UNLOCKING THE POTENTIAL: IMPACT OF PLANT GROWTH REGULATORS IMPACT HYBRID RICE GROWTH, GRAIN YIELD, AND HARVEST INDEX

Abstract:

Aim: This research focused on rice, especially in Asia, and examined how plant growth regulators, including hormones and synthetic compounds, affect crucial plant processes. The findings strongly support the use of foliar Indole-3-Acetic Acid (IAA) application to enhance hybrid rice growth, grain yield, and harvest index, promising advancements in agriculture.

Study design: Randomised Block Design with 11 treatments.

Place and duration of study: The study, conducted at the Student Instructional Farm of C. S. Azad University of Agriculture & Technology in Kanpur, aimed to investigate the impact of foliar application of plant growth regulators on rice growth and yield during 2021 and 2022.

Methodology The experiment employed a rigorous randomized block design, testing various treatments involving the foliar application of IAA (25 & 50 ppm), IBA (25 & 50 ppm), NAA (25 & 50 ppm), Ascorbic Acid (50 & 100 ppm), and Kinetin (5 & 10 ppm). The profound effects of these different regulator concentrations were observed at key developmental stages, including tillering, anthesis, dough, and maturity.

Result Significant improvements in growth parameters, such as leaf and stem dry weights per plant, along with total leaf area per plant, were evident with the application of IAA at 50 ppm. Moreover, a notable increase in grain yield per plant and harvest index was observed at maturity, primarily with the foliar spray of IAA at 50 ppm, followed closely by IAA at 25 ppm. This consistent trend was also observed in yield-related attributes.

Conclusion: The use of Indole-3-acetic acid (IAA) significantly impacted plant growth and yield, including leaf and stem dry weights, leaf area, grain yield, and harvest index, showing promise for enhancing hybrid rice production.

Keywords: Rice, PGR, Dry weight, Yield, Harvest Index

Introduction:

Rice, scientifically known as *Oryza sativa L.,* stands as the most crucial staple crop globally, serving as the primary source of sustenance for over half of the world's population. A staggering 90% of the world's rice is cultivated and consumed in Asia, where approximately 60% of the world's inhabitants reside. Rice holds a dominant position among the various food grains produced within a country. The consumption patterns of rice vary across different regions of the nation. In certain areas, it constitutes the dietary staple, while in others, it holds significance as a key food item alongside other cereals. Preference is given to high-quality rice over coarser grain varieties. Rice primarily consists of starch, comprising approximately 78-79% of amylose and amylopectin fractions, providing a calorific value of 32.8. It boasts a digestibility coefficient of 76, a biological value of 70, and a protein efficiency ratio of 2. Rice is a key food for many, providing 20% of the world's energy, with its nutritional value varying by type and growing conditions. Fortifying rice can combat malnutrition. Elevated CO_2 levels can reduce its nutrient content. In 2020, global paddy rice production reached 756.7 million metric tons, primarily driven by China and India, which contributed 52% of the total. Other significant producers included Bangladesh, Indonesia, and Vietnam, with the top five accounting for 72% of the world's production. Developing countries were responsible for 95% of this production. Rice plays a crucial role in food security and nutrition for Asia, Latin America, the Caribbean, and Africa, supporting over half of the world's population, particularly small farmers and wage laborers.

Plant growth regulators, whether they occur naturally or are meticulously crafted carbon-based compounds, assume pivotal roles in the intricate life journey of plants, reshaping and invigorating their growth patterns [1]. When administered in modest quantities, these regulators ignite the innate mechanisms governing growth, precipitating swift alterations in plants, either catalyzing or impeding their growth processes. Consequently, they can be categorized as growth promoters or growth inhibitors. These compounds are commonly recognized as phytohormones, encompassing gibberellins, auxins, ethylene, cytokinins, and synthetic analogs that imitate or counteract their effects [2]. Auxins control plant development, with IBA mimicking IAA but being less potent, influencing growth and various processes like phototropism and root formation [3], [4]. Exogenous IAA enhances rice plant height, leaf count, fruit size, and seed yield. An increase in plant height leads to higher dry leaf and stem weight, greater leaf area, and ultimately boosts grain yields, positively affecting the harvest index. Naphthalene Acetic Acid (NAA) is a colorless solid that dissolves in organic solvents. It's a synthetic auxin plant hormone, found in rooting products, aiding in plant propagation from cuttings and tissue culture. IBA stimulates root growth in plant cuttings, applies to various crops, and reduces transplant shock in nursery stock. Ascorbic acid serves as a vital redox buffer and cofactor for enzymes in photosynthesis, hormone production, and antioxidant regeneration. Cytokinins are pivotal in stimulating cell division, nucleic acid metabolism, and interactions between roots and shoots. Therefore, PGRs enhance crop growth, withstand stress, and boost yield in challenging conditions, promoting healthier plants[5].

Material and methods:

1. Leaves dry weight plant^{-1} at different growth stages (g):

The leaves were plucked from five chosen plants and left out in the sun to dry. Subsequently, the samples were subjected to oven drying at a temperature range of 70±5°C for a duration of 8 to 10 hours. Following the drying process, the samples were weighed using an electronic balance.

2. Stem dry weight plant^{-1} at different growth stages (g):

The stems were carefully harvested from a handpicked selection of five plants and left to bask in the sun's gentle embrace. Following this, the samples underwent precise oven drying at a controlled temperature of 70±5°C for a duration of 8 to 10 hours. Subsequently, the dried samples were meticulously weighed using a state-of-the-art electronic balance.

3. Total Leaf Area plant^{-1} at different growth stages (cm^{-2}):

Leaf area per plant was calculated with the help of formula given by Tsunoda (1964).

Total Leaf Area = Length of the leaf X Breadth of Leaf X Correction Factor (0.725) X Number of leaves plant^{-1}.

4. Grain yield plant^{-1}:

The weight of grains per plant was determined following the harvest and threshing process to collect the grains. Grain weight was individually measured in grams for each treatment, along with its fractions, utilizing an electronic weighing machine.

5. Harvest Index (%):

The harvest index was calculated by using the following formula and expressed in percentage, given by the **Donald, (1962).**

$$\mathbf{HI} = \frac{\textbf{Economic yield}}{\textbf{Biological yield}} \times \mathbf{100}$$

Result and Discussion:

1. Leaves dry weight plant^{-1} at different growth stages (g):

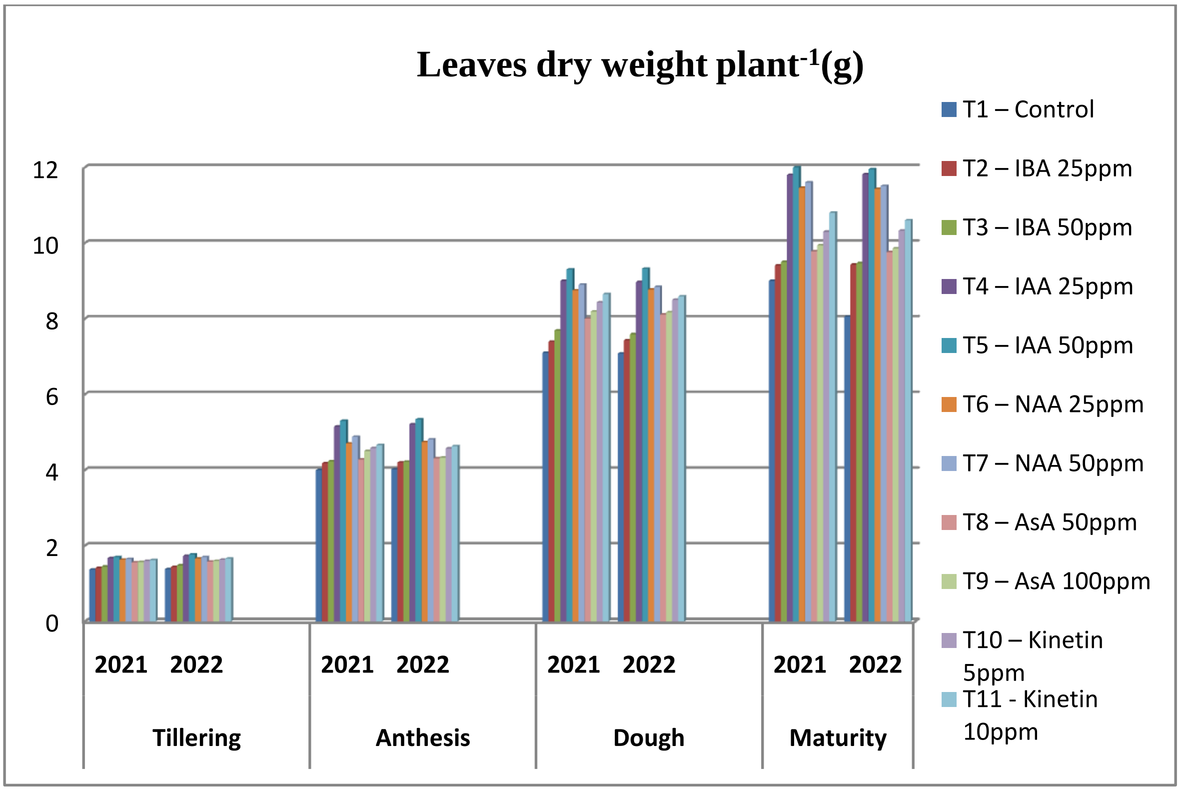
The data in Table-1 and Figure-1 reveals a significant increase in leaf dry weight per plant when various concentrations of plant growth regulators were applied, compared to the control. Leaf dry matter accumulation increased throughout the crop growth stages. On overall basis, application of IAA 50ppm helped maximum increase in leaf dry weight production at all the stages. Findings were supported by [6], [7], [8], [9].

Table-1 Effect of plant growth regulators on Leaves dry weight plant^{-1}(g) in hybrid rice (*Oryza sativa* L.) at different crop growth stages.

S. No.	Treatments	Leaves dry weight plant^{-1} (g)							
		Tillering		Anthesis		Dough		Maturity	
		2021	2022	2021	2022	2021	2022	2021	2022
1	T_1 – Control	1.37	1.38	4.00	4.02	7.10	7.08	9.00	8.05
2	T_2 – IBA 25ppm	1.41	1.44	4.18	4.20	7.39	7.43	9.41	9.43
3	T_3 – IBA 50ppm	1.45	1.48	4.23	4.22	7.69	7.59	9.50	9.47

4	T_4 – IAA 25ppm	1.67	1.73	5.15	5.21	9.00	8.97	11.80	11.82
5	T_5 – IAA 50ppm	1.70	1.77	5.30	5.34	9.30	9.32	12.00	11.95
6	T_6 – NAA 25ppm	1.63	1.66	4.70	4.74	8.75	8.77	11.46	11.43
7	T_7 – NAA 50ppm	1.65	1.70	4.88	4.81	8.90	8.84	11.60	11.51
8	T_8 – AsA 50ppm	1.56	1.58	4.28	4.31	8.00	8.11	9.78	9.76
9	T_9 – AsA 100ppm	1.57	1.60	4.50	4.33	8.19	8.17	9.94	9.86
10	T_{10} – Kinetin 5ppm	1.60	1.63	4.58	4.57	8.43	8.50	10.30	10.33
11	T_{11} - Kinetin 10ppm	1.62	1.66	4.66	4.63	8.65	8.59	10.80	10.60
	SE(d)	**0.04**	**0.03**	**0.12**	**0.11**	**0.18**	**0.17**	**0.20**	**0.23**
	CD at 5%	**0.08**	**0.07**	**0.25**	**0.23**	**0.38**	**0.36**	**0.43**	**0.49**

Figure-1 Effect of plant growth regulators on Leaves dry weight plant^{-1}(g) in hybrid rice (*Oryza sativa* L.) at different crop growth stages.



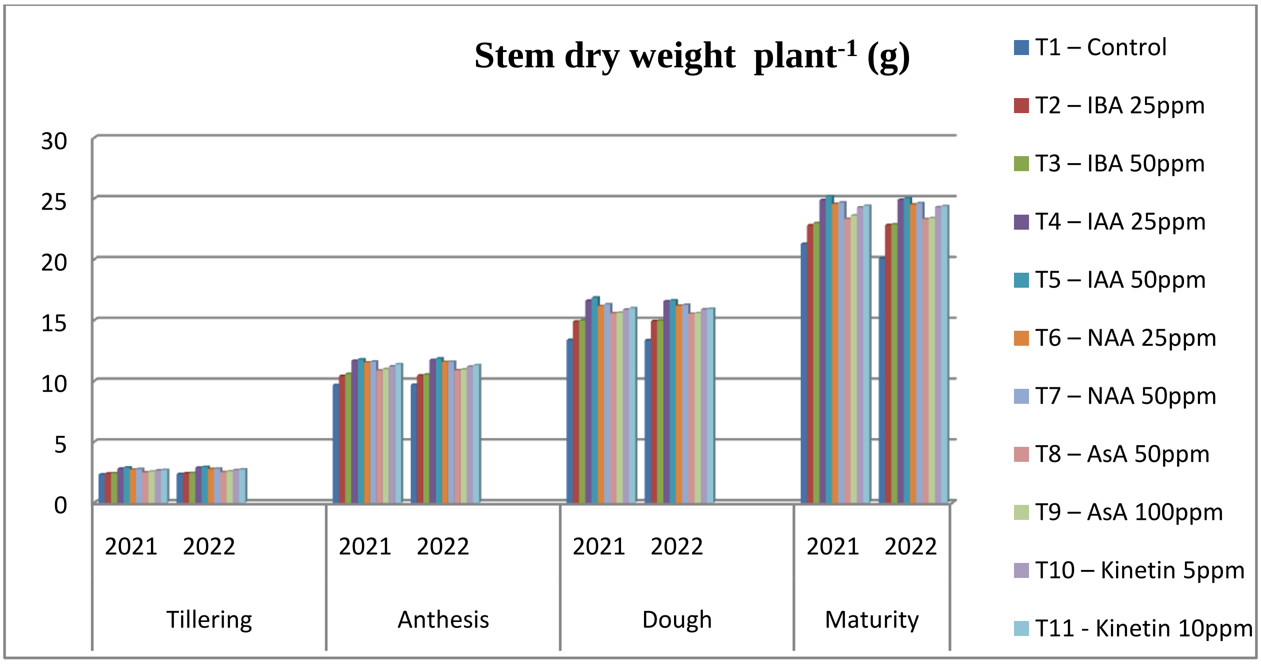
2. Stem dry weight plant^{-1} at different growth stages (g):

Data regarding the stem's dry weight is presented in Table-2 and figure-2. Upon analyzing the data from Table-2, it was observed that all the treatments exhibited a significant increase compared to the control group. Different concentrations of plant growth regulators enhanced stem dry weight at various stages of crop growth. These growth regulator concentrations had differing effects on stem dry weight across different crop growth stages. At the tillering stage, the most substantial increase in stem dry weight was achieved with a foliar spray of IAA at 50ppm, resulting in measurements of 2.90 and 2.99 (g) in both years. This increase was statistically superior to other treatments. The second-highest increase was observed with a foliar spray of IAA at 25ppm, measuring 2.80 and 2.89 (g) in both years. This pattern persisted in the anthesis, dough, and maturity stages. These findings align with the studies conducted by [7], [8], [10].

Table-2 Stem dry weight plant^{-1} was influenced by the foliar applied growth regulators at different crop stages in hybrid rice.

S. No.	Treatments	Leaves dry weight plant^{-1} (g)							
		Tillering		Anthesis		Dough		Maturity	
		2021	2022	2021	2022	2021	2022	2021	2022
1	T_1 – Control	2.32	2.36	9.68	9.70	13.39	13.37	21.30	20.10
2	T_2 – IBA 25ppm	2.40	2.42	10.42	10.47	14.90	14.93	22.81	22.83
3	T_3 – IBA 50ppm	2.42	2.45	10.60	10.54	15.00	14.98	23.00	22.90
4	T_4 – IAA 25ppm	2.80	2.89	11.68	11.74	16.62	16.57	24.89	24.92
5	T_5 – IAA 50ppm	2.90	2.95	11.80	11.86	16.87	16.65	25.20	25.04
6	T_6 – NAA 25ppm	2.73	2.78	11.54	11.58	16.17	16.20	24.57	24.53
7	T_7 – NAA 50ppm	2.78	2.81	11.61	11.60	16.33	16.28	24.69	24.64
8	T_8 – AsA 50ppm	2.50	2.52	10.87	10.89	15.59	15.54	23.35	23.34
9	T_9 – AsA 100ppm	2.57	2.59	11.00	10.96	15.63	15.60	23.62	23.42
10	T_{10} – Kinetin 5ppm	2.66	2.69	11.21	11.20	15.89	15.91	24.29	24.31
11	T_{11} - Kinetin 10ppm	2.70	2.74	11.40	11.32	16.00	15.95	24.43	24.40
	SE(d)	**0.04**	**0.05**	**0.29**	**0.20**	**0.28**	**0.33**	**0.52**	**0.45**
	CD at 5%	**0.09**	**0.11**	**0.61**	**0.43**	**0.60**	**0.69**	**1.10**	**0.96**

Figure-2 Stem dry weight plant^{-1} was influenced by the foliar applied growth regulators at different crop stages in hybrid rice.



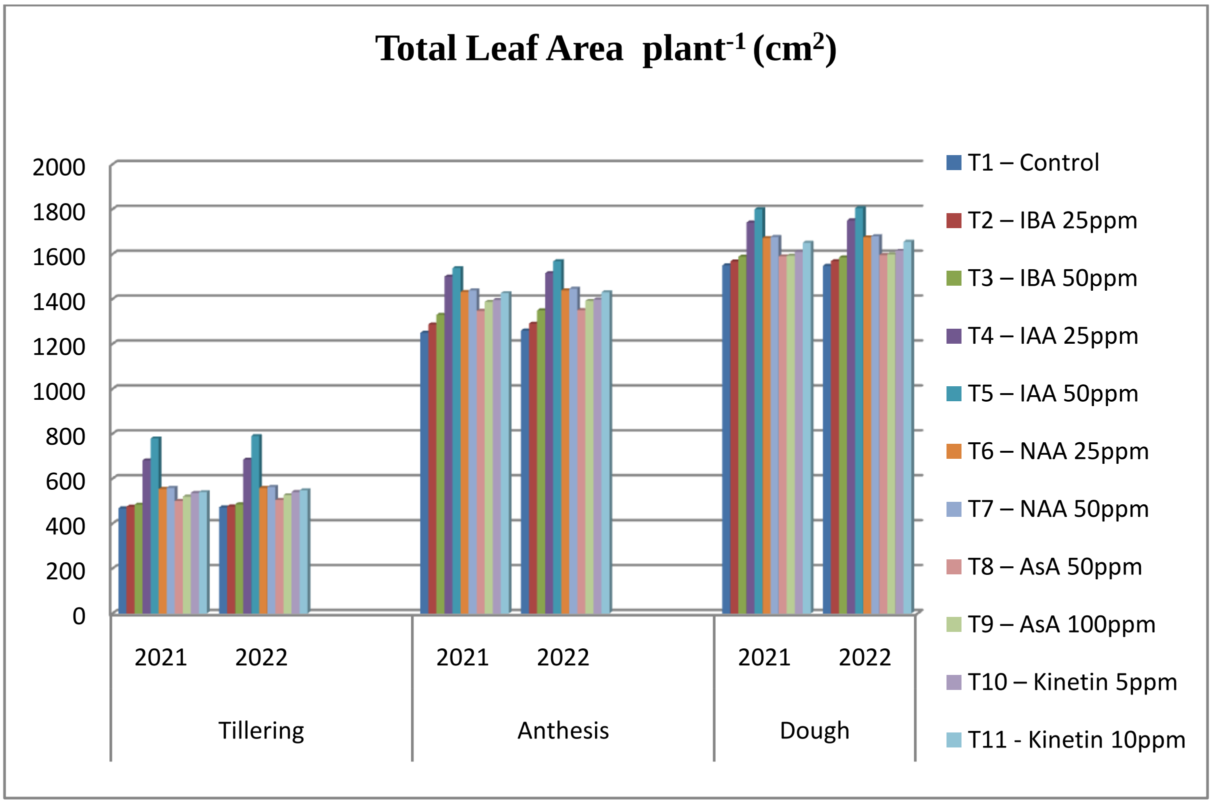
3. Total Leaf Area plant^{-1} at different growth stages (cm^{-2}):

Upon examining the data in Table-3 and figure-3, it became clear that various concentrations of plant growth regulators significantly increased the total leaf area per plant compared to the control group. The most substantial expansion in leaf area occurred during the tillering stage when an exceptional foliar spray of IAA at 50ppm was applied, resulting in leaf areas of 779.64 and 790.34 square centimeters for both years. IAA at 25ppm also had a notable effect, with values of 682.10 and 685.00 square centimeters. In contrast, the control group exhibited the smallest increase. This trend persisted as the experiment progressed through the stages to the anthesis phase. At dough, the leaf area flourished under the influence of a foliar spray of IAA at 50ppm for both years, reaching its peak. These findings are in alignment with the research conducted by [10], [11], [12] providing additional support for the observed effects of plant growth regulators on leaf area.

Table-3 Effect of plant growth regulators on Total leaf area plant^{-1} in hybrid rice (*Oryza sativa* L.) at different crop growth stages.

S. No.	Treatments	Leaves dry weight plant^{-1} (g)							
		Tillering		Anthesis		Dough		Maturity	
		2021	2022	2021	2022	2021	2022	2021	2022
1	T_1 – Control	468.32	472.22	1250.10	1260.15	1550.40	1548.19	468.32	472.22
2	T_2 – IBA 25ppm	475.81	476.50	1287.59	1290.64	1567.37	1569.40	475.81	476.50
3	T_3 – IBA 50ppm	484.82	486.25	1330.09	1350.00	1588.78	1585.66	484.82	486.25
4	T_4 – IAA 25ppm	682.10	685.00	1500.24	1515.52	1740.94	1750.54	682.10	685.00
5	T_5 – IAA 50ppm	779.64	790.34	1538.32	1568.40	1799.84	1805.35	779.64	790.34
6	T_6 – NAA 25ppm	554.96	559.45	1431.90	1439.10	1672.23	1675.10	554.96	559.45
7	T_7 – NAA 50ppm	559.39	563.24	1438.89	1446.25	1676.93	1680.29	559.39	563.24
8	T_8 – AsA 50ppm	501.53	505.33	1347.95	1351.30	1590.78	1596.32	501.53	505.33
9	T_9 – AsA 100ppm	520.39	526.67	1387.88	1392.19	1593.37	1600.05	520.39	526.67
10	T_{10} – Kinetin 5ppm	536.84	540.89	1395.87	1398.58	1610.56	1615.35	536.84	540.89
11	T_{11} - Kinetin 10ppm	540.60	548.35	1426.55	1430.20	1651.15	1655.20	540.60	548.35
	SE(d)	**12.23**	**12.96**	**27.24**	**26.72**	**37.71**	**37.48**	**12.23**	**12.96**
	CD at 5%	**25.51**	**27.05**	**56.82**	**55.73**	**78.67**	**78.02**	**25.51**	**27.05**

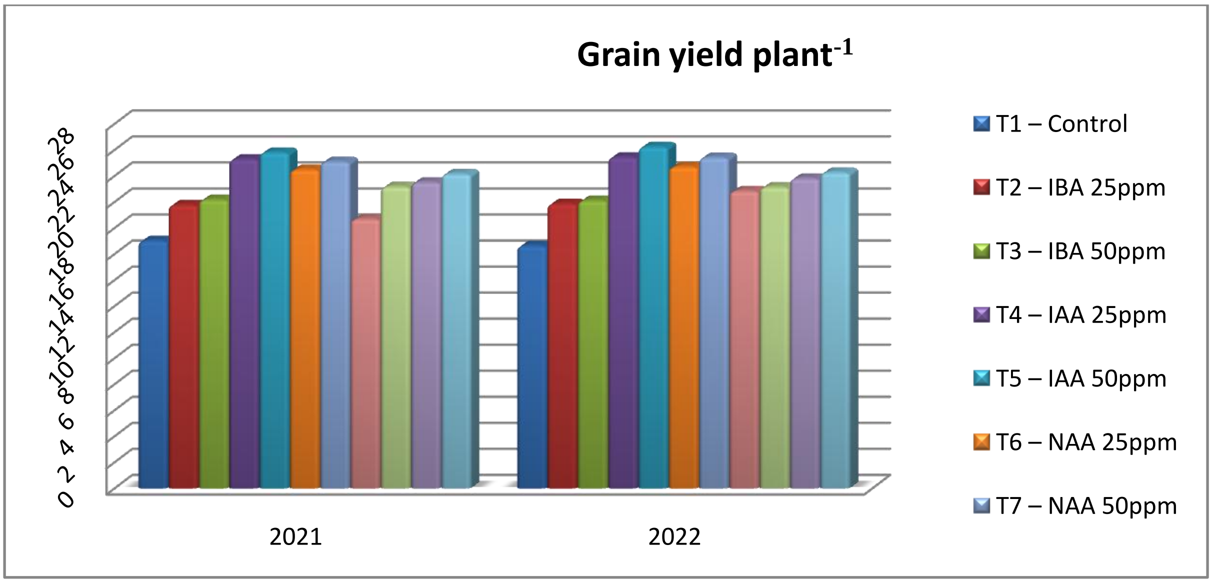
Figure-3 Effect of plant growth regulators on Total leaf area plant^{-1} in hybrid rice (*Oryza sativa* L.) at different crop growth stages.



4. Grain yield plant^{-1}:

The data previously collected on grain yield per plant, influenced by the application of various plant growth regulators as displayed in Table-4 and figure-4, indicated a substantial increase in grain yield per plant compared to the control group. The most significant boost in grain yield per plant was achieved with IAA at 50ppm (25.79g & 26.22g), closely followed by IAA at 25ppm (25.27g & 25.42g), while the lowest increase was observed with IBA at 25ppm (21.76g & 21.85g) when compared to the control group yield (19.00g & 18.62g). All treatments demonstrated a notable response over the control, affirming their significance. Additionally, foliar spraying with NAA had a pronounced effect on the grain production of hybrid rice plants. These findings received support from previous studies conducted by [10], [13], [14], [15], [16], [17], [18], [19], [20], [21].

Figure-4 Effect of plant growth regulators on Grain yield plant^{-1} in hybrid rice (*Oryza sativa* L.) at different crop growth stages.



5. Harvest Index (%):

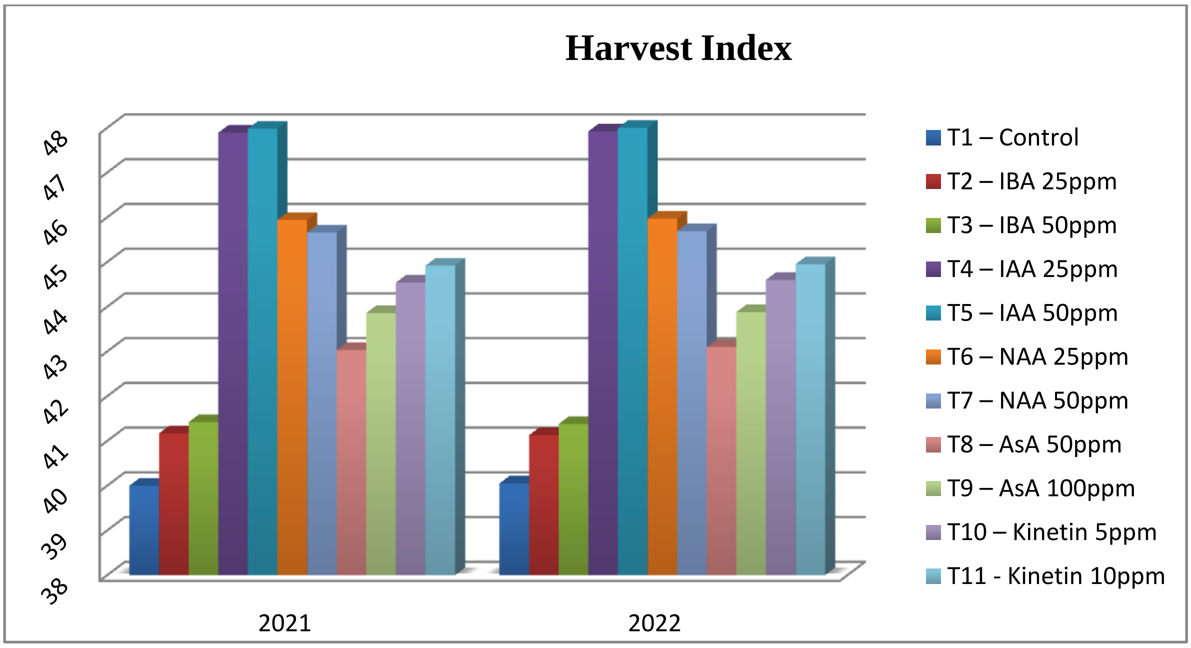
The data, which was recorded regarding the harvest index (%) in response to the application of various plant growth regulators, has been presented in Table-4 and figure-5. The plant growth regulators demonstrated an increase in the harvest index value compared to the control group in both years. The highest harvest index exhibited the most efficient translocation, with IAA @ 50 ppm achieving a record of (47.98% & 48.00%), followed closely by IAA @ 25 ppm (47.89 % & 47.92%). On the other hand, the control group recorded the lowest harvest index (40.00% & 40.05%). All the treatments yielded significant responses. Additionally, the foliar spray of NAA and Kinetin positively influenced the harvest index. These findings find support in previous studies conducted by [19],[14],[18],[22].

Table-4 Impact of plant growth regulators on Grain yield plant^{-1}and Harvest Index of hybrid rice.

S. No.	Treatments	Grain yield plant^{-1}	Harvest index (%)

		2021	2022	2021	2022
1	T_1 – Control	19.00	18.62	40.00	40.05
2	T_2 – IBA 25ppm	21.76	21.85	41.17	41.13
3	T_3 – IBA 50ppm	22.16	22.09	41.42	41.38
4	T_4 – IAA 25ppm	25.27	25.42	47.89	47.92
5	T_5 – IAA 50ppm	25.79	26.22	47.98	48.00
6	T_6 – NAA 25ppm	24.47	24.68	45.94	45.97
7	T_7 – NAA 50ppm	25.08	25.40	45.66	45.69
8	T_8 – AsA 50ppm	20.68	22.83	43.03	43.10
9	T_9 – AsA 100ppm	23.16	23.13	43.86	43.88
10	T_{10} – Kinetin 5ppm	23.50	23.79	44.54	44.60
11	T_{11} - Kinetin 10ppm	24.14	24.25	44.92	44.95
	SE(d)	**0.44**	**0.47**	**0.81**	**1.04**
	CD at 5%	**0.93**	**0.97**	**1.70**	**2.17**

Figure-5 Effect of plant growth regulators on Harvest Index in hybrid rice (*Oryza sativa* L.) at different crop growth stages.



Conclusion:

This research focused on the crucial role of plant growth regulators, specifically Indole-3-acetic acid (IAA), in transforming rice growth and yield. The study revealed that foliar application of IAA at 50 ppm resulted in significant improvements in various growth parameters and grain yield per plant. These findings underscore the promising potential of IAA foliar application for enhancing hybrid rice growth and yield, suggesting exciting possibilities for agricultural advancements in the future.

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Competing interests:

The authors declare that they have no competing interests.

Author contributions:

[1*]**Shikha Shahi** **:** Data collection, wrote the first draft of the manuscript, analysis of the study
[3]**S. P. Kushwaha** **:** Conceived and designed the research program
[2]**P. K. Singh** **:** Offering support for research paper writing.
[4]**Mayank Pratap** **:** Managed the literature searches
[5]**Saurabh Singh** **:** Managed the literature searches
All the authors read and approved the final manuscript.

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