モウソウチク両用林の生産に及ぼすホウ素とマグネシウムの効果

Effects of Elements Boron and Magnesium on Growth in Culm and Shoot-producing Stands of Moso Bamboo

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Summary

In the paper, the effect of boron (B) and magnesium (Mg) in combination with NPK fertilizers on bamboo growth in culm and shoot-producing stands of Moso bamboo was studied. The results indicated the addition B fertilizer (NPK+B) gave high potential in increasing the number of 1-yr-old bamboo and the bamboo biomass. On the other hand, the addition Mg (NPK+Mg) was beneficial in increasing the yield of bamboo shoot. To the mean DBH (diameter at breast height) of 1-yr-old bamboo, no significant increment was observed for almost all of the treatments. The benefits analysis suggested that the annual incomes of treatments NPK+B and NPK+Mg were 293, 975 yuan(RMB)/ha more than that of NPK applied alone, respectively. In the present trials, it was also found that the effect of fertilization on bamboo growth was positively related to the parent bamboo density of Moso bamboo stands remarkably.

Key words : boron, magnesium, fertilization, Moso bamboo (*Phyllostachys pubescens*), culm and shoot-producing stands
キーワード：キーワード：ホウ素、マグネシウム、施肥、モウソウチク、両用林

I. Introduction

Moso bamboo (*Phyllostachys pubescens*) is mainly distributed in Asia, as well as other areas, shared the broadest distribution and highest value in all bamboo species (Encyclopedia of Agriculture of China, 1989; Lichao Wu, 1997). Cultivation of Moso bamboo has a long history in China (Mao Dashang, 1959; Forestry publication of China, 1991; Jin Chuan, 2000), but so far in most cases, the widely distributed bamboo plantations are still growing under natural conditions (Ma Naishun, 1989; Wang Xiaoming, 1991; Zhang Guofang, 2000). Along with the

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Sci.Bull.Fac.Agr.Univ.Ryukyus **49** : 223 ～ 229 (2002)

development of national industrial plantation, the reforming of low-yielding plantation of Moso bamboo has been given great attention in China during the last 20 years, (Luo Fuxing, 1984; Cooperation group of Moso bamboo research on the reforming of low-yielding stands, 1986; Chen Cunji, 1994). Fertilization has been regarded as the main measures for Moso bamboo nutrient management (He Zhunchao, 1992; Chen Jinlin, 1996).

In China, the fertilization of Moso bamboo began at the 50's of last century (Mao Dashang, 1958; Li Songmao, 1958; Xong Wenyu, 1959). The problems in the study of fertilization were reviewed by Lichao Wu et al(Lichao Wu, 1997). Some researchers have studied the effect of NPK on growth of Moso bamboo. Yang Shide reported the effect of element silicon on growth of Moso bamboo (Yang Side, 1982). Wang maozhi et al pointed out that it takes not only a abundant of elements NPK from soil, but also a large of Mg, calcium, and some of trace elements for the growth of Moso bamboo (Wang maozhi, 1985; Zhang Guofang, 2000). However, except of NPK, the study of other elements, especially, trace elements, on bamboo growth is insufficient. To develop adequate fertilization techniques, the quantity determination of fertilization for the major types of forests in south China under different site conditions were conducted as a cooperative project "Fertilization in Chinese Plantation Forest in South China" between Central South Forestry University and Norsk Hydro a.s, Oslo, Norway since 1995. The paper is one part of the studies (Lichao Wu, 2001).

In the paper, we focus on the effect of B and Mg on growth of Moso bamboo in combination with NPK fertilizers, which were recommended by site nutrient effect model (Wu Xiaofu, HuYueli. 1994; Lichao Wu, 2001).

Ⅱ. Material and Methods

1. Material

The study was carried out at Taojiang Forest Farm, located in Taojiang County(28° 30′ N, 111° 36′ E), Hunan province, China. The place is famous for its abundant resource of Moso bamboo and long history of bamboo cultivation, thus being named "Bamboo Counties". The mean annual temperature is 15～17℃, and the mean temperature in the hottest month, and the coldest month, are 40℃ and -10.3℃, respectively. The mean annual rainfall is 1550mm with the annual relative humidity 81%. The topography of the area is hilly. The summit is 648m a.s.l, and the altitude at the study site is between 245～350m a.s.l. The gradient is between 15～25.° The parent bedrock is sandy slate, and the red soil develops. In addition, the thickness of soil horizon is more than 60cm. The trial was conducted in the existing Moso bamboo (*Phyllostachys pubescens*) forests. The densities of Moso bamboo were 1400～2500stems/ha. The soil chemical and physical properties of the study site are showed in Table 1.

Table 1. Soil chemical and physical properties at the study site

pH	Organic matter ($g.kg^{-1}$)	Total nitrogen ($g.kg^{-1}$)	Available phosphorus ($mg.kg^{-1}$)	Exchangeable potassium ($mg.kg^{-1}$)	Delayed potassium ($mg.kg^{-1}$)	Bulk density of top layer (g/cm^3)	Soil texture
4.5-5.0	27.3	2.5	4.0	42.0	168.3	1.0	loam

2. Methods

1). Investigation and fertilization

Before the fertilization all bamboos in study plots were recorded including height, DBH, age of the bamboo. After the fertilization, the 1-yr-old bamboos were recorded including height and DBH in June every year. The fertilizers were manured to the eyebrow-like ditch, which is 100cm long, 15cm in width and 20cm depth. The fertilization period was in June 1997.

2). Experimental design

The experimental design included 2 rates of N (0, 71kg N/ha), 2 rates of P (0, 31kg P/ha) and 2 rates of K (0, 59kg K/ha) with 3 treatments for both element boron and magnesium, showed in Table 2. The fertilizer amount for B and Mg were put according the conventional applied amount. NPK fertilizers were applied according to the site nutrient effect models (Hu Yueli, Wu Xiaofu, 1994; Lichao Wu et al, 2001). The treatments in same block were arranged in contour line. Plot area is 667㎡ and the fixed labels were set in four corners of each plot.

Table 2 Amount of fertilizers in fertilization treatments

Unit : kg/ha

Element	Treatment	N	P	K	B or Mg
B	NPK-B	71	31	59	0.5
	NPK (CK_1)	71	31	59	0
	Control (CK_0)	0	0	0	0
Mg	NPK-Mg	71	31	59	0.5
	NPK (CK_1)	71	31	59	0
	Control (CK_0)	0	0	0	0

Ⅲ. Results and discussion

1. Effect of B fertilizer on bamboo forest growth

The effect of B on growth of Moso bamboo is given in Table 3. The results showed that addition boron, namely NPK+B treatment, had a positive effect on both the number of 1-yr-old bamboo and the biomass compared with the conventional fertilization treatment CK_1. For the number of 1-yr-old Moso bamboo, the treatment NPK+B gave the increment of 20.0% compared with that of CK_1. At the same time, CK_1 was 32.0% more than that of non-fertilizer treatment CK_0. For the biomass of 1-yr-old bamboo, the NPK+B treatment, increased the growth of 20.6%, 50.4%, respectively, compared with treatments CK_1 and CK_0. These suggested the addition B gave the further increase for the number of the 1-yr-old bamboo and the biomass. To the average DBH of 1-yr-old Moso bamboo, negative effects were found for all three treatments. This indicated that in a short period the growth for DBH of 1-yr-old bamboos was limited although there is a trend of increase in average diameter of a bamboo forest after fertilization. The result was coincided with the previous report (Lichao Wu, 2001).

To the yield of bamboo shoot, there was no significant difference observed between the

treatments NPK+B and CK_1 although both of them were obviously higher than that of treatment CK_0. This suggested addition B did not appear to be necessary for bamboo shoot increment.

Table 3. Effect of applied B on growth of Moso bamboo

Treatment	Parent bamboo		1-yr-old bamboo					Bamboo shoot	
	No/ha	DBH (cm)	No/ha	Increment (%)	DBH (cm)	Biomass (ton/ha)	Increment (%)	Yield (kg/ha)	Increment (%)
NPK+B	1480	8.82	450	20	8.61	7.6	20.6	2,265	3.4
NPK(CK_1)	1420	8.80	375	0	8.40	6.3	0	2,190	0
Control(CK_0)	1450	8.95	255	-32	8.80	4.4	-29.8	720	-67.1

2. Effect of Mg fertilizer on bamboo forest growth

The effect of Mg fertilizer on Moso bamboo growth is shown in Table 4. The results showed that to the yield of bamboo shoot, the significant differences were observed among the three treatments. The additional Mg treatment, namely NPK+Mg, gave the further increment of 17.3% more than that of the conventional treatment CK_1.

To the number of 1-yr-old Moso bamboo, NPK+Mg treatment shared the highest increment amongst the three treatments, with 930 stems/ha, which was 43.9% more than that of CK_0 (555 stems/ha), and 8.8% more than that of CK_1.

To the biomass of 1-yr-old bamboo, no significant difference was observed between the treatment NPK+Mg and CK_1 although both of them were much bigger than that of treatment CK_0. This indicated that additional Mg was not necessary for bamboo biomass increment. Furthermore, to the DBH of 1-yr-old bamboo, the increment was also limited although there were a certain of increments for treatments NPK+Mg and CK_0.

The results from the present trials indicate clearly the additional B fertilizer given high potential in increasing the number of 1-yr-old bamboo and bamboo biomass. Relatively, the addition Mg is beneficial in increasing the yield of bamboo shoot.

Table 4. Effect of applied Mg on growth of Moso bamboo

Treatment	Parent bamboo		1-yr-old bamboo					Bamboo shoot	
	No/ha	DBH (cm)	No/ha	Increment (%)	DBH (cm)	Biomass (ton/ha)	Increment (%)	Yield (kg/ha)	Increment (%)
NPK+Mg	2082	9.02	930	8.8	9.27	17.3	2.8	3,885	17.2
NPK(CK_1)	2100	8.59	855	0.0	9.55	16.8	0.0	3,315	0
Control(CK_0)	2108	8.36	555	-35.1	8.43	8.6	-48.8	720	-78.3

3. Economic profits and density effect

The economic analysis following fertilization is given in Tables 5. The calculation of the yield increment is based on the increment of the 1-yr-old bamboo culm and bamboo shoot. The price of the bamboo culm is estimated as 420 yuan (RMB) per ton of wet matter, and 2.0 yuan per Kg for fresh bamboo shoot. Tax is estimated as 12% of rough income. The result showed that both of fertilization treatments NPK+Mg and NPK+B increased the annual income by more than 50% compared with those of CK_0 in all of two density areas. Addition of B gave 9 % of annual income increment than CK_1. And addition of Mg hit annual income increment higher than 14%. The annual incomes of treatments NPK+B and NPK+Mg were 293, 975 yuan (RMB)/ha more than that of NPK applied alone, respectively.

In the present trials, the effect of fertilization on bamboo growth is related to the original densities of Moso bamboo stands remarkably. The higher the original density, the higher the yield of 1-yr-old bamboo and its biomass. For the treatment of addition of Mg whose density located in density higher than 2000 stems/ha, both of the yield of 1-yr-old bamboo and annual income, were 2 times higher than those of trials located in lower density area with density lower than 1500 stems/ha. From the view of annual income, NPK+Mg treatment, with the annual income over 7800 yuan/ha, was much better than NPK+B, with annual income lower than 3600 yuan/ha.

In Taojiang, the optimal bamboo forest density is determined as about 4000 stems/ha under local site conditions. In the present study, the field fertilization was carried out between 1400~2200 stems/ha. As the density of the bamboo in the trial areas was much lower than the determined optimal figure, the consecutive density fertilization trial should conduct to confirm the effect of Mg and B fertilization on bamboo growth.

Table 5 Economic benefits analysis for different treatments

Treatment	Parent bamboo	1-yr-old bamboo		Bamboo shoot	Rough income	Cost			Tax	Annual income	Increment
	No/ha	No/ha	No/ha	kg/ha	Yuan/ha	Fertilizer	Fertilizer-tion	Cut	Yuan/ha	Yuan/ha	(%)
NPK+B	1480	450	7.6	2,265	6448	1000	450	637	774	3587	9
NPK(CK_1)	1420	375	6.3	2,190	5970	950	450	560	716	3294	0
Control(CK_0)	1450	255	4.4	720	2556	0	0	311	307	1938	-41
NPK+Mg	2082	930	17	3,885	12125	1000	450	1322	1455	7898	14
NPK(CK_1)	2100	855	17	3,315	10866	950	450	1239	1304	6923	0
Control(CK_0)	2108	555	8.6	920	4010	0	0	557	481	2972	-57

* The percentage of culm is estimated as 60% of total biomass; fee of fertilization 450yuan/ha Fee of cutting 90yuan/t; fee of bamboo shoot collecting 10% of its rough income.

Acknowledgments

The authors are grateful to all staff of Technological Section of Taojiang Forest Farm who helped in the field works. Financial support was partly provided by Norsk Hydro a.s, Oslo, Norway.

References

1. Chen Cunji, Dong Jianwen, Jiang Qixiang. 1994. The factors of forming, types and reforming of low-yielding stands of Moso bamboo. Journal of Fujian college of forestry, 14(4):366～370*
2. Chen Jinlin 1996. Preliminary study of fertilization technology of high-yielding of Moso bamboo. Forestry Research. (3):323～327*.
3. Cooperation group of Moso bamboo research on the reforming of low-yielding stands 1986. Study on consecutive cultivation technology of Moso bamboo plantation. Journal of bamboo research, (2):64～77*.
4. Forest publication of China, 1991. Study on ecological economical plan and development method for Moso bamboo in China. Beijing*
5. He Zhunchao 1992. Four-time fertilization methods for high-yielding of bamboo shoot. Journal of bamboo research. (2):97～100*.
6. Hu Yueli, Wu Xiaofu. 1994. Study on forest fertilization: I. Principle of fertilization efficiency and basic models. Journal of Central-South Forestry University. Vol.14, No.1:1～6.
7. Jin Chuan, Wang Yueying, Zhen Wenjie 2000. The current situation and prospect of bamboo shoot research. Journal of Zhejinang College of Forestry, (1)*.
8. Lichao WU, Hu Yueli and Wu Xiaofu. 1997. The development of research on Moso bamboo calculated fertilization. Guangxi Forestry Science, No.4:164～169(in Chinese).
9. Lichao Wu, Wu Xiaofu, Hu Yueli and Takakazu Shinzato. 2001. Models for predicting biomass and fertilizer utilization coefficient for Moso bamboo, Sci. Bull. Fac. Agr. Univ. Ryukyus No. 48:175～183.
10. Lichao Wu, Wu Xiaofu, Hu Yueli and Takakazu Shinzato. 2001. Application of forest fertilization models in culm-producing stands for Moso bamboo, Sci. Bull. Fac. Agr. Univ. Ryukyus No. 48:185～194.
11. Li Songmao, 1958. A new way to increase Moso bamboo production-by use of Chinese tallow tree oil as fertilizer. Journal of Zhejiang Forestry, (5) :36*
12. Luo Fuxing, 1984. Technological measures to reform the low-yield Moso bamboo forest. Bamboo Research, (1):65～69*
13. Mao Dashang, 1958. Human beings cultivate the forest and the forest supports the human beings, the keys of high yielding measures are fertilization, loosening the soil and keeping bamboo shoots in Spring. Journal of Zhejiang Forestry, (3)*
14. Ma Naishun. Bamboo 1989. Bamboo study in China. Journal of Bamboo Research. Vol.8, No. 1:76～83.
15. Publication of Agriculture of China, 1989. Encyclopedia of Agriculture of China. Volume of forestry. : 604*
16. Wang Maozhi 1985. Effect of loosening of the soil and fertilization on Moso bamboo plantation. Journal of bamboo research, (2):46～54*.
17. Wang Xiaoming, 1991. The current situation of bamboo research in China. Bamboo Research, (2):90～102*.
18. Xong Wenyu, 1959. Fertilization experiment of high yielding cultivation for Moso bamboo

forest. Journal of Nanjing Forestry University, (2):17～23*

19. Yang Shide, 1982. Significant effect observed on Moso bamboo growth by apply of silicate fertilizer. Bamboo Research, (1):76～80*
20. Zhang Guofang 2000. The development of research on Moso bamboo management. Journal of Fujian college of forestry, 20(4)*.
21. Zhou Fangchun, 1983. Bamboo production of our country and preview of its research situation. Bamboo Research, (1)*.

* The titles are tentative translations from Chinese titles by the authors of the paper.

モウソウチク両用林の生産に及ぼすホウ素とマグネシウムの効果

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摘 要

モウソウチク（*Phyllostachys pubescens*）は主にアジアに分布するが、経済的価値が高いことから広く栽培され、中国では栽培の長い歴史を有している。だがその生産性は未だ低く、ほとんど天然林からの収穫に依存しており、林地肥培などによる栽培技術の向上が望まれている。最近では肥料元素とモウソウチク生産関連の研究も多くなってきた。本報告では筍と竹材の生産を目的とした両用林において、モウソウチクの成長に関与する一般NPK肥料とホウ素、マグネシウムの配合による効果に注目した。

実験は中国湖南省、桃江県にある国有林林場で実施した。一般肥料（N-71Kg/ha, P-31Kg/ha, K-59Kg/ha）にホウ素0.5Kg/haを配合した処理区は、一般肥料区と無肥料区に比較して1年生茎の数量、バイオマス量の増大に効果があった。ホウ素配合肥料区は一般肥料区より１年生茎の発生量で20%、バイオマス量で20.6%増大したが、生産量には顕著な差がなかった。マグネシウム配合肥料区(0.5Kg/ha)は、一般肥料区より生産量で17.2%増大したが、1年生茎とバイオマス量に対する効果は明確ではなかった。全実験林で、ホウ素、マグネシウム配合肥料区と一般肥料区は、無肥料区に比較して1年生茎の発生数量、バイオマス量、生産量とも増大効果が見られた。

年間収入は、２つの配合肥料区で、無肥料区に比較して50%以上、一般肥料区に比較してホウ素配合肥料区で９%、マグネシウム配合肥料区で14%増大した。林地肥培はモウソウチク林の密度に影響し、マグネシウム配合肥料区では2000本／ha以上で、1年生茎と年間収入とも1500本／ha以下の林分の２倍以上であった。桃江県におけるモウソウチク林の最適密度は約4000本／haである。今回の実験は1400～2000本／haで遂行された。ホウ素とマグネシウムの効果についてはさらに多くの密度で検証していく必要があろう。

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琉球大学農学部学術報告 49：223 ～ 229 (2002)