# Effects of Sowing Date and Planting Density on Yield of Different Sorghum Varieties

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**Abstract.** To investigate the effects of sowing date and planting density on the yield of different sorghum varieties in the northeastern Sichuan Basin and to identify optimal cultivation patterns for high yield, a field experiment was conducted using an $L_9(3^4)$ orthogonal design with three factors (variety, sowing date, and planting density). Three sorghum varieties, Jianianghong 7, Nanuohong 1, and Langnuohong 19, were planted on three sowing dates (April 28, May 7, and May 16) at three planting densities (10, 548 plants·mu$^{-1}$, 12, 254 plants·mu$^{-1}$, and 14, 005 plants·mu$^{-1}$). Growth stages and yield were observed, and range and variance analyses were employed to evaluate the effects of each factor. The results showed that sowing date significantly influenced the growth process of sorghum, with the whole growth period shortening as sowing was delayed. Range analysis indicated that the order of factors affecting yield was sowing date (R=121.4) > variety (R=16.5) > density (R=9.31). Variance analysis revealed that sowing date had a highly significant effect on yield ($p < 0.01$), variety had a significant effect ($p<0.05$), while planting density showed no significant effect. Treatment T2 (Jianianghong 7 + sowing on May 7 + 12, 254 plants·mu$^{-1}$) achieved the highest yield (262. 45 kg·mu$^{-1}$). Although its yield did not differ significantly from six other treatments, including T1, it was highly significantly higher than those of T3, T6, and T9 (124.3 - 134.18 kg·mu$^{-1}$). In conclusion, sowing date is the dominant factor affecting sorghum yield in this region, with early May being the optimal sowing window. The variety Jianianghong 7 demonstrated favorable comprehensive performance, and the suitable planting density ranges from 10, 548 to 12, 254 plants·mu$^{-1}$. These findings provide a technical reference for high-yield sorghum cultivation in the northeastern Sichuan Basin and similar ecological regions.

**Keywords:** sorghum; sowing date; planting density; variety; yield.

## 1 Introduction

Sorghum (*Sorghum bicolor* L.) is the fifth most widely cultivated cereal crop globally, following maize, wheat, rice, and barley [1]. It also serves as a high-quality raw material

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for Chinese liquor production, serving as the primary ingredient for numerous renowned liquors such as Wuliangye, Moutai, Luzhou Laojiao, Langjiu, and Fenjiu [2]. The successful development and adoption of new sorghum varieties or lines necessitate the support of optimized high-yield cultivation techniques. Sorghum yield is not only influenced by variety, weather conditions, genetic characteristics, and pest and disease incidence but is also closely related to sowing date and planting density [3-5]. Appropriate sowing dates and planting densities significantly impact sorghum growth and development, organ formation, yield components, and the coordinated progression of vegetative and reproductive growth. Timely sowing allows for optimal utilization of light and heat resources, promoting the establishment of robust seedlings. Optimal planting density helps mitigate the conflict between individual plant growth and population development, facilitating the formation of a rational population structure conducive to the coordinated development of panicle number, grain number per panicle, and grain weight [6]. Therefore, this study investigates the effects of sowing date and planting density on sorghum cultivation using two conventional varieties independently bred by the Nanchong Academy of Agricultural Sciences, Jianianghong 7 and Nanuohong 1, along with Langnuohong 19, a conventional variety registered by the Rice and Sorghum Research Institute, Sichuan Academy of Agricultural Sciences. The aim is to establish a foundation for high-yield sorghum cultivation practices.

## 2 Materials and Methods

### 2.1 Experimental Site Description

The field experiment was conducted from April to August 2025 at the Luxi Experimental Base of the Nanchong Academy of Agricultural Sciences, located in Mao'ergou Village, Luxi Town, Shunqing District, Nanchong City (latitude 30°57'30" N, longitude 106°8'18" E). The topography consisted of levelled land, and the soil type was sandy loam with medium fertility. The preceding crop was soybean. Land preparation was performed using mechanical rotary tillage. The sorghum varieties used in this study were A01 (Jianianghong 7), A02 (Nanuohong 1), and A03 (Langnuohong 19). Phosphorus and potassium fertilizers were applied entirely as basal dressing, while nitrogen fertilizer was split equally, with 50% applied as basal and 50% as topdressing at the jointing stage.

### 2.2 Experimental Design

A three-factor, three-level orthogonal design $L_9(3^4)$ was employed, with variety, sowing date, and planting density as the factors. The experiment consisted of nine treatments arranged in a randomized complete block design with three replications. The factor levels and treatment combinations are presented in Tables 1 and 2, respectively. Each plot measured 15.2 $m^2$ (3.8 m × 4 m). No pathways were left between plots within replicates, while a 0.5 m pathway separated replicates. Border rows were planted around the entire experimental area.

**Table 1.** Factors and levels of the orthogonal experimental design.

| Level | Variety (A) | Sowing Date (B) (month/day) | Planting Density (C) (plants·mu$^{-1}$) |
|---|---|---|---|
| 1 | Jianianghong 7 | April 28 | 10548 (0.158 m × 0.40 m, 24 plants·row$^{-1}$) |
| 2 | Nanuohong 1 | May 7 | 12254 (0.136 m × 0.40 m, 28 plants·row$^{-1}$) |
| 3 | Langnuohong 19 | May 16 | 14005 (0.119 m × 0.40 m, 32 plants·row$^{-1}$) |

**Table 2.** Treatment combinations of the $L_9(3^4)$ orthogonal experimental design.

| Treatment | Variety (A) | Sowing Date (B) | Planting Density (C) |
|---|---|---|---|
| T1 | A1 | B1 | C1 |
| T2 | A1 | B2 | C2 |
| T3 | A1 | B3 | C3 |
| T4 | A2 | B1 | C2 |
| T5 | A2 | B2 | C3 |
| T6 | A2 | B3 | C1 |
| T7 | A3 | B1 | C3 |
| T8 | A3 | B2 | C1 |
| T9 | A3 | B3 | C2 |

### 2.3 Observations and Measurements

**Growth Stages.**

Starting from emergence, the dates when each plot reached specific growth stages were recorded.

**Yield Determination.**

When 80%-90% of the grains reached maturity, each plot was harvested individually. Grains were threshed, air-dried, and weighed to determine yield. The yield was then converted to unit area yield (kg·mu$^{-1}$) for statistical analysis.

**Data Analysis.**

Data were organized using Microsoft Excel. Analysis of variance (ANOVA) was performed using the online statistical software SPSSAU (https://spssau.com/).

## 3 Results and Analysis

**Table 3.** Main growth stages of sorghum under different treatments.

| Treatment | Sowing Date (month/day) | Emergence Date (month/day) | Heading Date (month/day) | Initial Flowering Date (month/day) | Maturity Date (month/day) | Harvest Date (month/day) | Whole Growth Period (days) |
|---|---|---|---|---|---|---|---|
| T1 | 4/28 | 5/3 | 7/3 | 7/12 | 8/7 | 8/9 | 97 |
| T2 | 5/7 | 5/11 | 7/7 | 7/15 | 8/12 | 8/12 | 94 |
| T3 | 5/16 | 5/19 | 7/12 | 7/20 | 8/19 | 8/22 | 93 |
| T4 | 4/28 | 5/3 | 7/2 | 7/12 | 8/6 | 8/9 | 96 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| T5 | 5/7 | 5/11 | 7/6 | 7/13 | 8/11 | 8/12 | 93 |
| T6 | 5/16 | 5/19 | 7/18 | 7/25 | 8/19 | 8/22 | 93 |
| T7 | 4/28 | 5/3 | 7/5 | 7/15 | 8/5 | 8/9 | 95 |
| T8 | 5/7 | 5/11 | 7/9 | 7/17 | 8/11 | 8/12 | 93 |
| T9 | 5/16 | 5/19 | 7/15 | 7/23 | 8/20 | 8/22 | 94 |

### 3.1 Effects of Different Treatments on Sorghum Growth Stages

As shown in Table 3, sowing date treatments significantly influenced various growth stages and the whole growth period of sorghum. With delayed sowing, the emergence, heading, flowering, and maturity dates of all varieties were correspondingly postponed; however, the whole growth period exhibited a shortening trend. Treatment T1 (sown on April 28) had a whole growth period of 97 days, whereas treatments T3, T6, and T9 (sown on May 16) had whole growth periods of 93, 93, and 94 days, respectively. This indicates that late sowing accelerated the growth process, possibly due to higher temperatures during the later stages promoting faster development. Under the same sowing date, slight differences in the whole growth period were observed among varieties, but the variation was minimal.

### 3.2 Effects of Different Treatments on Sorghum Yield

**Range Analysis of Yield.**

Range analysis of yield (Table 4) revealed that sowing date exhibited the largest range value (R=121.4), indicating that sowing date had the greatest impact on yield and was the key determining factor. Variety had the second largest range value (R=16.5), while planting density showed the smallest range value (R=9.31), suggesting that within the density range tested in this experiment, density variation had a relatively minor effect on yield. Regarding the optimal combination of levels, the theoretical maximum yield would be achieved with variety A1 (Jianianghong 7), sowing date B2 (May 7), and planting density C1 (10548 plants·mu$^{-1}$).

**Table 4.** Range analysis of sorghum yield.

| Factor | Variety | Sowing Date | Planting Density |
|---|---|---|---|
| *K1* | 1943.42 | 2178.71 | 1901.22 |
| *K2* | 1843.01 | 2247.63 | 1862.65 |
| *K3* | 1794.89 | 1154.99 | 1817.46 |
| *k1* | 215.94 | 242.08 | 211.25 |
| *k2* | 204.78 | 249.74 | 206.96 |
| *k3* | 199.43 | 128.33 | 201.94 |
| Range (R) | 16.5 | 121.4 | 9.31 |
| Optimal Level | 1 | 2 | 1 |

**Analysis of Variance and Multiple Comparisons of Yield.**

Analysis of variance (Table 5) showed highly significant differences in yield among treatments (F=76.86, p=0.0001), indicating that different combinations of sowing date, variety, and planting density significantly affected yield. Analysis of the main effects

of each factor revealed that sowing date had the most substantial impact on yield, with an F-value of 297.92 ($p<0.01$), reaching a highly significant level. Variety also had a significant effect on yield ($F=4.57$, $p=0.0248$). However, the effect of planting density was not significant ($F=1.40$, $p=0.2726$), indicating that density variation did not cause significant yield changes under the conditions of this experiment.

**Table 5.** Analysis of variance for sorghum yield under different sowing dates, planting densities, and varieties.

| Source of Variation | Sum of Squares | Degrees of Freedom | Mean Square | F-value | p-value |
|---|---|---|---|---|---|
| Treatment | 85862.14 | 8 | 10732.77 | 76.8555 | 0.0001 |
| Variety | 1276.148 | 2 | 638.0739 | 4.5691 | 0.0248 |
| Sowing Date | 83208.54 | 2 | 41604.27 | 297.9211 | 0.0001 |
| Planting Density | 390.6005 | 2 | 195.3003 | 1.3985 | 0.2726 |
| Error | 2513.675 | 18 | 139.6486 | | |

Multiple comparisons of yield among the nine treatments were conducted using Tukey's HSD test (Table 6). The results showed that Treatment T2 achieved the highest yield (262.45 kg·mu$^{-1}$), which was not significantly different from T1 (261.05 kg·mu$^{-1}$), T5 (248.25 kg·mu$^{-1}$), T8 (238.51 kg·mu$^{-1}$), T7 (233.27 kg·mu$^{-1}$), and T4 (231.91 kg·mu$^{-1}$). However, these six treatments all had yields highly significantly ($p<0.01$) higher than those of T3, T6, and T9. The yields of T3, T6, and T9 were 124.3 kg·mu$^{-1}$, 134.18 kg·mu$^{-1}$, and 126.52 kg·mu$^{-1}$, respectively, with no significant differences among them, but all were highly significantly lower than the other treatments. As shown in Tables 1 and 2, T3, T6, and T9 all involved sowing date B3 (May 16), indicating that sowing on May 16 led to a substantial yield reduction, which is consistent with the range analysis results.

**Table 6.** Significance analysis of sorghum yield under different treatments.

| Treatment | Plot Yield (15.2 m²) / kg | | | Mean Plot Yield Converted to kg·mu⁻¹ | Yield Rank | Significance of Differences | |
|---|---|---|---|---|---|---|---|
| | I | II | III | | | 0.05 | 0.01 |
| T1 | 5.92 | 6.03 | 5.90 | 261.05 | 2 | a | A |
| T2 | 5.56 | 6.24 | 6.15 | 262.45 | 1 | a | A |
| T3 | 3.04 | 2.77 | 2.69 | 124.30 | 9 | b | B |
| T4 | 5.28 | 5.43 | 5.15 | 231.91 | 6 | a | A |
| T5 | 5.69 | 5.43 | 5.86 | 248.25 | 3 | a | A |
| T6 | 3.12 | 3.39 | 2.66 | 134.18 | 7 | b | B |
| T7 | 5.22 | 5.01 | 5.73 | 233.27 | 5 | a | A |
| T8 | 5.23 | 5.82 | 5.27 | 238.51 | 4 | a | A |
| T9 | 3.07 | 2.78 | 2.80 | 126.52 | 8 | b | B |

## 4 Discussion and Conclusion

The results of this study demonstrate that sowing date is the dominant factor affecting sorghum yield in the northeastern Sichuan Basin, which is consistent with previous

findings in other sorghum-growing regions [5, 6]. Delayed sowing significantly shortened the whole growth period and led to substantial yield reductions, particularly under the May 16 sowing date. This yield loss may be attributed to the accelerated growth rate under higher temperatures during later growth stages, which reduces the duration of critical reproductive phases such as grain filling, thereby limiting photosynthetic accumulation and kernel development [7]. Additionally, late-sown sorghum often encounters unfavorable climatic conditions during flowering and grain filling, including high temperatures or drought stress, which can impair pollination and reduce grain weight [8].

Compared with previous studies that reported significant density effects under similar ecological conditions [5], the present study found no significant yield response to planting density within the tested range. This discrepancy may be due to the relatively narrow density gradient or the specific morphological traits of the varieties used, which may exhibit greater plasticity in tillering and panicle compensation. Nonetheless, the trend toward higher yields under moderate to low densities suggests that optimizing population structure remains important for achieving high yield.

Overall, the findings underscore the critical role of timely sowing in sorghum production and highlight the need to integrate variety selection and density management to fully realize yield potential. Further research is warranted to explore the physiological mechanisms underlying the yield decline under late sowing and to validate optimal cultivation patterns across multiple seasons and locations.

Under the conditions of this study, sowing date was identified as the dominant factor affecting sorghum yield in the northeastern Sichuan Basin. The optimal sowing window was determined to be early May (around May 7). Sowing either too early (April 28) or too late (May 16) resulted in significant yield reductions, with late sowing causing the most substantial losses. Significant yield differences were observed among varieties, with Jianianghong 7 demonstrating superior comprehensive performance compared to Nanuohong 1 and Langnuohong 19. Planting density within the range of 10, 548 to 14, 005 plants·mu$^{-1}$ did not significantly affect yield; however, a trend towards higher yields was observed with moderately lower densities (10, 548 - 12, 254 plants·mu$^{-1}$). Treatment combinations T2 (Jianianghong 7 + sowing on May 7 + 12, 254 plants·mu$^{-1}$) and T1 (Jianianghong 7 + sowing on April 28 + 10, 548 plants·mu$^{-1}$) exhibited excellent yield performance and can serve as reference models for high-yield sorghum cultivation in Nanchong and similar ecological regions. In production practice, priority should be given to timely sowing, selection of suitable varieties, and adoption of moderate to low planting densities to fully realize the yield potential of the varieties.

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## Disclosure of Interests

The authors declare no conflict of interest.

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