Plant Archives Vol. 26, Supplement 1, 2026 pp. 608-617 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.083

EFFECT OF DIVERS PLANTING SYSTEM AND WEED MANAGEMENT PRACTICES ON GROWTH INDICES OF RICE (*ORYZA SATIVA* L.)

Suryabhan [1]*, M. Z. Siddiqui[1], Mukesh Kumar[2], Rajat Yadav[1], Pradeep Kumar[1], Krishna Kumar Singh[3], Abhinav Yadav[1], Vinay Kumar Patel[4], Sudhir Pal[1], and Janardan Prasad Bagri[1]

[1]Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur Uttar Pradesh – 208002, India

[2]Indian institute of pulses research, Kanpur, Uttar Pradesh – 208024, India

[3] Department of Soil Science and Agricultural Chemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur Uttar Pradesh – 208002, India

[4]Indian Institute of Vegetables Research, Varanasi, Uttar Pradesh- 221305 India

*Corresponding author: E-mail: sb781914@gmail.com

(Date of Receiving : 07-09-2025; Date of Acceptance : 08-11-2025)

ABSTRACT

The field experiment was conducted at the Student Instructional Farm (SIF), Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, during the *Kharif* seasons of 2023 and 2024, to evaluate the influence of different crop establishment methods and weed management practices on growth indices of rice (*Oryza sativa* L.). The experiment followed a split-plot design with three replications, assigning three crop establishment methods to the main plots and seven weed management treatments to the subplots. The main plot treatments included P_1-Conventional transplanting, P_2-Direct seeded rice (Dry) and P_3- Drum seeded rice (wet/sprouted seed) and sub-plots treatment were W_1-Unweeded check, W_2-Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence, W_3- Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence (30 DAS/DAT), W_4-Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence + one hand weeding (45 DAS/DAT), W_5-Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence fb bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT), W_6-Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *f*b Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT) and W_7-Weed free (hand weeding at 25 and 45 DAS/DAT). Results revealed that the different planting systems, the result was observed significantly maximum growth indices *viz*., Dry matter accumulation (g m^{-2}), Leaf area index, Crop Growth Rate (g m^{-2} day^{-1}), Relative Growth Rate (g g^{-1} day^{-1}) and Net Assimilation Rate (g m^{-2} day^{-1}) with Conventional transplanting, however lowest under direct seeded rice (Dry). In weed management practices were recorded significantly maximum growth indices with Weed free (hand weeding at 25 and 40 DAS/DAT), and among herbicidal treatments recorded significantly result of the maximum growth indices with treatments W_6- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *f*b Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT). However, lowest growth indices were recorded with the treatment Unweeded check, during 2023, 2024 as well as pooled basis respectively.

***Keywords* :** Growth indices, Dry matter, Leaf area, DSR, Herbicide.

Introduction

Rice is the staple cereal crop of India plays a key role in food security. The country has to produce about 130 million tonnes of rice by 2025 to feed the ever-increasing growing population (Hugar *et al*., 2009). It is grown on approximately 161.7 million hectares of cultivated area towards more than 100 countries with a production of more than 749 million tonnes (Mt) and productivity of 4.63 t ha^{-1} (Agricultural Statistics at a Glance, 2021). Weeds cause significant losses in dry matter accumulation, leading to a reduction in yield. Uncontrolled weeds can lead to a reduction in grain yield of up to 80% and, in some cases, may result in the complete failure of the crop (Pandey *et al*., 2000; Gopinath and Kundu, 2008). The plant faced the least competition from weeds, allowing it to access maximum nutrients, sunlight, and moisture, which helps it accumulate a greater quantity of dry matter. The total crop dry matter represents the spatial and temporal integration of all plant processes. Consequently, it is the most significant parameter when studying crop canopies. The rate of dry matter accumulation varies throughout the crop's life cycle, and both dry matter and leaf area are sampled at intervals ranging from days to weeks. This sampling helps quantify the effects of environmental influences or analyze genotypic differences among crop cultivars, (Echarte *et al.*, 2008). The quantification of crop growth can be determined using various physiological growth indices such as leaf area index, crop growth rate, relative growth rate, and net assimilation rate (Azeem *et al*., 2015). Hand weeding is expensive, time consuming, difficult and often limited by lack of laborers in time. Herbicides provide economic and effective weed control when applied at the proper dose and growth stage. Herbicide use has been an extremely important component of weed management in conservation agriculture systems (Bhullar *et al.,* 2016). The application of pre-emergence herbicides is considered one of the most effective components of weed management in dry-seeded systems (Mahajan *et al*., 2014) Weeds controlled by manual weeding resulted in the highest number of effective tillers, grains per panicle, 1000-grain weight, and overall grain yield (Khaliq *et al*., 2012). This enabled the rice crop to grow with an adequate supply of essential resources such as space, sunlight, nutrients, water, and air due to reduced crop-weed competition, thereby resulting in better growth attributes (Suryabhan *et al.*, 2025). These results were in agreement with those reported by (Walia *et al*., 2012). Transplanted rice produces a higher yield because the plants utilize edaphic conditions more efficiently than in direct-seeded rice (Javaid *et al*., 2012).

Materials and Methods

The study was conducted during *Kharif* seasons for two consecutive years (2023 and 2024) at Student Instructional Farm of the Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Utter Pradesh India. The site is located at 26°20'35" N latitude and 80°18'35" E longitude, with an elevation of 125.9 meters above mean sea level. The field was levelled, well-drained, had a uniform soil texture, stable soil fertility and reliable irrigation. The cropping period was 21th June to 5th November in 2023 and 25th June to 8th November in 2024. The agrometeorological data was collected from the meteorological observatory, department of agronomy, CSAUA&T, Kanpur. The crop received 747.8- and 922.6-mm rainfall during both the year, respectively, the mean maximum temperature varied from 30.4-42.2 ºC and 31.4–44.8 ºC and mean minimum temperature for two years ranged from 14.5-29.8 ºC and 17.4–30.9 ºC during both the year respectively. The mean minimum and maximum relative humidity ranged from 29-73% and 48-93% for 2023 and 17-80% and 35-91% during 2024 respectively. The mean bright sunshine hours recorded per day was between 4–8 hrs / day.

The experiment followed a split-plot design with three replications, assigning three planting system to the main plots and seven weed management practices to subplots. The main plot treatments included P_1- Conventional transplanting, P_2- Direct seeded rice (Dry) and P_3- Drum seeded rice (wet/sprouted seed) and sub-plots treatment were W_1- Unweeded check, W_2- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence, W_3- Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence (30 DAS/DAT), W_4- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence + one hand weeding (45 DAS/DAT), W_5- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence fb bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT), W_6- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence fb Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT) and W_7- Weed free (hand weeding at 25 and 45 DAS/DAT).

Crop Management Practices, the hybrid rice variety 27p37 was selected for sowing. The nursery seedlings were uprooted at twenty-one days after sowing and transplanted into the main experimental field at the rate of one to two seedling hills^{-1} with row and plants spacing 20 cm under conventional transplanting. While, Direct-seeded rice (dry) seeds are sown directly into the main puddled field without prior germination under line sowing with 20 cm spacing. However, Drum seeded rice (wet/sprouted seed) pre germinated seeds are sown perfectly puddled and leveled field apart 20cm spacing. The seed was soaked in water for 24 hours and then incubated for 12 hours to allow sprouting and lightly air dried in the shade before sowing into the field. The dry matter accumulation and leaf area were calculated at 30, 60, 90 DAS/DAT and at harvest stage during both the years and the physiological growth indices, namely, LAI, CGR, RGR and NAR were calculated by the equation provided by Williams 1946, Watson 1956 and Radfold, 1967. The data was statistically analyzed by using analysis of variance (ANOVA), standard error of mean (Sem. ±) and least significant difference at 5% probability level of significance (Gomez and Gomez, 1984). Further, the excel software (Microsoft office home and student version 2021-en us, and online opstat website was used for statistical analysis). The growth indices analysis was done as per standard procedure are-

Dry matter accumulation (DMA)

To determine dry matter accumulation, rice plants were cut at ground level from a randomly selected 0.5-meter length of running row. Plants were then uprooted from the ground with the help of a sharp knife. The collected samples were oven-dried at 70°C for 48 hours to obtain a constant dry biomass. After drying, the average weight of the samples was calculated and expressed as dry matter accumulation in g m^{-2}.

Leaf Area Index (LAI)

The term Leaf Area Index was proposed by Williams (1946). It is the ratio of the leaf area of the crop to the ground area over a given period of time. The value of the leaf area index should be optimal when the ground is maximally covered, allowing the crop canopy to receive the maximum solar radiation, which in turn leads to higher total dry matter accumulation.

$$\mathrm{LAI} = \frac{\text{Leaf area (cm)}}{\text{Ground area (cm)}}$$

Crop Growth Rate (CGR)

The crop growth rate of a species is usually closely related to the interception of solar radiation. The method was suggested by Watson (1956). It represents dry weight gained by a unit area of crop in a unit time expressed as g day^{-1} m^{-2}. It is given as:

$$\mathrm{CGR} = \frac{1}{A} \times \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_1 and W_2 are plant dry weight (g) at time interval $t_1 - t_2$ (days) respectively and A is land unit area.

Relative Growth Rate (RGR)

The term was coined by Williams (1946). An index that measures the amount of new growth produced per unit of the plant's dry weight during a specified period. (Radfold, 1967). It is also called efficiency index and can be expressed in g g^{-1} day^{-1}. The mean value of RGR for the time interval t_1 to t_2 is given as:

$$\mathrm{RGR} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where,

W_1 and W_2 are the total dry weights at time $t_1 - t_2$ respectively.

Net assimilation Rate (NAR)

The term, NAR was used by Williams (1946). NAR as a measure of dry matter increase relative to leaf area or leaf dry weight over time. The NAR is a measure of the average photosynthetic efficiency of leaves in a crop community. (Radfold, 1967). NAR is calculated from the following equation and it expressed as g day^{-1} m^{-2}.

$$\mathrm{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

Where,

L_2 and L_1 are total leaf area at time t_2 and t_2 and W_1 and W_2 are the total dry weights at time $t_1 - t_2$ respectively.

Result and Discussion

Dry matter accumulation (g m^{-2})

A plant's accumulation of dry matter is a direct measure of the solar energy captured during growth. The production of biomass is influenced by several factors including the quantity of solar radiation absorbed, the size of the plant's surface area that intercepts the light, the efficiency with which the intercepted radiation is converted into dry matter, and the loss of dry matter due to physiological processes, diseases, and competition from weeds. The data on dry matter accumulation (gm^{-2}) has recorded at 30, 60, 90 DAS/DAT and at harvest stage of crop both the year during field experimentation has been presented in table 1. clearly indicate that the dry matter accumulation (gm^{-2}) increases consistently from 30^{th} days to 90 days stage under different crop establishment methods and weed management practices during year of investigation. However, the rate of dry matter accumulation was differed with different treatment. Among the planting system at 30 DAS/DAT did not significantly affect the dry matter accumulation during 2023, 2024 and pooled basis respectively. While at 60, 90 days after sowing /transplanting and at harvest stage Conventional transplanting recorded significantly higher dry matter accumulation (749.20, 1128.47 and 1229.50 g m^{-2}) during 2023, 2024 as well as pooled basis respectively. followed by P_3-Drum seeded rice (wet/sprouted seed) and lowest under P_2-Direct seeded rice (Dry) (679.51, 994.56 and 1063.88 gm^{-2}) during 2023, 2024 as well as pooled basis respectively. The weed management practices significantly influenced on dry matter accumulation at all growth stage. Whereas, significantly recorded maximum dry matter accumulation with weed free (hand weeding at 25 and 40 days after sowing /transplanting (249.72, 836.53, 1286.36 and 1420.72 g m^{-2}) which was statistically at par with W_6 (Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence fb Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding, 45 DAS/DAT). However, lowest dry matter accumulation was recorded with treatment W_1 - Unweeded check (245.65, 811.90, 1204.08 and 1331.32 gm^{-2}) at 30, 60, 90 DAS/DAT, and at harvest stage during 2023, 2024 and pooled basis respectively. This might due to enhanced biomass accumulation under weed management practices (Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence fb Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding, 45 DAS/DAT) and weed free (hand weeding at 25 and 40 days after sowing /transplanting) can be attributed to efficient and prolonged weed control, resulting in improved light interception, nutrient availability, and photosynthetic efficiency. The application of pre-emergence Pyrazosulfurone ethyl followed by post-emergence Bentazone, supplemented with hand weeding, effectively minimized weed interference during critical growth stages. Similar finding was reported by Thakur *et al.* (2011). A.N. Rao *et al.* (2017); Bhaskar *et al.* (2019); Dhaker *et al.* (2022); Nazir *et al.* (2022); Nazir *et al.* (2023). Chaudhary *et al.* (2023). Sairam *et al.* (2024); The interaction between crop establishment methods and weed management practices was found to be non-significant up to 90 DAS/DAT, but became significant at harvest. The highest dry matter accumulation at harvest was observed in conventional transplanted rice under weed free (hand weeding at 25 and 40 days after sowing /transplanting), while the lowest occurred in direct-seeded rice under unweeded check.

Leaf area index

The data on leaf area index recorded at 30, 60, 90 DAS/DAT and at harvest stage of both the year during the investigation. The leaf area index presented in table 2. clearly shows that the leaf area index increases consistently from 30th days to 90 DAS/DAT under different crop establishment methods and weed management practices during both the year as well as pooled. Among the planting system at 30 DAS/DAT did not significantly affect the leaf area index during 2023, 2024 and pooled basis respectively. While observed at 60, 90 days after sowing /transplanting and at harvest stage Conventional transplanting recorded significantly higher leaf area index (4.76, 4.70 and 3.27) during 2023, 2024 as well as pooled basis respectively. Followed by P_3-Drum seeded rice (wet/sprouted seed) and lowest under P_2- Direct seeded rice (Dry) (4.38, 4.30 and 2.97) during 2023, 2024 as well as pooled basis respectively. The weed management practices significantly influenced on leaf area index at 60 DAS/DAT to harvest stage during both years and in pooled basis. Whereas, significantly recorded maximum leaf area index with weed free (hand weeding at 25 and 40 days after sowing /transplanting (4.85, 4.79 and 3.30) followed by W_6 (Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence fb Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding, 45 DAS/DAT). However, lowest leaf area index was recorded with treatment W_1 - Unweeded check (3.87, 3.79 and 2.60) at 60, 90 DAS/DAT, and at harvest stage during 2023, 2024 and pooled basis respectively. This might due to uniform plant establishment in transplanting, may be attributed to favorable soil nutrient and water availability, and reduced early weed competition, leading to more vigorous vegetative growth and greater leaf expansion. However, efficient weed control suppresses the weed growth, leading to improved crop vigor and light interception and reduce the crop weed competition for nutrients, moisture, light and space, allowing better leaf proliferation and expansion. Higher leaf area index indicates a greater photosynthetic surface area, which contributes to higher biomass accumulation. Similar finding was reported by Duttarganvi *et al.* (2016). Bhaskar *et al.* (2019). Dhaker *et al.* (2022); Kamara *et al.* (2024); Sairam *et al.* (2024); Nazir *et al.* (2023). The interaction effect between crop establishment methods and weed management practices does not significantly impact on leaf area index at all growth stages during 2023, 2024 as well as pooled basis.

Crop Growth Rate (g m^{-2} day^{-1})

The data on crop growth rate recorded at 30-60, 60-90 DAS/DAT and 90 DAS/DAT - at harvest stage of the crop in both the year during the investigation. The crop growth rate presented in table 3.0, clearly shows that the crop growth rate increases consistently from 30th days to 90 DAS/DAT under different crop establishment methods and weed management practices during both the year as well as pooled. This indicate that the planting systems significantly affect the crop growth rate at all growth stage during 2023, 2024 and pooled basis respectively. In the planting systems Conventional transplanting recorded significantly maximum result on crop growth rate (16.93, 12.57 and 2.50 g m^{-2} day^{-1}) during 2023, 2024 as well as pooled basis respectively. followed by P_3 - Drum seeded rice (wet/sprouted seed) and lowest under P_2- Direct seeded rice (Dry) (13.84, 11.15 and 1.77 g m^{-2} day^{-1}) at 30-60, 60-90 days after sowing /transplanting and 90 days after sowing /transplanting to harvest stage, during 2023, 2024 as well as pooled basis respectively. The weed management practices significantly influenced on crop growth rate at all growth stage. Whereas, significantly observed maximum crop growth rate with weed free (hand weeding at 25 and 40 days after sowing /transplanting (19.96, 14.89 and 2.97 g m^{-2} day^{-1}), followed W_6 (Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha-1as pre-emergence fb Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding, 45 DAS/DAT). Whereas, lowest crop growth rate was recorded under treatment W_1- Unweeded check (9.96, 9.62 and 1.28 g m^{-2} day^{-1}) at 30-60, 60-90 days after sowing /transplanting and 90 days after sowing /transplanting to harvest stage, during 2023, 2024 as well as pooled basis respectively. The higher crop growth rate in transplanting due to easily availability of resources reduced early weed competition, and better root development, which promoted efficient nutrient uptake and photosynthetic activity during the vegetative and reproductive phases. Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence fb Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding, 45 DAS/DAT suppressed the weed growth throughout the crop duration, which facilitated greater availability of nutrients, light, and space to rice plants. Therefore, plants exhibited more vigorous vegetative growth and dry matter accumulation. Similar finding was reported by Gill and Walia (2013); Maurya *et al.* (2023); Kamara *et al.* (2024); Sairam *et al.* (2024). The interaction effect between crop establishment methods and weed management practices on crop growth rate was significantly influenced at 30 to 90 DAS/DAT growth stages, while, not significantly affect at later stage during both years as well as pooled basis.

Relative Growth Rate (g g^{-1} $day^{-1} \times 10^{-3}$)

The data on relative growth rate recorded at 30-60, 60-90 DAS/DAT and 90 DAS/DAT - at harvest stage of the crop in both the year during the investigation. The relative growth rate presented in table 4.0, clearly shows that the relative growth rate increases consistently from 30^{th} days to 90 DAS/DAT under different crop establishment methods and weed management practices during both the year as well as pooled. The pooled data revealed that planting systems significantly affect the relative growth rate at all growth stage during 2023, 2024 and pooled basis respectively. In the planting methods Conventional transplanting recorded significantly maximum result on relative growth rate (36.46, 14.65 and 2.11 g g^{-1} day^{-1}×10^{-3}) during 2023, 2024 as well as pooled basis respectively. followed by P_3-Drum seeded rice (wet/sprouted seed) and lowest under P_2- Direct seeded rice (Dry) (33.66, 12.68 and 1.53 g g^{-1} day^{-1} × 10^{-3}) at 30-60, 60-90 days after sowing /transplanting and 90 days after sowing /transplanting to harvest stage, during 2023, 2024 as well as pooled basis respectively. The weed management practices significantly influenced on relative growth rate at all growth stage. Whereas, significantly recorded maximum relative growth rate under weed free (hand weeding at 25 and 40 days after sowing /transplanting (40.74, 15.55 and 2.42 g g^{-1} day^{-1} × 10^{-3}), followed W_6 (Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha-1as pre-emergence fb Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding, 45 DAS/DAT). Whereas, minimum relative growth rate was recorded under treatment W_1- Unweeded check (27.94, 10.14 and 1.16 g g^{-1} day^{-1} × 10^{-3}) at 30-60, 60-90 days after sowing /transplanting and 90 days after sowing /transplanting to harvest stage, during 2023, 2024 as well as pooled basis respectively. This might due to higher relative growth rate in conventional transplanting could be attributed uniform plant spacing, and improved nutrient availability, leading to enhanced biomass accumulation at vegetative phase because, effective weed suppression, improved light interception, and better nutrient and moisture availability to the crop. Similar finding was reported by Maurya *et al.* (2023); Kamara *et al.* (2024); Sairam *et al.* (2024). The interaction effect between crop establishment methods and weed management practices does not significantly impact on relative growth rate at all growth stages during both years as well as pooled basis.

Net Assimilation Rate (g m^{-2} day^{-1})

The data on Net Assimilation rate recorded at 30-60, 60-90 DAS/DAT and 90 DAS/DAT - at harvest stage of the crop in both the year during the investigation. The Net Assimilation rate presented in table 5.0, clearly shows that the Net Assimilation rate increases consistently from 30^{th} days to 90 DAS/DAT under different crop establishment methods and weed management practices during both the year as well as pooled. The pooled data revealed that planting systems significantly affect the Net assimilation rate at all growth stage during 2023, 2024 pooled basis. Among the planting systems Conventional transplanting recorded significantly maximum result on Net assimilation rate (7.30, 3.52 and 2.70 g m^{-2} day^{-1})

during 2023, 2024 pooled basis respectively. followed by P_3-Drum seeded rice (wet/sprouted seed) and lowest under P_2- Direct seeded rice (Dry) (6.26, 2.84 and 1.91 g $m^{-2}day^{-1}$) at 30-60, 60-90 days after sowing /transplanting and 90 days after sowing /transplanting to harvest stage, during 2023, 2024 pooled basis respectively. The weed management practices significantly influenced on Net assimilation rate at all growth stage. Whereas, observed significantly recorded maximum Net assimilation rate with weed free (hand weeding at 25 and 40 days after sowing /transplanting (8.04, 3.79 and 2.82 g $m^{-2}day^{-1}$) which followed W_6 (Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence fb Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding, 45 DAS/DAT). Whereas, lowest Net assimilation rate was recorded under treatment W_1 - Unweeded check (5.07, 2.25 and 1.63 g m^{-2} day^{-1}) at 30-60, 60-90 days after sowing /transplanting and 90 days after sowing /transplanting to harvest stage, during 2023, 2024 pooled basis respectively. This might due to efficient utilization of light, water, and nutrients, leading to better canopy structure and photosynthetic activity and dry matter production more in conventional transplanting then direct seeded rice. Similar finding was reported by Singh *et al.* (2023); Maurya *et al.* (2023). Kamara *et al.* (2024); Sairam *et al.* (2024). The interaction effect between crop establishment methods and weed management practices does not significantly impact on Net Assimilation rate at all growth stages during both years as well as pooled basis.

Table 1 : Effect of divers planting system and weed management practices on Dry matter accumulation (g m^{-2}) during 2023 and 2024.

Treatments	Dry matter accumulation (g m^{-2})											
	30 DAS/DAT			60 DAS/DAT			90 DAS/DAT			At Harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A- Main Plot - 3 (Crop Establishment Methods)												
P_1- Conventional transplanting	249.96	250.96	250.46	747.37	751.03	749.20	1125.66	1131.28	1128.47	1227.07	1231.93	1229.50
P_2 - Direct seeded rice (Dry)	231.96	232.88	232.42	677.86	681.15	679.51	992.09	997.04	994.56	1061.76	1066.01	1063.88
P_3 - Drum seeded rice (wet/sprouted seed)	236.41	237.36	236.88	706.30	709.68	707.99	1038.68	1043.87	1041.28	1125.63	1130.17	1127.90
SE(m) ±	**3.97**	**4.05**	**3.99**	**7.76**	**7.87**	**7.81**	**17.12**	**17.25**	**17.18**	**13.711**	**13.19**	**13.44**
C.D at 5%	**NS**	**NS**	**NS**	**31.30**	**31.73**	**31.50**	**67.20**	**67.72**	**67.46**	**55.28**	**53.18**	**54.20**
B- Sub plot -7 (Weed management practices)												
W_1- Un weeded check	227.35	228.26	227.81	526.66	528.39	527.53	807.48	811.51	809.50	845.85	848.21	847.03
W_2- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence	237.31	238.26	237.78	619.24	622.27	620.75	885.04	889.46	887.25	974.66	978.56	976.61
W_3- Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence (30 DAS/DAT)	235.96	236.90	236.43	672.59	675.88	674.24	956.45	961.22	958.84	1051.38	1055.59	1053.49
W_4 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence + one hand Weeding (45 DAS/DAT)	242.35	243.32	242.83	762.55	766.28	764.42	1064.91	1070.23	1067.57	1122.86	1127.35	1125.10
W_5 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *fb* Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence at 30 DAS/DAT	238.76	239.71	239.23	748.42	752.08	750.25	1166.88	1172.71	1169.80	1226.27	1231.17	1228.72
W_6 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *fb* Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT)	245.16	246.14	245.65	809.92	813.88	811.90	1201.08	1207.08	1204.08	1328.66	1333.98	1331.32
W_7 - Weed free (hand weeding at 25 and 40 DAS/DAT)	249.22	250.22	249.72	834.18	838.87	836.53	1283.15	1289.56	1286.36	1417.39	1424.06	1420.72
SE(m) ±	**3.77**	**3.71**	**3.68**	**7.50**	**7.52**	**7.51**	**27.28**	**27.41**	**27.35**	**13.20**	**13.34**	**13.25**
C.D at 5%	**10.86**	**10.68**	**10.59**	**21.59**	**21.65**	**21.61**	**78.23**	**78.61**	**78.42**	**38.01**	**38.41**	**38.16**
Interaction - A × B												
SE(m) ±	**7.23**	**7.20**	**7.12**	**14.31**	**14.40**	**14.35**	**47.25**	**47.48**	**47.36**	**25.22**	**25.13**	**25.14**
C.D at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**81.21**	**80.34**	**80.68**

Table 2 : Effect of divers planting system and weed management practices on Leaf area index during 2023 and 2024.

Treatments	Leaf area index											
	30 DAS/DAT			60 DAS/DAT			90 DAS/DAT			At Harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A- Main Plot - 3 (Crop Establishment Methods)												
P_1- Conventional transplanting	1.56	1.61	1.58	**4.70**	4.84	4.76	4.63	4.77	4.70	3.12	3.42	3.27
P_2 - Direct seeded rice (Dry)	1.52	1.58	1.55	4.31	4.44	4.38	4.22	4.38	4.30	2.83	3.11	2.97
P_3 - Drum seeded rice (wet/sprouted seed)	1.54	1.61	1.58	4.39	4.51	4.45	4.30	4.45	4.38	2.89	3.17	3.03
SE(m) ±	**0.05**	**0.06**	**0.04**	**0.08**	**0.05**	**0.06**	**0.05**	**0.06**	**0.05**	**0.04**	**0.05**	**0.05**
C.D at 5%	**NS**	**NS**	**NS**	**0.30**	**0.18**	**0.24**	**0.21**	**0.25**	**0.20**	**0.17**	**0.19**	**0.18**
B- Sub plot -7 (Weed management practices)												
W_1- Un weeded check	1.48	1.53	1.51	3.83	3.90	3.87	3.75	3.84	3.79	2.50	2.71	2.60
W_2- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence	1.54	1.60	1.57	4.37	4.50	4.44	4.29	4.45	4.37	2.89	**3.24**	3.03
W_3- Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence (30 DAS/DAT)	1.51	1.56	1.54	4.45	4.58	4.51	4.36	4.52	4.44	2.93	**3.26**	3.08
W_4 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence + one hand Weeding (45 DAS/DAT)	1.53	1.59	1.56	4.59	4.72	4.65	4.51	4.66	4.59	3.04	3.34	3.19
W_5 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *fb* Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence at 30 DAS/DAT	1.56	1.62	1.59	4.56	4.69	4.62	4.46	4.63	4.55	3.00	3.30	3.15
W_6 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *fb* Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT)	1.58	1.64	1.61	4.69	4.84	4.76	4.62	4.78	4.70	3.11	3.42	3.26
W_7 - Weed free (hand weeding at 25 and 40 DAS/DAT)	1.59	1.65	1.62	4.77	4.93	4.85	4.69	4.88	4.79	3.16	3.44	3.30
SE(m) ±	**0.18**	**0.20**	**0.14**	**0.18**	**0.17**	**0.17**	**0.13**	**0.18**	**0.10**	**0.11**	**0.11**	**0.11**
C.D at 5%	**NS**	**NS**	**NS**	**0.51**	**0.50**	**0.50**	**0.38**	**0.52**	**0.29**	**0.30**	**0.31**	**0.31**
Interaction - A × B												
SE(m) ±	**0.29**	**0.32**	**0.22**	**0.29**	**0.28**	**0.28**	**0.22**	**0.30**	**0.17**	**0.17**	**0.18**	**0.18**
C.D at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 3 : Effect of divers planting system and weed management practices on Crop Growth Rate (g m^{-2} day^{-1}) during 2023 and 2024.

Treatments	Crop Growth Rate (g m^{-2} day^{-1})								
	30-60 DAS/DAT			60-90 DAS/DAT			90 DAS- At Harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A- Main Plot - 3 (Crop Establishment Methods)									
P_1- Conventional transplanting	16.79	17.06	16.93	12.38	12.78	12.57	2.40	2.61	2.50
P_2 - Direct seeded rice (Dry)	13.71	13.97	13.84	10.98	11.32	11.15	1.70	1.85	1.77
P_3 - Drum seeded rice (wet/sprouted seed)	15.77	16.05	15.91	11.63	**11.96**	11.81	1.86	2.03	1.96
SE(m) ±	**0.21**	**0.22**	**0.22**	**0.16**	**0.20**	**0.18**	**0.03**	**0.04**	**0.03**
C.D at 5%	**0.86**	**0.89**	**0.87**	**0.63**	**0.81**	**0.72**	**0.09**	**0.10**	**0.10**
B- Sub plot -7 (Weed management practices)									
W_1- Un weeded check	9.86	10.06	9.96	9.48	9.77	9.62	1.23	1.34	1.28
W_2- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence	12.07	12.29	12.18	9.53	9.82	9.67	1.41	1.54	1.47
W_3- Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence (30 DAS/DAT)	14.11	14.36	14.23	9.91	10.22	10.06	1.68	1.83	1.75
W_4 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence + one hand Weeding (45 DAS/DAT)	15.51	15.78	15.64	12.00	12.36	12.18	2.19	2.38	2.28
W_5 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *fb* Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence at 30 DAS/DAT	17.47	17.77	17.62	13.34	13.75	13.54	1.95	2.13	2.04
W_6 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *fb* Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT)	19.15	19.46	19.31	12.72	13.12	12.92	2.60	2.83	2.72
W_7 - Weed free (hand weeding at 25 and 40 DAS/DAT)	19.80	20.13	19.96	14.67	15.11	14.89	2.84	3.09	2.97
SE(m) ±	**0.32**	**0.35**	**0.33**	**0.31**	**0.33**	**0.31**	**0.06**	**0.06**	**0.06**
C.D at 5%	**0.92**	**1.01**	**0.95**	**0.88**	**0.94**	**0.91**	**0.18**	**0.19**	**0.18**
Interaction - A × B									
SE(m) ±	**0.56**	**0.60**	**0.57**	**0.52**	**0.56**	**0.53**	**0.10**	**0.10**	**0.10**
C.D at 5%	**1.69**	**1.83**	**1.74**	**1.54**	**1.70**	**1.61**	**NS**	**NS**	**NS**

Table 4 : Effect of divers planting system and weed management practices on Relative Growth Rate (g g^{-1} day^{-1} × 10^{-3}) during 2023 and 2024.

Treatments	Relative Growth Rate (g g^{-1} day^{-1} × 10^{-3})								
	30-60 DAS/DAT			60-90 DAS/DAT			90 DAS- At Harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A- Main Plot - 3 (Crop Establishment Methods)									
P_1- Conventional transplanting	36.38	36.53	36.46	13.89	15.41	14.65	2.10	2.14	2.11
P_2 - Direct seeded rice (Dry)	33.47	33.85	33.66	12.02	13.35	12.68	1.51	1.55	1.53
P_3 - Drum seeded rice (wet/sprouted seed)	36.25	36.55	36.40	12.37	13.73	13.05	1.65	1.70	1.67
SE(m) ±	**0.54**	**0.59**	**0.26**	**0.30**	**0.33**	**0.31**	**0.03**	**0.04**	**0.03**
C.D at 5%	**2.16**	**2.38**	**1.05**	**1.18**	**1.31**	**1.25**	**0.12**	**0.15**	**0.13**
B- Sub plot -7 (Weed management practices)									
W_1- Un weeded check	27.77	28.11	27.94	9.61	10.67	10.14	1.14	1.18	1.16
W_2- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence	30.69	30.95	30.82	11.83	13.13	12.48	1.31	1.34	1.33
W_3- Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence (30 DAS/DAT)	34.13	34.40	34.27	12.60	14.00	13.30	1.52	1.55	1.53
W_4 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence + one hand Weeding (45 DAS/DAT)	35.79	36.06	35.92	13.56	15.05	14.30	1.94	1.99	1.97
W_5 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *f*b Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence at 30 DAS/DAT	38.36	38.62	38.49	13.02	14.46	13.73	1.76	1.80	1.78
W_6 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *f*b Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT)	40.23	40.49	40.36	13.94	15.47	14.71	2.17	2.24	2.20
W_7 - Weed free (hand weeding at 25 and 40 DAS/DAT)	40.60	40.87	40.74	14.74	16.36	15.55	2.38	2.45	2.42
SE(m) ±	**0.76**	**0.76**	**0.38**	**0.50**	**0.55**	**0.52**	**0.05**	**0.06**	**0.06**
C.D at 5%	**2.18**	**2.17**	**1.10**	**1.42**	**1.57**	**1.49**	**0.16**	**0.16**	**0.16**
Interaction - A × B									
SE(m) ±	**1.33**	**1.35**	**0.66**	**0.84**	**0.93**	**0.89**	**0.09**	**0.10**	**0.10**
C.D at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 5 : Effect of divers planting system and weed management practices on Net Assimilation Rate (g m^{-2} day^{-1}) during 2023 and 2024.

Treatments	Net Assimilation Rate (g m^{-2} day^{-1})								
	30-60 DAS/DAT			60-90 DAS/DAT			90 DAS- At Harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
A- Main Plot - 3 (Crop Establishment Methods)									
P_1- Conventional transplanting	7.17	7.43	7.30	3.38	3.66	3.52	2.59	2.81	2.70
P_2 - Direct seeded rice (Dry)	6.18	6.35	6.26	2.73	2.95	2.84	1.83	1.99	1.91
P_3 - Drum seeded rice (wet/sprouted seed)	6.64	6.72	6.63	2.99	3.23	3.10	2.12	2.30	2.21
SE(m) ±	**0.19**	**0.18**	**0.18**	**0.07**	**0.09**	**0.08**	**0.05**	**0.06**	**0.05**
C.D at 5%	**0.76**	**0.73**	**0.75**	**0.28**	**0.35**	**0.31**	**0.19**	**0.22**	**0.21**
B- Sub plot -7 (Weed management practices)									
W_1- Un weeded check	5.00	5.14	5.07	2.19	2.32	2.25	1.56	1.70	1.63
W_2- Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence	5.21	5.38	5.30	2.65	2.85	2.75	1.70	1.84	1.77
W_3- Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence (30 DAS/DAT)	6.24	6.44	6.34	2.97	3.22	3.10	2.06	2.23	2.14
W_4 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence + one hand Weeding (45 DAS/DAT)	7.40	7.65	7.52	3.24	3.53	3.38	2.41	2.62	2.52
W_5 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *f*b Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} as post emergence at 30 DAS/DAT	7.01	7.23	7.12	3.08	3.33	3.20	2.26	2.46	2.36
W_6 - Pyrazosulfurone ethyl 10% WP @ 25g *a.i.* ha^{-1} as pre-emergence *f*b Bentazone 48 SL @ 0.96 kg *a.i.* ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT)	7.62	7.85	7.73	3.35	3.76	3.61	2.55	2.78	2.67
W_7 - Weed free (hand weeding at 25 and 40 DAS/DAT)	7.92	8.16	8.04	3.63	3.96	3.79	2.70	2.93	2.82
SE(m) ±	**0.26**	**0.27**	**0.26**	**0.09**	**0.10**	**0.09**	**0.09**	**0.10**	**0.092**
C.D at 5%	**0.74**	**0.76**	**0.75**	**0.27**	**0.28**	**0.27**	**0.25**	**0.28**	**0.27**
Interaction - A × B									
SE(m) ±	**0.45**	**0.46**	**0.46**	**0.16**	**0.33**	**0.17**	**0.15**	**0.16**	**0.15**
C.D at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Conclusions

In conclusion, among the planting system and herbicidal treatment, conventional transplanting with application of Pyrazosulfurone ethyl 10% WP @ 25g a.i. ha^{-1} as pre-emergence fb Bentazone 48 SL @ 0.96 kg a.i. ha^{-1} (30 DAS/DAT) + one hand weeding (45 DAS/DAT) recorded significantly superior maximum growth indices at all growth stages.

Disclaimer (Artificial Intelligence)

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

Acknowledgement

We are deeply grateful to Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, for their generous support of this study. The recipient was Professor and Head of the Department of Agronomy, M. Z. Siddiqui, who provided valuable suggestions regarding the conception, design, and execution of the experiment, as well as the writing of the manuscript.

Competing interests

Authors have declared that no competing interests exist.

References

Agricultural Statistics at a Glance. 2021. Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture Cooperation and Farmers Welfare, Directorate of Economics and Statistics.

Arun babu Talla, A. T., & Jena, S. N. (2015). Effect of different crop establishment and weed management practices on yield, yield attributing characters and economies of rice under rainfed conditions. *Environment and Ecology*, **33**(1): 23-27.

Azam, K., Singh, A. K., Singh, V., Singh, M., Kumar, R., & Nand, V. (2024). Evaluation of Crop Establishment Methods and Nano Urea Versus Conventional Urea on Growth Indices in Rice Crop (*Oryza sativa* L.). *Journal of Advances in Biology & Biotechnology*, **27**(7), 493-501.

Azeem, K., Shah, S., Ahmad, N., Shah, S. T., Khan, F., Arafat, Y., ... & Ilyas, M. (2015). Physiological indices, biomass and economic yield of maize influenced by humic acid and nitrogen levels. *Russian Agricultural Sciences*, **41**(2), 115-119.

Beckie, H. J. (2011). Herbicide‐resistant weed management: focus on glyphosate. *Pest management science*, **67**(9), 1037-1048.

Bhaskar, O. P., Kumar, M., Thakur, A. K., Chandrakar, T., & Singh, D. P. (2019). Evaluation of the Rice Establishment Methods for Higher Productivity and Profitability under Dry Seeded Condition. *International Journal of Current Microbiology and Applied Sciences*, **8**(12), 2654-2663.

Bhullar, M.S., Pandey, M., Kumar, S. and Gill, G. (2016). Weed management in conservation agriculture in India. *Indian Journal of Weed Science*, **48**(1): 1-12.

Chaudhary, A., Venkatramanan, V., Kumar, M.A., Sharma, S. (2023). Agronomic and Environmental Determinants of Direct Seeded Rice in South Asia. *Circ Econ Sustain*, **3**(1): 253-290.

Chen, J.M., Pavlic, G., Brown, L., Cihlar, J., Leblanc, S.G., White, H.P., Hall, R.J., Peddle, D.R., King, D.J., Trofymow, J.A., Swift, E., Van der Sanden, J., Pellikka, P.K.E. (2002). Derivation and validation of Canadawide coarse-resolution leaf area index maps using high-resolution satellite imagery and ground measurements. *Remote Sens. Environ*. **80**, 165–184.

Cutini, A., Matteucci, G., Scarascia Mugnozza, G. (1998). Estimation of leaf area index with the Li-Cor LAI 2000 in deciduous forests. *Forest Ecol. Manag*. **105**, 55–65.

Dhaker, D. L., Kumar, B., Karthik, R. and Raj, M. (2022). Effect of sequential application of herbicides on weed management, productivity and nutrient uptake of direct seeded rice. *Indian Journal of Ecology,* **49**(6), 2149-2153.

Duttarganvi, S., Kumar, R. M., Desai, B. K., Pujari, B. T., Tirupataiah, K., Koppalkar, B. G., ... and Reddy, K. Y. (2016). Influence of establishment methods, irrigation water levels and weed-management practices on growth and yield of rice (*Oryza sativa* L.). *Indian Journal of Agronomy*, **61**(2), 174-178.

Echarte, L., Rothstein, S. and Tollenaar, M. (2008). The response of leaf photosynthesis and dry matter accumulation to nitrogen supply in an older and a newer maize hybrid. *Crop Science*, **48**(2), 656-665.

Ewert, F. (2004). Modelling plant responses to elevated CO_2: how important is leaf area index? *Ann. Bot*. **93**, 619–627.

Gill, J.S., Walia, S.S. (2013). Effect of establishment methods and nitrogen levels on basmati rice (*Oryza sativa* L.). *Indian J. of Agronomy*, **58**(4): 506-511.

Hugar, H.Y., Chandrappa, H., Jaydeva, H.M., Satish, A. and Mallikarjun, G.B. (2009). Comparative performance of differ-ent rice establishment methods in Bhadra command area. *Karnataka Journal of Agricultural Science*, **22**(5): 992–994

Indian society of agronomy (2017). Agronomy terminology, *reprinted (sixth edition), Cambridge printing works*, B-85, Naraina industrial area, phase-II, New Delhi, ISBN:978-81-934541-4-5.

Javaid, T., Awan, I.U., Baloch, M.S., Shah, I.H., Nadim, M.A., Khan, E.A., Khakwani, A.A. and Abuzar, M.R. (2012). Effect of planting methods on the growth and yield of coarse rice. *The Journal of Animal & Plant Sciences*, **22**(2): 358-362.

Maurya, S., Kumar, R., Verma, R., Baboo, K., Prakash, R. and Singh, A.K. (2023). Effect of different crop establishment methods and weed management practices on growth indices and yield of rice (*Oryza sativa* L.). *International Journal of Plant and Soil Science*, **35**(17), 31-37.

Nazir, A., Bhat, M. A., Bhat, T. A., Bhat, S. F., Qayoom, S., Hussain, A., ... and John, J. (2023). Impact of crop establishment techniques and weed management practices on Oryza sativa L. growth and yield. *Agronomy Journal*, **115**(4), 1812-1826.

Nazir, A., Bhat, M. A., Bhat, T. A., Fayaz, S., Mir, M. S., Basu, U., and El Sabagh, A. (2022). Comparative analysis of rice and weeds and their nutrient partitioning under various establishment methods and weed management practices in temperate environment. *Agronomy*, **12**(4), 816.

Radfold, P.J. (1967). Growth analysis formulae- their use and abuse, *Crop science*, **7**: 171-175.

Rao, A.N., Wani, S. P., Ahmed, S., Haider Ali, H., & Marambe, B. (2017). An overview of weeds and weed management in rice of South Asia, *Asian-Pacific Weed Science Society* 247-281.

Sairam, M., Maitra, S., Sain, S., Gaikwad, D.J. and Sagar, L. (2024). Dry matter accumulation and physiological growth parameters of maize as influenced by different nutrient management practices. *Agricultural Science Digest*, **44**(2), 219-225.

Singh, S., Ghosh, A., Das, T.K., Dhar, S., Prasad, S.M., Tripathy, S., Verma, G., Tomar, J. (2023). Influence of nitrogen and weed management practices on crop-growth indices and productivity of dry direct seeded rice (*Oryza sativa* L.). *Indian Journal of Agronomy*; **68**(1):89-92

Soltani, A., Galeshi, S. (2002). Importance of rapid canopy closure for wheat production in a temperate sub-humid environment: experimentation and simulation. *Field Crop. Res*. **77**, 17–30.

Siddiqui, M. Z., Kumar, S., Khan, N., Sarvesh, K., Kumar, A., Yadav, R., ... & Pal, S. (2025). Effect of Crop Establishment Methods and Weed Management Practices on Growth Characteristics and Grain Quality of Rice (*Oryza sativa* L.). Journal of Scientific Research and Reports, **31**(1), 84-96.

Thakur, R. Sawarkar, SD. Vaishya, U.K. and Singh M. (2011). Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. *J. Indian Society of Soil Science*, **59**(5): 74-81.

Walia, U.S., Walia, S.S., Sidhu, A.S. and Nayyar, S. (2012). Bioefficacy of pre- and postemergence herbicides in direct-seeded rice in Central Punjab. *Indian Journal of Weed Science*, **44**(1): 30-33.

Watson, D.J. (1947). Comparative physiological studies in the growth of field crops. I. Variation in net assimilation rate and leaf area between species and va rieties, and within and between years. *Ann. Bot.* **11**, 41–76.

Williams, R.F. (1946). The physiology of plant growth with special reference to the concept of net assimilation rate. *Ann. Bot*. **10**, 41-62.