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# Efficacy of Metamifop against grassy weeds in direct-sown rice (*Oryza sativa*) and its impact on succeeding crop

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ABSTRACT

Metamifop is an aryloxyphenoxypropionate herbicide that controls grassy weeds. Insufficient information is available on the dose of application of metamifop for post-emergence weed control. A field experiment was conducted during 2014-15 and 2015-16 at ICAR-National Rice Research Institute to determine the most effective dose of metamifop in direct-sown rice (*Oryza sativa* L.) and its impact in rice-rice cropping sequence. The treatments consisted of 4 doses of metamifop 10% EC at 75, 100, 150 and 200 g/ha along with oxyfluorfen 23.5% EC at 240 g/ha as standard check. Application of metamifop at 200 g/ha effectively controlled all the grassy weeds (weed control efficiency, 80-84%) except *Leptochloa chinensis*. Similar trend was observed with metamifop at 150 g/ha (weed control efficiency, 76-82%). Metamifop at 150 g/ha recorded 4.59 tonnes/ha grain yield and it was at par with metamifop applied at 200 g/ha (4.84 tonnes/ha). There was no negative effect of the herbicide treatments on the germination percentage, growth and yield of the succeeding rice crop in rice-rice cropping sequence. Therefore, metamifop 10% EC at 150 g/ha would be optimum recommendation for the control of grassy weeds in rice crop, considering the lower dose for reducing the herbicide load in the environment.

**Key words**: Direct-sown rice, Efficacy, Grassy weeds, Metamifop, Succeeding crop

Rice (*Oryza sativa* L.) is a leading cereal crop and staple food of more than half of the world population. World's rice demand was projected to increase by 25% from 2001 to 2025 (Maclean *et al*. 2002). According to Mittal (2008), a supply demand gap is pegged at 8.98 million tonnes in India. Eastern India accounts 56.3% of the total rice area in India (GoI 2016) and the crop is mainly grown during wet season. Manual transplanting of seedlings under continuous flooding is common practice for rice establishment and it consumes large amount of water due to intensive tillage under wet conditions. Water resources, both surface and underground, are shrinking and in the future, rice farmers may likely have limited access to irrigation water. Scarcity of labour particularly during peak period of transplanting and increase in labour wages are the associated constraints in transplanted rice cultivation. Higher water inputs, labour costs and labour requirements for transplanted rice have reduced the profit margins (Chauhan 2012). One of the approaches in reducing labour and water demand is direct-sown rice (DSR) (Mahajan *et al*. 2013). The sustainability of direct seeded rice systems, however, is threatened by heavy weed infestation especially early emergent grassy weeds. Weed control is challenging in this system because of the severity of infestation; absence of standing water to suppress weeds at the time of crop emergence; alternate wetting and drying conditions; and the absence of a seedling-size advantage between rice and grassy weed seedlings, as both emerge simultaneously, causing grain yield losses of 50–91% (Rao *et al.* 2007). Manual weeding two to three times in a season by engaging up to 150 person days/ha is a common practice to manage weeds by most rice farmers in DSR that involves huge cost for weed control. Chemical weed control is easy, economical and effective way to suppress weeds (Bhurer *et al*. 2013). These factors have made the use of herbicides irreplaceable in weed management (Mallikarjun *et al*. 2014). A number of pre-emergence herbicides like butachlor, pretilachlor, pendimethalin, oxadiazon, anilofos etc. were recommended for controlling early flushes of grassy weeds. Control of weeds by applying recommended pre-emergence herbicides is often not successful in DSR due to emergence of subsequent flushes of weeds (Mahajan *et al*. 2013), which could not be controlled by these herbicides. Low-dosage high-efficacy post-emergent herbicides with no phyto-toxicity to rice and no toxicity to succeeding crops can be a purposeful intervention to suppress grassy weeds during the critical period of weed competition, i.e. up to 35-40 days of crop emergence. Thus, the present investigation was undertaken to evaluate the efficacy of metamifop as a new generation post emergent herbicide for managing grassy weeds in direct-sown rice

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and its impact on succeeding rice crop.

## MATERIALS AND METHODS

A field experiment was carried out at the research farm of ICAR-National Rice Research Institute, Cuttack ($20.5^0$ N, $86^0$ E and 23.5 m above mean sea-level), Odisha, India during two consecutive years 2014-15 and 2015-16. The soil of the experimental field was Aeric (Endoaquept) with sandy clay loam in texture, bulk density 1.40 g/cm$^3$, slightly acidic to neutral in reaction with pH 6.7 (using 1:2.5, soil: water suspension), cation exchange capacity (CEC) 15.2 cmol (p+)/kg, electrical conductivity (EC) 0.50 dS/m, total carbon 0.78%, available nitrogen 216 kg/ha; available P 18.4 kg/ha and available K 121 kg/ha. The treatments consisted of metamifop at 4 doses of 75.0, 100.0, 150.0 and 200.0 g/ha applied at 10 days after sowing (DAS) with oxyflurofen (23.5% EC) at 240 g/ha as standard check applied at 4 DAS and weed-free and weedy check. The experiment was arranged in randomized complete block design with four replications. The rice variety Naveen (120 days duration) was established by spot seeding (dibbling) at 20 cm × 15 cm spacing on June 08 and June 06 of 2014 and 2015, respectively. All the herbicides were applied using knapsack sprayer fitted with flat fan nozzle at spray volume of 350 l/ha. Manual weeding was done at 15, 30, 45 and 60 DAS in weed free plots. For establishment of crop, irrigation was applied immediately after seeding. Soil was kept saturated for first one week and then 1-2 cm water was maintained up to three weeks. Later irrigation was applied at saturation after disappearance of water from the field up to 15 days prior to harvest. Full dose of $P_2O_5$ and $K_2O$ (50 kg/ha) were applied before sowing at final land preparation and N (100 kg/ha) was applied in 3 equal splits, at 15, 35 and 55 DAS. All the other recommended agronomic and plant protection measures were adopted to raise the crop uniformly in all the plots. Direct-sown rice crop was taken as succeeding crop (var. Naveen) after harvest of main rice crop to study any negative effect of herbicides on the succeeding rice crop. The succeeding crop was sown in undisturbed layout plan of the experiment. Normal recommended package of practices were followed to raise the crop except application of herbicides. The observations were made for crop germination, plant height, panicles/m, number of grains/ panicle$^2$, grain yield and straw yield at harvest.

Rice plants were evaluated for visual symptoms of phytotoxicity using a rating scale from 0 to 10 (0-1= up to 10% or no damage; 1-2=11-20% damage; 2-3=21-30% damage; 3-4=31-40% damage; 4-5=41-50%; 5-6=51-60%; 6-7=61-70% damage; 7-8=71-80% damage; 8-9=81-90% damage; 9-10=91-100% damage) at 1, 3, 7, 10, 20 and 30 days after spray (Buck *et al.* 2003). The data on individual grassy weed density (30, 45 and 60 DAS) were recorded with the help of a quadrat (0.5 m × 0.5 m) at 2 fixed places in each plot and then converted into per square meter. These were subjected to square root transformation to normalize their distribution. Dry weight of weeds was recorded at 45 and 60 DAS after oven-drying at 70°C to constant weight. Weed control efficiency (%) was computed using the dry weight of weeds (Sharma 2008). Grain yield of rice along with other yield components were recorded at harvest. Sampling was done from an area of 1 m$^2$ in each plot to determine aboveground total dry weight (total biomass) and yield components. Panicle number was counted in each hill to determine number of panicle/m$^2$. Plant samples were separated into straws and panicles. Panicles were hand threshed and the filled grains were separated and counted to determine number of grains per panicle. Crop growth rate was computed by dividing aboveground total dry weight with growth duration in days. Grain and straw yield was determined from the net area of 6.0 m × 4.0 m (24 m$^2$) in each plot presented on hectare basis. Straw dry weight was determined after oven-drying at 70°C to constant weight.

## RESULTS AND DISCUSSION

*Observation on crop phytotoxicity*

Visual observations on phytotoxicity parameters were recorded at 1, 3, 7, 10, 20 and 30 days after spray in the plots treated with metamifop 10% EC, oxyflurofen 23.5% EC and checks. There was no phytotoxicity in terms of leaf injury on tips/ surface, wilting, vein clearing, epinasty and hyponasty in any treatment during both the years. However, the highest dose of metamifop (200 g/ha) recorded 21-30% (scale 3) and 11-14% (scale 2) leaf discoloration (necrosis) at 7 days after spray in 2014 and 2015, respectively. The recovery of plants started after 20 days. Severe necrosis was recorded in oxyfluorfen at 240 g/ha treated plots which resulted in 81-90% damage (scale 9) at 3 days after spray and 83-89% damage (scale 9) at 7 day after spray during 2014 and 2015, respectively. Thereafter plants started to recover and there was no leaf discoloration by 20 days after spray (Table 1). Abraham *et al.* (2010) also reported that oxyfluorfen at 240 g/ha caused phytotoxicity to rice.

*Weed composition, dry weight and weed-control efficiency*

The experimental field consisted of grassy weeds, sedges and broad-leaved weeds in plots. The major grassy weeds were *Echinochloa colona* (L.), *Echinochloa crus-galli* (L.), *Dactyloctenium aegyptium* (L.), *Digitaria sanguinalis* (L.), *Panicum repens* (L.) and *Leptochloa chinensis* (L.); the major sedges were *Cyperus difformis* (L.) and *Fimbristylis mileacea* (L); and the broad-leaved weeds were *Sphenoclea zeylanica* Gaertn. and *Ludwigia octovalvis* (Jacq.) in the crop field.

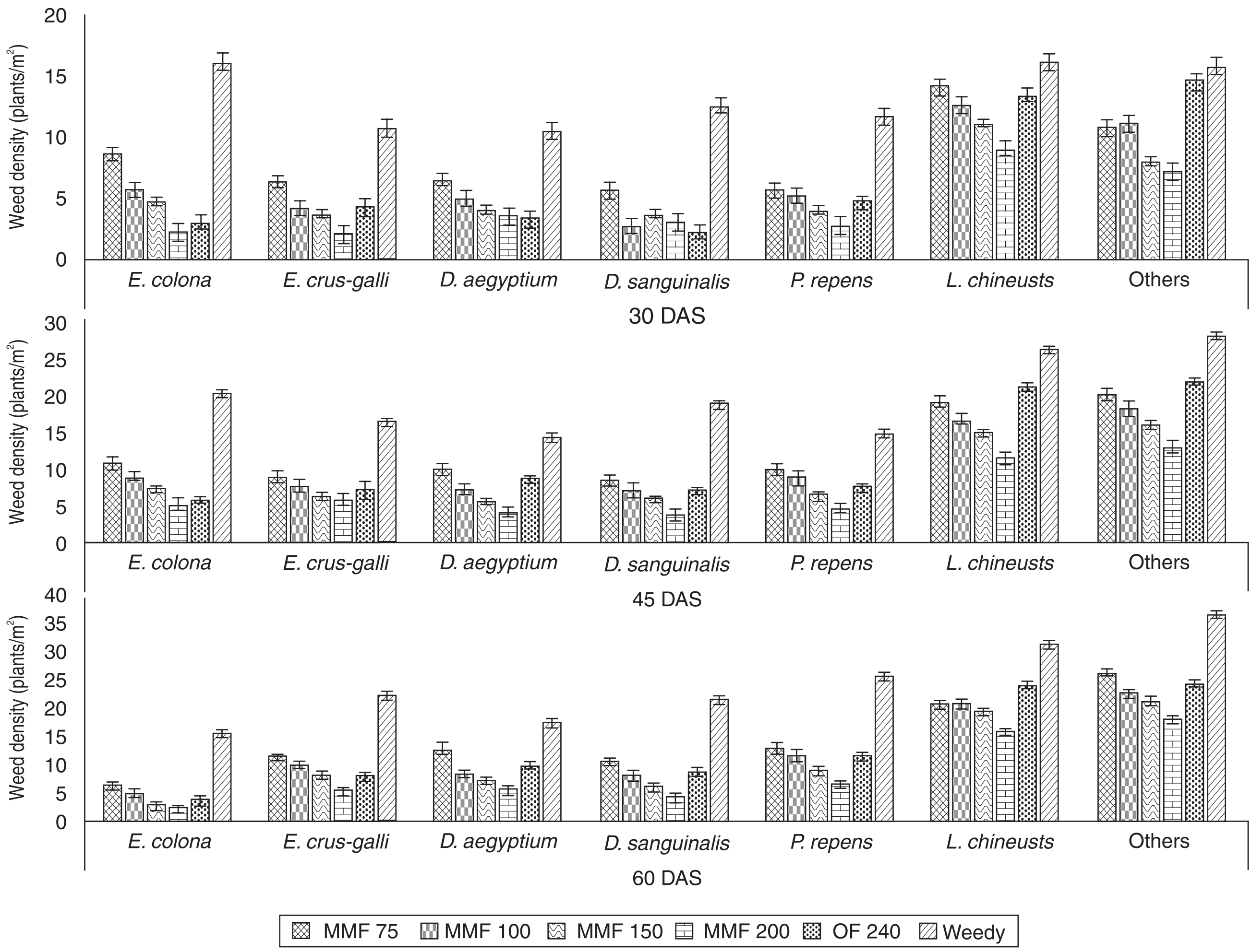
Metamifop 10% EC at 200 g/ha and oxyflurofen 23.5% EC at 240 g/ha were found effective to suppress all the grassy weeds except *L. chinensis* at 30 DAS (Fig 1). However, few sedges (*C. difformis*) and broad-leaved weeds (*S. zeylanica*) appeared in the plots at this stage. The tested herbicide, metamifop at relatively lower dose of 150 g/ha also showed good suppression of grassy weeds except *L. chinensis.* No major occurrence of grassy weeds were recorded in metamifop at 200 g/ha and oxyflurofen at 240 g/ha at 45 DAS, except *L. chinensis* along with few

Table 1 Phytotoxicity evaluation based on leaves discoloration (necrosis)

| Treatment | Phytotoxicity rating (day after spray) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2014 | | | | | | 2015 | | | | | |
| | 1 | 3 | 7 | 10 | 20 | 30 | 1 | 3 | 7 | 10 | 20 | 30 |
| Metamifop at 75 g/ha | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Metamifop at 100 g/ha | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Metamifop at 150 g/ha | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Metamifop at 200 g/ha | 1 | 1 | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 |
| Oxyfluorfen at 240 g/ha | 3 | 9 | 7 | 4 | 1 | 1 | 1 | 4 | 9 | 6 | 1 | 1 |
| Weed free | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Weedy | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

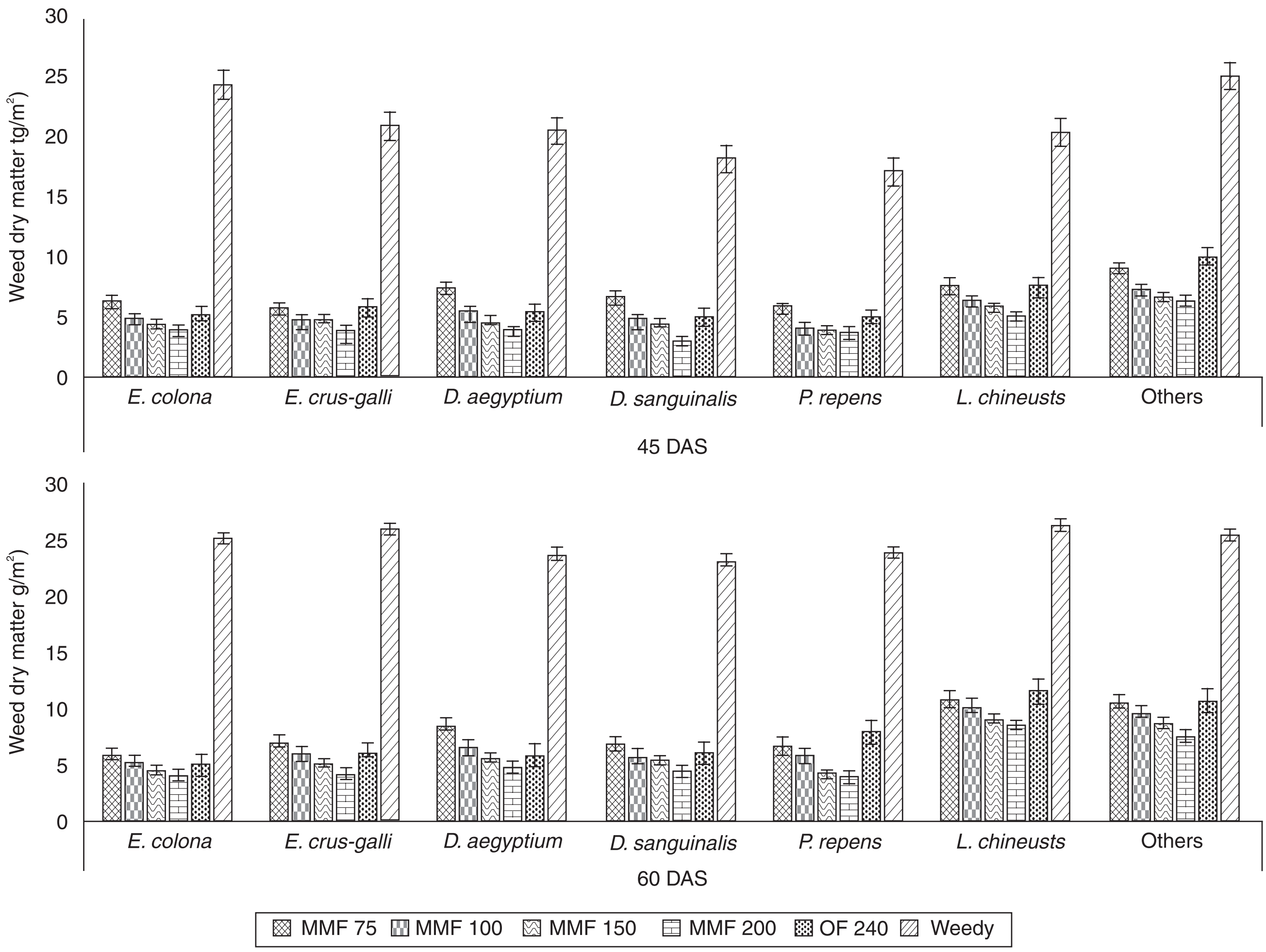
0-1= up to 10% or no damage; 1-2=11-20% damage; 2-3=21-30% damage; 3-4=31-40% damage; 4-5=41-50%; 5-6=51-60%; 6-7=61-70% damage; 7-8=71-80% damage; 8-9=81-90% damage; 9-10=91-100% damage

sedges, viz. *C. difformis* and *F. mileacea* and broad-leaved weeds, viz. *S. zeylanica* and *L. octovalvis* (Fig 1). Similar trend was recorded at 60 DAS. Among the herbicide treated plots, the highest population of *L. chinensis* was recorded in oxyflurofen treated plots at 60 DAS. Weed population was remarkably less in metamifop at 200 g/ha treated plots followed by 150 g/ha at this stage. Kim *et al*. (2003a) also reported that metamifop provides excellent control on a wide range of annual grassy weeds. In the present study, *L. chinensis* could not be suppressed due to its late emergence, however, Jaiswal, 2010 reported that metamifop applied at 90-200 g/ha gave excellent control of major grassy weeds




MMF: Metamifop; OF: Oxyfluorfen

Fig 1 Weed density (plants/m$^2$) as influenced by different treatments at 30, 45, and 60 DAS (mean of 2 years).




MMF: Metamifop; OF: Oxyfluorfen

Fig 2. Weed dry matter (g/m$^2$) as influenced by treatments at 45 and 60 DAS (mean of 2 years)

including *L. chinensis*.

Weed dry biomass at 30 DAS was negligible hence not presented. The weed dry weight (at 45 and 60 DAS) was significantly low in all the treatments over weedy plots (Fig 2). However, weed dry weight in metamifop at 75 g/ha treated plots were marginally higher compared to other treatments. The overall performance of the treatments was similar as observed for weed population.

Metamifop at 200 g/ha recorded the highest efficacy with weed control efficiency (WCE) 84.28% for *E. colona*, 84.15% against *E. crus-galli* and more than 80% against other major grassy weeds, viz. *D. aegyptium*, *D. sanguinalis* and *P. repens* but the response was poor against *L. chinensis* (67.63 ) (Table 2). Metamifop at relatively lower dose of 150 g/ha also showed excellent control of *E.* spp. and *P. repens* (WCE > 80%). Our results suggest that metamifop is effective at relatively lower dose, however, Kim *et al*. (2003b) reported that metamifop shows an exclusive whole plant safety even at higher dose to rice with a high control efficacy against annual grass weeds. The selectivity of metamifop between rice and *Echinochloa crus-galli*, the major invasive weeds in rice, could be due to both

Table 2 Weed control efficiency (%) based on dry weight of different weed flora at 60 DAS (mean of 2 years)

| Treatment | *E. colona* | *E. crus-galli* | *D. aegyptium* | *D. sanguinalis* | *P. repens* | *L. chinensis* | Others |
|---|---|---|---|---|---|---|---|
| Metamifop at 75 g/ha | 77.1 | 73.7 | 64.3 | 71.1 | 72.1 | 58.8 | 58.9 |
| Metamifop at 100 g/ha | 79.8 | 77.1 | 72.3 | 75.5 | 75.9 | 61.2 | 65.7 |
| Metamifop at 150 g/ha | 82.2 | 80.7 | 76.3 | 76.5 | 82.4 | 65.9 | 70.6 |
| Metamifop at 200 g/ha | 84.3 | 84.2 | 80.0 | 80.7 | 83.9 | 67.6 | 62.3 |
| Oxyfluorfen at 240 g/ha | 80.4 | 77.2 | 75.4 | 73.7 | 66.8 | 56.1 | 57.6 |
| Weed free | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Weedy | | | | | | | |

Table 3 Yield attributes, grain and straw yield of rice as influenced by different treatments (mean of 2 years)

| Treatment | Plant height (cm) | Panicles/m$^2$ | Grains/panicles | Grain yield (tonnes/ha) | Straw yield (tonnes/ha) |
|---|---|---|---|---|---|
| Metamifop at 75 g/ha | 106.1 | 210.8 | 75.3 | 4.29 | 4.58 |
| Metamifop at 100 g/ha | 107.2 | 217.2 | 80.0 | 4.48 | 4.76 |
| Metamifop at 150 g/ha | 107.9 | 224.3 | 83.2 | 4.59 | 4.89 |
| Metamifop at 200 g/ha | 110.9 | 231.8 | 88.3 | 4.84 | 5.24 |
| Oxyfluorfen at 240 g/ha | 103.9 | 213.0 | 76.1 | 4.21 | 4.48 |
| Weed free | 112.4 | 246.2 | 92.3 | 5.26 | 5.68 |
| Weedy | 102.6 | 176.9 | 69.0 | 2.78 | 3.09 |
| LSD ($P \leq 0.05$) | 3.61 | 18.37 | 6.23 | 0.27 | 0.35 |

Table 4 Growth and yield attributes, grain and straw yield of succeeding rice crop (mean of 2 years)

| Treatment (applied in main rice crop) | % crop germination | Plant height at harvest (cm) | Panicles/m$^2$ | Grains/ panicle | Grain yield (tonnes/ha) | Straw yield (tonnes/ha) |
|---|---|---|---|---|---|---|
| Metamifop at 75 g/ha | 91.3 | 105.0 | 227 | 74.4 | 3.09 | 3.51 |
| Metamifop at 100 g/ha | 92.3 | 105.9 | 227 | 75.6 | 3.11 | 3.52 |
| Metamifop at 150 g/ha | 91.6 | 106.1 | 230 | 76.1 | 3.17 | 3.57 |
| Metamifop at 200 g/ha | 92.5 | 107.0 | 234 | 77.2 | 3.22 | 3.63 |
| Oxyfluorfen at 240 g/ha | 91.6 | 104.0 | 226 | 75.8 | 3.00 | 3.44 |
| Weed free | 92.5 | 108.3 | 236 | 77.8 | 3.28 | 3.65 |
| Weedy | 92.3 | 103.8 | 223 | 76.9 | 3.02 | 3.42 |
| LSD ($P \leq 0.05$) | NS | NS | NS | NS | NS | NS |

differential foliar absorption rate and differential ACCase sensitivity (Kim *et al*. 2003b). The susceptibility of grassy weed species, *C. dactylon* to metamifop was, about 20 times greater than diclofop-methyl (McCullough *et al*. 2016). These levels of injury are consistent with previous field research on metamifop efficacy (Doroh *et al.* 2011). However, the test herbicide metamifop was not found effective against the grassy weed. *L.chinensis* along with the sedges and broadleaved weeds.

*Growth and yield performance of rice crop*

The height of rice plant was remarkably reduced in oxyfluorfen treated plots (103.9 cm) as compared to plots treated with metamifop irrespective of doses (Table 3). This might be due to the phytotoxic effect of oxyfluorfen on rice plants during early vegetative phase. The panicles/m$^2$ and grains per panicle were also reduced in this treatment plots though major grassy weed species were remarkably suppressed. Among the herbicide treated plots, the highest plant height (110.9 cm); panicles/m$^2$ (231.8) and grains/panicle (88.3) were recorded with metamifop at 200 g/ha, which was followed by metamifop at 150 g/ha. The highest grain yield of rice (5.26 tonnes/ha) was achieved in weed free plots. Among the different herbicide treatments, the highest grain yield (4.84 tonnes/ha) was recorded in metamifop at 200 g/ha which was at par with metamifop at 150 g/ha (4.59 tonnes/ha). The better yield in these treatments might be due to effective control of major grassy weeds in terms of population and biomass, which was reflected in different yield attributing characters as well as WCE. The grain yield in weedy control was 2.78 tonnes/ha and the reduction due to weed infestation was 47% over weed free check. These results are in conformity with Nithya *et al.* (2012). Similar trend of results was observed for straw yield (Table 3).

The results on negative effect showed that there was no negative impact of any herbicide treatment to the succeeding rice crop (Table 4). The effect was non-significant on the germination percentage (91.3-92.5%) of succeeding rice crop. Similar trend was observed in plant height at harvest. The yield attributing parameters viz., panicle/m$^2$ and grains/panicle also did not show any significant effect of the preceding herbicide treatments. Similarly, there was no negative effect of the preceding herbicide treatments in grain and straw yield of succeeding rice crop. Earlier, Singh *et al*. (2015) reported that application of metamifop at higher doses does not cause any phytotoxicity to the succeeding crop of wheat.

Based on the results it may be concluded that metamifop 10% EC even at higher doses of 150-200 g/ha did not show any phytotoxic effect to rice crop. Metamifop at 200 g/ha recorded the highest herbicide efficacy and produced higher rice grain yield but it was at par with metamifop at 150 g/ha. There was no toxic effect of metamifop at higher doses in the succeeding rice crop. Therefore, metamifop 10% EC at 150 g/ha would be optimum recommendation for the control of predominant grassy weeds in direct-sown rice field, considering the lower dose for reducing the herbicide load in the environment.

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