DRIP IRRIGATION, A NEW WAY FOR WATERING, DURING *AGARICUS BISPORUS* CULTIVATION: INCREASED PRODUCTION AND LOWER CARBON FOOTPRINT

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ABSTRACT

Drip irrigation was invented in Israel, more than 50 years ago. Today, it is the most efficient way for irrigation of field crops and orchards worldwide. Nevertheless, there was no attempt to adjust this way for water supply, to mushroom cultivation, probably due to technical constrains. The development of new low flow, pressure adjusted, leak less, drippers enabled the needed accurate water spread and opened the way to their use in mushroom cultivation. Drip irrigation overcomes the watering obstacles for mushroom cultivation. Drip irrigation enabled the keeping of optimal water contents in compost and casing during entire crop cycle. The value of mushroom yields (quantity and quality), was found to be higher with drip irrigation, mainly at the third picking flush. Decreasing relative humidity (RH), in the cultivation room, after spraying, is avoided with drip irrigation, decreasing the energy needs for room's drying. Higher mushroom quality, using drip instead of spray irrigation, mainly at the second and third flushes, increased the entire crop value. The reduction in energy needs and in thickness of casing reduces the carbon "footprint" of mushroom cultivation. The mentioned data collected until now, reveals the commercial advantage of drip irrigation, over spray watering for mushrooms cultivation.

Keywords: drip irrigation, watering system, mushroom yield, Mushroom quality, carbon footprint

INTRODUCTION

In recent years we have seen continual attempts to improve quality and reduce picking costs, mainly by growing bigger and heavier mushrooms, without wetting the cups. Most of mushrooms are being sold as "medium cup" at a size of 35-60 mm. In order to achieve this, we need to supply: suitable compost, growing space for the cups, evaporation conditions and available water. Sonnenberg and Blok [1] demonstrated that the drops in compost, humidity during the first and second flushes were the limiting factor in mushroom production during the end of 2nd and the 3rd flushes. Dry substrate can lead to stalk conditions such as 'hollow stem' (excessive water up take followed by rapid evaporation), 'early-openers' (restricted water at a critical stage in mushroom enlargement), 'hard gill' (excessive evaporation with insufficient substrate moisture) and clefts and craters in mushroom fruits, thought to be related to low moisture, between mushroom's flushes [2].

We have recently reported, that the use of drip irrigation can overcome, the above mentioned obstacles in mushroom cultivation [3,4], since watering is done inside the casing, below the developing mushrooms and water can be added, to fit the needs at each growing stage. Drip irrigation allows careful management of moisture balance in the compost and casing layers. Excessive moisture in the substrate, can lead to anaerobic conditions, that can prevent lignin degradation and cause significant abiotic symptoms such as 'false mummy' (dried mummified mushrooms similar to those of Mummy disease caused by *Pseudomonas* spp.), or waterlogging (clear glassy patches on the fruit surface),'weepers' (moisture exudation from the marginal edge of the mushroom cap) or 'brown stems', bruised waterlogged stem tissue [5].

In the present work we report on further studies that were carried out in order to develop the optimal use of the drip irrigation system, together with picking management, to increase the size and quality of the picked mushrooms, mainly at the second and third flushes grown for "medium cup" size.

Optimal mushroom growth is dependent on continuous water supply, since the ability to evaporate water, is essential for mushroom growth. It is therefore crucial to insure that high water availability remains, during the entire cultivation cycle.

MATERIALS AND METHODS

Irrigation experiments took place in commercial mushroom farm "The Champignon Farm" in Zarit at northern Israel. The rooms, where the experiments took place, were of 385m^2 shelf growing area, in two rows of six shelves high. The compost was phase 1 compost, produced on farm. Casing soil was composed of (mainly) black peat and limestone (Hartpeat - Ireland). The white *Agaricus bisporus* strain "Lambert 901", was used (8 liter/ton compost). At the end of spawn run nutrition supplement at 15 kg/ton compost (Champfood, The Netherlands) was added to the compost on the shelves and they were cased. Casing was done mechanically, with mixing some compost into the casing, a method called: compost added at casing (Cacing). The thickness of the casing layer was 5cm in the spray irrigated parts. In drip irrigated parts this thickness was reduced by 35%.

Experimental Design: In each experiment two mushroom cultivation rooms were used for the two treatments: the control, spray watering room, and the drip irrigation room. In each room there were six plots of 64.166 m^2 shelf area. Every plot was separately picked and yield's quantity and quality were recorded. The mushrooms were picked at the "stretch stage" as can be seen in Fig.1, for "medium cup" at a size of 35-60mm. Each mushroom was measured for its diameter and weight.

As demonstrated in Fig. 1, at the logarithmic phase of the growth curve, the mushroom weight is increasing faster than its cap size. Mushrooms are picked at the stretch stage to ensure quality and shelf live. The shape of the mushrooms at this stage is demonstrated in Picture 1.

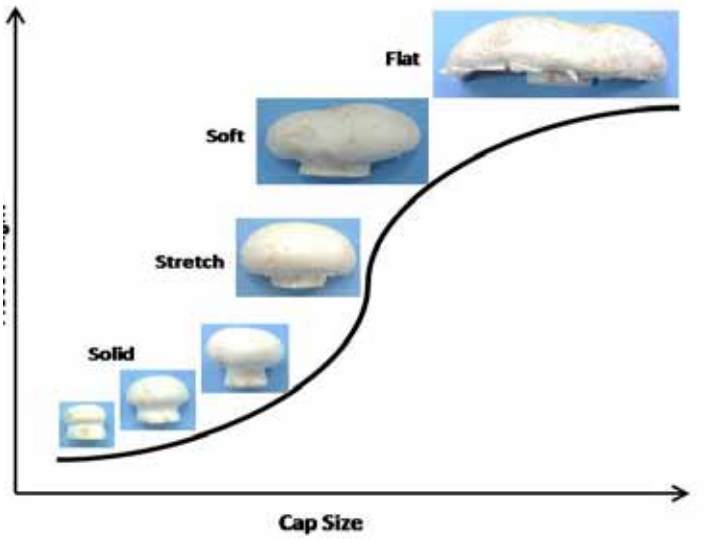
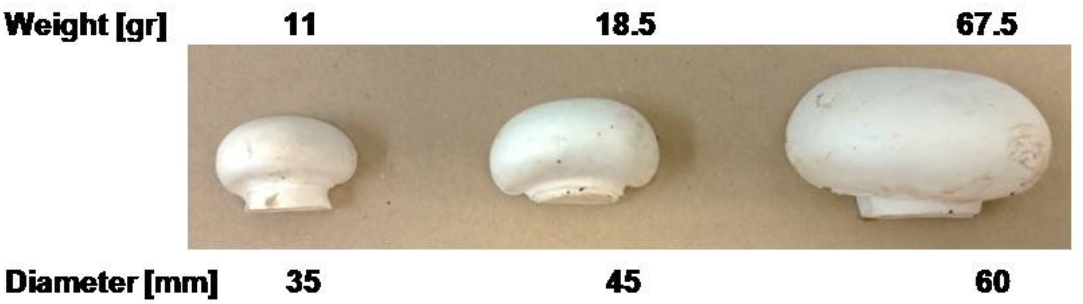


Figure 1. Mushroom growth stages



Picture 1. Medium cup at a size of 35-60 mm Diameter and Weight changes

Irrigation Methods. The control rooms were irrigated by Dofra automatic watering systems (The Netherlands). In the drip irrigated rooms a system, that was recently developed [4] in cooperation with Netafim Irrigation Systems (Israel) was used. The drip pipelines with Uniram 0.7 liter/hr drippers were incorporated into the casing, during Cacing, into the middle of the casing depth. Water amounts of 30-50 liter/m^2 were added to the treatments, during the cropping cycle. During the periods when spray irrigation is halted (pin-head development, flush beginning), drip irrigation continued, in order to avoid water content decrease in the casing and to minimize compost drying.

Energy consumption. The use of cooling and heating was measured separately from the Dalsem climate control system, in each room, in order to compare, energy consumption, by the two different irrigation systems. Cooling coil output was 75 kW heating coil output 37 kW.

RESULTS

Mushroom's growth is measured as the increase in diameter and weight of each mushroom. The ratio between mushroom's diameter and weight growth, under the two irrigation methods, is presented in Figures 2.a, b, c.

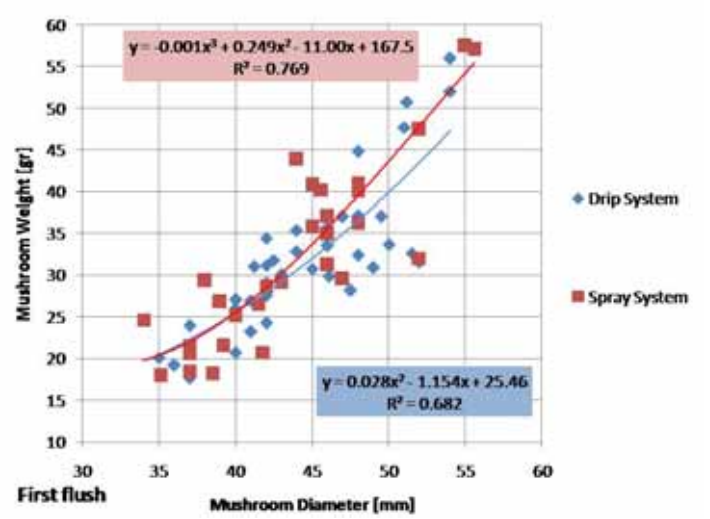


Figure 2a. The ratio between mushroom's cups diameter and weight during the first flush

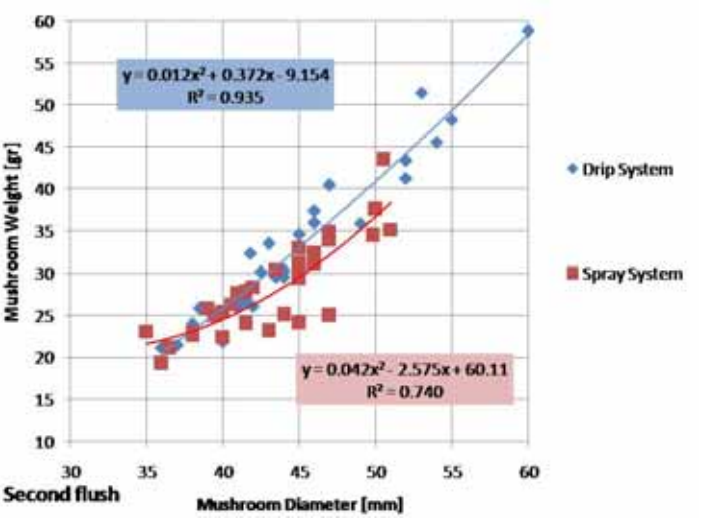


Figure 2b. The ratio between mushroom's weight and cups diameter at the second flush

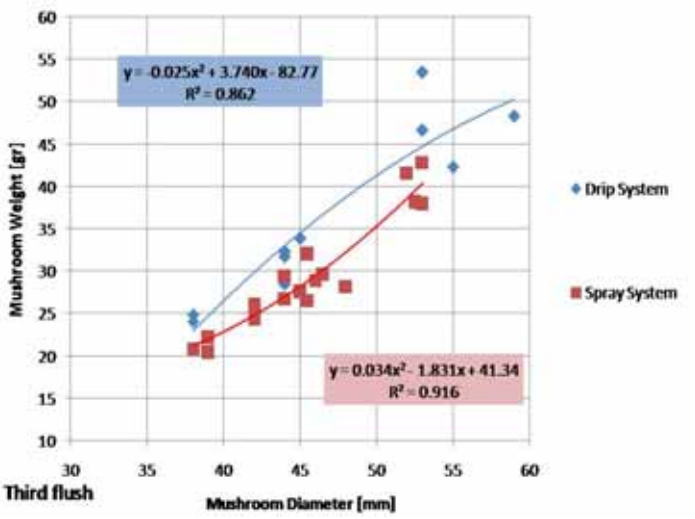
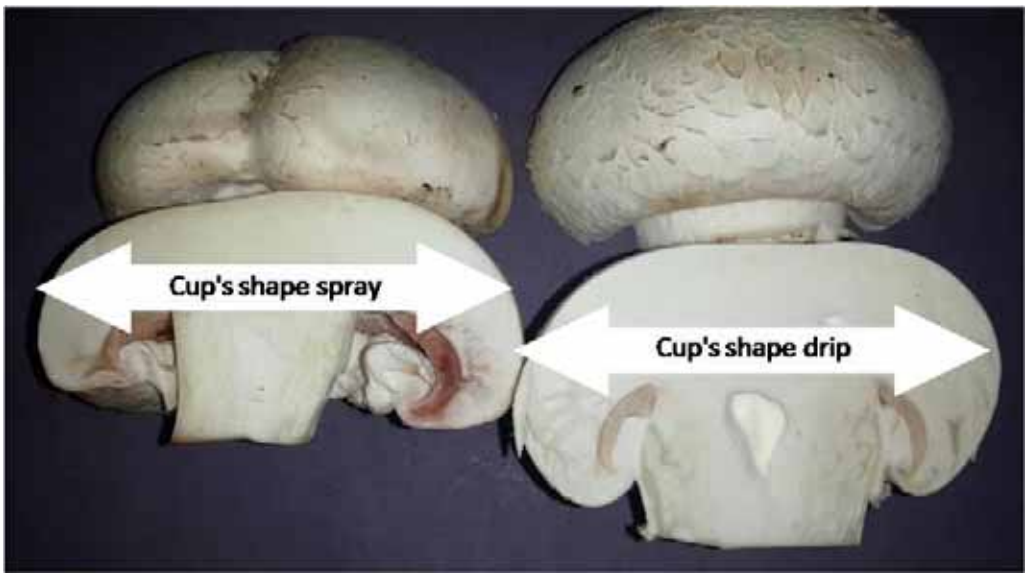


Figure 2c. The ratio between mushroom's weight and cups diameter at the third flush

In Fig. 2a it can be seen that in the first flush, increasing of the cups diameter from 35 mm to 50 mm increased the cups average weight from 20 gram/mushroom to 40-45 gram/mushroom in both treatments. Cups were picked at a diameter of 55 mm, with an average weight of 55 gram/mushroom.

In Fig. 2b it can be seen that in the second flush, increasing of the cups diameter from 35 mm to 50 mm, increased the cups weight from 20 gram/mushroom to 37 gram/mushroom in the spray system treatment and to 41 gram/mushroom with the drip irrigation treatment. In the drip irrigation treatment only, 55 mm cups were picked with an average weight of 50 gram/mushroom.

In Fig. 2c it can be seen that in the third flush, increasing of the cups diameter from 38 mm to 53 mm, increased the cups weight from 20 gram/mushroom to 40 gram/mushroom in the spray system treatment and to 41 gram/mushroom with the



Picture 2. The effect of the watering system on cups shape in the third flush

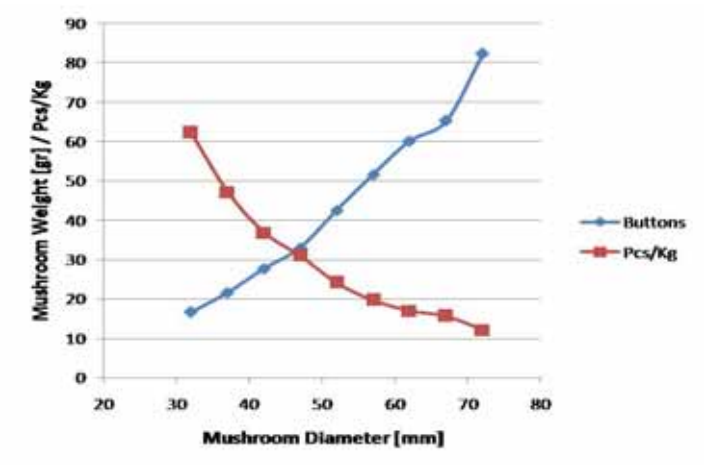


Figure 3. The relationship between mushroom's cup size and number of mushrooms in 1.0 kg

drip irrigation treatment, but only in the drip irrigation treatment 55 mm cups were picked with an average weight of 50gr/mushroom, as demonstrated in Picture 2.

It is demonstrated, that the use of drip irrigation during mushroom cultivation allows managing carefully the moisture balance in the compost and casing layers during the 2nd and 3rd flushes. This allows the cups to grow to bigger size as "medium cup" and to gain more weight compared to the same size of caps that were spray irrigated.

The use of drip irrigation allows the cups to grow to bigger size as "medium cup" and to gain more weight compared to the same diameter of caps that were spray irrigated. The shape of the cups of drip irrigated mushrooms is full and therefore they heavier than the opened shape of the spray irrigated mushrooms.

Increasing mushroom's diameter from 35mm to 50mm is accompanied by reducing the number of mushroom in a kg from 60 to 30 cups. Accordingly this phenomenon is followed by increased picking rate and reduced picking costs. The continuous water supply by drip irrigation leads to this situation.

Table 1. The average energy use, in spray and drip irrigation rooms, during the summer

Treatment	% Cooling	% Heating	Cooling [kW]	Heating [kW]	% Difference in average summer energy consumption
Spray Irrigation	76	21	57	10	
Drip Irrigation	44	26	33	8	-26 kW Cooling and Heating

In table 1 it can be seen, that during the summer, in spray irrigation rooms the need for cooling was higher than in the drip Irrigation rooms, since drying the cultivation room, after spraying, is avoided with drip irrigation. In order to transfer this data to energy saving costs, energy meters will be installed in the future.

DISCUSSION

Water is taken up by the mushroom mycelium and fruiting bodies and evaporated during the entire cultivation cycle. Water had to be replaced by applying water to the casing. That is, however, halted during certain periods (aeration and flushing). To overcome this situation the concept of drip irrigation was developed. The use of under-surface drip irrigation, allows continuous water supply to the casing and compost throughout the cultivation cycle. It was proved in our previuos studies that the use of this system minimized the decrease in casing and compost water content. Furthermore, the use of drip irrigation allowed a decrease of up to 35% in thickness of the casing layer, and reduction of bacterial blotch disease.

In the present study we examind the impact of drip irrigation on the development of the individual fruit body. The use of drip irrigation with proper growth conditions (growth space and evaporation conditions) avoided the decrease of mushroom's quality at the second and third flushes. This quality decrease, is mainly due to low water availabilty, that cause faster growth in the fruit body dimention (diameter) than in its weight. This is demonstrated, when drip irrigation is used by decrease in ratio between "weight/"diameter. These results enable increase in the size and quality of the picked mushrooms, mainly at the second and third flushes grown for "medium cup" size. The increased mushroom weight enhanced their picking rate and reduced picking costs. Drip irrigation allows this option, insuring better mushroom quality and higher yields.

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