Several Cotton Rotation and Intercropping Systems in Cotton Planting Area of Eastern Henan Province

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Abstract In recent years, the area dedicated to cotton cultivation in eastern Henan Province has experienced a continuous decline. Developing efficient multi-cropping systems for cotton and increasing the multiple cropping index represent effective strategies to stabilize the cotton planting area and enhance the income of cotton farmers. This paper presents an overview of intercropping systems and the benefits associated with cotton rotation and intercropping practices. Specifically, it discusses the "early maturing cotton-wheat" rotation system, the "cotton-watermelon" intercropping system, the "cotton-Dutch bean" intercropping system, and the "early maturing cotton-peanut-garlic" intercropping system.

Key words Cotton; Intercropping; Crop rotation; Wheat; Dutch bean; Watermelon

1 Introduction

Cotton is a significant economic crop in China. The cultivated land in eastern Henan predominantly consists of loam and sandy loam soils. The region's climatic conditions are favorable for the cultivation of various crops, including wheat, corn, garlic, cotton, sweet potatoes, and vegetables. In recent years, farmers in eastern Henan Province have exhibited a decreased level of activity in cotton cultivation due to several factors, including elevated labor costs, low profitability associated with cotton farming, and competition between land designated for grain and cotton production. Under the assumption that the complete mechanization of the cotton production process can not be achieved in a single step, one effective strategy to stabilize the area dedicated to cotton cultivation and enhance the income of cotton farmers is to implement efficient multi-cropping practices. This approach aims to improve the multiple cropping index and increase land productivity[1]. During the seedling stage, cotton plants are relatively small, and a significant portion of the land remains bare and unutilized, leading to considerable wastage of land resources. However, intercropping with other crops can enhance the effective utilization of the land[2]. Numerous studies have demonstrated that interplanting and intercropping can significantly diminish the prevalence of diseases and pests affecting cotton crops[3-7]. These practices also contribute to a reduction in pesticide application, enhance the population of beneficial microorganisms in the soil, and consequently improve soil quality[8]. The practice of intercropping in cotton fields has been shown to enhance vegetation coverage, suppress weed growth, decrease weeding costs, and conserve labor resources[9].

To stabilize the cotton planting area and enhance the income of cotton farmers, various stakeholders, including researchers, companies, and professional cooperatives associated with the Kaifeng Academy of Agriculture and Forestry, have actively engaged in a range of experiments and demonstrations involving cotton rotation and intercropping models. This initiative has been supported by the national cotton industry technology system and other related projects. These efforts, conducted in the cotton planting region of eastern Henan Province in recent years, have yielded significant economic and social benefits, which are detailed in the following sections.

2 "Early maturing cotton-wheat" rotation system and its advantages

2.1 "Early maturing cotton-wheat" rotation system In the "early maturing cotton-wheat" rotation system, high-yielding and high-quality early maturing cotton varieties are typically selected. Mechanical precision sowing occurs in early June, following the harvest of wheat and the removal of stubble. This process is conducted without mulching, with row spacing maintained at 70 - 80 cm, resulting in the planting of approximately 6 800 plants/666.7 m^2. The cotton harvest is concluded in early November, after which the cotton stalks are mechanically crushed and returned to the field to facilitate the cultivation of wheat. In the context of medium soil fertility in eastern Henan Province, the average yield of cotton seeds per 666.7 m^2 is approximately 300 kg, while the yield of wheat exceeds 400 kg/666.7 m^2. This system has been effectively demonstrated and widely adopted in the wheat and cotton cultivation regions of Weishi County, in Kaifeng City.

2.2 Advantages The "early maturing cotton-wheat" rotation system plays a crucial role in mitigating the scarcity of cultivated land resources, stabilizing grain production areas, and reducing the competition between grain and cotton for land use. In comparison to the conventional spring cotton intercropping with wheat planting method, this approach minimizes the need for manual cultivation and transplanting of cotton. It also mitigates the overshadowing of cotton seedlings by wheat during the early growth stage,

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decreases the incidence of diseases and pests at this stage, and facilitates the mechanized harvesting of wheat. The growth period of early-maturing cotton is relatively brief. During this period, practices such as appropriate dense planting, the avoidance of thinning and final singling are implemented. These practices are complemented by suitable chemical regulation to eliminate the need for pruning. Additionally, the adoption of efficient, lightweight, and simplified cultivation technologies, such as the use of unmanned aerial vehicles (UAVs) for disease and pest prevention, as well as UAV-assisted chemical topping, can significantly reduce the reliance on mulch film. This, in turn, diminishes non-point source pollution in agricultural fields and substantially lowers the labor input associated with physical and chemical interventions. These strategies are crucial for promoting the green and sustainable development of cotton production[10]. The "early maturing cotton-wheat" rotation system facilitates the integration of agricultural machinery with agricultural practices, as well as the alignment of superior varieties with effective methodologies. This approach aligns with the current trends in agricultural development, which are characterized by principles of simplicity, cost-effectiveness, sustainability, and efficiency.

3 "Cotton-watermelon" intercropping system and its advantages

3.1 "Cotton-watermelon" intercropping system The "cotton-watermelon" intercropping system typically involves the selection of early-maturing watermelon varieties. Transplanting is conducted promptly when the ground temperature stabilizes above 15 ℃ in late March. Following the transplanting process, an arch cover is applied. High-quality, high-yield spring cotton varieties are typically sown with adequate moisture in mid to late April, generally employing either the "1 – 2 type" or "double 1 type" planting methods. "1 – 2 type" refers to a planting arrangement in which one row of watermelon is interplanted with two rows of cotton, maintaining a spacing of 180 cm. The row spacing for cotton is 40 cm, while the row spacing for watermelon is 180 cm. Additionally, the narrow row spacing for cotton is 80 cm, and the wide row spacing is 100 cm. The spacing between individual plants is approximately 23 cm. "Double 1 type" configuration consists of one row of cotton and one row of watermelon. The bandwidth measures 1.5 m, with a narrow row spacing of 15 cm between the cotton and watermelon, and a wider row spacing of 135 cm. When watermelon is cultivated, it is covered with a mulch film that is 90 cm wide. Similarly, cotton is also planted beneath the film, with 2 to 3 plants per planting hole, and the distance between the holes is approximately 40 cm. In early to middle June, following the harvest of ripe watermelons, the melon seedlings are promptly removed from the field. This practice does not impede the growth of cotton during the intermediate and later stages of its development. Under this planting system, the yield of seed cotton is typically approximately 250 kg, while the yield of watermelon is around 4 000 kg per 666.7 m^2. After accounting for a cost of 1 500 yuan, the net benefit can reach approximately 6 000 yuan per 666.7 m^2. This model is extensively utilized in regions known for watermelon production, including Weishi County in Kaifeng City and Suiyang District in Shangqiu.

3.2 Advantages Under the "cotton-watermelon" intercropping system, the 60-day symbiotic period between early cotton and mid to late watermelon allows for minimal competition for growth space. The growth peaks of both watermelon and cotton are effectively staggered, resulting in negligible interference between the two crops[11]. Under this cultivation method, the height of cotton plants typically exceeds 1 m, whereas watermelons are primarily cultivated at ground level, allowing for optimal utilization of edge growth effects. The wide row spacing of cotton facilitates improved ventilation and light penetration within the cotton field, thereby maximizing the potential for increased yield per plant. This approach also contributes to a reduction in cotton boll shedding and boll rot, ultimately resulting in the production of high-quality, high-yield cotton[12].

4 "Cotton – Dutch bean" intercropping system and its advantages

4.1 "Cotton – Dutch bean" intercropping system Dutch beans are characterized by their crisp texture and nutritional value, and they have gained increasing popularity in recent years. The intercropping of Dutch beans with cotton typically involves the selection of early-maturing cotton varieties. In this method, cotton is sown in early June, with a row spacing of 0.8 m and a plant spacing of 0.13 – 0.15 m, resulting in a planting density of 6 000 plants/666.7 m^2. Following the cotton harvest, the stalks are preserved, and Dutch beans are planted in the intervals between the cotton rows from late October to early November. Specifically, two rows of Dutch beans are sown between every two rows of cotton, maintaining a distance of 0.15 m between the cotton stalks and the Dutch beans. Dutch beans are harvested in April and May of the subsequent year, which does not interfere with the planting of cotton in the following season. The cultivation of "summer cotton – Dutch bean" allows for the production of two crops annually. The gross income per 666.7 m^2 can reach 9 700 yuan, which significantly surpasses the economic benefits derived from single-season cotton cultivation. Additionally, this method reduces investment costs by more than 1 200 yuan compared to the conventional planting of single-season Dutch beans. This planting model has been implemented in various locations, including Suiyang District of Shangqiu City, Weishi County of Kaifeng City, and Zhongmou County of Zhengzhou City[13]. In recent years, it has been promoted across an area exceeding 1 200 hm^2.

4.2 Advantages This planting model effectively leverages the characteristics of cotton stalk lateral branches, which can support the climbing growth of Dutch bean vines. It facilitates the utilization of cotton stalks following the cotton harvest, thereby minimizing the need for artificial construction of Dutch bean scaffolds[14]. This approach not only reduces the physical and chemical costs associated with Dutch bean cultivation but also lowers labor expenses. Furthermore, it enhances field management efficiency, con-

serves labor and time, mitigates the incidence of diseases and pests, reduces investment costs, and improves overall economic benefits. The interplanting system of "cotton – Dutch bean" effectively integrates the distinct characteristics of both crops, including their preferences for temperature (heat-loving versus cool-loving), growth habits (upright versus climbing stalks), root depth (deep versus shallow roots), and nutrient requirements (nitrophilic plants versus nitrogen-fixing plants). This approach enhances the efficiency of land, light, heat, and cotton stalk resource utilization[15].

5 "Early maturing cotton-peanut-garlic" intercropping system and its advantages

5.1 "Early maturing cotton-peanut-garlic" intercropping system Following the harvest of garlic, cotton and peanuts are sown concurrently. High-quality, early-maturing varieties of cotton are chosen, while high-quality varieties of peanuts with elevated oleic acid content are selected. The planting configuration employs equal spacing between cotton and peanuts, with a total width of 4.8 m. Cotton is cultivated in three rows, maintaining an equal spacing of 0.8 m and a total bandwidth of 2.4 m. Peanuts are sown in two rows on a film, with one to two seeds placed in each hole concurrently with the cotton planting. Additionally, six rows are established across three ridges, with an equal spacing of 0.4 m and a bandwidth of 2.4 m. In the subsequent year, the cultivation of cotton and peanuts is alternated. This agricultural practice yields approximately 300 kg of seed cotton, 400 kg of wet peanut pods, and 1 500 kg of garlic per 666.7 m^2, resulting in significant overall benefits. This model is applicable in the primary garlic-producing regions, including Qixian and Weishi in Kaifeng City.

5.2 Advantages In this agricultural system, the intercropping of garlic, cotton, and peanuts is effectively integrated. Cotton and peanuts are cultivated in equal proportions, with alternating planting occurring annually. This approach facilitates convenient mechanized operations. In the later stages of growth, cotton can provide shade to peanuts, which inhibits the growth of the latter while simultaneously promoting the accumulation of dry matter in peanuts. Additionally, cotton effectively utilizes the benefits of lateral shade, good ventilation, and light transmission, resulting in fewer instances of rotten bolls, improved quality, and higher yields[16]. This practice also mitigates the issues associated with the heavy prevalence of diseases and pests that often arise from the continuous cropping of peanuts, thereby ensuring a balanced and stable production of peanuts[17]. The nitrogen-fixing properties of the peanut root system facilitate the practice of crop rotation between cotton and peanuts. This agricultural strategy aims to decrease the quantity of nitrogen fertilizer required in the subsequent cotton planting season, while simultaneously maintaining a stable yield of cotton. The interplanting system of "early maturing cotton-peanut-garlic" is an environmentally sustainable production approach. This method facilitates the integration of land utilization and cultivation practices, as well as the implementation of multiple cropping strategies. Consequently, it effectively mitigates land-use conflicts and enhances the yield per unit area[18]. This approach holds significant potential for promoting sustainable agricultural development and merits extensive dissemination.

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