



# Yield of Blackgram as Influenced by Residual Effects of Crop Establishment Methods and Weed Management Practices in Rice

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## ABSTRACT

**Background:** The performance of rice fallow black gram is strongly influenced by prevailing soil conditions and the residual effects of weed management practices adopted in the preceding rice crop. Herbicide residues and changes in soil properties resulting from different rice establishment methods can influence the germination, growth and yield of the succeeding black gram crop. The impacts of weed management techniques and rice crop establishment techniques on crop performance and weed control effectiveness on the subsequent black gram were assessed in this study.

**Methods:** The study was conducted at Tamil Nadu Rice Research Institute, Tamil Nadu Agricultural University, Aduthurai (11°01'N, 79°48'E, 19.5 MSL.), Tamil Nadu, India. Three techniques for rice establishment were used in the split-plot design of the field trial, viz, dry direct-seeded rice, drum seeding and non-puddled transplanted rice (NPTR) - as main plots and seven weed management practices as subplots. In addition to the growth and yield characteristics of the subsequent black gram, weed dry weight and weed control efficiency (WCE) were measured at 60 DAS. Each treatment's crop was collected and threshed independently and the yield for each plot was measured.

**Result:** The results showed that weed dry weight and WCE were significantly affected by rice establishment techniques and weed control strategies. Among establishment methods, NPTR recorded lower weed dry weight and higher WCE compared to dry direct seeding. The maximum black gram seed yield was attained under pendimethalin followed by Florypyrauxifen-benzyl + cyhalofop-butyl, indicating the absence of adverse residual effects of herbicides, whereas the weedy check resulted in poor growth and yield. The study concluded that non-puddled transplanted rice (NPTR) combined with integrated herbicide-based weed management is an efficient and sustainable option for effective weed control in rice and enhanced productivity of rice fallow black gram.

**Key words:** Herbicides, Rice, Succeeding Blackgram, Weed control efficiency, Weed dry weight.

## INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population and plays a critical role in food and livelihood security, particularly in Asia (Asma *et al.*, 2023; Bishwajit *et al.*, 2013). Rice is grown on around 165 million hectares worldwide, with an annual production of more than 780 million tons, with India being among the main producers and consumers (Glauber and Mamun, 2024). Rice covers around 44 million hectares in India, playing an important role in national food security and rural employment (Debnath *et al.*, 2018). However, increasing water scarcity, rising labour costs and climate variability have prompted the use of alternative rice establishment methods to maintain production.

Different rice establishment methods such as dry direct-seeded rice, drum-seeded rice and non-puddled transplanted rice are being increasingly evaluated as alternatives to conventional puddled transplanting due to their potential to save water, labour and energy (Bhatt and Kukal, 2015; Nandini *et al.*, 2025). However, changes in establishment techniques significantly influence weed flora, weed dynamics and crop-weed competition, often making weed management more complex and critical to achieving optimum yields (Ameena *et al.*, 2025; Mehdizadeh *et al.*, 2025).

Weeds are one of the most severe biological constraints in rice cultivation, causing yield losses of 15 to

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50% depending on the establishment method, weed density and control practices. Effective weed management, including the use of pre- and post-emergence herbicides, mechanical methods and integrated approaches, is therefore critical for increasing rice productivity (Liang *et al.*, 2025). At the same time, the indiscriminate or frequent use of herbicides raises concerns about their persistence in soil and potential residual effects on subsequent crops, particularly in rice-based cropping systems (Shah *et al.*, 2025).

In several regions of India, rice fallow blackgram (*Vigna mungo* L.) is a significant pulse crop that is grown after rice, helping to improve soil fertility, protein availability and agricultural profitability. The success of blackgram in rice fallows is largely dependent on soil conditions and the residual impact of weed management measures used in the preceding rice crop. Herbicide residues and altering soil conditions caused through different rice establishment methods can affect the germination, growth and yield of the subsequent blackgram crop (Verma *et al.*, 2025). The performance of subsequent crops in rice-based systems is greatly impacted by the residual effects of crop arrangement techniques and weed control. Effective weed suppression and reduced weed seed bank create favorable conditions for crops like blackgram. Improved nutrient availability and soil conditions further enhance growth and yield. Thus, integrating suitable establishment techniques with efficient weed management is crucial for sustaining productivity and improving weed control efficiency in succeeding crops (Suryabhan *et al.*, 2025).

In this regard, the current study was conducted to evaluate the effects of different weed control and rice establishment techniques on rice yield and growth, as well as any residual effects on rice fallow blackgram. The study aims to uncover optimum combinations that ensure effective weed management in rice without negatively influencing the performance of the subsequent blackgram crop, thus enabling sustainable and profitable rice-pulse cropping systems.

## MATERIALS AND METHODS

During the 2024 *khari* season, a field experiment was conducted at the Tamil Nadu Rice Research Institute in Aduthurai, Thanjavur district, Tamil Nadu. The experimental site was situated in Tamil Nadu's Cauvery Delta Zone at 11°N latitude, 79°E longitude and 19.5 meters above mean sea level (MSL). The mean annual rainfall is approximately 1190.2 mm, predominantly received during the Northeast monsoon. The mean temperature is 24.6°C at the minimum and 33.8°C at the maximum. The experimental site had an alluvial clay soil texture with soil pH about 7.5. Rice variety ADT 58 was cultivated during the Thaladi season, followed by blackgram variety ADT 6 as the succeeding crop.

Three main plots and seven subplots made up the split-plot design used for the experiment, with each plot measuring 5 m × 4 m. The rice variety ADT 58 was assigned to the main plots with three establishment methods:

M<sub>1</sub>-Dry direct seeded rice, M<sub>2</sub>- Drum-seeded rice and M<sub>3</sub>- Non-puddled transplanted rice. The succeeding crop was blackgram variety ADT 6, having a crop duration of 70 days. The treatment imposed were S<sub>1</sub>- Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 6.7.5 g/ha (EPoE), S<sub>2</sub>- Pendimethalin @ 1.0 kg a.i/ha (PE) fb Floryprauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE), S<sub>3</sub>- Pendimethalin @1.0 kg ai/ha (PE) fb Cono weeding, S<sub>4</sub>- Pretilochlor @ 0.75 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG 67.5 g/ha (EPoE), S<sub>5</sub>- Pretilochlor @ 0.75 kg a.i/ha (PE) fb Floryprauxifen- benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec. 160 g a.i/ha (EPoE), S<sub>6</sub>- Pretilochlor @ 0.75 kg a.i/ha (PE) fb Cono weeding, S<sub>7</sub>- Weedy check.

A shallow water depth of 2 cm was maintained up to 7 days after sowing (DAS) to ensure proper seedling establishment. During the subsequent crop growth period, a water depth of 5 cm was consistently maintained. Irrigation was discontinued 10 days prior to harvest.

Weed management practices were implemented according to the treatment schedule. A high-volume sprayer with a flat-fan nozzle was used to apply herbicides and the amount needed was determined by calculating the area of each experimental plot.

The data on weed parameters were recorded *viz*, weed species, weed dry weight (g m<sup>-2</sup>) and weed control efficiency (%). The following blackgram parameters were measured: plant height (cm), number of pods/plant and seed yield (kg ha<sup>-1</sup>). Weed control efficiency was calculated using 60 DAS and expressed as the percentage reduction in weed owing to weed management measures against control.

Numerous weed species, including grasses, sedges and broad-leaved weeds, were present in the experimental plot. Among the grassy weeds, *Echinochloa colona*, *Echinochloa crus-galli* and *Leptochloa chinensis* were the most prevalent. The dominant sedge species identified were *Cyperus difformis* and *Fimbristylis miliacea*, while *Eclipta prostrata* were the most commonly observed broad-leaved weeds.

### Weed dry weight

The quadrant was randomly put in four separate spots within each plot and all weeds that fell within the frame were carefully removed. After being completely cleaned and shade-dried, the collected weed samples were put in a hot air oven set at 70±5°C until they reached a consistent weight. The final weed dry matter was recorded and expressed in kg ha<sup>-1</sup>.

### Weed control efficiency (%)

The methods suggested by Mani *et al.* (1973) was used to calculate weed control efficiency (WCE).

$$\text{WCE\%} = \frac{\text{Dry weight of weeds in the weedy check} - \text{Dry weight of weeds in the treated plot}}{\text{Dry weight of weeds in the weedy check}} \times 100$$

### Succeeding black gram

Herbicides applied on rice had no substantial effect on the growth and establishment of blackgram. There was no significant difference in plant height at the harvest stage between treatments.

## RESULTS AND DISCUSSION

### Weed dry weight (g m<sup>-2</sup>)

Various methods of weed control significantly reduced weed dry weight at 60 DAS in NPTR and DSR. The details of weed dry weight were provided in the Table 1.

The minimum weed dry weight in mainplot is 19.97 g at 60 DAS recorded under M<sub>2</sub> (Drum seeding) and which is on par with 20.95 g m<sup>-2</sup> recorded under M<sub>3</sub> (NPTR). The maximum weed dry weight of 23.16 g were recorded in M<sub>1</sub> (Dry direct seeded rice).

Among the weed management practices at 60 DAS, Pendimethalin @ 1.0 kg a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE), (S<sub>2</sub>) recorded a lower weed dry weight of 4.96 g m<sup>-2</sup>, which is followed by Pretilochlor @ 0.75 kg a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec. 160 g a.i/ha (EPoE), (S<sub>5</sub>) is 11.0 g m<sup>-2</sup> and which is on par with Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE), (S<sub>1</sub>) with recorded value of 10.62 g. the higher weed

dry weight of 50.14 g m<sup>-2</sup> were recorded in Weedy check (S<sub>7</sub>). Kaur *et al.* (2025) stated that application of a premix herbicide containing florypyrauxifen-benzyl and cyhalofop-butyl as a post-emergence treatment effectively controlled major weed species such as *Echinochloa crusgalli* and *Cyperus iria* in the direct-seeded rice (DSR) production system. This efficient weed management significantly contributed to improved crop growth and resulted in higher grain yield of rice.

### Weed control efficiency (%)

Different rice establishment procedures and weed management approaches had a substantial influence on weed control efficiency (WCE), as shown in Table 2. Among the crop establishment methods, non-puddled transplanted rice (M<sub>3</sub>) recorded the highest mean weed control efficiency (73.24%), followed by dry direct seeded rice (M<sub>1</sub>) with 65.70%. The lowest mean WCE (59.95%) was observed under drum seeding in puddled field (M<sub>2</sub>).

Among the weed management practices, Pendimethalin @ 1.0 kg a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE), (S<sub>2</sub>) registered the highest weed control efficiency, with values of 93.64%, 82.54% and 92.30% under M<sub>1</sub>, M<sub>2</sub> and M<sub>3</sub>, respectively. This treatment recorded the highest mean WCE (89.49%), indicating its superior effectiveness in suppressing weeds across establishment techniques.

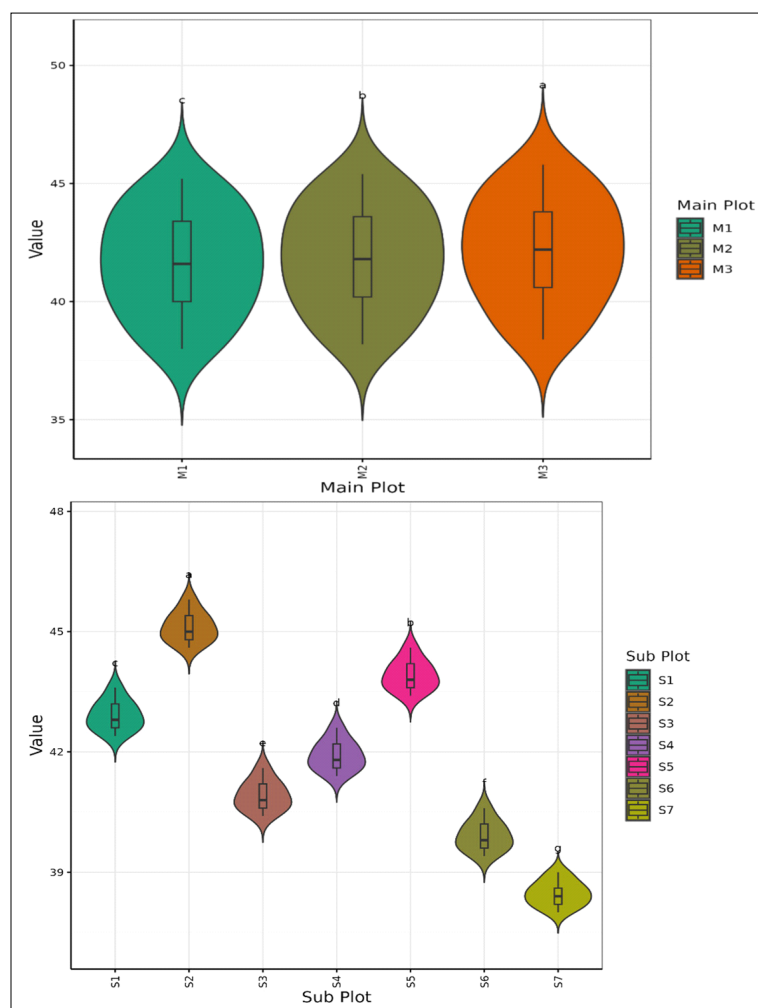
**Table 1:** Effect of rice establishment methods and weed management practices on weed dry weight (g m<sup>-2</sup>) in rice at 60 DAS.

| Main plot       |   |                                                                                                                            | WDW (g m <sup>-2</sup> )   |
|-----------------|---|----------------------------------------------------------------------------------------------------------------------------|----------------------------|
| M <sub>1</sub>  | - | Dry direct seed rice (Seed Drill)                                                                                          | 4.86 (23.16 <sup>a</sup> ) |
| M <sub>2</sub>  | - | Drum seeding (DSR)                                                                                                         | 4.52 (19.97 <sup>b</sup> ) |
| M <sub>3</sub>  | - | Non-puddled transplanted rice (NPTR)                                                                                       | 4.63 (20.95 <sup>b</sup> ) |
| SE.d            |   |                                                                                                                            | 0.51                       |
| CD (P = 0.05)   |   |                                                                                                                            | 1.42                       |
| Sub plot        |   |                                                                                                                            |                            |
| S <sub>1</sub>  | - | Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE)                            | 3.33 (10.62 <sup>e</sup> ) |
| S <sub>2</sub>  | - | Pendimethalin @ 1.0 kg a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE) | 2.34 (4.96 <sup>f</sup> )  |
| S <sub>3</sub>  | - | Pendimethalin @ 1.0 kg a.i/ha (PE) fb Cono weeding                                                                         | 5.03 (24.80 <sup>c</sup> ) |
| S <sub>4</sub>  | - | Pretilochlor @ 0.75 a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG 67.5 g/ha (EPoE)                                 | 4.44 (19.22 <sup>d</sup> ) |
| S <sub>5</sub>  | - | Pretilochlor @ 0.75 a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec.160 g a.i/ha (EPoE)    | 3.39 (11.00 <sup>e</sup> ) |
| S <sub>6</sub>  | - | Pretilochlor @ 0.75 a.i/ha (PE) fb Cono weeding                                                                            | 5.41 (28.80 <sup>b</sup> ) |
| S <sub>7</sub>  | - | Weedy check                                                                                                                | 7.12 (50.14 <sup>a</sup> ) |
| SE.d            |   |                                                                                                                            | 0.69                       |
| CD (P = 0.05)   |   |                                                                                                                            | 1.39                       |
| Main × Sub plot |   |                                                                                                                            |                            |
| SE.d            |   |                                                                                                                            | 1.19                       |
| CD (P = 0.05)   |   |                                                                                                                            | 2.41                       |

\*Figure in parentheses in the table indicated square root transformed value

**Table 2:** Effect of rice establishment methods and weed management practices on weed control efficiency (%) in rice at 60 DAS.

|                 |   | Main plot                                                                                                                                  | WCE (%) |
|-----------------|---|--------------------------------------------------------------------------------------------------------------------------------------------|---------|
| M <sub>1</sub>  | - | M <sub>1</sub> - Dry direct seed rice (seed drill)                                                                                         | 65.7    |
| M <sub>2</sub>  | - | M <sub>2</sub> - Drum seeding (DSR)                                                                                                        | 59.95   |
| M <sub>3</sub>  | - | M <sub>3</sub> - Non-puddled transplanted rice (NPTR)                                                                                      | 73.24   |
| <b>Sub plot</b> |   |                                                                                                                                            |         |
| S <sub>1</sub>  | - | S <sub>1</sub> - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE)                           | 180.05  |
| S <sub>2</sub>  | - | S <sub>2</sub> - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE) | 89.49   |
| S <sub>3</sub>  | - | S <sub>3</sub> - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Cono weeding                                                                        | 109.04  |
| S <sub>4</sub>  | - | S <sub>4</sub> - Pretilochlor @ 0.75 a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG 67.5 g/ha (EPoE)                                | 61.09   |
| S <sub>5</sub>  | - | S <sub>5</sub> - Pretilochlor @ 0.75 a.i/ha (PE) fb Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec. 160 g a.i/ha (EPoE)   | 77.29   |
| S <sub>6</sub>  | - | S <sub>6</sub> - Pretilochlor @ 0.75 a.i/ha (PE) fb Cono weeding                                                                           | 41.69   |
| S <sub>7</sub>  | - | S <sub>7</sub> - Weedy check                                                                                                               | 0       |

**Fig 1:** Violin plots showing the effect of rice establishment techniques on plant height of succeeding black gram.

This was followed by Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE), ( $S_1$ ) and Pretilachlor @ 0.75 kg a.i/ha (PE) fb Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec. 160 g a.i/ha (EPoE), ( $S_5$ ), which recorded moderate to higher weed control efficiency across all main plots. In contrast, cono weeding ( $S_3$ ) and pretilachlor alone ( $S_4$ ) resulted in comparatively lower WCE values.

The lowest weed control efficiency (0%) was consistently recorded under the weedy check ( $S_7$ ) across all establishment methods, indicating severe weed infestation due to the absence of weed control measures.

The interaction effect revealed that  $M_3S_2$  (Non-puddled transplanted rice combined with pendimethalin followed by florpyrauxifen-benzyl + cyhalofop-butyl) recorded the maximum weed control efficiency (92.30%), closely followed by  $M_1S_2$  (93.64%), highlighting the synergistic effect of effective establishment method and integrated herbicide application.

### Residual effects on succeeding blackgram

#### Plant height at harvest

The plant height of the subsequent black gram crop was significantly influenced by rice cultivation practices and weed management practices, as shown in Fig 1.

Among the rice establishment methods, Non-puddled transplanted rice ( $M_3$ ) produced the tallest plants with a mean height of 42.15 cm, which was significantly higher

than that of drum seeding in a puddled field  $M_2$  (41.84 cm) and dry direct-seeded rice  $M_1$  (41.64 cm).

Among the methods to manage weeds, Pendimethalin @ 1.0 kg a.i/ha (PE) fb Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE), ( $S_2$ ) recorded the maximum plant height of black gram, with values of 44.87 cm, 45.07 cm and 45.40 cm under  $M_1$ ,  $M_2$  and  $M_3$ , respectively. This treatment also recorded the highest mean plant height (45.11 cm), indicating its favorable residual effect on the growth of succeeding black gram.

This was succeeded by Pretilachlor 0.75 kg a.i ha<sup>-1</sup> (PE) fb Florpyrauxifen-benzyl + Cyhalofop-butyl ( $S_5$ ) and Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE), ( $S_1$ ), which recorded comparatively higher plant height across all crop establishment techniques. In contrast, cono weeding ( $S_3$ ) and pretilachlor alone ( $S_4$ ) resulted in shorter plant of black gram.

The minimum plant height of black gram was consistently recorded under the weedy check ( $S_7$ ) across all rice establishment methods, which may be attributed to intense weed competition during the preceding rice crop, leading to unfavourable residual soil conditions for the succeeding crop.

The combination of Non-puddled transplanted rice with pendimethalin 1.0 kg/ha followed by florpyrauxifen-benzyl + cyhalofop-butyl ( $M_3S_2$ ) produced the highest black gram plants (45.40 cm), further demonstrating the beneficial

**Table 3:** Number of pods per plant of black gram as influenced by residual effects of rice establishment techniques and weed management practices.

|                        |   | Main plot                                                                                                                         | Pods plant <sup>-1</sup> |
|------------------------|---|-----------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| $M_1$                  | - | $M_1$ - Dry direct seed rice (seed drill)                                                                                         | 24.48 <sup>b</sup>       |
| $M_2$                  | - | $M_2$ - Drum seeding (DSR)                                                                                                        | 25.29 <sup>ab</sup>      |
| $M_3$                  | - | $M_3$ - Non-puddled transplanted rice (NPTR)                                                                                      | 26.48 <sup>a</sup>       |
| SE.d                   |   |                                                                                                                                   | 0.48                     |
| CD (P = 0.05)          |   |                                                                                                                                   | 1.33                     |
| <b>Sub plot</b>        |   |                                                                                                                                   |                          |
| $S_1$                  | - | $S_1$ - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE)                           | 26.33 <sup>c</sup>       |
| $S_2$                  | - | $S_2$ - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE) | 35.00 <sup>a</sup>       |
| $S_3$                  | - | $S_3$ - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Cono weeding                                                                        | 23.11 <sup>de</sup>      |
| $S_4$                  | - | $S_4$ - Pretilachlor @ 0.75 a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG 67.5 g/ha (EPoE)                                | 24.11 <sup>d</sup>       |
| $S_5$                  | - | $S_5$ - Pretilachlor @ 0.75 a.i/ha (PE) fb Florpyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec. 160 g a.i/ha (EPoE)   | 30.00 <sup>b</sup>       |
| $S_6$                  | - | $S_6$ - Pretilachlor @ 0.75 a.i/ha (PE) fb Cono weeding                                                                           | 22.11 <sup>e</sup>       |
| $S_7$                  | - | $S_7$ - Weedy check                                                                                                               | 17.22 <sup>f</sup>       |
| SE.d                   |   |                                                                                                                                   | 0.63                     |
| CD (P = 0.05)          |   |                                                                                                                                   | 1.27                     |
| <b>Main × Sub plot</b> |   |                                                                                                                                   |                          |
| SE.d                   |   |                                                                                                                                   | 1.08                     |
| CD (P = 0.05)          |   |                                                                                                                                   | NS                       |



interaction between a suitable rice establishment technique and effective weed management practice.

#### Number of pods plant<sup>-1</sup>

Different rice establishment techniques and weed management practices substantially influenced the number of pods per plant of succeeding black gram, as illustrated in Table 3.

Among the crop establishment methods, Non-puddled transplanted rice ( $M_3$ ) recorded the maximum average number of pods per plant (26.48), which was substantially superior to dry direct seeded rice ( $M_1$ ) with 24.48 pods plant<sup>-1</sup> and was on par with drum seeding in puddled field ( $M_2$ ), which recorded 25.29 pods plant<sup>-1</sup>.

Among the methods for controlling weeds, Pendimethalin @ 1.0 kg a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE), ( $S_2$ ) recorded the maximum number of pods per plant, with values of 34.00, 35.00 and 36.00 under  $M_1$ ,  $M_2$  and  $M_3$ , respectively. This treatment also registered the highest mean number of pods per plant (35.00), indicating a strong positive residual effect of effective weed management on the reproductive performance of succeeding black gram.

This was followed by Pretilochlor @ 0.75 kg a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec. 160 g a.i/ha (EPoE), ( $S_5$ ) and Pendimethalin

@ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE), ( $S_1$ ), which recorded comparatively higher number of pods per plant across all rice establishment methods. In contrast, cono weeding ( $S_3$ ) and pretilachlor alone ( $S_4$ ) resulted in lower pod numbers.

The lowest number of pods per plant was consistently recorded under the weedy check ( $S_7$ ) across all establishment techniques, which may be attributed to severe weed infestation during the preceding rice crop, leading to poor residual soil fertility and crop growth environment for black gram.

The interaction effect revealed that  $M_3S_2$  (Non-puddled transplanted rice combined with pendimethalin followed by florypyrauxifen-benzyl + cyhalofop-butyl) recorded the maximum number of pods per plant (36.00), highlighting that efficient weed management and an improved rice establishment method combine to improve the yield characteristics of subsequent black gram.

#### Seed yield (kg ha<sup>-1</sup>) of black gram

The seed yield of the succeeding black gram crop differed significantly as influenced by various rice establishment techniques and weed management practices (Table 4). Among the crop establishment methods, Non-puddled transplanted rice ( $M_3$ ) produced the highest mean seed yield (693.43 kg ha<sup>-1</sup>), which was statistically on par with

**Table 4:** Influence of rice establishment techniques and weed management practices on seed yield (kg ha<sup>-1</sup>) of succeeding black gram (residual effect).

|               |   | Mainplot                                                                                                                           | Seed yield (kg ha <sup>-1</sup> ) |
|---------------|---|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| $M_1$         | - | $M_1$ - Dry direct seed rice (seed drill)                                                                                          | 674.62 <sup>b</sup>               |
| $M_2$         | - | $M_2$ - Drum seeding (DSR)                                                                                                         | 685.62 <sup>a</sup>               |
| $M_3$         | - | $M_3$ - Non-puddled transplanted rice (NPTR)                                                                                       | 693.43 <sup>a</sup>               |
| SE.d          |   |                                                                                                                                    | 2.9                               |
| CD (P = 0.05) |   |                                                                                                                                    | 8.05                              |
|               |   | <b>Sub plot</b>                                                                                                                    |                                   |
| $S_1$         | - | $S_1$ - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE)                            | 706.44 <sup>c</sup>               |
| $S_2$         | - | $S_2$ - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE) | 807.44 <sup>a</sup>               |
| $S_3$         | - | $S_3$ - Pendimethalin @ 1.0 kg a.i/ha (PE) fb Cono weeding                                                                         | 645.78 <sup>e</sup>               |
| $S_4$         | - | $S_4$ - Pretilochlor @ 0.75 a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG 67.5 g/ha (EPoE)                                 | 675.78 <sup>d</sup>               |
| $S_5$         | - | $S_5$ - Pretilochlor @ 0.75 a.i/ha (PE) fb Florypyrauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec. 160 g a.i/ha (EPoE)   | 745.11 <sup>b</sup>               |
| $S_6$         | - | $S_6$ - Pretilochlor @ 0.75 a.i/ha (PE) fb Cono weeding                                                                            | 625.56 <sup>f</sup>               |
| $S_7$         | - | $S_7$ - Weedy check                                                                                                                | 585.78 <sup>g</sup>               |
| SE.d          |   |                                                                                                                                    | 1.01                              |
| CD (P = 0.05) |   |                                                                                                                                    | 2.04                              |
|               |   | <b>Main × Sub plot</b>                                                                                                             |                                   |
| SE.d          |   |                                                                                                                                    | 1.74                              |
| CD (P = 0.05) |   |                                                                                                                                    | NS                                |

drum seeding in puddled field ( $M_2$ ) recording 685.62 kg ha<sup>-1</sup> and significantly superior to dry direct seeded rice ( $M_1$ ) with 674.62 kg ha<sup>-1</sup>.

With respect to weed management practices, Pendimethalin @ 1.0 kg a.i/ha (PE) fb Floryprauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 20.5% w/w Ec. 160 g a.i/ha (EPoE), ( $S_2$ ) resulted in the maximum seed yield of black gram, recording 798.33, 807.33 and 816.67 kg ha<sup>-1</sup> under  $M_1$ ,  $M_2$  and  $M_3$ , respectively. This treatment also registered the highest mean seed yield (807.44 kg ha<sup>-1</sup>), reflecting the beneficial residual influence of effective weed control in rice on the succeeding black gram crop.

The next best treatments Pretilachlor @ 0.75 kg a.i/ha (PE) fb Floryprauxifen-benzyl 2.13% w/w + Cyhalofop-butyl 10.64% w/w Ec. 160 g a.i/ha (EPoE), ( $S_5$ ) and Pendimethalin @ 1.0 kg a.i/ha (PE) fb Triafamone 20% + Ethoxysulfuron 10% WG @ 67.5 g/ha (EPoE), ( $S_1$ ), which produced significantly higher seed yields compared to the remaining treatments. In contrast, cono weeding ( $S_3$ ) and pretilachlor alone ( $S_4$ ) recorded moderate seed yield levels.

Non-puddled tillage (NPTR) resulted in higher productivity of the succeeding blackgram crop compared to puddled tillage (PTR). This improvement can be attributed to better soil physical properties under NPTR, especially lower soil penetration resistance, which favored enhanced crop growth and development. As a result, blackgram yield was higher under NPTR, demonstrating its superiority in the rice-blackgram relay cropping system (Subrahmaniyan *et al.*, 2024).

The lowest seed yield was observed under the weedy check ( $S_7$ ) across all crop establishment methods, which could be attributed to severe weed competition during the preceding rice crop, adversely affecting soil nutrient availability and growth conditions for the succeeding black gram.

The interaction effect indicated that  $M_3S_2$ , non-puddled transplanted rice combined with pendimethalin followed by floryprauxifen-benzyl + cyhalofop-butyl produced the highest seed yield (816.67 kg ha<sup>-1</sup>), demonstrating the cumulative advantage of an improved rice establishment technique and an efficient weed management strategy. Raja (2018) concluded that non puddle transplanted rice establishment method improved seed yield of blackgram under rice fallow condition.

## CONCLUSION

The current study clearly demonstrated that weed dynamics in rice were significantly influenced by rice establishment techniques and weed management strategies, which also had significant long-term effects on the growth and yield of subsequent rice fallow black gram. Among the establishment techniques, non-puddled transplanted rice (NPTR) proved superior by recording lower weed dry weight, higher weed control efficiency and better residual benefits to black gram in terms of plant height, yield attributes and seed yield.

Among the weed management practices, the application of pendimethalin as a pre-emergence treatment followed by floryprauxifen-benzyl + cyhalofop-butyl as early post-emergence ( $S_2$ ) consistently ensured effective weed suppression in rice, resulted in higher weed control efficiency and enhanced the performance of the succeeding black gram, without exhibiting any adverse residual effects. The integrated herbicide treatments ( $S_5$  and  $S_1$ ) were also superior to mechanical methods and single-herbicide applications.

The weedy check exhibited the maximum weed pressure in rice and resulted in the lowest growth and yield of the succeeding black gram, emphasizing the critical role of effective weed management in rice-based cropping systems. Overall, the integration of non-puddled transplanted rice with appropriate herbicide-based weed management emerged as a sustainable and productive approach for rice-black gram cropping systems, providing efficient weed control in rice and improved productivity of the succeeding pulse crop.

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## Disclaimers

The opinions and conclusions presented in this article are solely those of the authors and do not necessarily represent the perspectives of their affiliated institutions or the journal Legume Research. The authors assume entire responsibility for the content and are accountable for the accuracy of the information presented.

## Conflict of interest

Regarding the publishing of this work, the authors state that they have no conflicts of interest.

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