Biology and Biotechnology Communications

Biotech-Journal.com

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Vol: 3 Issue: 1, 2025

Physiological and Yield Responses of Rice to Foliar Applied Auxins

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Received: Februaty 03, 2025 --- Revised: March 11, 2025, Accepted: April 19, 2025

Abstract

A field experiment was conducted at the University of Agriculture Faisalabad to evaluate the effects of foliar-applied indole-3-acetic acid (IAA) on the physiological performance and yield of rice (Shaheen Basmati). The study employed a randomized complete block design with four treatments: control, 10 µM, 20 µM, and 30 µM IAA, applied at tillering and panicle initiation stages. Physiological parameters and yield components were assessed to determine auxin's efficacy. Results showed that foliar IAA significantly enhanced chlorophyll content (from 35.2 to 46.1 SPAD units), photosynthetic rate (from 18.3 to 24.8 µmol CO_2 m^{-2} s^{-1}), stomatal conductance (from 0.21 to 0.29 mol H_2O m^{-2} s^{-1}), and relative water content (from 78.2% to 87.1%), with 30 µM showing the highest values. Yield-related traits were also markedly improved: tillers per plant increased from 10.2 to 15.1, panicles per plant from 9.6 to 13.7, and grains per panicle from 95.3 to 132.1. The 1000-grain weight rose from 22.5 to 26.3 g, and grain yield improved significantly from 4520 to 5985 kg ha^{-1}. Notably, no significant differences were observed between the 20 µM and 30 µM treatments for most parameters, suggesting that 20 µM may be the optimal concentration. These findings underscore the potential of foliar-applied auxin in improving rice productivity by enhancing physiological efficiency and reproductive success, offering a promising strategy for yield optimization under field conditions.

Keywords: Rice, Physiology, Auxin, Basal Fertilization, Yield, Biomass.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food crops globally, feeding more than half of the world's population. Ensuring its sustainable production under varying environmental conditions is essential to meet the increasing food demand. Plant growth regulators (PGRs) such as auxins have emerged as important tools to enhance crop productivity by modulating physiological processes, improving nutrient use efficiency, and promoting reproductive development (Taiz L,)⁻(Baiyin).

Auxins are a class of phytohormones that regulate numerous traits of plant growth i.e., cell elongation, root initiation, vascular differentiation, and reproductive development (Adem). Among the auxins, indole-3-acetic acid (IAA) is the most biologically active and extensively studied. Foliar application of auxins has shown promising results in improving plant physiological responses such as photosynthetic rate, stomatal conductance, and chlorophyll content (Tajdari). These responses are crucial for enhancing assimilate production and translocation during critical growth stages, particularly in cereals like rice.

Recent studies have described that exogenous application of auxins can enhance the growth and development of rice by improving leaf area index, root-shoot ratio, and enzymatic activity associated with nitrogen assimilation (Salehin)، (Tang J,). Moreover, auxins play a critical role in grain development by influencing panicle initiation, grain filling, and spikelet fertility (Li K). Foliar sprays allow for quick absorption and translocation of auxins into plant tissues, thereby providing a rapid physiological response compared to soil application (Jiang W).

Environmental stresses such as drought, salinity, and nutrient deficiencies adversely affect rice productivity. Auxins have shown potential in alleviating these stresses by promoting osmotic adjustment, improving water uptake, and enhancing antioxidant activity (Khandani). Thus, foliar application of auxins may serve as a cost-effective and efficient strategy to mitigate environmental stress and boost rice yield.

Despite the growing interest, comprehensive studies focusing on the synergistic effects of foliar-applied auxins on rice physiology and yield components are still limited. Understanding these effects can contribute significantly to integrated crop management practices and sustainable rice production. Therefore, this study aims to appraise the physiological and yield responses of rice to foliar-applied auxins under field conditions.

2. MATERIALS AND METHODS

A field experiment was piloted during the rice growing period at the Research field of Institute of Soil & Environmental Sciences (ISES), University of Agriculture Faisalabad (UAF), Pakistan. The soil at the experimental site was sandy clay loam with physical and chemical characteristics, i.e., pH (7.9), EC (2.56 dSm^{-1}), organic matter content (0.56%), Bulk Density (1.33 g cm^{-3}). The climatic conditions during the experiment were recorded throughout the season.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Treatments consisted of different concentrations of foliar-applied auxin (Indole-3-acetic acid, IAA), including:

- **T_1**: Control (no auxin)
- **T_2**: 10 µM IAA
- **T_3**: 20 µM IAA
- **T_4**: 30 µM IAA

Crop Husbandry

Certified seeds of rice variety Shaheen Basmati were used. Seeds were sown in a nursery and 25-30 days old saplings were transferred into the field at a 20 cm^2 spacing. Suggested dosages of fertilizers N @ 120 kg ha^{-1}, P_2O_5 @ 90 kg ha^{-1}, and K_2O @ 60 kg ha^{-1}, with nitrogen split into three equal applications at transplanting, tillering, and panicle initiation stages.

Auxin Application

Foliar application of IAA solutions was done using a hand-held sprayer at two growth stages: tillering and panicle initiation. The spray was applied in the early morning to avoid photodegradation, ensuring uniform coverage on leaf surfaces. Control plots received foliar spray of distilled water only.

Physiological Measurements

Physiological parameters were recorded at the flowering stage. These included:

- **Chlorophyll content** was measured using a SPAD chlorophyll meter
- **Photosynthetic & transpiration rate** and **stomatal conductance** were calculated using a transportable photosynthesis system (e.g., LI-COR LI-6400)
- **Relative water content (RWC)** determined using fresh, turgid, and dry leaf weights

Yield and Yield Components

At maturity, ten plants were randomly selected from each plot to assess yield attributes i.e., tillers & panicles $plant^{-1}$, panicle length & grains, 1000 grain weight and yield.

Statistical Analysis

Data were scrutinized using ANOVA in Statistix 8.1 and means compared using LSD @ 0.05. Correlation and regression analyses were also

performed to evaluate relationships among physiological traits and grain yield.

3. RESULTS AND DISCUSSION

The foliar application of indole-3-acetic acid (IAA) at various concentrations significantly influenced the physiological performance and yield-related attributes of rice. The results clearly demonstrate that exogenous auxin application can enhance rice growth and productivity, with the most prominent effects observed at 20 µM and 30 µM concentrations. The physiological and agronomic improvements appear to be dose-dependent up to 30 µM, beyond which diminishing returns or toxicity effects might be expected, although not observed in this study.

Physiological Responses

Chlorophyll content, photosynthetic rate, stomatal conductance, and RWC were significantly improved by foliar-applied IAA (Fig 1-4). Chlorophyll content increased from 35.2 ± 1.1 SPAD units in the control to 46.1 ± 1.4 SPAD units in the 30 µM IAA treatment. Chlorophyll is a vital pigment for light harvesting in photosynthesis, and its increase reflects improved photosynthetic potential. Auxins are known to delay leaf senescence and enhance chloroplast development by modulating gene expression related to chlorophyll biosynthesis (Syahriridani). These results are dependable on the findings of Singh et al. (Singh RR,), who reported amplified chlorophyll content in wheat under foliar IAA treatment.

Photosynthetic rate followed a similar trend, improving from 18.3 ± 0.8 µmol CO_2 m^{-2} s^{-1} in the control to 24.8 ± 1.0 µmol CO_2 m^{-2} s^{-1} under 30 µM IAA. The improved photosynthetic activity may be attributed to increased chlorophyll content, better stomatal regulation, and enhanced sink strength due to accelerated cell division in growing tissues (Tajudin). Exogenous auxins may also increase the activation of Rubisco and other photosynthetic enzymes, enhancing carbon assimilation. Improved stomatal conductance in auxin-treated plants (0.29 ± 0.02 mol H_2O m^{-2} s^{-1} at 30 µM IAA) further supports enhanced gas exchange capacity. Similar enhancements in gas exchange parameters with foliar auxins have been documented by Naveed et al. (Naveed)in maize.

Relative water content (RWC) improved significantly with increasing auxin concentration, reaching 87.1 ± 1.3% at 30 µM IAA compared to 78.2 ± 1.5% in control. Higher RWC is indicative of better water status and cell turgor maintenance under foliar auxin application. Auxins are believed to improve membrane stability and water uptake by promoting root growth and aquaporin activity, thereby enhancing plant hydration under both optimal and stress conditions (Liao Z,).

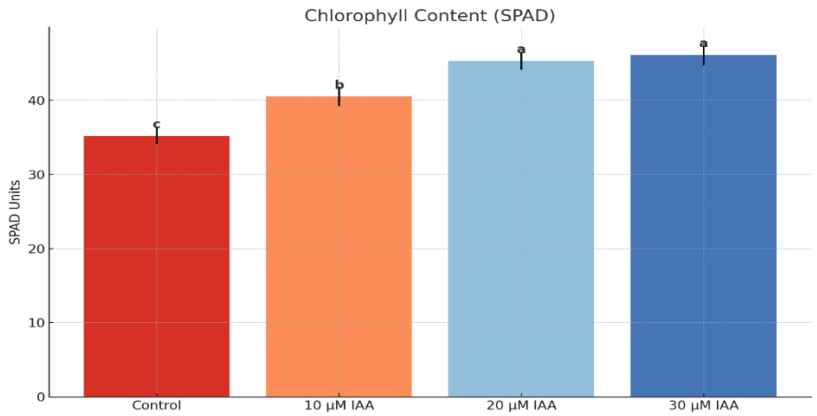

Figure 1. Effect of foliar-applied indole-3-acetic acid (IAA) on chlorophyll content (SPAD values) of rice leaves.

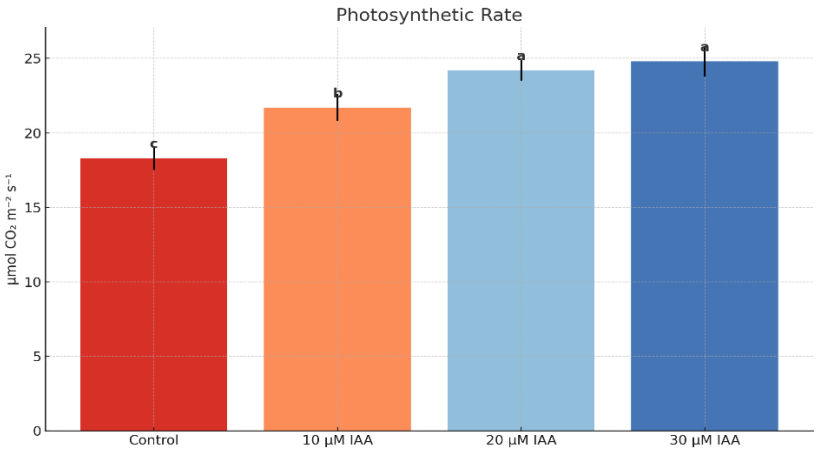

Figure 2. Photosynthetic rate (µmol CO_2 m^{-2} s^{-1}) of rice as influenced by foliar application of different concentrations of IAA.

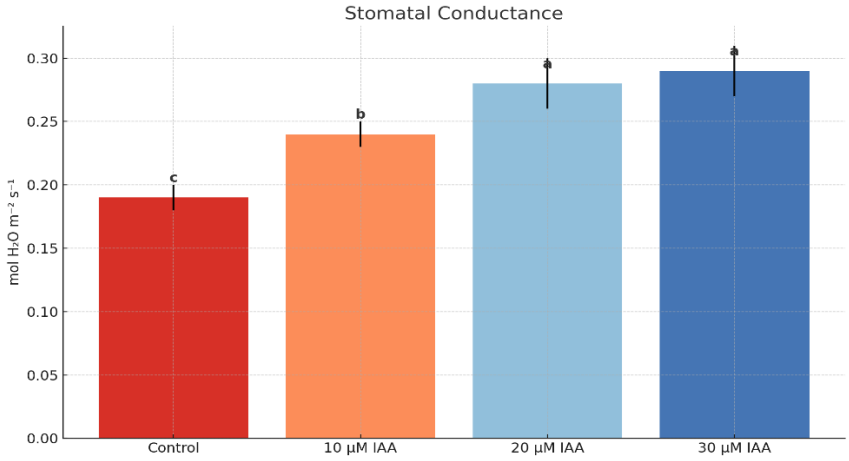

Figure 3. Stomatal conductance (mol H_2O m^{-2} s^{-1}) of rice plants under varying foliar IAA treatments.

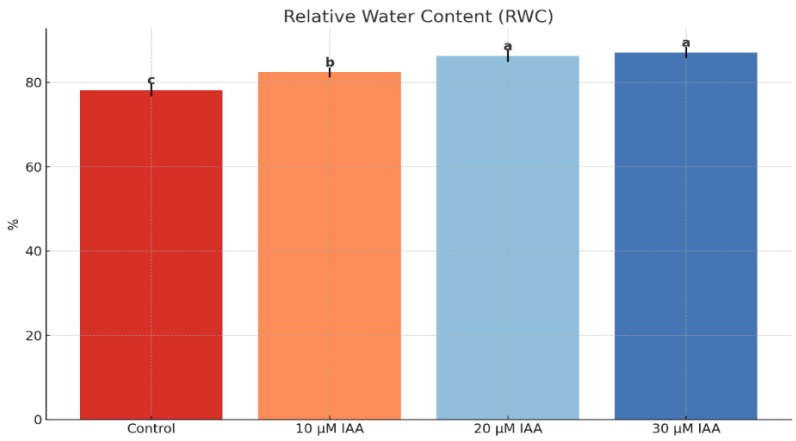

Figure 4. Relative water content (%) of rice leaves as affected by foliar-applied IAA.

Yield and Yield Components

Yield-related traits including tillers & panicles per plant, length & grains per panicle, 1000-grain weight, and grain yield were all significantly enhanced with IAA application Table 1. The number of tillers per plant amplified from 10.2 ± 0.3 in control to 15.1 ± 0.4 in the 30 µM treatment, indicating enhanced tiller initiation. Auxins stimulate the outgrowth of lateral buds by altering hormonal balance, particularly the auxin-cytokinin interaction, which regulates apical dominance (Ali M). Increased panicle numbers and their lengths further suggest better transition from vegetative to reproductive growth stages, a process known to be facilitated by auxin-mediated cell elongation and floral differentiation.

The number of grains per panicle increased remarkably from 95.3 ± 2.6 in control to 132.1 ± 3.0 in the 30 µM IAA treatment. This enhancement is a result of improved floret initiation and fertility, potentially due to increased carbohydrate supply from higher photosynthetic activity and stronger sink strength of developing grains. Higher 1000-grain weight in auxin-treated plants (26.3 ± 0.4 g) also reflects improved grain filling and assimilate partitioning. Exogenous auxins can stimulate phloem loading and sucrose translocation, which are critical for grain development (Poelmans).

Grain yield, the ultimate agronomic trait, was significantly improved by IAA application. The 30 µM treatment recorded the highest yield (5985 ± 95 kg ha^{-1}), followed by 20 µM (5920 ± 85 kg ha^{-1}), whereas the control plot yielded only 4520 ± 80 kg ha^{-1}. These outcomes align with the studies by Javed et al. (Javed S,)and Hussain (Hussain S,), who also reported auxin-induced yield enhancement in cereal crops through improved growth and resource utilization efficiency.

Interestingly, no momentous difference in most traits was experiential between 20 µM and 30 µM IAA treatments, suggesting that 20 µM may be the optimum concentration for maximum physiological and yield benefit without risk of hormonal overstimulation or wastage of resources. This is consistent with the concept of the dose-response curve of plant growth regulators, where an optimum exists beyond which additional input does not translate into proportional output (Tariq A,).

Table 1. Yield and yield components of rice affected by foliar application of indole-3-acetic acid (IAA)

Treatment	Tillers per plant	Panicles per plant	Panicle length (cm)	Grains per panicle	1000-grain weight (g)	Grain yield (kg ha^{-1})
Control	10.2 ± 0.3 c	9.6 ± 0.2 c	21.1 ± 0.5 c	95.3 ± 2.6 c	22.5 ± 0.6 c	4520 ± 80 c
10 µM IAA	12.5 ± 0.4 b	11.3 ± 0.3 b	23.8 ± 0.4 b	112.5 ± 3.1 b	24.3 ± 0.5 b	5180 ± 90 b
20 µM IAA	14.8 ± 0.5 a	13.5 ± 0.3 a	26.5 ± 0.3 a	130.4 ± 2.8 a	26.1 ± 0.4 a	5920 ± 85 a
30 µM IAA	15.1 ± 0.4 a	13.7 ± 0.3 a	26.7 ± 0.5 a	132.1 ± 3.0 a	26.3 ± 0.4 a	5985 ± 95 a

4. CONCLUSION

These findings confirm that foliar application of auxins, particularly IAA, has a profound effect on rice physiology and yield. Auxin-induced improvements in chlorophyll content, photosynthesis, water relations, and yield components collectively contribute to enhanced productivity. These results advocate for the potential use of foliar auxins as a component of integrated nutrient and hormone management practices in rice cultivation.

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