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The Effects of Total Nitrogen and Residual Ammonia Contents of Compost on the Yield of Cultivated Mushroom, *Agaricus Bisporus*

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堆肥의 全窒素와 암모니아 含量이 양송이 收量에 미치는 影響

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Abstract: Among the factors which affect the mushroom yield, this investigation was aimed to confim the relationship between nitrogen content of rice straw compost and crop yield, residual ammonia content and yield. In this investigation the nitrogen content in dry weight of compost ranged from 1.10 to 2.06% and the residual ammonia content between 0.01 and 0.8% at spawning according to the sources of organic or inorganic nitrogen and the formulas of compost materials.

The results obtained are summarized as follows:

1. The relationship between nitrogen content of rice straw compost and mushroom yield was represented by the formula: $y=13.95+0.048(r=0.68^{**})$.
2. Nitrogen content and mushroom yield of compost supplemented with organic nitrogen sources were increased as compared with control or inorganic treatments.
3. The relationship between the residual ammonia content and mushroom yield is represented by the formula: $y=0.38086-0.011948+0.00012x^2(r=-0.75^{**})$. In order to obtain high cropping yield the residual ammonia content at spawning should be below 0.03% (expressed as nitrogen content).
4. Application of ammonium sulfate increased the nitrogen content of compost slightly, but the residual ammonia content was increased considerably and yield decreased. On the other hand, the residual ammonia content of urea treatment was low and increased mushroom yield remarkably.

Introduction

Commercial mushroom growing of *Agaricus bisporus* has been practised since 1700 using horse manure as the natural medium, but in recent years since 1940's synthetic medium substitutes for horre manure made from straw, hay, corn cobs and other fibrous materials combined with organic and inorganic fertilizers have been used for the cropping of the *A. bisporus*. From that time, much research on the role of nitrogen and residual ammonia as a factor affecting mushroom yields has been especially conducted. Some workers found increases in yield with increased nitrogen content, while others did not.

Edwards (1949) suggested that the increase of nitrogen had a slight but not significant effect on the number of mushrooms produced; it had more effect on the average weight per mushroom and hence on the total yield.

Early '50's, Lambert (1950) had obtained linear increase with addition of nitrogen. Especially the addition of proteineous materials such as cottonseed meal and brewer's grain significantly increased the yield of mushrooms.

Rasmussen(1963) reported 2.5% nitrogen at spawning gave some increase with two extra days on the 16 days system.

Brezloff and Fluegel(1962) pointed out nitrogen contents of the high yielding composts were always higher than those of the low-yielding composts.

O'Donoghue(1965) at the Irish Agricultura- Institute also found a highly significant correlation between nitrogen and yield for synthetic composts.

R.C. Ross(1968) also obtained relationship between nitrogen and yield. On the other hand, Fryer Bros(1955—56) found 1.85% of nitrogen was sufficient, at spawning, for maximum crops and no increase in yield was gained with extra nitrogen.

Gerrits(1965) also reported equal yields were obtained on composts with nitrogen varying from 1.6 to 2.7 percent and they stressed there was no cor elation at all between the percentage of nitrogen and the yield of mushroom, neither per m^2 nor per kilogram dry matter of compost.

Schisler and Sinden(1960) found yield increase resulted as the amount of nitrogen in the compost was increased up to about 3% of the finished compost at the time of mushroom spawning however, at about the 3% level a sharp limit to further increases in yield occurred.

Residual ammonia is well known to be toxic for the growth of mushroom mycelium and the initiation of fruit bodies.

At Ireland Agricultural Institute it has been recommended not to allow the residual ammonia content of compost at spawning to exceed 0.025 percent expressed as nitrogen.

Sinden and Tschierpe(1962) also found a level above 0.05% of volatile alkaline nitrogen to be inhibitive to growing of mycelium; therefore, the composting process must be regulated to produce a minimal amount of ammonia content.

O'Donoghue(1965) found the relation between the residual ammonia content(expressed as nitrogen content) and crop yield was adversely significant.

Rasmussen et al. used ammonium sulfate as an inorganic source that produced a high nitrogen content and a minimal amount of ammonia which controlled the crop yields, but Gerrits et al. used urea.

And in Europe where is a plentiful supply, cottonseed meal, brewers grain, malt sprout, dry blood, wool dust, sugar beet pulp, etc. are used as organic sources. Furthermore, they also prepare mushroom compost with horse manure or wheat straw.

However, in Korea rice straw is mainly used as compost material and the sources and production of organic, inorganic nitrogen are limited; therefore, it is necessary to confirm the relationship between nitrogen content and yield, residual ammonia content and yield, which is suitable in our cropping conditions.

And so this experiment was aimed to clarify how nitrogen and residual ammonia content of rice straw compost affect mushroom yield.

Materials and Methods

The rice straws used as compost material were chopped into approximately 30cm. lengths. Adding sufficients water, straws were piled up densely for absorbing moisture into a stack of 1.8x1.8x1.5m.

After two or three days stacking was perfor med adding the organic sources such as poultry manure, seasame meal, rice bran, etc.. At this time considerable amounts of water was sprinkled to wet the sources and dry parts of straws. At two or three days intervals the composts were turned to promote aerobic fermentationl. Inorganic sources such as urea, ammonium sufate, etc. were added at stacking time and at the first two turnings, gypsum was added at the last turning.

After 25 day's out-door composting for spring cropping, 15 day's for autumn cropping, the shelves were uniformly filled with compost in cropping house, as quickly as possible.

The peak-heating of compost was maintained at 60°C for 6 hrs(for pasteurization) and prolonged fermentation for 8 days at about 50~55°C with live or dry steam. During the period of indoor fermentation the room was ventilated with fresh air occasionally not to allow falling the desired temperature and then the compost was cooled down to 30°C by forced ventilation, subsequently it was spawned at the rate of 3 lbs/3.3m^2 of bed area.

After spawning, the temperature of compost was maintained about 25°C and relative humidity of the growing room was about 95%. When the compost was densely growned with mushroom mycelium, two weeks after spawning, the beds were cased with mixed clay loam 75% plus humus soil 25% of pH 7.5—8.0.

During the cropping period, temperature of the growing room was controlled 15 to 17°C. Samples of compost for analysis were taken from each treatment just before spawning. In order to represent genuinely all the compost, the samples were collected from at least ten different spots in several beds of same treatments, situated at various heights. These samples were thoroughly mixed and placed in a plsatic bag. Analysis was performed for dry matter, total nitrogen was determined by means of Kjeldahl method and residual ammonia by MgO alalkaline Aoatile method.

Results and Discussion

1. Total nitrogen content and mushroom yields.

In this investigation the nitrogen content of rice straw compost in dry weight ranged from 1.10% to 2.06% according to the sources of organic, inorganic nitrogen and the formulas of compost materials(Tab. 1.). In proportion to the increase in nitrogen content of compost, cropping yield also increased. This result was in accordance with Fryer Bros(1956), Gerrit's(1965) findings, but the level of nitrogen percentage which represents the limit of further mushroom yield, 3% according to Schisler and Sinden(1962), was not reached. The reason why nitrogen content of composts was not so high compared

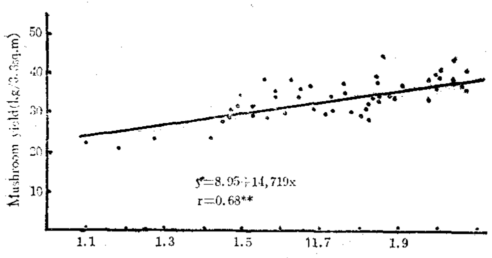
Table 1. Effect of total nitrogen content of compost on mushroom yield

Total nitrogen (%)	Mushroom yield(gr/3.3sq.m)	Number of treatments
1.10—1.30	23,997	3
1.31—1.60	32,370	14
1.61—1.90	35,886	23
1.91—2.06	38,734	11

with those in urope is probably becaure organc sources used in our experiments were low in proteineous nitrogen.

Relationship between nitrogen content of compost and mushroom yield per 3.3m^2 of bed area was a positive linear regression with correlation coeffecient significant at the 1% level($r=0.69^{**}$) as shown Fig. 1.

This is in accord with O'Donoghue(1965), Brezloff and Fluegel(1962), R.C. Ross's(1968) results, but differs from Fryer Bros(1956), Gerrits et al's(1965) opinion which set a limit on



Total nitrogen content(%)

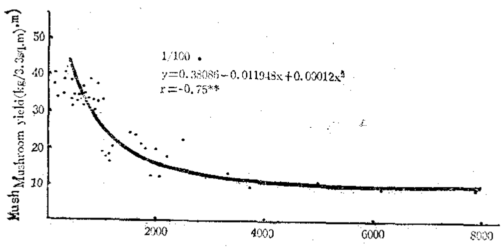
Fig. 1. Relationship between total nirtogen content of compost and mushroom yield.

the nitrogen content affecting mushroom yields Judging from these results, it is suggested that forms of nitrogen are more important than its quantity; therefore, research is necessary on the proteineous nitrogen and nitrogen-rich lignin-humus complex which directly nourish the growth of mushroom mycelium and the development of fruit bodies.

2. Residual ammonia content and mushroom yield.

Relation between ammonia content(expressed as nitrogen content) which is residual in composts after composting process and mushroom yield per $3.3m^2$ of bed area was shown as Fig. 2. The negative quadratic regression was significant and the correlation coefficient was also significant at the 1% level. This result agrees with O'Donoghue's(1965).

As the residual ammonia content increases it tended to increase pH of compost and caused contamination with Chatomium, Sepedomium Stysanus, etc., which is harmful for growing of mushroom mycelium. The injurious residual ammonia increased when the level of nitrogen supplementation was high, ammonium sulfate was used as inorganic source and indoor fermentation was performed with a high level of moisture content of compost and anaerobic conditions. However, it was impossible to eliminate the residual ammonia content completely, and it seems that for high cropping, the residual ammonia content at spawning should be below 0.03%(expressed as nitrogen content).



Ammonia content of compost(ppm)

Fig. 2. Relationship between residual ammonia content(expressed as nitrogen content) of compost and mushroom yield.

3. Organic sources, nitrogen content and mushroom yield.

The effect of organic sources which controlled fermenting conditions of microorganisms from

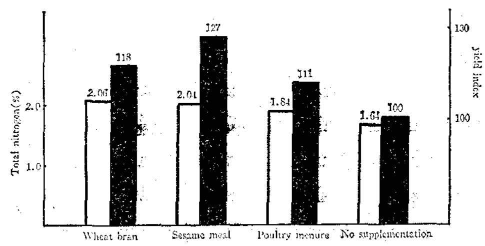


Fig. 3. Effect of supplementation of some organic nitrogen sources on increase of nitrogen content in compost and mushroom yield.

□ Percent of total N, ■ Yield index

the start of stacking is shown as Fig. 3.

Nitrogen contents with organic sources treatments were all higher than those of control and mushroom yields were also remarkably higher.

In addition, fermentation temperature, which were favourable for the preparation of mushroom compost were always higher than those of control or inorganic sources treatemts. Especially in the spring cropping period when the weather was cold the organic sources treatment produced highly effective results.

4. Inorganic sources, residual ammonia content and mushroom yield.

With application of ammonium sulfate, nitrogen content was slightly increased over that of urea, but there was considerably less conversion into microbial nitrogen in the composts containing ammonium sulfate and these had a very high level of soluble nitrogen, 36% of the total nitrogen. These high soluble nitrogen levels, mainly ammonia nitrogen, were associated with a lower pH, suggesting that much of the added ammonium sulfate remained unchanged in the compost. Therefore, with the lack of the favourable nitrogen content for mushroom growth and the increase of residual ammonia content it would be possible to eliminate the ammonia from the compost with a prolonged peak-heating period, but this would be a costly and in some cases impractical method of increasing nitrogen content. Consequently, these findings suggested that ammonium sulfate is unsuitable as a supplement for compost. However, Rasmussen et al. recommended ammonium sulfate as an inorganic source and he reported that when ammonium sulfate was used together with calcium carbonate considerably high yields were obtained.

Judging from the fact no increase in yield could be obtained by adding gypsum in combination with ammonium sulfate and calcium carbonate, it is suggested that from the sulfate of ammonium sulfate and the calcium of calcium carbonate, gypsum was formed during the composting process.

Because of this, the addition of calcium carbonate seems to be valuable. The other hand, urea was rapidly broken into ammonia, which is built partly into the microbial cell substances, partly into the nitrogen-rich lignin-humus complex, whiles till another part volatilizes as ammonia.

Application of urea gave always lower residual ammonia content than ammonium sulfate and high yield were obtained from urea treatment as shown Fig. 4. When using urea, there was consistently an increase in yield with addition of gypsum.

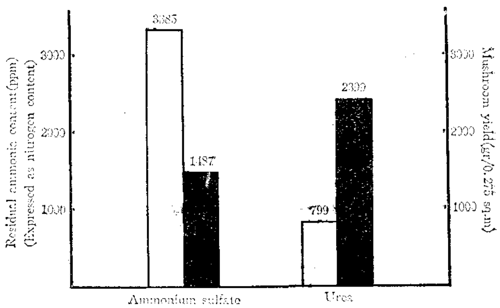


Fig. 4. Residual ammonia content in compost supplemented with urea and ammonium sulfate, andits effect on mushroom yield.

▭ Ammonia content of compost. ■■ Yield.

적　　요

양송이 수량을 지배하는 여러인자중에서 퇴비의 전질소 함량과 암모니아 잔류량이 양송이 수량에 미치는 영향을 구명하고자 본시험을 실시한 결과 다음과 같은 결론을 얻었다.

1. 퇴비의 전질소 함량과 양송이 수량간에는 $y=1395+0.048x$ (r=0.068**)의 관계가 있었으며 전질소 함량이 높을수록 암모니아 잔류량도 증가하는 경향이었다.

2. 유기태급원은 무처리나 무기태급원에 비해 퇴비의 전질소가 증가되었으며 수량도 높았다.

3. 퇴비의 암모니아 잔류량과 양송이 수량간에는 $y=0.38086-0.011948x+0.00012x^2$ (r=−0.75**)의 관계가 있었으며 안전다수확을 위해서는 0.03%(질소함량으로서)를 넘지 않아야 했다.

4. 유안의 사용은 암모니아 잔류량이 높았으며 양송이 수량이 낮은 반면 요소는 그 잔류량이 낮고 수량이 유안에 비해 현저히 높았다.

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