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ORIGINAL ARTICLE

Effect of Organic Supplements on Productivity of *Ganoderma lucidum*

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ABSTRACT

Ganoderma lucidum is a medicinal, facultative parasitic fungus known as reishi mushroom. It produces fruiting body on different living and dead trunks. Different lignocellulosic agricultural wastes are also used as substrate for its artificial cultivation. Among the different factors, supplements play an important role in affecting its productivity. Therefore, five different supplements such as boiled paddy, boiled wheat, wheat bran, neem cake along with control were evaluated. During preparation of bags for *G. lucidum*, paddy straw was used as substrate along with different supplements. The bags were quadruplicated for each treatment and kept in different tiers following Randomised Block Design (RBD). Among five treatments maximum yield of 28.8g/bag with an average of 3.5 numbers of mushroom obtained from bags supplemented with boiled paddy followed by 27.0g/bag each as in case of boiled wheat and wheat bran. In contrast, neem cake supplementation resulted with the lowest yield, even below that of without any supplements i.e. control. However further study is required to elucidate about the bioactive components of mushroom among different treatments to determine the potential pharmacological variability.

KEYWORDS

- *Ganoderma lucidum*, supplement and productivity

INTRODUCTION

Ganoderma lucidum, commonly known as Reishi or Lingzhi, is a well-known medicinal mushroom valued for its wide range of therapeutic properties, including immunomodulatory, anti-inflammatory, anticancer and antioxidant effects. Due to increasing global demand, especially in the

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pharmaceutical and nutraceutical industries, recent research has focused on optimizing cultivation techniques to improve yield and bioactive compound content. Among the various cultivation factors, the supplementation of growth substrates plays a significant role in enhancing both biomass and metabolite production. Recent studies have explored the use of various agricultural byproducts and nutrient rich supplements such as wheat bran, rice bran, corn cob, sugarcane bagasse and soybean meal to enhance the growth performance of *G. lucidum* (Jadhav *et al*., 2021). These supplements not only serve as a nutrient source but also influence the mycelial colonization rate, fruiting body development and pharmacologically important metabolite synthesis. Moreover, the utilization of agro-industrial waste as substrate supplements helps the principles of sustainable mushroom farming reducing environmental impact as well as reducing the production cost. Integrating substrate optimization with modern biotechnological tools enables researchers to fine-tune the metabolic pathways of *G. lucidum*, thereby increasing its medicinal value (Zhang *et al*., 2022). Understanding the growth behaviour of *Ganoderma lucidum* on different supplements is thus critical for advancing commercial cultivation practices and enhancing the functional properties of this high value medicinal fungus. Therefore, an attempt has been taken to study the impact of organic supplements on productivity of *Ganoderma lucidum*.

MATERIALS AND METHODS

Collection and Maintenance of Pure Culture

To conduct the experiment, the pure culture of *Ganoderma lucidum* was sourced from the ICAR–Directorate of Mushroom Research, Chambaghat, Solan, Himachal Pradesh. The pure culture of *Ganoderma lucidum* was maintained in nutrient-rich media i.e Potato Dextrose Agar (PDA) and regularly sub cultured every 4–6 weeks under aseptic conditions, to avoid contamination and maintain the vigour of the culture.

Preparation of PDA medium

For the preparation of the culture medium, 200 gram of peeled and sliced potatoes were boiled in 500 ml of distilled water until softened. The resulting extract was filtered through muslin cloth and collected in a graduated cylinder. Separately, 20 gram of agar powder were dissolved in 500 ml of distilled water by boiling. The two solutions were then combined, and 20 gram of dextrose were added. The final volume was adjusted to 1000 ml by adding warm water. In order to prepare slants, 10 ml aliquots of the medium were dispensed into culture tubes, while the remaining medium was transferred to conical flasks. Both tubes and flasks were plugged with non-absorbent cotton plugs and sterilized in autoclave at 15 psi for 15–20 minutes. To prevent bacterial contamination, streptomycin sulphate (0.75mg/l) was added before sterilisation. Slants were prepared by keeping the warm culture tubes to solidify in a slanted position.

Commercial Mushroom Spawn Preparation

Mushroom spawn is the primary inoculum that act as seed in mushroom production. Wheat grains were used as a substrate for spawn due to their nutrient content, availability and ability to support vigorous mycelial growth. The grains are thoroughly cleaned, boiled until softened without loss of starch and air-dried under shade. To enhance alkalinity and prevent clumping, calcium carbonate was added at a concentration of 2–2.5% (w/w) based on dry grain weight. For spawn preparation, the processed grains were filled into 375 ml glass bottles followed by cotton plug with non-absorbent cotton. The bottles were sterilized at 22 psi pressure for 2 hours and cooled to room temperature. The cooled grains were inoculated with 15-day-old mycelial cultures of *Ganoderma lucidum* under aseptic condition and incubated at 25 ± 2 °C. After two weeks, the fully colonised spawns were used for cultivation.

Mushroom bag preparation

The preparation of mushroom cultivation bags was conducted through standardized procedure. Well dried, hand-threshed paddy straw and soaked in water for six hours. Subsequently, the straw was pasteurized in hot water for one hour, followed by cooling and drying under shade till the moisture content of 60–65%. Two hundred gram of the treated substrate was aseptically packed into sterile polythene bags and incorporated with spawn along with different supplements each at a rate of 10% by weight. To facilitate exchange of gases, 10 to 15 small perforations were made throughout each bag. The bags were then incubated in a controlled dark environment, maintained at temperatures between 28–35 °C and arranged on shelves to support uniform mycelial colonization.

Care and Harvest

After full colonization of the substrate by the mycelium, the bags were transferred to the cropping room, spaced 15–20 cm apart on wooden shelves. Fruiting conditions were optimized by providing 800 lux of diffused light for 8–12 hours per day, temperatures within 25-28 °C, and relative humidity between 70–80%.

The experiment was quadruplicate and the data on days to spawn run, pinhead formation, first harvest, number of fruiting bodies, total yield were recorded. Biological efficiency (%) was calculated using following formula.

$$\text{Biological Efficiency}(\%) = \frac{\text{Fresh weight of mushroom }(g)}{\text{Dry weight of substrate}(g)} \times 100$$

RESULTS AND DISCUSSIONS

The incorporation of organic supplements during mushroom cultivation has been found to significantly enhance not only the overall yield but also key morphological characteristics of the fruiting bodies.

Analysed data in *table* 1 revealed notable differences in the rate of mycelial colonization in different treatments. The time required for spawn run ranged between 17.5 to 23.0 days. Among the treatments, significantly minimum time for spawn run 17.5 days was recorded in the substrate supplemented with neem cake which followed by boiled paddy (21.5 days) and boiled wheat (21.8 days). Similarly, maximum 23.0 days was observed as in case of wheat bran and 22.5 days in the substrate without any supplement. Early spawn run was observed in neem cake, boiled paddy and boiled wheat than control. Gume *et al*. (2020), reported that organic supplements can significantly influence the spawn run duration due to their nutrient content and ease of mycelial absorption. The days to pinhead initiation, varied significantly among the treatments, ranging from 35.8 to 43.3 days. Interestingly, the earliest pinhead formation occurred in the control which indicates absence of external nutrient induce faster initiation of fruiting bodies. However, the neem cake supplementation resulted delayed pinhead initiation (43.3 days). Boiled paddy and boiled wheat supplements showed intermediate responses. Similar trends were reported by Singh *et al*. (2018), who observed that certain organic substrates may prolong vegetative growth, delaying reproductive development depending on their carbon-nitrogen ratio. Regarding the days to first harvest, the control again recorded the shortest duration of 54.5 days, suggesting that the absence of supplements might expedite early fruiting but at the cost of reduced yield and morphological development. The data on yield revealed that application of supplements significantly influence mushroom production per bag. The yield per bag varied from 21.5g to 28.8g. The highest yield was achieved with boiled paddy grain supplementation, highlighting its effectiveness in supporting mycelial growth and fruiting. Substrates supplemented with boiled wheat and wheat bran yielded 27.0g each, indicates their suitability as viable

Table 1: Effect of different supplements on yield potential of *G. lucidum*

Sl. No	Supplements	Days to spawn run (d)	Days to pin head initiation (d)	No. of fruiting bodies	Days to first harvest (d)	Yield (g)	BE (%)	Avg. weight (g)	Size of cap (mm)	Stipe length (mm)
1	Boiled Paddy	21.5	40.5	3.5	58.8	28.8	14.4	8.2	61.8	53.3
2	Boiled Wheat	21.8	40.8	3.8	57.3	27.0	13.5	7.1	56.3	53.5
3	Wheat Bran	23.0	38.3	3.0	56.8	27.0	13.5	9.0	55.3	58.3
4	Neem cake	17.5	43.3	2.5	58.8	21.5	10.8	8.6	52.8	53.5
5	Control	22.5	35.8	2.3	54.5	23.3	11.6	10.1	54.8	55.0
	SE(m)+	0.3	0.4	0.4	0.4	1.5	-	-	2.5	1.1
	CD (5%)	1.1	1.2	1.1	1.3	4.4	-	-	7.5	3.3

organic supplements. In contrast, the control and neem cake resulted lower yield, shows limited enhancement in productivity. These results are consistent with findings of Chang and Miles (2004), who emphasized that cereal-based substrates such as boiled grains provide essential nutrients for enhanced biomass production in mushrooms. Das and Mukherjee (2007), observed that application supplements significantly improved biological efficiency in oyster and milky mushrooms. For instance, supplementation with wheat bran and soybean meal has been shown to significantly improve biological efficiency and triterpenoid content in *G. lucidum* (Chang *et al*., 2021).

In terms of the number of mushrooms produced, the boiled wheat treatment outperformed all others with an average of 3.8 mushrooms per bag which was statistically at par with that of boiled paddy (3.5) and wheat bran (3.0). Lowest number of mushrooms, 2.3 was recorded from control bags followed by neem cake. Comparable patterns have been reported in similar trials by Royse *et al*. (2017), who noted that the type of supplement affects the balance between fruit body quantity and size.

The pileus diameter of the harvested mushrooms exhibited a range from 52.8 mm to 61.8 mm. The largest pileus size, measuring 61.8 mm, was observed in mushrooms grown in bags supplemented with boiled paddy, indicating a pronounced enhancement in cap development due to this specific treatment. This was statistically at par with other treatments such as boiled wheat (56.3 mm), wheat bran (55.3 mm) and the control (54.8 mm), suggested that supplements also contribute positively to cap expansion, although to a lesser extent. Conversely, the smallest pileus size (52.8 mm) was recorded in mushrooms with neem cake supplementation, highlighting a possible inhibitory effect of this particular additive on pileus development. Regarding stipe length, values ranged between 53.3 mm and 58.3 mm across the treatments. The maximum stipe elongation was observed in mushrooms grown in bags supplemented with wheat bran, recorded a length of 58.3 mm. This was followed by the control with a stipe length of 55.0 mm. Statistical analysis indicates that the stipe lengths resulting from all other supplements, with the exception of wheat bran, differ significantly from the control. This suggests that while wheat bran significantly enhanced stipe elongation, other supplements such as boiled paddy, boiled wheat, and neem cake unable to induce markedly superior effect in comparison to the untreated control.

These findings corroborate with previous research that has documented the positive impact of organic supplements particularly cereal based byproducts such as wheat bran and paddy on the morphological and yield characteristics of cultivated mushrooms (Gume *et al*., 2013). Supplements such as wheat bran are known to be rich in nutrients that promote vigorous mycelial growth and fruit body development (Karthikeyan *et al*., 2015). On the other hand, some supplements, like neem cake, may introduce inhibitory compounds or alter substrate composition in ways that are less conducive to optimal morphological development (Sohi *et al*., 2010).

In summary, the supplementation of mushroom cultivation substrates with organic amendments had a differential impact on morphological characteristics. Boiled paddy was most effective in increasing pileus size, while wheat bran significantly improved stipe length. Neem cake, on the other hand, appeared to have a less favourable influence on these parameters. These findings underline the importance of selecting appropriate supplements to optimize the morphological quality and marketability of cultivated mushrooms.

CONCLUSION

The present investigation underscores the critical role of substrate supplementation in optimizing the growth, yield and morphological attributes of *Ganoderma lucidum*. Among the evaluated treatments, boiled paddy supplementation demonstrated superior performance with evidence of the highest biological efficiency (14.4%), maximum yield per bag (28.8 g), and enhanced pileus development (61.8 mm), confirming its efficacy as a nutrient-rich additive. In summary, the application of organic supplements, particularly boiled grains such as paddy and wheat, substantially improved both the yield and morphological features of mushrooms. These treatments facilitated better substrate colonization, improved fruiting body development, and resulted in higher biological efficiency. While neem oil cake accelerated the spawn run but, its overall contribution to productivity and morphology was limited. The findings underscore the importance of supplement selection in optimizing mushroom cultivation outcomes and making them suitable for commercial and research based mushroom production systems.

Author statement

Barsharani Sethi: Conduct of experiment

Niranjan Chinara: Supervision of experiment and primary draft preparation

Pranaballava Sahani: Resource and maintenance of culture

Bikram Keshari Pani: Supervision of experiment

Declaration of competing interest

The authors declare that they have no competing interest and personal relationships that could have appeared the confluence the work reported in the paper.

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