**Effect of different establishment and weed management techniques on growth and yield of rice (*Oryza sativa L.*) under irrigated condition**

**ABSTRACT**

During the *Kharif* season of 2018, a field experiment was conducted at the Agronomy Research Farm of Narendra Deva University of Agriculture and Technology (Kumarganj), Ayodhya, Uttar Pradesh, to assess the impact of various crop establishment methods and weed management techniques on growth and yield of rice. The experiment included three rice establishment methods i.e., transplanting, drum seeding, and direct seeding along with five weed management techniques i.e., pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 at 5 days after sowing (DAS) or transplanting (DAT), chlorimuron-ethyl + Metsulfuron-methyl @ 4 g ha-1 at 10 DAS/DAT, bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT, hand weeding twice at 20 and 40 DAS/DAT, and weedy check. These treatments were arranged in a Factorial Randomized Block Design with three replications, forming fifteen treatment combinations. According to the findings, the transplanting method of rice establishment considerably improved growth metrics such as plant height, number of tillers m-2, leaf area index, and dry matter accumulation at all development stages except 30 days. It also improved yield attributes, including the number of productive tillers, panicle length, grains panicle-1 and 1000-grains weight, leading to higher biological yield (9.71 t ha⁻¹), grain yield (4.78 t ha⁻¹), and straw yield (4.93 t ha-1) compared to the drum-seeded and direct-seeded methods for the NDR-2065 rice variety. Further, among the weed management techniques, two hand weeding applied at 20 and 40 DAS/DAT resulted in the best growth performance, with increased initial plant population, plant height, number of tillers, leaf area index and dry matter accumulation. This practice also led to improved yield attributes such as the number of productive tillers, grains panicle-1, panicle length, 1000-grains weight, biological yield (10.99 t ha-1), grain yield (5.41 t ha-1), straw yield (5.58 t ha-1) and harvest index (49.25%). Bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT, Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1, and chlorimuron-ethyl + Metsulfuron-methyl @ 4 g ha-1, in that order, were the next best-performing methods after manual weeding Twice. Thus, the combination of the transplanting method for rice establishment and two-handed weeding showed to be the most beneficial in terms of rice growth, yield characteristics, and total yield.

**Keyword:** Direct seeding, Drum seeding, Establishment methods, Rice, Transplanting, Weed management

**INTRODUCTION**

Nearly half of Asia's population relies on rice (*Oryza sativa* L.) for calories, and over half of the world's population eats it as a staple diet. Asia is home to 60% of the world's population and produces and consumes more than 90% of the world's rice. Because of the increasing population's desire for food, rice will continue to be the primary food source. The productivity of rice ecosystems is crucial to India's food security system since rice is the primary crop grown there (Jat *et al.,* 2020). In India, there are 47.83 million hectares of rice planted, and 135.76 million tons were produced, with a productivity of 2838 kg ha-1. (Anonymous, 2023).

The primary technique for producing rice in Asia is the manual transplantation of seedlings into puddled soil. Puddling, which involves cultivating soil in standing water, uses a lot of water (Chauhan *et al.,* 2015a; Kalita *et al.,* 2020; Alam *et al.,* 2019), which can occasionally cause the soil's structure to deteriorate and negatively impact the next non-rice crop (Alam *et al.,* 2020; Reddy *et al.,* 2020). Dry seeding has been shown to be an effective method for growing rice in a number of experiments conducted in China (Wang *et al.,* 2021; Tian *et al.,* 2022), South Asia (Mohanta *et al.,* (2021); Chaudhary *et al.*, 2023), and Australia (Champness *et al.*, 2023). In order to increase or sustain economic output and alleviate issues with soil degradation, direct-seeded rice (DSR) has been created as an alternate way of rice establishment that requires fewer workers and other materials (Sandhu *et al.,* 2021; Chaudhary *et al.*, 2023). An alternative to traditional transplanting that shows promise is drum seeding, especially in regions with water and labor shortages. However, its success depends on effective weed management and proper field preparation (Sudharani *et al.,* 2019)

Weed flora composition varies greatly among agricultural cropping systems. These alterations occurred from selection pressures exerted by modifications and advancements in agricultural methods, which changed weed habitats to some extent (Clements and Jones, 2021). Weed flora varies depending on the rice establishment method employed. In conventional-till DSR systems, a variety of perennial weed species [*Paspalum distichum* L., *Cynodon dactylon* (L.) Pers., *Cyperus rotundus* L.], annual grasses (*Ischaemum rugosum* Salisb.), and annual sedges [*Cyperus difformis* L. and *Fimbristylis miliacea* (L.) Vahl] were discovered (Raj *et al.,* 2022;Kumar *et al.,* 2023). In the same study, reduced growth of perennial weeds (*C. dactylon*, *P. distichum*, and *C. rotundus*) and annual weeds (*I. rugosum* and *F. miliacea*) were detected in the zero till DSR system than in the conventional-till DSR system (Chauhan et al., 2015a; Shrestha *et al.*, 2021; Raj *et al.,* 2022). Weed management employs weed control strategies that, on the one hand, do not enable weeds to exceed yield losses above the economic threshold level while also having no negative effects on various agro-ecosystems. Herbicides, on the other hand, are regarded as the most effective and cost-efficient weed control method. Herbicides can be administered either pre-emergence (PRE) or post-emergence (POST), however PRE herbicides are preferable in DSR systems. PRE herbicides such as oxadiazon, oxadiargyl, pendimethalin, pyrazosulfuron, pretilachlor, butachlor, and clomazone are currently accessible globally and have been reported to give a fair degree of weed control (Chauhan *et al.*, 2015b; Pervaiz *et al.,* 2024). Taking this into account, the current study sought to determine an ideal rice establishment methods in conjunction with an efficient weed control techniques.

**MATERIALS AND METHODS**

At the Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, which is situated between 24.4° North latitudes and 82.10° East longitudes, with an elevation of roughly 113 meters mean sea level, the field experiment was carried out during the *Kharif* season of 2018. The area has a sub-tropical climate with exceptional humidity. The soil of experimental field was silty loam in texture, basic in reaction (pH 8.1), and electrical conductivity of 0.28 mm hos/cm, low in organic carbon (0.43%), available nitrogen (200.45 kg ha-1), available phosphorous (18.40 kg ha-1), and high in available potassium (295.35 kg ha-1). The experiment consisted of three rice establishment methods, *viz;* transplanting, drum seedig and direct-seedig and five weed management techniques, *viz;* pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 applied at 5 days after sowing (DAS)/days after transplanting (DAT), chlorimuron-ethyl + Metsulfuron-methyl @ 4 g ha-1 applied at 10 DAS/DAT, bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT, Hand weeding twice at 20 and 40 DAS/DAT and weedy check, making fifteen treatment combinations which were assigned in a Factorial Randomized Block Design (FRBD) and replicated thrice. The paddy variety NDR-2065 was sown on 6th July 2018, transplanted on 30th July 2018 and crop was harvested on 15th November 2018. The prescribed fertilizer dose was 120 kg nitrogen, 60 kg phosphorous, and 60 kg potassium ha-1, which were distributed equally across each plot. The initial plant population m-2 was recorded at 15 DAS/DAT, plant height, number of tillers m-2, dry matter accumulation, at different growth stages of rice crop. Leaf area index was computed by using the formula as given by yosihida *et al.* (1972). Yield contributing characters like productive tillers, panicle length, number of grains panicle-1,biological yield, straw yield as well as grain yield were recorded at harvest. Harvest index was calculated by using the following formula:

Harvest index =

Where, biological yield= grain yield + straw yield

**RESULTS AND DISCUSSION**

**Weed flora composition**

Weed flora of the experimental field were collected, identified and classified as grassy, broad leaved weeds (BLWs) and sedges and presented in Table 1.

Table 1: **Weed flora of the experimental field**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S. No.** | **Weed species** | **Common Name** | **Family** | **Habitat** |
| **Grassy weeds** | | | | |
| 1. | *Echinochloa crusgalli* L. | Barnyard grass, Samaghas | Poaceae | Annual |
| 2. | *Echinochloa colona* L. | Jungli rice, Sawan | -- | -- |
| 3. | *Panicum maximum* L. | Jheerua | -- | -- |
| 4. | *Eleusine indica* | Makra | Poaceae | Annual |
| **Broad leaf weeds** | | | | |
| 5. | *Commelina benghalensis* L. | Day flower | Commelinaceae | Annual |
| 6. | *Eclipta alba* | Bhangra | Compositae | -- |
| 7. | *Ludwigia parviflora* | Water-primrose | Onagraceae | Annual |
| 8. | *Caesulia axillaries* | Pink node flower | Asteraceae | Annual |
| **Sedges** | | | | |
| 9. | *Cyperus* *esculentus* L. | Yellow nut grass | Cyperaceae | Annual/ Perennial |
| 10. | *Cyperus* *difformis* L. | Small flower | Cyperaceae | Annual |
| 11. | *Cyperus rotundus* L | Java grass, coco grass | Cyperaceae | Perennial |

**Effect of rice establishment methods**

The rice establishment methods showed significant effect on growth parameters (Table 2), *viz;* plant height, number of tillers m-2, leaf area index, dry matter accumulation. Transplanting method recorded more plant height (79.90 cm), number of tillers (310.77 m-2), leaf area index (4.65), dry matter accumulation (950.33 g m-2) over direct seeding method but being at par with drum seeding method. While initial plant population did not affected significantly due to different establishment methods. Numerically the maximum plant population (52.60 m-2) was found under transplanting and lowest (52.04 m-2) was recorded under direct seeded. The plant population remained statistically unaffected due to uniform seed rate across methods, the transplanting method's superiority in plant height, tiller number, leaf area index, and dry matter accumulation is attributed to better seedling establishment, reduced early weed competition, and efficient nutrient uptake. The results of this study are consistent with those of Netam *et al.* (2018), Bhagavathi *et al.* (2020), Mohanta *et al.* (2021), and Saha *et al.* (2021).

**Table 2: Effect of different establishment and weed management techniques on growth parameters of rice**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatment** | **Initial plant population**  **(m-2)** | **Plant height (cm)** | **Number of tillers (m-2)** | **Leaf Area Index** | **Dry matter accumulation**  **(g m-2)** |
| **Methods of rice establishment (M)** | | | | | |
| Transplanting | 52.60 | 79.90 | 310.77 | 4.65 | 950.33 |
| Drum seeded | 52.26 | 76.33 | 295.18 | 4.41 | 903.34 |
| Direct seeded | 52.04 | 72.47 | 279.59 | 4.22 | 858.13 |
| SEm± | 0.95 | 1.38 | 5.38 | 0.08 | 16.42 |
| LSD (P=0.05) | NS | 4.03 | 15.65 | 0.23 | 47.82 |
| **Weed management techniques (W)** | | | | | |
| Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 | 52.35 | 75.01 | 298.47 | 4.33 | 954.34 |
| chlorimuron-ethyl + Metsulfuron-methyl @ 4 g ha-1 | 51.39 | 73.82 | 293.62 | 4.29 | 935.15 |
| Bispyribac sodium @ 25 g ha-1 | 52.98 | 80.93 | 319.65 | 4.65 | 1037.33 |
| Hand weeding | 53.67 | 86.47 | 343.90 | 4.99 | 1112.77 |
| Weedy check | 51.11 | 64.94 | 220.27 | 3.86 | 480.06 |
| SEm± | 1.23 | 1.79 | 6.94 | 0.10 | 21.20 |
| LSD (P=0.05) | NS | 5.20 | 20.21 | 0.30 | 61.73 |
| Interaction (M×W) | NS | NS | NS | NS | NS |

Different crop establishment methods exhibited significant influence on all the yield attributes studied (Table 3). Among them, transplanting method produced higher yield contributing characters *viz;* number of productive tillers (294.09 m-2), panicle length (22.92 cm), number of grains panicle-1 (100.01) over direct seeded, however it was at par with the drum seeded. This might be due to better seedling vigor, less intra-plant competition, and effective resource use in the transplanting method. The results are consistent with the findings of Tao *et al.* (2016), Bhagavathi *et al.* (2020), Mohanta *et al.,* (2021), and Saha *et al.* (2021).While 1000-grains weight did not influence significantly due to establishment methods but numerically maximum value (22.57 g) was recorded under transplanting and as a minimum (22.02 g) was found under direct seeding method. 1000-grains weight was unaffected because it is mostly determined by genetic variables rather than establishment techniques. Bhagavathi *et al.* (2020), Mohanta *et al.* (2021), Jehangir *et al.* (2021), and Saha *et al.* (2021) observed similar findings.

The crop's growth and yield features have a direct impact on grain and straw production. The various rice establishment methods showed significant impact on rice yield (Table 4) *viz;* biological yield, grain yield, and straw yield. The transplanting method being recorded higher biological yield (9.71 t ha-1), grain yield (4.78 t ha-1), and straw yield (4.93 t ha-1) over direct seeded rice. While drum seeding method of rice establishment being recorded at par with both of the treatment. The percentage increment over drum seeding of 7.43%, 4.87% and direct seeding of 13.27%, 10% in grain and straw yield, respectively during the year of investigation. Although harvest index did not significantly influenced by various methods of establishment but numerically highest value (49.10 %) was found under transplanting and lowest value (48.04 %) was found under direct seeding method. The transplanting method's increased grain, straw, and biological yields are ascribed to improved growth and yield features brought about by improved crop establishment, increased tillering capacity, and effective nutrient uptake. Direct seeding produced lower yields because of increased early weed competition and less-than-ideal root development, whereas drum seeding performed similarly to transplanting in terms of plant stand and resource usage. The result were in co-ordination with earlier finding of Kumar *et al.* (2018), Bhagavathi *et al.* (2020), Mohanta *et al.,* (2021), Jehangir *et al.* (2021), Saha *et al.* (2021) and Pratap *et al*. (2023).

**Effect of weed management techniques**

Growth characteristics such as plant height, number of tillers m-2, leaf area index, and dry matter accumulation represent the process of effective resource use in a more productive agricultural situation. Dramatic variation in growth parameters of rice was noticed due to different weed control techniques (Table 2). Two-hand weeding produced the tallest plant (86.47 cm), the maximum tillers (343.90 m-2), the highest dry matter accumulation (1112.77 g m-2), and the maximum leaf area index (4.99). These results were noticeably better than those of the other treatments. After that, bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT was administered. In contrast to all other weed management techniques, the weedy check treatment produced noticeably shorter plants (64.94 cm), fewer tillers (220.27 m⁻²), minimum leaf area index (3.86), and the least amount of dry matter accumulation (480.06 g m⁻²). The initial plant population did not influenced significantly due to various weed management techniques but numerically highest was recorded under manual weeding twice at 20 and 40 DAS/DAT (53.67) followed by bispyribac-sodium @ 25 g ha-1 at 30 DAS/DAT (52.98) and lowest was observed under weedy check (51.11). Effective weed management lowers competition for vital resources like nutrients, water, and sunlight, increasing plant vigor and biomass accumulation. This is why the maximum growth parameters were seen during the two hand weeding sessions. Due to intense competition from weeds, crop development was inhibited and resource availability was restricted, resulting in noticeably lower values in the weedy check. The findings align with the findings of Kumar *et al.* (2018), Bhagavathi *et al.* (2020), and Choudhary *et al.* (2022).

**Table 3: Effect of different establishment and weed management techniques on yield contributing characters of rice**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Productive Tiller**  **(No. m-2)** | **Panicle Length**  **(cm)** | **No. of grains panicle-1** | **1000-grains weight (g)** |
| **Methods of rice establishment (M)** | | | | |
| Transplanting | 294.09 | 22.92 | 100.01 | 22.57 |
| Drum seeded | 280.10 | 21.80 | 96.03 | 22.20 |
| Direct seeded | 267.29 | 20.67 | 91.10 | 22.02 |
| SEm ± | 5.11 | 0.39 | 1.75 | 0.40 |
| LSD (P=0.05) | 14.87 | 1.15 | 5.10 | NS |
| **Weed management techniques (W)** | | | | |
| Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 | 283.79 | 21.42 | 94.04 | 22.34 |
| Chlorimuron-ethyl + Metsulfuron-methyl @ 4 g ha-1 | 279.14 | 20.59 | 92.40 | 21.38 |
| Bispyribac sodium @ 25 g ha-1 | 304.50 | 23.41 | 103.49 | 22.96 |
| Hand weeding | 329.85 | 25.01 | 112.44 | 23.57 |
| Weedy check | 205.18 | 18.54 | 76.19 | 21.07 |
| SEm ± | 6.59 | 0.51 | 2.26 | 0.52 |
| LSD (P=0.05) | 19.20 | 1.48 | 6.58 | 1.52 |
| Interaction (M×W) | NS | NS | NS | NS |

The yield contributing characters such as productive tillers, number of grains panicles-1 and panicle length were influenced significantly with different weed management techniques (Table 3). Among various weed management techniques, hand weeding twice recorded significantly higher value of these yield contributing characters followed by bispyribac-sodium @ 25 g ha-1 applied at 30 DAS/DAT, these were statistically at par with each other while significantly superior over Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1, chlorimuron-ethyl + Metsulfuron-methyl @ 4 g ha-1 and thereafter weedy check. Numerous weed management techniques did not significantly affect the weight of 1000 grains; however, hand weeding twice applied at 20 and 40 DAS/DAT produced the highest 1000-grains weight (23.57 g), followed by bispyribac-sodium @ 25 g ha-1 applied at 30 DAS/DAT (22.96 g), and weedy check produced the lowest 1000-grains weight (21.07 g). Due to efficient weed removal, which reduced competition for nutrients, water, and light, hand weeding twice improved tiller production, panicle length, and grain formation, all of which led to greater yield qualities. Since 1000-grains weight is mostly determined by the rice variety's genetic potential rather than weed control techniques, it remained statistically unaltered. These findings are in agreement with the results reported by Kumar *et al.* (2018), Bhagavathi *et al.* (2020), Mohanta *et al.* (2021), Jehangir *et al.* (2021), Saha *et al.* (2021), and Choudhary *et al.* (2022).

The biological, grain yield and straw yield varied significantly with various weed management techniques (Table 4). Two hand weeding applied at 20 and 40 DAS/DAT achieved significantly higher biological yield (10.99 t ha-1), grain yield (5.41 t ha-1) and straw yield (5.58 t ha-1) followed by bispyribac-sodium @ 25 g ha-1 applied as post emergence alone at 30 DAS/DAT over rest of weed management techniques. The percentage increment of hand weeding over Pyrazosulfuron-ethyl was 14.26%, 12.89%, chlorimuron-ethyl + Metsulfuron-methyl was 17.72%, 16.62%, bispyribac-sodium was 6.19%, 7% and weedy check of 111.15%, 85.68% in grain and straw yield, respectively. The percentage increment of bispyribac-sodium over Pyrazosulfuron-ethyl was 7.59%, 5.50%, chlorimuron-ethyl + Metsulfuron-methyl was 10.85%, 8.99%, and weedy check was 98.82%, 73.53% in grain and straw yield, respectively. The lowest biological yield (5.57 t ha-1), grain yield (2.57 t ha-1) and straw yield (3.00 t ha-1) were recorded under weedy check. While harvesting index did not significantly influenced by various weed management techniques but numerically highest value (49.43 %) was given by bispyribac-sodium @ 25 g ha-1 applied at 30 DAS/DAT and lowest value (45.79 %) was found under weedy check. Due to efficient weed removal that reduces competition for nutrients, water and light, the superior yields achieved with two hand weeding applied at 20 and 40 DAS/DAT improve crop growth and yield characteristics. High yields were also demonstrated with bispyribac-sodium @ 25 g ha-1 applied at 30 DAS/DAT, which successfully suppressed weeds during the crucial growth periods and lessened their negative effects. Due to intense weed competition, which inhibited crop development, decreased nutrient availability, and impeded biomass buildup, the weedy check had the lowest yield. Bhagavathi *et al.* (2020), Jehangir *et al.* (2021), Mohanta *et al.* (2021), Saha *et al.* (2021), and Choudhary *et al.* (2022) all arrived to similar conclusions.

**Table 4: Effect of different establishment and weed management techniques on yield of rice**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Grain yield**  **(t ha-1)** | **Biological yield**  **(t ha-1)** | **Straw yield**  **(t ha-1)** | **Harvest index**  **(%)** |
| **Methods of rice establishment (M)** | | | | |
| Transplanting | 4.78 | 9.71 | 4.93 | 49.10 |
| Drum seeded | 4.45 | 9.15 | 4.70 | 48.32 |
| Direct seeded | 4.22 | 8.70 | 4.48 | 48.04 |
| SEm± | 0.08 | 0.17 | 0.09 | 0.88 |
| LSD (P=0.05) | 0.24 | 0.48 | 0.25 | NS |
| **Weed management techniques (W)** | | | | |
| Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 | 4.74 | 9.68 | 4.94 | 48.95 |
| chlorimuron-ethyl + Metsulfuron-methyl @ 4 g ha-1 | 4.60 | 9.38 | 4.78 | 49.02 |
| Bispyribac sodium @ 25 g ha-1 | 5.10 | 10.31 | 5.21 | 49.43 |
| Two hand weeding | 5.41 | 10.99 | 5.58 | 49.25 |
| Weedy check | 2.57 | 5.57 | 3.00 | 45.79 |
| SEm± | 0.10 | 0.21 | 0.11 | 1.14 |
| LSD (P=0.05) | 0.30 | 0.62 | 0.32 | NS |
| Interaction (M×W) | S | NS | S | NS |

**Effect of interaction**

The interaction effect between different establishment methods and weed management techniques led to significant variations in grain and straw yields (Table 5 and 6), while growth attributes and yield-contributing characteristics remained unaffected. The highest grain yield (5.62 t ha⁻¹) and straw yield (5.79 t ha⁻¹) were achieved by the application of hand weeding at 20 and 40 DAS/DAT in transplanted rice. This was followed by two hand weeding in drum seeded rice, post emergence application of bispyribac sodium @ 25 g ha⁻¹ in transplanted rice, two hand weeding in direct seeded rice, and post emergence application of bispyribac sodium @ 25 g ha⁻¹ in drum seeded rice, all of which were statistically at par and significantly superior to other treatment combinations. Conversely, the lowest grain yield (1.84 t ha⁻¹) and straw yield (2.30 t ha⁻¹) were recorded with the weedy check treatment in direct seeded rice.

**Table 5: Interaction effect of different establishment and weed management techniques on grain yield of rice**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Grain yield (t ha-1)** | | | | | |
| **Treatments** | Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 | Almix @ 4 g ha-1 | Bispyribac sodium @ 25 g ha-1 | Two hand weeding | Weedy check |
| Transplanting | 4.90 | 4.72 | 5.30 | 5.62 | 3.36 |
| Drum seeded | 4.70 | 4.58 | 5.09 | 5.38 | 2.49 |
| Direct seeded | 4.62 | 4.49 | 4.91 | 5.24 | 1.84 |
| SEm± | 0.18 | | | | |
| LSD (P=0.05) | 0.53 | | | | |

**Table 6: Interaction effect of different establishment and weed management techniques on straw yield of rice**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Straw yield (t ha-1)** | | | | | |
| **Treatments** | Pyrazosulfuron-ethyl 10% WP @ 30 g ha-1 | Almix @ 4 g ha-1 | Bispyribac sodium @ 25 g ha-1 | Two hand weeding | Weedy check |
| Transplanting | 5.00 | 4.83 | 5.29 | 5.79 | 3.75 |
| Drum seeded | 4.99 | 4.83 | 5.24 | 5.49 | 2.96 |
| Direct seeded | 4.84 | 4.69 | 5.11 | 5.45 | 2.30 |
| SEm± | 0.19 | | | | |
| LSD (P=0.05) | 0.55 | | | | |

This might be because the transplanting method promotes better root establishment, which leads to efficient nutrient and water uptake, whereas hand weeding reduces weed competition, maximizing yield potential. Bispyribac sodium and hand weeding effectively controlled weeds, preventing them from competing with rice plants for essential resources, resulting in significantly higher grain and straw yields. Bhagavathi *et al.* (2020), Jehangir *et al.* (2021), Mohanta *et al.* (2021), Saha *et al.* (2021), and Choudhary *et al.* (2022) all arrived to similar conclusions.

**CONCLUSION**

In comparison to other crop establishment and weed management techniques, the transplanting method of rice establishment combined with two hand weeding applied at 20 and 40 DAS/DAT was the most successful in encouraging the development and production of the rice crop, according to the results of the one-year trial.

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Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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