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EFFECTS OF REDUCED APPLICATION OF SPECIAL ORGANIC FERTILIZERS ON TEA PRODUCTION

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Abstract

A trial of special fertilizer reduction and combined application of organic fertilizer on tea production, nutrients and economic benefits was carried out in the tea garden at Shihe Port, Xinyang, Henan Province, China. The experiment has six treatments of customary fertilization (CK), 100% special fertilizer for tea (T1), nitrogen reduction 20% (T2), 40% (T3), 60% (T4) and 100% (T5), and special fertilizers at the same time. Among the special fertilizer treatments for tea plants, the germination density, 100-bud weight, fresh tea yield, N, P, and K content of new shoots and economic benefits were the highest in T1 treatment, Results showed that the yield range of the five treatments was 460～632.4kg hm^2. Compared with CK, the yield increase rates were 6.11, 1.99, -4.21, -13.76 and -22.82%, respectively. The growth rates of barber bud density and 100-bud weight were -20.00～25.83 and 8.40～ 8.40%, respectively. The content of nitrogen, phosphorus and potassium in the new shoots varied by 0.623～1.070, 0.047～0.183 and 1.380～2.237%, respectively. Therefore, the special fertilizer for tea plants can reduce the nitrogen by 20% to save costs and increase efficiency.

Introduction

Tea trees are perennial cash crops and picked many times a year (Costa *et al*. 2007). Fertilization is one of the important means to increase the nutrient supply of the tea trees from the soil, ensure the normal growth of the tea trees, and improve the yield and quality of tea (Sun *et al*. 2016). The contribution rate of fertilizer input to the increase tea production is as high as 41%, which exceeds the contribution rate of land (25%) and labor (8%) (Bora *et al*. 2019, Shen *et al*. 1990). With the expansion of the area of tea gardens, some tea farmers have used a large amount of chemical fertilizers in pursuit of economic benefits resulting imbalances in the structure of tea garden fertilizers, imbalances in nutrient ratios, decline in tea quality, increased production costs, reduced soil organic matter content, soil acidification compaction, water pollution, etc. (Maltas *et al*. 2013). Zwa *et al*. (2019) and Maghanga *et al*. (2013) reported that it is consistent with habitual fertilization, through a reasonable proportion of nitrogen, phosphorus and potassium, and the appropriate addition of organic matter and trace elements, which not only effectively increase the weight of buds and leaves, increase the yield, but also improve the quality of crops. Simultaneously, the application of special fertilizer for tea trees increased the yield of fresh leaves by an average of 2.5 kg/hm^2 and the output value by 24.5 yuan/hm^2 (Ji *et al*. 2018). Compared with the blank, the output-to-input ratio could reach 1:7.67 (Ruan *et al*. 2004). The increased application of organic fertilizers in tea gardens can increase soil carbon content and nutrient content, improve soil humification and increase its activity, and at the same time can promote tea tree growth and improve the quality of fresh leaves. The combined application of chemical fertilizers and organic fertilizers has more obvious effects (Gu *et al*. 2019, Xie *et al*. 2020). Because of its unique geographical location, good ecological environment and suitable climate

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conditions, Xinyang Maojian has become a famous and special product in Henan Province. At present, the research on Xinyang Maojian tea leaves mainly focuses on the soil environment (Yatoo *et al.* 2021), quality components, microbial community (Zhang *et al.* 2020) etc., and the reduction of special fertilizer for tea trees and the combined application of organic fertilizers affect Xinyang tea leaves. There are few reports on the impact of yield and nutrients.

The present study is based on the "excessive application of nitrogen fertilizer, single compound fertilizer ratio, chaotic ratio of chemical fertilizers and organic fertilizers, and small application area of special fertilizers" in Xinyang tea fertilization. Thus this study was aimed to analyze the effects of the appropriate amount of special fertilizer for tea plants and the combined application of organic fertilizers on the tea quantity, nutrient utilization and absorption and economic benefits, and initially integrated the technology model of reducing application and increasing efficiency of special fertilizer for tea plants in Xinyang tea garden. These findings would provide a theoretical reference for the healthy and green development of Xinyang tea gardens.

Materials and Methods

The experimental site of this research is located at Xinyang Chadu Tea Co., Ltd., Shihegang, Xinyang City, Henan Province, China. It has a northern subtropical monsoon continental climate with an annual average temperature of 15.2～15.5°C, ≥ 10°C, active accumulated temperature 4900～5200°C/d, annual rainfall 900～1500 mm, the average annual relative humidity is 77%, the annual sunshine hours are 1904～2180 hrs, the total annual solar radiation is 4700～5100 MJ/m^2, and the frost-free period is 220～245 d. The soil is yellow brown soil (Sun *et al.* 2009).

The tea tree variety is Fuding Dabai Tea, all of which are more than 10 years old. The test fertilizer is a special fertilizer for tea trees, with total nutrients of 38% (N-P_2O_5-K_2O is 18-8-12), adding 6% of trace elements such as magnesium, zinc, and boron; organic fertilizer organic matter ≥ 45%, N+P_2O_5 + K_2O ≥ 6%, 45% (14-16-15) potassium sulfate compound fertilizer.

The experiment was conducted from October 2016 to May 2017. A total of 6 treatments were set up with an area of 1334 m^2 (Table 1). The plots were separated by field ridges to prevent the occurrence of stringing water and fertilizer in each plot. The conventional nitrogen application rate was 315 kg/hm^2 as the target (Hong *et al.* 2018), and the amount was reduced by 20, 40, 60, and 100% in sequence, and the same amount of organic fertilizer was applied. The conventional fertilization was used as the control (CK). Fertilizers in each community were applied as a base fertilizer at one time on January 12, 2016. In order to facilitate data collection, 30 m^2 of each treatment area was randomly selected as a small area, and 3 repetitions were set up and arranged according to random block groups.

Table 1. Experimental design for fertilizers.

Treatment	Type of fertilizer	Application amount /(kg/hm^2)	Nitrogen reduction ratio
CK	Potassium sulfate compound fertilizer	2250	-
T1	Special fertilizer for tea tree	1750	0%
T2	Special fertilizer for tea tree + organic fertilizer	1400,1200	20%
T3	Special fertilizer for tea tree + organic fertilizer	1050,1200	40%
T4	Special fertilizer for tea tree + organic fertilizer	700,1200	60%
T5	organic fertilizer	1200	100%

During the spring tea in 2017, the germination density of each treatment was investigated. When the 1 bud and 2 leaf stage was passed, 5 spots were randomly selected from each plot, and the number of bud tips per spot (0.3m× 0.3m) was investigated, and 100 1 buds were randomly sampled 1 leaf new shoot, weight, and the average value of more than three times is the hundred shoots weight of the new shoot. After all the plots were picked, they were individually weighed and calculated.

After the sample was dried and crushed, accurately 0.2000g were weighed with a one-tenth electronic balance and was digested with H_2SO_4-H_2O_2 until it was clear. Kjeldahl method, molybdenum antimony colorimetric method and flame spectrophotometer were used to determine total nitrogen, total phosphorus and total potassium content, respectively the contents of N, P and K in this article refer to the total nitrogen, total phosphorus and total potassium content of one bud and one leaf of the tea plant (Bao 2000).

The SPAD value was measured using the chlorophyll content analyzer SPAD-502. When measuring the SPAD value, it is required to avoid the leaf veins and measure the upper, middle and lower parts of the leaf once, and calculate the average value.

Fertilizer input was calculated according to the actual fertilizer price per 667/m2; tea income was calculated according to the price of fresh leaf output. Net income was calculated according to tea income-fertilizer input.

Statistical analysis used SPSS20 and Excel2010 software for analysis.

Results and Discussion

The germination density, 100-bud weight, and fresh tea yield range were 64-100 pieces/0.09m2, 10.9-12.9g, and 632-460kg/hm^2, respectively (Table 2). Among the six treatments, T1 (100% special fertilizer for tea plants) treatment had the highest germination density, 100-bud weight and fresh tea yield, followed by T2 (20% nitrogen reduction), and T5 (100% organic fertilizer) was the smallest; T1, T2 treatments germinated compared with CK, the density increased by 25.83 and 3.75%, respectively; the growth rate of germination density of T3 (reduced nitrogen by 40%), T4 (reduced by 60%) and T5 was lower than that of CK. Compared with CK, T1 and T2 increased production by 6.11 and 1.99%, and T3, T4, and T5 decreased production by 4.21, 13.76 and 22.82% compared with CK. The analysis of variance showed that the germination density and fresh tea yield were not significantly different from CK when the nitrogen reduction was less than 50%, and the difference was significant compared with CK. When the nitrogen reduction was higher than 50%, the 100-bud weight changes in different treatments did not show regularity. The difference between the treatments was not significant.

The determination results of the main mineral elements content of mature leaves showed that different treatments have a certain effect on the content of nitrogen, phosphorus and potassium in mature leaves (Table 3). Fertilization treatments T1, T2 new shoots nitrogen uptake was higher than CK, but the difference is not significant, T3, T4, T5 treatments were significantly different compared with CK; T1, T2 treatments new shoots phosphorus uptake was significantly higher than CK, T3, T4, Except for the significant difference between T5 and CK, the other differences were not obvious between T5 treatments. Compared with CK, the potassium uptake of the new shoots of T1 treatment was significantly different, and the other treatments were not significant compared with CK. When a certain amount of organic fertilizer was applied, the appropriate amount of special fertilizer for tea plants has a better absorption effect on nitrogen, phosphorus and potassium compared with conventional treatment.

Table 2. Effects of different Fertilization treatment on tea yield.

Treat-ment	Germination density/ (Pieces/ 0.09 m^2)	Growth rate compared with CK /%	Hundred bud weight/g	Growth rate compared with CK /%	Fresh tea output /(kg/hm^2)	Compared with CK increase production /(kg/hm^2)	Yield growth rate /%
Q	80b	-	11.9a	-	596a	-	-
T1	100a	25.83	12.9a	8.40	632.4a	36.41	6.11
T2	84b	3.75	12.3a	3.36	607.8a	11.83	1.99
T3	76b	-5.00	11.7a	-1.68	570.9a	-25.10	-4.21
T4	70c	-12.50	11.6a	-2.52	514.0bc	-82.00	-13.76
T5	64cd	-20.00	10.9a	-8.40	460cd	-136.02	-22.82

Lowercase letters indicate significant differences, and the same letters indicate insignificant differences.

Table 3. Effects of different Fertilization treatment on new shoots.

Treatment	N content /%	P content /%	K content /%
CK	1.023a	0.093c	1.653b
T1	1.070a	0.183a	2.237a
T2	1.027a	0.153b	1.850b
T3	0.640b	0.067c	1.690b
T4	0.563b	0.053cd	1.433b
T5	0.623b	0.047de	1.380b

The same lowercase letters in the same column indicate significant differences, and the same letters indicate insignificant differences.

Chlorophyll is closely related to nitrogen, and nitrogen deficiency will affect the biosynthesis of chlorophyll or cause its decomposition, thereby reducing the chlorophyll content (Guo *et al.* 2006). The SPAD value determines the chlorophyll content by the difference between the light absorption of the two wavelengths by the leaves, and the measurement result is a relative value reflecting the chlorophyll content in the leaves of the plant (Zhou *et al*. 2012). The overall SPAD value decreases with the decrease of nitrogen application rate, which was also consistent with the trend of tea production (Fig. 1). It showed that the SPAD value of mature leaves can better characterize the nitrogen nutrient level of tea plants; it also has a relatively obvious relationship with tea plant yield, which shows that SPAD value can be used as a method for diagnosing the lack of nitrogen nutrition in tea plants.

It is apparent from Table 4 that the output values of T1 and T2 were all higher than those of CK, and the output values of T3, T4, and T5 were all lower than CK, and the output value of T6 was lower than that of CK. Compared with CK, the fertilization cost of special fertilizer for tea plant was 0.10~4200 yuan/hm^2, which was lower than the input cost of CK fertilizer. Compared with CK treatment, the net income of T1 and T2 treatment increased by 6.44 and 2.35% respectively. The net income of T3, T4, and T5 was lower than that of CK treatment. It can be seen that the application of special fertilizer for tea trees in tea gardens can reduce the cost of

fertilization and increase the income of tea farmers. Among them, the T2 treatment has a certain income increase effect compared with the CK treatment under the treatment of reducing nitrogen by 20%.

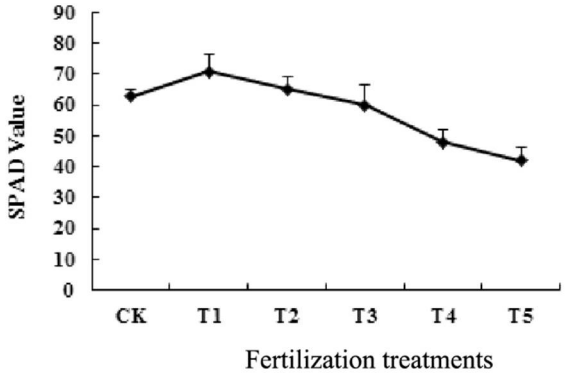

Fig. 1. Effects of different fertilization treatments on SPAD value of mature leaves.

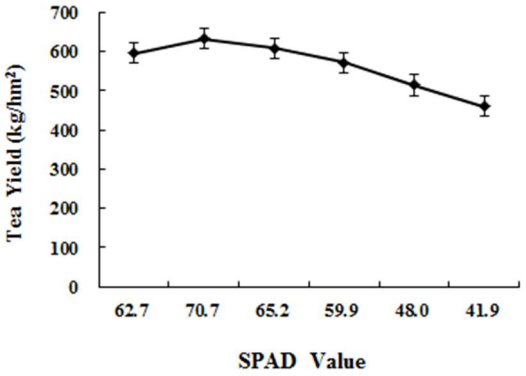

Fig. 2. The relationship between SPAD reading of mature leaves and the tea yield.

Table 4. Economic benefit analysis of fertilization.

Treatment	Fresh tea production value/(yuan·hm^{-2})	Compared with CK ± output value/ (yuan·hm^{-2})	Fertilization cost/ (yuan/hm^2)	Net income/ (yuan/hm^2)
CK	11.92×10^4	-	0.43×10^4	11.49×10^4
T1	12.65×10^4	0.73×10^4	0.42×10^4	12.23×10^4
T2	12.16×10^4	0.24×10^4	0.39×10^4	11.76×10^4
T3	11.42×10^4	-0.50×10^4	0.31×10^4	11.11×10^4
T4	10.28×10^4	-1.64×10^4	0.23×10^4	10.05×10^4
T5	9.20×10^4	-2.72×10^4	0.10×10^4	9.10×10^4

Tea tree is a kind of leaf plant, and a reasonable combination of organic and inorganic fertilizers based on nitrogen can effectively promote the improvement of tea yield and quality (Li *et al*. 2009). Wang *et al*. (2018) showed that the application of biomass charcoal can significantly enhance the nitrogen adsorption capacity of the tea garden soil, reduce nutrient leakage and leaching, thereby increasing the yield and quality of tea. In the present experiment, 20% of the special fertilizer for tea plants and the combined application of quantitative organic fertilizers were reduced, and the germination density, 100-bud weight and fresh tea yield of tea increased slightly, the increase was 3.75, 3.36 and 1.99%, but it did not reach a significant level. The difference indicates that a reasonable nutrient supply is in line with the characteristics of tea plant growth. At the same time, the application of a certain amount of organic fertilizer improved the soil and fertilization, and increased the utilization rate of fertilizer. Compared with the control, the plant nutrient content was not significant. Both the phosphorus and potassium content of the plants showed significant differences. This may be because the application of organic fertilizers reduces the soil's fixation of phosphorus and improves the effective use of phosphate fertilizers. Similarly, the application of organic fertilizers also increases the effective potassium content in the soil and improves the potassium supply capacity. The fertilization costs of T1, T2, T2, T3, and T4 in the present study were all lower than CK treatment, but the benefits of T1, T2 are significantly higher than conventional treatments, and the benefits of T2, T3, T4 are lower than conventional treatments. The present research results showed that compared with conventional fertilizers, special fertilizers for tea combined with organic fertilizers have the advantage of reducing fertilization and increasing efficiency.

In the present study, the experiment of substituting special fertilizers with organic fertilizers can achieve the goals of promoting tea plant growth, increasing tea production and improving tea quality. It can effectively solve the problem of large total nitrogen fertilizer usage in Xinyang tea gardens, single types of fertilizers, the demand for trace elements and the supply of trace elements in the soil. However, due to the short duration of this experiment, there are certain limitations to draw any conclusion. In the future, more systematic and comprehensive research is needed, such as to study the ratio of organic-inorganic application, to conduct in-depth research on the improvement of the physical properties of the tea garden soil and the influence of the microbial community by the organic alternative model to further clarify the effect of reducing the application of special fertilizers in the tea garden.

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