Synergistic and sustainable impact of reducing nitrogen fertilizer on growth, yield, and quality of ramie (Boehmeria nivea L.)

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ABSTRACT
Ramie (Boehmeria nivea L.) is China’s unique environmentally friendly cash crop. To protect the environment more strictly and develop sustainably, the planting process will reduce the input of fertilizer (nitrogen fertilizer). The effect of reduced nitrogen fertilizer on the yield and quality of ramie is still under systematic investigation. Taking the fiber variety ‘H2’ as the target, 4 N application rates of 100% (N 390 kg/hm²), 85%, 70%, and 55% were set, with no N application as the control (marked as N100, N85, N70, N55, and CK), to study the effects of N reduction on ramie yield, N uptake and utilization, and soil fertility. The results showed that the total production of ramie first harvest raw fiber and nitrogen accumulation showed a trend of first rising and then falling with the decrease of nitrogen application, the output of secondary and tertiary harvest ramie decreased with the reduction of nitrogen application, and the total production of N85 treatment was the highest. Compared with N100, N70 and N85 can improve N utilization, N agronomic utilization, N partial productivity, and N harvest index. Nitrogen reduction can reduce the content of soil organic matter, available phosphorus, and available potassium in ramie, and the difference between N85 and N100 is not significant. Nitrogen fertilizer application can be reduced by 15% in ramie production.

1. Introduction
Nitrogen is an essential nutrient element for the growth and development of crops, which affects maize (Badu-Apraku et al., 2018), rice (Hou et al., 2019), wheat (Hitz et al., 2017), and rape (Storer et al., 2018) are among the major factors influencing abiotic stress. For a long time, heavy nitrogen application has been regarded as an essential measure to improve the yield of ramie. However, excessive nitrogen fertilizer application resulted in decreased yield from fresh ramie stem, fiber yield from fresh ramie skin, and fiber quality (LIU et al., 2012). If the amount of nitrogen applied was too little, the leaf nitrogen content of ramie decreased, and the growth was inhibited until stopped, and a large number of HSP family proteins were down-regulated (Deng et al., 2014), which affected the development of ramie. An appropriate amount of

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selective fertilization can improve the quality of ramie, obtain higher economic benefits, and reduce environmental pollution (Ullah et al., 2017).

Excessive application of nitrogen fertilizer causes diminishing returns and environmental pollution. Nitrogen fertilizer can be lost to the environment through ammonia volatilization, leaching, leakage, nitrification, and denitrification after being applied to the soil, which not only wastes a lot of resources but also causes enormous economic losses and environmental severe pollution (Bähring et al., 2017; Rehman, Saleem et al., 2020, 2020). How to apply nitrogen fertilizer reasonably and establish efficient management technology of nitrogen fertilizer application has become the focus of many researchers. To avoid the excessive application of nitrogen fertilizer, the proper application amount of nitrogen fertilizer is selected to minimize the application amount of nitrogen fertilizer and improve the utilization rate of nitrogen fertilizer based on guaranteeing the yield (Frasier et al., 2017). Nitrogen is the main nutrient element of crops and the main component of an important enzyme in physiological metabolism. The two main factors affecting nitrogen absorption efficiency is to absorb activity (e.g. high nitrogen transporter affinity) and the root structure, through the transcription and the transcription level of nitrogen supply regulation and control, optimize plant under low nitrogen utilization efficiency of nitrogen for efficiency, metabolites may participate in low nitrogen regulation and help to nitrogen deficiency the genetic improvement of rice yield (Kiba & Krapp, 2016; Zhao et al., 2018), semi-dwarf hybrid rape showed better yield performance under low nitrogen conditions (Miersch et al., 2016).

Ramie (Boehmeria nivea L.) is China’s traditional characteristic cash crop. Its planting area and fibre output in China account for more than 90% of the world. It is critical quality raw textile materials and export to earn foreign exchange best-selling products. Ramie is widely cultured in the Yangtze valley and its southern areas in China. China is the native home of ramie and has plenty of wild species in the genus Boehmeria, 32 species, and 11 varieties. The wild species in the genus Boehmeria are the important genetic resourcecriticalman does not yet utilize. In the fertilizer management of ramie in China, excessive nitrogen fertilizer is standard (Rehman, Gang et al., 2019). The utilization efficiency of nitrogen fertilizer decreases year by year, and the relative production cost increases gradually, bringing substantial economic loss and environmental pollution (Rehman, Gang et al., 2019). Under this background, reduced N application is a nitrogen fertilizer management technology developed, that is, under the premise of ensuring stable crop yield, reducing N fertilizer input as far as possible, improving N fertilizer utilization efficiency and reducing environmental pollution (Rehman, Gang et al., 2019). Substituting Azolla biofertilizer for 25% of urea-N provides a financial option for farmers to substantially improve nitrogen use efficiency (NUE) and yield and effectively reduce N loss in intensive rice cropping Systems (Yao et al., 2018). The effects of nitrogen reduction on ramie yield, nitrogen absorption, and soil fertility were studied, which provided a theoretical basis for the research on sustainable planting technology of ramie with reduced nitrogen application.

2. Materials and methods

2.1. Experimental design and materials

The high yield variety Huazhu No. 5 (H5) was used in this study during 2017–2018. The following 4 treatments were set in the experiment: 100% fertilizer (390 kg/ha, conventional fertilizer dose) (N100), 85% nitrogen (N85), 70% nitrogen (N70), 55% nitrogen (N55), and no nitrogen (CK). Random block arrangement was adopted and repeated three times. The test site’s main soil fertility indexes: organic matter 15.91 g/kg, total nitrogen 1.18 g/kg, available phosphorus 18.83 mg/kg, available potassium 220.05 mg/kg, pH 6.23.

Test fertilizers: nitrogen-urea (Hubei yihua, China; nitrogen content 46.4%), calcium superphosphate (Hubei yihua, China; P2O5 12%), potassium chloride (Russia, K2O 60%).

Ramie base transplanting density of 60 thousand plants/ha2. Each box was planted with four rows of ramie, with a wide row spacing of 80 cm and a narrow row spacing of 50 cm. The area of the plot is 10.12 m2. Base fertilizer was applied by the experimental design at the end of October 2017. 100% nitrogen fertilizer application: pure nitrogen content 390 kg/ha2, according to the base fertilizer, before the second harvest and after second harvest 2:1 ratio. P2O5 150 kg/ha2, K2O 300 kg/ha2, essential fertilizer was applied one time. Seedlings were raised in spring 2016 and transplanted to the experimental site on October 9. The official trial period is 2017–2018.

Ramie can harvest three times a year: first harvest (FHR) on June 5, second harvest (SHR) on August 2, and third harvest (THR) on October 13. During harvest, plant height, stem diameter, and yield of raw fiber were measured.
2.2. Sample collection and determination

2.2.1. Soil samples

Soil samples were collected in each treatment area after each season’s ramie harvest. The soil layer 0–20 cm deep was composed with a soil shovel. Soil samples of 6 points were collected by the ‘S’ shape route in each community and then mixed into a mixed soil sample. Place the soil sample in a clean and well-ventilated place and dry naturally. During the drying process, large lumps of soil are crushed to pick out plant debris rock.

Crush the dried soil sample with a mallet, then pass through a 20-mesh sieve set aside. Take part of the soil sample through a 20 mesh screen and continue to crush it to pass through 100 mesh screens.

2.2.2. Index measurement method

(1) determination of yield and agronomic traits

Harvest ramie in the mature stage and measure the biomass. Agronomic characters such as plant height and stem diameter were investigated.

(2) Plant nitrogen content

Total nitrogen of plants: after being boiled by the H₂SO₄-H₂O₂ method, the semi-micro Barbanco (Barbano et al., 1990) method was used for determination.

Nitrogen accumulation amount (kg/hm²) = nitrogen accumulation amount of plants per unit area in a certain growth period;

Nitrogen utilization efficiency rate (Nt(%)) = (nitrogen accumulation in aboveground in nitrogen application area – nitrogen accumulation in aboveground in non-nitrogen application area)/nitrogen application amount *100;

Nitrogen agronomic efficiency, (Nₐₑ kg/kg) = (yield in N application area – yield in N application area)/N application amount;

Nitrogen partial factor productivity (Nₚₚₚ kg/kg) = N fertilizer area yield/N fertilizer amount;

Nitrogen harvest index (Nₜₕ(%)) = total N accumulation in phloem/total N accumulation in plants *100

(3) soil nutrients

Using a pH meter, soil pH was determined in a 2.5:1 water/soil suspension (LY/T 1239–1999). The extraction determined soil available P with HCl and NH₄F (LY/T 1233–1999). Soil organic matter (SOM): organic matter and sulfides bound fraction (OM-As) (5 ml of 30% H₂O₂ and 3 ml of 0.02 M HNO₃ for two h, a second 3 ml of 30% H₂O₂ for three h, at 85°C; Ondrasek et al., 2019);

Soil total nitrogen: semi – trace Kjeldahl (Ondrasek et al., 2019)

Soil available phosphorus: 0.5 mol/L NaHCO₃ extraction – molybdenum-antimony anticolorimetric method

Soil available potassium: 1 mol/l NH₄OAc extraction – flame photometry

2.3. Data processing and analysis

Microsoft Excel 2013 and SPSS 20.0 were used for data statistics and analysis, and Graphpad prism was used for mapping, and correlation analysis was constructed using RStudio.

3. Results

3.1. Ramie yield

Compared with CK, the yield of the first harvest (FHR), second harvest (SHR), and third harvest (THR) were increased by 136.97 ~ 255.00 kg/hm², 11.00 ~ 77.84 kg/hm² and 146.81 ~ 218.67 kg/hm², respectively, with yield increasing rates of 25.43 ~ 47.33%, 2.91 ~ 20.54%, and 64.27 ~ 95.73%, respectively. Application of nitrogen fertilizer can significantly increase the yield of third ramie harvest (THR)> first harvest (FHR) > second harvest (SHR; Table 1).

With the decrease of nitrogen application amount, the yield of the first harvest fiber increased and then decreased. The highest product of N₈S treatment was 793.72 kg/hm², followed by N₁₀₀ and N₁₀ treatment. The yield of the first harvest fiber was significantly higher than CK. The yield of N₈S was 18.41 kg/hm² higher than that of N₁₀₀ fiber, with an increased rate of 2.37%. There was no significant difference in yield of N₁₀₀, N₈S, N₇₀, and N₅₅ (p= 0.05). The result of N₁₀₀ of the third harvest was the highest, reaching 447.1 kg/hm², with no significant difference from N₈S, N₇₀, and N₅₅ (p= 0.05). The yield of CK fiber was significantly lower than that of nitrogen treatment.

| Treatment | FHR (kg/hm²) | SHR (kg/hm²) | THR (kg/hm²) | Total yield (kg/hm²) |
|-----------|--------------|--------------|--------------|----------------------|
| N₁₀₀      | 775.21 ± 16.96a | 456.90 ± 22.80a | 447.10 ± 29.86a | 1652.04               |
| N₈S       | 793.72 ± 36.85a | 433.12 ± 9.94ab | 419.83 ± 17.65a | 1673.94               |
| N₇₀       | 744.21 ± 32.81ab | 429.63 ± 3.83ab | 406.88 ± 5.65a | 1580.72               |
| N₅₅       | 675.69 ± 13.43b | 390.06 ± 32.62ab | 375.24 ± 23.25a | 1440.99               |
| CK        | 538.72 ± 19.84c | 379.06 ± 23.02b | 228.43 ± 17.24b | 1146.21               |

FHR (first harvest) on June 5; SHR (second harvest) on August 2, and THR (third harvest) on October 13; Different lowercase letters after the same column data indicate significant differences at p = 0.05 level.
The annual yield of ramie raw fiber increased first and then decreased with the decrease of nitrogen application, and the highest yield of N100 was found (1673.94 kg/hm²). Compared with N100, N85 production increased by 1.33%.

### 3.2. Agronomic traits

The effect of reduced nitrogen fertilizer on the plant height of ramie is shown in Table 2; the plant height of FHR was 138.63 ~ 171.43 cm. The SHR plant height was 109.60 ~ 132.07 cm. The THR plant height was 80.73 ~ 104.40 cm. With the growth period of ramie, the plant height of ramie decreased gradually. During the harvest period of the first and third harvest, the plant height of ramie showed a trend of first increasing and then decreasing with the decrease of nitrogen application, among which the plant height of N85 treatment was the highest, which was 171.43 cm and 104.4 cm. During the harvest period of THR, the plant height of N100 treatment was significantly higher than that of N70, N85, and CK. The plant height of ramie decreased with nitrogen application during the harvest period.

It can be seen from Table 2 that ramie stem diameter is FHR>SHR>THR. The stem diameter of the N100 treatment was the largest (11.80 mm), and that of CK treatment was the smallest (11.80 mm), but the difference between the four treatments was not significant. In the harvest period of secondary and third hemp, the stem diameter of other nitrogenous fertilizer treatments decreased to different degrees than that of N100. Compared with N100, the difference of N85, N70, and N85 did not reach the significant level, and the stem diameter of CK was significantly lower than that of N100.

### 3.3. Effects on the nitrogen utilization rate

As shown in Table 3, N utilization rate, N agronomic utilization rate, and N harvest index all rose first and then fill with the decrease of N application. Compared with N100, N70 and N85, N85 treatment had the highest nitrogen utilization rate, which was 10.08%, 7.82%, and 13.74% lower than that of N70 and N85 treatment, and the difference reached a significant level of 5%. The agronomic utilization rate of nitrogen fertilizer treated with N85 and N70 was higher than that treated with N100 and N85, but the difference did not reach the significant level of 5%. Compared with CK, N100 (1.56%~3.41%) of all nitrogen treatments increased, indicating that N application could increase the N harvest index. N treatment with N85 had the highest partial productivity (14.88%), which did not reach the significant level of 5% compared with other treatments. The partial productivity of N fertilizer in ramie increased with the decrease of N application. The partial productivity of N fertilizer in N85 treatment was significantly higher than that in N100, N85, and N70 treatment.

### 3.4. Effects on soil nutrients

#### 3.4.1. Effects on soil pH

In different growth stages of ramie, the pH value of all treatments showed a similar trend, first decreasing and then increasing, and the soil pH value of SHR was the smallest (Table 4). CK soil pH was 5.73, significantly higher than that of other nitrogen application treatments. CK of secondary hemp was substantially higher than that of N100 and N85 but not substantially different from that of N70 and N85. Compared with CK, the pH of treatment with N100, N85, and N70 decreased by 0.66, 0.55, and 0.48, respectively, and the difference reached a significant level of 5%.

#### 3.4.2. Effects on soil organic matter

Soil organic matter of each treatment of FHR decreased with nitrogen application (Table 4). Soil organic matter of N100 and N85 treatment was significantly higher than that of

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**Table 2. Effect of direct reduction of nitrogen application on plant height and stem diameter of ramie.**

| Treatment | Height (cm) | Stem diameter (mm) |
|-----------|-------------|--------------------|
|           | FHR         | SHR                | THR    | FHR     | SHR     | THR     |
| N100      | 156.50 ± 3.55b | 132.07 ± 4.68a     | 96.67 ± 9.56ab | 11.80 ± 0.07a | 10.09 ± 0.12a | 10.08 ± 0.12a |
| N85       | 171.43 ± 2.71a | 131.77 ± 5.63a     | 104.40 ± 5.8a  | 11.64 ± 0.29a | 9.22 ± 0.13ab | 9.02 ± 0.37ab |
| N70       | 164.43 ± 3.29ab| 129.13 ± 5.73a     | 83.57 ± 10.43b | 11.72 ± 0.17a | 9.78 ± 0.40a  | 9.36 ± 0.20ab |
| N85       | 161.70 ± 4.05ab| 126.53 ± 6.99ab    | 80.83 ± 11.09b | 11.25 ± 0.63a | 9.00 ± 0.38ab | 8.67 ± 0.74ab |
| CK        | 138.63 ± 2.44c | 109.60 ± 5.52b     | 80.73 ± 8.64b  | 11.05 ± 0.19a | 8.62 ± 0.44b  | 8.59 ± 0.42b  |

FHR (first harvest) on June 5, SHR (second harvest) on August 2, and THR (third harvest) on October 13; Different lowercase letters after the same column data indicate significant differences at p = 0.05 level

**Table 3. Effect of direct reduction of nitrogen fertilizer on nitrogen utilization rate of ramie.**

| Treatment | Nf (%) | NAE (kg/kg) | NPP (kg/kg) | Nh (%) |
|-----------|--------|-------------|-------------|--------|
| N100      | 17.46bc| 1.30a       | 4.24c       | 13.03a |
| N85       | 27.54a | 1.59a       | 5.05bc      | 14.88a |
| N70       | 19.72b | 1.59a       | 5.79b       | 13.97a |
| N85       | 13.79c | 1.37a       | 6.72a       | 13.79a |
| CK        |        |             |             | 11.47a |

Different lowercase letters after the same column data indicate significant differences at p = 0.05 level. Nf: Nitrogen use rate; NAE: Nitrogen use agronomic efficiency; NPP: Nitrogen partial factor productivity; Nh: Nitrogen harvest index.
N55 and CK treatment. The N100 of SHR increased by 2.60 g/kg compared with CK, and the difference reached a significant level of 5%. Compared with N100 treatment, the organic matter in N85, N70, and N55 treatment decreased by 0.49 ~ 1.55 g/kg, but the difference did not reach the significant level of 5%. The soil organic matter content in THR N100 treatment was the highest, and the range of soil organic matter in nitrogen reduction treatment decreased but did not reach the significant level of 5%.

### 3.4.3. Effects on soil total nitrogen

Compared with the content of total soil nitrogen (1.18 g/kg) before the experiment, the total nitrogen in FHR soil increased by 0.07 ~ 0.29 g/kg (Table 5). SHR increased by 0.20 ~ 0.37 g/kg. During THR, the entire nitrogen content of soil treated with N100, N85, and N70 increased by 0.11 ~ 0.14 g/kg, while entire soil treated with N55 and CK decreased by 0.03 g/kg and 0.09 g/kg, respectively. Effects of different treatments on soil total nitrogen content: SHR > FHR > THR, and N100, N85, and N70 treatments can improve soil nitrogen content. The difference of total nitrogen content in soil treated with both did not reach the significant level of 5%.

### 3.4.4. Effects on soil available phosphorus

Compared with the available phosphorus in soil (18.83 mg/kg) before the test, the available phosphorus in the soil of FHR ranged from 22.40 to 25.33 mg/kg, SHR from 25.58 to 34.23 mg/kg, and THR from 14.13 to 31.18 mg/kg (Table 5). The content of available phosphorus in the soil of N85 was not significantly lower than that of N100.

### 3.4.5. Effects on soil available potassium

Compared with the content of available potassium (220.05 mg/kg) in the soil before the experiment, the available potassium content in the soil before the investigation increased by 1.85 ~ 40.85 mg/kg (Table 6). SHR was increased by 37.89 ~ 61.27 mg/kg. The range of THR was 231.80 ~ 287.03 mg/kg. The effects of different treatments on soil available potassium were as follows: SHR > THR > FHR, N100, N85, N70, and N55 could increase the content of available potassium in the soil.

In the present study, the application of N100 and N85 were significantly higher than N55 and CK. The available potassium content in SHR N100 was the highest (281.32 mg/kg), which was not substantially different from other treatments (5%). Compared with the N100 treatment, there was no significant decrease of available soil potassium in N85 and N70. The content of N70 was the highest in the soil treated with the THR, which was significantly higher than that treated with N55 and CK.
3.5. **Relationship**

We constructed a correlation graph, and heatmap analysis to quantify the relationship between various growth and yield attributes in ramie grown under different reducing levels of nitrogen. According to Pearson’s correlation analysis, all growth parameters were showed a positive relationship with each other ([Figure 1](#)); Heatmap analysis also led that most of the growth-related attributes were non-significant with the rest of the parameters while a significant relation was shown on control at their various yield and growth harvesting times ([Figure 2](#)). These relationships show that nitrogen application significantly affected growth and yield in ramie.

4. **Discussion**

4.1. **Effects on ramie yield and agronomic characters**

Nitrogen application plays a vital role in increasing crop yield. However, excessive nitrogen fertilizer application will lead to resource waste, lower nitrogen utilization rate, environmental pollution, and lower crop yield and quality ([Frasier et al., 2017](#)). Rational application of nitrogen fertilizer can reduce the application of nitrogen fertilizer and improve the utilization rate of nitrogen fertilizer without reducing the yield ([Yao et al., 2018](#)). This experiment showed that compared with the control group without fertilization (CK), the yield of nitrogen fertilizer increased in different degrees. The effect of applying nitrogen fertilizer to increase FHR > SHR > THR. Drought in the growing period of secondary and tertiary harvest ramie will reduce ramie production, and drought is one of the main factors limiting the yield of secondary and tertiary ramie ([LIU et al., 2012](#)). The annual yield of ramie raw fiber increased first and then decreased with the decrease of nitrogen application, and the highest yield of N85 treatment was 1673.94 kg/hm². Compared with N100, N85 yield increased by 1.33%, and N70 yield decreased by 4.32%, but 55% of N85 yield decreased significantly compared with full nitrogen application, reducing 211.05 kg/hm². Therefore, the yield of ramie will not decrease significantly if nitrogen is reduced by 15%~30%. Compared with the total nitrogen treatment, the stem diameter of the plants treated with reduced or no nitrogen fertilizer decreased to different degrees, but the difference was not significant. This may be because the growth period of the first harvest is long, the climate is suitable, and the rain is suitable, which is beneficial to the growth of ramie ([Rehman, Gang et al., 2019](#)). The short growth period, high temperature, and long drought limit the growth of ramie and reduce the plant height and yield. Continuous drought affected the development of ramie ([Rehman, Yang et al., 2020](#)). In the late growth stage of ramie, the growth of nutrition was slowed down by drought, decrease of air...
4.2. Effects showed soil long-term and yield growth. Nitrogen. Figure with application.

**Figure 2.** Heatmap analysis between various growth-related attributes in ramie when cultivated under reducing levels of nitrogen.

temperature and short sunshine, and the reproductive growth of ramie was induced, which further reduced the yield and affected the agronomic characters of ramie (Rehman, Gang et al., 2019).

### 4.2. Effects on nitrogen absorption and utilization of ramie

In this experiment, the N fertilizer utilization rate, \( N_{AE} \) and \( N_{Hi} \) of ramie increased first and then decreased with the decrease of N application, while the \( N_{PFP} \) of ramie increased gradually with the decrease of N application. Compared with 100% nitrogen application, \( N_{E}, N_{AE}, N_{PFP} \) and \( N_{Hi} \) of ramie were all increased with 15%~30% reduction of nitrogen application, which was consistent with the results of previous studies (Deng et al., 2014; Ullah et al., 2017). It can be shown that proper reduction of nitrogen application can promote the efficient absorption and utilization of nitrogen in ramie, affect the transfer and distribution of nitrogen in ramie, and be beneficial to the growth and development of ramie.

### 4.3. Effects on soil nutrients

Long-term application of nitrogen fertilizer changes soil pH. Rehman et al. (Rehman, Yang et al., 2020) showed that long-term application of fertilizer transformed nitrogen into ammonium nitrogen in the soil, which was then oxidized and released H\(^+\), leading to a decrease in soil pH value and soil acidification. (Yan et al. 2013) conducted a long-term positioning test on red soil paddy soil in Jiangxi province, which showed that long-term fertilization would acidify the soil and decrease the pH value of the soil, while unreasonable fertilization would lead to degradation of the basic properties of the soil. The results of this experiment showed that the pH of soil with nitrogen fertilizer decreased compared with that without fertilizer. This is consistent with the results of previous studies. (Xu et al. 2008) showed that the active organic matter and carbon pool management index of soil were both reduced during 10 years of cultivation without fertilizer application. Application of fertilizers, especially nitrogen alone, resulted in the greatest reduction in soil organic matter. In this study, it was found that compared with before the experiment (organic matter 15.91 g/kg), the content of soil organic matter during the harvest period of SHR increased with the full amount of nitrogen application, while all the others decreased, and the difference between treatments did not reach a significant level. This may be due to the fact that there were more dead branches and leaves treated with full nitrogen application, which increased the content of organic matter in the soil. Hou (Hou et al., 2019), after 2 years of localized fertilization experiment, concluded that fertilization could significantly improve the content of alkali-hydrolyzed nitrogen, available phosphorus and available potassium in soil. (Zhang et al. 2009) showed that the application of fertilizer could increase the content of alkali-hydrolyzed nitrogen and total nitrogen in the soil, and the accumulation of fertilizer phosphorus in the soil could significantly increase the content of available phosphorus and total phosphorus in the soil. In this experiment, compared with the soil before the experiment (1.18 g/kg), the total nitrogen content of the soil during the harvest period of SHR decreased by 45% and that of the control soil without fertilization, while the total nitrogen content of the rest was higher than that before the experiment. Therefore, nitrogen reduction of 45% and no fertilizer treatment could not provide the nitrogen needed for annual growth of ramie. In the harvest period of THR, with the decrease of nitrogen application, the available phosphorus in soil showed a trend of decrease, and the content of available potassium showed a trend of first increase and then decrease. This may be because higher nitrogen treatment
increased the yield of ramie and promoted the uptake of phosphorus and potassium from the soil (Carrubba, 2009). Compared with the total nitrogen application, the content of available phosphorus and available potassium in soil treated with 85% n fertilizer did not decrease significantly.

Under the condition of low nitrogen, the optimization of nitrogen distribution in leaves is the key adaptive mechanism to maximize the yield and when the nitrogen level of maize is limited during the filling period (Rehman, Saleem et al., 2020). Foxtail millet may preferentially transport carbon to roots, promote root thickening/nutrient transport, and allocate N to buds to maximize photosynthesis/carbon fixation, as the main adaptive strategy for limiting (Nadeem et al., 2018).

5. Conclusion

In conclusion, we conducted a field study using ‘Huazhu No. 5’ under various levels of reducing nitrogen fertilization. Application of various nitrogen concentrations in the soil showed that nitrogen is helpful for ramie to grow up to certain level (N85 and N70), but increasing from this concentration (N100) ramie growth and yield started declined. In addition, N85 and N70 also can improve nitrogen utilization nitrogen partial productivity and nitrogen harvest index. However, increasing nitrogen concentration further decrease the contents of soil organic matter, available phosphorus and available potassium in ramie. However, necessary adaptations should follow to make sure a safe consumption of ramie leaves or stems.

Highlights

- Ramie was fertilized at various levels of N.
- Ramie production at first harvest increases then decreases with varying N levels.
- Application of N improved soil properties while increasing N application can decrease ramie production.

Disclosure statement

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Data availability

Data will be available on demand.

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