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Effect of Row Spacing Configuration Modes on Growth and Development of Xinluzao 63 and Amount of Residual Film in Agricultural Fields

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Abstract [**Objectives**] To provide a reference for the promotion of appropriate row spacing configuration modes for cotton planting in the Bortala Mongol Autonomous Prefecture of Xinjiang. [**Methods**] Xinluzao 63 was employed as the research subject to examine the effects of three different configuration modes: three rows with one film, four rows with one film, and six rows with one film, on the growth and development of cotton, as well as on yield and the amount of residual film in the field. [**Results**] In comparison to the configuration modes of four rows with one film and six rows with one film, the development process in the row spacing configuration mode of three rows with one film was accelerated by 1 – 4 d. This configuration mode exhibited variability in several agronomic traits, particularly in plant height, the number of fruiting branches per plant, and the number of leaves per plant, with the observed trend indicating T3 > T2 > T1. Conversely, the height of the first fruiting branch node displayed an inverse trend. In terms of yield composition, no significant differences were observed in boll weight and yield among various configuration modes. However, T3 exhibited the highest boll weight at 5.68 g and a yield of 462.67 kg/667 m^2. Additionally, significant differences were noted in harvesting density and the number of bolls per plant. T3 demonstrated the lowest harvesting density at 1.11×10^4 plants/666.7 m^2, the highest number of bolls per plant at 8.63, and the highest boll opening rate at 97.48%. Furthermore, T3 also resulted in the least amount of agricultural film residue during the current season. [**Conclusions**] Among the three planting configuration modes examined, the low-density planting configuration mode consisting of three rows and one film demonstrated a significant advantage at the individual plant level. This approach yielded results comparable to those of the high density planting configuration mode while also reducing costs. Furthermore, low density planting positively influenced the cotton boll opening rate, leading to a decreased amount of residual film and promoting ecological health within the agricultural land.

Key words Cotton, Row spacing configuration mode, Growth and development, Yield, Amount of residual film

1 Introduction

The advancement of modern agriculture has led to an increase in the level of mechanization in agricultural production. This trend is particularly evident in Xinjiang, where the implementation of comprehensive mechanization in the large-scale production of cotton and other crops has reached a high level of maturity[1]. The ongoing and continuous cultivation of cotton in Xinjiang has garnered significant attention due to issues related to agricultural film pollution, as well as the excessive application of chemical fertilizers and pesticides[2]. Concurrently, the input costs associated with agricultural production and cultivation have been rising annually. To enhance the protection of the agricultural environment, minimize film residue, increase the recycling rate of residual film, mitigate film pollution, lower production input costs, and improve the profitability of cotton cultivation[3-4], the cotton mechanized light cultivation technology was implemented in field tests. These tests were conducted in the same experimental field under three distinct configuration modes: three rows with one film, four rows with one film, and six rows with one film. This study investigates the effects of various configuration modes on the development process, agronomic traits, yield, and the amount of film residue in cotton. The objective is to establish a reference framework that supports the promotion of cost-saving practices and enhances efficiency while simultaneously reducing ecological pollution in agricultural land caused by mulch film.

2 Materials and methods

2.1 Materials The cotton variety for the test was Xinluzao 63, provided by Xinjiang Zhongnong Youmian Cotton Co., Ltd. The test film was 2.05 m in width and 0.01 mm in thickness, and was purchased from Zhongnong Boxi (Jinghe) Technology Co., Ltd.

2.2 Overview of the test site The experiment was conducted on the northern side of the 8th Brigade in Daheyanzi Town, Jinghe County, Bortala Mongol Autonomous Prefecture (hereafter referred to as Bozhou), Xinjiang. The study site featured sandy loam soil characterized by medium to high fertility, with a soil salinity of less than 8.0 g/kg, and cotton was cultivated as the preceding crop.

2.3 Experimental design The field trial was conducted with three treatments: three rows with one film, four rows with one

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film, and six rows with one film. Each treatment covered an area of 2 hm^2, resulting in a total planting area of 6 hm^2. Among the configurations examined, the treatment designated as T1, which employed one film with six rows and three pipe belts, exhibited a row spacing arrangement of (13 + 63 + 13 + 63 + 13 + 63) cm, resulting in an average row spacing of 38 cm. The plant spacing was established at 9 cm, leading to a theoretical planting density of 19 500 plants/666.7 m^2. T2 treatment, which employed one film with four rows and three pipe belts, exhibited a row spacing configuration of (69.5 + 13.0 + 69.5 + 76.0) cm, resulting in an average row spacing of 57 cm. The plant spacing was established at 7.5 cm, leading to a theoretical planting density of 15 600 plants/666.7 m^2. T3 treatment, which utilized one film with three rows and three pipe belts, demonstrated a row spacing configuration of (76 + 76 + 76) cm, yielding an average row spacing of 76 cm. The plant spacing was set at 6 cm, resulting in a theoretical planting density of 14 600 plants/666.7 m^2. The plots were situated within the same field, and the fertilizer, medication, and field management practices were consistent across all plots, with the exception of the varying row spacing configuration modes implemented during sowing.

2.4 Survey items and methods

2.4.1 Reproductive period. The seedling emergence, budding, flowering, and boll opening of Xinluzao 63 were examined at the point when 50% of the cotton plants had reached each respective stage.

2.4.2 Agronomic traits. In the field survey, a five-point sampling method was employed, whereby five sample points were selected from each treatment group for the fixed-point survey. Following a period of 10 d post-topping, each sampling point involved the selection of 10 consecutive, uniform, and representative cotton plants to assess various parameters, including plant height, the number of fruiting branches per plant, the number of leaves per plant, and the height of the first fruiting branch node. Subsequently, after 10 d of defoliant application, 10 consecutive cotton plants exhibiting optimal boll opening were selected at each sampling point to evaluate the number of opened bolls and the total number of bolls, from which the boll opening rate was calculated.

2.4.3 Yield and yield components. During the boll opening period, five sample points were established for each treatment. From each sample point, 10 consecutive cotton plants exhibiting normal boll opening were selected for the purposes of boll harvesting and the determination of boll weight. Additionally, an area of 6.67 m^2 was designated at each sample point to assess the number of plants per unit area and the number of bolls per plant. The seed cotton yield was calculated based on the number of plants per unit area, the number of bolls per plant, and the weight of the bolls, utilizing a comprehensive correction coefficient of 0.85[5-6].

2.4.4 Amount of soil residual film. Prior to sowing, five sample points were designated for each treatment, and soil samples were collected from the tillage layer at depths ranging from 0 to 30 cm within a 1 m × 1 m area. Residual film was extracted from the soil samples, sieved, and subsequently bagged separately. The samples were then washed and dried indoors for weighing. The resulting measurement represented the amount of soil residual film present before sowing. Following the cotton harvest, the film was recycled in the field, and the same method was employed to quantify the soil film residue in each treatment once more. The variation in the amount of soil film residue between these two surveys represented the amount of soil film residue for the season.

2.5 Water and fertilizer management Based on the high-yield and high-efficiency fertilization technology for cotton cultivation, a total of 2 m^3 of decomposed farmyard manure, along with 35 – 40 kg of urea, 8 – 10 kg of diammonium phosphate, 12 – 15 kg of monoammonium phosphate, 13 – 15 kg of potassium sulfate, and 1 kg of zinc sulfate, were applied per 666.7 m^2. A total of 10 kg of diammonium phosphate and 5 kg of urea were utilized as the base fertilizer, while the remaining fertilizers were applied during the topdressing phase. Additionally, an appropriate quantity of humic acid fertilizer was incorporated to enhance soil quality. Throughout the entire reproductive period, approximately 360 m^3 of water was applied via drip irrigation over an area of 666.7 m^2, distributed across 9 applications.

2.6 Data analysis Microsoft Excel software and DPS software were applied to collate the data. The boll opening rate was subjected to normality test and *chi*-square test. Additionally, multiple comparisons were conducted utilizing the least significant difference (LSD) method.

3 Results and analysis

3.1 Cotton development process under different row spacing configuration modes As illustrated in Table 1, the seedling emergence stage of cotton exhibited consistency across various row spacing configuration modes. Notably, the budding stage in the T3 treatment occurred 1 – 3 d earlier compared to the T1 and T2 treatments, while the flowering and boll opening stages were observed to be 2 – 3 and 3 – 4 d earlier, respectively. Additionally, the budding stage in the T2 treatment was 2 d earlier than that in the T1 treatment, with the flowering and boll opening stages occurring 1 d earlier.

Table 1 Cotton development process under different row spacing configuration modes month – day

Treatment	Sowing date	Seedling emergence stage	Budding stage	Flowering stage	Boll opening stage
T1	04 – 11	04 – 19	05 – 31	07 – 01	09 – 03
T2	04 – 11	04 – 19	05 – 29	06 – 30	09 – 02
T3	04 – 11	04 – 19	05 – 28	06 – 28	08 – 30

3.2 Effect of different row spacing configuration modes on agronomic traits in cotton As indicated in Table 2, the plant height observed in the T3 treatment was significantly greater than that of the T1 and T2 treatments by 17.13 and 5.08 cm, respectively. Furthermore, the plant height in the T2 treatment exceeded that of the T1 treatment by 12.05 cm, which also demonstrated a statistically significant difference. The T3 treatment exhibited a significantly greater number of fruiting branches per plant and a higher number of leaves per plant compared to the T1 treatment. Nevertheless, the differences observed between the T3 and T2 treatments were not statistically significant, and no significant differences were found between the T2 and T1 treatments. The height of the first fruiting branch node in the T3 treatment exhibited a statistically significant difference when compared to the T2 and T1 treatments, measuring 4.30 and 5.77 cm lower than the heights observed in the T2 and T1 treatments, respectively. Furthermore, the height of the first fruiting branch node in the T2 treatment was 1.47 cm lower than that in the T1 treatment. The differences among the three treatments were found to be statistically significant.

Table 2 Comparison of cotton agronomic traits under different row spacing configuration modes

Treatment	Plant height//cm	Number of fruiting branches per plant	Number of leaves per plant	Height of the first fruiting branch node//cm
T1	76.30 ±0.95 c	7.87 ±0.48 b	14.02 ±0.31 b	28.60 ±0.31 a
T2	88.35 ±0.71 b	8.68 ±0.19 ab	15.85 ±0.70 ab	27.13 ±0.37 b
T3	93.43 ±0.65 a	9.93 ±0.24 a	16.33 ±0.31 a	22.83 ±0.37 c

NOTE The data are presented as mean ± standard error; lowercase letters within the same column denote significant differences between treatments at the 0.05 level. The same below.

3.3 Effect of different row spacing configuration modes on yield components and yield of cotton As illustrated in Table 3, there was no statistically significant difference in harvest density between the T3 and T2 treatments. However, the harvest densities of both the T2 and T3 treatments were significantly lower than that of the T1 treatment. Regarding the number of bolls per plant, the T3 treatment exhibited an increase of 1.68 and 0.54 bolls compared to the T1 and T2 treatments, respectively, and the T3 treatment was significantly greater than the T1 treatment. The boll weight associated with the T3 treatment was 0.17 and 0.07 g greater than that of the T1 and T2 treatments, respectively. Additionally, the boll weight for the T2 treatment exceeded that of the T1 treatment by 0.10 g. However, the differences in boll weight among the treatments were not statistically significant. Regarding seed cotton yield per 666.7 m^2, the T1 treatment yielded 16.16 and 12.56 kg more than the T2 and T3 treatments, respectively. Furthermore, the T3 treatment produced 3.60 kg more than the T2 treatment. Nonetheless, the differences in seed cotton yield among the treatments were also not statistically significant.

Table 3 Cotton yield components under different row spacing configuration modes

Treatment	Harvest density//10^4 plants/666.7 m^2	Number of bolls per plant	Boll weight//g	Cotton yield//kg/666.7 m^2
T1	1.46 ±0.04 a	6.95 ±0.38 b	5.51 ±0.04 a	475.23 ±36.27 a
T2	1.19 ±0.05 b	8.09 ±0.23 ab	5.61 ±0.04 a	459.07 ±28.66 a
T3	1.11 ±0.06 b	8.63 ±0.39 a	5.68 ±0.11 a	462.67 ±53.36 a

3.4 Effect of different row spacing configuration modes on cotton boll opening rate and amount of seasonal film residues As illustrated in Table 4, the boll opening rate for the T3 treatment exhibited an increase of 0.93% and 1.24% when compared to the T2 and T1 treatments, respectively. Additionally, the boll opening rate for the T2 treatment showed an increase of 0.31% relative to the T1 treatment. It is noteworthy that no significant differences were observed in the boll opening rates of cotton across the various spacing configuration modes. Following the recovery of film residues at the conclusion of the cotton harvest, the T1 treatment exhibited the highest levels of seasonal film residues, while the T3 treatment demonstrated the lowest levels. The T2 treatment presented intermediate levels of film residues, situated between those of the T3 and T1 treatments. Notably, the film residues in the T3 treatment were significantly lower in comparison to those in the T1 treatment.

Table 4 Comparison of cotton boll opening rate and amount of seasonal film residues under different row spacing configuration modes

Treatment	Boll opening rate//%	Amount of seasonal film residues//kg/666.7 m^2
T1	96.24 ±0.25 a	0.55 ±0.03 a
T2	96.55 ±0.55 a	0.52 ±0.03 ab
T3	97.48 ±0.42 a	0.46 ±0.02 b

4 Discussion

Zhang Xiling *et al.* [7] and Wang Hongbin *et al.* [8] proposed that an alternative planting mode of wide, early, and excellent planting, characterized by wider row spacing and reduced planting density, is more effective than the traditional method of short, dense, and early planting. This revised approach optimizes the utilization of light and temperature resources, thereby enhancing the individual growth advantages of cotton plants. The implementation of this planting mode has been shown to significantly improve seedling rates, increase plant height, augment the number of bolls per plant, and enhance boll weight. Additionally, it contributes to a reduction in the physical and chemical costs associated with cotton production, such as seed expenses, ultimately achieving the objectives of cost savings and increased efficiency. Furthermore, several studies have indicated that increasing row spacing and decreasing planting density can enhance the light interception area within the middle and lower regions of the cotton canopy, thereby raising the photosynthetic utilization rate of cotton. Additionally, as the canopy height increases, the available space expands, thereby enhancing ventilation. This enhanced ventilation is beneficial for the formation of cotton bolls, as well as for defoliation and boll opening during the later stages of growth, ultimately contributing to increased yield[9-12]. The reduction in planting density leads to a decrease in the number of seed holes, which subsequently minimizes physical damage to the mulched agricultural film. This practice enhances soil warming and moisture retention to a certain degree, thereby facilitating the growth and development of cotton. Additionally, it promotes the maturation of cotton and supports the recycling of residual film[13-14]. In this study, we observed that the three distinct row spacing configuration modes had minimal impact on the seedling emergence stage of Xinluzao 63. However, significant differences were noted during the budding, flowering, and boll opening stages, with developmental processes varying by 1 - 4 d at the same reproductive stage. The analysis of agronomic traits and boll opening rates revealed significant differences among various row spacing configuration modes. Specifically, the configurations of one film with three rows and one film with four rows exhibited lower planting densities compared to the configuration of one film with six rows. The average row spacing in these configuration modes was wider, which facilitated improved ventilation and light transmission. These conditions were more conducive to the growth and development of cotton plants, thereby promoting individual growth advantages that enhanced the boll opening rate. These findings are consistent with the results of previous studies[15-16]. The three modes of row spacing configuration modes, which vary in planting density, exhibited distinct yield differences per unit area. However, an analysis of seed, labor, and other material and chemical cost savings indicates that these yield discrepancies can be offset. Furthermore, when considering factors such as increased boll weight, reduced residual film pollution in cotton fields, and the protection of the ecological environment, the advantages of the one film with three rows configuration mode become significantly more pronounced.

In this study, a single variety was utilized to conduct a one-year field trial in sandy loam soil characterized by medium fertility and salinity levels below 8 g/kg in Jinghe County, Bozhou, Xinjiang. The test year was marked by favorable temperature conditions, a lower incidence of pests and diseases, and was not influenced by extreme meteorological events such as prolonged chilling, freezing, or hailstorms. In future research, we will conduct a comprehensive investigation into the effects of various row spacing configuration modes on agronomic traits, yield, boll opening rate, and film residue of different cotton varieties. This study will take place in clay soils, saline conditions (≥8 g/kg), and during cold spells in late spring, as well as under other climatic extremes, infertile soils, and in the presence of significant pest and disease pressures in the experimental plots.

5 Conclusions

Xinluzao 63, when cultivated under a row spacing configuration mode of one film with three rows, demonstrates a shortened reproductive period and exhibits significant advantages at the individual plant level. This method enhances the number of fruiting branches and leaves per plant, as well as increases bolling, and boll weight, achieving the highest values in boll opening rate. In terms of yield, this approach effectively allows for cost-saving low-density planting while producing yields comparable to those obtained through high-density planting, and also reducing the amount of film residue left in the field. The preliminary findings indicate that the strategic implementation of the one film with three rows row spacing planting configuration mode for Xinluzao 63 and other cotton varieties exhibiting similar biological characteristics in Bozhou, Xinjiang, is advantageous for local cotton cultivation. This approach not only contributes to cost savings and enhanced efficiency but also mitigates the environmental impact of plastic film on agricultural land.

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ous year, pyrethroid insecticides (*e. g.*, sumicidin) at a dilution of 3 000 times may be applied. If leaf-eating caterpillars are detected, a solution of 48% chlorpyrifos at a dilution of 1 200 times can be utilized. It is imperative to cease the application of any pesticides 20 d prior to harvesting.

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