Effects of Deep Tillage and Reclamation on Important Agronomic Traits and Soil Physicochemical Properties of Castanea henryi (Postprint)

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Date: 2018-10-26T00:00:00+00:00

Abstract

To explore efficient soil management practices for Castanea henryi forests, enhance the technical level of C. henryi cultivation management in China, and thereby improve its yield, quality, and economic benefits, this study conducted continuous 4-year deep tillage on C. henryi forest land using two methods: complete tillage and ring tillage. Changes in soil physicochemical properties before and after tillage were measured, along with important agronomic traits including tree growth, leaf phenotypic and physiological characteristics, fruiting traits, yield, and quality; statistical data were collected and comparative analyses were performed. The results showed: (1) Deep tillage significantly improved soil physicochemical properties in C. henryi forests. Soil bulk density under both tillage methods decreased by 31.21% or more compared with pre-tillage (at 0-30 cm depth), while soil water content, soil porosity, organic matter content, and various macroelement contents increased to varying degrees compared with both pre-tillage and the control, with soil fertility and its water and nutrient retention capacity being significantly enhanced; (2) The organic matter content, available phosphorus content, and exchangeable magnesium content in the ring tillage zone were higher than those in the complete tillage zone, with soil organic matter content increasing by 40.59% compared with pre-tillage, far exceeding the increase in the complete tillage zone (17.76%). From the perspective of soil nutrient retention capacity, the ring tillage effect was superior to complete tillage; (3) The enhancement of soil fertility improved its nutrient supply capacity to C. henryi leaves, resulting in significant increases in leaf water content, chlorophyll content, and various mineral element contents, thereby enhancing photosynthetic capacity; (4) Deep tillage also significantly promoted C. henryi tree growth, bearing capacity, yield, and quality, with yields per unit area in the complete tillage and ring tillage zones being 1.75 times and 1.33 times that of the control, respectively. Moreover, total chestnut bur weight, single fruit weight, kernel extraction rate, soluble sugar content, and phosphorus and potassium element contents were significantly higher than those of the control, while the empty bur rate was significantly lower than that of the control. In summary, deep tillage is an effective measure for improving forest soil and enhancing C. henryi productivity.

Full Text

Effects of Deep Digging and Reclamation on Important Agronomic Traits of *Castanea henryi* and Soil Physical and Chemical Properties

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Abstract

To explore efficient soil management strategies for *Castanea henryi* orchards, improve cultivation and management techniques, and ultimately enhance yield, quality, and economic benefits, this study conducted continuous deep digging and reclamation for four years using two methods: whole-area reclamation and ring-area reclamation. We measured changes in soil physical and chemical properties before and after reclamation, along with key agronomic traits including tree growth, leaf phenotypic and physiological characteristics, fruiting behavior, yield, and nut quality. Statistical analysis and comparative evaluation were performed. The results showed: (1) Deep digging and reclamation significantly improved soil properties in *C. henryi* orchards. Soil bulk density in both reclamation treatments decreased by 31.21% or more (in the 0–30 cm layer) compared with pre-reclamation levels, while soil moisture content, porosity, organic matter content, and various macroelement concentrations increased to varying degrees, substantially enhancing soil fertility and water/nutrient retention capacity. (2) The ring reclamation area exhibited higher soil organic matter, available phosphorus, and exchangeable magnesium contents than the whole reclamation area. Soil organic matter content increased by 40.59% compared with pre-reclamation levels, far exceeding the 17.76% increase observed in the whole reclamation treatment. From the perspective of soil nutrient retention capacity, ring reclamation outperformed whole reclamation. (3) Improved soil fertility enhanced nutrient supply to *C. henryi* leaves, significantly increasing leaf water content, chlorophyll content, and various mineral element concentrations, thereby boosting photosynthetic capacity. (4) Deep digging and reclamation also significantly improved tree growth, fruiting capacity, yield, and nut quality. The yields per unit area in whole and ring reclamation plots were 1.75 and 1.33 times that of the control, respectively. Total burr weight, single nut weight, seed emergence rate, soluble sugar content, and phosphorus and potassium concentrations were significantly higher than in the control, while empty burr rate was significantly lower. In summary, deep digging and reclamation is an effective measure for improving woodland soil and enhancing *C. henryi* productivity.

Keywords: *Castanea henryi*; deep digging and reclamation; soil physical and chemical properties; fruiting ability; yield; nutritional quality

Introduction

Castanea henryi is a renowned dry fruit and characteristic economic forest tree species in southern China, widely distributed across 14 provinces (municipalities and autonomous regions) south of the Qinling Mountains and Huai River, including Zhejiang, Fujian, Anhui, Jiangxi, and Hunan, with the most concentrated resources found in the southern Zhejiang and northern Fujian regions. Its nuts are conical in shape, with unique flavor and excellent quality, rich in starch, soluble sugars, protein, and various vitamins and mineral elements essential for human nutrition (Gong and Liu, 2013; Ma et al., 2013; Fan et al., 2015).

Currently, China' s artificial cultivation area of *C. henryi* is approximately 1.2 million mu, with an annual output of only 75,000 tons, a unit yield of less than 70 kg/mu, and an income of less than 1,500 yuan per mu. Land use efficiency and economic benefits have not been fully realized (Yang et al., 2018). Apart from varietal factors, backward cultivation and management techniques constitute the main constraint on yield and profit growth, with soil management being the most critical component of *C. henryi* cultivation. Tree growth, nutrient accumulation, yield, and quality are strongly associated with soil management practices (Peng, 2017). *C. henryi* is typically planted in relatively barren mountainous and hilly areas. With increasing stand age, combined with frequent irrigation, fertilization, pesticide application, and extreme drought events, soil compaction has become prominent, leading to 逐年降低的 soil permeability, water retention capacity, and organic matter content. In severe cases, soil erosion and rocky desertification occur, with inadequate nutrient absorption and utilization, resulting in malnourished trees, poor growth, and suboptimal yield and quality.

Deep digging and reclamation is an effective measure for improving woodland soil structure and fertility, widely applied in economic forest species such as oil tea (*Camellia oleifera*) and walnut (*Juglans regia*) with good results (Huang, 2009; Jiang, 2012; Fei, 2013). Although this method has been sporadically used in *C. henryi* orchards, systematic research on its effects on soil properties and tree growth, fruiting, yield, and quality remains lacking. Therefore, this study applied continuous multi-year deep digging and reclamation to mature *C. henryi* stands using both whole-area and ring-area methods. We observed and comparatively analyzed changes in soil physical and chemical properties, tree growth, leaf phenotypic and physiological characteristics, fruiting behavior, yield, and quality to explore efficient soil management strategies for *C. henryi* orchards and provide technical support for improving cultivation management and economic benefits.

1.1 Experimental Site and Materials

The experiment was conducted in a *C. henryi* orchard at Yangbei Village, Pingdu Subdistrict, Qingyuan County, Zhejiang Province, at an elevation of 350 m. The soil was yellow loam with poor fertility. Grafted *C. henryi* seedlings were planted in spring 2006 at a spacing of 4 m × 4 m. The main cultivar was the Zhejiang-approved superior variety 'Zaoxiangli', with a small number of pollinizer trees. Field management conditions were average. Due to the lack of deep tillage and tending management over the years, severe soil compaction had developed, with poor aeration and water retention capacity.

1.2 Experimental Methods

The experiment ran from January 2014 to December 2017 (four years). Two reclamation treatments—whole-area reclamation (area beyond a 1 m radius from the tree base) and ring-area reclamation (a 2 m wide ring at the canopy drip line)—were applied for deep digging and reclamation to a depth of 40–50 cm, with no reclamation as the control. A randomized block design was used, with each treatment covering 0.1 hm^2 of mature *C. henryi* stand and three replicates.

Soil sampling: An "S" shaped sampling method was employed, with five quadrats selected per treatment and three replicates. Sampling positions were established before the experiment began and marked with wooden stakes. A cylindrical stainless steel tube (30 cm length, 4.5 cm diameter) was used to collect soil samples at depths of 0–30 cm and 30–60 cm below the ground surface. Samples were immediately weighed for wet mass and placed in plastic bags with labels. Sampling times were January 2014 (pre-reclamation) and December 2017 (the fourth year of the experiment).

Soil physical and chemical index determination: Soil samples were brought to the laboratory for drying to constant weight, after which dry mass was measured. Soil moisture content and bulk density were calculated based on wet mass, dry mass, and volume. Soil specific gravity was determined using the pycnometer method. Soil organic matter content, hydrolyzable nitrogen, available phosphorus, available potassium, exchangeable calcium, exchangeable magnesium, and pH were measured according to LY/T 1237-1999, LY/T 1228-2015, LY/T 1232-2015, LY/T 1234-2015, LY/T 1245-1999, LY/T 1245-1999, and LY/T 1239-1999, respectively.

Leaf sampling and phenotypic and physiological index determination: In July 2017, when leaf nutrient elements were stable, *C. henryi* leaves were collected from both reclamation treatments and the control area. Sampling period and methods followed Liu et al. (2017). For each treatment, 5–10 healthy, uniformly developed large trees without pests or diseases were randomly selected. Thirty to fifty intact functional leaves were collected from the upper-middle part of the canopy around each tree and brought to the laboratory for measurement of phenotypic and physiological indices. Leaf length, width, shape index, and area were measured using a CI-202 portable leaf area meter. Petiole length was measured with vernier calipers. Leaf wet mass was weighed using a 1/100 balance. After measurement, leaves were oven-dried to constant weight and dry mass was measured to calculate specific leaf weight and leaf water content. Chlorophyll and carotenoid contents were determined according to Wang et al. (2009). Leaf soluble sugar content was measured using the anthrone colorimetric method. Leaf nitrogen content was determined according to Fan et al. (2007). Leaf phosphorus, potassium, calcium, and magnesium contents were determined according to LY/T 1270-1999.

Investigation and determination of tree growth, fruiting, and yield: In August–September 2017, tree growth, fruiting characteristics, and yield were observed in different reclamation treatments and the control area. For each treatment, 15 healthy, uniformly developed large trees without pests or diseases were selected per block, with three replicates. Tree growth, fruiting characteristics, and yield were measured on a per-tree basis, with averages calculated from 45 trees per treatment.

Determination of fruit phenotypic and nutritional quality indices: In September–October 2017, fruit phenotypic and nutritional quality indices were determined. For each treatment, 5–10 healthy, uniformly developed large trees without pests or diseases were randomly selected. Thirty to fifty full, pest-free mature burrs were collected from the upper-middle part of the canopy around each tree and brought to the laboratory for measurement of phenotypic and nutritional quality indices. Starch and soluble sugar contents were determined using the anthrone colorimetric method. Protein, phosphorus, potassium, calcium, magnesium, and total amino acid contents were determined according to GB 5009.5-2010, GB/T 5009.87-2003, GB/T 5009.91-2003, GB/T 5009.268-2016, GB/T 5009.90-2003, and GB/T 8314-2013, respectively.

1.3 Data Analysis

Original data were entered and summarized using Excel to calculate means for different traits or indices. SAS 8.2 software was used for multiple comparisons (Duncan’ s method) and simple correlation analysis (Pearson product-moment correlation coefficient) on the statistical data.

2.1 Effects of Different Reclamation Methods on Soil Physical and Chemical Properties

The study found that deep digging and reclamation significantly improved soil conditions in *C. henryi* orchards. Table 1 presents the measured and analyzed soil physical and chemical properties in the two reclamation treatment areas, the control area, and pre-reclamation conditions in the fourth year of reclamation. The results show that in both whole-area and ring-area reclamation plots, soil moisture content, porosity, organic matter content, and various mineral element concentrations increased to varying degrees compared with the control and pre-reclamation levels, while soil bulk density decreased. Specifically, in the 0–30 cm layer, soil moisture content in whole-area and ring-area reclamation plots increased by 58.46% and 34.09% compared with pre-reclamation, and by 108.65% and 76.56% compared with the control, respectively. Soil bulk density decreased by 35.46% and 31.21% compared with pre-reclamation, and by 31.58% and 27.07% compared with the control. Soil porosity increased by 33.71% and 28.37% compared with pre-reclamation. Organic matter content increased by 17.76% and 40.59% compared with pre-reclamation. In the 0–30 cm layer, hydrolyzable nitrogen, available phosphorus, available potassium, exchangeable calcium, and exchangeable magnesium contents in both reclamation plots were significantly higher than in the control and pre-reclamation conditions, with available potassium content in reclamation plots exceeding three times that of the control and exchangeable magnesium content doubling that of the control. Additionally, soil pH values in both whole-area and ring-area reclamation plots were significantly higher than in the control and pre-reclamation conditions. These results fully demonstrate that deep digging and reclamation not only improves soil aeration and increases soil moisture and organic matter content but also promotes effective absorption and rational utilization of fertilizers in woodland soil.

2.2 Effects of Different Reclamation Methods on Leaf Phenotypic and Physiological Characteristics of *C. henryi*

Analysis results of leaf phenotypic traits under different reclamation methods are shown in Table 2 . The table indicates that mean differences in leaf length, width, shape index, and area among whole-area reclamation, ring-area reclamation, and control plots were not significant, whereas petiole length, specific leaf weight, and water content showed significant differences. Specific leaf weight was highest in the whole-area reclamation plot at 85.52 g/m^2, followed by the ring-area reclamation plot, both significantly higher than the control. Leaf water content was highest in the ring-area reclamation plot at 57.18%, followed by the whole-area reclamation plot, while the control had only 43.63%.

Analysis results of leaf physiological characteristics under different reclamation methods are shown in Table 3 . The results demonstrate that various leaf physiological indices differed among reclamation treatments, with carotenoid content, calcium content, and magnesium content showing significant differences among all treatment areas. Total chlorophyll content, chlorophyll a/b ratio, soluble sugar content, nitrogen content, phosphorus content, and potassium content showed significant differences between some treatments. Except for the chlorophyll a/b ratio, all other leaf physiological indices in whole-area and ring-area reclamation plots were equal to or significantly higher than those in the control plot.

2.3 Effects of Different Reclamation Methods on Tree Growth, Fruiting, and Yield of *C. henryi*

Investigation and statistical analysis of tree growth, fruiting, and yield in the fourth year of reclamation (Table 4) revealed no significant differences in tree height among whole-area reclamation, ring-area reclamation, and control plots. However, ground diameter and crown area were greater in the ring-area reclamation plot than in the whole-area reclamation and control plots, with significant differences between ring-area and whole-area reclamation. Fruiting performance differed among treatments, with the number of fruiting branches and fruit number in whole-area and ring-area reclamation plots significantly greater than in the control plot. Empty burr rate was highest in the control plot, significantly higher than in both reclamation treatments. Yield per unit area was highest in the whole-area reclamation plot at 0.21 kg/m^2, followed by the ring-area reclamation plot, both significantly higher than the control. These results indicate that both whole-area and ring-area reclamation enhance fruiting capacity and yield in *C. henryi*.

2.4 Effects of Different Reclamation Methods on Fruit Phenotypic and Nutritional Quality of *C. henryi*

As shown in Table 5 , fruit phenotypic traits differed among reclamation treatments, with total burr weight showing significant differences among all treatments, following the order: whole-area reclamation > ring-area reclamation > control. Single nut weight, nut transverse diameter, nut longitudinal diameter, and seed emergence rate in whole-area and ring-area reclamation plots were equal to or significantly greater than those in the control plot, whereas kernel rate showed no significant differences among treatments. Nut moisture content was highest in the control plot, significantly higher than in both reclamation treatments.

Analysis results of nut nutritional components under different reclamation methods are shown in Table 6 . Soluble sugar content and phosphorus content showed significant differences among treatments, with the highest values in the whole-area reclamation plot, followed by the ring-area reclamation plot. Starch content, potassium content, magnesium content, and total amino acid content in whole-area and ring-area reclamation plots were equal to or significantly higher than those in the control plot, whereas protein content and calcium content showed no significant differences among treatments.

2.5 Correlation Analysis Between Soil Physical and Chemical Properties and Tree Growth, Fruiting, Leaf and Fruit Phenotypes, and Nutritional Quality

Correlation analysis was performed between soil physical and chemical properties (0–30 cm layer) and various traits of *C. henryi* including growth, fruiting, leaf and fruit phenotypes, and nutritional quality. The results are presented in Table 7 . The analysis shows that, except for soil bulk density, all other soil physical and chemical indices were positively correlated with each other, with the positive correlation between soil porosity and hydrolyzable nitrogen content reaching a significant level. Soil bulk density was negatively correlated with soil porosity and hydrolyzable nitrogen content at extremely significant and significant levels, respectively.

In the correlation analysis between leaf phenotypic and physiological indices and soil physical and chemical indices, except for petiole length and chlorophyll a/b ratio, all other leaf traits were negatively correlated with soil bulk density, with the negative correlations of leaf soluble sugar content and calcium content with soil bulk density reaching significant levels. Additionally, leaf length was significantly positively correlated with soil pH, petiole length was significantly negatively correlated with soil exchangeable calcium content, chlorophyll a/b ratio was significantly negatively correlated with soil available potassium content, leaf soluble sugar content was significantly positively correlated with soil porosity and available potassium content, leaf phosphorus content was significantly positively correlated with soil exchangeable magnesium content, leaf potassium content was significantly positively correlated with soil pH, and leaf calcium content was significantly positively correlated with soil porosity and hydrolyzable nitrogen content at significant and extremely significant levels, respectively.

In the correlation analysis between tree growth, fruiting, and yield traits and soil physical and chemical indices, except for tree height and empty burr rate, all other indices were negatively correlated with soil bulk density. Furthermore, fruit number was significantly positively correlated with soil moisture content, ground diameter was extremely significantly positively correlated with soil organic matter content, and empty burr rate was significantly and extremely significantly negatively correlated with soil porosity and hydrolyzable nitrogen content, respectively.

Correlation results between fruit phenotypic traits, nutritional quality indices, and soil physical and chemical properties showed that, except for nut moisture content and protein content, all other indices were negatively correlated with soil bulk density. Additionally, single nut weight and starch content were extremely significantly and significantly positively correlated with soil moisture content, respectively; total burr weight was significantly positively correlated with soil exchangeable calcium content; starch content was significantly positively correlated with hydrolyzable nitrogen content; and nut moisture content was significantly negatively correlated with soil available potassium content.

Discussion

Soil is the primary source of water, organic matter, and nutrient elements required for fruit tree growth and development, and orchard soil management constitutes an important foundation in fruit cultivation. Scientific orchard soil management practices and favorable soil physical and chemical properties provide a good water, nutrient, gas, and thermal environment for root growth and development, maintain and improve soil fertility, and thereby promote tree growth while increasing fruit yield and quality (Zhang, 2004; Sun et al., 2011; Li et al., 2012).

In this study, continuous multi-year deep digging and reclamation produced significant improvements in *C. henryi* orchard soil. The most direct effects were substantial reductions in soil bulk density and significant increases in soil organic matter content. Soil bulk density refers to the mass or weight per unit volume of soil (including soil particles and pores) under natural field conditions. Deep digging and reclamation altered the original surface and deep soil structure of *C. henryi* stands, reducing weight per unit volume, significantly increasing soil porosity, loosening the soil, and enhancing aeration, thereby facilitating root nutrient uptake. These findings are consistent with Fan (2014). Simultaneously, reclamation incorporated large amounts of weeds and shrubs into deep soil layers, where they decomposed and transformed into humus, providing substantial carbon sources for the soil. Decomposition of soil organic carbon can supply large quantities of nutrients to the stand, continuously increasing soil organic matter content (Liu et al., 2011). The substantial increases in soil organic matter content in both whole-area and ring-area reclamation plots in this study confirm this result. Organic matter is an important energy and nutrient source for tree growth and development and serves as the foundation of fertility in dryland orchards, often used as a key indicator of soil fertility level (Wei et al., 2015; Shen, 2016). Therefore, continuously increasing soil organic matter content through deep digging and reclamation represents an important and effective measure for enhancing soil fertility and promoting high and stable fruit yields. Additionally, hydrolyzable nitrogen, available phosphorus, available potassium, exchangeable calcium, and exchangeable magnesium contents in both reclamation plots were higher than pre-reclamation and control levels, indicating that reclamation plots could effectively absorb, store, and utilize various fertilizers, further confirming the significant soil improvement effects of deep digging and reclamation. Interestingly, soil organic matter, available phosphorus, and exchangeable magnesium contents were higher in the ring reclamation area than in the whole reclamation area, with soil organic matter content in the fourth year reaching 20.2 g/kg and 23.9 g/kg in whole-area and ring-area reclamation plots, respectively—representing increases of 17.76% and 40.59% over pre-reclamation levels. This difference likely occurred because the larger reclamation area in whole-area plots accelerated nutrient consumption, which was unfavorable for nutrient accumulation, similar to the conclusions of Wu (2003). Therefore, from the perspective of soil nutrient retention capacity, ring reclamation may be superior to whole reclamation.

Leaves are the primary organs for photosynthesis in plants, synthesizing organic matter to provide power for root water and mineral nutrient absorption, and serving transpiration functions. The main phenotypic and physiological characteristics of leaves directly affect photosynthetic capacity and efficiency (Teng et al., 2017). This study showed that multi-year deep digging and reclamation significantly improved main leaf phenotypic traits, chlorophyll content, and various mineral element contents in *C. henryi*. Leaf water content in whole-area and ring-area reclamation plots reached 51.10% and 57.18%, respectively, significantly higher than the control (43.63%). Chlorophyll content, soluble sugar content, and mineral element contents including nitrogen, phosphorus, and potassium were also equal to or significantly higher than the control. Research has shown that adequate soil nutrient supply can significantly increase leaf protein and chlorophyll content in *C. henryi* and greatly promote photosynthetic capacity (Xu and Hu, 2001). Nitrogen, phosphorus, and potassium all participate in plant photosynthesis. Nitrogen, known as the "life element," is an important component of chlorophyll and chlorophyll proteins, directly participating in photosynthesis and affecting photosynthetic rate and dry matter accumulation. Leng et al. (2009) demonstrated that within a certain range, plant chlorophyll content and net photosynthetic rate increased with nitrogen levels. Phosphorus participates in photophosphorylation, controlling carbohydrate metabolism and sucrose export in leaves. Adequate phosphorus supply increased daily photosynthetic output by 1.5 times compared with phosphorus deficiency, significantly enhancing leaf function (Tian et al., 2015). Deep digging and reclamation improved soil physical and chemical properties and increased soil fertility in *C. henryi* orchards, thereby enhancing nutrient supply to leaves and enabling better photosynthesis. The photosynthetic products, in turn, provided power for *C. henryi* roots to absorb and store more nutrients, creating a virtuous cycle.

Multi-year deep digging and reclamation also significantly improved tree growth, fruiting capacity, unit area yield, and nut quality and nutritional value. Ground diameter and crown area in the ring reclamation plot reached 18.2 cm and 27.1 m^2, respectively—7.69% and 8.40% higher than the control. Unit area yield, nut starch content, and soluble sugar content were highest in the whole-area reclamation plot, with unit area yield reaching 0.21 kg/m^2, 1.75 times that of the control. Empty burr rates in both reclamation treatments were significantly lower than in the control. Fei (2013) reported that stand reclamation significantly improved walnut tree height, crown width, fruit number, single fruit weight, and per-tree yield, with fruit number and per-tree yield in reclaimed stands being 1.96 and 1.80 times those of unreclaimed stands, respectively. Huang et al. (2004) found that woodland reclamation significantly improved *C. henryi* per-tree yield, with three reclamation methods increasing per-tree yield by over 80% compared with unreclaimed stands. Furthermore, correlation analysis in this study showed that, except for nut moisture content and protein content, *C. henryi* unit area yield, fruit phenotypic traits, and nutritional quality indices were positively correlated with soil moisture content, porosity, organic matter, and various element contents. Deep digging and reclamation increased soil organic matter content, enabling balanced supply of mineral elements including nitrogen, phosphorus, and potassium. Hu et al. (2014) reported that soil organic matter and nitrogen, phosphorus, and potassium contents all promoted chestnut yield, with organic matter having the greatest direct effect. Nitrogen, phosphorus, and potassium are essential macronutrients for plant growth and development, playing irreplaceable roles in plant life activities and exhibiting clear coupling with carbon, water, phosphorus, and sulfur in ecosystems (Zhejiang Agricultural University, 1991). Nitrogen significantly promotes fruit tree vegetative growth, while phosphorus and potassium fertilizers significantly enhance tree vigor and fruit quality. For example, adequate phosphorus increases cell soluble sugar and phospholipid contents (Liu and Li, 2000), while potassium promotes fruit sugar accumulation (He et al., 2002). Deep digging and reclamation simultaneously improved soil physical and chemical properties, water conservation capacity, nutrient retention and supply ability, and nutrient availability. The improved soil structure and fertility effectively promoted *C. henryi* growth, fruiting capacity, and fruit development, thereby significantly increasing unit area yield and contents of nutrients such as starch and soluble sugar, ensuring sustained high productivity in *C. henryi*.

Conclusion

Both reclamation methods produced significant soil improvement effects in *C. henryi* orchards. In the fourth year of reclamation, soil bulk density decreased substantially, soil organic matter content increased significantly, and soil fertility and water/nutrient retention capacity were markedly enhanced, with ring reclamation demonstrating superior nutrient retention capacity compared with whole reclamation. Improved soil fertility subsequently enhanced nutrient supply to trees, fruiting branches, and leaves, significantly increasing leaf chlorophyll content and photosynthetic capacity, effectively promoting tree growth and development, and significantly improving fruiting performance, yield, and nut quality and nutritional value. Unit area yields in whole-area and ring-area reclamation plots were 1.75 and 1.33 times that of the control, respectively, with empty burr rates substantially reduced. In summary, deep digging and reclamation is an effective measure for improving woodland soil and enhancing *C. henryi* productivity.

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Note: Figure translations are in progress. See original paper for figures.