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# Soybean Paired Row Planting: Maximizing Yield and Resource Use Efficiency Through Spatial Geometry

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## INTRODUCTION

Soybean (Glycine max L. Merrill) is a paramount global commodity, widely recognized as the "miracle crop" (Chauhan et al., 1988) due to its unparalleled dual utility as a premier oilseed and high-density protein source (Bellaloui et al., 2015). With escalating pressures to enhance agricultural productivity per unit area, optimizing resource use efficiency is the primary focus of modern agronomy. While traditional methodologies relied on uniform row spacings, researchers are increasingly adopting highly engineered spatial reconfigurations to maximize the interception of photo synthetically active radiation (PAR) and improve micro-environmental conditions within the crop stand (Singh et al., 2023).

This transition shifts conventional linear planting (such as the standard 45 × 5 cm configuration) to intensive, asymmetrically structured systems like paired row (twin-row) and narrow row paradigms (e.g., 30-60 × 5 cm or 45-90 × 5 cm). These advanced arrangements foster a highly robust canopy architecture. By manipulating spatial distribution, growers can fundamentally alter intraspecific competition dynamics, optimize water use efficiency, and achieve substantially higher economic returns without a proportional increase in costly agrochemical or mechanical inputs (Smith et al., 2019).

## THE PARADIGM OF PAIRED ROW PLANTING: GREAT EFFECTS WITH LESS EFFORT

The agronomic principle of paired row planting involves sowing two closely spaced crop rows followed by a significantly wider unplanted inter-space. This asymmetric geometry fundamentally transforms field dynamics, yielding great effects with considerably less effort. Its core advantage lies in the biological "edge effect."

By exposing more plants to wider inter-row spaces, competition for ambient light and carbon dioxide is reduced, promoting prolific lateral branching and increased dry matter accumulation (Andrade et al., 2019).

Simultaneously, this configuration optimizes above-ground canopy spread and below-ground rhizosphere interactions. The wider gaps facilitate unobstructed movement for intercultural operations—drastically reducing labor and energy requirements—while improving air circulation to naturally lower fungal pathogen incidence. Conversely, the tightly packed pairs achieve rapid canopy closure, creating a localized shading effect that immediately suppresses weed emergence within the rows (Devi & Singh, 2016). Ultimately, this structural methodology empowers cultivators to achieve superior morphological development and higher yields while minimizing the physical exertion and systemic inputs traditionally required for crop management.

## COMPARATIVE ANALYSIS OF PLANTING GEOMETRIES

### 1. Normal Planting (45 × 5 cm)

The 45 × 5 cm configuration serves as the traditional baseline for soybean cultivation, subjecting plants to a consistent level of intra-row and inter-row competition (Smith et al., 2019). While this uniform spacing facilitates straightforward mechanical harvesting and standard intercultural operations, it frequently results in delayed canopy closure. This delay significantly extends the critical crop-weed competition period, necessitating intensive herbicide applications or manual weeding. Furthermore, during the early vegetative stages, a substantial portion of solar radiation strikes bare soil rather than the plant's photosynthetic apparatus, leading to increased evaporative soil moisture loss and reduced overall resource use efficiency (Andrade et al., 2019) (Dixit et al., 2026).

### 2. Narrow Paired Row System (30-60 × 5 cm)

The 30-60 × 5 cm paired row system optimizes plant density and spatial availability by alternating tight paired rows with broader gaps, all while maintaining a strict 5 cm intra-row spacing. The narrow intra-pair gap facilitates exceptionally rapid canopy interlocking, whereas the wide inter-pair gap ensures edge-row plants receive maximum solar penetration into the lower canopy strata (Zhou *et al.,* 2022). Recent field trials confirm that this wide-narrow spacing increases radiation use efficiency (RUE) and significantly boosts SPAD values in upper leaves (Carvalho *et al.,* 2024). Ultimately, this specific geometry promotes a deeper root volume and enhances macro-nutrient uptake, frequently achieving statistically superior yields compared to conventional methods.

### 3. Wide Paired Row System (45-90 × 5 cm)

The 45-90 × 5 cm configuration utilizes pairs spaced 45 cm apart, separated by an expansive 90 cm gap. This highly asymmetrical geometry is predominantly engineered for complex intercropping or mixed-cropping systems. The vast 90 cm corridor is ideal for integrating secondary crops without subjecting them to deleterious shading from the dominant soybean canopy. Even in a sole-crop scenario, this spacing substantially increases land equivalent ratios when evaluated for sunlight utilization. It provides immense structural stability to the basal stems, effectively minimizing the lodging risks associated with heavy pod-bearing branches during the later reproductive phases (Singh *et al.,* 2023).

| Spacing Configuration | Arrangement Type | Agronomic Characteristics | Yield & Efficiency Impact |
|---|---|---|---|
| 45 × 5 cm | Normal Linear Planting | Uniform spacing; delayed canopy closure; higher soil evaporation rates (Andrade *et al.,* 2019). | Provides baseline yields; heavily susceptible to early-season weed pressure; standard nutrient uptake. |
| 30-60 × 5 cm | Narrow Paired Row Planting | Asymmetric layout; accelerated localized canopy closure; optimized edge effect (Zhou *et al.,* 2022). | Statistically superior yield generation; enhanced RUE and light interception; deep root proliferation (Carvalho *et al.,* 2024). |
| 45-90 × 5 cm | Wide Paired Row Planting | Maximum asymmetry; expansive inter-row corridors; high structural stability. | Ideal for intercropping integration; minimizes lodging; maximizes individual plant branching (Singh *et al.,* 2023). |

## CANOPY MANAGEMENT AND MICROCLIMATE OPTIMIZATION

Manipulating crop geometry profoundly influences the soybean canopy microclimate. In paired and narrow row systems, Leaf Area Index (LAI) progression is heavily accelerated, with canopies under the 30-60 × 5 cm geometry achieving complete closure up to 15 to 20 days faster than conventional spacings (Rasool *et al.,* 2021). This early canopy establishment is critical for early monsoon sowings in rainfed systems to capitalize on early-season moisture.

This rapid foliar expansion intercepts significantly more solar radiation during critical growth phases, translating into greater biomass accumulation, increased floral retention, and reduced pod abortion (Dixit *et al.,* 2026). Furthermore, paired configurations actively alter physiological parameters by enhancing stomatal conductance and regulating transpiration, creating a highly favorable, humid microclimate above the soil (Carvalho *et al.,* 2024). This regulation conserves rhizosphere moisture and boosts beneficial microbial activity, ultimately improving biological nitrogen fixation and enhancing protein and oil partitioning within the seed (Bellaloui *et al.,* 2015).

## RESOURCE USE EFFICIENCY AND WEED SUPPRESSION DYNAMICS

A major benefit of paired row geometry is its passive, yet highly aggressive weed suppression, which addresses one of modern agronomy's highest input costs. By achieving accelerated and dense canopy closure, these systems severely restrict photosynthetically active radiation from reaching the soil (Bradley, 2006). This biological smothering essentially starves emerging weed seedlings of the light required for photosynthesis (Devi & Singh, 2016). Comprehensive meta-analyses reveal that narrow row spacings can dramatically suppress weed density and reduce total weed biomass by up to 71% compared to conventional wide rows (Suhre *et al.,* 2012).

Therefore, this structural advantage curtails weed dry matter accumulation and depletes the weed seed bank over successive seasons. Leveraging this natural shading allows cultivators to drastically reduce their reliance on chemical herbicides and manual labor. This enhanced weed control directly increases net resource use efficiency, ensuring that applied fertilizers and available soil moisture are separated exclusively to the crop rather than competing weeds (Andrade *et al.,* 2019).

## STATISTICAL YIELD VARIATIONS AND TREATMENT EFFICACY

From an analytical perspective, the transition to paired row planting yields highly quantifiable agronomic benefits. When evaluating split-plot field experiments via ANOVA, the 30-60 × 5 cm geometry consistently exhibits significant positive variances in critical yield attributes—such as primary branches, pods per plant, and 100-seed weight—compared to the normal 45 × 5 cm control (Smith *et al.,* 2019) and (Dixit *et al.,* 2026).

Although specific genotypes in conventional geometries may produce yields statistically "at par" under ideal conditions, they consistently fail to maintain equivalence under abiotic stress. Paired row architecture buffers against this environmental volatility, ensuring a consistently elevated harvest index. This strategic spatial grouping tightly controls the coefficient of variation (CV%) across replications, optimizing the source-sink relationship and driving assimilates toward developing seeds with maximum statistical reliability and biological efficiency (Singh *et al.,* 2023).

## CONCLUSION

The strategic adoption of paired row systems (specifically 30-60 × 5 cm or 45-90 × 5 cm configurations) is a sophisticated yet highly practical strategy for sustainable soybean cultivation. Compared to traditional 45 × 5 cm linear planting, paired rows deliver exceptionally great effects with substantially less effort (Dixit *et al.,* 2026). By systematically altering field geometry, this method organically suppresses weeds, maximizes solar interception, and optimizes canopy and rhizosphere health. As global agriculture shifts toward climate-resilient, resource-efficient models, this low-cost structural transition yields substantial economic dividends and ensures long-term agronomic sustainability for progressive producers (Carvalho *et al.,* 2024).

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