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EFFECT OF DIFFERENT GROWTH REGULATORS ON MORPHOLOGICAL PARAMETERS, YIELD AND NUTRITIONAL STATUS OF *Pleurotus florida* (Mont.) SINGER

Anirudha Priya[1], Shivam[2*], S. K. Biswas[1], Saurabh Kumar[1] and Ankit Kumar[1]
[1]Department of Plant Pathology, C. S. Azad University of Agriculture & Technology, Kanpur-208002, U.P., India
[2]Department of Plant Pathology, Rani Lakshmi Bai Central Agricultural University, Jhansi-284003, U.P., India
*Corresponding author- Email: - shivamag668@gmail.com
ORCID Id: - 0009-0007-5856-190X
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ABSTRACT

The rapid growth of the global population, coupled with shrinking agricultural land has created a pressing need for alternative food sources that are nutritious, affordable and space-efficient. Oyster mushrooms (*Pleurotus florida*) represent one such promising solution. They can be cultivated on agricultural wastes, require minimal resources and are well known for their rich nutritional composition, including protein, dietary fiber, vitamins and essential minerals. Despite this potential, productivity remains constrained by conventional cultivation approaches that overlook the role of plant growth regulators in enhancing yield and quality. The present study was designed to investigate how three widely used plant growth regulators- Naphthalene Acetic Acid (NAA), Indole Butyric Acid (IBA) and Gibberellic Acid (GA_3)-applied at three concentration levels (5, 10 and 20 ppm), influence the growth, morphology, yield and nutritional composition of *Pleurotus florida* cultivated on wheat straw substrate. Among all nine treatments and the untreated control, the treatment designated T9 (wheat straw 5 kg + GA_3 at 20 ppm) emerged as the most effective across nearly all parameters measured. T9 produced the fastest spawn running (12 days), earliest pin head initiation (16 days) and the quickest cropping timeline overall. In terms of morphology, T9 yielded the greatest number of fruiting bodies (90 per bag), the longest stalk (6.10 cm) and the widest cap diameter (8.93 cm). Total yield under T9 reached 1,416.66 g per bag, with a biological efficiency of 113.33%, compared to just 956.66 g and 76.53% in the untreated control. In terms of nutritional output, T9 recorded the highest levels of Iron (53.41 mg/100 g DW) and Zinc (5.49 mg/100 g DW). The second-best overall performer was T6 (wheat straw + IBA at 20 ppm), which led in Calcium (10.16 mg) and Nitrogen (4.32 mg) content, while T3 (wheat straw + NAA at 20 ppm) gave the highest Phosphorus (1.25 mg) and Magnesium (49.53 mg) values. The findings demonstrate that judicious application of growth regulators, especially GA_3 at 20 ppm, can substantially improve both the productivity and nutritional value of *Pleurotus florida*. This has important implications for smallholder farmers, landless cultivators and agri-entrepreneurs seeking to enhance income and food security without requiring additional land or high capital input.

***Keywords*:** Oyster mushroom, *Pleurotus florida*, Plant growth regulators (PGRs), gibberellic acid, indole butyric acid, naphthalene acetic acid, biological efficiency, nutritional quality, wheat straw.

Introduction

Fungi have fascinated human civilizations for millennia. The word 'mycology' itself derives from the Greek 'mykes', a term ancient Greeks used to describe mushrooms-organisms they observed springing from the soil seemingly without cause. The classical Indian text Samhita of the Atreya Charak, dating as far back as 3000 B.C., already recognized the diversity of mushrooms and classified them into edible, poisonous and medicinal categories. The Romans revered them as 'Food of the Gods', while Chinese traditions hailed them as the 'Elixir of Life'. Today, mushrooms sit at

the intersection of nutrition science, sustainable agriculture and biotechnology.

The cultivation of oyster mushrooms under the genus Pleurotus represents one of the most accessible and economically viable aspects of modern mushroom farming. Oyster mushrooms were first cultivated in Europe on tree logs and stumps at the beginning of the 20th century. Approximately 38 species have been described globally under the genus Pleurotus, of which more than 25 have been reported from the Indian subcontinent alone. Among the commercially important species are *P. ostreatus*, *P. florida*, *P. sajor-caju*, *P. eryngii*, *P. citrinopileatus* and several others, together constituting a significant share of global mushroom production (Singer, 1986).

Pleurotus florida is a tropical oyster mushroom variety that has gained traction across subtropical and temperate countries due to its adaptability and straightforward cultivation requirements. The name 'Pleurotus' is derived from the Greek word *pleuro*, meaning 'to be created laterally', describing the lateral attachment of the stipe relative to the pileus. The oyster-like shape of the fruiting bodies gives it the common name 'oyster mushroom' or 'Dhingri' as it is known in India (Jandaik, 1997).

From a nutritional perspective, Pleurotus mushrooms are remarkably complete. They are rich in protein, dietary fiber, B-glucan, B-complex vitamins, vitamin C and a range of essential minerals. Specific amino acids such as methionine, cysteine, and aspartic acid are present in proportions that compare favourably to many plant-based protein sources. Beyond nutrition, oyster mushrooms have demonstrated a range of bioactive properties, including hypocholesterolaemia, anti-bacterial, anti-diabetic, anti-oxidant, anti-carcinogenic, hepatoprotective and anti-viral activities, making them attractive not only as food but also as functional health products (Kumar, 2019).

According to FAO STAT data from 2019, India contributes approximately 1.5% of global mushroom production, while China and Japan together account for over 64.5% of Asia's output. India produced an estimated 21,272 tonnes of oyster mushrooms during this period. White button mushroom dominates India's mushroom market at 73%, followed by oyster mushrooms at 16% and paddy straw mushrooms at 7%. Despite this growing output, India's per capita consumption of mushrooms remains below 100 g annually-a figure that highlights the vast untapped potential for domestic growth in mushroom production and consumption (Sharma *et al*., 2017).

One of the most compelling arguments for promoting Pleurotus cultivation lies in its capacity to utilize lignocellulosic agricultural wastes as substrate. Cotton lint, maize stalks, sugarcane bagasse, jatropha cake, wood shavings and wheat straw have all been documented as effective growing media. This characteristic makes mushroom cultivation a natural ally for efforts to recycle agricultural by-products, reduce environmental waste and improve farm sustainability (Chitamba *et al*., 2012; Girmay *et al*., 2016; Yamarchi *et al*., 2018).

While substrate selection and management techniques have been well studied, comparatively less attention has been given to the role of plant growth regulators (PGRs) in oyster mushroom cultivation. PGRs are organic compounds-commonly referred to as phytohormones-that, even in small concentrations, can profoundly influence plant and fungal growth, morphology, and metabolite accumulation (Prajapati *et al*., 2015). Previous studies have established that PGRs such as gibberellic acid (GA_3), indole-3-acetic acid (IAA) and indole butyric acid (IBA) can stimulate mycelial growth, increase fruiting body size and number, reduce the crop cycle duration and improve the nutritional content of harvested mushrooms. For instance, Mukhopadhyay *et al*. (2005) reported that GA, IAA, and kinetin increased biomass production in *Pleurotus sajor-caju* by 15–26% and Pani (2011) observed that spraying GA at 50 ppm on emerging primordia significantly boosted mushroom number and size.

Given this background, the present investigation was designed to systematically evaluate the effects of three PGRs-Naphthalene Acetic Acid (NAA), Indole Butyric Acid (IBA) and Gibberellic Acid (GA_3) each applied at three concentrations (5, 10 and 20 ppm), on the growth periods, morphological attributes, yield potential, biological efficiency, fresh and dry weight and nutritional composition of *Pleurotus florida* cultivated on wheat straw.

Materials and Methods

The present investigation was conducted at the Mushroom Unit, Department of Plant Pathology, Chandra Shekhar Azad University of Agriculture and Technology, Uttar Pradesh, during 2021–2023. The study followed a Completely Randomized Design (CRD) with 10 treatments and 3 replications per treatment. The experimental organism was *Pleurotus florida*, grown on wheat straw substrate (5 kg per bag) at a spawning rate of 10% of dry substrate weight.

Laboratory Setup and Equipment

All laboratory procedures were carried out under rigorously maintained aseptic conditions. The equipment used included a laminar air flow chamber, hot air oven, autoclave, BOD (Bio-Oxygen Demand) incubator, electric balance, hot plate, Atomic Absorption Spectrophotometer (AAS), digital pH meter and digital conductivity meter. Miscellaneous materials such as inoculation needles, burner lamps, Whatman filter paper, polypropylene bags, forceps, scissors and various types of glassware were also employed.

All glassware used in the study was cleaned by immersion in a solution of 60 g potassium dichromate ($K_2Cr_2O_7$) and 60 ml concentrated sulphuric acid (H_2SO_4) per 1000 ml of water for 24 hours. After thorough washing with tap water and distilled water, glassware was sterilized either in an autoclave at 121°C and 15 psi for 15–20 minutes or in a hot air oven at 160–180°C for 1.5–2 hours. The laminar air flow chamber was decontaminated with 70% ethyl alcohol before all laboratory work.

Culture Media Preparation

Potato Dextrose Agar (PDA) medium was used throughout the study for fungal isolation and culture maintenance. The medium was prepared using 200 g peeled potato, 20 g dextrose, 20 g agar-agar, and 1000 ml distilled water, following the protocol described by Waller *et al*. (2001). Potatoes were boiled until soft, filtered through muslin cloth and the filtrate was made up to 1 litre. Dextrose and agar were dissolved in the boiling filtrate sequentially. The prepared medium was dispensed into conical flasks (200 ml capacity) and culture tubes (10 ml capacity), plugged with non-absorbent cotton, and sterilized at 121.6°C and 15 psi for 15–20 minutes.

Fungal Culture: Isolation and Maintenance

Fresh, young fruiting bodies of *Pleurotus florida* were collected and brought to the laboratory for tissue culture. Each basidiocarp was surface-sterilized with 0.1% mercuric chloride solution for one minute, washed in sterile distilled water and then split longitudinally. Mycelial tissue from the collar region the junction between the pileus and stipe was excised aseptically and placed on PDA-containing petri plates. Inoculated plates were incubated in a BOD incubator at 24 ± 1°C. The resulting pure cultures were maintained on PDA slants at 25°C for subsequent use.

Spawn Preparation

Wheat grain spawn was prepared for this study owing to the wide availability and low cost of wheat grains. Selected grains were cleaned, boiled for 20–25 minutes and excess water was drained by sieving. After shade-drying for 4–6 hours, the grains were blended with calcium carbonate ($CaCO_3$ at 0.5%) and calcium sulphate ($CaSO_4$ at 2%). For master spawn, approximately 300 g of the treated grain mixture was filled into glucose bottles; for commercial spawn, 500 g was filled into heat-resistant polypropylene bags. All containers were plugged with non-absorbent cotton and autoclaved at 22 psi for two hours. Inoculation was carried out under aseptic laminar flow conditions. Commercial spawn bottles received 10–15 g of master spawn. After inoculation, bags were shaken 3–4 times during incubation at 24°C. Both master and commercial spawn were ready within 15–25 days.

Substrate Preparation and Chemical Treatment

Wheat straw was obtained from the Student Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Before use, the straw was thoroughly washed in fresh water and chemically sterilized by soaking in 2–4% formalin solution for 18–20 hours. Excess water was drained the following day and the substrate was spread on a formalin-disinfected concrete floor for air-drying. Nine growth regulator treatments and one untreated control were then prepared and applied as follows:

T1: Wheat straw 5 kg + NAA @ 5 ppm
T2: Wheat straw 5 kg + NAA @ 10 ppm
T3: Wheat straw 5 kg + NAA @ 20 ppm
T4: Wheat straw 5 kg + IBA @ 5 ppm
T5: Wheat straw 5 kg + IBA @ 10 ppm
T6: Wheat straw 5 kg + IBA @ 20 ppm
T7: Wheat straw 5 kg + GA3 @ 5 ppm
T8: Wheat straw 5 kg + GA3 @ 10 ppm
T9: Wheat straw 5 kg + GA3 @ 20 ppm
T10 (Control): Wheat straw 5 kg only (no growth regulator)

Bag Filling, Spawning and Incubation

Polypropylene bags (75 × 450 cm) were filled using the layer-by-layer method: a layer of treated substrate was placed first, followed by an even distribution of 50 g of freshly prepared spawn and this sequence was repeated until each bag was filled. The topmost layer was substrate. Each filled bag was made airtight, placed on iron racks in the cropping room and 8–10 holes were punctured in each bag to facilitate mycelial breathing and gas exchange.

The cropping room was sterilized prior to use by fumigation with 2% formalin for 48 hours, after which all ventilation openings were aired for at least 24 hours to remove residual formalin. During the spawn running phase, bags were maintained at 24°C, 85–90% relative humidity with CO_2 levels kept below 0.6% and

exposed to light in the range of 360–420 nm. The spawn run was typically completed within 12–17 days depending on the treatment.

Cultivation: Pin Heading, Fruiting and Harvesting

Following complete mycelial colonization, the bags were cut open and allowed to initiate pin head formation. Pin heads typically emerged 6–7 days after spawn run completion. High relative humidity (75–85%) was maintained during the fruiting stage and the bags were watered once or twice daily, with watering discontinued one day before each harvest. Fruiting bodies were harvested across three successive flushes and all yield data were recorded per flush and cumulatively. The biological efficiency of each treatment was calculated using the formula:

$$\text{Biological Efficiency}\,(\%) = \frac{\text{Fresh weight of fruiting bodies}}{\text{Dry weight of substrate}} \times 100$$

Nutritional Analysis

Nitrogen - micro-Kjeldahl Method

Mushroom samples were dried in a hot air oven at 60 ± 2°C for 2-4 hours and ground into fine powder using a grinder. The powder was sieved through a 2 mm stainless steel sieve. A 0.5 g sample was digested in 10 ml concentrated sulphuric acid with 5 g catalyst mixture using a block digester at an initial temperature of 100°C, progressively raised to 400°C until the sample became colourless. Distillation was performed using 40 ml of 40% NaOH, with ammonia absorption in 20 ml of 4% boric acid containing mixed indicator. Titration was conducted against 0.02 N sulphuric acid. Total nitrogen was calculated from the titration data.

Phosphorus — Bray No. 1 Method

One gram of dried plant material was subjected to diacid digestion (3:1 nitric acid : perchloric acid) on a hot plate. The digest was filtered and made up to 100 ml with distilled water. An aliquot of 10 ml was transferred to a 50 ml volumetric flask, 10 ml ammonium molybdate vanadate reagent was added and absorbance was measured at 420 nm using a colorimeter. Phosphorus content was calculated using a pre-drawn standard curve.

Mineral Elements (Ca, Mg, Fe, Zn, Cu) -Atomic Absorption Spectrophotometry

Standard solutions at 5, 10, 15, 20, and 25 ml concentrations were prepared from a stock solution and made up to 50 ml with deionized water. Mineral contents were measured directly using an Atomic Absorption Spectrophotometer (AAS), with the appropriate element selection made for each analysis. The data were read directly from the instrument against standard curves established for each element.

Statistical Analysis

All experimental data were subjected to analysis of variance (ANOVA) under the Completely Randomized Design (CRD) framework. Treatment means were compared using the Critical Difference (CD) at the 5% level of significance. The CD was calculated using the formula:

$$\mathbf{CD = \sqrt{(2VE/r)} \times t\ (at\ 5\%)}$$

where VE is the error variance, r is the number of replications and t is the tabulated t-value at 5% significance for the error degrees of freedom. Standard Error of Mean (SE(m)), Standard Error of Difference (SE(d)) and Coefficient of Variation (CV%) were also reported for each parameter.

Results

The experiment was designed to assess the effect of three plant growth regulators -NAA, IBA and GA3 each at three concentrations, on the cultivation performance of *Pleurotus florida* on wheat straw. The results are systematically presented below across four broad parameter categories: growth periods, morphological attributes, yield and biological efficiency and nutritional composition.

Effect of Growth Regulators on Growth Periods

Spawn Running

The number of days required for complete spawn running is a critical indicator of how quickly a mushroom crop is ready to proceed to the fruiting stage. The data presented in Table 1 show that all nine growth regulator treatments significantly shortened the spawn running duration compared to the untreated control. Across all treatments, spawn running took between 12 and 16 days. The fastest spawn running just 12 days was observed in T9 (GA3 at 20 ppm), followed by T6 (IBA at 20 ppm) at 13 days, T8 (GA3 at 10 ppm) at 14 days and T3 (NAA at 20 ppm) at 15 days. The control required the longest period of 17 days. Within each PGR type, a clear dose-response relationship was evident: higher concentrations invariably led to faster spawn running and GA3 was the most potent of the three regulators tested.

Pin Head Initiation

Pin head initiation was similarly accelerated in all treated bags. The minimum 16 days for pin head appearance was recorded in T9 (GA3 at 20 ppm), which was tied with T6 (IBA at 20 ppm). T3 (NAA at 20 ppm) followed closely at 17 days. The control bags took the longest 21 days for visible pin head

emergence. These findings confirm that all three growth regulators, especially at higher concentrations, effectively trigger earlier and more synchronized pin head formation.

First, Second and Third Harvesting

All treated bags also matured earlier across each of the three harvest flushes. T9 consistently led the way: first flush harvest occurred at 20 days after spawning, second flush at 28 days and the third flush at 39 days. The untreated control required 27, 35 and 45 days for the first, second and third harvests, respectively. T6 was the next best performer at 21, 30 and 40 days for the three flushes. These reductions in crop duration are practically significant, as they allow cultivators to complete more crop cycles within a given time period, thereby increasing overall productivity.

Table 1 : Effect of Different Growth Regulators at Different Concentrations on the Growth Periods (in days) of *Pleurotus florida*

Treatment Details	Spawn Run (days)	Pin Head Initiation (days)	1st Harvest (days)	2nd Harvest (days)	3rd Harvest (days)	Total Crop Period (days)
T1 (WS 5kg + NAA 5ppm)	16.00	20.00	26.00	33.00	43.00	43.00
T2 (WS 5kg + NAA 10ppm)	15.00	19.00	24.00	32.00	41.00	41.00
T3 (WS 5kg + NAA 20ppm)	14.00	17.00	23.00	31.00	41.00	41.00
T4 (WS 5kg + IBA 5ppm)	16.00	19.00	25.00	33.00	42.00	42.00
T5 (WS 5kg + IBA 10ppm)	15.00	18.00	23.00	31.00	41.00	41.00
T6 (WS 5kg + IBA 20ppm)	13.00	16.00	21.00	30.00	40.00	40.00
T7 (WS 5kg + GA_3 5ppm)	16.00	21.00	26.00	32.00	43.00	43.00
T8 (WS 5kg + GA_3 10ppm)	15.00	18.00	23.00	33.00	41.00	41.00
T9 (WS 5kg + GA_3 20ppm)	12.00	16.00	20.00	28.00	39.00	39.00
Control (Wheat Straw)	17.00	21.00	27.00	35.00	45.00	45.00
CD at 5%	2.25	2.05	1.90	2.14	2.19	—
SE(m)	0.76	0.69	0.64	0.72	0.73	—
CV%	8.71	6.43	4.63	3.99	3.06	—

Effect of Growth Regulators on Morphological Attributes

Number of Fruiting Bodies

All treated bags produced significantly more fruiting bodies than the control. T9 again led with 90 fruiting bodies per bag a 34.32% increase over the control value of 67 bodies. T6 followed with 88 bodies (31.34% increase) and T3 with 85 bodies (26.34% increase). Treatments using lower concentrations of each PGR produced correspondingly fewer fruiting bodies but all outperformed the control illustrating the positive dose-response pattern.

Maximum Weight of Fruiting Body

Individual fruiting body weight was highest in T9 at 27.72 g per fruiting body, followed by T6 (25.51 g) and T3 (24.76 g). The control yielded a mean individual fruiting body weight of only 20.14 g. The consistent superiority of higher-concentration GA_3 and IBA treatments indicates that these regulators promote more vigorous and heavier fruit body development, likely through their effects on cell elongation and expansion.

Stalk Length

The highest average stalk length of 6.10 cm was recorded in T9, compared to just 3.50 cm in the control representing a 74.3% improvement. T6 and T3 achieved stalk lengths of 5.46 and 5.13 cm, respectively. Gibberellic acid is well known for its role in promoting stem elongation in plants and the present data suggest a parallel stimulatory effect in *Pleurotus florida.*

Cap Diameter (Pileus Width)

The maximum cap diameter was 8.93 cm (T9) with both T3 and T6 recording 8.13 cm each and the control producing the smallest cap diameter at 5.53 cm. Wider cap diameter translates directly into greater surface area per fruiting body, higher visual appeal and better market value of the harvested mushroom.

Table 2 : Effect of Different Growth Regulators at Different Concentrations on the Morphological Attributes of Oyster Mushroom (*Pleurotus florida*)

Treatment Details	Max. Weight of Fruiting Body (g)	Stalk Length (cm)	Cap Diameter (cm)	No. of Fruiting Bodies	% Increase over Control
T1 (WS 5kg + NAA 5ppm)	20.39	3.95	5.98	71	5.97
T2 (WS 5kg + NAA 10ppm)	22.60	4.16	7.50	70	4.47
T3 (WS 5kg + NAA 20ppm)	24.76	5.13	8.13	85	26.34
T4 (WS 5kg + IBA 5ppm)	20.95	3.53	6.36	72	7.46
T5 (WS 5kg + IBA 10ppm)	23.78	4.36	7.13	79	17.90
T6 (WS 5kg + IBA 20ppm)	25.51	5.46	8.13	88	31.34
T7 (WS 5kg + GA_3 5ppm)	21.38	4.26	7.30	76	13.43
T8 (WS 5kg + GA_3 10ppm)	24.24	5.26	8.06	84	25.37
T9 (WS 5kg + GA_3 20ppm)	27.72	6.10	8.93	90	34.32
Control (Wheat Straw)	20.14	3.50	5.53	67	—
CD at 5%	2.59	0.36	0.47	7.72	—
CV%	6.53	4.72	3.82	5.66	—

Yield Potential and Biological Efficiency

Yield Across Three Flushes

Pleurotus florida was harvested across three successive flushes, and yield data were recorded for each flush as well as cumulatively. T9 consistently produced the highest yield across all three flushes: 470.00 g (1st flush), 460.00 g (2nd flush) and 486.66 g (3rd flush), giving a total yield of 1,416.66 g per bag. The control yielded only 348.33, 298.33, and 310.00 g across the three flushes, for a total of 956.66 g nearly one-third less than T9. T6 (IBA at 20 ppm) was the second-best overall treatment at 1,366.65 g total followed by T3 (NAA at 20 ppm) at 1,323.32 g.

Biological Efficiency

Biological efficiency the ratio of fresh mushroom yield to dry substrate weight ranged from 76.53% (control) to 113.33% (T9). T9's biological efficiency of 113.33% indicates that the mushrooms produced more than their substrate's dry weight in fresh matter, a remarkable outcome attributable to the stimulatory effect of GA_3 on mycelial growth and fruiting body development. T6 achieved 109.33% and T3 achieved 105.86%, both comfortably exceeding 100%.

Table 3 : Effect of Different Growth Regulators at Different Concentrations on Yield Potential and Biological Efficiency of *Pleurotus florida*

Treatment Details	1st Flush Yield (g)	2nd Flush Yield (g)	3rd Flush Yield (g)	Total Yield (g)	Biological Efficiency (%)
T1 (WS 5kg + NAA 5ppm)	366.66	326.66	340.00	1033.32	82.66
T2 (WS 5kg + NAA 10ppm)	410.00	366.66	350.00	1126.66	90.13
T3 (WS 5kg + NAA 20ppm)	416.66	446.66	460.00	1323.32	105.86
T4 (WS 5kg + IBA 5ppm)	360.00	336.66	330.00	1026.66	81.74
T5 (WS 5kg + IBA 10ppm)	368.33	383.33	366.66	1118.32	89.46
T6 (WS 5kg + IBA 20ppm)	446.66	463.33	456.66	1366.65	109.33
T7 (WS 5kg + GA_3 5ppm)	366.66	373.33	310.00	1049.99	83.99
T8 (WS 5kg + GA_3 10ppm)	371.66	403.33	363.33	1098.32	87.86
T9 (WS 5kg + GA_3 20ppm)	470.00	460.00	486.66	1416.66	113.33
Control (Wheat Straw)	348.33	298.33	310.00	956.66	76.53
CD at 5%	41.69	41.75	31.31	41.90	—
CV%	6.19	6.30	4.89	6.36	—

Fresh and Dry Weight

Because the total yield data (Table 4) directly correspond to fresh weight per bag T9 again tops the list at 1,416.66 g fresh weight and 169.99 g dry weight representing increases of 48.03% and 77.70% over the control, respectively. The control recorded the minimum fresh weight (956.66 g) and dry weight (95.66 g). The oyster mushroom has a naturally high moisture content, typically in the range of 85–90%, which was confirmed across all treated groups. Interestingly, the untreated control exhibited a higher

moisture content (~95%), suggesting that growth regulator treatments may slightly enhance dry matter accumulation.

Table 4 : Effect of Different Growth Regulators at Different Concentrations on the Fresh and Dry Weight of *Pleurotus florida*

Treatment Details	Total Fresh Weight (g)	Fresh Wt. Increase over Control (%)	Total Dry Weight (g)	Dry Wt. Increase over Control (%)
T1 (WS 5kg + NAA 5ppm)	1033.32	8.01	103.33	8.01
T2 (WS 5kg + NAA 10ppm)	1126.66	17.77	123.93	29.55
T3 (WS 5kg + NAA 20ppm)	1323.32	38.32	158.79	65.99
T4 (WS 5kg + IBA 5ppm)	1026.66	7.31	99.39	3.89
T5 (WS 5kg + IBA 10ppm)	1118.32	16.90	111.83	16.90
T6 (WS 5kg + IBA 20ppm)	1366.65	42.85	163.99	71.43
T7 (WS 5kg + GA_3 5ppm)	1049.99	9.83	98.99	3.40
T8 (WS 5kg + GA_3 10ppm)	1098.32	14.80	120.81	26.29
T9 (WS 5kg + GA_3 20ppm)	1416.66	48.03	169.99	77.70
Control (Wheat Straw)	956.66	—	95.66	—
CD at 5%	41.90	—	10.02	—
CV%	6.36	—	3.41	—

Nutritional Composition

Dried mushroom powder from each treatment was subjected to chemical analysis for seven key nutrients: nitrogen (N), phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn) and copper (Cu). The data (Table 5) reveal that growth regulator treatments consistently enhanced the content of all nutrients compared to the control although the magnitude of improvement varied by nutrient and treatment.

Nitrogen content was highest in T6 at 4.32 mg/100 g DW (IBA at 20 ppm), with T4 and T7 also performing well at 4.01 and 4.03 mg, respectively. The minimum nitrogen was found in the control at 3.73 mg. The highest phosphorus was recorded in T3 (NAA at 20 ppm) at 1.25 mg/100 g DW, nearly 40% more than the control (0.89 mg).

For calcium, T6 recorded the maximum at 10.16 mg/100 g DW, followed jointly by T3 and T9 at 10.05 mg each. The control had the minimum at 9.83 mg. Magnesium was highest in T3 at 49.53 mg/100 g DW versus 47.55 mg in the control. Iron content was greatest in T9 (GA3 at 20 ppm) at 53.41 mg/100 g DW, marginally but consistently higher than the control (52.12 mg). Zinc was also best in T9 at 5.49 mg compared to 5.14 mg in the control a modest but statistically significant difference. Copper peaked in T5 (IBA at 10 ppm) at 39.46 mg/100 g DW against a minimum of 37.07 mg in the control.

Table 5 : Effect of Different Growth Regulators at Different Concentrations on Nutritional Constituents of *Pleurotus florida* (mg/100 g DW)

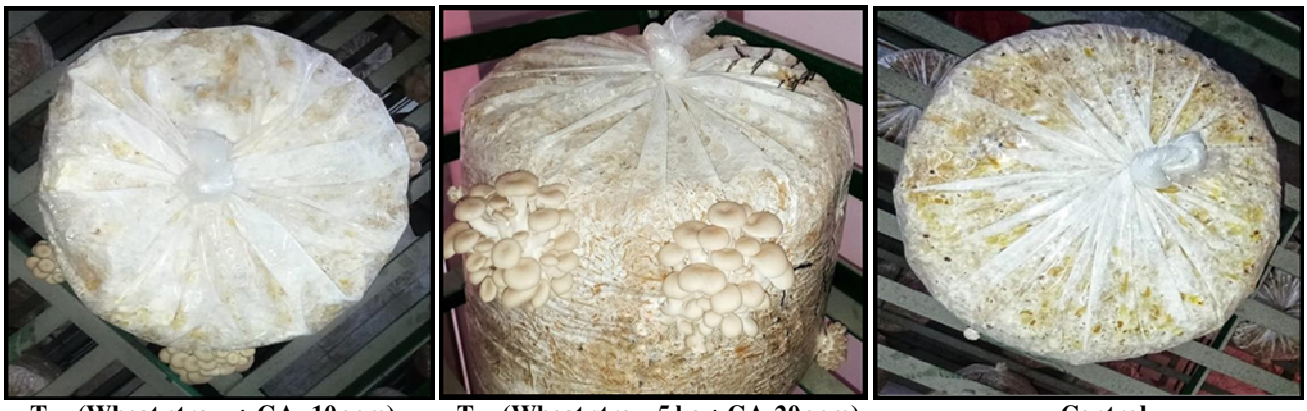
Treatment Details	N	P	Ca	Mg	Fe	Zn	Cu
T1 (WS 5kg + NAA 5ppm)	3.84	1.00	9.84	47.55	52.12	5.29	37.02
T2 (WS 5kg + NAA 10ppm)	4.09	0.93	9.55	48.41	52.01	5.31	38.07
T3 (WS 5kg + NAA 20ppm)	3.98	1.25	10.05	49.53	53.19	5.38	38.45
T4 (WS 5kg + IBA 5ppm)	4.01	0.93	9.83	47.94	50.21	5.20	37.00
T5 (WS 5kg + IBA 10ppm)	4.00	0.94	9.85	47.23	50.26	5.21	39.46
T6 (WS 5kg + IBA 20ppm)	4.32	1.03	10.16	48.65	53.20	5.39	38.45
T7 (WS 5kg + GA_3 5ppm)	4.03	1.02	9.91	47.86	52.63	5.32	38.24
T8 (WS 5kg + GA_3 10ppm)	3.84	0.94	9.92	46.94	52.02	5.29	37.00
T9 (WS 5kg + GA_3 20ppm)	3.96	0.97	10.05	47.87	53.41	5.49	38.26
Control (Wheat Straw)	3.73	0.89	9.83	47.55	52.12	5.14	37.07
CD at 5%	2.33	1.26	1.12	1.28	0.874	0.04	0.240
CV%	4.85	1.54	1.07	1.03	0.97	0.48	0.368

Plate 1: Effect of different growth regulators on spawn running periods of *Pleurotus florida.*

T2= (Wheat straw 5 kg + NAA 10ppm) **T_3= (Wheat straw 5 kg + NAA20ppm)** **T_6= (Wheat straw 5 kg + IBA20 ppm)**

Plate 2: Effect of different growth regulators on pin head initiation of *Pleurotus florida.*

T_2= (Wheat straw 5 kg + NAA 10pp m) **T_3= (Wheat straw + NAA 20ppm)** **T6= (Wheat straw + IBA 20ppm)**



T_8= (Wheat straw + GA_3 10ppm) **T_9= (Wheat straw 5 kg + $GA_3$20ppm)** **Control**

Plate 3: Effect of defferent growth regulators on *Pleurotus florida.*

T_2= (Wheat straw 5 kg + NAA10ppom) **T_3= (Wheat straw 5 kg + NAA20ppm)** **T_6= (Wheat straw 5 kg + IBA20ppm)**

T_8= (Wheat straw 5 kg + $GA_3$10ppm) **T_9= (Wheat straw 5 kg + $GA_3$20ppm)** **Control**

Discussion

Mushroom cultivation particularly of oyster mushrooms represents one of the most promising avenues for sustainable food production in both rural and peri-urban settings. It requires minimal land, can utilize agricultural waste substrates and yields a highly nutritious crop within a relatively short time. Against this backdrop, the present investigation sought to determine whether plant growth regulators could further elevate the productivity and quality of *Pleurotus florida* and the results clearly affirm that they can.

Growth Period

The ability of growth regulators, especially GA_3 at 20 ppm (T9), to reduce spawn running and pin head initiation periods aligns well with findings from earlier studies. Khandakar (2004), Pal *et al.* (2014) and Chourasia *et al.* (2020) all reported that GA_3-based treatments effectively shortened spawn running durations. Khan *et al.* (2001), Pathmashini *et al.* (2009) and Kumar *et al.* (2023) observed similar accelerating effects on pin head initiation. The mechanism is well understood: GA_3 stimulates cell division and elongation at the meristematic level, effectively 'priming' the mycelium for faster transition to the reproductive phase.

The reduction in harvesting time across all three flushes in T9 is of particular practical significance. Godse *et al.* (2021) similarly found that GA_3-treated bags produced the first harvest in just 19 days closely paralleling the 20-day first flush recorded here. Quimio (1978) also demonstrated that growth regulator treatments consistently advanced pin head initiation compared to untreated controls. Taken together, these observations suggest that the time-saving benefit of GA_3 treatment is a repeatable and reliable finding.

Morphological Attributes

The marked improvements in stipe length, pileus width, individual fruiting body weight and total number of fruiting bodies in T9 are consistent with the well-documented role of gibberellins in promoting cell expansion and organ elongation. Debargaina *et al.*

(2022) and Singh and Prasad (2012) reported the highest stipe lengths in GA3-treated bags, with values around 5.132 cm slightly lower than the 6.10 cm recorded in the present study, potentially reflecting differences in substrate, genotype, or environmental conditions. Alam *et al.* (2007) and Zerihun Tsegaye (2015) showed that PGRs, particularly at concentrations of 10 and 20 ppm, significantly increased the number of effective fruiting bodies, while Sarkar and Chowdhury (2013) found that 20 ppm GA_3 produced 84 fruiting bodies very close to the 90 bodies recorded in T9 here.

Yield and Biological Efficiency

The superior yield of T9 (1,416.66 g per bag; biological efficiency 113.33%) is strongly supported by literature. Kannaujiya *et al.* (2020) working with related Pleurotus species found maximum yield at GA_3 @ 20 ppm, reporting biological efficiency values of 51.33% for *P. djamor* and 70% for P. *sajor-caju* figures that are lower than those recorded here, which may reflect the higher responsiveness of P. florida to GA_3 or the particular substrate-treatment combination employed. Rostrum *et al.* (2010) observed a maximum yield of 910.8 g per bag with GA_3-treated substrate, again somewhat lower than the current results but confirming the direction of the effect.

The very high biological efficiency values achieved in this study (>100% in T9, T6 and T3) demonstrate that, under optimal growth regulator conditions, *P. florida* can produce fresh biomass that exceeds the dry weight of the substrate a compelling argument for adopting PGR-based cultivation protocols at a commercial scale.

Fresh and Dry Weight, and Moisture Content

The highest fresh and dry weights in T9 are directly consistent with the yield data. Tolera *et al.* (2017) reported moisture content in freshly harvested oyster mushrooms at 88.75%, while Rashidi *et al.* (2016) found 90.10% moisture in freshly harvested *P. ostreatus* fruiting bodies. The present study's observations 85 to 90% moisture in treated bags and ~95% in the control are in agreement with these figures and suggest that growth regulator treatment may promote slightly greater dry matter accumulation relative to water content.

Nutritional Composition

Mushrooms are increasingly valued not just as a calorie source but as a functional food rich in specific minerals and bioactive compounds. The nutritional data from the present study indicate that growth regulator treatments modestly but consistently elevated the content of macro and micronutrients. Jacues *et al.* (2021) and Ha *et al.* (2021) reported that mushrooms treated with growth-promoting compounds were richer in Cu (36.35%), Fe (52.65%), Mg (47.84%) and Na (14.50%) than controls, with relatively lower calcium and phosphorus a pattern partially mirrored in the present results. The somewhat differential effects of the three PGRs on individual nutrients (IBA leading for N and Ca; NAA leading for P and Mg; GA_3 leading for Fe and Zn) reflect the distinct biochemical pathways through which each hormone operates and suggest that blended regulator protocols could potentially optimize the nutritional profile more holistically.

Summary and Conclusions

Across all parameters spawn running speed, pin head initiation, harvesting timeline, morphological development, total yield, biological efficiency, fresh and dry weight and nutrient content the treatment T9 (wheat straw 5 kg + GA_3 at 20 ppm) emerged as the most effective. It reduced the spawn running period by 29% and the first harvesting date by 26% relative to the untreated control. It produced the maximum number of fruiting bodies (90 per bag) the largest individual fruiting body (27.72 g) the longest stalk (6.10 cm) and the widest cap (8.93 cm). The total yield of 1,416.66 g per bag and biological efficiency of 113.33% in T9 represent the highest values recorded in this study and compare favourably with similar work reported in the scientific literature.

The second-best overall performer was T6 (IBA at 20 ppm), which was particularly superior in calcium (10.16 mg) and nitrogen (4.32 mg) content and achieved a biological efficiency of 109.33%. T3 (NAA at 20 ppm) led in phosphorus (1.25 mg) and magnesium (49.53 mg) and was the third-best in yield performance overall.

A clear dose-response pattern was evident for all three growth regulators: higher concentrations consistently produced better outcomes than lower concentrations. Among the three PGRs, the order of effectiveness was GA_3 > IBA > NAA particularly for growth period reduction and yield enhancement.

These findings have direct implications for mushroom cultivators. Incorporating GA_3 at 20 ppm into the *Pleurotus florida* production protocol on wheat straw substrate can meaningfully increase productivity per growing cycle, while simultaneously enriching the nutritional quality of the harvested crop. This is achieved without requiring additional land, infrastructure or complex technology making it particularly suitable for landless farmers, rural

entrepreneurs and youth seeking income-generating opportunities through agribusiness. Future research should explore the optimal application timing and frequency of growth regulators (e.g., pre-spawning vs. pin head stage vs. both) the effect of PGR combinations, their use across different substrates beyond wheat straw, and any long-term effects on substrate microbiome composition. Economic analysis of the cost-benefit ratio of PGR application at different scales of production would also be valuable for translating these findings into practical recommendations for farmers and agro-extension services.

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