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Growth Attributes and Growth Indices of Aerobic Rice as Influenced by Urease and Nitrification Inhibitors

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ABSTRACT: Slowing down the mineralization of urea fertilizers is imperative for achieving higher crop yields, as it allows for a more controlled release of nutrients, promoting optimal plant absorption. Additionally, this practice contributes to eco-friendly crop production by reducing nitrogen losses into environment. Hence, a field experiment was conducted to assess the impact of combined application of urease and nitrification inhibitors along with urea on growth attributes and growth indices of aerobic rice at Agronomy field unit, Zonal Agricultural Research Station, UASB, GKVK, Bengaluru for two years during summer, 2022 and 2023. The experiment was laid out in Randomized Complete Block Design with nine treatments (Urea, Urea + HQ @ 4000 mg kg^{-1} urea, Urea + HQ @ 8000 mg kg^{-1} urea, Urea + HQ @ 12000 mg kg^{-1} urea, Urea + DCD @ 4000 mg kg^{-1} urea, Urea + DCD @ 8000 mg kg^{-1} urea, Urea + DCD @ 12000 mg kg^{-1} urea, Neem coated urea and Absolute control) replicated thrice. Significantly higher leaf area, leaf area index and dry matter production at different crop stages were recorded with application of Urea + HQ @ 12000 mg kg^{-1} urea compared to other treatments on pooled basis. Growth indices *viz.*, absolute growth rate, crop growth rate, relative growth rate and net assimilation rate during different growth phase of aerobic rice were also higher under combined application of urease and nitrification inhibitors than sole urea or neem coated urea application.

Keywords: Hydroquinone, Dicyanamide, Absolute growth rate, Crop growth rate, Net assimilation rate and Relative growth rate.
Abbreviations used: HQ- Hydroquinone, DCD- Dicyanamide.

INTRODUCTION

In the face of mounting global challenges, agriculture stands at the forefront, grappling with the need for sustainable solutions to ensure food security. One of the most critical concerns is the scarcity of water, an issue exacerbated by climate change and population growth (Bouman and Toung 2001). In this context, aerobic rice cultivation emerges as a promising alternative, offering a water-efficient approach to rice production (Nawaz *et al*., 2022). As we navigate the complexities of present-day water scarcity, understanding and optimizing the growth attributes and growth indices of aerobic rice becomes paramount for sustainable agricultural practices.

Aerobic rice, unlike its traditional flooded counterpart, is cultivated in well-aerated soils without standing water. This innovative method not only conserves water but also addresses concerns related to greenhouse gas emissions and soil health (Poojitha *et al*., 2022). However, achieving optimal yields in aerobic rice cultivation requires a nuanced understanding of the crop's growth attributes and growth indices. This research endeavors to bridge this knowledge gap, shedding light on the intricate dynamics of aerobic rice growth under water-scarce conditions.

The scope of this research extends beyond mere academic curiosity; it delves into the practical implications of cultivating rice aerobically, emphasizing its potential to revolutionize agriculture in water-scarce regions. With a focus on growth attributes and growth indices, the study aims to unravel the factors influencing the productivity of aerobic rice, providing valuable insights for farmers and policymakers alike (Theerthana *et al*., 2021). By deciphering the intricate interplay of environmental factors, soil conditions, and crop performance, we aim to pave the way for a more resilient and sustainable future for rice production.

In the pursuit of sustainable agriculture, the role of urease and nitrification inhibitors cannot be overstated. Urease inhibitors play a crucial role in mitigating nitrogen losses by slowing down the conversion of urea to ammonia, thereby enhancing nutrient use efficiency.

Likewise, nitrification inhibitors curb the transformation of ammonium to nitrate, minimizing nitrogen leaching and contributing to environmental conservation. In the context of aerobic rice cultivation, the judicious use of these inhibitors becomes imperative, not only for maximizing yields but also for minimizing the environmental footprint of agricultural activities.

As we stand at the intersection of environmental responsibility and food security, the necessity of urease and nitrification inhibitors becomes increasingly apparent. The judicious application of these inhibitors not only boosts crop productivity but also aligns with the principles of sustainable and environmentally friendly agriculture (Freney *et al*., 1995; Lan *et al*., 2022). By reducing nitrogen losses, these inhibitors contribute to the overall efficiency of nutrient use, mitigating the environmental impact associated with excess nitrogen in water bodies and the atmosphere (Amrutha *et al*., 2022).

The urgency of this research lies in its potential to offer a comprehensive guide for farmers and policymakers seeking to transition towards environmentally sustainable rice production in water-scarce regions. As global water resources dwindle and the pressure on agriculture intensifies, it is imperative to equip stakeholders with knowledge and tools that foster a balance between productivity and environmental conservation. This study aspires to be a beacon in this endeavor, providing evidence-based recommendations for the integration of urease and nitrification inhibitors into aerobic rice cultivation practices.

MATERIAL AND METHODS

The field experiment was conducted at the Agronomy field unit, Zonal Agricultural Research Station, UASB, GKVK, Bengaluru. This site comes under Eastern Dry Zone (Agro-Climatic Zone V) of Karnataka at a latitude of 12º 58' North, longitude of 77º 33' East and an altitude of 930 m above mean sea level. The soil was red sandy loam in texture that comes under *Alfisol* soil order. The experiment was laid out in Randomized Complete Block Design with nine treatments and three replications. The nine nitrogen management treatments were, T_1: Urea, T_2: Urea + HQ @ 4000 mg kg^{-1} urea, T_3: Urea + HQ @ 8000 mg kg^{-1} urea, T_4: Urea + HQ @ 12000 mg kg^{-1} urea, T_5: Urea + DCD @ 4000 mg kg^{-1} urea, T_6: Urea + DCD @ 8000 mg kg^{-1} urea, T_7: Urea + DCD @ 12000 mg kg^{-1} urea, T_8: Neem coated urea and T_9: Absolute control [Note: HQ- Hydroquinone (Urease inhibitor), DCD- Dicyanamide (Nitrification inhibitor)]. For T_1- T_7 treatments, lab grade urea was used and in T_8 treatment neem coated urea is used at 100 kg N ha^{-1}. FYM @ 10 t ha^{-1}, phosphorous and potassium @ 50 kg each ha^{-1} was commonly applied to all the treatments except absolute control treatment. Rest of the agronomic practices were followed as per the recommendation for all the treatments in common. Hydroquinone (urease inhibitor) and Dicyanamide (nitrification inhibitor) were procured from Sigma Aldrich Chemicals Pvt. Ltd. As per the treatments, the quantity of chemicals was weighed and made into water solution prior to use. Immediately after application of urea fertilizer (at sowing, 30 and 60 DAS), the inhibitors solution were applied to soil through foliar application as per treatments.

Five plants from each plot were randomly selected from the net plot and tagged. These plants were used for recording the observations on growth attributes. The plants from the gross plot were cut above the ground and leaves were fed to leaf area meter for estimating the photosynthetically active area (leaf area). The same plants were oven dried at 65-70°C and the dry weight per plant was noted. The average of all the replications was is expressed as mean values of the respective treatments. Further, growth indices were calculated using following formulas as given by Ramachandrappa and Jayadeva (2021).

$$\text{Leaf area index} = \frac{\text{Leaf area (cm}^2)}{\text{Land area (cm}^2)}$$

$$\text{Absolute growth rate (g plant}^{-1}\text{ day}^{-1}) = \frac{W_2 - W_1}{t_2 - t_1}$$

W_1 and W_2 are dry weights at times t_1 and t_2, respectively

$$\text{Crop growth rate (g m}^{-2}\text{ day}^{-1}) = \frac{1}{P} \times \frac{W_2 - W_1}{t_2 - t_1}$$

p- land area (m^2)

$$\text{Relative growth rate (g g}^{-1}\text{ day}^{-1}) = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

$$\text{Net assimilation rate (g day}^{-1}\text{ m}^{-2}) = \frac{(W_2 - W_1)(\text{Log}_e L_2 - \text{Log}_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

L_1 and L_2 – leaf area at t_1 and t_2, respectively

The data recorded on various parameters were subjected to Fisher's method of analysis of variance and interpretation of the data was made as given by Gomez and Gomez (1984). The level of significance used in 'F' and 't' test was P = 0.05. Whenever F-test was significant for comparison amongst the treatments means an appropriate value of critical differences (CD) was worked out. Otherwise against CD values abbreviation 'NS' (Non-significant) is indicated.

RESULTS AND DISCUSSION

A. Growth attributes

Data pertaining to leaf area of aerobic rice as influenced by urease and nitrification inhibitors is presented in Table 1. At 30, 60 and 90 DAS, significantly maximum leaf area $plant^{-1}$ was recorded in treatment receiving urea + HQ @ 12000 mg kg^{-1} urea (14.56, 776 and 2108 cm^2 $plant^{-1}$, respectively), which was at par with treatment receiving urea + HQ @ 8000 mg kg^{-1} urea (14.49, 762 and 2074 cm^2 $plant^{-1}$, respectively) whereas, minimum leaf area $plant^{-1}$ was noticed under absolute control (11.10, 404 and1038 cm^2 $plant^{-1}$, respectively) on pooled basis. Table 2 shows that significantly higher leaf area index was observed in treatment receiving urea + HQ @ 12000 mg kg^{-1} urea at 60 and 90 DAS (1.24 and 3.37, respectively), which was at par with treatment receiving urea + HQ @ 8000 mg kg^{-1} urea (1.22 and 3.32, respectively) and lesser leaf area index was recorded in absolute control (0.65 and1.66, respectively) on pooled basis. Similar trend was observed with respect to dry matter production as showed in Table 3. At 30, 60 and 90 DAS, significantly greater dry matter production plant^{-1} was recorded in treatment receiving urea + HQ @ 12000 mg kg^{-1} urea (1.36, 32.06 and 53.70 g plant^{-1}, respectively) which was at par with treatment receiving urea + HQ @ 8000 mg kg^{-1} urea (1.36, 31.48 and 52.83 g plant^{-1}, respectively) while, lesser dry matter production plant^{-1} was noticed under absolute control (1.04, 16.76 and 26.43 g plant^{-1}, respectively) on pooled basis.

This is attributed to supply of nitrogen to the plants slowly and steadily for longer period of time due to application of inhibitors along with the urea. The connection between the increased leaf number and area with greater dry matter production under higher nitrogen supply is rooted in the intricate physiological dynamics of nitrogen's impact on plant growth. Nitrogen is an essential component in chlorophyll, crucial for photosynthesis. Elevated nitrogen availability promotes chlorophyll production, leading to more efficient photosynthesis (Lemraski *et al*., 2017; Lalitha, 2020). This increased photosynthetic activity results in the development of a greater number of leaves and increased leaf area, facilitating enhanced light capture and CO_2 assimilation. As a result, plants grow taller and produce more tillers to harness additional resources, ultimately leading to greater dry matter production due to improved metabolic processes and resource utilization driven by ample nitrogen supply (Zhang *et al*., 2017). Availability of this essential nutrient at minute quantities under absolute control treatment resulted in significantly lower growth attributes.

In general, there was better growth of plant in terms of growth attributes was observed under the application of urease or nitrification inhibitors over only urea due to continuous supply of nitrogen to plants. Urease inhibitors reduce the conversion of urea into ammonia, preventing nitrogen loss through volatilization. Nitrification inhibitors slow down the conversion of ammonium to nitrate, retaining ammonium nitrogen in the soil. These mechanisms collectively extend the availability of nitrogen to plants over a more extended period, ensuring a consistent and efficient nutrient supply for sustained plant growth (Abalos *et al*., 2014; Rose *et al*., 2018).

B. Growth indices

The data pertaining to growth indices of aerobic rice as influenced by urease and nitrification inhibitors is depicted in Fig. 1-4. Application of urea + HQ @ 12000 mg kg^{-1} urea recorded significantly higher absolute growth rate (1.02and 0.72 g plant^{-1} day^{-1}) and crop growth rate (16.37 and 11.54 g m^{-2} day^{-1}) during 30-60 DAS and 60-90 DAS, respectively which was found to be at par with application of urea + HQ @ 8000 mg kg^{-1} urea (1.00 and 0.71 g plant^{-1} day^{-1} and 16.07 and 11.39 g m^{-2} day^{-1}, respectively). Significantly lower absolute growth rate (0.52 and 0.32 g plant^{-1} day^{-1}) and crop growth rate (8.38 and 5.16 g m^{-2} day^{-1}) during 30-60 and 60-90 DAS, respectively. In general, combined application of urease and nitrification inhibitors has enhanced the growth rate of crop compared to sole urea and neem coated urea application. It can be seen that, same trend of difference among the treatments was observed during 30-60 DAS and 60-90 DAS. These results are in line with the findings of Modol *et al*. (2018); Lasisi *et al*. (2020).

The observed increase in absolute growth rate during different growth phases, as depicted in Fig. 1, suggests that the inhibitors play a crucial role in promoting enhanced plant development. This outcome is particularly pronounced during the critical 60-90 days after sowing (DAS) phase, signifying the sustained positive impact of inhibitors on absolute growth. Madhurya *et al*. (2022) reported that for maximum crop growth, enough leaves must be present in the canopy to intercept most of the incident NAR which was significantly higher under the same treatment in terms of leaf area (Table 1). Similarly, the crop growth rate as illustrated in Fig. 2, exhibits a clear advantage for the treatments incorporating urea with inhibitors. The accelerated crop growth rates during both 30-60 DAS and 60-90 DAS periods underscore the efficacy of the inhibitor-enhanced urea formulations in promoting robust crop development. This finding implies a potential for increased biomass accumulation and, consequently, improved overall yield.

In contrary to the results of absolute growth rate and crop growth rate, relative growth rate and net assimilation rate showed a reverse trend. During 30-60 DAS, significantly higher relative growth rate (4.58 $\times 10^{-2}$ g g^{-1} day^{-1}) and net assimilation rate (2.093 g day^{-1} m^{-2}) were noticed under application of urea + HQ @ 12000 mg kg^{-1} urea, which was at par with application of urea + HQ @ 8000 mg kg^{-1} urea (4.56$\times 10^{-2}$ g g^{-1} day^{-1} and 2.085g day^{-1} m^{-2}, respectively). Surprisingly during 60-90 DAS, application of only urea resulted in significantly higher relative growth rate (22.95 $\times 10^{-2}$ g g^{-1} day^{-1}) and net assimilation rate (0.217 g day^{-1} m^{-2}) which was found to be at par with application of neem coated urea (22.78$\times 10^{-2}$ g g^{-1} day^{-1} and 0.215 g day^{-1} m^{-2}, respectively). Mohammed *et al*. (2016) and Liu *et al*. (2019) also reported similar results in other cereals.

Examining the relative growth rate (Fig. 3), it becomes evident that the incorporation of urease and nitrification inhibitors with urea surpasses the performance of both sole urea and neem-coated urea. Higher relative growth rates signify an enhanced efficiency in resource utilization, highlighting the inhibitors' positive influence on the plants' ability to convert available resources into increased biomass. Furthermore, the net assimilation rate (Fig. 4) provides crucial insights into nutrient assimilation during different growth phases. The treatments involving urea and inhibitors consistently exhibit higher assimilation rates compared to both sole urea and neem-coated urea. This suggests that the inhibitors facilitate improved nutrient uptake and utilization, contributing to the overall health and vigor of the plants. These results are in line with the findings of Zhu *et al*. (2008); Mahmoodzadeh *et al*. (2013); Vanitha and Dass (2014); Singh and Kumar (2017); Beeresha (2018).

In general, the utilization of urease and nitrification inhibitors in conjunction with urea has emerged as a promising strategy for enhancing various growth parameters in aerobic rice cultivation, surpassing the effects observed with sole urea application and neem-coated urea. The analysis of absolute growth rate, crop growth rate, relative growth rate, and net assimilation rate provides valuable insights into the efficacy of these inhibitors.

Table 1: Effect of urease and nitrification inhibitors on leaf area (cm^2 plant^{-1}) at different growth stages of aerobic rice.

Treatment		30 DAS			60 DAS			90 DAS		
		2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	Urea	15.42	12.86	14.14	747	631	689	1953	1838	1896
T_2	Urea + HQ @ 4000 mg kg^{-1} urea	15.68	13.09	14.39	804	679	741	2086	1960	2023
T_3	Urea + HQ @ 8000 mg kg^{-1} urea	15.80	13.18	14.49	826	698	762	2138	2009	2074
T_4	Urea + HQ @ 12000 mg kg^{-1} urea	15.89	13.23	14.56	841	711	776	2174	2042	2108
T_5	Urea + DCD @ 4000 mg kg^{-1} urea	15.59	13.01	14.30	780	658	719	2031	1908	1970
T_6	Urea + DCD @ 8000 mg kg^{-1} urea	15.66	13.07	14.36	792	669	730	2059	1935	1997
T_7	Urea + DCD @ 12000 mg kg^{-1} urea	15.72	13.13	14.42	812	686	749	2106	1979	2042
T_8	Neem coated urea	15.54	12.96	14.25	775	654	714	2019	1897	1958
T_9	Absolute control	11.94	10.26	11.10	434	373	404	1065	1010	1038
S.Em.±		0.17	0.13	0.10	9.23	7.88	5.89	21.49	20.14	14.29
CD at 5%		0.50	0.40	0.30	27.53	23.63	16.93	64.12	60.38	41.06

Table 2: Effect of urease and nitrification inhibitors on leaf area index at different growth stages of aerobic rice.

Treatment		30 DAS			60 DAS			90 DAS		
		2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	Normal urea	0.0247	0.0206	0.0226	1.19	1.01	1.10	3.13	2.94	3.03
T_2	Urea + HQ @ 4000 mg kg^{-1} urea	0.0251	0.0210	0.0230	1.29	1.09	1.19	3.34	3.14	3.24
T_3	Urea + HQ @ 8000 mg kg^{-1} urea	0.0253	0.0211	0.0232	1.32	1.12	1.22	3.42	3.21	3.32
T_4	Urea + HQ @ 12000 mg kg^{-1} urea	0.0254	0.0212	0.0233	1.35	1.14	1.24	3.48	3.27	3.37
T_5	Urea + DCD @ 4000 mg kg^{-1} urea	0.0249	0.0208	0.0229	1.25	1.05	1.15	3.25	3.05	3.15
T_6	Urea + DCD @ 8000 mg kg^{-1} urea	0.0251	0.0209	0.0230	1.27	1.07	1.17	3.29	3.10	3.20
T_7	Urea + DCD @ 12000 mg kg^{-1} urea	0.0251	0.0210	0.0231	1.30	1.10	1.20	3.37	3.17	3.27
T_8	Neem coated urea	0.0249	0.0207	0.0228	1.24	1.05	1.14	3.23	3.04	3.13
T_9	Absolute control	0.0191	0.0164	0.0178	0.69	0.60	0.65	1.70	1.62	1.66
S.Em.±		0.0003	0.0002	0.0002	0.01	0.01	0.01	0.03	0.03	0.02
CD at 5%		0.0008	0.0006	0.0005	0.04	0.04	0.03	0.10	0.10	0.07

Table 3: Effect of urease and nitrification inhibitors on dry matter production plant^{-1} (g) at different growth stages of aerobic rice.

Treatment		30 DAS			60 DAS			90 DAS		
		2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	Urea	1.45	1.20	1.32	30.24	26.71	28.48	51.31	45.29	48.30
T_2	Urea + HQ @ 4000 mg kg^{-1} urea	1.47	1.22	1.35	32.54	28.72	30.63	54.80	48.29	51.55
T_3	Urea + HQ @ 8000 mg kg^{-1} urea	1.48	1.23	1.36	33.44	29.52	31.48	56.17	49.49	52.83
T_4	Urea + HQ @ 12000 mg kg^{-1} urea	1.49	1.23	1.36	34.06	30.06	32.06	57.10	50.31	53.70
T_5	Urea + DCD @ 4000 mg kg^{-1} urea	1.46	1.21	1.34	31.58	27.86	29.72	53.35	47.01	50.18
T_6	Urea + DCD @ 8000 mg kg^{-1} urea	1.47	1.22	1.34	32.08	28.30	30.19	54.10	47.67	50.88
T_7	Urea + DCD @ 12000 mg kg^{-1} urea	1.47	1.22	1.35	32.88	29.02	30.95	55.32	48.74	52.03
T_8	Neem coated urea	1.46	1.21	1.33	31.37	27.67	29.52	53.03	46.73	49.88
T_9	Absolute control	1.12	0.96	1.04	17.65	15.87	16.76	27.97	24.89	26.43
S.Em.±		0.02	0.01	0.01	0.37	0.33	0.24	0.56	0.50	0.36
CD at 5%		0.05	0.04	0.03	1.11	0.99	0.69	1.68	1.49	1.05

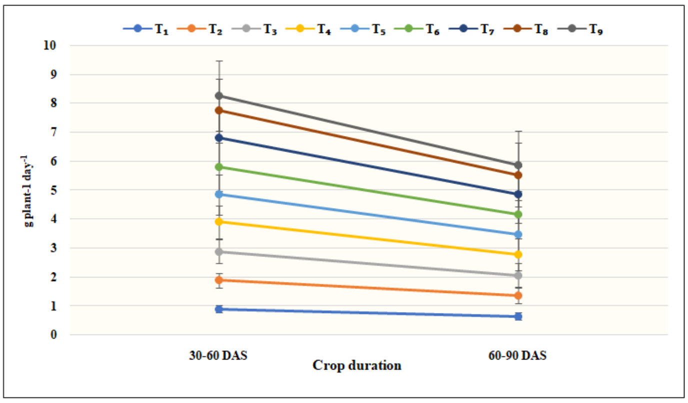

Fig. 1. Effect of urease and nitrification inhibitors on absolute growth rate during different growth phases of aerobic rice.

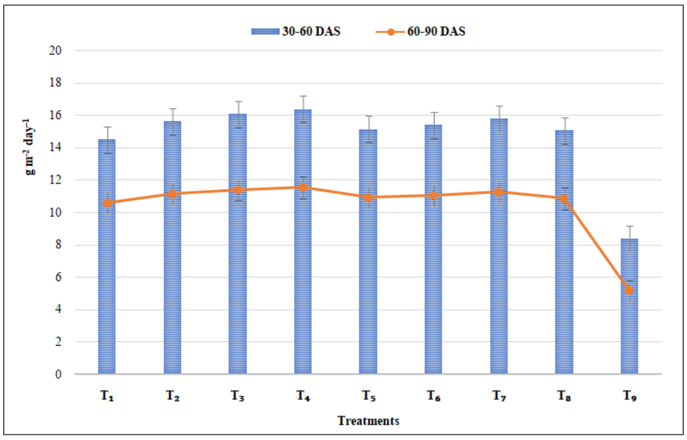

Fig. 2. Effect of urease and nitrification inhibitors on crop growth rate during different growth phases of aerobic rice.

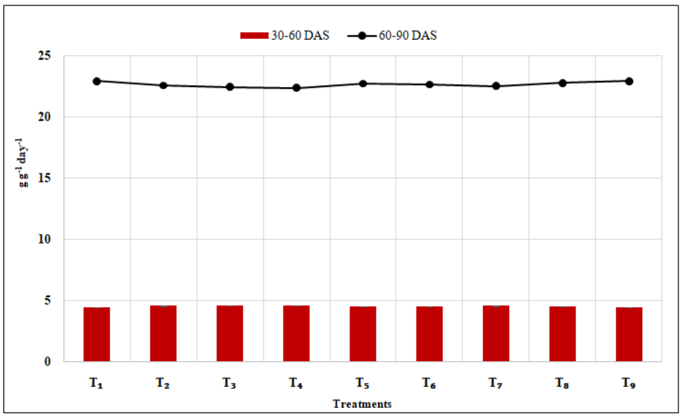

Fig. 3. Effect of urease and nitrification inhibitors on relative growth rate during different growth phases of aerobic rice.

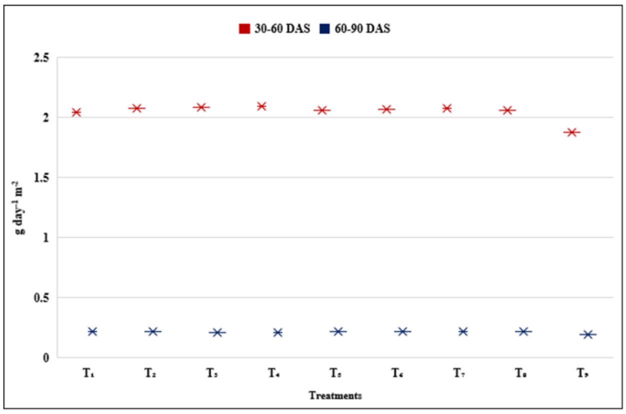

Fig. 4. Effect of urease and nitrification inhibitors on net assimilation rate during different growth phases of aerobic rice.

CONCLUSIONS

The combined use of urease and nitrification inhibitors with urea proves to be a superior approach in promoting enhanced absolute growth rate, crop growth rate, relative growth rate and net assimilation rate in aerobic rice cultivation. The positive outcomes observed across these growth parameters indicate the potential of inhibitor-enhanced urea formulations for optimizing crop performance, thereby contributing to increased agricultural productivity and sustainability.

FUTURE SCOPE

There is substantial potential for the cost-effective production of urease and nitrification inhibitors. It is essential to raise awareness and encourage farmers to adopt these inhibitors for environmentally sustainable agricultural production.

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Conflict of interest. None.

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