GROWTH PROMOTION OF TEA TREES BY PUTTING BAMBOO CHARCOAL IN SOIL

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Summary

To produce high-quality green tea with reduced amounts of agricultural chemicals and fertilizers, a 10-year field experiment was started in 1998 to determine the feasibility of using bamboo charcoal in the soil. The experiment, conducted in the eastern part of Shizuoka Prefecture, Japan, consisted of 8 plots with an actual cultivating area of 1,600m^2.

Today, after three years of this experiment, the bamboo charcoal has tended to retain the supplied fertilizers in the rhizosphere. The bamboo charcoal also tended to keep the soil pH in a range that was suitable for the growth of tea trees. The heights and volumes of the tea trees in the plots in which the charcoal was used were, on average, 20% and 40% greater, respectively, than they were in the negative control. However, no differences were observed in the number of new shoots per tree or in the length of new shoots (stem length of three leaves and the shoot apex). The plot that had the best tea tree growth had been treated with 100g crushed bamboo charcoal (particle size approximately 5 millimeters) per square meter per year.

At this point in the experiment, the use of charcoal in the soil has not yet resulted in any clear differences in key elements in the green tea product made from plucked new shoots.

Keywords

Cultivation, Field experiment, Reducing fertilizer use, Soil improvement

Introduction

The use of charcoal in farmlands is considered to be effective for improving the soil and promoting crop growth. However, there have been no long-term studies on the effects of charcoal on tea cultivation.

Abandoned Moso bamboo (*Phyllostachys heterocycla* (Carriere) Mitf.) forests with no economic value are found near many farming villages in Japan. Moreover, the spreading of the bamboo trees remaining in these forests is a problem because they interfere with the growth of surrounding trees and crops. It has been proposed that the surplus bamboo could be put to practical use by making charcoal for cultivation.

Much fertilizer, especially nitrogen fertilizer, is used to produce high-quality tea in Japan. This has increased production costs and caused environmental loading of nutrients (*e.g.*, Okano *et al.*, 1995). Various methods for reducing fertilizer use by raising the efficiency with which fertilizers are retained by the soil have been proposed. The use of coated urea fertilizer (*e.g.*, Shiwa *et al.*, 2000) is one such proposal. Improving the soil with bamboo charcoal so that it better retains fertilizer has been proposed as another method.

A long-term (10-year) field experiment was started in 1998 to clarify the effect of bamboo charcoal on the growth of tea trees (Hoshi *et al*., 2001). A long-term experiment was needed because it takes over 10 years for tea fields to fully mature and because the results of a short-term experiment could be masked by yearly fluctuations. Here I describe some of the results obtained in the first three years of this experiment.

Materials and Methods

A flat test field with a cultivating area of 1,600m^2 was prepared. The surface soil was removed to provide uniform conditions for each of eight plots (Table 1). The plots consisted of six small plots (S1-S6) of 100 m^2 and two large plots (L1 and L2) of 500 m^2. S1 was a negative control. Two-year-old transplants by cutting of two cultivars (*Camellia sinensis* var. *sinensis* cv. “Yabukita” and cv. “Okuhikari”) were planted in rows on March 15, 1998. The intrarow spacing was 0.5 m and the distance between rows was 1.8 m, resulting in a transplant density of 1.11 m^{-2}. Homemade bamboo charcoal was made by carbonizing Moso bamboo at 300 - 400 °C in a Miura-type charcoal kiln. A commercially available charcoal was used in S3 and S6. Table 2 shows the mineral contents of the charcoal as determined by particle induced X-ray emission (PIXE) analysis (Johansson *et al*., 1988). Two methods were used to apply the charcoal. In one method, referred to as “single application” in Table 1, rough-crushed charcoal (5 – 10 cm in size) was applied a single time at the start of the experiment to the root zone (under ridges) at a density of 0.5 kg m^{-2}.

In the other method, referred to as "annual application", finely crushed charcoal (5 mm in size) was applied annually in the spring in furrows at a density of 0.1 kg m^{-2} y^{-1}. The amounts of fertilizer (N, P, and K) each plot received during the first 3 years are shown in Table 3. The fertilizer use in each plot differed slightly because of the use of different kinds of composite fertilizers (organic, inorganic, etc.).

Table 1. Specifications of the plots.

Plot	Cultivar	Testing Area (m^2)	Primary fertilizer	Charcoal use		
				Origin	Quantity of dose (kg m^{-2})	Application
S1	Yabukita	100	Inorganic	-	-	-
S2	Okuhikari	100	Inorganic	Bamboo (H)*	0.5	Single
S3	Yabukita	100	Inorganic	Bamboo (P)**	0.1	Annual
S4	Yabukita	100	Organic	Bamboo (H)*	0.1	Annual
S5	Yabukita	100	Organic	Bamboo (H)*	0.5	Single
S6	Yabukita	100	Inorganic	Wood pulp waste***	0.6	Single
L1	Yabukita	500	Inorganic	Bamboo (H)*	0.1	Annual
L2	Yabukita	500	Inorganic	Bamboo (H)*	0.5	Single

*: Homemade Moso bamboo charcoal. **: Commercial bamboo charcoal.
***: Commercial processing charcoal added fertilizer (N:P:K = 1.59%:2.14%:2.02%).

Table 2. Mineral contents of homemade Moso bamboo charcoal as determined by PIXE analysis.

Element	Mg	Si	P	S	Cl	K	Ca	Cr
(ppm)	2240.57	8001.22	301.39	344.83	2413.60	4299.80	480.46	5.43
Element	Mn	Fe	Ni	Cu	Zn	Br	Rb	Sr
(ppm)	20.29	25.51	-	6.15	17.85	2.62	1.94	5.50

Standard element: Pd (1000 ppm)   PIXE: Particle induced X-ray emission

Table 3. Amount of fertilizer applied to the eight plots.

Plot	S1			S2			S3			S4		
Element (g m^{-2})	N	P	K	N	P	K	N	P	K	N	P	K
Before planting	132	440	176	132	440	176	132	440	176	139	413	176
1998	64	43	43	64	43	43	64	43	43	43	43	43
1999	66	50	52	66	50	52	66	50	52	66	56	58
2000	64	46	52	64	46	52	64	46	52	64	46	52
Plot	S5			S6			L1			L2		
Element (g m^{-2})	N	P	K	N	P	K	N	P	K	N	P	K
Before planting	139	413	176	142	385	188	133	387	176	133	387	176
1998	43	43	43	43	43	43	65	43	43	64	43	42
1999	66	56	58	66	56	58	31	23	24	30	23	23
2000	64	46	52	64	46	52	41	29	32	41	29	32

To measure soil pH, dry soil was mixed with 2.5 times it weight of distilled water. The water was filtered and measured with a pH-meter. Soil electric conductivity (E.C.) was measured with an E.C. meter using soil solution that had been filtered 5 times. The numbers of bacteria, fungi and yeast in the soil were counted by the plate dilution method. Four indices were used to measure tea tree growth: tree height, tree volume, and number of new shoots per tree and shoot length (stem length from node of the third leaf to the shoot apex). To determine water content, total nitrogen content and fiber content in new shoots, shoots were picked and analyzed with a near infrared spectroscope (Hara *et al.*, 1994). Total ascorbic acid and caffeine contents in new shoot were determined by HPLC, glutamic acid and theanine contents were determined with an automatic amino acid analyzer, and tannin content was determined by the Folin-Denis method.

Results and Discussion

Soil pH and E.C. Figure 1 shows the soil pH and E.C. in each of the eight plots on December 30, 1998 and June 30, 1999. The soil pH values of the plots that had charcoal in the soil were 1 to 1.5 pH units lower than the pH in the control plot (S1) and were close to the range suitable for tea tree growth (pH 4.0-5.0). The E.C. values in the charcoal plots were higher than the value in the control plot. This was thought to be due to the charcoal in the soil retaining components of the fertilizer salts, because the testing conditions except for the charcoal use were almost the same in each plot. No differences in the numbers of bacteria, fungi and yeast in the soil were observed among the plots.

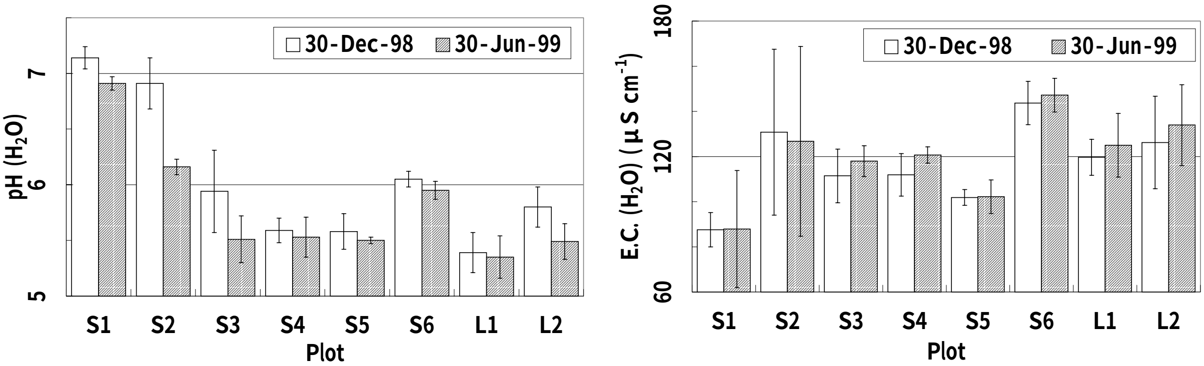

Fig. 1. Soil pH and E.C. in each plot.
Boxes represent means (n = 15 for each of S1 to S6, n = 45 for L1 and L2) and error bars represent ± standard deviation.

Table 4. Tea tree growth in each plot.

Plot	Tree height (cm)	Tree volume (10^3 cm^3)	Number of new shoots (shoots $tree^{-1}$)	Shoot length (cm)
S1 (control)	68.6 ±16.3	304 ±160	25.3 ±6.1	3.4 ±1.0
S2	86.4 ±12.4*	306 ± 85	19.3 ±5.3	3.7 ±0.8
S3	83.1 ±12.0*	482 ±175*	23.0 ±6.6	3.7 ±0.8
S4	93.9 ±10.5*	593 ±187*	24.1 ±5.2	3.5 ±0.9
S5	96.5 ±11.5*	580 ±188*	24.0 ±5.3	3.5 ±0.8
S6	86.1 ±8.7*	439 ±153*	26.2 ±6.4	3.5 ±0.8
L1	91.1 ±9.6*	533 ±175*	25.6 ±7.4	3.7 ±0.9
L2	83.8 ±13.8*	471 ±171*	25.1 ±9.2	3.9 ±0.9
Year/Month	2000/11	2000/11	2000/9	2000/9

Fifteen samples were used for S1 to S6, and 45 samples were used for L1 and L2. Values show means ± standard deviation. * indicates significance at 5% level.

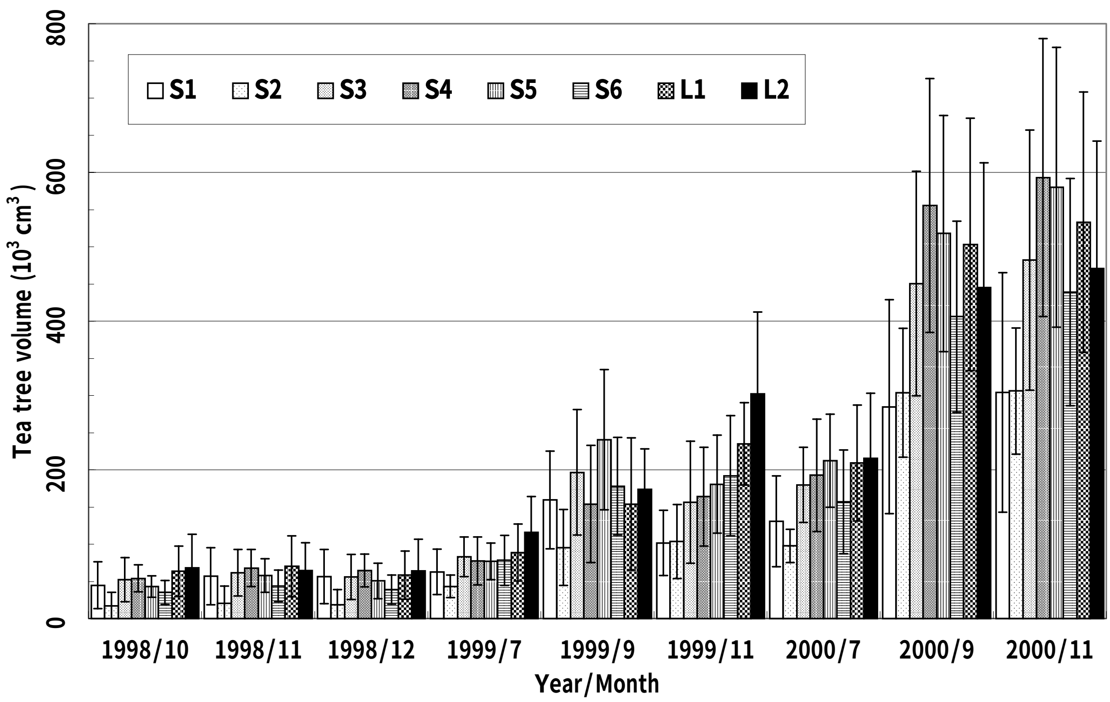

Fig. 2. Tea tree volume in each plot.
Boxes represent means (n = 15 for each of S1 to S6, n = 45 for L1 and L2) and error bars represent ± standard deviation.

Tea tree growth Table 4 shows the tea tree growth in the eight plots as measured by four growth indices. Tree height and tree volume were significantly greater in the charcoal plots than in the control plot. The tree volume and number of new shoots in S2 were relatively low, possibly due to the use of a different cultivar (Okuhikari) in this plot. The difference in tree volume between the trees in the control plot and those in the other plots except S2 appeared to increase with time (Fig. 2). Tea trees in S4, which had the greatest tree volume, were visibly larger than those in S1 (Fig. 3). Tree height was an average of 20% greater in the charcoal plots than in the control plot, and tree volume was an average of 40% greater. In addition, among the charcoal plots, a reduction in the amount of fertilizer applied did not result in a decrease in tree growth. Tree growth tended to be greater with the annual application of charcoal than with the single application, although the difference was not statistically significant.

Fig. 3. Side view and downward view of rows in the control (S1) plot and a charcoal plot (S4) on December 15, 2000.

Ingredients of picked shoots Water content and total nitrogen content were slightly higher in the testing plots receiving organic fertilizer (S4 and S5) than in the plots receiving inorganic fertilizer (Table 5). However, there was not a large difference in quality of the tea, as measured by total ascorbic acid, glutamic acid, theanine, caffeine and tannin, in the new shoots between the negative control plot and the charcoal plots. Further studies of tea quality will be needed to determine the effects of charcoal. The effects, if any, will not be clear until the trees are more fully grown.

Table 5. Water content, total nitrogen content and fiber content in picked new shoots.

Plot	Water content (%)	Total nitrogen content (%)	Fiber content (%)
S1	4.3	6.9	14.8
S2	4.5	6.6	16.8
S3	4.6	6.6	15.8
S4	5.5	7.4	13.7
S5	5.4	7.1	15.0
S6	5.3	7.0	15.5
L1	4.8	6.8	16.7
L2	4.8	6.7	16.2

Samples were picked on May 2, 2000. Picked new shoots of 40 g F.W. were dried by microwave oven and homogenized by grinder before analysis.

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