***Original Research Article***

**Weed Management Practices in Organic Rice System (*Oryza sativa* L.): An Evaluation of Combining Cultural Practices for Improved Productivity and Sustainability**

**Abstracts**

A field experiment was conducted at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Ayodhya (U.P.) during the *kharif* season of 2018–19 to evaluate effective weed management practices under organic systems in rice. In this experiment, seven treatments were examined in three replicates using Randomized Complete Block Design (RCBD). The soil of the experimental field was silty loam in texture. The rice variety NDR-2065 was transplanted. All nutrients were supplied through farm yard manure (75%) and vermicompost (25%). Results concluded that stale-seed bed+reduce spacing up to 25%+mulching with rice straw+1 hand-weeding at 50 days after transplanting (DAT) were most effective in controlling weeds, followed by hand-weeding at 25 and 50 DAT in rice. Grain (3.39 t ha-1), straw (3.96 t ha-1), and biological yield (7.35 t ha-1) were increased significantly under stale-seed bed+reduce spacing-up to 25%+mulching with rice straw+1 hand-weeding at 50 DAT, which was statistically similar with treatment hand-weeding at 25 and 50 DAT. The combination of a stale-seed bed, 25% reduced spacing, rice straw mulch, and one hand-weeding at 50 DAT resulted in a significant grain yield increase of 87% (p < 0.05) compared to the control, achieving a weed control efficiency of 75%. Not only did this treatment produce the highest gross return (₹67517.5 ha-1), net returns (₹33,906 ha⁻¹) and B:C ratio (1.01), it also showed that it was economically viable. Thus stale-seed bed+reduced spacing up to 25%+mulching with rice straw+1 hand-weeding at 50 days after transplanting was most effective at controlling the weeds and ultimately produced a more productive rice crop and proved to be more economically feasible than any other treatment.

**Keywords:**  mulching, neem cake, Organic farming, rice, weed management, stale-seed bed, hand-weeding

**1. Introduction**

 Rice is arguably the most critical crop of the *kharif* season. It belongs to the *poaceae* family, and is extremely popular as a staple food throughout the world, resulting in the United Nations declaring 2004 the 'International Year of Rice' (Anonymous, 2003). 'Rice is life' is a very appropriate term for India since this crop plays a crucial role in the country's food security. Rice is cultivated on 47.83 mha in India and is produced in 135.76 mt, with a productivity of 2838 kg ha-1. India's largest rice producing state is Uttar Pradesh, which has 5.90 mha area and a production of 16.14 mt. As compared with Punjab, Andhra Pradesh, West Bengal, Haryana and Tamil Nadu, Uttar Pradesh has a low rice productivity of 2737 kg ha-1 (Anonymous, 2023).

 Organic farming is “one of the broad spectrum of production systems that is supportive of the environment” (Durham andMizik*,* 2021). “Organic farming systems largely depends on crop rotations, crop residues, animal manures, green manures, off-farm organic wastes, mechanical cultivation, mineral bearing rocks and aspects of biological pest control to maintain soil productivity, to supply plant nutrients and to control insects, pathogens and weeds” (Gamage *et al.,* 2023). “Organic materials are the safer plant nutrients that do not adversely affect crops and soil. Today, the awareness on organic agricultural produce is increasing and the demand for organic food is also rising, leading to increase in land area under organic farming” (Ferdous *et al.,* (2021); Eyinade *et al.,* 2021). About 71.5 mha of land is devoted to organic farming worldwide with 2.8 million producers (Willer *et al.,* 2020; Sailaja and Manohari, 2021).

 The majority of cereal crops are severely infested with weeds. Uncontrolled weed growth in lowland and upland rice causes yield losses ranging from 12‒81% (Berhan and Bekele, 2021; Yakadri *et al.,* 2022; Kumar *et al.*, 2023). Weeds are reported to be one of the key constraints in organic production system (Singh *et al.,* 2012; Arlauskienė *et al*., 2021; Merfield, 2023). Weed management promotes weed suppression, rather than weed elimination, by enhancing crop competition and phytotoxic effects on weeds (Hasan *et al.,* 2021; Scavo and Mauromicale, 2021; Nath *et al.,* 2024). Under organic production, none of the cultural practices were found to be effective to control weeds in rice, and rice yields were reduced by 57‒61% as a result of weed competition (Maimunah *et al.,* 2021; Kushal *et al.,* 2024). The practice of improving the competitive availability of the crop and weed can reduce the adverse effects of weeds on rice crops (Nazir *et al.,* 2022).

 In the early growing stage, stale-seed bed preparation might assist in minimizing weed populations (Sanbagavallis *et al.,* 2016). Intercropping is a method of improving weed control by utilizing a large percentage of available resources to improve weed control (Gu *et al.,* 2021). Due to the shade and allelopathic effect of sesbania, green manuring of rice significantly suppresses weed growth (Yadav *et al.,* 2010). As a result of mulching rice straw, weed growth was successfully controlled and agronomic traits were enhanced (Wayayok *et al.,* 2014). It has been reported that cultivating rice with narrow or close row spacing reduces weed growth and increases its yield (Chauhan and Johnson, 2011). In order to maintain a high level of production while cultivating crops organically, a great deal of effort is needed. Hence, the goal of the present study was to evaluate the effectiveness of suitable weed management practices under organic system in rice crop.

**2. Methods and Materials**

 The field experiment was conducted during the *kharif* (June to November,2018) season at the Agronomy Research Farm of Narendra Deva University of Agriculture and Technology (Kumarganj) Ayodhya (U.P.). The experimental site falls under the subtropical climate with high humidity level and lies between 24.4°N latitude and 82.10°E longitude, at an altitude of about 113 m above mean sea level. The experimental plot had silty loam in texture, having basic in reaction (pH 8.6), and Ec of 0.34 dS m-1. low in organic carbon (0.35%), available Nitrogen (140.34 kg ha-1), available Phosphorous (14.50 kg ha-1), and high in available Potassium (240.20 kg ha-1). Seven treatments comprising of T1-hand-weeding at 25 and 50 days after transplanting (DAT), T2-ITK treatment on weed control practiced by farmer as mulching with *cassia tora*, T3-inter cropping with dhaincha, T4-stale-seed bed+reduce row × plant spacing up to 25% (from 20 cm×10 cm to 15 cm × 5cm) +mulching with rice straw+1 hand-weeding at 50 DAT, T5-locally available weed mulch-*kanss*+1 hand pulling, T6-incorporation of neem cake 15 days before transplanting @ 2 t ha-1+one weeding, T7-without weed controlwere assigned in a Randomized Complete Block Design (RCBD) replicated thrice. The rice variety NDR- 2065 was transplanted on 9th July 2018. The cropping system was Rice–potato–okra and all nutrients were supplied through farm yard manure (75%) and vermicompost (25%). All the recommended agronomic practices were adopted to raise the crop. The data on weed density, and dry weight were recorded at different growth stages of rice crop. These were subjected to square root transformation $\sqrt{X+0.5 }$ before statistical analysis to normalize their distribution. According to Abdullah *et al.*,(2020), The weed control efficiency (%) of treatment was calculated by using following formula:

$$WCE (\%)=\frac{DWC-DWT}{DWC} $$

Where,

WCE = Weed Control Efficiency,

DWC= Weed dry weight in control plot,

DWT= weed dry weight in treated plot.

Grain and straw yield of rice were recorded at harvest along with different economic indices, viz. gross return, net return and benefit-cost ratio (BCR) were calculated based on prevailing market price of the input and output. The one season data was statistically analyzed as suggested by Gomez and Gomez (1984). Statistical significance was tested by F test at a critical difference (CD) of 0.05 level of probability.

**3. Results and Discussion**

*3.1. Effect on weed*

 Ten weed species were recorded in the experimental field (table 1). *Echinochloa colonum* (21.89%), *Cynodon dactylon* (20.82%), *Monochoria vaginalis* (12.80%), *Alternanthera sessilis* (11.62%), *Eclipta alba* (11.52%), and *Jussia suffrusticosa* (10.19%) comprised the most dominant weed flora of the experimental field during the year of study. Besides these, *Echinochloa crsugali*,*Fibristylis dichotoma* and some other weeds were also found.

**Table 1: Effect of treatments on weed density, weeds dry weight and weed control efficiency of transplanted rice at harvest stages in organic production system**

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Weed density (No. m-2) | weeds dryweight(g m-2) | WEC (%) |
| *Echinochloa colonum* | *Monochoria vaginalis* | *Cynodon dactylon* | *Jussia suffrusticosa* | *Eclipta alba* | *Alternanthera sessilis* | Other | Total |
| T1: Hand-weeding at 25 and 50 DAT | 4.94(24.00) | 3.84(14.30) | 4.82(22.80) | 3.33(10.60) | 3.67(13.00) | 3.67(13.00) | 3.50(11.80) | 10.47(109.50) | 8.18(66.52) | 56.43 |
| T2: ITK treatment on weed control practiced by farmer as mulching with *Cassia tora* | 5.85(33.86) | 3.91(14.80) | 5.62(31.20) | 3.37(10.90) | 3.87(14.54) | 3.88(14.60) | 3.78(13.80) | 11.57(133.70) | 9.06(81.85) | 46.39 |
| T3: Intercropping with Dhaincha (*Sasbania aculeate*) | 5.20(26.60) | 4.03(15.80) | 5.09(25.50) | 3.53(12.00) | 3.83(14.20) | 3.86(14.40) | 3.68(13.10) | 11.04(121.60) | 8.88(78.46) | 48.61 |
| T4: Stale-seed bed+reduce spacing up to 25%+mulch with rice straw+one hand-weeding at 50 DAT  | 4.11(16.40) | 3.24(10.00) | 3.89(14.70) | 2.51(5.80) | 2.34(5.00) | 2.57(6.10) | 2.53(5.90) | 8.01(63.90) | 6.19(37.92) | 75.19 |
| T5: Locally available weed mulch-*kanss*+one hand pulling  | 5.17(26.30) | 4.03(15.70) | 5.04(25.00) | 3.49(11.70) | 3.82(14.10) | 3.84(14.30) | 3.67(13.00) | 10.96(120.10) | 8.76(76.49) | 49.90 |
| T6: Incorporation of neem cake 15 days before transplanting @ 2 t ha-1+one hand-weeding  | 5.07(25.20) | 3.95(15.10) | 4.97(24.20) | 3.42(11.20) | 3.77(13.70) | 3.78(13.80) | 3.60(12.50) | 10.77(115.70) | 8.45(71.01) | 53.49 |
| T7: Without weed control | 6.04(36.10) | 4.64(21.10) | 5.90(34.34) | 4.15(16.80) | 4.41(19.00) | 4.43(19.16) | 4.34(18.40) | 12.85(164.90) | 12.36(152.67) | 0.00 |
| SEm± | 0.19 | 0.13 | 0.18 | 0.11 | 0.12 | 0.12 | 0.13 | 0.38 | 0.31 | - |
| C.D (*p*≤0.05) | 0.59 | 0.40 | 0.55 | 0.35 | 0.37 | 0.38 | 0.40 | 1.18 | 0.94 | - |
| \*Figure in parenthesis are the original value. The data was transformed to SQRT $\sqrt{x+0.5 }$ before analysis. |

 The lowest density (8.01 m-2) as well as dry weight (6.19 g m-2) of total weeds was recorded in T4- stale-seed bed+reduce spacing up to 25%+mulch with rice straw+1 hand-weeding at 50 DAT followed by the T1- Hand-weeding at 25 and 50 DAT. The highest weed density and dry weight of total weed was observed in T7 - Without weed control. This is mainly due to different weed management practices which resulted in reducing the weed density in respective plots during course of investigation. Similar findings were also reported by Murthy et al. (2012), Jadhav and Pawar (2013) Singh (2014), Aske *et al.,* (2018), Choudhary *et al.,* (2021), Nalayini *et al.,* (2023)

 Weed control efficiency (75.19 %) was recoded maximum in T4- stale-seed bed+reduce spacing up to 25%+mulch with rice straw+1 hand-weeding at 50 DAT followed by T1- hand-weeding at 25 and 50 DAT. Higher weed control efficiency under these treatments was reflected through lower dry weight of weeds. The increase in weed control efficiency was mainly due to different weed management practices i.e. hand-weeding, stale-seed bed, intercropping, space reducing, and ITK treatment which resulted in better availability of growth promoting factor and finally increased the weed control efficiency. Similar results are reported by Aske et al., (2018), Choudhary *et al.,* (2021), Liu *et al.,* (2023), Nalayini *et al.,* (2023)

*3.2. Effect on Yield and economics*

 Grain, straw and biological yield was influenced significantly by different weed management practices (Table 2). The maximum grain yield (3.39 t ha-1) and straw yield (3.96 t ha-1) was recorded highest in T4- stale-seed bed + reduce spacing up to 25% + mulch with rice straw+1 hand-weeding at 50 DAT which was statistically at par with the T1- hand-weeding at 25 and 50 DAT and significantly superior over other weed management practices. This might be due to increase in panicle length, number of grains panicle-1, tillers as well as rate of dry matter accumulation. These results are corroborated with the findings of Singh and Guru (2011), Choudhary *et al.,* (2021), Uno *et al.,* 2021, Liu *et al.,* (2023), and Nalayini *et al.,* (2023).

**Table 2: Effect of treatments on yield and economics of transplanted rice in organic production system**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment | Biological yield (t ha-1) | Grain yield(t ha-1) | Straw yield(t ha-1) | Gross return(₹ ha-1) | Net return(₹ ha-1) | B: C Ratio |
| T1: Hand-weeding at 25 and 50 DAT | 7.00 | 3.18 | 3.82 | 63600 | 28964 | 0.83 |
| T2: ITK treatment on weed control practiced by farmer as mulching with *Cassia tora* | 5.06 | 2.11 | 2.95 | 42795 | 11759 | 0.37 |
| T3: Intercropping with Dhaincha (*Sasbania aculeate*) | 5.48 | 2.46 | 3.02 | 49370 | 17934 | 0.57 |
| T4: Stale-seed bed+reduce spacing up to 25%+mulch with rice straw+one hand-weeding at 50 DAT | 7.35 | 3.39 | 3.96 | 67518 | 33907 | 1.01 |
| T5: Locally available weed mulch-*kanss*+one hand pulling  | 5.76 | 2.60 | 3.16 | 52079 | 19243 | 0.58 |
| T6: Incorporation of neem cake 15 days before transplanting @ 2 t ha-1 +one hand-weeding  | 6.11 | 2.76 | 3.35 | 54977 | 15441 | 0.39 |
| T7: Without weed control | 4.43 | 1.81 | 2.62 | 37445 | 7009 | 0.23 |
| SEm± | 0.26 | 0.13 | 0.12 | - | - | - |
| C.D (*p*≤0.05) | 0.87 | 0.39 | 0.36 | - | - | - |

 On the basis of data (Table 2) higher gross returns (67518 ₹ ha-1) was obtained in T4- stale-seed bed + reduce spacing up to 25%+mulch with rice straw+1 hand-weeding at 50 DAT, which was higher than other treatments. This might be owing to more seed yield and less weeds infestation. Net returns was influenced due to various weed management practices. The higher net return (33906.50 ₹ ha-1) was observed in T4- stale-seed bed+reduce spacing up to 25%+mulch with rice straw+1 hand-weeding at 50 DAT and the lowest in T7- Without weed control. The highest value (1.01) of B: C ratio was obtained with T4- stale-seed bed+reduce spacing up to 25%+mulch with rice straw+one hand-weeding at 50 DAT which was closely followed by T1- hand-weeding at 25 and 50 DAT. This might be due lower cost of cultivation and higher net return. All these above treatments were most effective weed control treatments recorded higher yield and weed control efficiency, and recorded higher benefit: cost ratio. Similar findings were reported by Choudhary *et al.,* (2021), Dhaigude *et al.,* (2021), and Nalayini *et al.,* (2023).

**4. Conclusion**

It is extremely difficult to manage weeds in organic production systems especially in rice crops. Resulting from the present investigation, we may conclude that the stale-seed bed+reduced spacing up to 25%+mulching with rice straw+1 hand-weeding at 50 days after transplanting was most effective at controlling the weeds and ultimately produced a more productive rice crop and proved to be more economically feasible than any other treatment. It achieved 87% higher grain yield as compared to without weed control treatment.

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**Competing interests**

Authors have declared that no competing interests exist.

**Disclaimer (Artificial intelligence)**

 Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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