Effect of diverse Rice-Based cropping sequences on growth, yield attributes and yield of Rice

Abstract

A field experiment was conducted at Agronomy research farm, A.N.D.U.A&T., Kumarganj, Ayodhya during 2023–2024 under ICAR-AICRP, IIFSR Modipuram. The experiment was comprised of 10 rice-based cropping sequences with 3 replications, viz., rice-wheat-fallow, rice-wheat-greengram, rice-chickpea-greengram, rice-pea-cowpea, rice-mustard-greengram, rice-linseed-blackgram, rice-berseem-sorghum(fodder), rice-oat-maize+cowpea (fodder), rice-pea-okra, rice-potato-cowpea were assigned to main crop as rice and after *kharif* season along with different crops impact on rice growth and yields attributes. Highest plant height, number of tillers, weight of panicle, grains per panicle and test weight was recorded in T_3 (rice-chickpea-greengram) while lowest value recorded in T_1 (rice-wheat-fallow). The height rice yield equivalent was recorded in rice-berseem-sorghum and lowest in T_6 (rice-linseed-blackgram).

Keywords- Rice, Cropping system, Rice Equivalent Yield, Straw yield and Legume straw incorporation.

Introduction

Rice (*Oryza sativa L.*) is a staple food for over half of the global population, particularly in Asia, Africa, and Latin America. It is primarily cultivated in tropical and subtropical regions, with China and India being the leading producers (Shukla *et al.,* 2024). Archaeological evidences indicate that rice cultivation began in the Yangtze River basin of China approximately 9,000 years ago, with subsequent domestication events in other regions, leading to the development of distinct subspecies such as *indica* and *japonica* (Choi *et al*., 2017; Fuller *et al*., 2010). Nutritionally, rice is a rich source of carbohydrates, providing a significant portion of daily caloric intake in many countries. It also contains essential amino acids, vitamins, and minerals, though it is relatively low in fat and protein. The nutritional profile can vary among different rice varieties, with some, like pigmented rice, offering additional bioactive compounds beneficial for human health (Verma *et al*., 2020).

Recent studies have highlighted additional benefits of diversifying rice-based cropping systems. For instance, integrating premium quality rice varieties and intensifying cropping sequences have been shown to enhance profitability, sustainability, and resilience of these systems (Islam *et al*., 2024). Diversified crop rotations not only improve soil health and yields but also provide broader ecosystem services (Singh *et al*., 2025). Furthermore, incorporating legumes and adopting conservation agriculture practices contribute to better nutrient cycling, reduced greenhouse gas emissions, and improved water use efficiency (Bera *et al*., 2024). Rice-based cropping systems (RBCS) are fundamental to global food security, particularly in Asia, where they support the livelihoods of millions and contribute significantly to staple food production. In India, the rice–wheat cropping system (RWCS) is predominant, covering approximately 9.2 million hectares, especially in the Indo-Gangetic Plains (Adarsh *et al*., 2024). However, the sustainability of conventional RBCS is increasingly challenged by factors such as soil degradation, water scarcity, declining nutrient use efficiency, and the impacts of climate change (Kalita *et al*., 2024). Long-term studies have shown that integrating legumes into rice-based systems, such as rice–chickpea–coriander rotations, can enhance soil organic carbon sequestration, improve soil physical and chemical properties, and increase system productivity (Nanda *et al*., 2024). Moreover, adopting conservation agriculture practices, including direct-seeded rice and zero-till wheat, along with efficient irrigation methods like drip fertigation, has demonstrated potential in improving resource use efficiency and reducing greenhouse gas emissions in RBCS (Reddy *et al*., 2025).

The rice–wheat cropping system plays an important role in global food security to the world's population. It is extensively cultivated over a 13.5-million-hectare area in Asia, with 57% in South Asia. Furthermore, more than 85% of the rice–wheat cropping system area is distributed in the Indo–Gangetic Plains of South Asia. It is the most important cropping system, followed by India with an about 10.5-million-hectare area. The cropping intensity of Eastern India (Bihar) is as low as 140%, and it needs to be increased to meet the food and nutritional demands of the ever-burgeoning population. In recent years, the sustainability of the rice–wheat cropping system has been adversely affected, as the productivity of both the cereals are either stagnant or declining due to the deterioration of soil health, the resurgence of insect pests, diseases, new weed flora and a reduction in profit margins. The large-scale occurrence of second-generation problems such as the overmining of soil nutrients, decline of factor productivity, lowering of ground water tables and build-up of new diseases and pests and the cereal-based production system, which are threatening agricultural sustainability. (Upadhyay *et al.* 2022).

Materials and Methods:

A field experiment was conducted during 2023-24 at Agriculture Research Farm of Acharya Narendra Dev University of Agriculture and Technology Kumarganj, Ayodhya. The agronomy research farm located in Agronomy research field of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, is positioned along the Ayodhya-Raebareli road, approximately 42 kilometers from Ayodhya. This research site is situated in a humid, subtropical zone within the Indo-Gangetic plains, characterized by specific geographical coordinates between 26° to 47° north latitude and 82° to 120° east longitude, at an elevation of around 113 meters above mean sea level. The treatment combinations of rice– based cropping sequences were T1:-rice-wheat-fallow, T2:-rice-wheat-greengram, T3:-rice-chickpea-greengram, T4:-rice-pea-cowpea[veg], T5: -rice-mustard-greengram, T6: -rice-linseed-blackgram, T7: -rice-berseem-sorghum, T8: -rice-oat-maize+cowpea[f], T9: -rice-pea -okra and T10: - rice-potato-cowpea [veg]. Plant height was recorded in these treatments using a meter scale, the height of five randomly chosen plants in each plot was measured at three different times: 30 days after sowing (DAT), 60 DAT, 90 DAT, and at harvesting. Tillers hill^{-1} was recorded in different rice plot at harvest stage, the numbers of tillers bearing spikes were counted in each plot using a meter scale that was positioned at three random locations. The number of effective tillers per square meter (m^2) for each plot was then determined by calculating the mean values. Grains panicle^{-1} were recorded after harvest the average number of grains per panicles was calculated after five chosen panicles were threshed and the grains were counted. Weight of grains panicle^{-1} were recorded after harvesting. Five chosen panicles' grains were weighed separately on an electronic balance, and the results were noted. The average grain weight per panicle for each plot was then calculated by averaging these weights. Test weight was recorded of different grain samples were randomly selected from each net plot's produce. An electronic balance was used to weigh, count, and randomly select 1000 grains from these samples. Yield of grains (q ha^{-1}) was recorded after harvest. The weight of grain collected from each net plot area after threshing and winnowing was measured in kilograms per plot and subsequently converted to q ha^{-1}. Yield of straw (q ha^{-1}) was recorded after harvest. Each net plot's straw yield was calculated by subtracting its grain yield from its biological yield. The straw yield was finally calculated on a hectare-by-hectare basis and expressed in qha^{-1}. Biological yield (q ha^{-1}) recorded after harvest. The biological yield was calculated by weighing each net plot's aboveground plant components and then converted to q ha^{-1}. Rice Equivalent Yield (kg ha^{-1}) calculated from rice yield. Rice equivalent yield (REY) was calculated DAT follows:

$$\text{Rice equivalent yield (REY)} = \frac{\text{Yield of crop (kg)x price of crop(Rs)}}{\text{Price of crop (Rs)}}$$

Results and discussion:

Plant height (cm):

The plant height is the most important growth factor of any crop. The observations of plant height were recorded at 30 DAT, 60 DAT, 90 DAT and at harvest and mean value was furnished in Table 1. At 30 DAT, the average plant height revealed the influence of various rice-based cropping systems on progressive plant height at different stages of crop growth, results are compared to the pre dominant rice-wheat-fallow (T_1) cropping system. Notably, the maximum plant height was recorded under the rice-chickpea-greengram (33.97 cm) (T_3), followed by rice-mustard-greengram (33.90 cm) (T_5) and Rice-Pea-Cowpea (33.82 cm) (T_4) treatments. The variations recorded in plant height among the rice-based cropping systems indicated that the cropping system compositions are essential for encouraging vegetative growth. The effects of the treatments at 30 days after transplanting (DAT) were not apparent as the crop developed. Specially at 60 DAT and onward stages, notable differences in plant height were recorded. The availability and management of legume crop leftover is responsible for the higher plant height performance of the Rice-chickpea-greengram (60.57 cm) (T_3) and rice-pea-cowpea (T_4) treatments. The highest plant height was recorded under the treatment (T_3 95.97 cm at 90 DAT) Rice-Chickpea-Greengram in and also at harvest (100.97cm) in same treatment because of the better nutrient availability in the legumes or fodder-based cropping system. Maintaining legume crop residues on the soil surface or incorporating them using conservation tillage techniques appears to significantly boost plant growth. While the rice-wheat-fallow combination has a wider C/N ratio, which is inappropriate, residues from other crops, such as legumes, have a narrower C/N ratio that promotes nutrient mineralization in the soil. This benefit is most likely due to the nitrogen (N) input from legume residues. The first 30 days after the rice-wheat-fallow system was put into place, soil N immobilization occurred, which would have prevented early rice growth. However, this effect diminished after 60 days, suggesting that nitrogen availability improved as the residues decomposed. According to table 1: plant heights were noticeably higher in rice grown in sequences involving leguminous crops such as cowpea, gram, chickpea, and green gram for fodder or vegetables than in rice–wheat sequences. This may be because sequences based on grain or fodder legumes offer superior nitrogen availability. Using a variety of rice-based cropping sequences, including legume crops, Banjara *et al*. (2021) discovered increases in the height of rice plants. These findings suggest that including leguminous crops in rice-based cropping systems may increase the availability of nitrogen, which could enhance the vegetative development and overall crop performance of rice. Upadhyaya *et al*. (2022) and Bastia *et al*. (2018) have also reported similar findings.

Table 1: Effect of various rice-based cropping sequences on plant height of rice at different growth stages.

Treatments	Plant height(cm)			
	30 DAT	**60 DAT**	**90 DAT**	**At harvest**
T_1-Rice-Wheat-Fallow	30.05	50.61	87.60	93.12
T_2-Rice-Wheat-Greengram	30.90	54.72	92.51	95.92
T_3-Rice-Chickpea-Greengram	33.97	60.57	95.97	100.97
T_4-Rice-Pea-Cowpea	33.82	60.23	95.81	100.34
T_5-Rice-Mustard-Greengram	33.90	57.06	92.02	97.87
T_6-Rice-Linseed-Blackgram	33.07	54.98	91.11	97.63
T_7-Rice-Berseem-Sorghum(F)	31.62	58.08	94.17	96.19
T_8-Rice-Oat-Maize+Cowpea(F)	30.19	59.12	94.56	96.58
T_9-Rice-Pea-Okra	32.03	59.55	95.02	99.78
T_{10}-Rice-Potato-Cowpea	32.64	60.3	95.20	99.89

SEm ±	0.64	1.11	0.99	1.08
C.D (0.05)	1.948	3.305	2.971	3.246

2. Number of tiller hill^{-1}:

Rice-based cropping systems had a major impact on the number of tiller hill^{-1}. The effects of several rice-based cropping sequences on tillers were illustrated by the data presented in Table 4.2 showed that the addition of residue from legume crops had an extensive effect on tillers development at various growth stages. Number of tillers insignificantly increased with the treatment (T_3 4.41) (rice-chickpea-green gram) followed by T_4 (3.80) and T_{10} (3.52). However minimum in (T_1 2.81) (rice-wheat-fallow) and T_9 (rice-pea-okra), because the leguminous components that were grown during the previous winter and summer seasons had beneficial effects. Incorporating leguminous crops into the cropping system appears to improve the characteristics of tiller growth and, ultimately, rice yield. This illustrates how crop diversification and residue management may increase rice yield (Kumar *et al.,* 2023). According to Bastia *et al.* (2018), who looked at a number of rice-based cropping sequences, rice with sequences based on vegetables, feed, and legumes had more tillers. Similarly, at 90 DAT and maturity, the same order was noted for tillers or branches plant-1 under different seasons. In this investigation, the nutrients used during the experiment have an impact on the number of tillers hill^{-1}. Kumar *et al.* (2014) discovered similar outcomes.

Table 2: Effect of various rice-based cropping sequences on Number of tillers plants^{-1} of rice crop.

Treatments	**Tillers hill^{-1}**			
	30 DAT	**60 DAT**	**90DAT**	**At harvest**

T_1-Rice-Wheat-Fallow	2.81	10.07	10.73	8.60
T_2-Rice-Wheat-Greengram	3.20	10.90	12.02	9.91
T_3-Rice-Chickpea-Greengram	4.41	11.79	12.21	10.03
T4-Rice-Pea-Cowpea	3.80	11.38	11.77	9.54
T_5-Rice-Mustard-Greengram	2.91	11.61	11.70	9.61
T_6-Rice-Linseed-Blackgram	3.12	11.51	10.82	8.52
T_7-Rice-Berseem-Sorghum(F)	3.09	11.31	10.02	8.91
T_8-Rice-Oat-Maize+Cowpea(F)	2.97	9.76	10.79	8.63
T_9-Rice-Pea-Okra	2.29	10.41	10.11	8.97
T_{10}-Rice-Potato-Cowpea	3.52	11.07	10.81	9.53
SEm ±	0.09	0.19	0.18	0.03
C.D. (0.05)	0.298	0.576	0.622	0.932

3. Weight of grains Panicle^{-1}, Grains panicle^{-1} and Test weight of rice:

Treatments involving vegetables, fodder, or legume crops had a significant impact on the weight of grains per panicle. Grain weights per panicle were highest in T_3 and T_{10}, then T_4, T_9, T_8, T_7, and T_2. T_1 (rice-wheat-fallow) consistently produced the lowest grain weight (3.30 g) per panicle. Another important measure of grain quality, test weight, varied significantly between treatment leguminous crops produced higher test weights (averaging 24.93g) than the lowest test weight (22.92g) recorded under T_1 (rice-wheat-fallow). Overall, the rice-based cropping system's grain weight per panicle varied from 3.30 g to 3.94 g. The impact of these cropping systems on rice yield characteristics was also evident. This data emphasizes how crucial it is to select suitable cropping sequences in order to enhance rice production and quality. The higher growth parameters observed when legume crop residues were applied are due to the crops' steady and sufficient supply of nutrients, which enables rapid growth. This facilitates root development, encourages quick cell division and elongation, and supports several metabolic processes, all of which enhance plant growth. These findings are consistent with the research conducted by Paramesh *et al*. (2023). The increased yield-attributable characteristics resulting from the increased fertilizer supply through residues are primarily caused by improved root proliferation and higher nutrient concentration in the soil. By accelerating cell division and elongation, this encourages root branching, tiller growth, plant height, and the production of dry matter. This enhances yield characteristics by increasing photosynthetic activity. Assimilate translocation from source to sink is also encouraged by higher nutrient supply conditions, contributing to the enhanced production characteristics. Similar findings were reached by Banjara *et al*. (2021), Bastia *et al*. (2018), and Prasad *et al*. (2013). Trace elements released by legume crop residues have a significant effect on rice output parameters because of their positive effects on a range of enzymatic reactions, growth processes, hormone production, protein synthesis, and the transfer of photosynthesis to reproductive regions. Overall, this results in better yield features. Similar finding was reported by Singh *et al*. (2018).

Table 3: Effect of various rice-based cropping sequences on weight of grains panicle^{-1}, grain panicle^{-1} and test weight of rice crop.

Treatments	weight of panicle(g)	Grain/ panicle	Test weight
T_1-Rice-Wheat-Fallow	3.30	143.8	22.92
T_2-Rice-Wheat-Greengram	3.59	147.09	24.4
T_3-Rice-ChickpeaGreengram	3.94	157.87	24.93
T4-Rice-Pea-Cowpea	3.84	156.79	24.46
T_5-Rice-Mustard-Greengram	3.66	155.23	23.57
T_6-Rice-Linseed-Blackgram	3.55	151.46	23.45
T_7-Rice-BerseemSorghum(F)	3.62	154.1	23.47
T_8-Rice-Oat-Maize+Cowpea(F)	3.75	156.09	24.04
T_9-Rice-Pea-Okra	3.79	154.13	24.56
T_{10}-Rice-Potato-Cowpea	3.86	155.03	24.87

4. Yields (q ha$^{-1)}$, rice yield equivalent (q ha^{-1}) and harvest index of rice crop:

The grain and straw yields of rice in different treatments illustrate in table .4 between 31.10 and 48.80 (q ha^{-1}) and 43.54 to 68.32 q ha^{-1}, respectively. Among the various treatments, the highest grain yield (48.80 q ha^{-1}) was observed in the (Rice (NDR-2065)-berseem-sorghum) sequence, followed by rice-oat-maize+cowpea, rice-gram-green gram, rice-wheat-green gram, and rice-pea-cowpea. These some treatments showed statistically similar yields. Incorporating legume crop residues (greengram, blackgram, and cowpea) resulted in increase in grain yield increase in straw yield. The highest straw yield (68.32 q ha^{-1}) was obtained with the T_7 treatment (rice (NDR-2065)-berseem-sorghum), followed by cropping sequences T_8, T_3, T_2 and T_4. However, these five treatments showed statistically similar results. The application of legume crop residue (green gram, black gram, and cowpea) led to increase in straw yield. Conversely, the lowest straw yield (43.54 q ha^{-1}) was observed under the T_6 treatment (rice-linseed-blackgram). The grain yield ranged from 31.10 and 48.80 q ha^{-1}, and the straw yield ranged from 43.54 to 68.32 q ha^{-1}. The highest biological yield was achieved with T_7 (rice-(NDR-2065)-berseem-sorghum), significantly surpassing other treatments. These findings indicate that optimal doses of nitrogen, phosphorus, potassium, and legume crop residue decomposers, along with their interactions, significantly increased grain weight, thereby enhancing grain and straw yields, and ultimately the biological yield of rice. The superior yields observed with rice (NDR-2065)-berseem-sorghum were primarily attributed to the adequate supply of major nutrients to plants, which in turn enhanced growth and yield attributes, resulting in higher yields. Harvesting index data ranged from 41.64 to 41.67 %. Among different cropping sequences, the highest harvesting index was noted in almost every cropping sequence, while the lowest was observed in the rice-pea-cowpea sequence. Cropping sequences did not significantly influence the harvest index of rice. The key factor in raising rice yields was the addition of legume crop residues, especially cowpea, black gram, and green gram, along with optimal nutrient dosages. In particular, the rice-chickpea-green gram sequence outperformed the sarjoo-52 variety in terms of grain and straw yields, underscoring the significance of residue incorporation and nutrient management in agricultural practices for maximizing crop productivity (Verma *et al.,* 2024). Furthermore, even though cropping sequences had no discernible impact on the rice harvest index, more research into how various crops interacted during rotation may yield important information for sustainable farming methods. Due to poor growth and metabolic processes that affect yield attributes, the lowest yield was obtained when recommended fertilizers for rice and wheat were applied without the addition of legume straw. Bowal *et al*. (2021) and Jat *et al*. (2018) also found this. On the other hand, higher grain yields were noted when legume crop residues were incorporated. This is probably because high yield varieties also use residues, which release trace elements in a beneficial way. These components are essential for growth, enzymatic reactions, and straw yield. Baheliya *et al.* (2025), Neeraj *et al.* Jain and Kushwaha (2014) and Singh *et al*. (2013) reported similar results.

Table 4: Effect of various rice-based cropping sequences on yields (kg ha^{-1}), harvest index (%) and rice equivalent yield (REY) of rice.

Treatments	Grain	Straw	B.Y	REY	Harvest Index
T_1-Rice-Wheat-Fallow	4555	6377	10932	4555	41.67
T_2-Rice-Wheat-Greengram	4630	6482	11112	4630	41.67
T_3-Rice-Chickpea-Greengram	4740	6636	11376	4740	41.67
T_4-Rice-Pea-Cowpea	4610	6461	11071	4610	41.64
T_5-Rice-Mustard-Greengram	3240	4536	7776	3240	41.67
T_6-Rice-Linseed-Blackgram	3110	4354	7464	3110	41.67
T_7-Rice-Berseem-Sorghum(F)	4880	6832	11712	4880	41.67
T_8-Rice-Oat-Maize+Cowpea(F)	4760	6664	11424	4760	41.67
T_9-Rice-Pea-Okra	3560	4984	8544	3560	41.67
T_{10}-Rice-Potato-Cowpea	3440	4816	8256	3440	41.67
SEm ±	116.04			116.04	
C.D. (0.05)	351.42			351.42	

Conclusion:

Based on findings of this experiment it can be concluded that under irrigated conditions of Eastern Uttar Pradesh, India. Rice-berseem-sorghum (T_7) followed by rice-oat-maize+cowpea (T_8), rice-chickpea-greengram (T_3) and rice-wheat-greengram (T_2). Treatment 7 and showed higher in yields parameters because the variety is using in these treatments is NDR-2065, which high yield variety use overall treatments and treatments 3, 2 and 4 showed higher in growth attribute because using previous legumes crop straw was incorporated in these treatments. It has been observed that incorporating legume-based cropping sequences, such as rice-chickpea–greengram and rice–gram–cowpea, enhances the physicochemical properties of soil. This improvement involves a reduction in bulk density, an increase in organic carbon content, and better water-holding capacity, all occurring with minimal impact on soil pH and a slight increase in electrical conductivity.

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