Productivity of transplanted rice as influenced by weed control methods

T. Parthipan* and V. Ravi

Department of Agronomy, Tamil Nadu Rice Research Institute, Tamil Nadu Agricultural University, Aduthurai-612 101, Tamil Nadu, India.

Received 15 April, 2013; Accepted 26 June, 2014

Rigorous research efforts are being made by scientists around the world to evolve different strategies for improving rice yield. Most of the improved crop management practices in rice cultivation failed due to poor and improper practices for containing weeds. At present, no single approach, that is, uses of herbicides or manual or mechanical weeding is effective in containing the weed menace. Hence, the present investigation was aimed to study the influence of integrated weed control (chemical + hand weeding) on the productivity of transplanted rice. Ten weed control treatments like application of herbicides alone and their integration with one-hand weeding, two-hand weeding and unweeded check were tested in randomised block design with three replications. The highest weed control efficiency (90 and 93%) and maximum grain yield (5831 and 8783 kg ha$^{-1}$) were recorded under two-hand weeding during both years respectively which was at par with post emergence application of bispyribac sodium 25 g ai ha$^{-1}$ supplemented with hand weeding at 45 DAT. Uncontrolled weed growth reduced grain yield to the tune of 47.02 and 53.79% during 2011 to 2012 and 2012 to 2013, respectively.

Key words: Transplanted rice, integrated weed control, herbicides, hand weeding, weed control efficiency, yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than 60% of the world population. It is the most important cereal crop and is extensively grown in tropical and subtropical regions of the world. Rigorous efforts are being made under several research programmes by scientists around the world to evolve different strategies for improving rice yield. Most of the improved crop management practices in rice cultivation failed due to poor and improper practices for containing weeds.

In India, rice is cultivated in an area of 44.07 million hectares annually with a production of 103.4 million tonnes, with an average productivity of 2.3 t ha$^{-1}$ (FAO, 2012). There are several reasons for low productivity and the one due to weeds is the most important. Weeds compete with rice for moisture, nutrients, light, temperature and space. Uncontrolled weeds have caused yield reduction of 28 to 45% in transplanted rice (Singh et al., 2007; Manhas et al., 2012). Furthermore, any delay in weeding will lead to increased weed biomass which has a negative correlation with yield.

Butachlor, anilofos, oxadiargyl and pretilachlor are herbicides presently used for weed control in transplanted rice. These herbicides provide effective control of annual grasses, but not annual sedges and broad leaved weeds.
For example, it has been reported that whenever there is effective control of grasses due to these herbicides, annual sedges and broad leaved weeds emerge in high density competing with crop and resulting into heavy yield losses (Singh et al., 2004). At present, no single approach of either use of herbicides or manual/mechanical weeding is effective in containing weed menace. Therefore, there is a necessity that these herbicides are supplemented with hand weeding to widen weed control spectrum. Hence, the present investigation was to study the influence of integrated weed management package on weed control efficiency and productivity of transplanted rice.

MATERIALS AND METHODS

Field experiment was conducted at Tamil Nadu Rice Research Institute, Aduthurai (11° N latitude, 79° E longitude and at an altitude of 19.5 m above mean sea level) in Cauvery Delta Zone of Tamil Nadu during wet seasons of 2011 to 2012 and 2012 to 2013 to study the effect of integrated weed management packages on weed control, growth and yield of transplanted rice. The soil of the experimental field was clay with slightly alkaline pH (8.2), medium in organic carbon (0.52%), low total nitrogen (161 kg ha$^{-1}$), high available phosphorus (54.5 kg ha$^{-1}$) and medium available potassium (206 kg ha$^{-1}$). The experiment was laid out in randomised block design with three replications. Treatments consisted of application of pre emergence (PE) herbicides viz., clomazone 500 g ai ha$^{-1}$, clomazone + 2, 4-DEE (ready mix) 500 g ai ha$^{-1}$ alone and their integration with one-hand weeding (HW) at 45 DAT; butachlor 1250 g ai ha$^{-1}$ + HW at 45 DAT; pretichlor 750 g ai ha$^{-1}$ + HW on 45 DAT; post emergence (POE) herbicide bispyribac sodium 25 g ai ha$^{-1}$ + HW at 45 DAT and pre plant incorporation of glyphosate at 15 days before transplanting followed by PE application of bensulfuron methyl plus pretilachlor 660 g ai ha$^{-1}$ and clopyralid 25 g ai ha$^{-1}$ alone and their integration with one-hand weeding on 25 and 45 DAT and unweeded control for weed control efficiency and productivity of transplanted rice. Hand weedicings were carried out as per the treatment schedule.

Long duration (155 days) high yielding paddy variety CR1009 was transplanted two seedlings per hill 7 and 17 September, 2011 and 2012, respectively with a spacing at 20 × 15 cm. The crop was fertilized with recommended dose of 150: 50 kg N,P$_2$O$_5$,K$_2$O ha$^{-1}$. The entire dose of phosphorus was applied as basal in addition to zinc sulphate 25 kg ha$^{-1}$ and gypsum 500 kg ha$^{-1}$ while nitrogen and potassium were applied in four equal splits at basal, active tillering (4 Weeks After Transplanting-WAT), panicle initiation (8 WAT) and heading stages (12 WAT). Pre emergence herbicides were mixed with sand at 50 kg/ha and applied uniformly to the field on 3 DAT. The post emergence herbicide was sprayed at 2 to 3 leaf stage of weeds (15 DAT) by using knapsack sprayer fitted with flat fan nozzle. A thin film of water was maintained at the time of herbicide application. All other agronomic and plant protection measures were adopted as per the standard recommendations.

Weed species present in the experimental plot were identified at flowering stage of crop from weedy check plot and grouped as grasses, sedges and broad leaved weeds. The data on weed density and weed dry weight (60 DAT) were recorded with the help of a quadrate (0.25 m$^2$) at four places randomly chosen and then expressed in number per square metre and kilogram per hectare. The weed control efficiency was worked out on the basis of weed dry matter recorded in each treatment at 30, 60 DAS/DAT and at harvest by using the formula suggested by Mani et al. (1973).

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\text{WEC (\%) } = \frac{\text{Total weed dry weight in unweeded control (kg ha}^{-1}) - \text{Total weed dry weight in treated control (kg ha}^{-1})}{\text{Total weed dry weight in unweeded control (kg ha}^{-1})} \times 100
\]

Values were subjected to square root transformation ($\sqrt{x}$×0.5) prior to statistical analysis to normalize their distribution. Observations on yield attributes like panicles per meter square (m$^{-2}$), grains per panicle, 1000 grain weight and grain yield of paddy were recorded at harvest.

The data recorded were analysed statistically in Randomized Block Design (RBD) as per the method suggested by Gomez and Gomez (1984). Wherever the treatment means were significant, critical differences were calculated at 5% probability level for comparisons of mean values. Non significant differences among treatment means were denoted as NS.

RESULTS AND DISCUSSION

Weed growth

The dominant weed flora of experimental fields consisted of *Echinochloa crusgalli*, *Echinochloa colorum* and *Leptochloa chinensis* among grasses, *Cyperus difformis*, *Cyperus iria* and *Fimbriatis* milicaea among sedges and *Marsella quadrifolia*, *Eclipta alba*, *Ammania baccifera*, *Bergia capensis* and *Ludwigia parviflora* among broad leaved weeds.

Effect on weeds

All the weed control treatments significantly reduced total density and dry weight of weeds during both years (Table 1). The lowest density (5.67 g No./m$^2$) and dry weight (2.04 and 1.47 g/m$^2$) of weeds were recorded under two-hand weeding on 25 and 45 DAT followed by post emergence application of bispyribac sodium 25 g ai ha$^{-1}$ supplemented with HW at 45 DAT during both years. The reduced density and dry weight of weeds might be attributed to broad spectrum and season long weed control by the application of post-emergence herbicides followed by HW as observed in the plots in which two-hand weeding were given. These results are in line with findings of Singh et al. (2012) who reported that density and dry weight of weeds were greatly reduced under two-hand weeding in transplanted rice. The highest weed density and dry matter was recorded with unweeded check during both years. It means that if weeds were not controlled properly within critical period of crop weed competition, their density continuously remained increasing and crop growth badly affected. The highest weed control efficiency (90 and 93%) was observed under two-hand weeding in both years (Table 1) which was at par with post emergence application of bispyribac sodium 25 g ai/ha supplemented with HW at 45 DAT (87 and 92%) during both years. Yadav et al. (2009) and Upendra Rao et al. (2009) also reported that results of post emergence herbicide bispyribac sodium were found comparable with two-hand weeding. No significant differences were observed on weed control efficiency among pre emergence application of pretichlor, butachlor and clomazone + 2,4-DEE ready mix followed by one-hand weeding at 45 DAT and pre plant post emergence application of glyphosate 2.5 L/ha at 15 days before
transplanting followed by post plant pre emergence application of bensulfuron methyl + pretilachlor 660 g ai/ha at 3 DAT. These results are in conformity with the findings of Ramachandra et al. (2010).

**Yield and yield attributes of rice**

From the research findings, it was found clearly that yield attributes like panicles per square metre, grains per panicle and grain yield of transplanted rice were significantly influenced by weed control treatments in both years (Table 2). Maximum number of panicles (319 and 362 m⁻²) was recorded in two-hand weeding at 25 and 45 DAT followed by post emergence application of bispyrribac sodium 25 g ai/ha supplemented with HW at 45 DAT (315 and 355 m⁻²) and unweeded check recorded minimum number of panicles (222 and 263 m⁻²) during both years. Increase in panicles per meter square, grains per panicle might be due to better environment with increased uptake of both macro and micro nutrients and ultimate development of large sink created out of reduced crop weed competition.

The highest grain yield (5831 and 8783 kg ha⁻¹) were recorded in two-hand weeding over application of herbicides alone, herbicides followed by one-hand weeding and unweeded check during both years of study. Similar results have been reported by Deepthi Kiran and Subramaniam (2010). Superiority of two-hand weeding could be attributed to reduced competition by weeds due to frequent elimination of weeds from the field and hence better crop growth.

Weeds in weedy plot caused 47.02 and 53.79% reduction in grain yield of paddy as compared to weeding. Higher grain yield under these treatments might be due to increased panicles/m² and grains/panicle. Similar findings were also obtained by Veeraputhiran and Balasubramanian (2010) and Nalini et al. (2012). Grain yield under pre plant application of glyphosate at 15 days before transplanting followed by post plant application of bensulfuron methyl + pretilachlor at 3 DAT were comparable with that of two-hand weeding. Higher grain yield under these treatments might be attributed to increased panicles/m² and grains/panicle. Similar findings were also obtained by Veeraputhiran and Balasubramanian (2010) and Nalini et al. (2012). Grain yield under pre plant application of glyphosate at 15 days before transplanting followed by post plant application of bensulfuron methyl + pretilachlor at 3 DAT were comparable with that of two-hand weeding. Higher grain yield under these treatments might be attributed to better growth of

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**Table 1. Influence of weed management practices on weed density, weed dry weight, and weed control efficiency (WCE) (60 DAT) in transplanted rice.**

| Treatment | Weed density (No./m²) | Weed dry weight (g/m²) | WCE (%) | Weed density (No./m²) | Weed dry weight (g/m²) | WCE (%) |
|-----------|-----------------------|------------------------|---------|-----------------------|------------------------|---------|
| Clomazone 500 g ai/ha | 7.65(58.00) | 3.28(10.29) | 51.68 | 7.56(56.67) | 3.24(9.99) | 53.03 |
| Clomazone + 2, 4 DEE 500 g ai/ha | 6.89(47.00) | 3.16(9.50) | 55.39 | 6.62(43.33) | 3.04(8.74) | 58.91 |
| Clomazone 500 g ai/ha + HW 45 DAT | 3.54(12.00) | 2.53(5.92) | 72.22 | 3.34(10.67) | 2.29(4.73) | 77.74 |
| Clomazone + 2, 4 DEE 500 g ai/ha + HW 45 DAT | 3.39(11.00) | 2.39(5.20) | 75.58 | 2.80(7.33) | 2.22(4.47) | 78.99 |
| Butachlor 250 g ai/ha + HW 45 DAT | 2.92(8.00) | 2.27(4.67) | 78.09 | 2.74(7.00) | 2.18(4.37) | 79.46 |
| Pretilachlor 500 g ai/ha + HW 45 DAT | 2.80(7.33) | 2.29(4.77) | 77.62 | 2.80(7.33) | 2.22(4.50) | 78.84 |
| Bispyrribac Sodium 25 g ai/ha + HW 45 DAT | 2.55(6.00) | 1.82(2.83) | 86.70 | 2.27(4.67) | 1.45(1.62) | 92.40 |
| PPI Glyphosate 2.5 L/ha. 15 DBT + Bensulfuron methyl + Pretilachlor 660 g ai/ha | 2.92(8.00) | 2.31(4.85) | 77.21 | 2.86(7.67) | 2.25(4.56) | 78.57 |
| Two HW at 25 and 45 DAT | 2.48(5.67) | 1.57(2.04) | 90.41 | 2.20(4.33) | 1.40(1.47) | 93.10 |
| Unweeded control | 10.06(100.67) | 4.67(21.30) | 0.00 | 10.01(99.67) | 4.65(21.26) | 0.00 |
| SEd | 0.21 | 0.12 | 0.20 | 0.20 | - |
| CD (P = 0.05) | 0.44 | 0.26 | NA | 0.42 | NA |

Figures in parentheses are original values, which were subjected to square root transformation (√x + 0.5) before statistical analysis, NA - Not Analysed, DBT - Days Before Transplanting, DAT - Days After Transplanting and HW – hand Weeding.
plants on account of reduced crop- weed competition resulting in increased availability of nutrients, water and light.

Conclusion
Application of post emergence herbicide bispyribac sodium 25 g ai/ha at 15 DAT followed by hand weeding at 45 DAT produced higher grain yield and this was at par with two-hand weeding due to lower crop-weed competition. Sequential application of herbicides viz., glyphosate 2.5 L/ha at 15 DBT followed by bensulfuron methyl + pretilachlor 660 g ai/ha at 3 DAT was also found promising and it can also be recommended for weed control in transplanted rice during the peak period of labour scarcity. No doubt, the results of two-hand weeding are significantly better in terms of weed control and rice grain yield, but as it is time consuming, laborious and expensive, it can not be recommended for large scale rice production. From the research findings, it can be concluded that application of post emergence herbicide bispyribac sodium 25 g ai/ha followed by HW at 45 DAT can be recommended for effective weed control and higher productivity in transplanted rice.

Conflicts of Interests
The authors have not declared any conflict of interests.

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Table 2. Influence of weed management practices on yield and yield attributes of transplanted rice.

| Treatment                                      | 2011 to 2012 | 2012 to 2013 |
|------------------------------------------------|--------------|--------------|
|                                                | Panicles/m²  | Grains/panicle | Grain yield (kg/ha) | Panicles/m²  | Grains/panicle | Grain yield (kg/ha) |
| Clomazone 500 g ai/ha                         | 238          | 115          | 4141               | 286          | 117          | 6162               |
| Clomazone + 2, 4 DEE 500 g ai/ha              | 249          | 118          | 4330               | 291          | 128          | 6643               |
| Clomazone 500 g ai/ha + HW 45 DAT             | 272          | 126          | 4701               | 308          | 131          | 7826               |
| Clomazone + 2, 4 DEE 500 g ai/ha + HW 45 DAT  | 293          | 132          | 4934               | 331          | 142          | 8013               |
| Butachlor 250 g ai/ha + HW 45 DAT             | 309          | 135          | 5180               | 347          | 147          | 8277               |
| Pretilachlor 500 g ai/ha + HW 45 DAT          | 300          | 133          | 5062               | 341          | 148          | 8067               |
| Bispyribac Sodium 25 g ai/ha + HW 45 DAT      | 315          | 141          | 5613               | 355          | 155          | 8653               |
| PPI Glyphosate 2.5 L/ha. + Bensulfuron methyl + Pretilachlor 660 g ai/ha | 319          | 142          | 5831               | 362          | 163          | 8783               |
| Two HW at 25 and 45 DAT                       | 319          | 142          | 5831               | 362          | 163          | 8783               |
| Unweeded control                              | 222          | 112          | 3089               | 263          | 114          | 4059               |
| SEd                                           | 14           | 8            | 230                | 13           | 8            | 297                |
| CD (P = 0.05)                                 | 29           | 17           | 483                | 27           | 17           | 624                |
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