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# Efficacy of herbicides under different methods of direct-seeded rice (*Oryza sativa*) establishments

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 2006 and 2007 to study the efficacy of herbicides under different methods of direct-seeded rice (*Oryza sativa* L.) establishment. Establishment of rice by drum seeding significantly reduced the weed density and their dry weight and increased the yield-attributing characters finally led to 0.28 and 0.64 tonnes/ha higher rice yield over the wet (4.27 tonnes/ha) and dry seeding (3.91 tonnes/ha) of rice. Application of pretilachlor fb 2,4–D (0.75 fb 0.5 kg/ha) was most effective in lowering the weed density of grassy and non-grassy weeds and their dry weight, and thus enhancing yield attributes and yield (4.73 tonnes/ha) of rice. Weed control efficiency (84.23%) was maximum under this treatment compared with the other sequential application of herbicides, ie butachlor (71.90%) and pendimethalin (73.85%), followed by 2,4–D as well as their alone applications.

**Key words**: Direct-seeded rice, Herbicides, Rice, Weeds

Rice (*Oryza sativa* L.) is grown in different ecosystems and physical conditions of soil. Cultivation of rice by transplanting in rice–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping system is most popular in north India but it is highly labour-intensive and expensive method of cultivation, as well as it requires large quantity of water for puddling, transplanting and establishment of rice seedlings. Most of the farmers are marginal, unable to bear the cost in carrying out these operations. In addition, long turn-around time and unpredictable monsoon rain delays the sowing of succeeding crop (Maity and Mukherjee 2008). Direct seeding either in puddled or in non-puddled conditions eliminates the need of raising, maintaining and subsequent transplanting of seedlings, which is labour-intensive. Besides, it is cost-effective can save water through earlier rice crop establishment and allows early sowing of wheat (Singh *et al*. 2007). However, the crop is subjected to greater weed competition for various growth resources, viz nutrients, light and space than transplanted rice because both crop and weed seeds emerge at the same time and its yield is reduced up to 50–100% (Rao *et al*. 2007). Uncontrolled weeds reduce the yield by 96% in dry direct-seeded rice, 61% in wet direct-seeded rice and 40% in transplanted rice (Kim and Pyon 1998). Therefore, control of weeds is important to reduce the weed competition as well as to maximize the efficient utilization of resources to raise the productivity of the crop. Herbicides are considered to be an economical alternative to manage weeds against age-old practice of hand weeding, which is costlier and also becomes impracticable due to non-availability of labourers during critical period of weeding. Herbicides are used to manage either grassy or non-grassy weeds in rice, and none of the herbicide is available to manage both the types of weeds. Further, weeds emerge in direct-seeded rice in different flushes, and pre-emergence application of herbicides fails to manage later emerging weeds after 3 weeks due to short persistence. Therefore, the present study was undertaken to evaluate the comparative performance of different methods of rice establishment and to evaluate efficacy of herbicides alone and in combination in different methods of direct-seeded rice establishment on weed density, weed dry weight, weed control efficiency and yield of rice.

## MATERIALS AND METHODS

A field experiment was conducted during rainy (*kharif*) seasons of 2006 and 2007 at the research farm of the University, Varanasi. The soil was Gangetic alluvial having sandy loam in texture with *p*H 7.4. It was moderately fertile, being low in available organic carbon (0.43%), available N (197.02 kg/ha), and medium in available P (23.41 kg/ha) and K (210 kg/ha). The experiment was laid out in split-plot design with 3 sowing methods, viz wet seeding (broadcasting of sprouted seeds under puddled condition), dry seeding in

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rows at 20 cm apart and drum seeding in puddled condition in main plots and 8 weed control treatments, i e butachlor (1.50 kg), butachlor fb 2,4–D (1.5 fb 0.50 kg), Pretilachlor (0.75 kg), pretilachlor fb 2,4–D (0.75 fb 0.50 kg), Pendimethalin (1.0 kg), pendimethalin fb 2,4–D (1.0 fb 0.50 kg/ha), hand weeding 20, 40 and 60 days after sowing (DAS) and weedy check in sub-plots during both the years. Hand weeding and weedy check treatments were kept for comparison with the herbicidal treatments. Thus, all the total 24 (3 main plot × 8 sub-plot) number of treatment combinations were replicated thrice. A uniform dose of 120 kg N, 60 kg $P_2O_5$, 60 kg $K_2O$ and 5 kg Zn/ha was applied. Half dose of N and whole of P, K and Zn were applied as basal before sowing. Remaining half dose of N was top-dressed in 2 equal splits at active tillering and panicle-initiation stage. The 'NDR 359' rice of 120–125 days duration was used as test crop. Dry seed of rice @ 60 kg/ha was used for dry seeding and pre-germinated seed @ 40 kg/ha was used for wet and drum seeding of rice. The total rainfall received during crop season was 665.6 and 780.8 mm during first and second year, respectively. The crop was irrigated with 4 and 3 irrigations during first and second year, respectively. The pre-emergence (just after sowing) and post-emergence (20 days after sowing) herbicides were applied with the help of a hand-operated knapsack sprayer fitted with flat-fan nozzle and weed density and weed dry weight data were collected at 30, 45 and 60 days after sowing and water as a carrier at 600 litre/ha. Weed observations were recorded from two places in each plot using 50 cm × 50 cm quadrate. The data on weeds were subjected to square-root transformation ( $\sqrt{x+0.5}$ ) to normalize their distribution. Weeds were cut at ground level, washed with tap water, sun-dried, dried at 65°C for 48 hr and then weighed. Grain yield and its attributes were also recorded during the course of investigation. Weed control efficiency was calculated using weed dry weight data at 60 days after sowing which was maximum during weed growth period irrespective of treatments.

## RESULTS AND DISCUSSION

The dominant weed species present in the experimental field during 2006 and 2007 were *Echinochloa crus-galli* P. Beaue, *E. colonum* (L.) Link in grasses, *Cyperus rotundus* L, *C. iria* L, *Fimbristylis miliacea* in sedges and *Eclipta alba* and *Ceasullia axillaries* in broad-leaved weeds.

The minimum total weed density, dry weight and maximum plant height, number of shoots, leaf area index and dry matter accumulation of rice (Table 1) were recorded under drum seeding and it was significantly superior wet and dry seeding of rice. This can be attributed to puddling which results suppression of initial emerging and emerged weeds on one hand and better crop growth on the other which thereby had minimum weed population and dry weight of weeds. The results are in agreement with the findings of Kandasamy and Chinnusamy (2005). Dry seeding of rice had significantly higher weed density, dry weight and lower plant height, number of shoots, leaf area index and dry matter accumulation of rice than wet and drum seeding. Higher weed density recorded under dry seeding might have been due to fact that weeds under this rice ecosystem had better conditions for their emergence, survival and growth, and poor crop growth also resulted in higher weed population. Results are in agreement with the results of Balasubramanian *et al*. (2003). Occurrence of more number of weed species, higher density/unit area and favourable growing conditions turning crop-weed competition in favour of weeds, resulted in increase in weed dry weight significantly under dry seeding of rice.

All herbicide treatments resulted in lower weed density and weed dry weight than the weedy check (Table 1). Application of pretilachlor fb 2,4–D (0.75 fb 0.5 kg/ha) was significantly superior over others in respect to minimizing weed density, dry weight and maximizing plant height, number of shoots, leaf area index and dry matter accumulation of rice. This may be attributed to more bioefficacy of pretilachlor fb 2,4–D which effectively controlled both the narrow and broad-leaved weeds, mainly grassy weeds which was contributed maximum in total density of weeds. Alone application of herbicides were least effective in minimizing the density of weeds, dry weight and maximizing the plant height, number of shoots, leaf area index and dry matter accumulation of rice as compared to sequential application of herbicides. This may be due to better control of weeds by pre-emergence herbicides in early stages and control of later emerging weeds, particularly sedges and broad-leaved weeds by sequential application of 2,4-D at later stages (Chinnusamy *et al*. 2006).

Yield is the function of complex interrelationship of all the growth (Table 1) and yield attributes (Table 2). The maximum weed control efficiency (67.02%) grain yield (4.55 tonnes/ha) and yield attributes, ie number of panicles/$m^2$ (325.19), panicle length (24.96 cm), grain/panicle (148.50) and 1000-grain weight (26.34 g) were recorded under drum seeding of rice. This was followed by wet and dry seeding of rice. It was due to low weed competition during critical growth period under the drum seeding which proved to be more beneficial in enhancing the yield attributes and finally grain yield. Superiority of rice grain yield under drum seeding over direct seeding under dry condition has also been reported by Kathirvelan and Vaiyapuri (2004) and Mohan *et al*. (2005).

The yields of rice with all herbicide treatments were higher than that of weedy check (Table 2). Sequential application, pretilachlor fb 2,4-D (0.75 fb 0.5 kg/ha) showed greater efficacy in increasing the weed control efficiency, yield attributes and yield of rice in comparison to other herbicidal treatments. This result can be attributed due to marked improvement in dry matter accumulation, maximum number of effective tillers, minimizing crop-weed competition and

Table 1 Effect of sowing methods and herbicides on weed density, weed dry weight and growth-attributes of rice (pooled over 2 years)

| Treatment | Total weed density (number/$m^2$) | | | Total weed dry weight ($g/m^2$) | | | Growth-attributing characters | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS | Plant height (cm) 90 DAS | Shoots/$m^2$ 90 DAS | Leaf area index 90 DAS | Dry matter accumulation ($g/m^2$) 90 DAS |
| *Sowing method* | | | | | | | | | | |
| Wet seeding | 7.80 (60.29) | 9.95 (98.43) | 8.73 (75.79) | 3.12 (9.25) | 8.30 (68.31) | 11.51 (132.05) | 90.16 | 342.21 | 4.32 | 760.75 |
| Dry seeding | 9.04 (81.18) | 11.05 (121.52) | 10.35 (106.62) | 3.60 (12.45) | 9.31 (86.14) | 14.05 (197.01) | 87.10 | 323.37 | 4.11 | 737.60 |
| Drum seeding | 6.99 (48.39) | 8.61 (73.59) | 7.84 (60.91) | 2.82 (7.43) | 7.16 (50.74) | 10.36 (106.82) | 98.53 | 369.08 | 4.65 | 835.40 |
| CD ($P$=0.05) | 0.27 | 0.33 | 0.30 | 0.11 | 0.28 | 0.40 | 3.60 | 13.76 | 0.18 | 31.95 |
| *Herbicides* | | | | | | | | | | |
| Butachlor (1.5 kg/ha) | 9.36 (87.10) | 11.71 (136.66) | 10.74 (114.82) | 3.67 (12.93) | 9.44 (88.60) | 14.03 (196.34) | 90.69 | 339.83 | 4.09 | 763.66 |
| Butachlor fb 2,4-D (1.5 fb 0.5 kg/ha) | 7.88 (61.66) | 9.87 (96.93) | 8.98 (80.16) | 3.11 (9.16) | 8.05 (64.37) | 11.91 (141.26) | 93.98 | 355.02 | 4.64 | 825.45 |
| Pretilachlor (0.75 kg/ha) | 8.35 (69.20) | 10.51 (109.91) | 9.62 (91.96) | 3.28 (10.26) | 8.62 (73.72) | 12.76 (162.26) | 91.89 | 346.89 | 4.29 | 785.40 |
| Pretilachlor fb 2,4-D (0.75 fb 0.5 kg/ha) | 6.03 (35.89) | 6.81 (45.89) | 6.46 (41.26) | 2.42 (5.35) | 5.71 (32.07) | 8.86 (77.95) | 96.08 | 374.31 | 5.05 | 889.48 |
| Pendimethalin (1.0 fb 0.5 kg/ha) | 9.17 (83.54) | 11.39 (129.32) | 10.49 (109.52) | 3.59 (12.37) | 9.18 (83.76) | 13.72 (187.80) | 91.10 | 326.66 | 4.17 | 768.99 |
| Pendimethalin fb 2,4-D (1.0 fb 0.5 kg/ha) | 7.59 (57.05) | 9.44 (88.59) | 8.61 (73.58) | 2.99 (8.45) | 7.69 (58.70) | 11.48 (131.35) | 94.20 | 356.10 | 4.68 | 829.35 |
| Hand weeding (20, 40 and 60 DAS) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 97.68 | 376.21 | 5.08 | 912.00 |
| Weedy check | 14.45 (208.41) | 18.49 (341.46) | 16.19 (261.52) | 5.67 (31.67) | 16.63 (276.20) | 22.34 (498.61) | 79.83 | 284.07 | 2.86 | 449.01 |
| CD ($P$=0.05) | 0.31 | 0.39 | 0.35 | 0.12 | 0.34 | 0.47 | 2.66 | 9.94 | 0.12 | 21.89 |

Figures in parentheses are the original values; fb, Followed by; DAS, days after sowing

better weed control efficiency. The treatment which had higher yield-attributing components and weed control efficiency produced higher grain yield. The minimum grain yield was recorded under weedy check which was attributed due to more weed growth, total weed dry weight and poor yield-attributing characters. Results are in agreement with the findings of Chinnusamy *et al*. (2005), Kathirvelan and Vaiyapuri (2004) and Mohan *et al*. (2005).

Interaction effect of sowing methods and herbicides were significant for total weed density (60 days after sowing) and dry weight (60 days after sowing), number of panicles and grain yield of rice (Table 3). Irrespective of sowing methods minimum weed density and weed dry weight was recorded under drum seeding of rice with all the herbicidal treatments. The minimum weed density and dry weight was associated with the crop treated with pretilachlor fb 2, 4-D in all the sowing methods. Application of pretilachlor fb 2, 4-D under drum seeding of rice was most effective in reducing the weed density and weed dry weight and found at par to pretilachlor fb 2,4–D under wet seeding of rice and significantly superior over rest of the treatments. The better efficacy of herbicides under drum seeding might be due to emergence of weeds in short span in which most of the weeds were affected by herbicides. This fact is well documented by Vaishya and Tomar (2000). The poor efficacy of herbicides under dry seeding was owing to extended period of weed emergence as it provided better environment for emergence of weeds in different flushes and smaller period of herbicide persistence. Drum seeding of rice recorded more number of panicles followed by wet and dry seeding of rice under all the herbicidal treatments. The treatment combination of pretilachlor fb 2, 4-D and drum seeding of rice was at par with pendimethalin fb 2, 4-D under same seeding and produced significantly more number of panicles over all the other treatment combinations. Pretilachlor fb 2, 4-D under drum seeding of rice recorded maximum grain yield than all the other treatment combinations but was found at par to pendimethalin fb 2, 4-D and butachlor fb 2, 4-D under drum seeding and pretilachlor fb 2, 4–D and pendimethalin fb 2, 4-D in wet seeding and pretilachlor fb 2, 4-D under dry

Table 2 Effect of sowing methods and herbicides on yield-attributes, yield and weed control efficiency of rice (pooled over 2 years)

| Treatment | Yield-attributing characters | | | | Grain yield (tonnes/ha) | Straw yield (tonnes/ha) | Harvest index (%) | Weed control efficiency (%) |
|---|---|---|---|---|---|---|---|---|
| | Panicle/m$^2$ | Panicle length (cm) | Grains/ panicle | 1000-grain weight (g) | | | | |
| *Sowing method* | | | | | | | | |
| Wet seeding | 299.43 | 22.84 | 128.88 | 24.37 | 4.27 | 5.77 | 42.33 | 65.78 |
| Dry seeding | 263.87 | 21.66 | 116.25 | 23.82 | 3.91 | 5.46 | 41.35 | 62.50 |
| Drum seeding | 325.19 | 24.96 | 148.50 | 26.34 | 4.55 | 6.02 | 42.89 | 67.02 |
| CD (*P*=0.05) | 11.79 | 0.93 | 5.38 | 0.97 | 0.17 | 0.23 | NS | |
| *Herbicides* | | | | | | | | |
| Butachlor (1.5 kg/ha) | 281.41 | 22.03 | 115.00 | 24.26 | 4.16 | 5.79 | 41.83 | 60.78 |
| Butachlor fb 2, 4-D (1.5 fb 0.5 kg/ha) | 303.49 | 24.53 | 138.00 | 25.08 | 4.52 | 5.94 | 43.13 | 71.90 |
| Pretilachlor (0.75 kg/ha) | 297.49 | 23.18 | 124.83 | 24.60 | 4.18 | 5.81 | 41.85 | 67.65 |
| Pretilachlor fb 2, 4-D (0.75 fb 0.5 kg/ha) | 319.86 | 25.83 | 162.67 | 26.43 | 4.73 | 6.03 | 43.95 | 84.23 |
| Pendimethalin (1.0 fb 0.5 kg/ha) | 292.78 | 22.90 | 118.00 | 24.26 | 4.17 | 5.80 | 41.82 | 62.37 |
| Pendimethalin fb 2, 4-D (1.0 fb 0.5 kg/ha) | 307.44 | 24.35 | 139.50 | 25.18 | 4.59 | 6.07 | 43.04 | 73.85 |
| Hand weeding (20, 40 and 60 DAS) | 323.04 | 25.50 | 165.33 | 26.49 | 4.87 | 6.05 | 44.56 | 100.00 |
| Weedy check | 243.80 | 16.92 | 86.33 | 22.44 | 2.72 | 4.51 | 37.35 | 0.00 |
| CD (*P*=0.05) | 8.55 | 0.66 | 3.77 | 0.72 | 0.12 | 0.16 | 1.35 | |

Table 3 Interaction effect between sowing methods and herbicides on total weed density, total weed dry weight, number of panicles/m$^2$ and grain yield of rice (pooled over 2 years)

| Treatment | Total weed density m$^2$ at 60 DAS | | | Total weed dry weight (g/m$^2$) at 60 DAS | | | Panicles/m$^2$ | | | Grain yield (tonnes/ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sowing methods/ herbicides* | Wet seeding | Dry seeding | Drum seeding | Wet seeding | Dry seeding | Drum seeding | Wet seeding | Dry seeding | Drum seeding | Wet seeding | Dry seeding | Drum seeding |
| *Herbicides* | | | | | | | | | | | | |
| Butachlor (1.5 kg/ha) | 10.53 (110.41) | 12.34 (151.79) | 9.34 (86.80) | 13.54 (182.96) | 16.47 (270.78) | 12.07 (145.30) | 297.55 | 227.73 | 318.95 | 4.12 | 3.91 | 4.47 |
| Butachlor fb 2, 4-D (1.5 fb 0.5 kg/ha) | 8.71 (75.30) | 10.77 (115.57) | 7.46 (55.19) | 11.32 (127.62) | 14.56 (211.41) | 9.84 (96.37) | 302.95 | 285.28 | 322.25 | 4.48 | 4.17 | 4.90 |
| Pretilachlor (0.75 kg/ha) | 9.23 (84.66) | 11.46 (130.78) | 8.16 (66.11) | 11.98 (142.99) | 15.46 (238.61) | 10.83 (116.81) | 298.52 | 273.11 | 320.83 | 4.17 | 3.97 | 4.41 |
| Pretilachlor fb 2, 4-D (0.75 fb 0.5 kg/ha) | 6.31 (39.25) | 7.04 (49.05) | 6.04 (36.02) | 8.51 (71.86) | 9.88 (97.04) | 8.19 (66.57) | 317.80 | 287.57 | 354.21 | 4.80 | 4.41 | 4.99 |
| Pendimethalin (1.0 fb 0.5 kg/ha) | 10.11 (101.75) | 12.00 (143.53) | 9.35 (87.00) | 13.01 (168.87) | 16.01 (255.96) | 12.14 (146.84) | 305.33 | 254.18 | 318.83 | 4.11 | 3.97 | 4.44 |
| Pendimethalin fb 2, 4-D (1.0 fb 0.5 kg/ha) | 8.16 (66.03) | 10.48 (109.29) | 7.19 (51.15) | 10.78 (115.79) | 14.11 (198.66) | 9.55 (90.72) | 306.90 | 273.55 | 341.88 | 4.67 | 4.21 | 4.88 |
| Hand weeding (20, 40 and 60 DAS) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 317.80 | 288.48 | 362.83 | 4.93 | 4.49 | 5.19 |
| Weedy check | 16.13 (259.60) | 18.00 (323.52) | 14.43 (207.81) | 22.25 (494.57) | 25.23 (636.10) | 19.54 (381.36) | 248.56 | 221.12 | 261.73 | 2.86 | 2.14 | 3.15 |
| CD (*P*=0.05) | | | | | | | | | | | | |
| Herbicides at same sowing methods | | | 0.49 | | | 0.67 | | | 12.09 | | | 0.17 |
| Sowing methods at same/different herbicides | | | 0.83 | | | 1.10 | | | 31.79 | | | 0.47 |

Figures in parentheses are the original values, fb, Followed by

seeding of rice. However, minimum grain yield was recorded under weedy check in all the sowing methods. This was owing to the fact that all the herbicidal treatments under drum seeding produced maximum crop growth, and thereby the increased accumulation of photosynthates in reproductive parts, which ultimately brought about marked improvement in yield. Gnanasambandan and Murthy (2000) have also reported that treatments which had better growth and yield attributes had resulted higher grains yields, accordingly.

Thus the present findings indicated that drum seeding of

rice was found to be the most effective in minimizing density of weeds and dry weight. It was also most effective in enhancing crop growth yield-attributing characters, grain yield and weed control efficiency of herbicides. Sequential application of pretilachlor fb 2, 4-D was most effective in reducing weed population, dry weight, minimizing crop weed competition, maximizing crop growth, yield-attributes and grain yield weed control efficiency.

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