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**RESEARCH ARTICLE**

# Efficacy of herbicide mixtures on weed dynamics in direct-dry-seeded rice under irrigated condition

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**ABSTRACT**

An experiment was conducted during three consecutive *Kharif* seasons of 2021, 2022 and 2023 at Regional Research Station, Anand Agricultural University, Anand, Gujarat, India, to study the effect of weed management practices on weeds and grain yield of dry-seeded rice. The dominant grassy weeds in fields were *Echinochloa crus-galli*, *Echinochloa colona*, *Leptochloa chinensis* and broad-leaf weeds were *Digera arvensis*, *Phyllanthus niruri* and *Trianthema monogyna* on three years pooled basis. Results revealed that, early post emergence application (EPoE) of triafamone 20% + ethoxysulfuron 10% WG (pre-mix) 44.0 + 22.5 g/ha at 10-15 days after sowing (DAS) followed by (*fb*) hand weeding (HW) at 30 DAS or penoxsulam 1.02% + cyhalofop-butyl 5.1% OD (pre-mix) 120 g/ha at 10-15 DAS *fb* HW at 30 DAS or pre-emergence application (PE) of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG (pre-mix) 600 + 15 g/ha at 1-2 DAS *fb* HW at 30 DAS or hand weeding 20 and 40 DAS recorded significantly lower density and dry biomass of weeds, higher weed contol efficiency, number of tillers, grain yield of rice and B: C. Moreover, there were no any residues of applied herbicides detected in the rice grain and in soil after harvest.

**Keywords:** Direct-seeded rice, Herbicides, Microbial roperties, Yield, Residue, Weeds

## INTRODUCTION

Rice (*Oryza sativa* L.) is an important food crop of India contributing 45% of the total food grain production. Direct-seeding eliminates the need of raising, maintaining and subsequent transplanting of seedlings besides, it is cost effective can save water through earlier rice crop establishment and allows timely sowing of wheat (Singh *et al*. 2007). There are so many factors which limit the cultivation of rice with transplanting method including water, high input costs, timely unavailability of skilled labour and suboptimal plant population. This factor leads to increase the production cost hence, economic returns are reduced. Looking to this, there has been shift in crop establishment method particularly in rice from transplanting to direct seeded rice in many Asian countries including India. Under this situation, direct seeding is a good alternative to transplanting as it is more economical and labour saving. Moreover, direct-seeded rice matures 7 to 10 days earlier than transplanted rice due to absence of transplanting shock (Rana *et al*. 2014). Under such circumstances, cultivation of rice with direct seeding may provide alternatives in sustainable production. Weeds are most severe and widespread biological constrains to crop production in India and alone cause 33% of losses out of total losses due to pests (Verma *et al.* 2015). However, direct seeding is subjected to greater weed competition than transplanted rice and high weed pressure in DSR are mainly due to absence of a weed-suppressive effect of stagnation of water at the time of crop emergence (Rao *et al*. 2007). According to Singh *et al.* (2004), weeds can reduce the grain yield of dry seeded rice (DSR) by 75.8%. Weeds by virtue of their high adaptability and faster growth dominate the crop habitat and reduce the yield potential. Therefore, the present investigation was undertaken to study the effect of herbicide mixtures for control of major weeds in irrigated dry seeded rice.

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## MATERIALS AND METHODS

A field experiment was conducted during three consecutive *Kharif* seasons of 2021, 2022 and 2023 at the farm of Regional Research Station, Anand Agricultural University, Anand, Gujarat on loamy sand soil. The experiment comprising of ten treatments *viz*., pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* HW at 30 DAS, pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* bispyribac-sodium 10% SC 25 g/ha PoE, pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* triafamone 20% + ethoxysulfuron 10% WG 44 + 22.5 g/ha (PM) PoE, pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha (PM) PoE, pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* metsulfuron-methyl 10% + chlorimuron-ethyl 10% WP 4 g/ha (PM) PoE, bispyribac-sodium 20% + pyrazosulfuron-ethyl 15% WDG 20 + 15 g/ha (PM) EPoE *fb* HW at 30 DAS, triafamone 20% + ethoxysulfuron 10% WG 44.0 + 22.5 g/ha (PM) EPoE *fb* HW at 30 DAS, penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha (PM) EPoE *fb* HW at 30 DAS, hand weeding at 20 and 40 DAS and weedy check was laid out in a randomized block design with three replications. Rice cv. *GAR 14* was sown on 5$^{th}$ August, 3$^{rd}$ August and 7$^{th}$ July of 2021, 2022 and 2023, respectively at a spacing of 30 cm by using seed rate of 60 kg/ha and was harvested on 1$^{st}$ December, 29$^{th}$ November and 11$^{th}$ November, respectively. The crop was fertilized with recommended rate of fertilizer (100-25-0 kg NPK/ha). Nitrogen was applied in three split, 50 kg N at basal and 25 kg N/ha each at active tillering and panicle initiation stage in the form of urea and 25 kg P in the form of single super phosphate was applied at land preparation. Other agronomical and plant protection measures were followed as per the recommendation during the crop growth. Herbicides were applied as per the treatment by using battery operated knapsack sprayer fitted with flat-fan nozzle by mixing in 500 litres of water/ha. Quadrat (0.25 $m^2$) was randomly placed at four places in each of the plot to count density and dry weight of weeds at 30, 60 DAS and at harvest. Observations on crop growth and yield parameters, *viz.* plant stand at 15 DAS (No./net plot), plant height at 30, 60 DAS and at harvest as well as grain and straw yield (kg/ha) were recorded. Data on various indices recorded during the experimental period was statistically analysed as per the standard procedure and weed data were transformed by square root transformation Ö(X+1) and transformed data were subjected to ANOVA analysis (Gomez and Gomez 1984).

For Soil microbial properties, representative soil samples were collected from each plot before sowing, at 1, 15 and 30 DAS as well as at harvest. All the soil samples were analyzed for total microbial populations using standard methodology inwhich, soil samples were serially diluted and inoculated on nutrient agar media and after incubation microbial count in terms of CFU was recorded (Bera and Ghosh 2014).

## RESULTS AND DISCUSSION

### Weed flora

In general, dominancy of grasses weed (58.7%) was observed in the experimental field during crop period wherein, major weeds in the experimental field were *Echinochloa crus-galli* (19.8%), *Echinochloa colona* (11.1%), *Leptochloa chinensis* (10.3%) and *Dactyloctenium aegyptium* (6.35%) in grassy weeds category whereas, *Digera arvensis* (16.7%), *Phyllanthus niruri* (15.9%) and *Trianthema monogyna* (5.56%) in *broad-leaf* weed category on three years pooled basis.

### Density and dry biomass of weeds

All the weed management practices significantly influenced density of weed at 60 DAS (**Table 1**). Pre-mix of triafamone 20% + ethoxysulfuron 10% WG 44.0 + 22.5 g/ha applied as early post emergence (EPoE) *fb* HW at 30 DAS recorded significantly lower density and dry biomass of grasses and *broad-leaf* weed but it was at par with penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha (PM) EPoE *fb* HW at 30 DAS and twice hand weeding at 20 and 40 DAS. Pre-emergence application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) *fb* HW at 30 DAS proved effective by reducing density and dry biomass of weeds as compared to pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) followed by sequential application of either bispyribac-sodium 10% SC 25 g/ha PoE, triafamone 20% + ethoxysulfuron 10% WG 44 + 22.5 g/ha (PM) PoE, penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha (PM) PoE and metsulfuron-methyl 10% + chlorimuron-ethyl 10% WP 4 g/ha (PM) PoE. The effectiveness of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG (600 + 15 g/ha) in direct-seeded rice in reducing the dry biomass of weed was also reported by Shamurailatpam *et al.* (2015). Among herbicidal treatments, higher density and dry biomass of grassy weed was recorded under application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* metsulfuron-methyl 10% + chlorimuron-ethyl 10% WP 4 g/ha (PM) PoE. This might be due to poor control of grassy weed under post-emergence application of metsulfuron-methyl 10% + chlorimuron-ethyl 10% WP 4 g/ha (PM). Integration of hand weeding with pre- and post-emergence application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) and bispyribac-sodium 20% + pyrazosulfuron-ethyl 15% WDG 20 + 15 g/ha (PM), respectively performed better by reducing density and dry biomass of weed as compared to sequential application of pre and post emergence herbicide.

The highest weed control efficiency was attained under triafamone 20% + ethoxysulfuron 10% WG 44.0 + 22.5 g/ha (PM) EPoE *fb* HW at 30 DAS (96.8%) followed by penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha (PM) EPoE *fb* HW at 30 DAS, hand weeding at 20 and 40 DAS and bispyribac-sodium 20% + pyrazosulfuron-ethyl 15% WDG 20 + 15 g/ha (PM) EPoE *fb* HW at 30 DAS. The effectiveness of this herbicide for effective control of weeds was also reported by Ramesha *et. al*. (2019). Application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600+15 g/ha (PM) PE *fb* metsulfuron-methyl 10% + chlorimuron-ethyl 10% WP 4 g/ha (PM) PoE recorded lower weed control efficiency (47.7%) due to poor control of grassy weed especially *Echinochloa crus-galli*, *Echinochloa colona* and *Leptochloa chinensis*. Treatment with pre-emergence application of herbicide followed by hand weeding at 30 DAS recorded higher weed control efficiency as compared to sequential application of herbicide.

### Effect on crop

Application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG (pre-mix) 600 + 15 g/ha and bispyribac-sodium 20% + pyrazosulfuron-ethyl 15% WDG 35 g/ha EPoE (pre-mix) showed some phytotoxicity symptoms of leaf injury and slightly necrosis on direct-seeded rice at 7 days after herbicide application. However, plants recovered from the phytotoxicity symptoms and none of the symptoms were observed at 14 days after herbicide application.

Plant height was observed higher under herbicide treatment as compared to weedy check at 60 DAS and at harvest (**Table 2**). Application of bispyribac-sodium 20% + pyrazosulfuron-ethyl 15% WDG 20 + 15 g/ha (PM) EPoE *fb* HW at 30 DAS, triafamone 20% + ethoxysulfuron 10% WG 44.0 + 22.5 g/ha (PM) EPoE *fb* HW at 30 DAS, penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha (PM) EPoE *fb* HW at 30 DAS and pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* HW at 30 DAS recorded significantly higher number of effective tillers as compared to other herbicide treatment. Twice hand weeding at 20 and 40 DAS equally effective as pre-emergence application of herbicide followed by integration of hand weeding at 30 DAS for recording higher number of tillers.

Different weed management practices had significant effect on grain yield of rice during all the three years (**Table 2**). Significantly higher grain and straw yields were recorded under triafamone 20% + ethoxysulfuron 10% WG 44.0 + 22.5 g/ha (PM) EPoE *fb* HW at 30 DAS followed by hand weding at 20 and 40 DAS, penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha (PM) EPoE *fb* HW at 30 DAS and pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* HW at 30 DAS. The higher yield under twice hand weeding and application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG (600 + 15 g/ha) PE (PM) *fb* HW at 30 DAS was also reported by Ramesha *et al.* (2019). Significantly lower grain yield was recorded under

**Table 1. Density and dry weight of weeds in DSR under different weed management practices at 60 DAS (three year pooled)**

| Treatment | Weed density (no./m$^2$) | | | Weed dry biomass (g/m$^2$) | | | WCE (%) |
|---|---|---|---|---|---|---|---|
| | Grasses | Broad-leaf | Total | Grasses | Broad-leaf | Total | |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* HW at 30 DAS | 2.90 (8.33) | 3.08 (8.78) | 4.15 (17.1) | 5.80 (36.3) | 3.44 (11.6) | 6.67 (47.9) | 87.2 |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* bispyribac-sodium 25 g/ha PoE | 3.72 (14.9) | 3.67 (12.9) | 5.19 (27.8) | 7.87 (71.2) | 4.15 (18.1) | 9.11 (89.3) | 76.1 |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* triafamone + ethoxysulfuron 44 + 22.5 g/ha (PM) PoE | 3.11 (9.33) | 3.88 (15.2) | 4.91 (24.6) | 7.41 (62.5) | 4.98 (24.2) | 8.97 (86.7) | 76.8 |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* penoxsulam + cyhalofop-butyl 120 g/ha (PM) PoE | 3.10 (10.3) | 4.45 (20.0) | 5.36 (30.3) | 6.44 (49.1) | 3.36 (11.1) | 7.23 (60.2) | 83.9 |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (PM) PoE | 4.83 (24.4) | 2.54 (6.56) | 5.54 (31.0) | 13.2 (188) | 2.58 (6.53) | 13.5 (195) | 47.9 |
| Bispyribac-sodium + pyrazosulfuron-ethyl 20 + 15 g/ha (PM) EPoE *fb* HW at 30 DAS, | 2.95 (8.56) | 3.71 (13.6) | 4.66 (22.1) | 4.71 (25.0) | 2.52 (5.64) | 5.33 (30.6) | 91.8 |
| Triafamone + ethoxysulfuron 44.0 + 22.5 g/ha (PM) EPoE *fb* HW at 30 DAS | 2.04 (3.78) | 2.39 (5.11) | 3.04 (8.90) | 2.90 (7.83) | 2.19 (4.21) | 3.50 (12.0) | 96.8 |
| Penoxsulam + cyhalofop-butyl 120 g/ha (PM) EPoE *fb* HW at 30 DAS | 2.12 (4.00) | 2.90 (7.56) | 3.50 (11.6) | 3.49 (12.1) | 2.04 (3.76) | 3.98 (15.8) | 95.8 |
| Hand weeding at 20 and 40 DAS | 2.31 (5.78) | 2.34 (4.89) | 3.20 (10.7) | 4.52 (25.1) | 1.71 (2.00) | 4.77 (27.1) | 92.8 |
| Weedy check | 5.36 (28.4) | 5.14 (26.2) | 7.42 (54.7) | 17.9 (328) | 6.79 (45.5) | 19.2 (374) | - |
| LSD (p=0.05) | 0.58 | 1.15 | 1.01 | 2.71 | 1.36 | 2.63 | - |
| CV % | 17.5 | 20.0 | 15.1 | 14.8 | 15.7 | 13.1 | - |

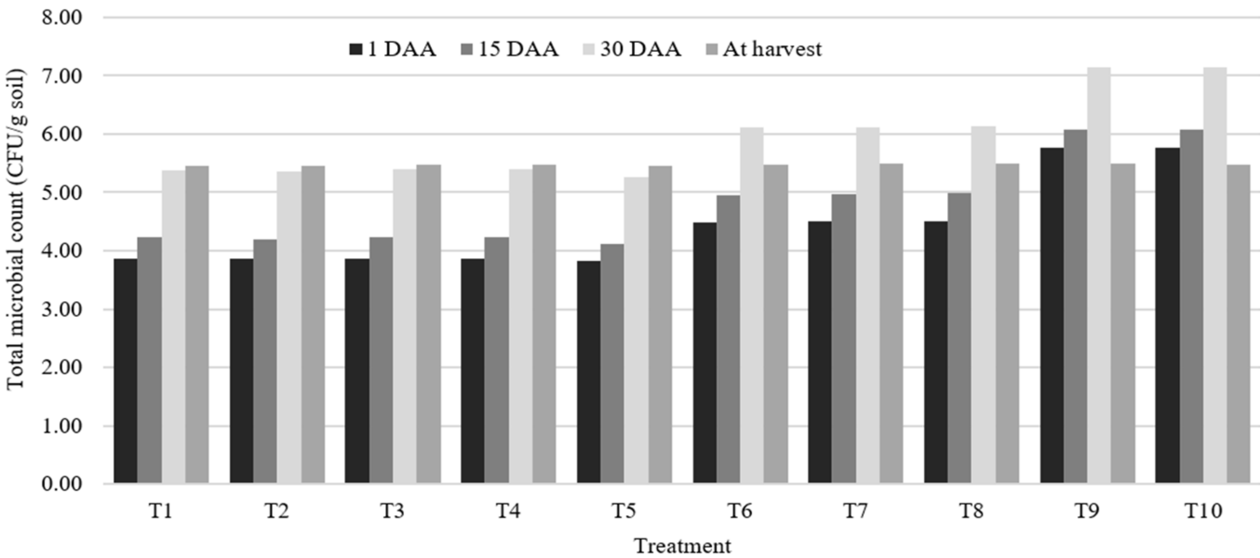
application of pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* metsulfuron-methyl 10% + chlorimuron-ethyl 10% WP 4 g/ha (PM) PoE due to poor control of grassy weed. Yield reduction due to presence of weed was observed maximum under weedy check (84.4%) followed by pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* metsulfuron-methyl 10% + chlorimuron-ethyl 10% WP 4 g/ha (PM) PoE.

## Soil microbial study

Initially significant differences were observed in the soil microbial population due to different treatments. The adverse effect on soil microbial population was observed in all the pre- emergence herbicides applied in the experiment from 1 to 15 days, but the effect of herbicide on soil microbial population was gradual decrease from 30 days onwards and no adverse effect of different weed herbicides was recorded at harvest (**Figure 1**).

**Table 2. Growth, yield and economics as influenced by weed management practices in DSR (three year pooled)**

| Treatment | Plant height (cm) At 30 DAS | Plant height (cm) At 60 DAS | Plant height (cm) At harvest | Effective tillers (no./m row length) | Grain yield (t/ha) 2021 | Grain yield (t/ha) 2022 | Grain yield (t/ha) 2023 | Grain yield (t/ha) Pooled | Straw yield (t/ha) | Weed index (%) | B:C |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* HW at 30 DAS | 37.5 | 84.7 | 98.8 | 109 | 3.05 | 3.20 | 5.54 | 3.93 | 6.97 | 4.29 | 1.38 |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* bispyribac-sodium 25 g/ha PoE | 36.8 | 85.3 | 98.2 | 104 | 2.79 | 2.93 | 4.36 | 3.36 | 6.21 | 18.2 | 1.30 |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* triafamone + ethoxysulfuron 44 + 22.5 g/ha (PM) PoE | 36.6 | 87.0 | 97.9 | 92.7 | 2.91 | 2.78 | 3.81 | 3.17 | 6.09 | 22.9 | 1.27 |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* penoxsulam + cyhalofop-butyl 120 g/ha (PM) PoE | 38.3 | 85.0 | 98.1 | 96.3 | 2.66 | 2.64 | 3.50 | 2.93 | 5.69 | 28.6 | 1.13 |
| Pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (PM) PoE | 38.2 | 82.2 | 94.5 | 47.0 | 2.06 | 1.61 | 0.47 | 1.38 | 2.95 | 66.4 | 0.56 |
| Bispyribac-sodium + pyrazosulfuron-ethyl 20 + 15 g/ha (PM) EPoE *fb* HW at 30 DAS, | 38.2 | 86.9 | 97.5 | 112 | 2.67 | 2.50 | 5.48 | 3.55 | 6.45 | 13.6 | 1.29 |
| Triafamone + ethoxysulfuron 44.0 + 22.5 g/ha (PM) EPoE *fb* HW at 30 DAS | 37.7 | 88.2 | 99.0 | 122 | 3.21 | 3.37 | 5.74 | 4.11 | 7.34 | - | 1.48 |
| Penoxsulam + cyhalofop-butyl 120 g/ha (PM) EPoE *fb* HW at 30 DAS | 38.2 | 83.4 | 98.4 | 123 | 3.16 | 3.18 | 5.63 | 3.99 | 7.26 | 2.97 | 1.46 |
| Hand weeding at 20 and 40 DAS | 39.6 | 85.9 | 109 | 114 | 3.24 | 3.44 | 5.61 | 4.10 | 7.38 | 0.24 | 1.29 |
| Weedy check | 39.7 | 76.0 | 94.1 | 26.3 | 0.89 | 0.67 | 0.36 | 0.64 | 1.49 | 84.4 | 0.29 |
| LSD (p=0.05) | NS | 5.43 | NS | 27.5 | 0.45 | 0.38 | 0.77 | 0.60 | 1.38 | - | - |




$T_1$: pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* HW at 30 DAS; $T_2$: pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* bispyribac-sodium 25 g/ha PoE; $T_3$: pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* triafamone + ethoxysulfuron 44 + 22.5 g/ha (PM) PoE; $T_4$: pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* penoxsulam + cyhalofop-butyl 120 g/ha (PM) PoE; $T_5$: pretilachlor + pyrazosulfuron-ethyl 600 + 15 g/ha (PM) PE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha (PM) PoE; $T_6$: bispyribac-sodium + pyrazosulfuron-ethyl 20 + 15 g/ha (PM) EPoE *fb* HW at 30 DAS; $T_7$: triafamone + ethoxysulfuron 44.0 + 22.5 g/ha (PM) EPoE *fb* HW at 30 DAS; $T_8$: penoxsulam + cyhalofop-butyl 120 g/ha (PM) EPoE *fb* HW at 30 DAS; $T_9$: hand weeding at 20 and 40 DAS; $T_{10}$: weedy check

**Figure 1. Soil microbial count as influenced by different weed management practices**

## Economics

Application of triafamone 20% + ethoxysulfuron 10% WG 44.0 + 22.5 g/ha (PM) EPoE *fb* HW at 30 DAS showed effective reduction in density and dry biomass of weed, higher WCE, grain yield and recorded maximum benefit cost ratio of 1.48 which was followed by application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha (PM) EPoE *fb* HW at 30 DAS and pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* HW at 30 DAS.

## Conclusion

It was concluded that application of triafamone 20% + ethoxysulfuron 10% WG 44.0 + 22.5 g/ha EPoE (pre-mix) *fb* HW at 30 DAS or penoxsulam 1.02% + cyhalofop-butyl 5.1% OD 120 g/ha EPoE (PM) *fb* HW at 30 DAS, pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG 600 + 15 g/ha (PM) PE *fb* HW at 30 DAS or two manual weeding carried out at 20 and 40 DAS were found effective for the management of complex weed flora in direct-seeded rice under middle Gujarat conditions with higher gross return, net return and benefit cost ratio.

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