Effect of environmental factors on the yield of selected mushroom species growing in two different agro ecological zones of Pakistan

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Abstract Mushrooms are a rich source of protein and vitamins as human food. In view of the growing importance of mushroom in Pakistan, a research study was initiated with the objective to examine the suitability of Oyster mushroom cultivation and to compare the growth and yield of Oyster mushroom in two different areas (Peshawar and Swat, North-West region of Pakistan) with different ecological conditions. Spawn running time, number of crops, stalk height, stalk diameter, cap size, fresh weight, number of production days, and the interval in days between the time of bag opening and the time of starting fruiting bodies formation were among the important parameters investigated in the current study. Stalk height, stalk diameter, cap size and fresh weight of mushrooms were found higher in Peshawar region as compared to those growing in Swat region. On the other side, the spawn running time, formation of fruiting bodies and the number of productions were higher in Swat region as compared to the mushroom under study in Peshawar region. Mild winter temperatures of Peshawar region, and low summer temperatures in Swat, were found most suitable for growth and yield of Pleurotus ostreatus.

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1. Introduction

The study area is located in the north west of Khyber Pakhtoon Khwa (KPK), lies between 34°34' to 35°07'N latitudes and 72°36' to 73°35'E longitudes in Pakistan (Map 1). The rapid population growth coupled with poverty and unabated natural and man made disaster in Northern parts of Pakistan including the study area raising questions that how the poor cope with the special challenges in the form of earn their livelihoods access to diets and food especially for the most vulnerable groups. Limited Livelihood opportunities followed by both the natural and man made disaster are the...
major constraint beyond the food insecurity (Sher et al., 2005). Food availability and household food security in mountain areas are closely related to agriculture and crisis in area. Moreover, the traditional ways of farming and livestock rearing have further reduce the income opportunity of the local, as a result about 60% of the population have very little purchasing power and most of the population especially children and women are suffering from malnutrition diseases (Sher and Hussain, 2009). The present study was therefore, undertaken with the over goal to demonstrate the mushroom cultivation technology to the farmers community with the aim to get protein and vitamins richest food and combat the threat of food insecurity and malnutrition diseases.

Fungi have been at work since life began on earth. Mushrooms are freshly spore bearing fungi and their edible nature is the main attraction to man as a source of food. In several cases, wild varieties of edible mushrooms were found less tasty and unpalatable. However, mushrooms are known to have a broad range of uses both as food and medicine (Chang and Miles, 1987). The complex and varying morphology, chemical composition, and biological activity of mushrooms attracted the attention of scientists. Among edible mushrooms, *Pleurotus pulmonarius* and *Pleurotus ostreatus*, exhibited strong anti-inflammatory and immunomodulatory properties due to their chemical composition (Lavi et al., 2010; Selegean et al., 2009), while *Morchella elata* showed highly potent radical scavenging activity (Kalvoncu et al., 2010). Grifolin derivatives isolated from *Boletus pseudocalopus* (Basidiomycetes) possessed anticancer and moderate radical scavenging activities (Song et al., 2009). Many mushrooms such as *Pleurotus ostreatus* and *M. giganteus*, were found to be active against bacteria and yeast (Kalvoncu et al., 2010; Ahmad et al., 2005), while *Galerina autumnalis*, *G. marginatus*, *G. venenate*, *Lepiota josserandii*, *L. helveola*, *L. castanea*, and *Amanita smithiana* were found toxic and contained dangerous toxins (West et al., 2009; Danel et al., 2001).

The toxicity of *Cortinarius speciosissimus* was attributed to its poisonous chemical constituent orellanine which caused irreversible kidney damage (Münstermann et al., 2002). Phallolysin isolated from *A. phalloides* was found to be a haemolytic toxin (Erguven et al., 2007; Seeger, 1975), while *A. phalloides* was reported life threatening poison because of causing acute multiorgan failure (Hydzik et al., 2008). In an earlier study conducted in Swat (Pakistan), amatoxin was established to be the main toxic compound of mushrooms from Swat region (Pakistan) which was responsible for gastrointestinal symptoms as well as hepatic and renal failure (Chandra and Perkaysth, 1977).
A total of 56 species of mushroom have been reported from Pakistan where most of the species (44 species) were habitant of North-West region of Pakistan and Kashmir region (Ahmad, 1941–48). It is well understood worldwide, that mushrooms are an important source of food. The nutritional values Oyster mushroom were found comparable or higher than dates, potatoes, banana, carrots, and various vegetables (Chang and Miles, 1987; Chang, 1980). Mushroom proteins contained all essential amino acid. In addition, fats, phosphorus, sodium, potassium, and iron contents were also predictable (Crisan et al., 1978). For essence, the comparison of protein contents of some edible mushrooms with some other plants is presented in Table 1.

The taxonomy and distribution of various fungal groups and edible mushroom were described earlier (Ahmad, 1941–48) while ecology and economic value of Morchella species and their conservation and cultivation in the northern hilly areas, southern coastal areas and central plains of Pakistan was described more recently (Sher, 2006). The cultivation of Oyster mushroom (P. ostreatus) on different substrates was found to influence its growth. Thus leading to make mushroom cultivation a rewarding agribusiness in Pakistan, that might improve the economic status of farmers (Flores, 2006; Shah et al., 2004; Alam and Raza, 2001).

Awareness about mushroom has significantly increased in Pakistan during the past two decades. It has been taken up as a part of household agriculture while some farmers are growing mushroom on commercial basis as well. The National Logistic Cell in Pakistan has already taken the initiative to grow mushrooms in Islamabad and Swat areas and reached an annual production capacity of 48 tons. About 80% of which is meant for export to earn foreign exchange (Latif an annual production capacity of 48 tons. About 80% of which is meant for export to earn foreign exchange (Latif 1987). Mushroom proteins contained all essential amino acid. In addition, fats, phosphorus, sodium, potassium, and iron contents were also predictable (Crisan et al., 1978). For essence, the comparison of protein contents of some edible mushrooms with some other plants is presented in Table 1.

The experiment was conducted in two locations with different ecological conditions of North-Western region of Pakistan and Kashmir region (KPK) Pakistan. After sterilization with boiling water (for 24 h), the wheat straw was inoculated with spawn in both locations. The spawn was placed in a small cavity of appropriate size on the upper side of each compact. All bags after inoculation were then closed tightly again with rubber bands and kept in a dark place (under real room conditions) in both locations. A trial experiment was conducted prior to the detailed study.

In Peshawar, all bags were opened on December 30, 2004 (i.e., 45 days after inoculation) while in Swat, bags opening was carried out on February 10, 2005 (i.e., 83 days after inoculation) in order to facilitate formation of the fruiting bodies. No watering was required during spawn running period because the wheat straw compact was tightly covered in polyethylene bags which helped in maintaining sufficient moisture level during this experimental period. However, after opening of bags, the loss of moisture through evaporation was compensated by moistening the compact twice a day, i.e., morning and then in the afternoon. Based on the fact that temperature, humidity, and fresh air are the basic requirements for proper growth of mycelium, these factors were regularly monitored during the whole investigation period in both experimental locations. The maximum and minimum temperatures and humidity were regularly recorded on daily basis during the trial duration.

All the mean values for seven parameters: spawn running time (days), number of crops/bag, stalk height (cm), stalk diameter (mm), cap size (mm), fresh weight (gm), number of

| Mushroom/food | Nutrients (% fresh weight basis) | Mineral/vitamin (Mg/100 fresh weight basis) |
|---------------|---------------------------------|------------------------------------------|
|               | Water | Protein | Fat | Carbohydrate | K | P | Ca | Fe | Thiamine | Riboflavin |
| P. ostreatus  | 90.0  | 27.4    | 0.6 | –            | 375 | 135 | 3.5 | 1.5 | 0.48      | 0.47 |
| Potato        | 77.7  | 1.4     | 0.1 | 19.1        | 260 | 56  | 11.0 | 0.7 | 0.10      | 0.04 |
| Spinach       | 90.8  | 3.1     | 0.6 | 3.6         | 324 | 33  | 124.0 | 2.0 | 0.08      | 0.20 |
| Cow milk      | 87.0  | 3.5     | 3.9 | 4.9         | 140 | 93  | 118.0 | 6.1 | 0.04      | 0.17 |
| Meat          | 74.2  | 21.4    | 3.6 | 0.0         | 300 | 250 | 8.3  | 15.0 | 0.18      | 0.27 |
| Hen’s egg     | 73.3  | 13.3    | 13.3 | 2.0       | 244 | 244 | 68.0 | 2.5  | 0.10      | 0.29 |
| Banana        | 30.8  | 1.1     | 0.5 | 15.7        | 14.01 | 10.4 | 0.1  | 0.4  | 7.0       | 8.09 |
| Carrot        | 45.2  | 0.6     | 0.1 | 3.4         | 13.01 | 22.0 | 7.04 | 91.9 | 1.0       | 4.8  |

The experiment was conducted in two locations with different ecological conditions viz: Khwazakhela area of district Swat with an altitude of less than 200 m.a.s.l. representing sub-tropical zone, in North-Western Khayber Phustunkhua region of Pakistan. The study was conducted during winter and summer seasons of years: 2004 and 2005.

In each case, for proper mushroom growth in the defined regions, the substrate wheat straw was purchased from a local market. It served as a compost, and substrate on which the selected mushroom species are known to grow up with good performance (Sher, 2006). On November 15, 2004, 96 kg of wheat straw was thrashed in to small pieces and soaked in boiling water for 25 min. In this step, the risk of substrate contamination used was eliminated. The excess water was then carefully drained out in such a way that the compact contained about 50% moisture. In each case, one set each of 24 polyethylene bags (192 sq. inch size), was filled with 2 kg of the compost material. Each bag was slightly pressed down and tightly rapped with a rubber band.

For the current study in the defined areas, ready made standard spawn was obtained in polyethylene bags from the “Agriculture Research Station Mingora Swat Khyber Puktoonkhwa (KPK) Pakistan”. After sterilization with boiling water (for 24 h), the wheat straw was inoculated with spawn in both locations. The spawn was placed in a small cavity of appropriate size on the upper side of each compact. All bags after inoculation were then closed tightly again with rubber bands and kept in a dark place (under real room conditions) in both locations. A trial experiment was conducted prior to the detailed study.

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All the mean values for seven parameters: spawn running time (days), number of crops/bag, stalk height (cm), stalk diameter (mm), cap size (mm), fresh weight (gm), number of
production days, and the interval in days between the time of
bag opening and the time of starting fruiting bodies formation,
were recorded according to standard protocol defined earlier
(Sher, 2006).

3. Results

Mean maximum, mean minimum, and relative humidity per-
sisting at the two experimental sites, Peshawar and Swat, during
the trial period (November, 2004 to May, 2005) are
presented in Table 2. Maximum and minimum temperatures
and relative humidity at the two sites varied greatly. Mean
maximum and mean minimum temperatures and the relative
humidity at Peshawar remained consistently higher than that
at Swat in almost all the 7 months of testing period. The differ-
ences in minimum temperatures between the two locations
were much greater than their corresponding maximum tempera-
tures for each of the 7 months (KPK, 2003). The results of
mean values for seven standard parameters are presented in
Table 3 for both locations (Swat and Peshawar).

Both locations were found different from one another for
all seven parameters except for the number of crops/bag where
no appreciable difference between these locations was ob-
erved, i.e., 6.5 crops/bag for Peshawar vs. 6.7 crops/bag for
Swat (Table 3). Mean comparison of the two locations indicated
that four of the seven parameters, namely, stalk height,
stalk diameter, cap size and fresh weight had greater values
for these parameters at Peshawar as compared to those found
in Swat.

In contrast, the spawn running time, i.e., mycelium growth
took much longer time (83 days) at Swat as compared to that
at Peshawar (45 days). Formation of fruiting bodies (upcom-
ing crop) at Swat was found later (7 days after opening of
bags) than that at Peshawar (4 days after opening of bags).
Similarly, the production period of 70 days at Swat appeared
to have been much longer than that of Peshawar with 49 days
for this parameter.

4. Discussion

Various mushrooms are known to be sensitive to the climatic
conditions (van Peer et al., 2009; AMGA, 2004). In cultural
conditions high temperature tolerance of vegetative mycelia
of *Lentinula edodes* strains were investigated. Mycelium of long
culture age (70 days) showed significantly higher temperature
tolerance as compared to mycelium of shorter culture ages of
14 and 30 days (Mahmud and Ohmasa, 2008). During the
present investigations, differences for the mean maximum and
mean minimum temperatures and the relative humidity
observed between the two locations are not surprising since
these locations greatly differ in their altitudes and latitudes.
The experimental site at Swat is located in the north of
KPK, Pakistan with an altitude of 1000 m above sea level
(m.a.s.l) while Peshawar is situated in the plains with an alti-
itude of less than 200 m.a.s.l. Peshawar of KPK has milder win-
ter, in the months of November to May of the year as
compared to lower temperatures and lower relative humidity
at Swat during the same months of the year.

The major ecological factors that affect stalk height, stalk
diameter and cap size in mushroom are temperature, humid-
ity, fresh air, and compact material (AMGA, 2004; Stamets,
1993; Schmidt, 1983). The lowest temperature and drought
condition reduced the stalk height and cap size of mushroom
(Haugen, 1998). The mild winter temperatures of Peshawar
were probably more conducive for the growth of *P. ostreatus*
compared to lower temperatures at Swat. Our results are in

### Table 2
Mean monthly temperature (°C) and relative humidity at Swat and Peshawar from November, 2004 to May, 2005.

| S. no. | Month  | Swat       | Peshawar   |
|--------|--------|------------|------------|
|        |        | Temp.       | Temp.       | Relative | Temp.       | Temp.       | Relative |
|        |        | Mini.       | Max.        | Humidity | Mini.       | Max.        | Humidity |
| 1      | November | 6.93       | 18.23       | 68.23    | 9.84       | 22.23       | 70.54    |
| 2      | December | 3.65       | 15.41       | 67.21    | 6.41       | 18.94       | 69.31    |
| 3      | January  | 4.51       | 16.73       | 65.12    | 8.50       | 20.31       | 67.21    |
| 4      | February | 5.63       | 20.23       | 62.33    | 11.66      | 23.67       | 66.12    |
| 5      | March    | 8.63       | 22.59       | 70.33    | 15.73      | 24.90       | 72.23    |
| 6      | April    | 13.81      | 25.92       | 66.21    | 20.93      | 27.21       | 69.81    |
| 7      | May      | 18.64      | 27.21       | 67.81    | 23.93      | 30.31       | 70.92    |

### Table 3
Mean values for spawn running time, number of crops/bag, stalk height, stalk diameter, cap size, fresh weight, number of productions and fruiting bodies formation observed at Peshawar and Swat during 2005.

| S. no. | Parameter                        | Location |
|--------|----------------------------------|----------|
|        |                                  | Peshawar | Swat   |
| 1      | Spawn running time (day)         | 45       | 83     |
| 2      | Number of crops/bag              | 6.5      | 6.7    |
| 3      | Stalk height (cm)                | 5.0      | 3.9    |
| 4      | Stalk diameter (cm)              | 16.2     | 13.9   |
| 5      | Cap size (mm)                    | 11.01    | 9.5    |
| 6      | Fresh weight (gm)                | 1591     | 1388   |
| 7      | Number of production (day)       | 49       | 70     |
| 8      | Fruiting bodies formation (day)  | 4        | 7      |
agreement with the earlier reports where environmental factors were demonstrated to affect the growth of mushroom (Alexander et al., 2002). However, in the present study, the non-existence of any appreciable difference between number of crops per bag in Peshawar and Swat was contradictory to the earlier findings where temperature was reported to affect the emergence percentage of mushroom cultivars (Block et al., 1959).

The differences in the spawn running time (Mycelium growth) in the two specified locations indicated a strong positive relationship between temperature and the growth of mycelium, i.e., the higher the temperature, the faster the growth of the mycelium resulting in to shorter spawn running time. The results of our current experiment are substantiated by the results of earlier reports recommending optimum temperature for mycelium growth inside the spawn development room (Chandra and Perkayst, 1977). Furthermore, similar results were also reported by other workers which added support to our observations (Chang and Miles, 2004). Lower temperatures and relative humidity could be the plausible explanation for the longer time required for the formation of fruiting bodies after opening of bags under Swat conditions as compared to those of Peshawar environment. It is worth mentioning that, both temperature and relative humidity were lower at Swat as compared to Peshawar. Our results are well supported by an earlier report defining both temperature and humidity playing an important role in the spawn development (Bano and Srivastava, 1974).

In the present study, the production period of mushroom under Swat condition was found to be considerably longer than that of Peshawar. Such differences could be attributed to spring season optimum temperatures of Swat as more favorable for the longer period of crop production for Oyster species compared to hot season temperatures at Peshawar during the month of May. These results are in conformity with those reported earlier, thus verifying that certain variations in season seriously affect the number, weight and crop production period of mushroom (Das et al., 1987, 1991). In addition, further it was reported that favorable temperature and moisture conditions enhanced the production of fruiting bodies of mushroom (Das et al., 2011).

Based on the results of current study, it was concluded that the environmental conditions of Peshawar during winter months were more suitable for cultivation of Oyster mushroom as compared to those at Swat. Furthermore, the current experiment further supported the fact that both growth and yield of Oyster mushroom, under ecological conditions in the plains of Peshawar, were higher than at high altitudes in the valley of Swat.

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