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Evaluate the effect of different post emergence herbicides on growth and yield of rice (*Oryza sativa* L.)

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Abstract
The field experiment was conducted during *kharif*, 2022 to evaluate the effect of different post emergence herbicides on growth and yield of rice (*Oryza sativa* L.) at Agronomy Farm, College of Agriculture, Dapoli, District Ratnagiri (M.S.). The experiment was laid out in a randomized block design with ten treatments which were replicated three times *viz*., (T_1) Pyribenzoxim 3% + Penoxsulam 2% EC @ 500 ml ha^{-1}, (T_2) Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}, (T_3) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}, (T_4) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}, (T_5) Pyribenzoxim 5% EC @ 600 ml ha^{-1}, (T_6) Penoxsulam 2.67% OD @ 1000 ml ha^{-1}, (T_7) Bispyribac-Sodium 20% + Pyrazosulfuron Ethyl 15% WDG @ 100 g ha^{-1}, (T_8) Triafamone 20% + Ethoxysulfuron 10% WG @ 225 g ha^{-1}, (T_9) Hand weeding at 30 and 60 DAT and (T_{10}) Weedy check (Untreated). The results of the experiment showed that the application of post emergence herbicide Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1} has positive effect on growth and yield of rice. Significantly higher values of growth attributes such as plant height (cm), number of tillers $hill^{-1}$, dry matter accumulation $hill^{-1}$ (g) were observed with treatment (T_4) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1} at 60, 90 and 120 DAT and at harvest stage as compared to other treatments whereas, least values were recorded with treatment (T_{10}) Weedy check. Significantly higher grain yield (4050.55 kg ha^{-1}) and straw yield (5524.62 kg ha^{-1}) was observed with treatment (T_4) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1} and lower grain and straw yield was observed with treatment (T_{10}) Weedy check.

Keywords: Rice, weed, herbicide, growth, yield

1. Introduction

Rice plays a crucial role as the primary cereal crop in the developing world, providing a staple diet for over half of the global population. As a semi-aquatic annual grass, it not only sustains livelihoods but also addresses hunger on a large scale. The Oryza genus comprises more than 24 recognized species, with *Oryza sativa* L. being the predominant variety in cultivated rice. Beyond sustenance, rice significantly impacts agriculture, the economy, and global ecology, surpassing other crops in its capacity to feed populations, generate employment, and contribute to ecological balance. Particularly in Asia, where approximately 70% of the impoverished population relies heavily on rice for both sustenance and income, rice cultivation plays a crucial role in shaping societal structures and economic dynamics. This intricate relationship underscores rice's pivotal role in addressing food security and supporting the well-being of communities, with India being a major contributor to global rice production.

Globally, rice production faces a decline, primarily due to weed infestation, which presents a significant threat to transplanted rice. Weeds, known for their adaptability and rapid growth, can outcompete rice, resulting in reduced yields. Effective weed control is essential for successful transplanted rice cultivation, and control methods include manual, mechanical, or chemical approaches. Despite the effectiveness of manual weeding, farmers often opt for chemical weed control due to labor shortages and high costs. Herbicides are considered the most efficient, cost-effective, and practical means of weed control. Weed competition can lead to substantial reductions in grain output, with potential decreases of up to 32% (Singh *et al*., 2007) [7].

Establishing a weed-free environment within a month of transplanting is crucial for optimal crop growth, and post-emergence herbicides like bispyribac-sodium and pyrazosulfuron-ethyl have proven highly effective in managing rapid weed growth.

2. Materials and Methods

The present investigation took place in the *kharif* season of 2022 at the Agronomy Farm, College of Agriculture, Dapoli, District Ratnagiri (M.S.). The experimental plot no. 51, is located in the subtropical region at 17°76'24" N latitude and 73°17'33" E longitude, with an elevation of approximately 157.8 meters above mean sea level. The experiment was laid out in a randomized block design with ten treatments which were replicated three times *viz*., (T_1) Pyribenzoxim 3% + Penoxsulam 2% EC @ 500 ml ha^{-1}, (T_2) Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}, (T_3) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}, (T_4) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}, (T_5) Pyribenzoxim 5% EC @ 600 ml ha^{-1}, (T_6) Penoxsulam 2.67% OD @ 1000 ml ha^{-1}, (T_7) Bispyribac-Sodium 20% + Pyrazosulfuron Ethyl 15% WDG @ 100 g ha^{-1}, (T_8) Triafamone 20% + Ethoxysulfuron 10% WG @ 225 g ha^{-1}, (T_9) Hand weeding at 30 and 60 DAT and (T_{10}) Weedy check (Untreated). Throughout the growth phase of the rice crop, it experienced a substantial rainfall of 3530.1 mm. The average daily sunshine duration was 4.00 hours. The soil in which the crop was cultivated had 11.18 g kg^{-1} of organic carbon, pH level of 6.14, and an electrical conductivity of 0.11 dS m^{-1}. The climatic conditions were highly favorable for the growth and development of the rice crop.

3. Result and Discussion

3.1 Effect on growth parameters of rice

3.1.1 Plant height (cm)

Table 1 presents data on the effect of various treatments on the plant height of rice plants. The results show that plant height increases with the progression of crop age, peaking at harvest. Across all treatments, the rate of height increase is relatively low during the early vegetative growth stage (up to 30 days after transplanting - DAT) but rises from 60 to 90 DAT. Subsequently, the rate remains low until crop maturity. Average plant heights were 14.83 cm, 50.03 cm, 74.49 cm, 94.70 cm, and 96.84 cm at 30, 60, 90, 120 DAT, and harvest, respectively.

At 30 DAT, there is no significant difference in mean plant height among treatments. However, significant differences emerge at 60, 90, 120 DAT, and harvest based on the application of various post-emergence herbicides. Treatment T_4 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}) records significantly higher plant heights of 51.66 cm, 76.53 cm, 97.58 cm, and 100.02 cm at 60, 90, 120 DAT, and harvest, respectively. Treatments T_3 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}), T_2 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}), and T_9 (Hand weeding at 30 and 60 DAT) were statistically at par to treatment T_4.

Table 1: Plant height of rice as influenced periodically by different treatments.

Treatment	Plant height (cm) at				
	30 DAT	60 DAT	90 DAT	120 DAT	At harvest
T_1: Pyribenzoxim 3% + Penoxsulam 2% EC @ 500 ml ha^{-1}	14.85	50.03	74.28	94.65	97.05
T_2: Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}	15.19	51.17	75.47	96.32	98.71
T_3: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}	15.49	51.21	76.35	96.98	98.90
T_4: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}	15.29	51.66	76.53	97.58	100.02
T_5: Pyribenzoxim 5% EC @ 600 ml ha^{-1}	14.83	50.00	74.21	94.57	96.15
T_6: Penoxsulam 2.67% OD @ 1000 ml ha^{-1}	14.48	49.78	73.91	94.10	95.85
T_7: Bispyribac-Sodium 20% + Pyrazosulfuron Ethyl 15% WDG @ 100 g ha^{-1}	14.61	49.92	74.12	94.20	96.06
T_8: Triafamone 20% + Ethoxysulfuron 10% WG @ 225 g ha^{-1}	14.43	48.99	73.80	93.71	94.68
T_9: Hand weeding at 30 and 60 DAT	15.17	50.17	74.91	94.96	97.99
T_{10}: Weedy check (Untreated)	13.98	47.37	71.34	89.96	92.95
S.Em. (±)	0.40	0.51	0.69	0.90	0.99
C.D. at 5%	NS	1.50	2.04	2.69	2.94
General Mean	14.83	50.03	74.49	94.70	96.84

3.1.2 Number of tillers hill^{-1}

Table 2 displays data regarding the number of tillers hill^{-1} under various treatments. Analysis of the data at 30 days after transplanting (DAT) did not reveal any statistically significant differences in the mean number of tillers hill^{-1} due to different treatments. However, at 60, 90, 120 DAT, and at harvest, the mean number of tillers hill^{-1} was significantly influenced by the application of different post-emergence herbicides.

The results indicated that the number of tillers hill^{-1} was notably higher with treatment T_4 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}) compared to other treatments at 60 DAT (12.20), 90 DAT (15.00), 120 DAT (13.60), and at harvest (13.33). Treatment T_3 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}), T_2 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}), and T_9 (Hand weeding at 30 and 60 DAT) were statistically at par to treatment T_4.

3.1.3 Dry matter accumulation hill^{-1} (g)

Table 3 presents data on the periodic mean dry matter accumulation hill^{-1} of rice under different treatments. Generally, dry matter production hill^{-1} increased with the age of the crop, reaching its maximum at harvest. The mean dry matter accumulation hill^{-1} was 21.96 g, 45.01 g, 47.68 g, and 48.86 g at 60, 90, 120 days after transplanting (DAT), and at harvest, respectively.

At 30 DAT, the dry matter accumulation hill^{-1} did not show significant differences among the various treatments. However, from 60 DAT to harvest, significant variations were observed between treatments. Treatment T_4 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}) recorded significantly higher dry matter accumulation hill^{-1} at 60 DAT (23.93 g), 90 DAT (47.18 g), 120 DAT (50.23 g), and at harvest (51.95 g). Treatments T_3 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}), T_2 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}), and T_9 (Hand weeding at 30 and 60 DAT) were statistically at par with treatment T_4 at 60, 90, 120 DAT, and at harvest. Treatment T_{10} (Weedy check - Untreated) recorded the lowest dry matter accumulation hill^{-1} at various growth stages.

Table 2: Number of tillers hill^{-1} of rice as influenced periodically by different treatments.

Treatment	Number of tillers hill^{-1}				
	30 DAT	60 DAT	90 DAT	120 DAT	At harvest
T_1: Pyribenzoxim 3% + Penoxsulam 2% EC @ 500 ml ha^{-1}	5.87	11.00	12.93	12.73	12.60
T_2: Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}	6.33	11.40	13.93	13.40	13.13
T_3: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}	6.13	11.60	14.33	13.47	13.20
T_4: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}	6.73	12.20	15.00	13.60	13.33
T_5: Pyribenzoxim 5% EC @ 600 ml ha^{-1}	5.47	10.87	12.87	12.60	12.33
T_6: Penoxsulam 2.67% OD @ 1000 ml ha^{-1}	5.20	10.20	12.67	12.40	12.13
T_7: Bispyribac-Sodium 20% + Pyrazosulfuron Ethyl 15% WDG @ 100 g ha^{-1}	5.40	10.60	12.80	12.47	12.20
T_8: Triafamone 20% + Ethoxysulfuron 10% WG @ 225 g ha^{-1}	5.13	10.07	12.60	12.33	12.00
T_9: Hand weeding at 30 and 60 DAT	6.07	11.27	13.87	13.00	12.93
T_{10}: Weedy check (Untreated)	4.93	9.80	11.60	11.07	10.93
S.Em. (±)	0.39	0.32	0.39	0.25	0.23
C.D. at 5%	NS	0.96	1.17	0.76	0.67
General Mean	5.73	10.90	13.26	12.69	12.49

Table 3: Mean dry matter accumulation hill^{-1} (g) of rice as influenced periodically by different treatments.

Treatment	Dry matter accumulation (g) hill^{-1}				
	30 DAT	60 DAT	90 DAT	120 DAT	At harvest
T_1: Pyribenzoxim 3% + Penoxsulam 2% EC @ 500 ml ha^{-1}	2.30	21.86	45.00	47.40	48.44
T_2: Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}	2.40	22.41	46.01	48.92	50.33
T_3: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}	2.45	22.76	46.10	49.62	50.56
T_4: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}	2.74	23.93	47.18	50.23	51.95
T_5: Pyribenzoxim 5% EC @ 600 ml ha^{-1}	2.26	21.59	44.93	47.25	48.31
T_6: Penoxsulam 2.67% OD @ 1000 ml ha^{-1}	2.19	21.49	44.59	46.93	47.94
T_7: Bispyribac-Sodium 20% + Pyrazosulfuron Ethyl 15% WDG @ 100 g ha^{-1}	2.22	21.55	44.79	47.03	48.07
T_8: Triafamone 20% + Ethoxysulfuron 10% WG @ 225 g ha^{-1}	2.12	21.07	43.99	46.03	47.59
T_9: Hand weeding at 30 and 60 DAT	2.36	22.34	45.50	48.50	49.92
T_{10}: Weedy check (Untreated)	1.96	20.64	41.97	44.84	45.52
S.Em. (±)	0.14	0.57	0.70	0.99	1.13
C.D. at 5%	NS	1.69	2.08	2.94	3.34
General Mean	2.30	21.96	45.01	47.68	48.86

3.1.4 Number of effective tillers hill^{-1}

Table 4 presents data on the number of effective tillers hill^{-1} of rice under different treatments. The mean number of effective tillers hill^{-1} was significantly influenced by the various treatments. The data clearly showed that the mean number of effective tillers hill^{-1} was significantly higher with treatment T_4 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}), recording 9.13 effective tillers hill^{-1}. Treatments T_3 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}), T_2 (Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}), and T_9 (Hand weeding at 30 and 60 DAT) were followed by treatment T_4.

Table 4: Number of effective tillers hill-1 of rice as influenced by different treatments.

Treatment	Number of effective tillers hill^{-1}
	At harvest
T_1: Pyribenzoxim 3% + Penoxsulam 2% EC @ 500 ml ha^{-1}	8.07
T_2: Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}	8.47
T_3: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}	8.67
T_4: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}	9.13
T_5: Pyribenzoxim 5% EC @ 600 ml ha^{-1}	8.00
T_6: Penoxsulam 2.67% OD @ 1000 ml ha^{-1}	7.67
T_7: Bispyribac-Sodium 20% + Pyrazosulfuron Ethyl 15% WDG @ 100 g ha^{-1}	7.80
T_8: Triafamone 20% + Ethoxysulfuron 10% WG @ 225 g ha^{-1}	7.60
T_9: Hand weeding at 30 and 60 DAT	8.33
T_{10}: Weedy check (Untreated)	7.07
S.Em. (±)	0.30
C.D. at 5%	0.90
General Mean	6.48

3.2 Effect on yield of rice

Table 5 demonstrated data on grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), and harvest index (%) of the rice crop influenced by different post emergence herbicide treatments.

The data indicates a significant increase in grain yield (kg ha^{-1}) in treatment (T_4) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}, reaching 4050.55 kg ha^{-1}, surpassing all other treatments except for treatments (T_3) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}, (T_2) Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}, and (T_9) Hand weeding at 30 and 60 DAT, which were on par with T_4. In contrast, treatment (T_{10}) Weedy check recorded the lowest grain yield 2568.85 kg ha^{-1} among all the treatments under study.

The data reveals a notable influence of different treatments on the straw yield (kg ha^{-1}) of rice. Specifically, treatment (T_4) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1} resulted in a significantly higher straw yield at 5524.62 kg ha^{-1} compared to other treatments. However, treatments (T_3) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}, (T_2) Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}, and (T_9) Hand weeding at 30 and 60 DAT were statistically equivalent to treatment T_4. Conversely, treatment (T_{10}) Weedy check recorded the lowest straw yield 4274.09 kg ha^{-1}.

The data demonstrates a significant impact of various treatments on the biological yield (kg ha^{-1}) of rice. Specifically, treatment (T_4) Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1} resulted in a significantly higher biological yield at 9575.17 kg ha^{-1} compared to other treatments, except for T_3, T_2, and T_9, which were statistically equivalent to T_4. Treatment (T_{10}) Weedy check recorded the lowest biological yield 6842.94 kg ha^{-1}.

Table 5: Mean grain yield, straw yield, biological yield and harvest index of *kharif* rice as influenced by different treatments.

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1: Pyribenzoxim 3% + Penoxsulam 2% EC @ 500 ml ha^{-1}	3710.73	5024.25	8734.98	42.48
T_2: Pyribenzoxim 3% + Penoxsulam 2% EC @ 750 ml ha^{-1}	3893.94	5286.22	9180.16	42.42
T_3: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1000 ml ha^{-1}	3992.48	5395.33	9387.82	42.53
T_4: Pyribenzoxim 3% + Penoxsulam 2% EC @ 1500 ml ha^{-1}	4050.55	5524.62	9575.17	42.30
T_5: Pyribenzoxim 5% EC @ 600 ml ha^{-1}	3709.33	5018.16	8727.49	42.50
T_6: Penoxsulam 2.67% OD @ 1000 ml ha^{-1}	3699.30	4943.55	8642.85	42.80
T_7: Bispyribac-Sodium 20% + Pyrazosulfuron Ethyl 15% WDG @ 100 g ha^{-1}	3704.01	4983.82	8687.83	42.63
T_8: Triafamone 20% + Ethoxysulfuron 10% WG @ 225 g ha^{-1}	3685.73	4887.85	8573.58	42.99
T_9: Hand weeding at 30 and 60 DAT	3933.25	5286.55	9219.80	42.66
T_{10}: Weedy check (Untreated)	2568.85	4274.09	6842.94	37.54
S.Em. (±)	105.24	130.55	193.20	-
C.D. at 5%	312.69	387.89	574.01	-
General Mean	3694.82	5062.44	8757.26	42.09

4. Discussion

The data provided in Tables 1, 2, 3, and 4 delineate the influence of diverse treatments on rice growth parameters. The results consistently depict a rise in plant height with the progression of the crop, culminating at the harvest stage. The significant enhancements in rice growth attributed to chemical weed control can be chiefly ascribed to the reduction in competition between the crop and weeds, as indicated by studies on weed dynamics. Effective mitigation of weed populations through the application of post-emergence herbicides during optimal stages of rice growth led to diminished competition for essential resources such as light, nutrients, space, and other growth factors. This alleviation of competition enabled rice plants to flourish, gaining increased access to crucial growth resources, resulting in heightened values across various morphological parameters, indicating improved plant growth. This enhancement encompasses increased plant height, tillering, robust development of reproductive structures, and an overall augmentation in plant vigor. The augmented photosynthetic capacity, stemming from reduced competition, ultimately translated into increased yields, closely aligning with findings reported by Srinithan *et al.* (2020) [9], Abraham and Menon (2015) [1], Ganai *et al.* (2014) [2], and Soni *et al.* (2020) [8].

The data demonstrated in Table 5 shows the impact of various treatments on yield of rice. The significant rise in rice grain, straw, and biological yield can be directly attributed to a substantial improvement in overall yield. These improvements encompass various factors, including but not limited to an increased capacity for tillering, improved plant height, efficient development of panicles, enhanced photosynthetic efficiency, and more effective nutrient utilization. The notable increase in tillering capacity contributes directly to a higher number of productive tillers per plant, promoting enhanced panicle initiation and subsequent spikelet development, thereby increasing potential grain yield. Additionally, the improvement in plant height facilitates better light interception, optimizing the photosynthetic capacity of rice plants and subsequently contributing to increased biomass production. Furthermore, the combined impact of these enhanced growth characteristics significantly contributed to the biological yield improvement in rice highlighting the strength and productivity of the rice crop. Hence, the observed enhancements in grain, straw, and biological yield of rice can be attributed to the cumulative improvements in growth and yield attributes across the entire crop growth cycle. These findings align with those reported by Saranraj *et al.* (2018) [5], Khaliq *et al.* (2012) [3], Nazir *et al.* (2020) [10], and Sheeja *et al.* (2013) [6].

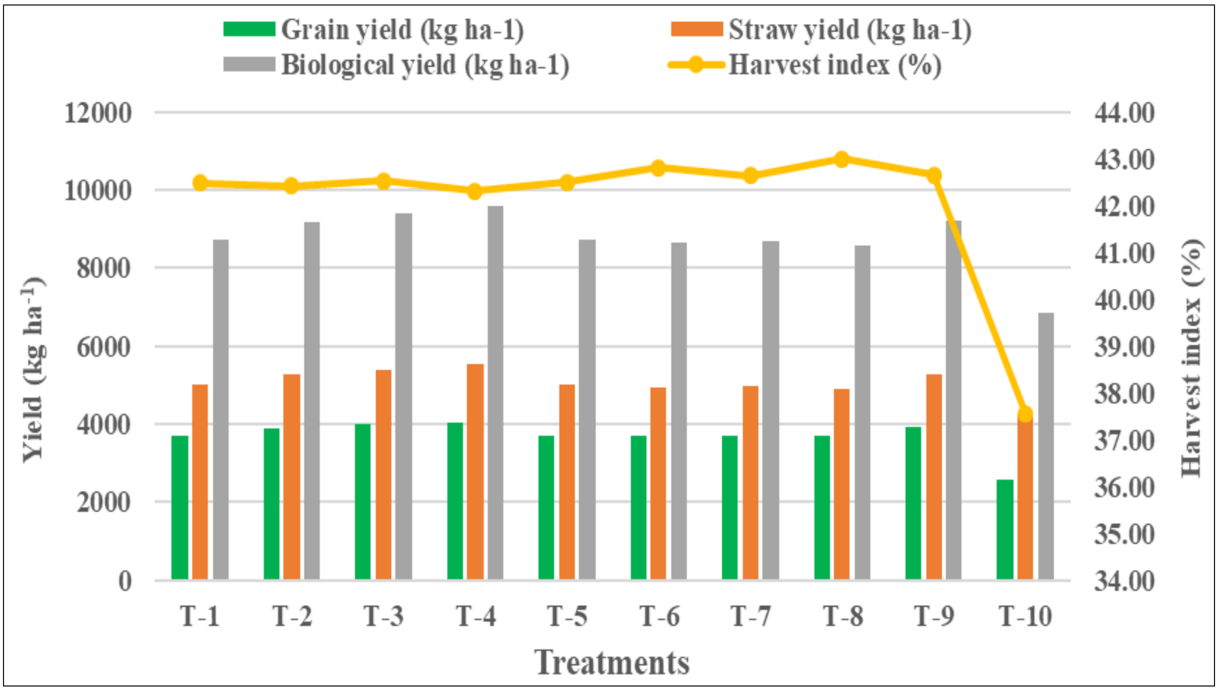

Fig 1: Mean grain yield, straw yield, biological yield (kg ha^{-1} and harvest index of *kharif* rice as influenced by different treatments.

5. Conclusion

Achieving optimal growth attributes such as plant height, number of tillers hill^{-1}, and dry matter accumulation hill^{-1} can be attained through the application of Pyribenzoxim 3% + Penoxsulam 2% EC @1500 ml hectare^{-1}. Utilizing this combination as a post-emergence herbicide in transplanted rice has proven to be effective in securing higher yields.

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