**Original Research Article**

**EFFECT OF CONSERVATION AGRICULTURE-BASED CROP ESTABLISHMENT OPTIONS ON RICE GROWTH IN RICE-WHEAT SYSTEM**

**ABSTRACT:**

Rice accounts for over 40% of India's total crop production, thereby reinforces the country's food security. However, rice production in India faces several challenges like high consumption of water, labour and energy, which are becoming scarcer and more costly. Keeping above facts in view, an experiment was conducted during *Kharif* season of 2021 and 2022 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi to evaluate the effect of different conservation agriculture-based crop establishment options on the growth of rice under rice-wheat system. The field experiment was arranged in a completely randomized block design having four replications and six different crop establishment methods, namely CE1: Conventional till puddled transplanted rice - Conventional till wheat (no residue retention/incorporation), CE2: Conventional till puddled transplanted rice - Conventional till wheat - Conventional till mung bean (Rice & Wheat residue removal, full mungbean residue incorporation), CE3: Conventional till direct seeded rice - Zero till wheat (anchored residue retention of Rice), CE4: Conventional till direct seeded rice - Zero till wheat - Zero till mung bean (anchored residue retention of Rice and full Mungbean residue incorporation), CE5: Zero till direct seeded rice – Zero till wheat (anchored residue retention of Rice and Wheat), and CE6: Zero till direct seeded rice – Zero till wheat – Zero till mung bean (anchored residue retention of Rice and Wheat and full mungbean residue retention). The CE6 treatment (ZTR–ZTW–ZTMB) demonstrated significant superiority over the conventional CE1 (CTR–CTW) method across all assessed growth parameters. Specifically, CE6 resulted in an increase of up to 26% in plant height, 33 % in number of tillers per m2, and nearly 16 % in the leaf area index during the early growth stage of rice.

**1. INTRODUCTION:**

The rice-wheat cropping system (RWCS) is a pivotal component of Indian agriculture, particularly within the Indo-Gangetic Plains. This system plays an indispensable role in ensuring national food security and is instrumental in achieving self-sufficiency in staple grain production (Dhanda *et al*., 2022; Singh and Sidhu, 2014). However, the sustainability of this system is jeopardized by various environmental and agronomic challenges. The continuous implementation of the RWCS, especially in north-western India, has led to the soil nutrient depletion, groundwater scarcity, and rising production costs. These issues highlight the urgent need for sustainable practices (Dhanda *et al*., 2022; Kaur *et al*., 2021). At the same time, management of rice residues is also a major concern, which are frequently disposed through open burning. This practice contributes to air pollution and degrades soil health by causing nutrient loss (Leharwan *et al*., 2023). Sustainable residue management techniques, such as retaining and incorporating residues into the soil, have demonstrated the potential for enhancing soil properties and minimizing environmental impacts (Singh & Sidhu, 2014). The persistent challenges and innovative practices within the rice-wheat cropping system underscore the need for advanced agricultural strategies. These strategies aim to sustain productivity while addressing environmental and resource-related issues, thereby ensuring the continued success and effectiveness of this vital agronomic practice in India (Dhanda *et al*., 2022; Jat *et al*., 2019).

Rice cultivation constitutes a fundamental aspect of India's agricultural sector and economy, serving as the primary food source for a substantial portion of the population and playing a pivotal role in ensuring food security. For millions of farmers, rice farming represents a principal means of livelihood. This indispensable crop forms the backbone of the nation's food security system, appropriately encapsulated by the proverb "rice is life" within the Indian context (Mahajan *et al*., 2017). This is critical because rice accounts for over 40% of India's total crop production, thereby reinforcing the country's food security (Gandhi *et al*. 2016). However, rice production in India faces several challenges. Traditional practices, such as puddled transplanting, are becoming increasingly untenable because of their high consumption of water, labour, and energy, which are becoming scarcer and more costly. This unsustainable method necessitates a transition towards alternatives, such as direct-seeded rice (DSR) (Chauhan and Singh, 2016). Furthermore, climate change poses a significant threat to rice yields, exacerbating the difficulties farmers encounter owing to unpredictable weather patterns and their impact on livelihoods (Gandhi *et al*., 2016). The sustainability and future productivity of rice hinge on the adoption of innovative farming techniques. Rice farming remains a crucial component of India's agricultural landscape, necessitating ongoing adaptation to evolving environmental conditions and efficient resource management to sustain its essential role in food security and rural livelihood. There is an increasing emphasis on conservation agriculture as a solution to the challenges faced by the RWCS. Techniques, such as zero or minimal tillage and improved crop residue management, are recommended to enhance yield, efficiency, and sustainability. Additionally, incorporating legumes into the cropping sequence improves productivity and economic returns (Banjara *et al*., 2021). Practices such as zero tillage contribute to the enhancement of soil health by increasing soil organic carbon content and mitigating soil compaction. Such conservation practices are pivotal for addressing the environmental challenges inherent in traditional rice cultivation, thereby fostering a more sustainable and resilient agricultural system (Kumar *et al*., 2021; Chang *et al*., 2024; Tran *et al*., 2024; Pervaiz *et al*., 2024). CA based options are needed under changing climatic and socio-economic conditions.

**2. MATERIALS AND METHODS:**

The study was conducted during *Kharif* season of 2021 and 2022 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The experimental sites remained consistent throughout the study period. The soil of the experimental field was characterized as sandy clay loam in texture, well-drained, and moderately fertile, with low levels of available nitrogen and phosphorus, and medium levels of available potassium. The field experiments were arranged in a completely randomized block design with four replications and six different crop establishment methods. The crop establishment methods were as follows: CE1: Conventional till puddled transplanted rice - Conventional till wheat [CTPTR-CTW (no residue retention/incorporation)], CE2: Conventional till puddled transplanted rice - Conventional till wheat - Conventional till mung bean [CTPTR - CTW - CTMB (full MB residue incorporation)], CE3: Conventional till direct seeded rice -Zero till wheat [CT DSR - ZT W (anchored residue retention of R)], CE4: Conventional till direct seeded rice - Zero till wheat - Zero till mung bean [CT DSR - ZTW - ZTMB (anchored residue retention of R and full MB residue incorporation)], CE5: Zero till direct seeded rice – Zero till wheat [ZT DSR - ZT W (anchored residue retention of R and W)], and CE6: Zero till direct seeded rice – Zero till wheat - Zero till mung bean [ZTDSR - ZTW - ZTMB (anchored residue of R and W and full MB residue retention)]. Field preparation was conducted as per the tillage requirements. The rice variety "Sarjoo 52" was sown/transplanted in all treatments, with a row spacing of 20 cm. In the transplanted rice treatments (CE1 and CE2), the field was tilled dry and wet, followed by puddling, and then 27-day-old seedlings were transplanted. For the conventional transplanted system*, i.e.* CE1 and CE2, the seeds were sown in nursery on the same day as the seeding for the DSR crop establishment systems (CE3, CE4, CE5, and CE6) for ensuring the same physiological age of the rice plants under different treatments. The crop was sown at a seed rate of 30 kg ha-1. In the CT DSR treatments (CE3 and CE4), the field was ploughed twice with a tractor-drawn cultivator, followed by planking. In the zero till DSR treatments (CE5 and CE6), sowing was done without soil disturbance, using a tractor-drawn zero-till seed cum fertilizer drill after the need-based application of glyphosate (1 kg ha-1) to control weeds. Pre-sowing irrigation was applied before sowing and subsequent irrigation was done as per crop demand.

**3. RESULTS:**

**3.1 PLANT HEIGHT**

Table 1 shows that the plant height of rice was significantly influenced by various conservation agriculture (CA)-based crop establishment methods across all the growth stages and in both the years of experimentation. CE6: ZTR-ZTW-ZTMB produced the significantly taller plants. Subsequently, CE5 (ZT DSR-ZTW) and CE4 (CT DSR-ZTW-ZTMB) also exhibited superior plant growth compared with traditional puddled transplanted systems. In contrast, the conventional tillage treatment (CE1: CTR-CTW) consistently resulted in the shortest plant height. The consistent advantages of zero tillage and residue retention/incorporation practices over both years highlighted the beneficial impact of CA-based methods on rice growth and development.

**Table 1: Effect of CA based crop establishment methods on plant height (cm) at different growth stages of rice**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Crop Establishment methods** | **30 DAS** | | **60 DAS** | | **90 DAS** | | **At harvest** | |
| **2021** | **2022** | **2021** | **2022** | **2021** | **2022** | **2021** | **2022** |
| CE1: CTPTR-CTW | 24.8 | 26.8 | 67.5 | 71.8 | 96.2 | 96.1 | 94.6 | 94.5 |
| CE2:CTPTR-CTW-CTMB | 27.0 | 27.5 | 69.8 | 74.0 | 98.1 | 98.8 | 97.0 | 96.5 |
| CE3: CTDSR - ZT W | 28.5 | 29.5 | 71.0 | 73.8 | 98.8 | 101.3 | 97.7 | 99.1 |
| CE4:CTDSR-ZTW-ZTMB | 32.5 | 33.5 | 74.5 | 76.3 | 103.0 | 103.0 | 101.1 | 100.9 |
| CE5: ZT DSR-ZT W | 32.0 | 33.0 | 73.8 | 78.3 | 102.8 | 105.5 | 100.5 | 102.6 |
| CE6:ZTDSR-ZTW-ZTMB | 33.8 | 35.0 | 76.0 | 80.1 | 105.7 | 108.6 | 104.0 | 106.8 |
| **S. Em. ±** | **1.57** | **1.86** | **1.87** | **1.64** | **2.03** | **2.60** | **1.77** | **2.06** |
| **CD (P=0.05)** | **4.74** | **5.62** | **5.65** | **4.95** | **6.13** | **7.82** | **5.33** | **6.21** |

**3.2 NUMBER OF TILLERS**

Table 2 shows that the number of tillers per square meter in rice. Tillers number was significantly affected by different conservation agriculture (CA)-based crop establishment methods across all growth stages and both years. The ZTR-ZTW-ZTMB (CE6) treatment consistently recorded the maximum tiller counts, with average values of 161.63 at 30 DAS, 392.50 at 60 DAS, and 470.00 at 90 DAS during both the years. This was closely followed by CE5 (ZT DSR–ZTW) and CE4 (CT DSR–ZTW–ZTMB), which also exhibited significantly higher tiller numbers than the conventional method. In contrast, the conventional puddled transplanted rice (CE1: CTR–CTW) recorded the lowest number of tiller density, an average of 108.35 at 30 DAS to 428.13 at 90 DAS. These findings clearly indicate that CA-based crop establishment methods, particularly those involving zero tillage and residue retention, significantly enhance rice tillering.

**Table 2: Effect of CA based crop establishment methods on number of tillers (m-2) at different growth stages of rice**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Crop Establishment methods** | **30 DAS** | | **60 DAS** | | **90 DAS** | |
| **2021** | **2022** | **2021** | **2022** | **2021** | **2022** |
| CE1: CTPTR-CTW | 107.50 | 109.25 | 344.75 | 350.25 | 424.75 | 431.50 |
| CE2: CTPTR-CTW-CTMB | 118.00 | 120.50 | 355.00 | 361.00 | 435.00 | 438.75 |
| CE3: CTDSR - ZT W | 139.50 | 141.75 | 363.25 | 369.70 | 443.25 | 447.20 |
| CE4: CTDSR-ZTW-ZTMB | 146.50 | 153.50 | 375.50 | 378.35 | 451.00 | 454.00 |
| CE5: ZT DSR-ZTW | 151.00 | 157.25 | 381.25 | 383.75 | 455.00 | 460.25 |
| CE6: ZTDSR-ZTW-ZTMB | 159.25 | 164.00 | 391.00 | 394.00 | 468.25 | 471.75 |
| **S. Em. ±** | **4.56** | **5.76** | **5.51** | **5.35** | **6.34** | **6.40** |
| **CD (P=0.05)** | **13.75** | **17.35** | **16.61** | **16.13** | **19.12** | **19.29** |

**3.3 LEAF AREA INDEX (LAI)**

Table 3 elucidates the substantial influence of various conservation agriculture (CA)-based crop establishment methods on the Leaf Area Index (LAI) of rice at distinct growth stages during 2021 and 2022. Among the treatments, ZTR-ZTW-ZTMB (CE6) consistently achieved the highest LAI across all stages, with average value of 1.46 at 30 DAS, 3.37 at 60 DAS, and 3.53 at 90 DAS during both the years. Treatments such as CE5 (ZTDSR-ZTW) and CE4 (CTDSR-ZTW-ZTMB) also exhibited higher LAI values, suggesting enhanced leaf expansion and canopy growth under these systems. Conversely, the lowest LAI was observed under the conventional puddled transplanted rice (CE1: CTR-CTW), with average values of 1.22 at 30 DAS and reaching up to 3.34 at 90 DAS. These data indicate that CA-based methods, particularly those incorporating zero tillage and residue retention, facilitate superior leaf development and more efficient light interception, thereby augmenting overall crop performance.

**Table 3: Effect of CA based crop establishment methods on Leaf Area Index (LAI) of rice at different growth stages**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Crop Establishment methods** | **30 DAS** | | **60 DAS** | | **90 DAS** | |
|  | **2021** | **2022** | **2021** | **2022** | **2021** | **2022** |
| CE1: CTPTR-CTW | 1.21 | 1.23 | 3.13 | 3.21 | 3.31 | 3.37 |
| CE2:CTPTR-CTW-CTMB | 1.27 | 1.28 | 3.17 | 3.25 | 3.36 | 3.43 |
| CE3: CTDSR - ZT W | 1.31 | 1.33 | 3.23 | 3.32 | 3.40 | 3.45 |
| CE4:CTDSR-ZTW-ZTMB | 1.36 | 1.38 | 3.28 | 3.33 | 3.42 | 3.47 |
| CE5: ZT DSR-ZTW | 1.39 | 1.43 | 3.33 | 3.35 | 3.44 | 3.51 |
| CE6:ZTDSR-ZTW-ZTMB | 1.45 | 1.47 | 3.36 | 3.38 | 3.50 | 3.55 |
| **S. Em. ±** | **0.03** | **0.03** | **0.03** | **0.03** | **0.04** | **0.04** |
| **CD (P=0.05)** | **0.08** | **0.08** | **0.08** | **0.10** | **0.11** | **0.11** |

**4. DISCUSSION:**

The implementation of zero till direct seeded rice (ZTDSR) followed by zero till wheat (ZTW) and zero till mung bean (ZTMB), with residue retention, is linked to enhanced rice growth owing to several critical factors. Conservation agriculture (CA) practices, such as ZTDSR-ZTW-ZTMB, contributed to increase soil organic carbon (SOC) levels, which are instrumental in maintaining and improving soil quality, and promoting plant growth. (Dey *et al*., 2016; Sapkota *et al*., 2017, Mishra *et al*., 2024). The retention of crop residues augments nutrient availability in the soil. This approach enhances soil nitrogen pools, as residues from rice and mung beans exhibit a varied C:N ratio, thereby improving nitrogen utilization by crops. This increase in nutrient availability supports the overall growth and development of rice plants. (Dey *et al*., 2016; Thind *et al*., 2023). Practices such as ZTDSR with residue retention also enhance the soil physical properties, including soil structure and porosity. These enhancements improve root penetration and water retention capacity, creating a more favourable environment for plant growth and resulting in superior plant architecture (Kumar *et al*., 2019). Residue retention enhances microbial activity in soil, which is essential for nutrient cycling and soil health. By providing continuous organic matter input, microbial biomass increases, improving nutrient accessibility and promoting plant health (Sharma *et al*., 2019). Overall, ZTDSR-ZTW-ZTMB system with residue retention improved growth in rice by enhancing soil health through increased organic carbon, nutrient availability, and soil physical properties, along with improved water & nutrient use efficiency, and increased microbial activity. Collectively, these factors supported robust plant growth and development.

**5. CONCLUSION:**

Based on the results presented here, it can be concluded that full conservation agriculture based crop establishment method, CE6: ZTR–ZTW–ZTMB (with anchored residue retention in all the crops) has the potential to improve the rice growth as compared to the conventional puddled transplanting method within rice-wheat system of the eastern U.P.

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