

MODELLING THE EFFECTS OF TEMPERATURE AND LIGHT INTENSITY ON THE DEVELOPMENT AND YIELD OF DIFFERENT *PLEUROTUS* SPECIES

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Abstract

This study was conducted to determine the effects of temperature (T) and light intensity (L) on spawn run period (SRP), days to first harvest (DFH) and mushroom yield (MY) of different *Pleurotus* species grown under an unheated high plastic tunnel in the Black Sea region of Turkey during the period of autumn and winter seasons. In this study, three disinfection methods (D) (autoclave, formaldehyde 1% and 3%), three substrate weights (1, 2 and 3 kg) and three *Pleurotus* species (*P. ostreatus*, *P. sajor-caju*, *P. sapidus*) were used. In this study, regression models were developed to estimate of spawn run period ($SRP = 466.14 - 40.56 \times T + 0.93 \times T^2$), days to first harvest ($DFH = 286\,610.7 - 46\,643.4 \times T - 40\,868.5 \times D + 1\,897.835 \times T^2 + 6657.039 \times T \times D - 270.99 \times T^2 \times D$) and mushroom yield ($MY = 137.223 - 23.221 \times D - 0.425 \times T^2 + 0.0424 \times L \times D - 0.0608 \times L \times S + 0.048 \times T^2 \times D + 11.854 \times S$). Spawn run period, days to first harvest and mushroom yield were able to estimate with probability of 98%, 81% and 82%, respectively, using developed regression models.

Key words: *Pleurotus* species, temperature, light intensity, model, spawn run period, days to first harvest, mushroom yield

INTRODUCTION

Pleurotus species are regarded as one of the commercially important edible mushrooms throughout the world. It consists of a number of different species including *Pleurotus ostreatus*, *P. sajor-caju*, *P. cystidiosus*, *P. cornucopiae*, *P. pulmonarius*, *P. tuber-regium*, *P. sapidus*, *P. citrinopileatus* and *P. flabellatus*, which have been cultivated in temperate and subtropical regions of the world. The *Pleurotus* species has many advantages as a cultivated mushroom: rapid mycelia growth, high ability for saprophytic colonization, simple and inexpensive cultivation techniques and several kinds of species, which are available for cultivation under different climatic conditions. Recently, commercial value of *Pleurotus* species significantly increased due to their advantages (Zervakis and Balis, 1996). *Pleurotus* species widely prevail in the macro mushroom flora of Turkey. In Turkey, wild *Pleurotus* species are traditionally collected from the forest during the rainy season from March to September. Nowadays, their artificial and commercial cultivation are not common in Turkey.

The optimal temperatures for the development of fruiting bodies can vary among the species. Some previous studies subjected to the effects of temperature on the spawn run for *Pleurotus* species were also carried out (Bano and Rajarathram, 1982; Koçyiğit and Günay, 1984; Zervakis *et al.*, 2001). The requirements for light are different for the various stages of growth. Many study results showed that light prevented spawn run, enhanced primordia formation and it was necessary for the mushroom formation in *Pleurotus* species

(Okwujiako, 2001; Datta and Chakraborty, 2002; Marino *et al.*, 2003). However, *Pleurotus* species can grow to benefit from natural light in greenhouses and high plastic tunnels throughout a year.

Recently, many studies have been carried out in order to describe plant growth using mathematical models. The models on plant growth and development are important to predict yield and duration of the plant development stages. They are also necessary for mushroom growing such as scheduling production number in a year or for a given period needs relationships among developmental components, temperature and light intensity. Although, there have been attempts to determine the effect of temperature and light intensity on the development of *Pleurotus* species, no work on producing regression models of temperature, light intensity and mushroom developmental components was performed.

The objective of this study was to determine the effects of temperature and light intensity on spawn run period, days to first harvest and mushroom yield of *Pleurotus* species grown under an unheated high plastic tunnel and also to produce regression models between developmental components of *Pleurotus* species and temperature and light intensity.

MATERIALS AND METHODS

The study was carried out under the unheated high plastic tunnel at Faculty of Agriculture of Ondokuz Mayıs University, Samsun, Turkey, during October 2001–April 2002. Mixture of wheat straw (94%), wheat bran (5%) and gypsum (1%) was used as substrate. In

this study, the effects of three disinfection methods (autoclave, formaldehyde 1% and 3%), three substrate weights (1, 2 and 3 kg) and three *Pleurotus* species (*P. ostreatus*, *P. sajor-caju*, *P. sapidus*) on spawn run period, days to first harvest and mushroom yield were investigated. Spawns of *Pleurotus ostreatus* (Jacq:Fr.) Kummer and *P. sajor-caju* (Fr.) Sing., and *P. sapidus* (Schulz. apud Kalchbr.) were provided from Agromycel company in Denizli and the Biology Department of Kirikkale University in Turkey, respectively.

Straw material used as cultivation medium was weighed in the predetermined ratios, added 5% wheat bran and homogenized. Prepared mixture was wetted with water for 1–2 days until its moisture content reached up to 70%. After wetting, gypsum was added into the mixture. In sterilization method, prepared substrates were filled into heat-resistant gelatin bags (15 × 30 cm), containing 1, 2 and 3 kg of substrates and sterilized by an autoclave at 121°C for 1.5 h. In disinfection method, prepared formaldehyde (v/v) as 1% and 3% were applied homogeneously to substrate. Substrate was covered with a plastic sheet for two days. Then, growing media was opened and ventilated for two days. Disinfected substrates were filled into the polyethylene bags, with 1, 2 and 3 kg wet substrate per bag. Afterwards, substrates were inoculated with spawn (4% of the wet mass of the substrate). The inoculated bags were re-plugged and transferred to the high plastic tunnel and covered with a black plastic sheet until the end of the spawn growth period. After the mycelium colonization was completed, the bags were exposed to daylight to promote mushroom formation in the plastic tunnel. The tops of the bags were cutted after primordia appearance. Substrates were moistened with a pulverizator and the plastic tunnel was ventilated throughout the harvest period. Spawn run period (day), days to first mushroom harvest (day) and total mushroom yield (kg/100 kg substrate) were determined. Spawn run period expressed as days from the mycelium inoculation to colonization completed. Days to first harvest determined as days from the mycelium inoculation to first harvest. Mushroom yields were obtained from three or four flushes in a harvest period of 125 days.

The experiment was carried out in Completely Randomized Design with 6 replications. Multi-regression analyses were carried out to determine relationships between developmental components of *Pleurotus* species and temperature and light intensity. To determine the most suitable equation, multiple regression analysis for all the parameters used in the When DFH was plotted against temperature (T) and disinfection method (D), Equation 2 was obtained. As a result of the multi-regression analysis, it was found that 81% of the variation regarding to the first mushroom harvest was explained by the selected independent variables, namely temperature and disinfection methods (Figure 4).

study was continued until the highest regression coefficient (r^2) with the least sum of squares for the residuals were obtained (Uzun, 1996).

RESULTS AND DISCUSSION

Results of multi-regression analysis applied to the data obtained from the present study showed that there was a negative linear relationship between spawn run period (SRP) and temperature (T) ($r^2 = 0.96$). As seen in Figure 1, spawn run period declined linearly with increasing temperatures.

The relationship between spawn run period and temperature was determined and Equation 1 was obtained. It was found that 98% of the variation in SRP was explained by temperature. The overall relationship between actual and predicted SRP by Equation 1 was given in Figure 2.

$$\begin{aligned} \text{SRP} &= 466.147 - 40.56 \times T + 0.93 \times T^2 \\ \text{SE} &= 19.66^{***}, 2.68^{***}, 0.90^{***} \\ r^2 &= 0.98 \end{aligned} \quad (1)$$

Bano and Rajarathram (1982) reported that SRP in *P. sajor-caju* continued for 12–14 days at 22–36°C, 18–20 days at 20–26°C and 22–24 days at 15–25°C. Several studies indicated that increasing temperatures up to 30°C shortened spawn run period in *Pleurotus* species (Oei, 1991). In another research, it was found that spawn run period in four different *P. sajor-caju* strain were 17–27 days at 27°C (Battick *et al.*, 1990). Bugarski *et al.* (1997) determined that the most suitable SRP of *P. ostreatus* NS 77 strain occurred at 35°C. However, spawn run rate of *P. ostreatus* was higher at 30°C than those of at both 20 and 25°C with enhance of spawn run in the absence of light (Furlan *et al.*, 1997). In addition, Zervakis *et al.* (2001) compared the influence of different temperatures on mycelial growth of *P. ostreatus* and the highest mycelium extension rates were determined at 30°C. Since the present study was carried out in an unheated high plastic tunnel during late autumn and winter period, temperatures did not exceed 20°C and spawn run period was prolonged accordingly. Growers of *Pleurotus* species aiming to use this period for mushroom production want to know spawn run period at lower temperate for scheduling.

Days to first harvest (DFH) declined linearly with increasing temperatures (Figure 3). The relationship between DFH and temperature was examined, the regression coefficient was found to be 0.70 (Figure 3).

$$\begin{aligned} \text{DFH} &= 286\,610.7 - 46\,643.4 \times T - 40\,868.5 \times D + \\ &+ 1\,897.835 \times T^2 + 6\,657.039 \times T \times D - 270.99 \times T^2 \times D \end{aligned} \quad (2)$$

$$\begin{aligned} \text{SE} &= 53\,138.07^{***}, 8\,702.10^{***}, 7\,589.88^{***}, \\ &356.23^{***}, 1\,242.97^{***}, 50.88^{***} \\ r^2 &= 0.81 \end{aligned}$$

Figure 1: The relationship between spawn run period and temperature

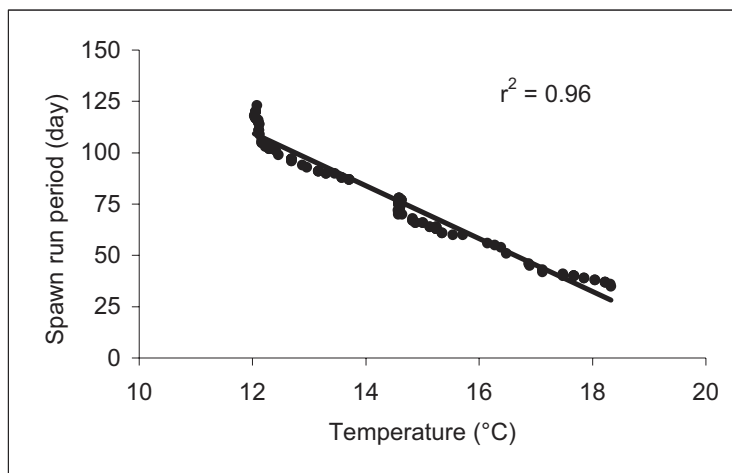


Figure 2: The overall relationship between actual spawn run periods and predicted spawn run periods

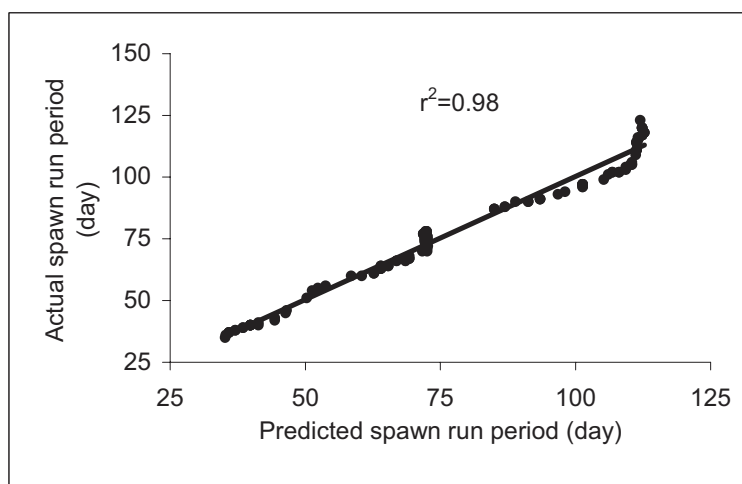


Figure 3: The relationship between days to first harvest and temperature

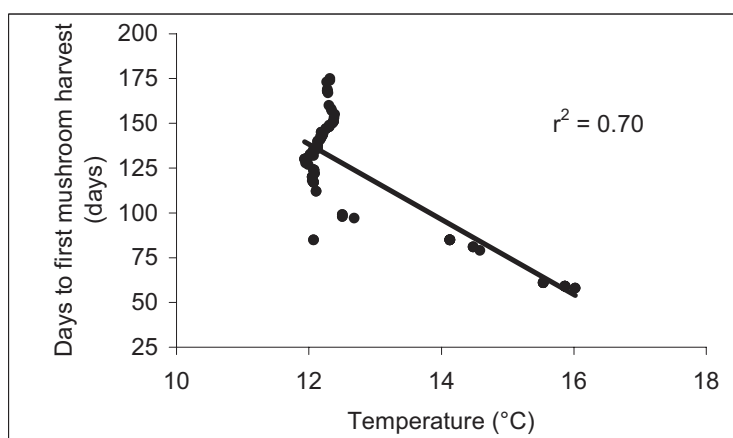


Figure 4: The overall relationship between actual days to first harvest and predicted days to first harvest

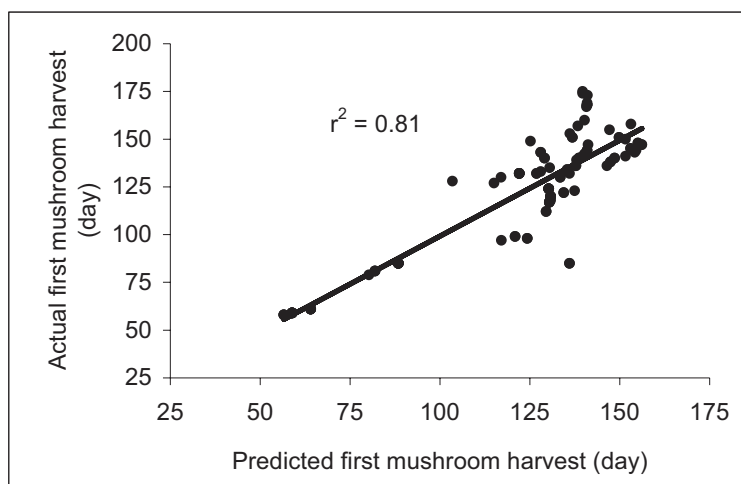
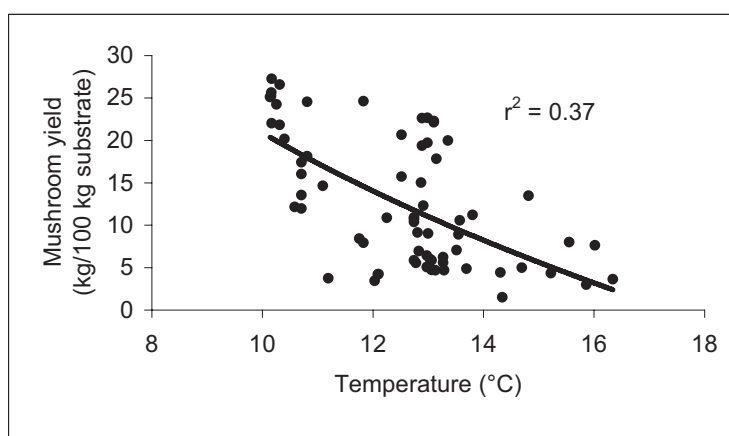


Figure 5: The relationship between mushroom yield and temperature



Oei (1991) reported that temperatures for mushroom formation varied from 10 to 20°C for *P. ostreatus*, from 18 to 30°C for *P. sajor caju* and from 15 to 25°C for *P. sapidus*. It was also indicated that *P. ostreatus*, which is called as *Pleurotus* for winter months, grown well at temperatures from 12 to 20°C while *P. sajor-caju* showed rapid grow at 25°C as well as tolerating higher temperatures (Anonymous, 2007). Studies on the effect of temperature on days to first harvest in *Pleurotus* species showed that days to first harvest varied from 25 to 80 days depending on temperature (Negi and Gupta, 1995).

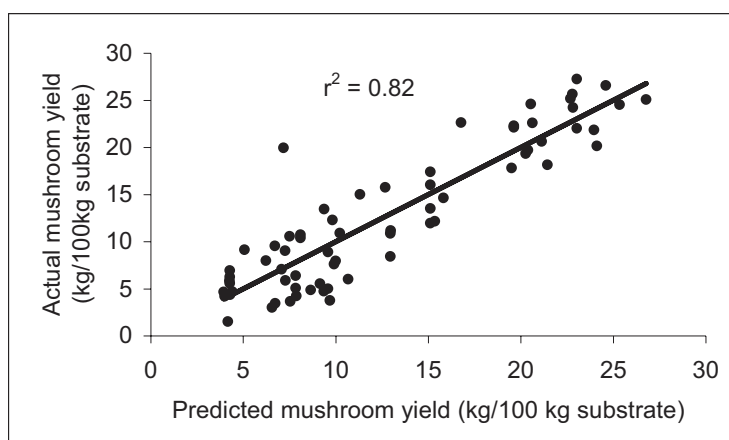
When total mushroom yield was plotted against temperature, the regression coefficient was found to be 0.37 (Figure 5). In present study, when mushroom yield was plotted against light intensity, the regression coefficient was found non significant ($r^2 = 0.01$). The highest mushroom yield was obtained at 210 mmol/m²/s light intensity. In regression analysis, mushroom yield was found to be variable as affected by disinfection

methods, temperature, light intensity and *Pleurotus* species. Therefore, mushroom yield (MY) was plotted against temperature (T), disinfection method (D), light intensity (L) and species (S) and Equation 3 was obtained.

$$MY = 137.223 - 23.221 \times D - 0.425 \times T^2 + 0.0424 \times L \times D - 0.0608 \times L \times S + 0.048 \times T^2 \times D + 11.854 \times S \quad (3)$$

$$SE = 21.29^{***}, 4.51^{***}, 0.12^{***}, 0.09^{***}, 0.012^{***}, 0.016^{***}, 3.35^{***} \\ r^2 = 0.82$$

The effect of independent variables such as temperature, light intensity, disinfection method and species on mushroom yield was a very significant ($p < 0.01$). 82% of the variation in mushroom yield was explained by the selected independent variables. The overall relationship between actual mushroom yield and predicted mushroom yield by Equation 3 was given in Figure 6.

Figure 6: The overall relationship between actual mushroom yield and predicted mushroom yield

Koçyiğit and Günay (1984) reported that there was combined effect of temperature and light in *P. ostreatus* cultivation and it was needed temperature at 10–15°C, light intensity of 15–350 lux for economically production. Okwujiako (2001) investigated influence of light on the vegetative growth and fruit body formation of *Pleurotus sajor-caju*. It was found that light inhibited vegetative growth of *P. sajor-caju*, but it was necessary for the production of fruiting bodies in vitro and in cultivation on rice straw and there was no stimulation effect of light on fruiting body initiation for mycelium less than 5 days old. Datta and Chakraborty (2002) found that darkness favored the spawn run in *P. sajor-caju* and during fructification phase, 5 lux light for 12 h followed by darkness for 12 h was optimum for *P. sajor-caju*. Effects of temperature (15°C and 28°C) and luminosity (120 and 900 lux) were evaluated for eight *P. ostreatus* strains in relation to precocity, yield, pileus area, stalk formation pattern, coloration and handling resistance. In relation to yield, the Pos 98/38 strain was significantly more efficient. The Pos 98/37 strain, at 28°C, as compared to the same strain at 15°C, was more efficient and had an asymmetric stalk formation pattern (Marino *et al.*, 2003)

According to results of the study, the regression models, developed to predicted spawn run period, days to first harvest and mushroom yield, can be acceptable. These models could be detailed using additional parameters. Additionally, becoming widespread of production and consumption of *Pleurotus* species in the Black Sea Region both can help improving the social as well as economic status of small farmers and can be benefited economically from greenhouses and high tunnels in the period of autumn and winter when greenhouses are not used intensively.

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