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Growth dynamics of rice and succeeding wheat under resource conservation practices in rice-wheat cropping system

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Abstract
The conventional puddled transplanted rice-conventional tilled wheat system is associated with high water, labour and energy requirements, leading to reduced resource use efficiency and sustainability concerns. Resource conservation technologies like ZTDSR, surface and sub surface drip irrigation, sesbania brown manuring and residue retention offer potential alternatives for improving crop growth in the rice-wheat cropping system. A field experiment was conducted at RLBCAU, Jhansi to evaluate the effect of different crop establishment and irrigation practices on growth of rice and succeeding wheat. The experiment was laid out in RBD comprising 11 treatments and replicated thrice. Growth parameters were recorded at different growth stages of rice and wheat. In rice, TPR-ZTW recorded higher plant height, tiller count and dry matter accumulation remained at par with the SDI and SSDI ZTDSR+ BM-ZTW and SDI and SSDI ZTDSR-30% residue retention ZTW. In succeeding wheat, SDI ZTDSR-30% residue retention ZTW recorded higher plant height, tiller count and dry matter accumulation and remained at par with SDI and SSDI ZTDSR+ BM-ZTW and SSDI ZTDSR-30% residue retention ZTW. These findings indicate that drip-based irrigation practices integrated with ZTDSR, ZTW, sesbania brown manuring and residue retention can sustain crop growth comparable to transplanted rice while improving the growth performance of succeeding wheat in the rice-wheat cropping system.

Keywords: Rice–wheat cropping system, Zero-till direct-seeded rice (ZTDSR), Zero-till wheat (ZTW), Surface drip irrigation (SDI), Subsurface drip irrigation (SSDI)

Introduction
Rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping systems (RWCS) are practised on ~24 Mha of cropped land in Asia under irrigated and rainfed conditions; ~13.5 Mha of this land is in South Asia (Nawaz *et al*. 2019) [13]. In India, the belt of rice–wheat (RW) rotation occupies almost 10.5 Mha areas and is the main source of food, nutrition and livelihood security in the country (Kakraliya *et al*. 2022) [7]. During past 2 decades, the RW system is showing the sign of fatigue because of continuous use of traditional practices which resulted in to yield stagnation and declining factor productivity. In addition, there has been enormous damage to available natural resources (soil, water and energy). The declining soil fertility, depletion of ground water, increasing shortage of labour and energy, rising problem of salinity and alkalinity, multiple micronutrient deficiency, emergence of herbicide resistant and shift of weed flora besides environmental pollution through emission of greenhouse gases and large scale burning of rice straw are very complex and serious issues in RW. These emerging challenges have put a big question mark on the sustainability of RW cropping system. The conventional farmers' practices of transplanting rice seedlings manually after repeated dry and wet tillage (Puddling) followed by conventionally tilled wheat seed broadcasting contributes significantly to the challenges described above and making RW system unsustainable. Conventional practices are water, capital and energy intensive and deteriorate soil health. Intensive puddling in rice increase in soil strength in surface and sub-surface layers due to illuviation of clay, iron and manganese compounds; decrease in hydraulic conductivity and infiltration leads to water stagnation, poor root development, and low recharge of aquifers. Economically, RW cropping system is becoming less and less profitable because of increasing input costs involved with conventional tillage (CT) practices (Kakraliya *et al*. 2018; Debangshi, and Ghosh. 2022; Bhatt *et al*. 2016) [2, 5, 8].

To maintain and improve the rice-wheat system's sustainability and productivity at a lower cost of production, resource-conserving technologies and climate smart agriculture (CSA) practices are important. Adoption of resource conservation technologies like, ZTDSR, ZTW, SDI and SSDI, irrigation scheduling based on climatological approach, residue retention and brownmanuring is expected to significantly reduce the challenges of traditional RW system (Kharia *et al*. 2017; Krishnasree *et al*. 2024[9, 10]; Arouna *et al*. 2023).

Growth parameters such as plant height, tiller count, dry matter accumulation are important indicators of crop growth and development. These parameters help in assessing the response of rice to different irrigation practices. Therefore, the present study was conducted to evaluate the impact of different irrigation practices on crop growth of rice wheat cropping system.

Material and Methods
A field experiment was conducted at the I-block of Rani Lakshmi Bai Central Agricultural university, Jhansi, Uttar

Pradesh, India, during 2023[12]-2025. The study site was located at 25.51^0 N latitude, 78.56^0 E longitude, at an elevation of 243.62 m above sea level. The study aimed to evaluate the RWCS under various irrigation practices like SDI, SSDI, IW/CPE ratio-based flood irrigation, with different crop establishment techniques under different tillage regimes, brown manuring, and residue retention practices. The initial physico-chemical and microbial properties of the experimental soil were determined prior to treatment imposition. The experimental soil had a sandy loam texture, with a bulk density of 1.34 g cm^{-3}, pH 6.8, EC 0.24 dS m^{-1}, organic carbon 0.42 % and available N, P, and K of 174.2, 9.8, and 204 kg ha^{-1}, respectively, along with initial microbial populations including bacteria (23×10^{-6} cfu g^{-1} soil), fungi (9×10^{-4} cfu g^{-1} soil), actinomycetes (15×10^{-4} cfu g^{-1} soil), and SMBC (251 µg C g^{-1} soil).

A field experiment was laid out in a simple RBD, with 11 treatments and 3 replications. Treatments were; T_1: Transplanted Rice - Conventional Wheat, T_2: Transplanted Rice - Zero Tilled Wheat, T_3: Surface Drip Irrigation - Zero Tilled Direct Seeded Rice - Zero Tilled Wheat, T_4: Surface Drip Irrigation - Zero Tilled Direct Seeded Rice + Brown manuring - Zero Tilled Wheat, T_5: Surface Drip Irrigation - Zero Tilled Direct Seeded Rice -30 % Rice Residue Retention Zero Tilled Wheat, T_6: Subsurface Drip Irrigation - Zero Tilled Direct Seeded Rice - Zero Tilled Wheat, T_7: Subsurface Drip Irrigation - Zero Tilled Direct Seeded Rice + Brown Manuring - Zero Tilled Wheat, T_8: Subsurface Drip Irrigation - Zero Tilled Direct Seeded Rice -30 % Rice Residue Retention Zero Tilled Wheat T_9: Flood Irrigation - Zero Tilled Direct Seeded Rice - Zero Tilled Wheat, T_{10}: Flood Irrigation - Zero Tilled Direct Seeded Rice + Brown Manuring - Zero Tilled Wheat T_{11}: Flood Irrigation - Zero Tilled Direct Seeded Rice -30% Rice Residue Retention Zero Tilled Wheat. In the course of RWCS, rice was cultivated during the *kharif* season with the variety PUSA-1509 and wheat was during the Rabi season with DBW-187 variety. Cultural practices followed as per the package of practices for the region. Plant height was measured from the ground surface to the tip of the tallest plant from five randomly selected plants in each plot and averaged. Tiller count recorded from the same plants at different growth stages. Dry matter accumulation was determined by harvesting representative plants, oven drying them at 65 ± 2°C until constant weight. The data were analysed using ANOVA and treatment means were compared using DMRT at the 5 % level of significance.

Results and discussion

1. Growth parameters of rice

Plant height and dry matter accumulation increased progressively from 30 DAS to harvest, whereas tiller count increased up to 60 DAS and declined thereafter under all treatments (Fig. 1-3). The continuous increase in Plant height and dry matter accumulation might be attributed to active vegetative growth, greater biomass production throughout the crop growth period. The decline in tiller count after 60 DAS may be due to the mortality of weaker tillers. A similar trend was also observed in succeeding wheat.

At 30 DAS, the highest plant height was recorded under T_2, which was at par with T_1, T_4, T_5, T_7, T_8 and T_{10} (Fig. 1). The highest tiller count and dry matter accumulation were recorded under T_4 which remained statistically at par with T_5, T_7, T_8 for tiller count and with T_5, T_6, T_7, T_8 for dry matter accumulation (Fig. 2,3). Lower tiller count and dry matter under transplanted rice at the early stage might be due to temporary transplanting shock, whereas drip irrigated DSR with sesbania brown manuring and residue retention supported better early growth.

At 60, 90 DAS and at harvest, significantly higher plant height, tiller count and dry matter accumulation were recorded under T_2, which was remained statistically at par with T_1, T_4, T_5, T_7, T_8 (Fig. 1-3). Similar results were reported by Kumar *et al*. 2023[12] who observed that significantly higher plant height was recorded under TPR followed by SRI and WDSR during both the years of study at 30 and 60 DAS/DAT stages. At 90 DAS/DAT, the maximum plant height was found under TPR which is statistically at par with SRI followed by DSR during both the years of study. Bhargav Reddy *et al*. 2022[1] reported higher tiller count in DSR during initial growth stages, whereas TPR recorded comparable or higher tiller count at later growth stages. Gill *et al*. 2026, who reported superior tiller production and dry matter accumulation under transplanted rice than DSR.

The lowest growth parameters were observed under T_9. The superior growth under TPR-ZTW may be due to better crop establishment, favourable moisture conditions, while the comparable performance of drip-based treatments with sesbania brown manuring and residue retention may be due to improved water availability, nutrient release and soil moisture conservation, resulting in better crop growth and biomass accumulation (Biswas and Das, 2024) [3].

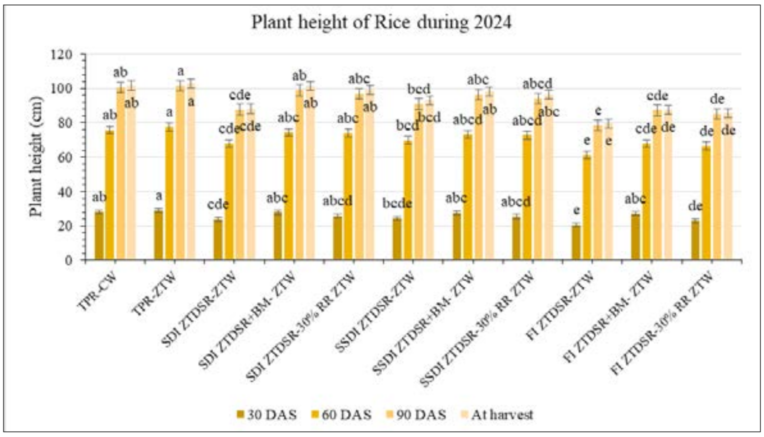

Fig 1: Plant height (cm) at different crop growth stages of transplanted rice and ZTDSR as influenced by different climate smart irrigation practices, brown manuring and residue + retention in rice – wheat cropping system.

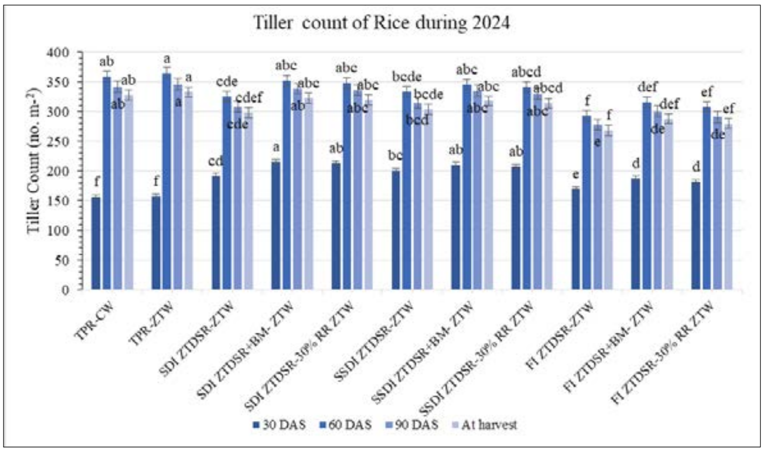

Fig 2: Number of tillers m^{-2} at different crop growth stages of transplanted rice and ZTDSR as influenced by different climate smart irrigation practices, brown manuring and residue + retention in rice – wheat cropping system.

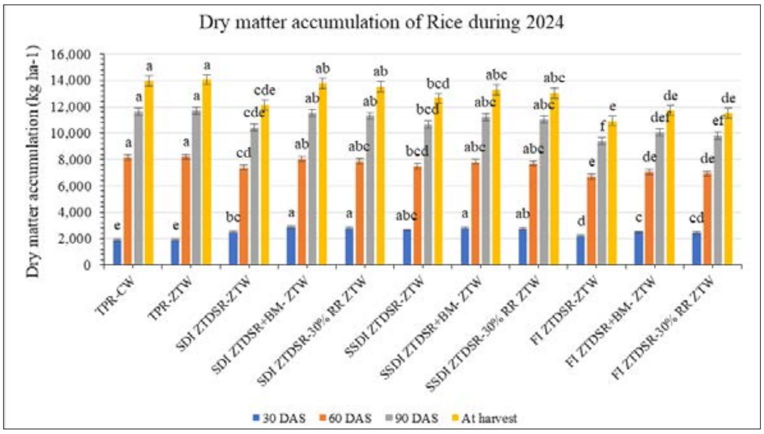

Fig 3: Dry matter accumulation (Kg ha^{-1}) at different crop growth stages of transplanted rice and ZTDSR as influenced by different climate smart irrigation practices, brown manuring and residue + retention in rice – wheat cropping system.

2. Growth parameters of succeeding wheat

The growth performance of succeeding wheat was significantly influenced by the carry over effects of climate smart irrigation practices and sesbania brown manuring in rice, along with residue retention during wheat cultivation (Fig. 4-6).

Significantly higher plant height, tiller count and dry matter accumulation throughout the crop growth period were recorded under T_5, which remained statistically at par with T_4, T_7 and T_8 at all growth stages (Fig. 4-6). Conversely, the lowest values were generally observed under T_2. The superior growth under drip irrigated sesbania brown manuring and residue retention treatments might be attributed to improved soil moisture conservation, favourable soil physical conditions and nutrient availability. In contrast, the reduced growth under T_2, could be due to the residual effects of puddling, which might have deteriorated soil structure and restricted root growth, thereby reducing plant height, tiller production and dry matter accumulation in succeeding wheat (Das *et al*. 2021; Kukal and Aggarwal, 2003) [4, 11].

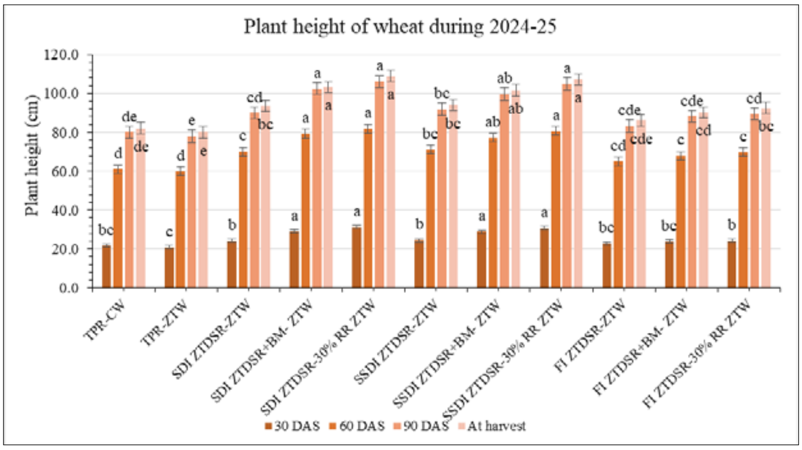

Fig 4: Plant height (cm) at different crop growth stages of succeeding wheat as influenced by different climate smart irrigation practices, brown manuring and residue + retention in rice – wheat cropping system.

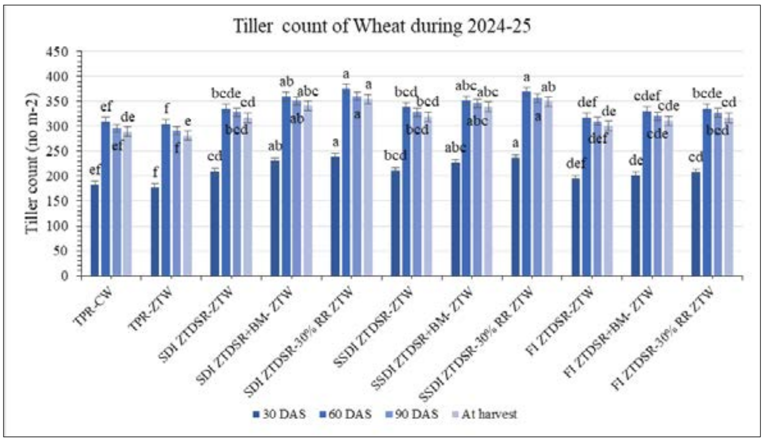

Fig 5: Number of tillers m^{-2} at different crop growth stages of succeeding wheat as influenced by different climate smart irrigation practices, brown manuring and residue + retention in rice – wheat cropping system.

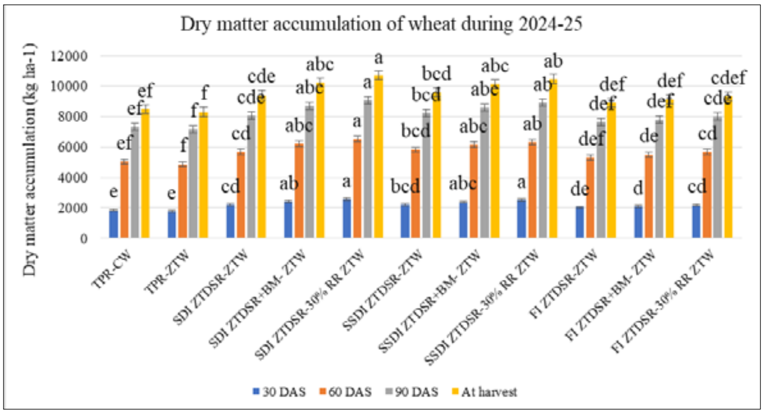

Fig 6: Dry matter accumulation (kg ha^{-1}) at different crop growth stages of succeeding wheat as influenced by different climate smart irrigation practices, brown manuring and residue + retention in rice – wheat cropping system.

Conclusion

Crop establishment and irrigation practices significantly influenced the growth of rice and succeeding wheat. In rice, TPR-ZTW recorded the highest plant height, tiller count and dry matter accumulation, while SDI and SSDI ZTDSR+ BM-ZTW and SDI and SSDI ZTDSR-30% residue retention ZTW produced comparable growth.

In succeeding wheat, SDI ZTDSR-30% residue retention ZTW recorded significantly higher plant height, tiller count and dry matter accumulation and remained at par with SDI and SSDI ZTDSR+ BM-ZTW and SSDI ZTDSR-30% residue retention ZTW. Thus, drip irrigation practices with sesbania manuring and residue retention were effective in sustaining crop growth in the rice-wheat cropping system.

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