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# Eco-friendly weed management in dry direct-seeded rice under organic production system

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**ABSTRACT**

A field experiment was conducted at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, India during rainy (*Kharif)* seasons of 2017 and 2018 to identify the eco-friendly weed management practice in dry direct-seeded rice under organic production system. The experiment was laid out on fixed site in two consecutive years in a split plot design with two main plot treatments and five sub plots. Along with main and sub-plot treatments, recommended weed management practice as outside uneven control was kept for comparison. The 25% higher rice population with the seed rate of 25 kg/ha along with rice bran at 2 t/ha followed by (*fb*) hand weeding (HW) recorded significantly lower total weed density (36.60, 46.72 and 42.94 g/m$^2$) and biomass (28.28, 66.95 and 49.40 g/m$^2$); higher weed control efficiency (62.82, 63.73 and 74.17% at 20, 30 and 50 DAS) and higher grain yield (4.81 t/ha) of dry direct-seeded rice under organic production system and it was at par with 25% higher rice population with the rice seed rate of 25 kg/ha along with one inter-cultivation (IC) and hand weeding.

## INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of world population and is one of the leading cereal crop being grown in many regions of world. Recently, there is trend towards adopting direct-seeded rice (DSR) because of labour and water scarcity (Mallikarjun *et al.* 2014). To overcome these twin problems especially that of human labour involved in nursery preparation and transplanting operations, researchers as well as farmers are looking at mechanical transplanting and direct-seeding options that were developed and adopted widely in Asian countries. The establishment of rice crop through direct-seeding technique is not only simple to use but also has been found effective in sustaining the production of rice. Currently, a keen awareness has sprung on the adoption of organic farming as a remedy to cure the negative impact of modern agriculture. There is an emerging awareness among public on the use of high-quality food materials which are free from chemical toxicants.

The direct-seeded rice is associated with the biggest biological constraint of profuse heterogeneous weeds growth (Rao *et al.* 2007). The success of DSR entirely depends on efficient weed management practices (Rao *et al.* 2007, Rao *et al.* 2015) because uncontrolled weeds in DSR can reduce yields to the tune of 53% to 90% (Bhat *et al.* 2011). Continuous use of the herbicides over a period of time on a same piece of land, leads to ecological imbalances in terms of weed shift and environmental pollution. Hence, emphasis is given for the use of organic resources and non-chemical management practices to maintain the soil quality and environmental health in order to produce food of high-quality (Sangeetha 2006). Organic weed control encourages weed suppression rather than elimination (Gnanasoundari and Somasundaram 2014). This is done by promoting soil health through a combination of biologically based bio-fertilizers, compost and mulch. Proper management through organic methods offer varied benefits over chemical herbicides, including increased biodiversity, improved soil nutrition, soil structure, and protection of ground and surface water (Gnanasoundari and Somasundaram 2014). Therefore, this study was conducted to identify non-chemical weed management treatments for effective weed management and higher rice yield and economic returns in organic dry direct-seeded rice (dry-DSR) system.

## MATERIALS AND METHODS

A field experiment was carried out during rainy *(Kharif)* seasons of 2017 and 2018 at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences (UAS), Raichur to identify the ideal weed management practice in organic dry direct-seeded rice production. The soil had 0.46% organic carbon, 286.20 kg/ha nitrogen, 25.40 kg/ha phosphorus and 440.10 kg/ha potassium in medium range available nutrients. The experiment was laid out on fixed site in two consecutive years in split plot design consisted of two main plot treatments, *viz.* normal plant population and 25% higher population. Each main plot was further divided in to five sub plots *i.e.*, weed management practices, *viz.* rice straw 3 t/ha on 3 DAS + HW on 40 days after seeding (DAS); rice bran at 2 t/ha on 3 DAS + hand weeding (HW) on 40 DAS; Azolla inoculation 500 kg/ha at 10 DAS and incorporation at 40 DAS, cono-weeder usage at 10, 20, 30 and 40 DAS; inter-cultivation (IC) with hand drawn hoe at 20 DAS *fb* HW twice at 25 and 50 DAS and unweeded check. Along with main and subplot treatments, recommended weed management practice as outside uneven control was kept for comparison. The experiment was initiated first time and in order to know the extent of yield reduction in organic production system with various treatments including higher seed rate (which is considered as one of the weed control measures in order to have weed suppression effect in organic systems) in comparison with conventional recommended DSR system, the uneven control treatment was included. If the investigation had been under organic field, uneven control treatment would have been eliminated.

The dry seeds of rice variety *GNV-1089* were sown on 19$^{th}$ August 2017 and 1$^{st}$ July 2018 at recommended seed rate. The dry-DSR was grown in organic manner following the package of practices suggested by Organic Farming Research Institute, UAS, Raichur. Weeds observations like weed flora, weed density and biomass were taken at 20, 30 and 50 DAS. The rice grain from each net plot was cleaned, sun dried and weight at 14% moisture content and the grain yield was expressed in t/ha. The straw yield was expressed in t/ha. The data were statistically analysed by the analysis of variance method as suggested by Gomez and Gomez (1984). The critical differences were worked out at 5% probability level and the values are furnished.

## RESULTS AND DISCUSSION

### Weed flora

The predominant weed flora observed in the experimental field included grasses like, *Chloris barbata, Cynadon dactylon, Dactyloctenium aegyptium, Echinochloa colonum, Elusine indica* and *Panicum repens*. Among broad-leaved weeds, *Ageratum conyzoides, Celosia argentia, Commelina benghalensis, Parthenium hysterophorus, Phyllanthus niruri, Portulaca oleraceae, Tridax procumbens* and the sedge *Cyperus rotundus* were noticed. Among the weed species, the density of *Cyperus rotundus, Cynodon dactylon, Echinochloa colonum, Ageratum conyzoides, Commelina benghalensis* and *Portulaca oleraceae* were more than other weed species indicating their dominance and competitiveness with the dry direct-seeded organic rice.

### Total weed density

Significantly lower total weed density was recorded with 25% higher rice population with the seed rate of 25 kg/ha (59.27, 80.28 and 84.25 /m$^2$, respectively on pooled basis) than normal population with the seed rate of 20 kg/ha (72.08, 104.3 and 100.3 /m$^2$, respectively on pooled basis) at 20, 30 and 50 DAS (**Table 1**). The rice crop had a competitive advantage over weeds at higher population due to earlier closer of canopy and thus reducing total weed density and growth (Chauhan *et al.* 2011 and Ahmed *et al.* 2014).

Among weed management practices, significantly lower total weed density was recorded with one IC *fb* HW twice (44.01, 41.24 and 43.60/m$^2$ at 20, 30 and 50 DAS, respectively, on pooled basis) but it was on par with rice bran at 2 t/ha *fb* HW (41.80, 58.49 and 47.59/m$^2$ at 20, 30 and 50 DAS, respectively on pooled basis). Significantly higher total weed density was recorded in unweeded check (139.5, 194.1 and 224.1/m$^2$ at 20, 30 and 50 DAS, respectively on pooled basis) which might be due to the control of weeds at the germination phase by rice bran and significant reduction at later stages as late germinating weeds were controlled by one hand weeding at 40 DAS. The suppressive effect of rice bran application to soil surface on weed population was considered to be associated with a decline in redox potential and dissolved oxygen concentration as reported by Kim *et al.* (2001) and Maeda *et al.* (2003).

Among various interactions, at 20 DAS 25% higher rice population with the seed rate of 25 kg/ha along with one IC and HW twice recorded significantly lower total weed density (33.99/m$^2$ on pooled basis) but it was at par with 25% higher rice population with the seed rate of 25 kg/ha along with rice bran at 2 t/ha + HW (36.60 m$^{-2}$ on pooled basis)

this might be due to effective weed control right from emerging stage of rice crop, while normal population with the seed rate of 20 kg/ha with unweeded check recorded significantly higher total weed density (146.3/m$^2$ on pooled basis) among all other treatment combinations. At 30 and 50 DAS, 25% higher rice population with the seed rate of 25 kg/ha along with one IC *fb* two HW recorded significantly lower total weed density (30.34 and 34.92/m$^2$, respectively on pooled basis) but it was at par with 25 higher rice population with the seed rate of 25 kg/ha along with rice bran at 2 t/ha *fb* HW (46.72 and 42.94/m$^2$, respectively on pooled basis), while normal population with the seed rate of 20 kg/ha with unweeded check recorded significantly higher total weed density (209.9 and 233.3/m$^2$, respectively on pooled basis) among all other treatment combinations except with 25% higher population with the seed rate of 25 kg/ha with unweeded check (178.4 and 214.9/ m$^2$, respectively on pooled basis).

Interestingly, population levels in combination with weed management practices recorded significantly higher total weed density over uneven control with recommended weed management practice (19.90, 13.39 and 12.94/m$^2$ at 20, 30 and 50 DAS, respectively on pooled basis).

**Table 1. Total weeds density and weeds biomass at 20, 30 and 50 days after seeding (DAS) as influenced by weed management treatments in direct-seeded rice under organic production system (pooled data 2017 and 2018)**

| Treatment | Total weeds density (no./m$^2$) | | | Weed biomass (g/m$^2$) | | |
|---|---|---|---|---|---|---|
| | 20 DAS | 30 DAS | 50 DAS | 20 DAS | 30 DAS | 50 DAS |
| *Rice plant population level (P)* | | | | | | |
| Normal rice plant population with recommended seed rate (20 kg/ha) – ($P_1$) | 8.37(72.1) | 9.96(104.3) | 9.63(100.3) | 7.63(58.0) | 10.21(110.9) | 9.36(92.1) |
| Higher rice plant population with 25% higher recommended seed rate (25 kg/ha) – ($P_2$) | 7.52(59.3) | 8.63(80.3) | 8.71(84.2) | 6.55(43.6) | 9.52(98.0) | 8.55(78.6) |
| LSD (p=0.05) | 0.47 | 1.51 | 0.45 | 0.20 | 4.44 | 0.54 |
| *Weed management treatment (W)* | | | | | | |
| Rice straw at 3 t/ha on 3 DAS *fb* HW once on 40 DAS – ($W_1$) | 7.09(49.6) | 8.81(77.3) | 7.58(57.0) | 6.53(42.1) | 9.33(86.5) | 7.93(62.0) |
| Rice bran at 2 t/ha on 3 DAS *fb* HW once on 40 DAS – ($W_2$) | 6.68(44.0) | 7.67(58.5) | 6.96(47.6) | 6.11(36.8) | 8.49(71.5) | 7.39(53.8) |
| *Azolla* inoculation at 500 kg/ha on 10 DAS and incorporation at 40 DAS – ($W_3$) | 8.25(67.0) | 10.61(112.9) | 11.08(122.0) | 8.08(64.3) | 12.43(159.7) | 9.23(84.7) |
| Cono-weeder at 10, 20, 30 and 40 DAS – ($W_4$) | 7.27(52.1) | 8.38(69.6) | 7.75(59.4) | 6.96(48.0) | 9.40(88.2) | 8.07(64.6) |
| One inter-cultivation (IC) at 20 DAS fb two HW twice at 25 and 50 DAS – ($W_5$) | 6.51(41.8) | 6.44(41.2) | 6.65(43.6) | 5.90(34.4) | 5.78(32.7) | 6.90(47.1) |
| Unweeded check – ($W_6$) | 11.85(139.5) | 13.88(194.1) | 15.00(224.1) | 8.95(79.0) | 13.74(188.1) | 14.18(200.1) |
| LSD (p=0.05) | 0.26 | 1.31 | 0.55 | 0.34 | 2.76 | 0.91 |
| *Interaction (P X W)* | | | | | | |
| $P_1W_1$ | 7.56(56.4) | 9.58(90.9) | 8.03(64.0) | 7.12(50.0) | 9.80(95.1) | 8.26(67.3) |
| $P_1W_2$ | 7.23(51.4) | 8.43(70.3) | 7.30(52.2) | 6.81(45.4) | 8.74(76.1) | 7.69(58.1) |
| $P_1W_3$ | 8.46(70.5) | 11.03(122.9) | 11.52(131.9) | 8.30(67.9) | 12.94(169.1) | 9.51(90.2) |
| $P_1W_4$ | 7.70(58.2) | 8.97(79.5) | 8.31(68.1) | 7.72(58.6) | 9.89(96.9) | 8.51(71.8) |
| $P_1W_5$ | 7.11(49.6) | 7.29(52.1) | 7.30(52.3) | 6.70(43.8) | 6.14(36.8) | 7.66(57.7) |
| $P_1W_6$ | 12.14(146.3) | 14.49(209.9) | 15.30(233.3) | 9.11(82.1) | 13.86(191.5) | 14.45(207.8) |
| $P_2W_1$ | 6.62(42.8) | 8.04(63.7) | 7.14(49.9) | 5.94(34.3) | 8.85(77.9) | 7.60(56.8) |
| $P_2W_2$ | 6.13(36.6) | 6.91(46.7) | 6.63(42.9) | 5.41(28.3) | 8.24(66.9) | 7.10(49.4) |
| $P_2W_3$ | 8.04(63.6) | 10.19(102.8) | 10.63(112.1) | 7.85(60.7) | 11.93(150.4) | 8.95(79.2) |
| $P_2W_4$ | 6.85(45.9) | 7.79(59.6) | 7.19(50.7) | 6.20(37.5) | 8.91(79.5) | 7.63(57.3) |
| $P_2W_5$ | 5.92(34.0) | 5.60(30.3) | 5.99(34.9) | 5.10(25.0) | 5.41(28.6) | 6.13(36.6) |
| $P_2W_6$ | 11.56(132.7) | 13.26(178.4) | 14.69(214.9) | 8.78(76.0) | 13.62(184.7) | 13.91(192.4) |
| LSD (p=0.05) | 0.30 | 1.50 | 0.64 | 0.39 | 3.17 | 1.04 |
| Pendimethalin - 0.677 kg/ha pre-emergence application (PE) *fb* one HW at 30DAS UC | 4.57(19.9) | 3.87(13.4) | 3.73(12.9) | 3.94(14.5) | 4.54(19.6) | 2.72(6.4) |
| LSD(p=0.05) | 0.32 | 1.47 | 0.60 | 0.36 | 3.29 | 0.96 |

Figures in the parentheses indicate the original value and the data subjected for transformation using square root of $(\sqrt{x+1})$, where X is weed count

**Total weed biomass**

Significantly lower total weed biomass was recorded with 25% higher rice population with 25 kg/ha rice seed rate (43.62, 98.00 and 78.64 g/m$^2$ at 20, 30 and 50 DAS, respectively on pooled basis) than normal population with the seed rate of 20 kg/ha (57.96, 110.9 and 92.15 g/m$^2$ at 20, 30 and 50 DAS, respectively on pooled basis) (**Table 1**) which might be due to the minimum number of total weeds with lesser biomass in the cropping period in one IC *fb* two HW plot. These results are in close conformity to the findings of Kathiresan and Manoharan (2002) and Moorthy and Saha (2005).

Among weed management practices, significantly lower total weed biomass at 20 and 50 DAS was recorded with one IC and two HW (34.41 and 47.14 g/m$^2$ at 20 and 50 DAS, respectively on pooled basis) but it was at par with rice bran at 2 t/ha + HW (36.82 and 53.77 g/m$^2$, respectively on pooled basis) might be due to the efficient weed control and lesser weed population as compared to other treatments (Bavaji and Somasundaram 2017). Significantly higher total weed biomass was recorded with unweeded check (79.05 and 200.1 g/m$^2$ at 20 and 50 DAS, respectively on pooled basis). At 30 DAS, significantly lower total weed biomass was recorded with one IC *fb* HW twice (32.67 g/m$^2$ on pooled basis) and it was on par with rice bran at 2 t/ha + HW (71.51 g/m$^2$ on pooled basis), while unweeded check recorded significantly higher total weed dry weight (188.1 g/m$^2$ on pooled basis) among all other weed management practices except with azolla incorporation (159.7 g/m$^2$ on pooled basis).

Among interaction effects, at 20 and 50 DAS, higher rice plant population with 25% higher population with the rice seed rate of 25 kg/ha along with one IC *fb* HW twice recorded significantly lower total weed biomass (24.97 and 36.62 g/m$^2$, respectively on pooled basis) and it was at par with 25% higher rice population with the seed rate of 25 kg/ha with rice bran at 2 t/ha + (28.28 and 49.40 g/m$^2$ at 20 and 50 DAS, respectively on pooled basis), while normal population with the seed rate of 20 kg/ha with unweeded check recorded significantly higher total weed dry weight (82.07 and 207.8 g/m$^2$ at 20 and 50 DAS, respectively on pooled basis) among all other treatment combinations except with 25% higher population with the seed rate of 25 kg/ha with unweeded check (76.04 and 192.4 g/m$^2$ at 20 and 50 DAS, respectively on pooled basis) because of effective weed control right from emerging stage of rice crop thus, resulted in obtaining the lower weed dry weight. At 30 DAS, 25% higher rice population with the seed rate of 25 kg/ha with one IC *fb* HW twice recorded significantly lower total weed biomass (28.56 g/m$^2$ on pooled basis) but it was at par with normal population with the seed rate of 20 kg/ha with one IC and two HW (36.77 g/m$^2$ on pooled basis) and 25% higher population with the seed rate of 25 kg/ha with rice bran at 2 t/ha + HW (66.95 g/m$^2$ on pooled basis), while normal population with the seed rate of 20 kg/ha with unweeded check recorded significantly higher total biomass (191.5 g/m$^2$ on pooled basis) among all other treatment combinations except with 25% higher population with the seed rate of 25 kg/ha with unweeded check (184.7 g/m$^2$ on pooled basis), normal population with the seed rate of 20 kg/ha with azolla incorporation (169.1 g/m$^2$ on pooled basis) and 25% higher population with the seed rate of 25 kg/ha with azolla incorporation (150.4 g/m$^2$ on pooled basis).

Interestingly, population levels in combination with weed management practices recorded significantly higher total weed biomass over uneven control with recommended weed management practice (14.54, 19.64 and 6.38 g/m$^2$ at 20, 30 and 50 DAS, respectively on pooled basis).

**Weed control efficiency**

Higher weed control efficiency was recorded in 25% higher rice population with the seed rate of 25 kg/ha along at 20 DAS (42.63% on pooled basis), 30 DAS (46.97% on pooled basis) and at 50 DAS (59.09% on pooled basis). Normal population with the seed rate of 20 kg/ha along recorded lower weed control efficiency at 20 DAS (29.26% on pooled basis), 30 DAS (42.19% on pooled basis) and at 50 DAS (55.23% on pooled basis) (**Table 2**).

One IC *fb* two HW gained higher weed control efficiency at 20 DAS (56.77% on pooled basis), 30 DAS (82.69% on pooled basis) and at 50 DAS (76.39% on pooled basis). It was followed by rice bran at 2 t/ha + HW (53.68, 62.12 and 72.95%, respectively on pooled basis) due to reduction of weed biomass by reducing the weed density in these treatments resulted in higher WCE as reported by Dutta and Bandyopadhyaya (2003).

At 20 and 50 DAS, 25% higher rice population with the seed rate of 25 kg/ha along with one IC *fb* HW twice recorded lower weed control efficiency (67.16 and 80.88%, respectively on pooled basis). It was followed by 25% higher rice population with the seed rate of 25 kg/ha along with rice bran at 2 t/ha + HW (62.82 and 74.17%, respectively on pooled basis). At 30 DAS, 25% higher rice population with the seed rate of 25 kg/ha along with one IC and two

HW recorded lower weed control efficiency (84.58% on pooled basis). It was followed by normal population with the seed rate of 20 kg/ha along with one IC and two HW (80.80% on pooled basis) and 25% higher rice population with the seed rate of 25 kg/ha along with rice bran at 2 t/ha + HW (63.73% on pooled basis). Higher population played favourable role in reducing the weed density and growth of varying weed fauna, added to that application of manual, mechanical or organic treatments further improved the suppressive effect on weeds there by increasing the weed control efficiency.

Uneven control with recommended weed management practice recorded higher weed control efficiency at 20 DAS (82.23% on pooled basis), 30 DAS (89.75% on pooled basis) and at 50 DAS (96.88% on pooled basis) than all other treatment combinations during both the years of study.

**Rice grain and straw yield**

Among the population levels, 25% higher rice population with the seed rate of 25 kg/ha recorded significantly higher rice grain (4.10 t/ha) and straw yield (4.90 t/ha) as compared to normal population with the seed rate of 20 kg/ha (**Table 3**). Normally, the grain and straw yield per plant decreases with increase in plant population but the grain and straw yield per unit area increases with increase in plant population. Decrease in yield per plant will be compensated by increased plant population and the reverse was true with lower plant population as observed by Kaur and Singh (2014). This implies that increased crop density had strong and consistent negative effects on weed and positive effects on grain and straw yield. Higher grain and straw yield with higher seed rate was also reported by Rajneesh *et al.* (2017).

With respect to weed management practices significantly higher grain (4.73 t/ha) and straw yield (5.44 t/ha) was recorded with one IC *fb* two HW and the next best treatment was application of rice bran at 2 t/ha + HW (4.69 and 5.38 t/ha grain and straw yield respectively), which was in conformity with the findings of Kato *et al.* (2010). Rice bran application

**Table 2. Weed control efficiency (%) at 20, 30 and 50 days after seeding (DAS) as influenced by weed management treatments in direct-seeded rice under organic production system (pooled data 2017 and 2018)**

| Treatment | Weed control efficiency (%) | | |
|---|---|---|---|
| | 20 DAS | 30 DAS | 50 DAS |
| *Rice plant population level (P)* | | | |
| Normal rice plant population with recommended seed rate (20 kg/ha) – ($P_1$) | 29.26 | 42.19 | 55.23 |
| Higher rice plant population with 25% higher recommended seed rate (25 kg/ha) – ($P_2$) | 42.63 | 46.97 | 59.04 |
| *Weed management treatment (W)* | | | |
| Rice straw at 3 t/ha on 3 DAS *fb* HW once on 40 DAS – ($W_1$) | 47.11 | 54.12 | 68.79 |
| Rice bran at 2 t/ha on 3 DAS *fb* HW once on 40 DAS – ($W_2$) | 53.68 | 62.12 | 72.95 |
| *Azolla* inoculation at 500 kg/ha on 10 DAS and incorporation at 40 DAS – ($W_3$) | 18.57 | 15.30 | 57.21 |
| Cono-weeder at 10, 20, 30 and 40 DAS – ($W_4$) | 39.54 | 53.25 | 67.47 |
| One inter-cultivation (IC) at 20 DAS fb two HW twice at 25 and 50 DAS – ($W_5$) | 56.77 | 82.69 | 76.39 |
| Unweeded check – ($W_6$) | 0.00 | 0.00 | 0.00 |
| *Interaction (P X W)* | | | |
| $P_1W_1$ | 39.29 | 50.32 | 67.16 |
| $P_1W_2$ | 44.54 | 60.51 | 71.73 |
| $P_1W_3$ | 16.92 | 12.10 | 55.78 |
| $P_1W_4$ | 28.42 | 49.40 | 64.80 |
| $P_1W_5$ | 46.38 | 80.80 | 71.90 |
| $P_1W_6$ | 0.00 | 0.00 | 0.00 |
| $P_2W_1$ | 54.93 | 57.92 | 70.42 |
| $P_2W_2$ | 62.82 | 63.73 | 74.17 |
| $P_2W_3$ | 20.23 | 18.51 | 58.64 |
| $P_2W_4$ | 50.66 | 57.11 | 70.13 |
| $P_2W_5$ | 67.16 | 84.58 | 80.88 |
| $P_2W_6$ | 0.00 | 0.00 | 0.00 |
| Pendimethalin - 0.677 kg/ha pre-emergence application (PE) *fb* one HW at 30DAS UC | 82.23 | 89.75 | 96.88 |

Figures in the parentheses indicate the original value and the data subjected for transformation using square root of $(\sqrt{x+1})$, where X is weed count

significantly increased both spikelet number per panicle and panicle number, leading to substantial increase in total spikelet number per unit area grain and straw yield compared to unweeded control as reported by Gnanasoundari and Somasundaram (2014). Significantly lower grain (2.22 t/ha) and straw yields (2.86 t/ha) were recorded in unweeded check due to increased weed competition for resources such as space, light, nutrients.

A significant interaction between population levels and weed management practices showed that a treatment combination of 25% higher rice population with the seed rate of 25 kg/ha along with one IC *fb* two HW gave the highest rice grain (4.91 t/ha) and straw yield (5.56 t/ha) which was significantly superior to all the treatment combinations except with 25% higher population with the seed rate of 25 kg/ha along with rice bran at 2 t/ha + HW (4.81 and 5.47 t/ ha grain and straw yield, respectively). These results clearly showed that under organic rice cultivation, 25% higher rice population with the seed rate of 25 kg/ha with a combination of weed management practice helped in controlling weeds resulting in significantly less density and dry matter accumulation of weeds, which led to better nutrient uptake and least crop weed competition under these treatment combinations.

The higher grain (5.10 t/ha) and straw yield (5.80 t/ha) with uneven control than weed management treatment combinations was due to application of nutrients to soil pool through recommended chemical fertilizer with FYM and chemical and cultural weed management practices.

**Economics**

Economic analysis clearly showed that significantly higher net returns (₹ 39,153/ ha) and B:C ratio (1.89) were noticed with the 25% higher rice

**Table 3. Rice grain yield, straw yield and economics as influenced by weed management treatments in direct-seeded rice under organic production system (pooled data 2017 and 2018)**

| Treatment | Grain yield (t/ha) | Straw yield (t/ha) | Gross return ($x10^3$ `/ha) | Net return ($x10^3$ `/ha) | B:C ratio (`/ha) |
|---|---|---|---|---|---|
| *Rice plant population level (P)* | | | | | |
| Normal rice plant population with recommended seed rate (20 kg/ha) – ($P_1$) | 3.94 | 4.73 | 79.48 | 35.97 | 1.83 |
| Higher rice plant population with 25% higher recommended seed rate (25 kg/ha) – ($P_2$) | 4.10 | 4.90 | 82.83 | 39.15 | 1.89 |
| LSD (p=0.05) | 0.08 | 0.86 | 1.56 | 1.56 | 0.04 |
| *Weed management treatment (W)* | | | | | |
| Rice straw at 3 t/ha on 3 DAS *fb* HW once on 40 DAS – ($W_1$) | 4.34 | 5.35 | 87.79 | 46.94 | 2.15 |
| Rice bran at 2 t/ha on 3 DAS *fb* HW once on 40 DAS – ($W_2$) | 4.69 | 5.38 | 94.55 | 41.72 | 1.79 |
| *Azolla* inoculation at 500 kg/ha on 10 DAS and incorporation at 40 DAS – ($W_3$) | 3.77 | 4.58 | 76.17 | 27.18 | 1.55 |
| Cono-weeder at 10, 20, 30 and 40 DAS – ($W_4$) | 4.36 | 5.31 | 88.06 | 46.75 | 2.13 |
| One inter-cultivation (IC) at 20 DAS fb two HW twice at 25 and 50 DAS – ($W_5$) | 4.73 | 5.44 | 95.42 | 53.66 | 2.28 |
| Unweeded check – ($W_6$) | 2.22 | 2.85 | 44.95 | 9.14 | 1.26 |
| LSD (p=0.05) | 0.12 | 0.08 | 2.37 | 2.37 | 0.06 |
| *Interaction (P X W)* | | | | | |
| $P_1W_1$ | 4.26 | 5.24 | 86.03 | 45.26 | 2.11 |
| $P_1W_2$ | 4.57 | 5.29 | 92.21 | 39.46 | 1.75 |
| $P_1W_3$ | 3.71 | 4.56 | 75.02 | 26.11 | 1.53 |
| $P_1W_4$ | 4.32 | 5.17 | 87.13 | 45.91 | 2.11 |
| $P_1W_5$ | 4.56 | 5.31 | 91.99 | 50.32 | 2.21 |
| $P_1W_6$ | 2.20 | 2.83 | 44.50 | 8.78 | 1.25 |
| $P_2W_1$ | 4.43 | 5.46 | 89.56 | 48.61 | 2.19 |
| $P_2W_2$ | 4.81 | 5.47 | 96.89 | 43.97 | 1.83 |
| $P_2W_3$ | 3.83 | 4.60 | 77.33 | 28.25 | 1.58 |
| $P_2W_4$ | 4.40 | 5.45 | 88.98 | 47.59 | 2.15 |
| $P_2W_5$ | 4.91 | 5.56 | 98.84 | 57.00 | 2.36 |
| $P_2W_6$ | 2.24 | 2.88 | 45.40 | 9.50 | 1.26 |
| LSD (p=0.05) | 0.14 | 0.09 | - | 2.72 | NS |
| Pendimethalin - 0.677 kg/ha pre-emergence application (PE) *fb* one HW at 30DAS UC | 5.10 | 5.80 | 102.82 | 62.60 | 2.56 |
| LSD (p=0.05) | 0.17 | 0.09 | - | 3.08 | 0.08 |

population with the seed rate of 25 kg/ha over normal population with the seed rate of 20 kg/ha (₹ 35,974 / ha and 1.83) (**Table 3**). Kaur and Singh (2014) also reported lower net returns with reduced seed rate of 20 kg/ha in direct-seeded rice.

Economic analysis clearly showed that significantly higher net returns (₹ 53,658 /ha) and B:C ratio (2.28) were noticed with one IC *fb* HW twice. Significantly lower net returns (₹ 9,140 /ha) and B: C ratio (1.26) were noticed with unweeded check. Rice bran at 2 t/ha + HW though gave higher grain yield, but as the cost of cultivation was more, net returns and B:C ratio were reduced compared to one IC *fb* two HW. This was in accordance with the findings of Bavaji and Somasundaram (2017).

Significantly higher net returns (₹ 56,996 /ha) and B: C ratio (2.36) were noticed 25% higher rice population with the seed rate of 25 kg/ha with one IC *fb* HW twice. Significantly lower net returns (₹ 8,776 /ha) and B: C ratio (1.25) were noticed with normal population with the seed rate of 20 kg/ha with unweeded check.

Interestingly, recommended weed management practice had significantly higher net returns (₹ 62,603 /ha on pooled basis) and B:C ration (2.56) than any of the population levels and weed management practice combinations.

## Conclusion

In organic dry-DSR production system, 25% higher rice population with the seed rate of 25 kg/ha along with rice bran at 2 t/ha + HW at 40 DAS would be the viable technique as it resulted in achieving comparable and better weed control efficiency and economic yields as recorded in 25% higher rice population with the seed rate of 25 kg/ha with one IC at 20 DAS *fb* two HW at 25 and 50 DAS.

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