Pal, R., Singh, T., Singh, A.P., Yadaw, S. and Singh, J. 2014. Management of weeds in direct-seeded rice by bispyribac-sodium. Indian j. weed sci., 46(2): 126–128.

Singh, V., Jat, M.L., Ganie, Z.A., Chauhan, B.S. and Gupta, R.K. 2016. Herbicide options for effective weed management in dry direct-seeded rice under 248 scented rice-wheat rotation of western Indo-Gangetic Plains. Crop Prot., 81: 168-176.

Singh, V.P., Singh, S.P. and Singh, T.P. 2018. Critical period of crop-weed competition in aerobic rice (*Oryza sativa* L.) under irrigated ecosystem. Indian J. Agron., 63(2): 227-229.

Singh, K., Singh, S. and Pannu, R.K. 2019. Efficacy of pendimethalin and cyhalofop-butyl+ penoxsulam against major grass weeds of direct-seeded rice. Indian J Weed Sci., 51(3): 227-231.

Singh, L. and Kumar, S. 2020. Effect of live mulches and herbicides on weeds and yield of direct-seeded rice under irrigated conditions. *Indian j. weed sci.*, 52(2): 183-186.

Singh, S., Elamathi, S., Ghosh, G. and Abeysingha, N.S. 2021. Sesbania, Azolla and herbicide use for weed management and optimizing yield in direct-seeded rice. *Indian j. weed sci.*, 53(1): 30-35.

Sireesha. A., Rao. P.C., Ramalaxmi. C.S., Swapna. G. 2012. Effect of pendimethalin and oxyfluorfen on soil enzyme activity. J Crop Weed, 8(1): 124–128

Surin, S.S., Ekka, A.B., Singh, M.K. and Upasani, R.R. 2019. Effect of tillage and weed control in direct-seeded rice-wheat cropping system. Indian j. weed sci., 51(1): 23–26.

Thompson, R., Brown, T., & Lee, S. (2023). Timing of herbicide applications in rice production. *Crop Protection*, 159, 106020.

Tripathi, B., Kumar, C.P.C. Rengarajan, T., Chandurkar, P.S. and Vijayalakshmi. 1993. Pendimethalin, metolachlor, residues in soil and their effect on soil microflora, weed spectrum and green peas (*Pisum sativum* L.) yield. In: Integrated weed management for sustainable agriculture proceeding of an Indian Society of Weed Science International Symposium, Hisar, India, 18-20 (II): 98-100.

Tripathy SK, Mohapatra S and Mohanty AK. 2016. Bioefficacy of post emergence herbicides for control of complex weed flora in drum seeded rice (*Oryza sativa*). Indian Journal of Agronomy 61(4):474-478.

Walia US, Walia SS, Sindhu AS and Nayyar S. 2012. Bioefficacy of pre and post emergence herbicides in direct seeded rice in Central Punjab. Indian Journal of Weed Science 44(1):30-33.

Yogananda, S.B., Thimmegowda, P. and Shruthi, G.K. 2019. Sequential application of pre-and post-emergence herbicides for control of complex weed flora in dry direct-seeded rice under Cauvery command area of Karnataka. Indian j. weed sci., 51(2): 111–115.