Improvement of Cultivation-method of Bean Sprouts by Using Rotary-type Box

(Studies on Cultivation and Keeping Quality of Bean Sprouts Part XI)

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A rotary-type cultivation box was developed for use in cultivation of thick bean sprouts. Using this box, an attempt was made to produce thick bean sprouts from soybean and mung bean by intermittently applying short time rotation, and growth and quality of the bean sprouts were studied. An octagon type box was devised and then was rotated at two different speeds (low speed : 5 rpm, high speed : 10 rpm). Material beans were germinated for two days in a usual way and, immediately thereafter, put in the rotary-type box and treated with rotation at 5 or 10 rpm for 10 min every 8 h every day. Cultivation in the rotary-type box had a remarkable effect on the growth and quality of the thick bean sprouts. The cultivation in octagon type box rotating at low speed made it possible to produce commercially favorable, high-quality "thick" sprouts, because it was extremely effective in increasing length and thickness of the hypocotyls. The high speed rotation of the box was judged to be inappropriate, since it gave an excessive growth inhibition resulting in commercially unfavorable products. Root growth was significantly inhibited by cultivation in the rotary-type cultivation box, where a considerable inhibition of elongation and increase in number of hypocotyls developed took place. The suitable time for harvest as judged in terms of market acceptance was reached after 5 days' rotation-treatment, which means reduction by 2 ~ 3 days of the cultivation time. It was also confirmed by a statistic examination of the results that this method presented an effective improvement. By using it, cultivation and production of commercially favorable thick bean sprouts that meet consumer requirements was made possible.

Among various kinds of bean sprouts, so-called thick bean sprouts, whose roots are thick and short, tend to be favored by consumers lately. We have investigated in the previous works^{1)~4)} the improvement of production and cultivation methods for thick bean sprouts by the single or combined use of artificial sunlight, ethylene and carbon dioxide. As the results of this improvement the production and cultivation of thick bean sprouts were made possible. However, growth inhibition of the roots, including the number of lateral roots developed and their elongation, was not enough and vigorous root growth took place after 5 ~ 7th day of cultivation. In addition, when they were cultivated on commercial scale, growth

inhibition and putrefaction of hypocotyls was observed at the central and lower part of the cultivation box. This phenomenon was ascribed to oxygen shortage and heat generation caused by germination and root growth in the cultivation box, defective spraying and draining and weight increase resulting from growth. These problems can greatly be alleviated by turning the bean sprouts mass in the cultivation box at middle stage (day 3 ~ 4) of their cultivation. Based on these findings, attempts were made to make water distribution and air ventilation in the box uniform and also make water draining more efficient by rotating the cultivation box. The rotating of the box was expected, at the same time, to inhibit geot-

ropism⁵⁾ of the roots and prevent roots and hypocotyls from getting entangled with one another, thus effecting inhibition of the individual-supporting function⁵⁾ of the roots. In this paper we will report on the effects of a rotary-type cultivation box for thick bean sprouts which has been developed by us.

Materials and Methods

The starting materials were soybeans (*Glycine max* Merr., cv. "Sodefuri", from Hokkaido), and mung beans (*Vigna radiata* R-wilcz, from Kawanishi). The outline of the method used in this work for cultivating thick bean sprouts are described in a previous report⁶⁾. Raw beans, which had been harvested 60 days before, were stored for 5 months at 0°C and 85

% ($\pm 2\%$) RH. Then, after steeping in water for 5 h at 28 ~ 30°C, steeped beans corresponding to 400 g raw beans per experiment were germinated on a germinating floor (50 cm³, 28 ~ 30°C) for 2 days, during which water (1 l/min) was sprayed for 15 min every 4 h. The germinated beans were then cultivated in a rotary-type cultivation box as shown in Fig. 1. The capacity of the box was set at 0.02 m³. The rotation speed was, 5 rpm in low speed groups and 10 rpm in high speed groups, and in each experimental groups rotation was made for 10 min. A gas cylinder part as shown in Fig. 1 was additionally equipped for further experiments. Production and cultivation of thick bean sprouts by the use of the rotary-type cultivation box was conducted as

Fig. 1 Treatment system of a rotary-type cultivation box for the cultivation of bean sprouts

follows : the material beans germinated for 2 days were put in the rotary-type cultivation box and, after 12 h water was sprayed at a rate of 1 l/min every 4 h for 15 min. The spraying water was supplied through an additionally equipped solenoid valve with a timer from a constant-temperature water bath kept at 28 ~ 30°C. At the same time, continuous ventilation was applied with a pressure pump at a rate of 1.2 kg/cm²/1.5 l/min.

The pressure pump has been used because it had been found in preliminary experiments that natural ventilation could not give enough draft owing to narrow ventilation pipes in the system and putrefaction took place. The spraying parameters were set on the basis of the experimental results in the previous report⁶⁾. The cultivation system drained very well since the box was given rotation. As regards the shape of the rotary-type cultivation box, octagon type were developed since, in the case of a cylinder type box, growth of the root and lateral roots was not uniform because they adhered closely to one another. Control section was soaked in 30°C water for 5 h and planted on sprouting beds (30 cm × 30 cm × 30 cm) in the dark at 30°C. Water was sprayed for 15 min at intervals of 4 h.

The produced thick bean sprouts were measured for hypocotyl and root elongation, and rheological parameters⁴⁾. The experiments were repeated ten times by using 20 individuals per experiment and samples were discarded after each measurement. T-test was employed to determine whether the data were statistically significant, ** and * in the test denoting significance at 1.0 and 5.0% levels, respectively.

Results

Hypocotyl length

Bean sprouts showed an increasing hypocotyl growth in all treatment groups during 1 ~ 5 days' cultivation in the box and after that, the growth slowed down. The same trend was observed in the control group.

When the effect of rotation speeds (low : 5 rpm × 10 min in the box ; high : 10 rpm × 10 min in the box) was compared on hypocotyl

growth of the bean sprouts, low speed rotation gave longer hypocotyls in bean sprouts. The hypocotyl growth reached commercially acceptable length of thick bean sprouts, i.e. 4.5 ~ 6.0 cm on 5th day cultivation in the rotation box, indicating that this stage is the most suitable for harvest in terms of hypocotyl growth. When low speed rotation was applied, soybean sprouts became harvestripe on 5.0 ~ 5.5th day of rotation treatment in the box, while mung bean sprouts became so on 5th day in the box. When high speed rotation was applied, on the other hand, no commercially acceptable growth was reached within 7 days of cultivation in the box, indicating an excessive inhibition of the hypocotyl growth. These results are shown in Fig. 2.

It can be seen from the results that hypocotyl growth on 5th day (at this stage, sprouts are harvest-ripe and commercially acceptable) of rotation treatment was significantly inhibited as compared with that on 5th day of the control cultivation : when low speed rotation was applied, soybean sprouts gave hypocotyl growth inhibitory of $54.3 \pm 1.06\%$ **, while mung bean sprouts gave $74.4 \pm 1.72\%$ **. A similar trend was observed when high speed rotation was applied : soybean sprouts gave

Fig. 2 Effect of treatment system of a rotary-type cultivation box on the elongation of hypocotyl bean sprouts

201.1 $\pm$ 1.94%**, while mung bean sprouts gave 167.6 $\pm$ 2.91 %**. High quality thick bean sprouts, both from soybean and mung bean, could be produced in the box when low speed rotation was applied. The most favorable hypocotyl growth in the cultivation of thick bean sprouts was obtained in rotating at low speed, in which highly significant growth inhibition was observed in all of the rotation treatment groups.

Thickening of hypocotyls

Hypocotyls of both bean sprouts including control groups tended to grow thicker until 4 ~ 5th days of cultivation then to become finer as shown in Fig. 3.

Thickening of hypocotyls was considerably promoted very much by cultivation in the rotary-type cultivation box. Meanwhile, low speed rotation promoted hypocotyl thickening more than high speed one. The difference in hypocotyl thickening of the two bean sprouts between the two rotation speeds was about 15 %. As the data indicate, low speed group gave the best result in terms of thickening suitability. The shape of cultivation box had a slightly greater influence, also in hypocotyl thickening, than the rotation speed. In thick bean sprouts, commercially acceptable diame-

ter at the central part of hypocotyls is supposed to be 4.0 ~ 4.5 mm. If the diameter is too large, a lot of fiber is contained in the hypocotyls and when eaten, the sprouts are felt less chewy. Moreover, too thick hypocotyls also make water tube part too thick and such a water tube part has a tendency to soften on cooking. After all, the lowered tissue strength brings about poor market acceptance.

Hypocotyl thickening of the bean sprouts was compared on 5th day of the rotation treatment, when hypocotyl length is suitable for harvest and commercially acceptable, with that of the control sprouts on the same day. When low speed rotation was applied, soybean sprouts gave hypocotyl thickness promoted to 72.4 $\pm$ 0.61 %**, and mung bean sprouts gave 62.9 $\pm$ 1.84 %**. When high speed rotation was applied, on the other hand, soybean sprouts yielded hypocotyl thickness promoted to of 96.5 $\pm$ 0.97 %**, and mung bean sprouts yielded 79.6 $\pm$ 0.46 %**. These results show a greatly promoted hypocotyl thickening in all rotation-treatment groups. In terms of market acceptance, the most suitable harvest time was considered to be 5th day of the rotation. Thus, rotary-type cultivation box for use in bean sprouts production was found effective for promoting hypocotyl thickening and its effect was observed highly significant.

Root elongation

One of the requirements consumers have for thick bean sprouts is that they have short roots and few lateral roots. Thick bean sprouts, both from soybean and mung bean, produced in a rotary-type cultivation box showed a significantly inhibited root elongation in each treatment and the root grew slowly, yielding a satisfactory performance as shown in Fig. 4.

There was almost no difference in root length and elongation speed between the two bean species, while a slight difference was observed between the two rotation speeds. The root elongation of the rotation-treated bean sprouts was compared on 5th day of cultivation, which was judged to be suitable for harvest on the basis of hypocotyl elongation and thickening,

Fig. 3 Effect of treatment system of a rotary-type cultivation box on the thickening of hypocotyl of bean sprouts

Fig. 4 Effect of treatment system of a rotary-type cultivation box on the elongation of root of bean sprouts

with that of control bean sprouts on the same day. When low speed rotation was applied, soybean sprouts gave a root elongation inhibitory of $164.1 \pm 1.19\%^{**}$, and mung bean sprouts gave $282.3 \pm 2.65\%^{**}$. When high speed rotation was applied, on the other hand, soybean sprouts gave $246.5 \pm 1.51\%^{**}$, and mung bean sprouts gave $398.7 \pm 1.81\%^{**}$. These results show that high speed rotation gives a greater inhibition effect than low speed one. The substantial difference between the two rotation speeds, in the root length in the box reached about 5 mm on 5th day of rotation treatment. In the cultivation of thick bean sprouts in as rotary-type box, the root elongation-inhibiting effect was highly significant in all treatment groups, and thus, production of high quality thick bean sprouts that are acceptable to consumers was made possible by the use of a rotary-type cultivation box.

Elongation and number of lateral roots developed

The inhibiting effect on the elongation and increase in number of lateral roots developed was, in terms of rotation speed and box shape, greater in high speed and in the box groups, respectively, as shown in Fig. 5.

In lateral root elongation, both bean sprouts exhibited a tendency to be inhibited to a similar extent in all treatment groups. The lateral root elongation was compared on 5th day of

Fig. 5 Effect of treatment system of a rotary-type cultivation box on the count and elongation of lateral root of bean sprouts

rotation treatment, which is supposed to be a suitable time for harvest as judged from market acceptance, with that on the same day of the control treatment. When low speed rotation was applied, soybean sprouts gave a lateral root elongation inhibition of $242.8 \pm 2.41\%^{**}$, and mung bean sprouts gave $143.2 \pm 1.71\%^{**}$. When high speed rotation was applied, on the other hand, soybean sprouts gave inhibition of $471.6 \pm 1.71\%^{**}$, and mung bean sprouts yielded $301.6 \pm 1.54\%^{**}$. As seen from these results, the elongation inhibiting effect was remarkable and was statistically significant in all treatment groups. The development of lateral root was significantly inhibited in both bean sprouts. The difference in inhibiting effect was slightly more remarkable between the two rotation speeds than between the shapes. The number of lateral roots developed in the rotation-treated bean sprouts was compared

with that in the control groups on 5th day of cultivation, which is supposed to be a suitable harvest-time in terms of market acceptance. When low speed rotation was applied, soybean sprouts gave a development ratio of inhibition of $206.1 \pm 1.65\%^{**}$, and mung bean sprouts gave $143.1 \pm 0.74\%^{**}$. When high speed rotation was applied, on the other hand, soybean sprouts yielded $400.6 \pm 2.14\%^{**}$, and mung bean sprouts yielded $242.7 \pm 2.14\%^{**}$. It is clear from these results that the lateral root development was considerably inhibited. This trend was observed in all treatments and the effect was statistically highly significant.

Thus, no entanglement of the roots took place and the sprout grew well and uniformly in the cultivation box.

Discussion

The rotary-type cultivation box was quite effective in cultivation of "thick" bean sprouts.

The above described results in the production of "thick" bean sprouts are considered to have been obtained by the rotation cultivation box, where metabolic process is partly put into disorder by a stress caused in water and temperature distribution and supporting capability of the roots during the growth of plants, resulting in a decreased growing rate⁷⁾. In this cultivation method, sprayed water was uniformly distributed and drained out by virtue of the rotation of the box unlike the fixed-type cultivation box, where the water stays in the lower parts, and difference in growth between upper and lower parts or putrefaction takes place. The rotation also brought about a uniform distribution of the heat generated during plant growth. These stresses are considered to have worked favorably in producing quality bean sprouts. The low speed rotation, in particular, seems to have effectively functioned. Meanwhile, these satisfactory results were also given by rotation, possibly because it inhibited root growth by preventing roots from adhering to one another, from being curved by gravity caused by weight increase, and by inhibiting supporting capability of the tissue and geotropism⁸⁾ of the root for nutrient uptake. An-

other explanation is that the stresses caused by rotation influence distribution of the surface water and heat in roots and hypocotyls of the bean sprouts, which lowers, in the whole parts of individuals, nutrient-absorbing capabilities or limits competition among them, resulting in inhibition of the function inherent in roots. This inhibition, in turn, causes insufficient absorption of ions contained in the spray water, etc. and a limited growth, especially of the roots⁹⁾¹⁰⁾. These phenomena might have jointly worked to inhibit hypocotyl growth, bringing about a delayed development of the secondary growth processes¹⁰⁾, which, in turn, brought about an increased hypocotyl growth. Further studies are needed to clarify the relationship between these stresses and some factors such as moisture, temperature and absorption of inorganic ions.

Statistical significance of the results was also examined. It was made statistically clear as a general tendency that the octagon type box rotating at low speed yielded the best results but there was no considerable difference with the sexangle-type box on the preliminary experiment, and the rotation treatment in the octagon type box was confirmed to present an effective improvement method of cultivating "thick" bean sprouts.

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回転型栽培床の開発と豆類太もやしの生長と品質

豆類もやし栽培と鮮度保持に関する研究 (第11報)

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豆類太もやし栽培法として回転型栽培床を開発し、間欠的、短時間の回転処理を行い、ダイズ、リョクトウの

太もやし栽培を試み、生長と品質について検討した。回転型栽培床は、低速回転区 5 rpm, 高速回転区 10 rpm とし、8 角型を考案した。常法で原料豆を 2 日間発芽させたのち、直ちに回転型栽培床に置床し、12 時間後より毎日 8 時間毎に 10 分間回転処理を行った。回転型栽培床による豆類太もやしの栽培は、生長、品質に顕著な影響を及ぼした。低速回転型 8 角区がはい軸部の伸長、肥大に極めて有効で、市場適性に合致した良質の“太もやし”の栽培が可能であった。高速回転型区は生長抑制が過度となり、市場性に欠け不適格となった。回転型栽培床による栽培では、根の生長抑制が顕著で、側根の伸長、発生数も大きく抑制された。栽培日数も市場適性度よりみて処理栽培 5 日が収穫適期となり、通常栽培より 2~3 日栽培日数は短縮された。豆類の太もやし栽培法として本法は有効なる改良法であることが統計学的にも確認され、消費者の要望に合致した市場性豊かな豆類もやしの栽培製造が可能となった。