The Effect of Calcium Chloride Irrigation on *Agaricus* Yield, Quality and Salinity of Casing Soil

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Abstract: Addition of calcium chloride to irrigation water on mushroom yield, dry matter, stiffness, calcium contents, bacterial population and salinity of casing soil was studied. Calcium chloride was added to the irrigation water at the time of pin formation at concentrations of 0.20%, 0.25% and 0.30%. Although in this experiment the electrical conductivity of local casing soil was increased, yields increased significantly. Statistical analysis showed a significant difference ($P<0.05$) in yields between the test and controls with addition of 0.25 % and 0.30% calcium chloride to irrigation water. On the other hand, analysis of casing soil revealed that the salinity (amount of sodium and potassium) decreased significantly when casing soil was irrigated with calcium chloride. Analysis of the mushrooms for calcium showed a clear increase in calcium content. Bacterial populations in the casing soil and mushroom caps were significantly reduced in all the treatments compare to controls.

Key words: *Agaricus*, bacterial blotch disease, calcium chloride, irrigation water, mushroom cultivation, postharvest quality

1 Introduction

It has been demonstrated by many workers that varying concentrations of calcium chloride, added to irrigation water, improve the quality of fresh and canned mushrooms.[1-10] However, there is some controversy regarding mushroom yields when calcium chloride is added to irrigation water. According to the results of some workers, addition of calcium chloride has no significant effect on mushroom yield. Result of works provided by Beelman and coworkers[10, 11] showed that addition of 0.3% calcium chloride improved the yield and quality of canned mushrooms without affecting fresh mushroom yields. Other data have indicated that there is a slight reduction in mushroom yield after adding $CaCl_2$.[7, 12]

One of the main reasons for yield reduction is the increase in electrical conductivity of the casing soil that occurs when calcium chloride is added to irrigation water. The increase of salt in casing soil coincides with the mushroom having a high dry matter content and is accompanied by lower crop yields.[13, 14] However, the tendency towards reduced yields does not appear to be related to increased casing soil calcium content resulting from addition of calcium chloride.[7] Salinity is harmful for mushroom mycelium when associated with potassium and sodium. The evidence suggests that post-harvest deterioration is directly related to the initial microbial population. Decreases in the bacterial population have a significant effect on shelf life and mushroom quality. The aim of this work was to study the effects of adding different concentrations of $CaCl_2$ to irrigation water on mushroom yield, quality and salinity of the casing soil.

2 Materials and Methods

This experiment was conducted over the past two years at the Malard mushroom farm which is the largest producer of mushrooms in Iran. Compost was made based on wheat straw, chicken manure and gypsum in a conventional yard, and then pasteurized in tunnels. Compost (14 kg) was spawned into bags, spawn run for 14

days, cased with 4 litres of casing soil, the crop was aired after 11/12 days then grown at a temperature of 17±1°C. All the tests were carried out in standard growing rooms. Each room with 1200 to 1600 bags was divided into two sections (right and left) with the same number of bags. Those bags on the right side were irrigated with calcium chloride whereas, on the left side, watering was carried out with tap water.

During a two-year period, three successive concentrations of calcium chloride (0.20%, 0.25% and 0.30%) were added to the irrigation water. Watering started at the time of pin formation. Mushroom yield was determined daily over a 3-week period. Weighing took place after removal of the stipes. A T-test was used with eight replications for 0.30%, ten replications for 0.20% and 0.25% concentrations, as well as controls. The initial and final electrical conductivity of casing soil, dry matter, stiffness of treated mushrooms and controls were investigated.

The amount of Ca, Na and K in the casing soil as well as mushroom caps before and after addition of calcium chloride was measured according to method given by Chang and Quimio.[15] The initial and final electrical conductivity of casing soil, dry matter, stiffness of treated mushrooms and controls were investigated.

Bacterial populations of treated mushroom caps were measured and compared with controls. Mushrooms (25 gm) were macerated in sterile deionizer water (225 ml) for 2 min. Dilutions of 10^{-5} and 10^{-6} were plated on to nutrient agar medium. For estimating bacteria in the casing soil, 10 gm of sample was added to 90 ml of sterilized distilled water. Serial dilutions were made and one ml of each dilution was inoculated on to nutrient agar. The plates were incubated at 25±1°C. Total viable counts were recorded after 72 hours.

3 Results and Discussion

Data from mushroom crops grown at MTDF or elsewhere from 1993 through 2004 indicated that addition of $CaCl_2$ to irrigation water improved the postharvest quality of mushrooms without affecting the mushroom yield. In contrast with the findings of previous workers, the results of this study revealed that addition of calcium chloride to irrigation water did not have any negative effect on mushroom yield. Statistical analysis showed significant differences ($P<0.05$) in yield between the test and controls with addition of 0.25% and 0.30% calcium chloride to irrigation water (Figure 1). The result of this experiment is totally different from those of previous workers. However, addition of 0.20% calcium chloride to irrigation water did not significantly increased the yield. The mushroom dry matter and stiffness are slightly positively influenced by addition of calcium chloride. This is due to an Ec increase in the casing soil (Table 1).

Table 1. The effect of various concentrations of $CaCl_2$ on mushroom and casing soil

Test	No of Crops	Yield (Kg)	Yield (Kg) increase	Dry matter	Stiffness	Ec	pH
0.20% $CaCl_2$	10	20429		8.60	1.87	1834	6.92
Control	10	19841	2.9	8.20	1.84	1686	6.98
0.25% $CaCl_2$	10	17740		8.62	1.75	2033	6.88
Control	10	14847	8.85	8.22	1.70	1940	6.80
0.30% $CaCl_2$	8	12163		9.10	1.81	2035	6.91
Control	8	11481	6.4	8.40	1.71	1945	6.92

According to Kalberer,[16] yields may be reduced due to increases in electrical conductivity. However, according to our results, the limiting factor is the salinity of casing soil. Salinity is harmful for mushroom mycelium and yields when it is associated with potassium, magnesium and sodium ions. Although in this experiment the electrical conductivity of local casing soil was increased, yields were not affected and increased significantly. On the other hand, analysis of the casing soil revealed that the salinity (amount of sodium and potassium) decreased significantly when casing soil was irrigated with calcium chloride (Table 2).

A possible explanation for this phenomenon is that the structure of our casing soil (local peat) contains inorganic matter and in that, cations such as calcium, sodium and potassium exist in the soil solution. If the concentration of cations increases, for example Ca^{2+}, then that cation is likely to exchange with other cations like Na^+ and K^+ and cause a reduction in soil salinity. This will ultimately increase mushroom yields. Calcium ions act antagonistically to balance the injurious effects of potassium, magnesium and sodium ions on mushroom mycelium when they are present at inhibiting concentrations. Calcium is said to be essential for fruit body formation and also forms a sheath of calcium oxalate crystals that surround mushroom mycelium in compost.[17]

Table 2. Assessment of Ca, Na and K in 100g of casing soil (mg/100g sample) before and after irrigation water with $CaCl_2$

Ion conten	Control	0.20% $CaCl_2$	0.25% $CaCl_2$	0.30% CaCl2
	375	325	225	225
Na^+*	305	265	235	160
	330	276	245	190
	675	500	562	437
K^+*	887	575	462	337
	862	625	500	425
	300	308	325	365
Ca^{+2}	275	338	313	365
	285	308	343	368

*Significant decrease ($p< 0.05$)

Analysis of calcium, sodium and potassium of mushrooms shows a clear increase in the calcium content with all the treatments (Table 3). To determine if increased calcium content in mushroom is caused by absorption of calcium from the casing, or whether it is due to deposition on the mushroom cap, the attached mushroom mycelium was removed from the casing (treated with 0.25% $CaCl_2$), washed with water and dried. Results showed that the calcium content of mycelium was not affected as a result of the calcium chloride addition. Hence, absorption of calcium is through mushroom cap (Table 4).

Table 3. Amount of Na, K and Ca in mushroom dry weight(mg/100g)

Ion conten	Control	0.20% $CaCl_2$	0.25% $CaCl_2$	0.30% CaCl2
	712	635	560	705
Na^+	675	775	850	820
	815	795	790	695
	1237	1325	1837	2012
K^+	1725	1500	2012	2025
	1900	2175	1275	1925
	100	125	200	250
Ca^{+2}	125	175	225*	238*
	122	150	218*	223*

*Significant increase ($p< 0.05$)

Table 4. Amount of Ca in mushroom mycelium (mg/100g) treated with 0.25% $CaCl_2$

Test	Sample I	Sample II	Sample III
With $CaCl_2$	552	643	540
Control	580	602	555

Estimation of bacterial population (CFU) in mushroom caps and casing soil treated with calcium chloride showed a significant decrease compared to controls (Table 5). The decrease in bacterial population could have a significant effect on shelf life and quality of the mushrooms. In later flushes, a much lower incidence of disease was observed when $CaCl_2$ was added to irrigation water. This was very obvious in the case of bacterial blotch disease.

Another advantage of adding calcium chloride to irrigation water consists of the earlier initiation of pin formation. The Malard mushroom farm, with a production of 2500 tons fresh mushroom per year, is using 0.25% calcium chloride in all irrigation water after this result.

Finally this work is recommended to countries like Iran where peat is not available and the salinity of casing soil is high due to sodium and potassium content.

Table 5. Assessment of CFU in mushroom cap and casing soil

Sample	Control	0.20% $CaCl_2$	0.25% $CaCl_2$	0.30% CaCl2
Mushroom cap	8.0×10^7	7.0×10^7	6.7×10^7	6.0×10^7
	7.5×10^7	6.9×10^7	6.5×10^7	5.8×10^7
	8.3×10^7	7.3×10^7	6.1×10^7	5.3×10^7
Casing soil	9×10^7	8.8×10^7	8.5×10^7	8.7×10^7
	8.6×10^7	6.3×10^7	8.2×10^7	8.1×10^7
	9.3×10^7	9.1×10^7	8.0×10^7	8.0×10^7

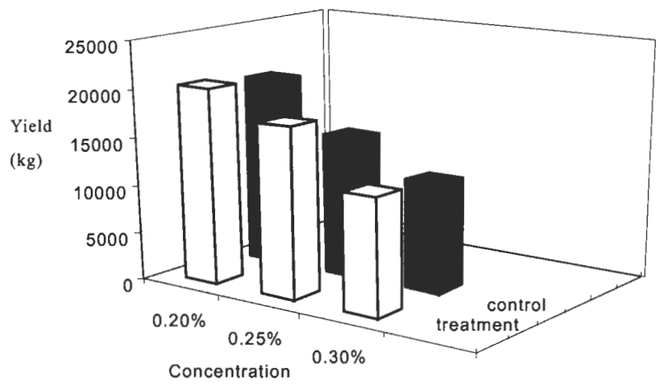

Figure 1. Influence of $CaCl_2$ on mushroom yield

References

[1] Barden CL, Beelman RB, Bartley CE, *et al.* The effect of calcium chloride added to the irrigation water on quality and shelf-life of harvested mushrooms. J. Food Protection, 1990, 53:759-762.
[2] Solomon JM, Beelman RB, Bartley CE. Addition of calcium chloride and stabilized chlorine dioxide to irrigation water to improve quality and shelf life of *Agaricus bisporus*. Mush. Sci. 1991, 13: 695-701.
[3] Bartley CE, Beelman RB, Winnet JR. Factors affecting colour of cultivated mushrooms (*Agaricus bisporus*) prior to harvest and during postharvest storage. Mush. Sci. 1991, 13:689-694.
[4] Mau JL, Miklus MB, Beelmam RB. The shelf life of *Agaricus* mushrooms. In C. Charlambous (ed), The Shelf Life of Food and Beverages, Elsevier Science Publishing Co., 1993, 255-288.
[5] Miklus MB, Beelman RB. $CaCl_2$ treated irrigation water applied to mushroom crops (*Agaricus bisporus*) increases Ca concentration and improves postharvest quality and shelf life. Mycologia, 1996, 88:403-409.
[6] Simons SS, Beelman RB. Influence of calcium chloride added to irrigation water on crop yield and quality attributes of fresh mushrooms. Mush. Sci. 1995, 14:733-740.
[7] Desrumaux B, Calus A. Water hardness and $CaCl_2$ in Dutch mushroom growing systems: Effect on yield and quality. Mush. Sci. 2000, 15:467-474
[8] Diamantopoulou P, Philippoussis A, Lahouvaris L, *et al.* The effect of calcium chloride irrigation on yield and quality of *Agaricus bisporus*. Mush. Sci. 2000, 15:475-482,
[9] Diamantopoulou P, Phlippoussis A. Production attributes of Agaricus bisporus white and off-white strains and the effect of calcium chloride irrigation on productivity and quality. Sci. Hort. 2001, 91:379-391.
[10] Beelman RB, Simons S. Improvement in yield and quality attributes of canned mushrooms by addition of calcium chloride to irrigation water. Mushroom World, 2004, 2.
[11] Beelman RB, Simons S, Beyer D. Cultural strategies to increase yield and improve quality of fresh and processed mushroom (*Agaricus bisporus*) products. Mush. Sci. 2000, 15:483-489.
[12] Hartman SC, Beelman RB, Simons S. Calcium and selenium enrichment during cultivation improves the quality and shelf life of *Agaricus* mushrooms. Mush. Sci. 2000, 15:499-505.
[13] Kalberer PP. Factors influencing the dry matter content of the fruit bodies of *Agaricus bisporus*. Mush. Sci. 1995, 14:417-422.
[14] Loon PCC, Swinkels HATI, van Griensven LJLD. Dry matter content in mushrooms (*Agaricus bisporus*) as an indicator for mushroom quality. Mush. Sci. 2000, 15:507-513.
[15] Chang ST, Quimio TH. Tropical mushrooms. Hong Kong:The Chinese University Press, 1984.
[16] Kalberer PP. Water relations of the mushroom culture (*Agaricus bisporus*): influence on the crop yield and dry matter content of fruit bodies. Mush. Sci. 1991, 13:269-274.
[17] Flegg PB, Spencer DM, Wood DA. The biology and technology of the cultivated mushroom. New York:Wiley Interscience Publication, 1985.