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Minerals and microelements in the mushroom substrate: A production-limiting factor?

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ABSTRACT: Although it has always been stated that poultry manure contains sufficient minerals and microelements to guarantee a maximum yield, experiments with the addition of the Micromax minerals' and microelements' additive indicate an average yield increase between 4.7% (60g Micromax/m^2) and 6.6% (120g Micromax/m^2). The results concerning the extra-yield are irregular and vary between -3.6% and +11.5% (60g Micromax/m^2) and between +0.8% and +21.3% (120g Micromax/m^2). From a correlation analysis comparing the initial manure composition to the final extra-yield, it cannot be deduced for the moment which added element or which modification of relation of elements caused the yield increase. At this moment, there are too few data available to obtain an answer through a correlation analysis. In any case, it is sure that the supply of minerals and microelements through manure can be insufficient and that further research is necessary.

1 INTRODUCTION

The need for minerals and microelements of *Agaricus bisporus* is a cultivation item that got relatively little attention in the past (Stone et al. 1991). On the one hand, this is probably due to the fact that the problem of microelements is rather complex. The complexity is amongst others based on the fact that the minerals and microelements, present by nature and added, very often do not directly help the mushroom, but only have an indirect effect through the incorporation in the microflora of the substrate (Wood et al. 1985) or that they intervene in enzymatic reactions without being taken up by the mushroom (Racz 1998). On the other hand, it may not be forgotten that it was supposed till recently that a classically composed substrate had enough of these elements to guarantee a maximum yield (Vedder 1971, Van Griensven 1987). Notwithstanding this generally accepted supposition, it becomes more and more obvious that these nutriment elements deserve more attention (Betterly 1993).

2 OBJECTIVE

The orientating series of tests aim to field-test the thesis that a classically composed substrate always contains sufficient minerals and microelements to guarantee a maximum mushroom yield.

3 MATERIALS AND METHODS

To obtain the aforementioned test objective, two series of tests, each grouping 5 tests, were carried out. The test settings that were used are represented in Table 1. In the first series, the addition of minerals and microelements was effected in combination with a variation of the

Table 1 : Supplementation and Micromax doses

	Object	Code	Treatment Supplementation	+	Micromax
Series 1	1	Bl	1 kg/m^2		
	2	B14	1.4kg/m^2		
	3	B18	1.8 kg/m^2		
	4	B1S6	1 kg/m^2		60 g Micromax/m^2
	5	B14S6	1.4 kg/m^2		60 g Micromax/m^2
	6	B18S6	1.8 kg/m^2		60 g Micromax/m^2
	7	B1S12	lkg/m^2		120 g Micromax/m^2
	8	B14S12	1.4 kg/m^2		120 g Micromax/m^2
	9	B18S12	1.8 kg/m^2		120 g Micromax/m^2
Series II	1	SO	1.4 kg/m^2		
	2	S6	1.4 kg/m^2		60 g MICROMAX / m^2
	3	S12	1.4 kg/m^2		120 g MICROMAX/ m^2

Table 2 : Micromax : product specifications

N, P, K	0%	-
Fe	12%	Iron sulfate
Mn	2.5 %	Manganese sulfate
Zn	1.0%	Zinc sulfate
Cu	0.5 %	Copper sulfate
B	0.2 %	Sodium borate
Mo	0.05 %	Sodium molybdate
S	15%	iron-, manganese-, zinc- and copper sulfate
MgO	5%	
CaO	7.5 %	

Source : Scotts Belgium bvba

supplementation dose. In the second series, a fixed supplementation quantity was used. Addition of the microelements took place after incubation, simultaneously with the supplementing (Millichamp 3000, Champfood). The additive was the commercial horticulture product Micromax, which, in previous tests gave a yield increase, though irregular, of oyster mushrooms (Overstijns et al. 1994). Table 2 gives a survey of the composition of the product.
All tests were carried out at the Belgian Mushroom Research Center. The substrate was bought after fermentation (out-door system) and further treated by our own staff. Pasteurization, conditioning and incubation took place in computer-controlled tunnels with a capacity of 12 tons of fresh substrate. The cultivation took place in cultivation rooms with a cultivation surface of 75m^2, also computer-controlled and equipped with an overpressure-ventilating-system. The varieties used were all large hybrids.

4 RESULTS AND DISCUSSION

4.1 *Substrate temperatures during the first 7 days after casing (Series I)*

Supplementing with inappropriate high-protein products or excessive doses often induces incontrollable substrate temperatures after the addition took place. Therefore, particular attention was paid to that aspect. The daily figures (Fig. 1) represent the average value for 2 measuring points per object.

By increasing the supplementation dose from 1 kg/m^2 to 1.4 kg/m^2 and to 1.8 kg/m^2, the substrate temperatures increased resp. with maximum 0.8°C and 0.9°C in relation to the control of 1 kg/m^2. The object with the highest supplementation dose (1.8 kg/m^2) gives the highest temperature increase. The object with the lowest dose (1 kg/m^2) gives the lowest temperature. This finding was recorded for every Micromax dose.

The influence of the Micromax addition on the temperature is inappreciably low. During the first 7 days after supplementing, a maximum temperature increase of 0.4°C was noted. The

influence of the Micromax addition on the temperature evolution is not as clear as for the addition of the supplementation product (Fig. 1). The differences seem to be most outspoken when the Micromax addition is made at a supplementation dose of 1 kg/m^2. At supplementation doses of 1.4 kg/m^2 and 1.8 kg/m^2 practically no differences are noticeable. In general, it can be found that the Micromax addition does not cause any considerable temperature increases.

4.2 *Yield (Series I and II)*

The mushroom yield was recorded during 4 flushes. Only marketable mushrooms were taken into account for weighing. The yield figures give the results after cutting-off the stipes.

In the first test series, a clear-cut tendency of yield increase can be noticed on average in the 5 tests as a result of the increase of the supplementation dose and the increase in the Micromax dose (Fig. 2). The statistical analysis of the data does not reveal any interaction between the supplementation dose and the addition of microelements.

When the yields are considered in function of the supplementation dose, a statistically significant difference can be noticed over all 5 tests between the dose of 1 kg/m^2 and the doses of 1.4 kg/m^2 and 1.8 kg/m^2. The doses of 1.4 kg/m^2 and 1.8 kg/m^2 do not significantly differ (Table 3). The results that are obtained in this series of tests therefore confirm the test results that were carried out previously by the Belgian Mushroom Research Center (Desrumaux et al 1998).

When the yields are considered per Micromax dose, it has to be found that the addition of this product also induces a significant yield increase. The additions of 60g/m^2 and 120g/m^2 have a significantly positive influence on the yield, but do not significantly differ from one another (Table 4). The average yield increase with 60g Micromax per m^2 amounts to 6.2%, with 120g Micromax added, the increase amounts to 9.3% (series I).

In general, it can be found that in 4 out of 5 tests, there is a tendency towards yield increase. However, the influence of Micromax on the yield is extremely irregular and varies between +11.5% and -3.6% for the dose of 60g/m^2 and between +21.3% and +3.3% for the dose of 120g/m^2. The cause of the irregularity could not be found on the basis of the test results noted down for the first series of tests. Possibly, the minerals' contents of the substrate causes these irregular results.

A second series of tests, aimed to verify the results of the first series and in an attempt to explain the irregularity in the yield increases, the minerals' and microelements' content of the substrate was analyzed.

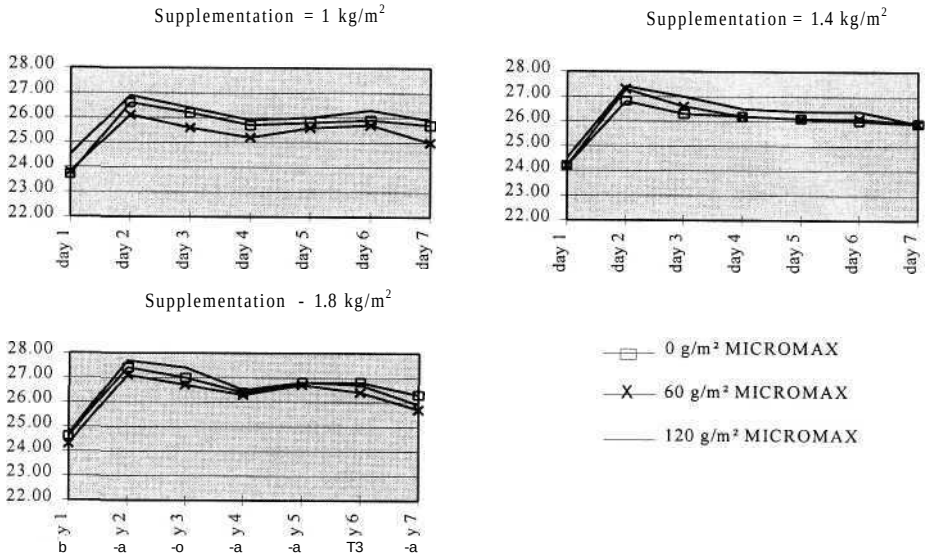

Figure 1. Substrate temperatures (°C) after casing - sorted by supplementation doses (average over series I)

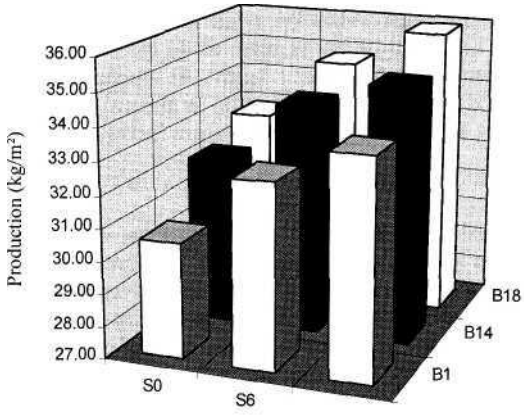

Figure 2 : Yields (kg/m^2) according to the supplementation and Micromax doses - average over series I

Table 3 : Production (kg/m^2) over 4 weeks - Average yield per supplementation dose - Series I

	Test I (**)	Test II (**)	Test III (**)	Test IV (**)	TestV (**)	Average (**)
Supplementation 1 kg/m^2	27.68 b	34.11 a	35.58 a	30.54 b	33.80 a	32.34 b
Supplementation 1.4 kg/m^2	30.14ab	36.35 a	36.39 a	32.03 ab	33.76 a	33.73 a
(*)	(+8.9%)	(+6.6%)	(+2.3%)	(+4.9%)	(-0.1%)	(+4.3%)
Supplementation 1.8 kg/m^2	32.17 a	36.39 a	36.20 a	33.49 a	34.34 a	34.52 a
(*)	(+16.2%)	(+6.7%)	(+1.8%)	(+9.7%)	(+1.6%)	(+6.7%)

(*): difference compared with lowest dose
(**) : applications with a common letter are not significantly different at p 0.05 level

Table 4 : Production (kg/m^2) over 4 weeks - average per Micromax dose - series I

	Test I (**)	Test II (**)	Test III (**)	Test IV (**)	TestV (**)	Average. (**)
Micromax Og/m^2	27.11 b	33.51 a	36.09 a	29.81 a	32.91 a	31.89 b
Micromax 60 g/m^2	30.01 ab	37.37 a	34.79 a	33.15 a	33.95 a	33.85 a
(*)	(+10.7%)	(+11.5%)	(-3.6%)	(+11.2%)	(+3.2%)	(+6.2%)
Micromax 120 g/m^2	32.88 a	35.96 a	37.29 a	33.09 a	35.05 a	34.85 a
(*)	(+21.3%)	(+7.3%)	(+3.3%)	(+11.0%)	(+6.5%)	(+9.3%)

(*): difference compared with lowest dose
(**): applications with a common letter are not significantly different at p 0.05 level

The results reveal as in the first series a significant difference between the control object SO and two objects to which Micromax was added. The Micromax objects 60g/m^2 and 120g/m^2 do not significantly differ from one another. The yield increase in relation to the control amounts respectively to 0.99 kg/m^2 or 3.26% and 1.18 kg/m^2 or 3.89% (Table 5).

Contrary to previous series of tests, the five tests show a practically uniform picture as to the yield increase. On the other hand, the yield increase is lower than in the previous series.

As mentioned before, the final results concerning the extra-yield are irregular (Figure 3). Over the 10 tests, the extra-yields with 60g Micromax per m^2 vary between -3.6% and +11.5% and for 120g Micromax per m^2 between +0.75% and +21.3% .

From a correlation analysis comparing the initial manure composition to the final extra-yield (series II), it cannot be deduced for the moment which added element or which modification of relation of elements caused the yield increase. At this moment, there are too few data available to obtain an answer through a correlation analysis.

Table 5 : Production (kg/m^2) over 4 weeks - series II

	Test I	Test II	Test III	Test IV	TestV	Average	(**)
Micromax Og/m^2	30.48	29.53	30.03	30.27	31.32	30.33	b
Micromax 60g/m^2	31.10	29.94	30.55	31.79	33.20	31.32	a
(*)	(+ 2.0%)	(+ 1.4%)	(+ 1.7%)	(+ 5.0%)	(+ 6.0%)	(+ 3.3%)	
Micromax 120g/m^2	31.59	29.75	31.03	31.63	33.55	31.51	a
(*)	(+3.6%)	(+ 0.7%)	(+3.3%)	(+ 4.5%)	(+7.1%)	(+3.9%)	

(*): difference compared with lowest dose
(**): applications with a common letter are not significantly different at p 0.05 level

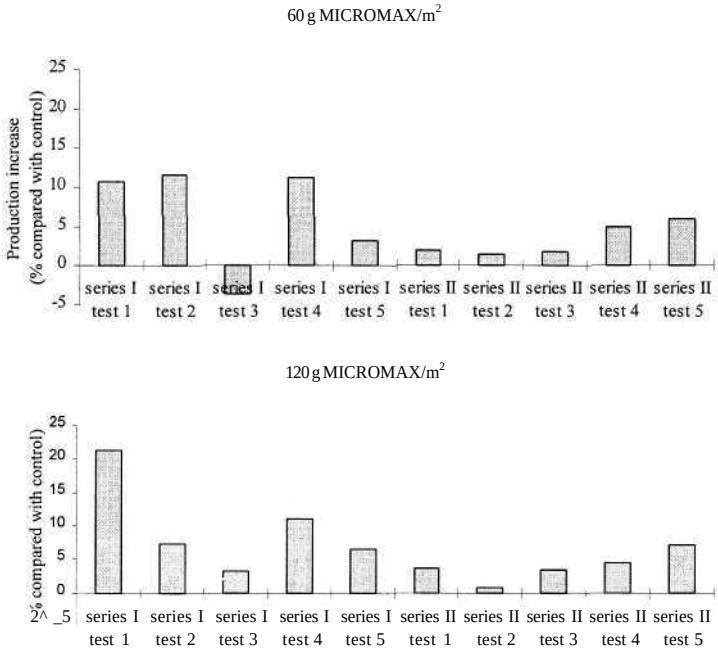

Figure 3 : Production increase (% in relation to the control) obtained with Micromax application

4.3 *Mushrooms 'piece weight (Series I and II)*

For a small part of the harvested quantity, the mushrooms' piece weight was determined. These weightings do not show any differences in either series of tests, neither for the supplementation dose nor for the Micromax dose.

4.4 *Harvest spreading (Series II)*

An important evaluation factor when considering the total mushroom yield, is the spreading of this yield over the successive harvest weeks. Whereas a classic supplementation product (protein addition) has the yield increase per flush with practically the same percentage, this does not seem to be the case for the Micromax addition in Series II. Exception made for test III, the yield increase appears to mainly concentrate in the last two harvest weeks. Per harvest week, the yield increase in relation to the control harvest week for the 60g Micromax addition resp. amounts to 1.02%, -0.25%, 13.22% and 14.31%. For the 120g/m^2, this is 0.21%, 2.54%, 13.7% and 13.47%.
When the spreading of the yield increase is considered over 4 weeks, it has to be found that for objects S6 and S12 the yield increase was realized for resp. 95% and 81% in the last two harvest weeks.

Table 6 : Series I: Piece weight (g) - average over 3 flushes

	Test I	Test II	Test III	Test IV	TestV	Average (*)
Supplementation 1 kg/m^2	19.57	21.13	19.62	15.82	20.06	19.24a
Supplementation 1.4 kg/m^2	20.70	20.78	19.65	15.67	20.86	19.54 a
Supplementation 1.8 kg/m^2	19.80	21.04	20.01	16.05	21.98	19.78 a
Micromax 0 g/m^2	19.67	21.92	18.62	16.14	20.69	19.41a
Micromax 60 g/m^2	19.49	20.28	20.45	15.53	20.74	19.30a
Micromax 120 g/m^2	20.91	20.75	20.22	15.87	21.48	19.85a

(*): applications with a common letter are not significantly different at p 0.05 level

Table 7 : Series II : Piece weight (g) - average over 3 flushes

Code	Test I	Test II	Test III	Test IV	TestV	Average (*)
Micromax 0 g/m^2	15.71	20.42	18.01	16.47	19.31	17.98 a
Micromax 60 g/m^2	16.55	19.74	18.16	16.96	19.97	18.28a
Micromax 120 g/m^2	16.41	20.20	17.27	16.93	20.37	18.24 a

(*): applications with a common letter are not significantly different at p 0.05 level

Table 8 : Yield increase (%) in relationship to the corresponding harvest week of the control object

Tester.	Object	week 1 (%)	week 2 (%)	week 3 (%)	week 4 (%)	total (%)
Test I	S6	4.07	-5.70	20.14	8.80	2.03
	S12	3.85	-2.44	24.26	6.80	3.64
Test II	S6	-0.70	0.98	5.07	3.90	1.39
	S12	-0.69	-0.66	8.15	-1.29	0.75
Test III	S6	-3.98	6.09	8.08	1.14	1.73
	S12	-4.81	15.25	-0.35	3.90	3.33
Test IV	S6	-0.66	2.14	24.71	24.37	5.02
	S12	-2.15	3.06	22.71	24.65	4.49
TestV	S6	6.36	-4.78	8.08	33.32	6.00
	S12	4.88	-2.51	13.71	33.29	7.12
Average	S6	1.02	-0.25	13.22	14.31	3.24
	S12	0.21	2.54	13.70	13.47	3.87

Table 9 : Procentual spreading of the yield increase over the harvest weeks (average over the 5 tests)

Object	week 1	week 2	week3	week 4	total
Micromax 60g/m^2	11.84	-6.99	51.23	43.80	100
Micromax 120g/m^2	1.32	18.11	45.46	35.20	100

4.5 *Mushroom composition (Series II)*

It is not impossible that an addition of microelements might also influence the composition of the mushroom. Nevertheless, there seems to be no influence of the treatment on the dry matter contents of the mushroom, nor on the elements N, P, K, Mg, Ca, Na and S (Fig. 4). On the contrary, Fe, Mn, Al and especially B show a clear-cut increase in the mushrooms (Fig. 4). For Cu and Zn, there is also an increase, though it seems not to be univocal.

4.6 *Absorption of nutriment elements from substrate (Series II)*

On the basis of the contents of the elements in the substrate (accounting for the additions) and the contents of the elements in the mushrooms, the absorption of elements from the substrate was calculated.

The calculation reveals that there is a clear-cut tendency for 5 elements. For the elements Fe, Mn, Cu and Zn, the absorption of the elements (relatively spoken) decreases as the concentrations in the substrate increase. The element B makes an exception : the higher the concentration of B in the substrate, the higher the percentual absorption will be (Fig. 5).

5 SUMMARY AND CONCLUSIONS

Two series of tests, grouping 5 tests each, verified the influence of the addition of minerals and microelements to the standard mushroom substrate on the yield, the piece weight, the flushing scheme and the mushroom composition. The mushroom substrate was enriched with the Micromax minerals' and microelements' additive at a dose of 60 and 120g/m^2. Adding took place after incubation, simultaneously with supplementing.

Though it has always been stated that poultry manure contains enough minerals and microelements to guarantee a maximum yield, the tests indicate that this not always seems to be true. In the 10 tests carried out, the addition gives an average yield increase of 4.73% (60g Micromax/m^2) and 6.6% (120g Micromax/m^2).

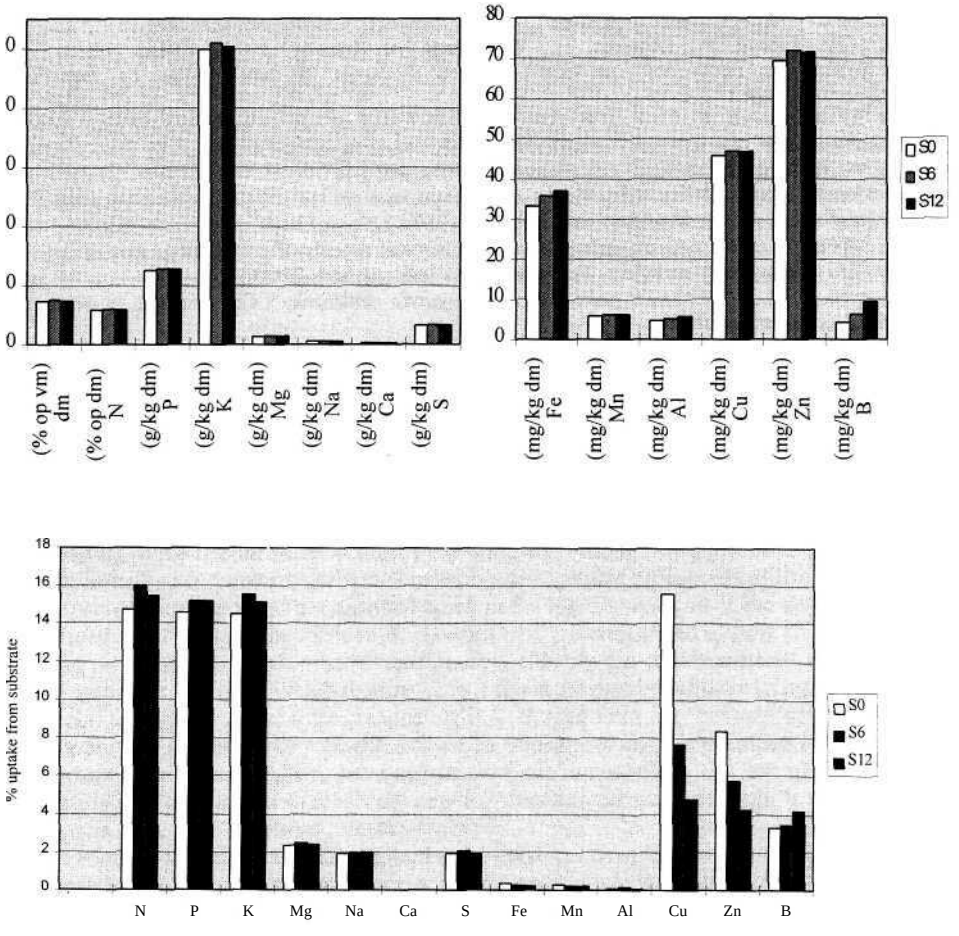

Figure 5. Nutrient-uptake from substrate - average over all flushes (Series II)

However, the results concerning the extra-yield are irregular. The extra-yields with 60g Micromax per m^2 vary in the 10 tests between -3.6% and +11.5% and for 120g Micromax per m^2 between +0.75% and +21.3%.

From a correlation analysis comparing the initial manure composition to the final extra-yield, it cannot be deduced for the moment which added element or which modification of relation of elements caused the yield increase. At this moment, there are too few data available to obtain an answer through a correlation analysis. Further research is necessary to put this clear. In any case, it is sure that the supply of minerals and microelements through manure can be insufficient and that research is more useful than thought before.

Data about harvest spreading indicate that the extra-yield is mainly concentrated in the last two flushes and is not equally distributed over the 4 flushes as it is with protein supplementation. The mushrooms' piece weight is not influenced by the Micromax addition.

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