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Research Article
Effect of Different Inorganic Additives on Spawn Run, Cropping Period and Yield Performance of Oyster Mushroom (*Pleurotus* Species)

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Abstract

Background and Objective: Due to the ability of *Pleurotus* species to convert crop residues into food protein, oyster mushrooms are least expensive commercial mushrooms and also easy to grow at various temperature ranges from 20-26°C with 75-85% relative humidity. With respect to these facts the present study was undertaken to assess the influence of different inorganic additives (0.075%) viz., salicylic acid, potassium di-hydrogen orthophosphate, magnesium sulphate, zinc sulphate, potassium chloride, ferrous sulphate and copper sulphate on the yield of two *Pleurotus* species i.e., *P. florida* and *P. flabellatus*. **Materials and Methods:** The experiment was carried out by using seven inorganic additives in wheat straw for cultivation of *Pleurotus* species (*P. florida* and *P. flabellatus*). Observations were recorded and biological efficiency was calculated for cropping period, days for spawn run, days of pin head initiation, number of loab, number of fruiting body, average weight of fruiting body (g/FB) and yield (g kg^{-1} dry substrate). **Results:** Data revealed that 0.075% concentration of different inorganic additives was significantly increased the yield compared to control. Maximum yield (g kg^{-1} dry substrate) was observed in magnesium sulphate 695.00 g followed by potassium di-hydrogen orthophosphate 660.00 g while minimum yield was found in zinc sulphate 505.00 g of *P. florida*. In case of *P. flabellatus* maximum yield observed in potassium di-hydrogen orthophosphate was 665.00 g followed by magnesium sulphate 625.00 g while minimum yield was found in zinc sulphate 517.00 g. **Conclusion:** It was concluded from the above findings that the magnesium sulphate and potassium di-hydrogen orthophosphate were proved as potential inorganic additives followed by zinc sulphate causing significant increase in spawn run, cropping period and yield of the two test species of oyster mushroom viz., *P. florida* and *P. flabellatus*. These chemical additives were also very cost effective and having no residual effect on the quality and taste of mushroom.

Key words: Oyster mushroom, spawn run, cropping period, inorganic additives, potassium di-hydrogen orthophosphate

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Mushrooms are the larger edible fungi which have been defined as "a macrofungus with distinctive fleshy and sub-fleshy fruiting bodies which can be either epigeous or hypogeous and large enough to be seen with naked eye and picked by hand"[1]. Among commercially cultivated mushrooms *Pleurotus* species range second after *Agaricus* commonly known as oyster mushroom or dhingri mushroom is extensively cultivated throughout the world and contributes about 27% of total world production[2]. Due to its ability to be grown on agricultural waste products, the cultivation of oyster mushroom is becoming popular throughout the world[3] and transforms the lignocellulosic biomass into nutritive food with high quality flavour. *Pleurotus* can be easily cultivated by simple method on number of base materials which do not need composting[4]. Along with the highest protein content, it has many other constituents like Vitamin B_1 and B_2 and low calorie levels. In addition, they are reported to be low in fat (2-3% by dry weight), a good source of essential amino acids and contain 5-9% fiber[5]. *Pleurotus* species have extensive enzyme systems capable of utilizing complex organic compounds that occur as agricultural wastes and industrial by-products[6]. *Pleurotus* spp. is also reported to have antiviral, anti-inflammatory, anticancer and immune modulation activities[7,8].

Pleurotus spp., has been reported to be capable of utilizing the largest variety of wastes with its fast mycelial growth and multilateral enzyme system capable of degrading nearly all types of wastes[9]. With respect to these facts the present study was carried out to evaluate the effect of various inorganic additives (0.075%) viz. salicylic acid, potassium di-hydrogen orthophosphate, magnesium sulphate, zinc sulphate, potassium chloride, ferrous sulphate and copper sulphate on the yield of two *Pleurotus* species i.e., *P. florida* and *P. flabellatus*.

MATERIALS AND METHODS

The experiments were conducted during the year 2015 in Mushroom Laboratory Department of Plant Pathology, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India which is situated on the western side of the Delhi-Dehradun high way NH-58 at a distance of 10.0 km away in the north of Meerut City. During the experiment the effect of seven chemical additives were evaluated for the growth and production of milky mushroom. All the chemicals were provided by the Laboratory of Agricultural Chemistry, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. Grading of all the chemicals were mentioned in Table 1.

Table 1: Grading of chemicals

Chemicals	Grading
Salicylic acid ($C_6H_4(OH)COOH$)	17 and 27% salicylic acid
Potassium di-hydrogen orthophosphate (KH_2PO_4)	52% P_2O_5 and 34% K_2O
Magnesium sulphate ($MgSo_4$)	10% Mg, 13% S
Zinc sulphate ($ZnSo_4$)	22-36% Zn
Potassium chloride (KCl)	60% K_2O
Ferrous sulphate ($FeSo_4$)	20% Fe
Copper sulphate ($CuSO_4$)	35% Cu

The experiment was carried out by using seven inorganic additives in wheat straw for cultivation of *Pleurotus* species (*P. florida* and *P. flabellatus*). The commonly used substrate for these experiments was bright, good quality wheat straw which was soaked in a water tank chemically treated with carbendazim 8 g and formalin 120 mL/100 L of water for overnight, so as to make it soft. The tank was covered with polythene sheet to prevent the evaporation of formalin. The sterilized substrate (dry weight bases) was dipped in water solution of salicylic acid (0.075%), potassium di-hydrogen orthophosphate (0.075%), magnesium sulphate (0.075%), zinc sulphate (0.075%), potassium chloride (0.075%), ferrous sulphate (0.075%) and copper sulphate (0.075%) for half an hour. Thereafter, straw was spread on cemented floor treated with 4% formalin for 2 h to drain out excess of water. Then ready to mix with spawn at 6% of the dry weight of substrate and after spawning this mixture was filled in polythene bags at the rate 1.0 kg/bag. The upper portion of the polythene bags was folded and stapled. Thereafter, 8-10 small holes were made on polythene bags, with the help of nail, to permit proper aeration during spawn run. These bags were placed in the mushroom crop room at relative humidity of 75-85% and temperature maintained $25\pm2°C$. After the full spawn run in the straw, it became compact mass which was also sticking to the polythene bag after 2-3 weeks. The polythene was removed from the mass of compact wheat straw (stack). Observations were recorded for cropping period, days for spawn run, days of pin head initiation, number of loab, number of fruiting body, average weight of fruiting body (g/FB) and yield (g kg^{-1} dry substrate).

Biological efficiency was calculated at 1 kg dry weight of wheat straw substrate per bag using the following formula:

$$\text{Biological efficiency} = \frac{\text{Fresh weight of fruit body}}{\text{Dry weight of substrate}} \times 100$$

Statistical analysis: Data with appropriate transformations were analyzed with the help of one way analysis of variance table wherever required. The F-value was tested and critical difference (CD) was calculated at 5% of significance under the programme of OPSTAT for comparing treatment means[10,11].

In order to compare the means of various entries, calculating the critical difference (CD) by the following formula:

$$\text{Critical difference (CD)} = \text{SE}\times\text{'t'}$$

where, SE is standard error of the difference of the treatment means to be compared and:

$$\text{SE} = (2\text{MS}_e/r)^{1/2}$$

RESULTS

It was evident from the data presented in Table 2 and 3 that different inorganic additives viz., salicylic acid (0.075%), potassium di-hydrogen orthophosphate (0.075%), magnesium sulphate (0.075%), zinc sulphate (0.075%), potassium chloride (0.075%), ferrous sulphate (0.075%) and copper sulphate (0.075%) significantly increased the yield. Maximum yield was observed in magnesium sulphate (695.00 g kg^{-1} dry substrate) followed by potassium di-hydrogen orthophosphate (660.00 g kg^{-1} dry substrate) while minimum yield was found in zinc sulphate (505.00 g kg^{-1} dry substrate) of *P. florida*. In case of *P. flabellatus* maximum yield was observed in potassium di-hydrogen orthophosphate (665.00 g kg^{-1} dry substrate) followed by magnesium sulphate (625.00 g kg^{-1} dry substrate) while minimum yield was found in zinc sulphate (517.00 g kg^{-1} dry substrate). Maximum number of fruiting body was found in magnesium sulphate (117.50) followed by potassium di- hydrogen orthophosphate (109.25) while minimum number of fruiting body was observed in zinc sulphate (50.75) of *P. florida.*

In case of *P. flabellatus* maximum number of fruiting body was observed in potassium di-hydrogen orthophosphate (148.25) followed by magnesium sulphate (131.50) while minimum number of fruiting body was observed in zinc sulphate (63.50). Maximum average weight of fruiting bodies (9.95 and 8.14 g) was observed in zinc sulphate for both species *P. florida* and *P. flabellatus*, respectively followed by control (8.99 and 6.77 g) in both species *P. florida* and *P. flabellatus*, respectively. Minimum weight of fruiting bodies (5.91 and 4.48 g) was found in magnesium sulphate and potassium di-hydrogen orthophosphate of *P. florida* and *P. flabellatus*, respectively. Period of spawn run 14 days was recorded in magnesium sulphate followed by 15 days in potassium di-hydrogen orthophosphate of *P. florida* and in case of *P. flabellatus* period of spawn run 15 days was recorded in potassium di-hydrogen orthophosphate and 16 days in magnesium sulphate which was minimum than zinc sulphate (20-20 days) in both species *P. florida* and *P. flabellatus*, respectively. Similarly result with the findings of Kumar *et al.*[12] reported that, minimum time was observed for spawn run in *P. sajor caju* (16.33 days), *P. fossulatus* (16.66 days) and *P. sapidus* (15.00 days) supplemented with ferrous sulphate followed by magnesium sulphate (18.00, 16.66 and 16.00 days), respectively. Maximum numbers of fruiting bodies were harvested from *P. sajor cajsu* (79.95) supplemented with $ZnSO_4$, *P. florida* (77.03) supplemented with salicylic acid, *P. flabellatus* (76.12) supplemented with $CuSO_4$, *P. fossulatus* (79.91) supplemented with $MnSO_4$ and *P. sapidus* (80.62) supplemented with K_2SO_4. Yield was harvested significantly well in all the five species, *P. sajor caju* (602.90 g kg^{-1}), *P. florida* (592.10 g kg^{-1}), *P. flabellatus* (566.55 g kg^{-1}), *P. fossulatus* (604.00 g kg^{-1}) and *P. sapidus* (612.12 g kg^{-1}) supplemented with ferrous sulphate.

Data also revealed that minimum days for cropping period was observed in magnesium sulphate (52.50 days) followed by potassium di-hydrogen orthophosphate (53.25 days) while maximum days for cropping period was found in zinc sulphate (62.00 days) of *P. florida*. In case of *P. flabellatus* minimum days for cropping period was observed in potassium di-hydrogen orthophosphate (53.50 days) followed by magnesium sulphate (56.50 days) while maximum days for cropping period was found control and zinc sulphate (63.25 and 64.00 days), respectively. The results were in line with the Bhadana[13] reported that maximum yield and number of sporophores of *P. florida* were observed in calcium sulphate which is significantly superior than the control followed with calcium carbonate which is significantly at par magnesium sulphate. Maximum yield and number of sporophores of *P. djamor* were observed in calcium sulphate which was significantly superior to the control followed with calcium carbonate which was significant at magnesium sulphate. Minimum yield obtained in *P. florida* on ferrous sulphate and followed in zinc sulphate and sporophore in ferrous sulphate. Minimum days for first harvesting was recorded in magnesium sulphate (23.00 days) followed by potassium di-hydrogen orthophosphate (24.75 days) while maximum days found in zinc sulphate (31.25 days) of *P. florida.* In case of *P. flabellatus* minimum days for first harvesting was recorded in potassium di-hydrogen orthophosphate (24.00 days) followed by magnesium sulphate (25.00 days) while maximum days for first harvesting was observed in control and zinc sulphate (30.00 and 30.00 days), respectively. In case of *P. florida* maximum number of loab, pileus length, pileus width and stipe length (30.50, 11.9, 9.1 and 4.8 cm) was recorded in magnesium sulphate while minimum number of loab, pileus

Table 2: Effect of different inorganic additives on spawn run, cropping period and yield of *Pleurotus florida*

Inorganic additives at 0.075% (dry weight bases)	DFSR	DFFH	DFCP	NOFB	NOL	Pileus length (cm)	Pileus width (cm)	Stipe length (cm)	Yield (g kg^{-1} dry substrate)	Average weight of FB (g/FB)	Biological efficiency (%)
Salicylic acid	17.00	27.00	55.75	92.75	25.50	9.80	7.60	4.10	595.00	6.41	59.50
Potassium di-hydrogen orthophosphate	15.00	24.75	53.25	109.25	28.25	11.40	8.20	4.50	660.00	6.04	66.00
Magnesium sulphate	14.00	23.00	52.50	117.50	30.50	11.90	9.10	4.80	695.00	5.91	69.50
Zinc sulphate	20.00	31.25	62.00	50.75	20.50	7.40	6.00	3.60	505.00	9.95	50.50
Potassium chloride	16.00	25.50	54.50	102.00	27.00	10.10	7.80	4.40	632.00	6.19	63.20
Ferrous sulphate	19.00	29.25	58.50	68.75	22.00	8.40	7.00	4.00	547.00	7.95	54.70
Copper sulphate	18.00	28.00	57.00	81.25	24.75	8.70	7.20	4.00	567.00	6.97	56.70
Control (wheat straw without additives)	19.00	30.00	60.25	59.50	21.25	7.80	6.60	3.80	535.00	8.99	53.50
CD at 5%	1.19	1.31	1.77	1.79	1.44	0.14	0.14	0.12	18.53		

DFSR: Days for spawn run, DFFH: Days for first harvesting, DFCP: Days for cropping period, NOFB: Number of fruiting body, NOL: Number of loab

Table 3: Effect of different inorganic additives on spawn run, cropping period and yield of *Pleurotus flabellatus*

Inorganic additives at 0.075% (dry weight bases)	DFSR	DFFH	DFCP	NOFB	NOL	Pileus length (cm)	Pileus width (cm)	Stipe length (cm)	Yield (g kg^{-1} dry substrate)	Average weight of FB (g/FB)	Biological efficiency (%)
Salicylic acid	17.00	27.00	58.50	106.00	27.00	7.50	4.75	3.10	595.00	5.61	59.50
Potassium di-hydrogen orthophosphate	15.00	24.00	53.50	148.25	33.50	7.95	5.95	3.35	665.00	4.48	66.50
Magnesium sulphate	16.00	25.00	56.50	131.50	30.50	7.85	5.70	3.25	625.00	4.75	62.50
Zinc sulphate	20.00	30.00	64.00	63.50	20.25	5.65	4.10	2.80	517.50	8.14	51.75
Potassium chloride	18.00	28.00	60.00	96.50	26.25	6.80	4.70	2.90	567.50	5.88	56.75
Ferrous sulphate	19.00	29.00	62.50	84.00	24.00	6.15	4.65	2.90	545.00	6.48	54.50
Copper sulphate	17.00	26.00	58.00	120.25	28.50	7.60	5.10	3.20	605.00	5.03	60.50
Control (wheat straw without additives)	20.00	30.00	63.25	77.50	22.75	5.80	4.55	3.00	525.00	6.77	52.50
CD at 5%	1.19	1.99	1.86	2.27	1.87	0.24	0.32	0.22	21.08		

DFSR: Days for spawn run, DFFH: Days for first harvesting, DFCP: Days for cropping period, NOFB: Number of fruiting body, NOL: Number of loab length, pileus width and stipe length (20.50, 7.4, 6 and 3.6 cm) was recorded in zinc sulphate, while in case of *P. flabellatus* maximum number of loab, pileus length, pileus width and stipe length (33.50, 7.95, 5.95 and 3.35 cm) was recorded in potassium di-hydrogen orthophosphate while minimum number of loab, pileus length, pileus width and stipe length (20.25, 5.65, 4.10 and 2.80 cm) was recorded in zinc sulphate.

DISCUSSION

Maximum yield of both the species of *Pleurotus* were observed in magnesium sulphate and in potassium di-hydrogen orthophosphate while minimum yield was found in zinc sulphate and the results were almost in accordance with the findings of various scientists[14,15], who studied the growth requirements of *Pleurotus tuber-regium*[16]. The most suitable culture medium for the growth of *P. ostreatus* consisted of various nutrient sources, including magnesium sulphate (0.1%) was revealed by many experiments[17]. Maximum radial growth was observed in ferrous sulphate and copper sulphate supplemented medium in *P. sajor caju*, *P. florida*, *P. flabellatus*, *P. fossulatus* and *P. sapidus* after 6th day [12].

It was also noticed earlier, that maximum yield of *P. sajor caju* was observed in magnesium sulphate followed by ferrous sulphate[18]. The minimum reported time for spawn run in *P. sajor caju* (16 days), *P. fossulatus* (17 days) and *P. sapidus* (15 day) supplemented with ferrous sulphate followed by magnesium sulphate (18, 17 and 16 days), respectively[12]. It was also found by various scientists that supplementation with nitrogen can increase crop productivity, but to a certain level, as high nitrogen values could inhibit fruiting of mushrooms *Pleurotus* sp., "Florida"[19]. It was also accounted by many scientists that the yield and the quality of oyster mushroom depend on the chemical and nutritional content of substrates[20-22]. Kumar *et al.*[12] was observed that maximum average weight per fruit body was recorded significantly well in magnesium sulphate and ferrous sulphate supplemented treatment from most of the tested oyster species, respectively. The significant effect of various source of carbon (brown sugar, fructose, lactose, glucose, sucrose, starch and maltose), nitrogen (wheat bran, yeast cream, beef cream, peptone, $(NH_4)_2SO_4$, NH_4Cl and $(NH_4)_2CO_3$) and inorganic salts K_2SO_4, $MgSO_4$, $CaSO_4$, $MnSO_4$ and $FeSO_4$ on the mycelial growth of *P. ostreatus* was also studied previously. The mycelial growth was more pronounced with $MgSO_4$ as the inorganic salts source[15].

CONCLUSION

The addition of chemical additives to substrate significantly increased the mycelia extension, density and yield of oyster mushroom. In view of the presented results, it can be concluded that the yield, yield contributing characteristics and biological efficiency in the supplemented sets increased as compared to the unsupplemented control. So, accordingly magnesium sulphate and potassium di-hydrogen orthophosphate were proved as potential inorganic additives followed by zinc sulphate causing significant increase in spawn run, cropping period and yield of the two test species of oyster mushroom viz., *P. florida* and *P. flabellatus*. So, addition of these inorganic additives in the substrate will result significant increment in the yield of oyster mushroom which was the salient finding of the present study because these additives were cost effective and having no any residual effect on the quality and taste of mushroom.

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