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High-Density Tea Planting: A Case Study in Commercial Tea Gardens

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Abstract This study explores the impact of high-density planting on the yield, quality and earnings of tea. High-density planting means planting more tea trees than usual in plots of the same size. In actual planting, it has been found that doing so enables better utilization of sunlight, water and nutrients in the soil, thereby increasing the yield of tea. This study analyzed the influences of factors such as planting density, tea tree varieties, and local environmental conditions on the growth of tea trees and tea yield. It is also pointed out that daily management tasks such as watering, pruning and fertilizing are very important and play a key role in managing high-density tea gardens well. Although high-density planting can increase the yield and quality of tea, it also brings some problems, such as greater difficulty in pest and disease control and easier soil degradation. This study aims to strike a balance between increasing production and protecting the environment, ensuring the long-term sustainable development of high-density tea cultivation.

Keywords High-density planting; Tea yield; Plant quality; Sustainable tea production; Agricultural practices

1 Introduction

Tea is made from the leaves of the tea tree. It is one of the most popular beverages in the world and also an important money-making crop. It mainly grows in hot and relatively hot regions and is of great help in making money in countries such as China, India and Tanzania. In Tanzania, for instance, tea is an important cash crop, generating an annual income of over 45 million US dollars and supporting more than 30 000 small-scale farmers (Kigalu, 2007). Because tea tastes good and is beneficial to the body, and there are many good things in tea, more and more people around the world like to drink tea (Chen and Liu, 2024; Jibola-Shittu et al., 2024). In many places, tea has brought farmers the opportunity to make money and also helped the poor, which further highlights the economic value of tea (Jibola-Shittu et al., 2024).

High-density planting is an agricultural planting method, which means growing more crops on the same size of land than traditional methods. This method is being used more and more in tea cultivation, with the aim of increasing the yield and quality of tea. Studies have shown that high-density planting can make full use of the land, improve the growth environment of crops and significantly increase the yield of tea. Just as the research in Tanzania found, with and without irrigation, planting 20 000 to 40 000 specific tea varieties per hectare would yield higher (Kigalu, 2007). In addition, high-density planting can also improve the quality of tea by influencing factors such as soil nutrient supply and plant health (Xie et al., 2018). Moreover, this planting method is not only applied to tea but has also achieved success in the cultivation of other crops such as citrus, which can increase yield and early returns (Ladaniya et al., 2020; Ladaniya et al., 2021).

This study will explore the practical role of adopting high-density planting methods in commercial tea cultivation, understand the specific impact of this planting method on tea yield and quality, as well as the possible changes it may bring to the income of tea farmers. The research will determine the optimal planting density of different tea varieties under various growth conditions by analyzing actual planting cases and experimental data. This study aims to clarify the advantages and disadvantages of high-density planting in terms of the environment and economy, and then provide a sustainable tea planting plan, striving to increase tea yield while achieving effective protection of the ecological environment.

2 The Theoretical Basis of High-Density Tea Cultivation

2.1 Growth characteristics of tea plants

High-density planting will have a significant impact on the physiological characteristics of tea plants. Under dense planting conditions, the canopies of tea trees will grow more compact, which is crucial for better absorption of sunlight and improvement of photosynthetic efficiency. This compact canopy is formed by increasing the number of branches and raising the density of picking points, and is positively correlated with the efficiency of carbon dioxide absorption. A dense and compact canopy can intercept more sunlight, which is crucial for giving full play to photosynthesis and thus has a significant impact on the growth of tea trees and tea yield (Phukan et al., 2018). In addition, tea trees maintain a relatively stable height to adapt to the high-density planting environment, which helps to evenly distribute light in the planting garden (Phukan et al., 2018).

High-density planting can also affect the root system of tea trees. Although the total depth of the root system does not change significantly, the number of new buds and roots of the tea plant will decrease, thereby affecting the nutrient absorption effect. In a high-density planting environment, the appearance changes of tea trees are more of a response to insufficient light rather than the result of nutrient consumption. This indicates that in such an environment, light conditions are more important than nutrient supply (Figure 1) (Postma et al., 2020). In densely planted tea gardens, this adaptability of tea trees is crucial for maintaining their own health and tea production.

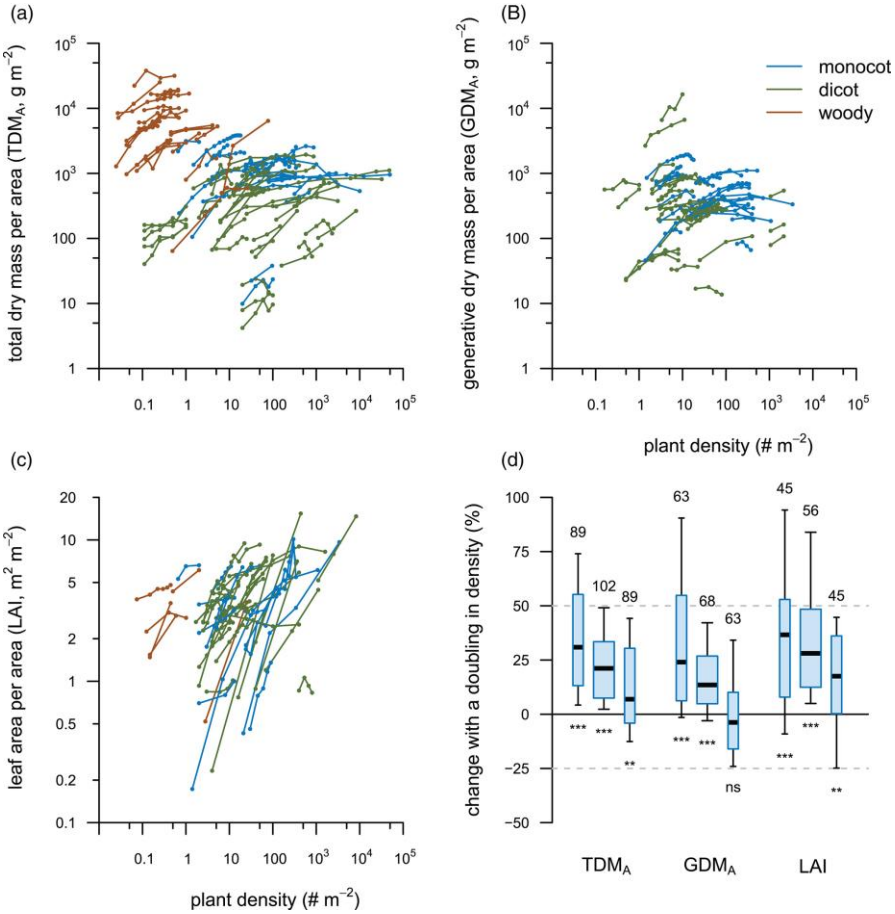

Figure 1 Density-response curves (a)-(c) and statistics on the number of experiments and their individual responses in (d) (Adopted from Postma et al., 2020)

Image caption: (a) Shoot or total plant biomass per unit ground area (TDM_A); (b) generative (seed or reproductive) biomass per unit ground area (GDM_A); (c) Leaf Area Index (LAI). (d) Box plots of the distribution of the percentage change per doubling in density for the three variables. In (a)-(c), points connected by a line represent one species or genotype within a given experiment. In (d), wide boxplots indicate % change per doubling of density across the whole range of densities. The narrow boxes at the left and right from the wide boxes indicate the slope between the two lowest densities and the slope between the two highest densities, respectively. *, **, ***, p <.05, .01, .001 in a t-test for deviation from zero (Adopted from Postma et al., 2020)

2.2 The influence of planting density

The relationship between planting density and tea yield is rather complex and is influenced by factors such as the type of tea tree variety and environmental conditions. Studies have found that a higher planting density can increase the total output per unit area. However, the yield of a single tea tree may decrease due to the competition for resources such as sunlight, water and nutrients. For example, in Tanzania, the yield of the AHP S15/10 variety has always been higher than that of the BBK35 variety under different planting densities, which indicates that some tea tree varieties are more suitable for high-density planting (Kigalu, 2007).

The planting density also affects the quality of tea. High-density planting may make each tea leaf thinner and poorer in quality, thereby affecting the contents of components such as chlorophyll and catechins in tea (Sano et al., 2018). These changes will alter the taste and quality of the tea, so it is necessary to reasonably control the planting density and strike a balance between yield and quality.

2.3 Theoretical basis

The theory that supports high-density planting can optimize resources mainly focuses on the efficient utilization of sunlight, water and soil nutrients. The core of high-density planting is to cultivate dense tree crowns to absorb as much sunlight as possible, thereby enhancing photosynthesis, increasing the growth of tea trees and improving the efficiency of sunlight utilization (Phukan et al., 2018). Studies have observed that tea trees with larger canopies absorb carbon dioxide more efficiently, which is very helpful for maintaining high yields and also confirms this theory (Phukan et al., 2018).

Water efficiency is also a key point in high-density planting. In water-scarce areas, such as arid regions, high-density planting will make the competition for water among tea trees more intense. However, tea tree varieties like AHP S15/10 can have relatively high yields even with less rainfall. This indicates that when planting at high density, choosing the right tea tree varieties is very important for making good use of water resources (Kigalu, 2007). In addition, nutrient management is also indispensable. If it is not managed properly, high-density planting will cause the nutrients in the soil to be absorbed dry. Using reasonable fertilization methods and choosing tea tree varieties that can efficiently utilize nutrients can help solve these problems and ensure sustainable tea production (Ruan et al., 2023).

3 High-Density Tea Planting Implementation Technology

3.1 Planning and layout: design of planting distance

In high-density tea gardens, planning the planting spacing properly is the key to making full use of space and ensuring the healthy growth of tea trees. A commonly used method is to plant tea trees in single rows, keeping the distance between rows at 1.2 to 1.5 meters and the distance between tea trees within the same row at 0.8 to 1.0 meters. In this way, 800 to 1 000 tea tree seedlings can be planted per unit area, which not only creates a sustainable growth environment but also reduces the risk of disease transmission among tea trees (Fang et al., 2014). Another method is row sowing, where tea seeds are sown in furrows with a row spacing of 180 cm and a plant spacing of 20~25 cm. This approach can effectively prevent tea trees from over-competing for nutrients and improve the quality of tea (Cui et al., 2014).

Intercropping methods such as camphor trees and ryegrass between tea houses can make the ecological balance of the tea garden more balanced. Doing so is not only beneficial to the growth of each tea tree, but also can help reduce pests and contribute to the sustainable development of tea gardens (Fang et al., 2014). Reasonable arrangement of tea tree spacing and the adoption of intercropping are conducive to enhancing the ecological and economic benefits of high-density tea gardens.

3.2 Selection of tea tree varieties

Selecting the right tea tree varieties is crucial for high-density planting, as it will affect the tea yield and the disease resistance of the tea trees. High-yielding and disease-resistant varieties like Liangye Huangjiao are particularly suitable for close planting. By applying techniques such as plastic film mulching and reasonable planting density, both the growth and yield of this variety of tea trees can be improved (Shi, 2014). Similarly, Anji

White Tea is famous for its good quality and high yield, which benefits from ecological planting methods, including intercropping tree species with high economic value and adopting a three-dimensional planting model (Xu and Luo, 2014).

When choosing tea tree varieties, the actual environment of the planting area should also be taken into consideration. For instance, when golden bud tea is grown in areas south of the Yangtze River, it requires acidic soil with a pH value ranging from 4.5 to 6.5. By adopting appropriate planting density and fertilization methods, both the yield and tea quality of this variety of tea trees will increase (Dai et al., 2013). By choosing the right tea tree varieties, growers can fully leverage the advantages of high-density planting.

3.3 Field management: irrigation, pruning and fertilization strategies

Good field management is a necessary condition for the success of high-density tea gardens. When irrigating, it is necessary to ensure that the tea trees have sufficient moisture and prevent water accumulation in the tea garden. This can be achieved by applying organic fertilizers and building a good drainage system (Jiang, 2015). Pruning is also very important. After the spring tea picking is completed, conducting large-scale or deep pruning can make the tea trees grow better and increase the tea yield (Cui et al., 2014).

When fertilizing, using more farmyard manure can make the soil more fertile and improve the quality of tea. For example, intercropping leguminous crops such as soybeans in tea gardens can increase the nutrients in the soil and thereby improve the quality of tea (Huang et al., 2022). In addition, applying sufficient base fertilizer when ploughing and timely topdressing during the growth period of tea trees can meet the nutrient requirements of tea trees (Fu, 2015). If these field management measures are well implemented, the tea trees in high-density tea gardens will grow well and the tea yield will also increase.

4 Economic Benefits of High-Density Tea Planting

4.1 The role of high-density planting in increasing the per-unit yield of tea

Practical experience has shown that high-density planting can enable each mu of land to yield more tea. The reason is very simple. On the same piece of land, more tea trees can be planted. In this way, sunlight, rainwater and fertilizers can all be fully utilized, and the efficiency of tea planting will naturally be high. Just like growing oranges, if the spacing is reduced, each tree will bear more fruits and the yield per mu will increase (Ferrarezi et al., 2018; Ladaniya et al., 2020). The same principle applies to tea gardens. When tea trees are planted densely and their branches and leaves are close to each other, photosynthesis can be carried out better, and naturally, more tea leaves are produced in the end (Kigalu, 2007).

Moreover, high-density planting can also reduce the impact of adverse weather conditions such as drought. Studies show that some tea tree varieties, when planted more densely, can still have a good harvest even with less rainfall. In areas prone to weather changes, growing tea in this way can ensure a stable annual tea output (Kigalu, 2007). Planting more tea trees means harvesting more tea leaves. Therefore, high-density planting is a good way to increase the yield of tea gardens.

4.2 Balance the labor and mechanization costs of dense tea gardens

High-density planting can also increase the income of tea gardens by rationally employing people and making good use of machinery. At the beginning of building a tea garden, buying tea seedlings and hiring people to plant trees cost a lot of money, but later on, it became easier to manage and the tea picking was also faster. For instance, in tea gardens with dense tea trees, using machines to pick tea is much faster than manual labor and can save a large amount of labor costs (Ladaniya et al., 2020).

In addition, the denser the tea trees are planted, the less fertilizer and pesticides are used. Studies have proved that when farmyard manure and chemical fertilizers are used in combination, tea is abundant and of good quality, and it will not pollute the environment (Wang et al., 2019; Tang et al., 2021). This way, not only can the tea garden make more money, but also spend less and damage the environment less, which meets the requirements of green tea planting.

4.3 Enhance the market value and demand for tea through high-density planting

High-density planting not only increases tea production but also enhances the quality of tea, making it more popular in the market. When the output increases, it can be sold to more customers and the market share can also expand. Moreover, after the tea trees are densely planted, the tea leaves that grow out have a more fragrant taste and a better texture. These are exactly what customers value most when buying tea (Zhang et al., 2020; Tang et al., 2021).

In addition to high quality, high-density planting can also create an environmentally friendly and efficient brand image. Nowadays, everyone is more concerned about environmental protection. Tea gardens that grow tea in this way can easily attract customers. Consumers are willing to spend more money on such tea, and thus the value of tea increases (Tang et al., 2021; Zhao et al., 2022).

5 Environmental and Ecological Benefits of High-Density Tea Planting

5.1 Optimize land use: maximize the efficiency of land use in tea gardens

High-density tea planting can effectively enhance land utilization and increase per-unit yield, which is particularly important in areas with limited arable land. This planting method can make better use of the existing resources without expanding the area, allowing the tea garden to earn more money. For instance, studies have shown that reasonable fertilization and proper control of planting density can not only increase the tea yield but also improve the quality, bringing more profits to the same area of land (Wang et al., 2019; Tang et al., 2021).

Furthermore, high-density planting can reduce the need to open up new cultivated land, avoid the ecological degradation problems caused thereby, and help improve land management methods. By increasing the output of existing plots, tea gardens can maintain ecological balance and prevent adverse consequences such as deforestation and the destruction of animal and plant habitats caused by land reclamation (Hajiboland, 2017; Su et al., 2017).

5.2 Ecological balance: the impact of dense planting on soil and water stability

High-density planting in tea gardens helps to enhance soil and water conservation and is very important for maintaining ecological balance. The dense branches and leaves of tea trees can increase ground coverage, reduce soil erosion and enable the soil to store more water. This effect is particularly obvious in hilly areas with poor soil and frequent drought (Xiao et al., 2004; Xiao et al., 2005).

Planting other crops or trees around the tea garden can make the soil more solid and of better quality. Doing so can increase the nutrients in the soil and make it more fertile, which is crucial for the continuous cultivation of tea. Creating diverse ecological environments in tea gardens, high-density planting can also reduce pests, use less pesticides, and make the surrounding environment better (Wang et al., 2020; Feng and Sunderland, 2023).

5.3 Sustainability: promote sustainable tea production through high-density planting

High-density tea planting can help achieve sustainable agricultural development and reduce the environmental burden of tea production. By applying fertilizers rationally and using less chemical fertilizers and pesticides, not only can greenhouse gas emissions be reduced, but also nutrients can be better utilized. For example, the use of slow-release fertilizers and farmyard manure in high-density tea gardens can reduce the emission of nitrous oxide and is helpful for mitigating climate change (Wang et al., 2020; Zheng et al., 2022). In addition, high-density planting takes into account both economic development and environmental protection, which is in line with the sustainable development goals. It can not only enhance production efficiency and income, but also protect the ecological environment of the planting area. This balance is very important for the long-term development of the tea industry. It can not only enable farmers' income to increase steadily, but also provide consumers with green and environmentally friendly tea (Su et al., 2017; Liu et al., 2020).

6 Challenges and Limitations of High-Density Tea cultivation

6.1 Risk of pests and diseases

In high-density tea gardens, because tea trees are planted too densely, the problem of pests and diseases will be

more prominent, which makes it easier for pests and diseases to spread rapidly. The dense leaves of tea trees create a moist environment, which is particularly suitable for the growth of fungal diseases, and fungal diseases are common problems in tea cultivation. In this case, it is necessary to frequently inspect the tea garden and may also require multiple spraying of pesticides for prevention and control. This will not only increase the planting cost, but also bring about environmental problems (Kigali, 2007; Lowe et al., 2022).

The prevention and control of pests and diseases in high-density tea gardens require specialized techniques and methods. If the tea trees are planted too densely, there will be trouble when spraying pesticides. It is not easy to approach tea trees that are too dense. This may lead to uneven spraying of the pesticide solution, reduce the control effect, and also easily cause pests to develop drug resistance (Kigalu, 2007).

6.2 Soil degradation

Over time, high-density planting may deteriorate the soil, mainly because a large amount of nutrients in the soil are consumed and the soil is compacted and hardened. As more and more tea trees are planted per hectare, the demand for soil nutrients also increases. If the management is not done well, the soil will lack nutrients. In areas where the soil conditions are already poor, high-density planting will make the problem even more serious (Ruan et al., 2023).

In addition, in tea gardens where tea trees are densely planted, frequent use of agricultural machinery and workers moving back and forth will cause the soil to be compacted, resulting in a decline in the soil's ability to aerate and absorb water. This will affect the growth of tea tree roots, be detrimental to the overall health of tea trees, and also accelerate soil degradation. Therefore, effective soil management measures must be adopted, such as regular soil testing and the use of organic conditioners, to mitigate these negative impacts (Ruan et al., 2023).

6.3 Mechanization challenges

High-density tea gardens bring great difficulties to mechanized operations, especially in the tea-picking process. When the distance between tea trees is small, special equipment is needed. Such equipment must be able to operate flexibly in the narrow tea shop and must not damage the tea trees. This will increase the cost of mechanized operations, and suitable mechanical equipment is not easy to find either, especially for small-scale farmers (Kigalu, 2007; Lowe et al., 2022).

Furthermore, it is often not easy to transform the existing agricultural machinery equipment to be suitable for high-density tea gardens. Therefore, either new technologies need to be developed or the existing equipment needs to be modified. This is a difficult problem for many tea growers, especially in those underdeveloped areas where it is hard to obtain advanced agricultural technologies. In this way, labor-intensive manual picking may still be the main method, and this method is inefficient and costly (Kigalu, 2007).

7 Case Study: Practices in High-Density Tea Planting

7.1 Case background: geographical and climatic conditions of the tea garden and planting objectives

In this case, the climate of the place where the tea garden is located is suitable for growing tea. It is warm and humid here, which is very conducive to the growth of tea trees. The local annual precipitation is abundant and the temperature is suitable. These conditions are very important for the growth of tea plants and the yield of tea (Ngoc et al., 2019; Tang et al., 2021). The tea garden mainly aims to increase the yield and income through high-density planting (Chen et al., 2022; Zhao et al., 2022).

The location of the tea garden, due to its climate and soil conditions, is very suitable for tea cultivation. The mutual coordination of local natural factors such as temperature, precipitation and soil quality is an essential condition for the good growth of tea trees (Tang et al., 2021; Chen et al., 2022). Thanks to its superior geographical location, the tea garden has been able to fully utilize these favorable conditions to achieve the planting goals, including increasing the tea yield as much as possible and ensuring the sustainability of tea production (Figure 2) (Ngoc et al., 2019; Zhao et al., 2022).

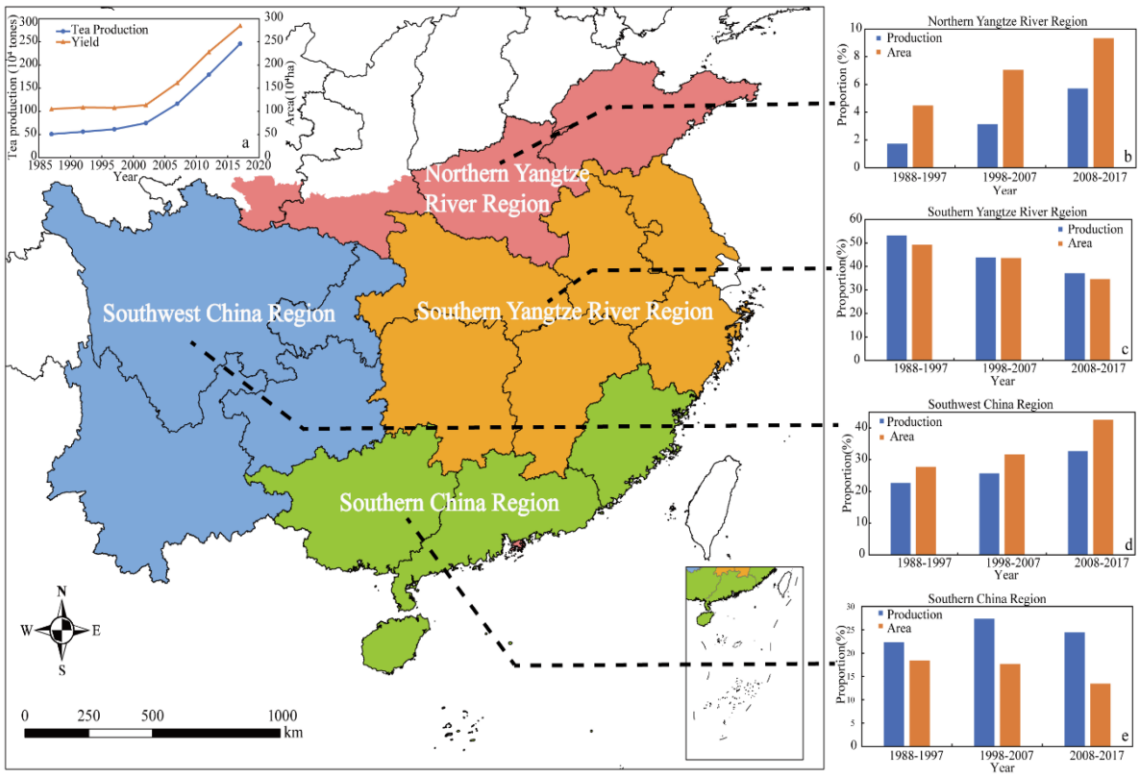

Figure 2 Distribution of climatic tea zoning in mainland China and changes of tea planting area and yield (Adopted from Zhao et al., 2022)

Image caption: (a) Time-series changes of five-year mean tea planting area and total production in China from 1987 to 2017; and changes of ten-year mean tea planting area and yield proportion in Northern Yangtze River Region (b), Southern Yangtze River Region (c), Southwest China Region (d), and Southern China Region (e) (Adopted from Zhao et al., 2022)

7.2 Design, planting and management practice of high-density tea gardens

The design of high-density tea gardens requires careful planning. The key lies in determining the appropriate spacing and arrangement between tea trees. This can prevent land waste, make full use of resources such as sunlight and water, and enable the tea trees to be planted more densely and the tea leaves to be harvested in greater quantities. When planting, tea tree varieties suitable for the local climate and soil should be selected to ensure that even if they are planted densely, the tea trees can grow healthily (Pramanik and Phukan, 2019; Ruan et al., 2023). The key point of tea garden management is to maintain fertile soil and ensure that tea trees do not lack nutrients, which is crucial for the high-density planting model (Pramanik and Phukan, 2019; Ruan et al., 2023).

It is also necessary to frequently inspect the tea garden in daily life. If any problems with the growth of the tea trees or the condition of the soil are found, they should be solved in a timely manner. The management methods include environmentally friendly fertilization methods such as combining farmyard manure with chemical fertilizers, as well as pest control and disease prevention measures that do not harm the environment. They can not only make tea trees grow vigorously and have a high tea yield, but also not damage the environment (Mao et al., 2022; Wang et al., 2023). With the help of new technologies and data analysis, management can also be done better to ensure the continuous high yield of tea gardens and achieve long-term development (Mao et al., 2022; Wang et al., 2023).

7.3 Case analysis of tea output, quality and economic benefits

After a tea garden adopted the high-density tea planting method, the tea leaves were abundant and of good quality. The denser the tea trees are planted, the more tea leaves will be picked, which can meet the demands of more customers. Moreover, the tea tastes more fragrant and contains more beneficial components for the human body, such as polyphenols and flavonoids (Pramanik and Phukan, 2019; Carloni et al., 2023). Such fine tea is particularly popular in the market and its reputation is growing (Pramanik and Phukan, 2019; Carloni et al., 2023).

In terms of economic benefits, high-density tea garden planting has significantly increased the income of tea gardens. With the increase in output and the improvement of tea quality, sales have risen accordingly, and the income of tea gardens has become more stable. This planting pattern has a positive impact on the surrounding areas. More tea picking requires more labor input, creating a large number of employment opportunities for the local area (Zhao et al., 2022; Wang et al., 2024). This successful practice provides a referential model for other tea gardens. Through innovative planting and management methods, more high-quality tea can be produced and long-term development can be achieved (Zhao et al., 2022; Wang et al., 2024).

8 Prospects and Suggestions

8.1 Research on the regional adaptability of high-density tea planting

High-density tea planting can increase the tea yield and make better use of the land, which is its major advantage. However, whether this planting method can succeed everywhere depends on whether it can adapt to the environment of different places. Therefore, comprehensive research needs to be conducted in many different regions. The research focus should be on observing whether high-density tea planting is effective under different weather and soil conditions, as these factors have a significant impact on how the tea grows and how much can be harvested. Just as the research conducted in Yingde, Guangdong Province, stated, the local weather and soil determine whether it is suitable for growing tea. Such research results can also provide references for planning high-density tea cultivation in other places (Chen et al., 2022). In addition, understanding the influence of altitude and terrain slope on the growth of tea can better arrange the planting location of tea trees and harvest more tea (Jayasinghe and Kumar, 2019; Chen et al., 2022).

In future research, the relationship between high-density tea planting and the local ecology will continue to be deeply examined. The expansion of tea gardens may affect the local ecology and have an impact on water sources, soil and the survival of animals and plants. The focus of the research is to strike a balance between increasing tea production and protecting the ecological environment. We should not damage the environment just to produce more tea. This requires clarifying the benefits and drawbacks of tea cultivation for the ecology and how to promote each other, just like the research conducted in a major tea-producing area such as Anxi County (Bao et al., 2024; Deng and Chen, 2024).

8.2 Agricultural policies and promotion strategies for high-density tea cultivation

To promote high-density tea cultivation, agricultural policies should be formulated to encourage sustainable planting methods and provide certain support to farmers. Policy makers can refer to those land use policies that have successfully coordinated the expansion of tea planting with ecological sustainable development, such as the policy implemented in Anji County, China. This policy comprehensively considers natural environment and socio-economic factors to guide tea planting planning (Zhang et al., 2017). Policies should also vigorously promote agricultural technologies that adapt to climate change, such as the use of controlled-release fertilizers and the addition of biochar, thereby reducing the emission of nitrous oxide in tea garden soil and lowering the negative impact on the environment (Wang et al., 2020).

To promote high-density tea cultivation, the key is to make tea farmers understand the benefits of such cultivation and also teach them the specific planting methods. The successful planting experiences and the latest research results of others can be presented to everyone through holding training courses and exchange meetings. In addition, the government can offer subsidies to tea farmers or provide financial assistance. In this way, when they switch to high-density tea cultivation, they will have to spend less money on purchasing tea seedlings and purchasing equipment at the beginning. As long as the government's supportive policies and scientific research are well coordinated, high-density tea planting can be promoted in more places, the efficiency of tea planting can be improved, and long-term development can also be achieved.

8.3 Strengthen the mechanization of tea gardens and ecological protection technologies

To improve the method of high-density tea planting, it is necessary to use more machines for work and apply ecological protection technologies. Only in this way can the tea be grown quickly and well and achieve long-term

development. Working with machines can save a lot of labor costs and enable tea gardens to earn more money. For example, Australia has invented a machine for cultivating tea seedlings, which can stably cultivate good tea seedlings and has been of great help for large-scale tea planting (Lowe et al., 2022). If some advanced tea-planting, pruning and tea-picking machines are introduced, the working speed in the tea garden can be even faster.

Ecological protection technologies cannot be lacking either. Only in this way can high-density tea planting avoid damaging the environment. There is a kind of "agroforestry hybrid" planting method in Indonesia. Some shade-tolerant crops are planted among tea trees, which can not only prevent the land from being wasted but also make the soil more fertile (Maharani et al., 2022).

In addition, allowing tea gardens to coexist harmoniously with the surrounding natural environment can also bring many benefits, such as storing more carbon dioxide and providing a better living environment for animals and plants. Anxi County, Fujian Province is a successful example (Bao et al., 2024). The tea garden combines machine operation with ecological protection, using high-density planting methods. This not only enables tea farmers to earn more money but also helps protect the environment.

9 Concluding Remarks

The high-density planting model has been proven to significantly increase yields. The principle is to plant more plants in the same area and make full use of resources such as sunlight, water and nutrients. This method has a remarkable effect on the cultivation of fruits such as acid lime. After adopting high-density planting, the fruit yield per unit area is more than twice that of the traditional method. The same is true for corn cultivation. Increasing the planting density can make better use of resources such as light and nitrogen, thereby enhancing the grain harvest. These achievements indicate that high-density planting is also applicable to tea gardens, which can increase tea yields and the efficiency of resource utilization.

In the tea planting industry, the method of high-density planting is particularly important. Doing so can not only make more full use of resources such as land and fertilizer, but also enable the tea leaves to grow more and better. Research shows that as long as the number of tea trees planted is well controlled and less chemical fertilizers and pesticides are used, not only can the damage to the environment be reduced, but also the soil can be made more fertile, which is indispensable for the continuous growth of good tea. By relying on high-density planting, tea gardens can harvest more high-quality tea leaves, earn more money and ensure the long-term development of the entire tea industry.

High-density planting in commercial tea gardens will have better development in the future, but there are still many areas that can be improved in terms of technology and management. Combining high-density planting with new fertilization methods, such as the simultaneous use of farmyard manure and chemical fertilizers, can not only increase the yield and quality of tea, but also reduce environmental pollution. In addition, by cultivating tea tree varieties suitable for dense planting and rationally adjusting the planting density of tea trees with precise planting techniques, resources can be utilized more fully, laying a foundation for establishing an efficient and environmentally friendly tea tree planting model. These new development directions may bring about significant changes to the tea industry, achieving the dual goals of increased production and environmental protection.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Bao J., Li W., Zhu J., Fan S., and Mao L., 2024, Impacts of land use structures on ecosystem services relationships within specialized tea planting regions: a case study of Anxi County, Frontiers in Environmental Science, 12: 1464490.
https://doi.org/10.3389/fenvs.2024.1464490

Carloni P., Albacete A., Martínez-Melgarejo P., Girolametti F., Truzzi C., and Damiani E., 2023, Comparative analysis of hot and cold brews from single-estate teas (*Camellia sinensis*) grown across Europe: an emerging specialty product, Antioxidants, 12(6): 1306.
https://doi.org/10.3390/antiox12061306

Chen P., Li C., Chen S., Li Z., Zhang H., and Zhao C., 2022, Tea cultivation suitability evaluation and driving force analysis based on AHP and Geodetector results: a case study of Yingde in Guangdong, China, Remote Sens, 14(10): 2412.
https://doi.org/10.3390/rs14102412

Cheng S.Y., and Liu C.C., 2024, Interaction between tea tree root probiotics and tea yellowing disease, Journal of Tea Science Research, 14(1): 10-20.
https://doi.org/10.5376/jtsr.2024.14.0002

Cui G.L., Wang S., and Cheng P., 2014, Novel tea seedling planting methods, China Patent, CN201210316457.4.

Dai Z.Y., Dai S.Q., and He Q., 2013, Golden bud tea planting method, China Patent, CN201310296452.4.

Deng Y.L., and Chen H.M., 2024, Probiotics from tea fermentation: potential applications in health products, Bioscience Methods, 15(5): 237-243.
https://doi.org/10.5376/bm.2024.15.0024

Fang H.S., Zhou Y.C., Zhou G.M., and Su Y.J., 2014, Tea planting method, China Patent, CN201310750451.2.

Feng Y., and Sunderland T., 2023, Feasibility of tea/tree intercropping plantations on soil ecological service function in China, Agronomy, 13(6): 1548.
https://doi.org/10.3390/agronomy13061548

Ferrarezi R., Wright A., and Schumann A., 2018, Increasing yield through high-density plantings, Citrus Industry, 99: 8-12.

Fu Q.Z., 2015, Tea tree planting method, China Patent, CN201410668348.8.

Hajiboland R., 2017, Environmental and nutritional requirements for tea cultivation, Folia Horticulturae, 29: 199-220.
https://doi.org/10.1515/fhort-2017-0019

Jayasinghe S., and Kumar L., 2019, Modeling the climate suitability of tea [*Camellia sinensis* (L.) O. Kuntze] in Sri Lanka in response to current and future climate change scenarios, Agricultural and Forest Meteorology, 272-273: 102-117.
https://doi.org/10.1016/j.agrformet.2019.03.025

Jiang J.Q., 2015, Tea slope planting method, Golden bud tea planting method, China Patent, CN201510311211.1.

Jibola-Shittu M., Heng Z., Keyhani N., Dang Y., Chen R., Liu S., Lin Y., Lai P., Chen J., Yang C., Zhang W., Lv H., Wu Z., Huang S., Cao P., Tian L., Qiu Z., Zhang X., Guan X., and Qiu J., 2024, Understanding and exploring the diversity of soil microorganisms in tea (*Camellia sinensis*) gardens: toward sustainable tea production, Frontiers in Microbiology, 15: 1379879.
https://doi.org/10.3389/fmicb.2024.1379879

Kigalu J., 2007, Effects of planting density and drought on the productivity of tea clones (*Camellia sinensis* L.): yield responses, Physics and Chemistry of The Earth, 32: 1098-1106.
https://doi.org/10.1016/j.pce.2007.07.022

Ladaniya M., Marathe R., Das A., Rao C., Huchche A., Shirgure P., and Murkute A., 2020, High density planting studies in acid lime (*Citrus aurantifolia* Swingle), Scientia Horticulturae, 261: 108935.
https://doi.org/10.1016/j.scienta.2019.108935

Liu S., Yao X., Zhao D., and Lu L., 2020, Evaluation of the ecological benefits of tea gardens in Meitan County, China, using the InVEST model, Environment, Development and Sustainability, 23: 7140-7155.
https://doi.org/10.1007/s10668-020-00908-6

Lowe G., Shepherd M., Rose T., and Raymond C., 2022, Effect of stock plant growing medium and density upon a cutting propagation system for tea tree, *Melaleuca alternifolia*, Plants, 11(18): 2421.
https://doi.org/10.3390/plants11182421

Maharani D., Sudomo A., Swestiani D., Murniati, Sabastian G., Roshetko J., and Fambayun R., 2022, Intercropping tuber crops with teak in Gunungkidul regency, Yogyakarta, Indonesia, Agronomy, 12(2): 449.
https://doi.org/10.3390/agronomy12020449

Mao S., Wu Z., Jiang N., and Lai X., 2022, Tea-vegetable gardens in Longsheng Nationalities Autonomous County: temporal and spatial distribution, agrobiodiversity and social-ecological values, International Journal of Agricultural Sustainability, 20: 1194-1208.
https://doi.org/10.1080/14735903.2022.2065960

Ngoc H., Van T., Hà N., Binh N., and Tân M., 2019, Bioclimatic assessments for tea cultivation in Western Nghe An, Vietnam Journal of Earth Sciences, 41(1): 81-94.
https://doi.org/10.15625/0866-7187/41/1/13586

Phukan M., Savapondit D., Hazra A., Das S., and Pramanik P., 2018, Algorithmic derivation of CO_2 assimilation based on some physiological parameters of tea bushes in North-East India, Ecological Indicators, 91: 77-83.
https://doi.org/10.1016/j.ecolind.2018.03.091

Postma J., Hecht V., Hikosaka K., Nord E., Pons T., and Poorter H., 2020, Dividing the pie: a quantitative review on plant density responses, Plant, Cell and Environment, 44(4): 1072-1094.
https://doi.org/10.1111/pce.13968

Pramanik P., and Phukan M., 2019, Assimilating atmospheric carbon dioxide in tea gardens of northeast India, Journal of Environmental Management, 256: 109912.
https://doi.org/10.1016/j.jenvman.2019.109912

Ruan L., Li X., Song Y., Li J., and Palansooriya K., 2023, Effects of tea plant varieties with high- and low-nutrient efficiency on nutrients in degraded soil, Plants, 12(4): 905.
https://doi.org/10.3390/plants12040905

Sano T., Horie H., Matsunaga A., and Hirono Y., 2018, Effect of shading intensity on morphological and color traits and on chemical components of new tea (*Camellia sinensis* L.) shoots under direct covering cultivation, Journal of the Science of Food and Agriculture, 98(15): 5666-5676.
https://doi.org/10.1002/jsfa.9112

Shi H.Q., 2014, Method for building shiny-leaved yellow horn tea garden and cultivating shiny-leaved yellow horn, China Patent, CN201410209801.9.

Su S., Wan C., Li J., Jin X., Pi J., Zhang Q., and Weng M., 2017, Economic benefit and ecological cost of enlarging tea cultivation in subtropical China: characterizing the trade-off for policy implications, Land Use Policy, 66: 183-195.
https://doi.org/10.1016/j.landusepol.2017.04.044

Tang J.X., Wang P.J., E Y.H., Ma Y.P., Wu D.R., and Huo Z.G., 2021, Climatic suitability zoning of tea planting in mainland China, J. Appl. Meteor. Sci., 32(4): 397-407.
https://doi.org/10.11898/1001-7313.20210402

Tang S., Zheng N., Ma Q., Zhou J., Sun T., Zhang X., and Wu L., 2021, Applying *Nutrient Expert* system for rational fertilisation to tea (*Camellia sinensis*) reduces environmental risks and increases economic benefits, Journal of Cleaner Production, 305: 127197.
https://doi.org/10.1016/j.jclepro.2021.127197

Wang C., Zhao M., Xu Y., Zhao Y., and Zhang X., 2023, Ecosystem service synergies promote ecological tea gardens: a case study in Fuzhou, China, Remote Sens, 15(2): 540.
https://doi.org/10.3390/rs15020540

Wang P., Li X., Tang J., Wu D., Pang L., and Zhang Y., 2024, Critical threshold-based heat damage evolution monitoring to tea plants with remotely sensed LST over mainland China, Remote Sens, 16(10): 1784.
https://doi.org/10.3390/rs16101784

Wang Y., Yao Z., Pan Z., Wang R., Yan G., Liu C., Su Y., Zheng X., and Butterbach-Bahl K., 2020, Tea-planted soils as global hotspots for N_2O emissions from croplands, Environmental Research Letters, 15: 104018.
https://doi.org/10.1088/1748-9326/aba5b2

Wang Z., Geng Y., and Liang T., 2019, Optimization of reduced chemical fertilizer use in tea gardens based on the assessment of related environmental and economic benefits, The Science of the Total Environment, 713: 136439.
https://doi.org/10.1016/j.scitotenv.2019.136439

Xiao R.L., Wang J.R., Chen Z.F., Liu Y.S., Peng W.X., Peng P.Q., and Tang Y., 2004, Ecological tea plantations and tea safetyefficiency production in the subtropical hill region of China, Research of Agricultural Modernization, 25(5): 360-363.

Xiao R.L., Wang J.R., Peng P.Q., Chen Z.F., Tang Y., and Peng W.X., 2005, Ecological problems in hilly tea plantations in the Yangtze Basin, Journal of Agro-Environment Science, 24(3): 585-589.

Xie S., Feng H., Yang F., Zhao Z., Hu X., Wei C., Liang T., Li H., and Geng Y., 2018, Does dual reduction in chemical fertilizer and pesticides improve nutrient loss and tea yield and quality, a pilot study in a green tea garden in Shaoxing, Zhejiang Province, China, Environmental Science and Pollution Research, 26: 2464-2476.
https://doi.org/10.1007/s11356-018-3732-1

Xu F.F., and Luo X.P., 2014, Anji white tea ecological and efficient cultivation method, China Patent, CN201410033496.2.

Zhang Q., Gao W., Su S., Weng M., and Cai Z., 2017, Biophysical and socioeconomic determinants of tea expansion: apportioning their relative importance for sustainable land use policy, Land Use Policy, 68: 438-447.
https://doi.org/10.1016/j.landusepol.2017.08.008

Zhang X., Jiang H., Wan X., and Li Y., 2020, The effects of different types of mulch on soil properties and tea production and quality, Journal of the Science of Food and Agriculture, 100(14): 5292-5300.
https://doi.org/10.1002/jsfa.10580

Zhao Y., Xu Y., Zhang L., Zhao M., and Wang C., 2022, Adapting tea production to climate change under rapid economic development in China from 1987 to 2017, Agronomy, 12(12): 3192.
https://doi.org/10.3390/agronomy12123192

Zheng R., Ma Y., Liu L., Jiang B., Ke R., Guo S., He D., and Zhan J., 2022, Synergistic improvement of production, economic return and sustainability in the tea industry through ecological pest management, Horticulturae, 8(12): 1155.
https://doi.org/10.3390/horticulturae8121155