Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

Maize Growth, Phenology, and Yield Responses to Longan Intercropping and Smart Farming

Maruli Tua[1], Purnama Wirawan[2], Juliarni[3], Muhammad Zulfahmi[4]
[1,2,3,4]*Department of Agricultural Science, Universitas Rokania, Rokan Hulu, Riau, Indonesia*
Corresponding email: marulitua@rokania.ac.id[1], purnama@rokania.ac.id[2], juliarni@rokania.ac.id[3], m.zulfahmi@gmail.com[4]

Received: 2026-10-31
Accepted: 2026-11-16
Publication: 2026-11-22

Abstract
Integrating annual crops into perennial orchards may diversify production, while smart farming may improve field management. Evidence for maize–longan combinations remains limited. Objective: This study quantified maize growth and phenology and recorded production under longan intercropping and smart farming. A factorial experiment used a completely randomized 2 × 2 design comparing maize monoculture and maize–longan intercropping under conventional watering or a fertigation-based smart farming treatment. Ten recorded replicate units per combination provided 40 observations. Plant height, leaf number, days to flowering, days to harvest, and reported production (g) were analyzed using two-way analysis of variance and Tukey's honestly significant difference test at 5%. Intercropped maize under smart farming reached 173.33 cm, 14.67 leaves, 54.45 days to flowering, 71.52 days to harvest, and 519.90 g of recorded production. Conventional monoculture recorded 112.27 cm, 10.00 leaves, 61.22 days, 79.66 days, and 412.00 g, respectively. Both main effects were statistically significant across all outcomes ($p < 0.001$). Interactions were significant for the four growth and phenology variables, but not for production ($p = 0.507$). The combined treatment showed favorable maize responses, providing an empirical basis for further precision agriculture research. Irrigation efficiency, land-use efficiency, and longan production could not be independently established from the available records.

Keywords— Factorial Experiment; Fertigation; Intercropping; Maize; Precision Agriculture

Introduction

Agricultural intensification has become an important strategy for increasing agricultural production while minimizing the expansion of cultivated land. One approach is intercropping, which involves cultivating two or more crop species simultaneously on the same land to improve land utilization and diversify agricultural outputs. Li et al., (2023) demonstrated that intercropping can provide land-saving advantages, although its effectiveness depends on crop combinations, resource availability, and management practices. In perennial horticultural systems, particularly young fruit orchards, the relatively open spaces between tree rows provide opportunities for cultivating annual crops. However, competition for sunlight, water, and nutrients may influence crop performance, making appropriate crop selection and cultivation management essential.

In Desa Petapahan, Tapung District, Kampar Regency, Riau Province, Indonesia, agricultural land management provides opportunities for integrating annual crops into perennial horticultural systems. According to BPS–Statistics Kampar Regency (2026), longan production in Kampar Regency reached 4,310.27 quintals in 2025, indicating the presence of longan cultivation in the region. However, these district-level statistics do not establish the total area of longan orchards or the extent of inter-row land utilization in Desa Petapahan. The experimental site comprised approximately 800 m² of agricultural land, including a young longan orchard with trees approximately three years old and planted at 7 × 7 m spacing. This planting configuration provides relatively open spaces between trees that may be utilized for annual crops such as maize. Nevertheless, the simultaneous cultivation of maize and longan requires

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture
e-ISSN: 2829-2421
Information Technology and Science (ITScience)

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

appropriate management of sunlight, water, and nutrient availability to minimize potential interspecific competition. Therefore, evaluating maize growth and production under intercropping and fertigation-based management is particularly relevant to the agricultural conditions of the experimental site.

Maize (*Zea mays* L.) is a promising annual crop for cultivation between young longan (*Dimocarpus longan* Lour.) trees because of its relatively short growing period and its potential contribution to crop diversification. Previous research has demonstrated that the performance of maize in intercropping systems is strongly influenced by companion species, plant density, row arrangement, and resource competition. Žalac et al., (2023) examined maize intercropping in walnut orchards and highlighted the importance of tree–crop interactions in determining agronomic responses. Similarly, Kou et al. (2024) and G. Li et al., (2024) reported that planting arrangements and crop management influence maize performance in maize–soybean intercropping systems. However, these studies primarily addressed different companion crops and cultivation environments. Consequently, their findings cannot be directly generalized to maize cultivated between young longan trees under the agroecological conditions of Rokan Hulu.

In addition to cropping-system management, the application of smart farming technologies offers opportunities to improve the delivery of water and nutrients during crop development. Fertigation, which integrates irrigation and fertilizer application, potentially enables more coordinated nutrient and water supply according to crop requirements. Dong et al., (2024) demonstrated the feasibility of Internet of Things (IoT)-based monitoring for precision irrigation, while Adamo et al., (2025) and Morchid et al., (2026) described technology-based approaches to irrigation and fertigation management. Furthermore, Bian et al., (2024) emphasized the importance of irrigation strategies for maize productivity and water-use efficiency. Nevertheless, the effectiveness of technology-assisted management may differ according to cropping configuration, plant competition, and environmental conditions. In particular, experimental evidence comparing conventional watering and fertigation-based management within maize–longan intercropping systems remains limited.

The novelty of the present study lies in its factorial evaluation of maize–longan intercropping and fertigation-based smart farming within a young longan orchard in Rokan Hulu Regency. Unlike previous studies that predominantly examined maize–legume intercropping, maize cultivation within other perennial orchards, or smart irrigation technologies separately, this research integrates two management dimensions: cropping system (maize monoculture versus maize–longan intercropping) and irrigation–fertilization management (conventional watering versus smart farming). The 2 × 2 factorial design allows the individual effects of these factors and their statistical interactions to be evaluated. In this study, smart farming refers specifically to the implemented fertigation-based management treatment rather than a fully validated autonomous sensor-control system. Accordingly, the research aimed to evaluate maize plant height, leaf number, flowering time, harvest time, and recorded production under the four treatment combinations. The findings are expected to provide site-specific empirical evidence for the agronomic evaluation of maize cultivation in young longan orchards and to support further research on integrated cropping and precision nutrient–water management.

Literature Review

Intercropping is based on the ecological principles of resource complementarity, interspecific competition, and the spatial and temporal utilization of agricultural resources. The simultaneous cultivation of different crop species may improve resource utilization when their growth characteristics and resource requirements are complementary. However, competition for sunlight, water, and soil nutrients may also limit plant growth when the resource demands of companion crops overlap. Li et al. (2023), through a comprehensive meta-analysis, demonstrated that intercropping can improve land-use performance when diversified crop production is considered, although higher productivity than the most productive monoculture is not consistently achieved. Similarly, Ji et al., (2024) emphasized that the

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture
e-ISSN: 2829-2421
Information Technology and Science (ITScience)

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

biological characteristics of companion species influence crop productivity and ecological responses. These findings provide a theoretical basis for evaluating cropping system as the first experimental factor (Factor A), comparing maize monoculture (A1) with maize–longan intercropping (A2). The comparison is intended to determine whether the presence of young longan trees is associated with differences in maize growth, phenological development, and recorded production.

The integration of annual crops into perennial orchards involves additional interactions associated with tree canopy development, root distribution, and changes in the surrounding microenvironment. In young orchards, relatively open spaces between tree rows may provide opportunities for annual crop cultivation, whereas expanding tree canopies and root systems may progressively increase competition for available resources. Žalac et al., (2023b), investigating maize intercropping in a walnut orchard, demonstrated the importance of tree–crop interactions and changes in the growing environment for crop performance. Meanwhile, Kou et al., (2024) and G. Li et al., (2024) reported that crop arrangement and planting density influence productivity in maize–soybean intercropping systems. These studies suggest that the performance of maize under intercropping depends on the characteristics of the companion species and the management of available resources. However, the ecological interactions within maize–longan systems may differ from those involving legumes or walnut trees because of differences in plant architecture, growth characteristics, and belowground resource requirements. In Desa Petapahan, Tapung District, Kampar Regency, the presence of approximately three-year-old longan trees planted at 7 × 7 m spacing provides a relevant setting for examining maize responses within a young perennial orchard. Nevertheless, the specific contributions of light interception, soil moisture, and nutrient competition cannot be established without direct measurements of these environmental variables.

Water and nutrient availability are important determinants of maize growth and productivity because they influence physiological processes, including cell expansion, leaf development, photosynthesis, and assimilate distribution. Fertigation integrates irrigation and fertilizer application, potentially improving the coordination of water and nutrient delivery to the crop root zone. (Zhao et al., 2024) demonstrated that irrigation and nitrogen management influence productivity and resource-use efficiency in maize–soybean intercropping systems. Similarly, (Bian et al., 2024) reported that irrigation strategies affect maize yield and water-use efficiency, while (Gao et al., 2025) demonstrated that water and fertilizer management influence photosynthetic characteristics and yield in maize–mung bean intercropping. These findings provide the agronomic foundation for the second experimental factor (Factor B), which compares conventional nutrient-solution watering (B1) with fertigation-based smart farming management (B2). The proposed relationship is that differences in water and nutrient delivery may influence maize growth and development. Nevertheless, the magnitude and mechanisms of these responses depend on the actual management conditions, which must be distinguished from the technical capabilities of the irrigation system.

The advancement of precision agriculture has introduced technologies capable of supporting more systematic irrigation and nutrient management. (Dong et al., 2024) demonstrated the feasibility of an in-field Internet of Things (IoT) system for precision irrigation monitoring. (Adamo et al., 2025) examined the integration of irrigation and fertigation within an IoT-based management framework, while (Morchid et al., 2026) described the application of IoT and cloud computing technologies to smart irrigation systems. Additional research by (Roy & Chakraborty, 2025) and (Bushnag et al., 2026) explored low-cost irrigation solutions and intelligent control strategies. Although these technologies offer opportunities for improving irrigation decision-making, their technical performance should be distinguished from experimentally demonstrated agronomic outcomes. In the present study, smart farming is operationally defined as the implemented fertigation-based management package rather than a fully validated automated irrigation system. Consequently, differences between conventional watering and smart farming treatments are evaluated through measured maize responses, without assuming independently verified improvements in water-use efficiency or sensor-control performance.

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

The selection of maize plant height, leaf number, flowering time, harvest time, and recorded production as response variables is supported by physiological principles of crop growth and development. Plant height reflects stem elongation and vegetative growth, which may respond to water availability, nutrient supply, and light conditions. However, increased plant height does not necessarily indicate greater biomass accumulation or productivity because stem elongation may also be influenced by shading. Leaf number represents an aspect of vegetative development and contributes to the establishment of the photosynthetic canopy, although actual photosynthetic capacity also depends on leaf area, chlorophyll status, and intercepted radiation. Flowering time indicates the progression from vegetative to reproductive development, while harvest time reflects the duration of the crop production cycle. These phenological characteristics may respond to environmental conditions and crop management, but earlier flowering or harvesting should not automatically be interpreted as improved productivity. Recorded maize production represents the final production response and is conceptually associated with assimilate production, allocation, and reproductive development. Evidence from (Gao et al., 2025), (Bian et al., 2024), and (Zhao et al., 2024) supports the importance of water and nutrient management for maize physiological performance and productivity. However, the interpretation of production in the present study remains restricted to its recorded unit in grams because the harvested product and measurement basis require confirmation.

Previous intercropping research provides important evidence that crop combinations, planting arrangements, and resource management can influence plant performance, yet the available findings do not establish a consistent response across all cropping systems. Research on maize–soybean and maize–mung bean intercropping has emphasized resource management, crop arrangement, physiological responses, and production outcomes (Kou et al., (2024); Zhao et al., (2024); Gao et al., 2025). In contrast, Žalac et al., (2023b) demonstrated the relevance of evaluating maize within a perennial orchard environment. Indonesian research by Sumarni et al., (2025) further highlighted the importance of considering land equivalent ratios when evaluating overall intercropping performance. However, evidence from these different systems cannot directly establish the performance of maize cultivated between young longan trees. Furthermore, studies of smart irrigation technologies have frequently emphasized monitoring and control capabilities, whereas their agronomic effects under different orchard cropping configurations require separate evaluation.

Based on these theoretical and empirical considerations, the present study examines the independent and interactive effects of cropping system (Factor A) and fertigation-based management (Factor B) on maize growth, phenology, and recorded production. The factorial approach enables an assessment of whether maize responses to management differ between monoculture and longan intercropping conditions. The study therefore contributes to the agronomic evaluation of maize–longan intercropping under contrasting management practices in Desa Petapahan, Kampar Regency. Its scope is limited to the measured maize response variables and does not independently establish improvements in land equivalent ratio, water-use efficiency, nutrient-use efficiency, or total maize–longan system productivity.

Research Method

Research location and factorial design

The field experiment was conducted in 2026 in Petapahan Village, Tapung District, Kampar Regency, Riau Province, Indonesia. The research site covered approximately 800 m² of agricultural land, including a young longan (*Dimocarpus longan* Lour.) orchard. The longan trees were approximately three years old and planted at a spacing of 7 × 7 m, providing relatively open spaces between tree rows for maize cultivation. Maize (*Zea mays* L.) was planted at a spacing of 50 × 50 cm. The experimental site was selected to evaluate maize growth and productivity under monoculture and intercropping conditions within a young perennial fruit orchard.

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

The experiment was designed using a 2 × 2 factorial arrangement in a Completely Randomized Design (CRD), consisting of two experimental factors. The first factor (A) was the cropping system, comprising maize monoculture (A1) and maize–longan intercropping (A2). The second factor (B) was the cultivation management method, consisting of conventional watering and nutrient-solution application (B1) and fertigation-based smart farming management (B2). The combination of these factors resulted in four treatments: A1B1 (maize monoculture with conventional management), A1B2 (maize monoculture with smart farming), A2B1 (maize–longan intercropping with conventional management), and A2B2 (maize–longan intercropping with smart farming).

Ten replicate units were recorded for each treatment combination, resulting in 40 experimental units included in the statistical analysis. According to the original research proposal, each experimental unit consisted of 20 maize plants, of which 10 plants were designated as samples for growth and production observations. The recorded observations were summarized at the experimental-unit level, with one value per response variable used for statistical analysis. The measured parameters included plant height (cm), number of leaves, days to flowering, days to harvest, and recorded maize production (g). The factorial arrangement was intended to evaluate the main effects of cropping system and management method, as well as their interaction, on maize growth, phenological development, and production. Confirmation of independently randomized experimental units and the physical allocation of treatment plots remains necessary to establish the validity of the experimental design and statistical inference.

Table 1. Factorial Treatment Definitions Used in the Field Study

Treatment	Cropping system	Management	Reported units
A1B1	Maize monoculture	Conventional watering	10
A1B2	Maize monoculture	Smart farming / fertigation	10
A2B1	Maize–longan intercropping	Conventional watering	10
A2B2	Maize–longan intercropping	Smart farming / fertigation	10

Management, measurements, and data integrity

The approved documents describe water and fertilizer solution delivery by fertigation in B2 and application of nutrient solution by watering in B1. They do not establish an independently audited sensor-control algorithm, water quantity, irrigation frequency, or fertilizer mass for each treatment; accordingly, the technology factor is interpreted as the implemented management package. Measurement records supplied by the research team provided plant height (cm), number of leaves, time to flowering (days after planting), harvest time (days), and a production variable labeled grams. For the final analysis, 40 unit-level observations per parameter were used without missing values. A separate harvest/production file reproduced the same records and was not treated as extra replication.

The field records did not specify whether production in grams represented a cob, individual maize plant, or plot average. No conversion to Mg ha^{-1} was attempted. Noninteger leaf counts and phenological dates may represent plant-level averages within units, but this interpretation requires confirmation from field books. The independence of the 10 reported units per treatment, including physical plot allocation and randomization, also remains to be verified from site records.

Statistical analysis

Each response was fitted with the factorial model $Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \varepsilon_{ijk}$, where A and B represent cropping system and management, respectively, and k indexes the ten reported replicates. Means and standard deviations described treatment-level observations. Two-way analysis of variance (ANOVA; Type II sums of squares) assessed A, B and their interaction at $\alpha = 0.05$. When the interaction was significant, Tukey's honestly significant difference (HSD) test compared treatment combinations. Residual normality was screened with Shapiro–Wilk tests and equality of combination-level variances with median-based Levene tests. For production, where the interaction was not significant, inference

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture
e-ISSN: 2829-2421
Information Technology and Science (ITScience)

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

focused on marginal main effects.

The statistical analysis was conducted using 40 recorded experimental-unit observations, comprising ten reported replicates for each of the four treatment combinations. The analysis followed the principles of a balanced factorial experiment and was based on the assumption that experimental units were independently assigned to treatments through a completely randomized design. The recorded data were analyzed using two-way analysis of variance (ANOVA) to evaluate the main effects of cropping system, cultivation management, and their interaction. The analytical approach was consistent with factorial comparisons applied in previous intercropping studies (Kou et al., 2024; Zhao et al., 2024).

To ensure the reliability of statistical interpretation, the primary dataset, field notebooks, treatment allocation records, and measurement documentation require verification against the original experimental procedures. Particular attention should be given to the independence of experimental units, consistency of treatment implementation, sampling procedures, and accuracy of recorded growth and production measurements. Until these records have been verified, the statistical findings should be interpreted as conditional on the validity of the reported experimental design and observations. This verification is essential to support reliable conclusions regarding the effects of maize–longan intercropping and fertigation-based smart farming on maize growth, phenology, and production.

Results and Discussion

Results

Descriptive comparison of maize responses

The descriptive analysis revealed differences in maize growth, phenological development, and recorded production among the four treatment combinations (Table 2). The results demonstrated a consistent pattern in which maize grown under the combination of longan intercropping and fertigation-based smart farming (A2B2) exhibited the highest mean plant height, leaf number, and recorded production, together with the shortest time to flowering and harvest. In contrast, maize monoculture under conventional management (A1B1) consistently showed the lowest vegetative growth and recorded production, as well as the longest flowering and harvest periods. The relatively small standard deviations within each treatment indicated limited dispersion among the reported experimental-unit observations, although the reliability of these estimates remains dependent on confirmation of the experimental-unit structure and measurement procedures.

Plant height increased across the treatment combinations, with mean values of 112.27 ± 1.32 cm (A1B1), 133.27 ± 1.08 cm (A1B2), 137.07 ± 1.52 cm (A2B1), and 173.33 ± 1.46 cm (A2B2). Compared with conventional monoculture (A1B1), the application of smart farming under monoculture (A1B2) was associated with an increase of 21.00 cm (18.70%), while conventional maize–longan intercropping (A2B1) showed an increase of 24.80 cm (22.09%). The A2B2 treatment produced the greatest plant height, exceeding A1B1 by 61.06 cm (54.39%). Furthermore, the difference between conventional and smart farming management was 21.00 cm under monoculture but increased to 36.26 cm under intercropping. This variation in treatment differences was consistent with the significant interaction between cropping system and management method observed in the factorial analysis. Plant height standard deviations ranged from 1.08 to 1.52 cm, indicating relatively low within-treatment variation in the recorded observations.

Table 2. Treatment Means ± Standard Deviations (N = 10 Reported Units Per Combination)

Treatment	Height (cm)	Leaves	Flowering (DAP)	Harvest (d)	Production (g)
A1B1	112.27 ± 1.32 d	10.00 ± 0.33 d	61.22 ± 0.52 a	79.66 ± 0.57 a	412.00 ± 6.57 d
A1B2	133.27 ± 1.08 c	11.33 ± 0.20 c	59.33 ± 0.81 b	75.15 ± 0.40 b	458.40 ± 4.70 c

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture
e-ISSN: 2829-2421
Information Technology and Science (ITScience)

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

Treatment	Height (cm)	Leaves	Flowering (DAP)	Harvest (d)	Production (g)
A2B1	137.07 ± 1.52 b	11.78 ± 0.33 b	58.89 ± 0.53 b	74.56 ± 0.43 c	470.50 ± 5.91 b
A2B2	173.33 ± 1.46 a	14.67 ± 0.42 a	54.45 ± 0.71 c	71.52 ± 0.50 d	519.90 ± 10.02 a

Note. DAP = days after planting. Different letters within a column indicate pairwise differences according to Tukey HSD at 5%. For production, letters compare the four means only and do not imply a significant factorial interaction. The object represented by "g" remains unconfirmed.

A similar pattern was observed for leaf number. The mean leaf counts were 10.00 ± 0.33 (A1B1), 11.33 ± 0.20 (A1B2), 11.78 ± 0.33 (A2B1), and 14.67 ± 0.42 (A2B2). The A2B2 treatment produced 4.67 more leaves than A1B1, representing an increase of 46.70%. Under monoculture conditions, smart farming increased the mean leaf number by 1.33 compared with conventional management, whereas under maize–longan intercropping, the corresponding difference was 2.89 leaves. Additionally, A2B2 produced 3.34 more leaves than A1B2, indicating a greater leaf count in the intercropping treatment under smart farming management. Standard deviations ranged from 0.20 to 0.42 leaves, suggesting relatively consistent observations within each treatment combination. These differences corresponded with the statistically significant cropping system × management interaction reported for leaf number.

Maize phenological development also differed among treatment combinations. The mean times to flowering were 61.22 ± 0.52 days after planting (DAP) for A1B1, 59.33 ± 0.81 DAP for A1B2, 58.89 ± 0.53 DAP for A2B1, and 54.45 ± 0.71 DAP for A2B2. Compared with A1B1, flowering occurred 1.89 days earlier under A1B2, 2.33 days earlier under A2B1, and 6.77 days earlier under A2B2. Although A2B1 showed a slightly earlier mean flowering time than A1B2, the difference of 0.44 days was not statistically significant according to the Tukey HSD grouping presented in Table 2. The reduction in flowering time associated with smart farming was greater under intercropping (4.44 days) than under monoculture (1.89 days), corresponding to the significant interaction between the experimental factors.

Harvest time exhibited a comparable trend, with mean values of 79.66 ± 0.57 days (A1B1), 75.15 ± 0.40 days (A1B2), 74.56 ± 0.43 days (A2B1), and 71.52 ± 0.50 days (A2B2). The A2B2 treatment reached harvest 8.14 days earlier than A1B1, while A1B2 and A2B1 reached harvest 4.51 and 5.10 days earlier, respectively. Under monoculture, smart farming was associated with a 4.51-day reduction in harvest time, compared with a 3.04-day reduction under intercropping. The relatively narrow standard deviation range of 0.40–0.57 days indicated limited variation in recorded harvest timing within treatments. These findings suggest that cropping system and management method were associated with changes in maize developmental timing. However, the underlying physiological mechanisms cannot be determined without additional measurements of environmental conditions and crop development.

Recorded maize production also differed across the four treatment combinations. Mean production values were 412.00 ± 6.57 g for A1B1, 458.40 ± 4.70 g for A1B2, 470.50 ± 5.91 g for A2B1, and 519.90 ± 10.02 g for A2B2. Compared with conventional monoculture, production was 46.40 g (11.26%) higher under A1B2, 58.50 g (14.20%) higher under A2B1, and 107.90 g (26.19%) higher under A2B2. The highest mean production was recorded in A2B2, although this treatment also had the largest standard deviation (10.02 g), indicating greater absolute dispersion than in the other treatment groups. Nevertheless, the standard deviations remained relatively small in relation to their corresponding means. The difference between smart farming and conventional management was 46.40 g under monoculture and 49.40 g under intercropping. Despite the differences among treatment means, the factorial analysis showed no statistically significant interaction between cropping system and management for production ($p = 0.507$). Therefore, the production response should be interpreted primarily in terms of the significant main effects rather than as evidence of a synergistic interaction between intercropping and smart farming.

Overall, the descriptive results showed favorable maize responses under the combined A2B2 treatment

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

across all five measured parameters. The relatively low standard deviations indicated limited variation within the reported treatment observations, while the differences in treatment means reflected distinct responses to cropping system and management practices. However, the interpretation of these findings must consider the different interaction patterns observed among the response variables. Significant interactions were detected for plant height, leaf number, flowering time, and harvest time, whereas production was characterized by significant main effects without a statistically supported interaction. Consequently, the observed superiority of A2B2 should be interpreted within the scope of the recorded agronomic variables and the validity of the experimental design, rather than as direct evidence of improved water-use efficiency or overall intercropping-system productivity.

Factorial ANOVA and interaction structure

The main effects of cropping system and management were significant ($p < 0.001$) for all five responses (Table 3). The A × B interaction was significant for plant height, leaf number, flowering time, and harvest time. This indicates that the response to management differed between monoculture and longan intercropping for these traits. For production, however, the interaction was not supported statistically ($F_{1,36} = 0.45$; $p = 0.507$); a claim that longan intercropping synergistically increased production specifically through smart farming would therefore exceed the evidence.

Table 3. Summary of Two-Way Factorial Analysis of Variance

Response variable	Factor A: F	Factor A: p	Factor B: F	Factor B: p	A × B: F	A × B: p
Plant height	5735.11	2.71×10^{-41}	4469.83	2.33×10^{-39}	317.47	1.93×10^{-19}
Leaf number	609.67	3.68×10^{-24}	414.17	2.46×10^{-21}	56.60	6.84×10^{-9}
Flowering time	303.78	3.94×10^{-19}	234.16	2.48×10^{-17}	38.02	4.17×10^{-7}
Harvest time	835.57	1.65×10^{-26}	624.95	2.41×10^{-24}	23.69	2.25×10^{-5}
Production (g)	718.48	2.22×10^{-25}	457.92	4.61×10^{-22}	0.45	0.507

Note. Factor A = cropping system (maize monoculture vs. maize–longan intercropping); Factor B = cultivation management (conventional watering vs. smart fertigation); A × B = interaction. All effects were tested with df = (1, 36) at α = 0.05. Approximate p-values were derived from rounded F-statistics.

Revised Interpretation of Factorial ANOVA Results

The two-way factorial analysis of variance revealed significant main effects of cropping system (Factor A) and cultivation management (Factor B) on all five measured maize response variables (Table 3). Both factors significantly affected plant height, leaf number, flowering time, harvest time, and recorded production (all $p < 0.001$). Significant interactions between cropping system and management were also observed for plant height ($F_{1,36} = 317.47$, $p < 0.001$), leaf number ($F_{1,36} = 56.60$, $p < 0.001$), flowering time ($F_{1,36} = 38.02$, $p < 0.001$), and harvest time ($F_{1,36} = 23.69$, $p < 0.001$). These interactions indicate that the magnitude of the management response differed between monoculture and maize–longan intercropping systems. In contrast, the interaction effect on recorded maize production was not statistically significant ($F_{1,36} = 0.45$, $p = 0.507$), although both cropping system and management independently showed significant main effects ($p < 0.001$). Therefore, production differences should be interpreted primarily through the marginal effects of the two experimental factors rather than as evidence of a statistically significant synergistic interaction.

Response	Factor A: F	Factor B: F	A × B: F	Interaction p
Plant height	5,735.11	4,469.83	317.47	< 0.001
Leaf number	609.67	414.17	56.60	< 0.001

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

Response	Factor A: F	Factor B: F	A × B: F	Interaction p
Flowering time	303.78	234.16	38.02	< 0.001
Harvest time	835.57	624.95	23.69	< 0.001
Production (g)	718.48	457.92	0.45	0.507

Note. Each factorial effect has 1 numerator degree of freedom and 36 residual degrees of freedom. All A and B main-effect p-values were < 0.001. A = cropping system; B = management technology.

Averaged across the management levels, the intercropping factor was associated with 60.00 g greater reported production than monoculture (95% confidence interval: 55.46–64.54 g). Averaged across cropping systems, the management factor was associated with 47.90 g greater reported production under smart farming than conventional watering (95% confidence interval: 43.36–52.44 g). These are marginal contrasts based on the reported unit-level model. As noted above, they should not be converted to yield per area or interpreted as evidence of higher land-use or water-use efficiency.

Residual diagnostics and precision of reported observations

Table 4. Assumption Diagnostics for the 40-Unit ANOVA Dataset

Response	Shapiro–Wilk p	Levene p	CV (%)
Plant height	0.184	0.846	0.97
Leaf number	0.619	0.319	2.74
Flowering time	0.610	0.722	1.12
Harvest time	0.448	0.847	0.63
Production	0.899	0.123	1.52

Residual Diagnostics and Precision of Reported Observations

The diagnostic assessment of the two-way factorial ANOVA indicated no statistically significant departure from residual normality or homogeneity of variance across the five measured maize response variables (Table 4). The Shapiro–Wilk test produced p-values ranging from 0.184 to 0.899, while the median-based Levene test yielded p-values between 0.123 and 0.847. All values exceeded the significance threshold of 0.05, indicating that the diagnostic tests did not detect substantial violations of these statistical assumptions. Furthermore, the coefficients of variation (CV) ranged from 0.63% to 2.74%, reflecting relatively low residual variability in the reported observations. However, these diagnostic results do not independently confirm the accuracy of the primary measurements, the independence of experimental units, or the validity of the treatment randomization procedures.

The statistical analysis was based on 40 reported experimental-unit observations, comprising four treatment combinations with ten recorded replicates per combination. According to the original experimental proposal, each experimental unit consisted of 20 maize plants, with ten plants designated for sampling. The analytical dataset contained one observation per experimental unit for each measured parameter, including plant height, leaf number, flowering time, harvest time, and recorded production. Nevertheless, the available records do not fully establish how individual plant measurements were aggregated into experimental-unit values. In addition, the measurement basis of the production variable, expressed in grams, requires confirmation to determine whether it represents production per cob, plant, or experimental unit.

To strengthen the reliability and reproducibility of the statistical findings, the original field notebooks, primary measurement records, treatment allocation documentation, and data aggregation procedures require systematic cross-checking against the analytical dataset. Particular attention should be given to verifying whether the ten reported replicates in each treatment combination represented independently randomized experimental units rather than subsamples collected from the same experimental plot. The recorded measurements should also be checked for consistency in measurement units, observation timing, sampling procedures, and treatment identification. Furthermore, the descriptive statistics,

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture
e-ISSN: 2829-2421
Information Technology and Science (ITScience)

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

ANOVA results, and assumption diagnostics should be recalculated using the verified primary dataset to confirm the consistency of the reported statistical outputs.

Although the diagnostic tests indicated relatively low residual variability and no statistically detected violations of normality or homogeneity of variance, these findings should be interpreted cautiously until the primary records and experimental-unit structure have been verified. Establishing the independence of replicates and consistency of measurement procedures is essential for ensuring that the reported F-statistics, p-values, and treatment comparisons provide valid inferential evidence regarding the effects of maize–longan intercropping and fertigation-based smart farming on maize growth, phenology, and production.

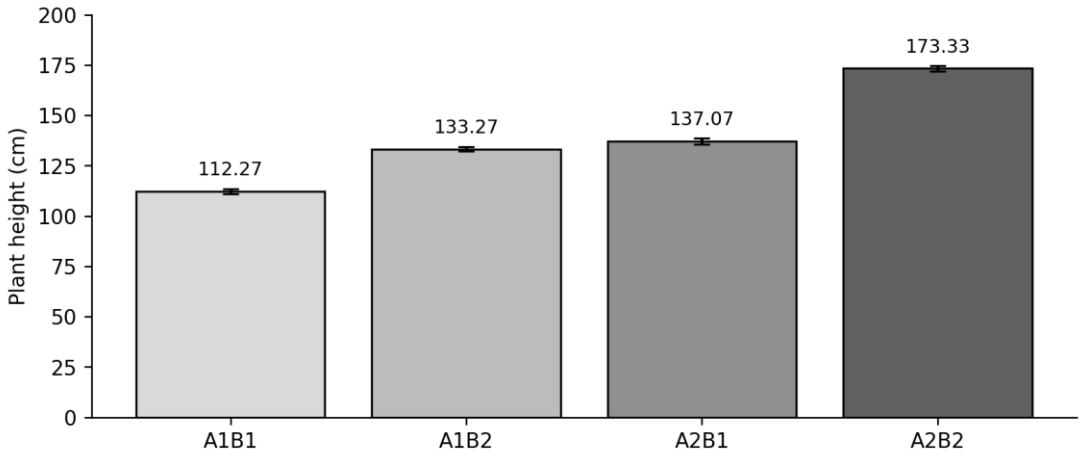

Figure 1. Reported Maize Plant Height Under Four Factorial Treatments (Means ± SD).

Discussion

Growth and phenology under contrasting management

The differences in maize growth and phenological development among treatment combinations may be explained by the combined influences of cropping configuration, water and nutrient availability, and potential tree–crop interactions. The factorial analysis revealed significant interactions between cropping system and management method for plant height, leaf number, flowering time, and harvest time ($p < 0.001$). These findings indicate that maize responses to fertigation-based management varied according to whether the crop was cultivated as a monoculture or intercropped with young longan trees. The highest plant height (173.33 cm) and leaf number (14.67) were recorded under the maize–longan intercropping and smart farming combination (A2B2), whereas conventional monoculture (A1B1) produced the lowest values of 112.27 cm and 10.00 leaves, respectively. These differences suggest that the combined treatment conditions were associated with more pronounced vegetative development. However, the underlying physiological mechanisms require careful interpretation because soil moisture, nutrient uptake, canopy light interception, and photosynthetic activity were not directly measured.

The observed differences in plant height may be associated with the physiological regulation of cell division, cell elongation, and assimilate availability. Adequate water supply is important for maintaining cell turgor pressure, which supports tissue expansion, while essential nutrients contribute to chlorophyll formation, protein synthesis, and metabolic processes involved in vegetative growth. Under monoculture conditions, fertigation-based smart farming increased mean plant height by 21.00 cm compared with conventional management. In contrast, the corresponding increase under maize–longan intercropping was 36.26 cm. This difference is consistent with the significant interaction between cropping system and management method. Bian et al., (2024) reported that irrigation strategies influenced maize growth and productivity, demonstrating the importance of water availability during crop development.

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

Similarly, Gao et al., (2025) found that irrigation and fertilizer management affected photosynthetic characteristics and crop performance in maize–mung bean intercropping systems. These studies provide physiological support for the possibility that differences in water and nutrient delivery contributed to the observed maize growth responses. Nevertheless, the present experiment did not quantify the irrigation volume or nutrient availability associated with each treatment, preventing confirmation of these mechanisms.

The higher plant height observed under maize–longan intercropping may also be related to the growing environment created by young perennial trees. At the experimental site, longan trees were approximately three years old and planted at 7 × 7 m spacing, providing relatively open spaces for maize cultivation. In agroforestry systems, tree canopies can influence radiation interception, air temperature, relative humidity, and evaporative demand, potentially modifying the conditions experienced by associated annual crops. Žalac et al., (2023b) demonstrated that walnut trees altered the microclimate of an intercropped maize system, although the effects on maize productivity depended on plant density and competition for resources. In the present study, the relatively young longan trees may have influenced the immediate growing environment of maize. However, increased plant height could reflect favorable growth conditions or a morphological response to differences in light availability. Therefore, greater plant height should not automatically be interpreted as improved photosynthetic efficiency or biomass production. Measurements of canopy shading, light intensity, soil moisture, and maize biomass would be necessary to distinguish these alternative explanations.

Leaf number exhibited a response pattern similar to that of plant height. The highest mean leaf number was recorded under A2B2 (14.67 leaves), followed by A2B1 (11.78 leaves), A1B2 (11.33 leaves), and A1B1 (10.00 leaves). Compared with conventional management, smart farming increased leaf number by 1.33 under monoculture and 2.89 under intercropping. Leaf development is closely associated with vegetative growth, meristem activity, and the availability of resources required for leaf initiation and expansion. Nitrogen availability is particularly important for the formation of photosynthetic proteins and chlorophyll, whereas adequate water availability supports cellular expansion and leaf development.Gao et al., (2025) demonstrated that coordinated water and fertilizer management influenced leaf area index, chlorophyll characteristics, and photosynthetic performance in maize-based intercropping systems. These findings suggest a plausible relationship between the management treatments and the greater leaf number recorded in the present study. Nevertheless, leaf number alone does not establish greater leaf area or photosynthetic capacity because leaf size, chlorophyll concentration, and actual carbon assimilation were not assessed.

The phenological responses further demonstrated differences among the treatment combinations. Maize under A2B2 reached flowering at 54.45 days after planting, compared with 61.22 days under A1B1, representing a difference of 6.77 days. Under monoculture, smart farming was associated with flowering 1.89 days earlier than conventional management, whereas the difference reached 4.44 days under intercropping. Flowering time in maize is influenced by genetic characteristics, temperature-dependent development, water availability, and nutrient conditions. Environmental stress can modify the progression from vegetative to reproductive growth, although its direction and magnitude depend on the intensity and timing of stress. Improved water and nutrient availability may support more consistent developmental progression, while changes in microclimate may alter developmental rates. The observed earlier flowering under A2B2 is therefore physiologically plausible in the context of different management and cropping environments. However, because soil moisture, canopy temperature, and plant nutritional status were not monitored, the present results cannot establish which factor was responsible for the observed differences in flowering time.

Harvest time followed a comparable overall pattern, with the earliest recorded harvest under A2B2 (71.52 days) and the latest under A1B1 (79.66 days), representing a difference of 8.14 days. Under monoculture, smart farming shortened the mean time to harvest by 4.51 days, whereas the corresponding

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

difference under intercropping was 3.04 days. This variation indicates that the magnitude of the management effect on harvest timing differed between cropping systems, consistent with the significant factorial interaction. Harvest timing is determined by the progression of crop development and the criteria used to identify harvest maturity. Changes in environmental conditions may influence the duration of vegetative and reproductive phases, but earlier harvest does not necessarily indicate greater physiological efficiency or higher economic productivity. The relationship between flowering and harvest timing should therefore be interpreted cautiously, particularly because the detailed maturity criteria and plant-level averaging procedures require confirmation from the original field records.

Taken together, the observed growth and phenological responses suggest that maize performance was associated with both the cropping system and the fertigation-based management treatment. The significant interactions indicate that the effects of management on maize development were not uniform between monoculture and longan intercropping. These findings are consistent with the broader physiological understanding that crop responses depend on the combined availability of light, water, nutrients

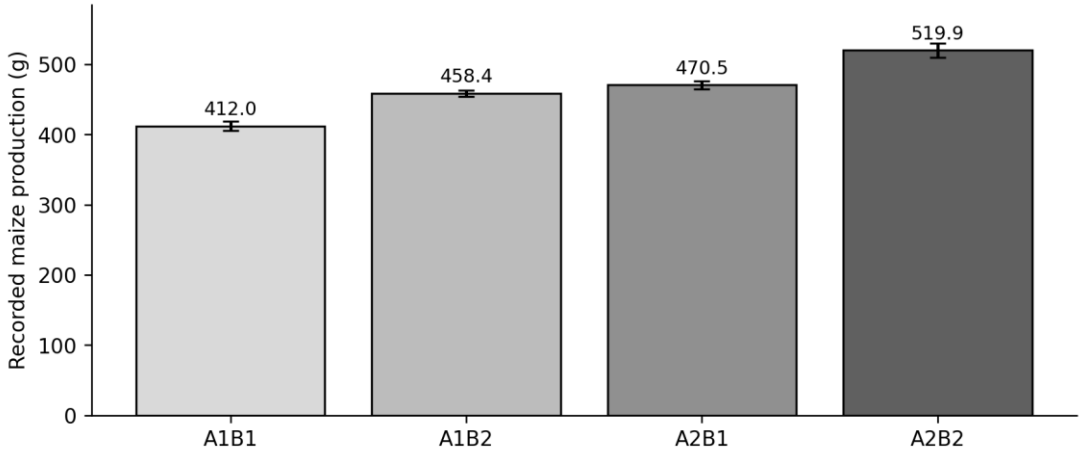

Figure 2. Reported Maize Production by Treatment (Means ± SD); Unit Basis of Grams Requires Field Verification.

Recorded production, relevance, and comparison with previous work

The recorded maize production differed among treatment combinations, following the order A2B2 > A2B1 > A1B2 > A1B1 (Figure 2). The highest mean production was observed under maize–longan intercropping with fertigation-based smart farming (A2B2), reaching 519.90 ± 10.02 g, whereas conventional maize monoculture (A1B1) produced the lowest mean of 412.00 ± 6.57 g. The difference between these treatments was 107.90 g, equivalent to a 26.19% increase relative to A1B1. Under monoculture conditions, smart farming increased recorded production from 412.00 to 458.40 g (11.26%), while under maize–longan intercropping, production increased from 470.50 to 519.90 g (10.50%). The factorial ANOVA demonstrated significant main effects of cropping system and management method ($p < 0.001$), but their interaction was not statistically significant ($p = 0.507$). Therefore, although A2B2 produced the highest recorded mean, the results do not provide statistical evidence of a synergistic interaction between intercropping and smart farming for maize production.

The present findings differ from those reported by Kou et al. (2024), who investigated maize–soybean strip intercropping under drip fertigation in arid northwestern China. Their study reported that intercropping reduced maize grain yield by 13.08% and soybean grain yield by 48.73% compared with monocropping, although particular row configurations improved overall water–land productivity and economic performance. In contrast, the present study recorded higher maize production under longan

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

intercropping than under monoculture at both management levels. This difference may be associated with the contrasting characteristics of the companion crops and planting configurations. In maize–soybean intercropping, both species are annual crops with overlapping growth periods and potentially substantial competition for available light, water, and nutrients. Conversely, the present experiment involved approximately three-year-old longan trees planted at 7 × 7 m spacing, providing relatively open spaces between tree rows. Such conditions may have resulted in a different competitive environment for maize. Nevertheless, this explanation remains hypothetical because light interception, root competition, soil moisture, and nutrient availability were not directly measured.

The positive production response associated with fertigation-based management is broadly consistent with (Zhao et al., 2024), who demonstrated that supplementary irrigation and appropriate nitrogen management improved productivity and resource-use efficiency in maize–soybean intercropping systems. Their study reported land equivalent ratios ranging approximately from 1.06 to 1.11, indicating an overall land-use advantage of intercropping, even though maize grain yield per unit area was generally lower under intercropping than under monoculture. In the present study, smart farming increased recorded maize production by 46.40 g under monoculture and 49.40 g under longan intercropping. These responses suggest that the management treatment was associated with improved maize production under both cropping configurations. Differences in water and nutrient delivery may provide a plausible agronomic explanation, as coordinated irrigation and fertilization can influence resource availability during vegetative and reproductive development. However, (Zhao et al., 2024) evaluated specific irrigation volumes and nitrogen application rates, whereas the present study did not provide sufficiently detailed records of water application, fertilizer quantities, or plant nutrient uptake. Consequently, the observed production differences cannot be attributed conclusively to improved irrigation efficiency or nutrient-use efficiency.

Comparable findings were reported in Indonesia by Sumarni et al., (2025), who investigated sweet corn–caisim intercropping under different planting densities and planting times. Their results demonstrated that intercropping configurations produced land equivalent ratios greater than 1.00, with the highest LER of 1.35 and an R/C ratio of 1.22 obtained from one row of caisim planted simultaneously with sweet corn. These findings indicate that appropriate crop arrangements can improve land-use performance and economic returns without necessarily reducing individual crop production. The present results are consistent with the broader observation that intercropping performance depends on crop combinations and management practices. However, important differences exist between the two studies. Sumarni et al., (2025) evaluated two annual vegetable crops and directly measured land-use and economic performance, whereas the present study combined maize with perennial longan trees and focused on maize growth, phenology, and recorded production. Therefore, the higher recorded maize production under A2B2 cannot be interpreted as proof of superior land-use efficiency or economic profitability without corresponding measurements of longan production, land equivalent ratio, and cultivation costs.

Overall, comparisons with previous studies demonstrate that the agronomic performance of intercropping systems is highly dependent on companion species, planting arrangements, crop developmental stages, resource availability, and cultivation management. The contrasting results between the present study and Kou et al., (2024) suggest that the competitive environment in a young perennial orchard may differ from that of annual crop strip intercropping. Meanwhile, the positive responses to irrigation-related management observed byZhao et al., (2024) and the land-use advantages reported by Sumarni et al., (2025) provide relevant context for interpreting the present findings. Nevertheless, the production variable in this study was recorded in grams without a fully verified measurement basis, preventing direct quantitative comparison with published grain yields expressed per hectare. In addition, the absence of longan yield, irrigation volume, nutrient uptake, and economic data limits conclusions regarding overall system efficiency. Future research should therefore incorporate

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

standardized maize yield measurements, longan production, soil moisture monitoring, nutrient-use indicators, and land equivalent ratio analysis to determine whether maize–longan intercropping with fertigation offers measurable agronomic and economic advantages.

Limitations and implications for follow-up research

The most consequential limitations concern the scope and validity of available field records. The research proposal included irrigation efficiency, land-use efficiency, and perennial-crop outputs, whereas the analyzable dataset addresses maize observations only. Neither the volume of water applied nor maize and longan output per unit land was documented in sufficient detail to estimate irrigation water productivity, water-use efficiency, or land equivalent ratio. Likewise, the research files do not include verified sensor readings, control thresholds, device uptime, or logged automation actions. The study therefore should not be presented as a validated sensor-controlled irrigation performance trial. Further field documentation is required to distinguish the technical capability of the installed system from the agronomic effects of the management treatment (Roy & Chakraborty, (2025); (Bushnag et al., 2026).

A second limitation is the need to confirm that ten replicates within each combination corresponded to ten independently randomized experimental units rather than subsamples of fewer plots or shared irrigation lines. If subsamples were incorrectly treated as independent units, the apparent precision and p-values could be inflated. Future studies should define randomized plot boundaries, record replicate-level irrigation inputs and sensor outputs, distinguish fresh-ear and grain yield, quantify longan yield, and collect a proper sole-longan comparison. Predeclared measures of water productivity, land equivalent ratio, energy use, and economic returns would connect the factorial agronomic findings more directly to the motivating objectives of efficient land use and sustainable food supply.

Conclusion

This study demonstrated that cropping system and fertigation-based smart farming management were significantly associated with maize growth, phenological development, and recorded production in a young longan orchard in Petapahan Village, Kampar Regency, Riau Province, Indonesia. Both cropping system (Factor A) and cultivation management (Factor B) showed significant main effects ($p < 0.001$) on plant height, leaf number, flowering time, harvest time, and recorded production. The combination of maize–longan intercropping and smart farming (A2B2) produced the highest plant height (173.33 cm), leaf number (14.67 leaves), and recorded production (519.90 g), while achieving the earliest flowering (54.45 days) and harvest (71.52 days). Compared with conventional maize monoculture (A1B1), this treatment increased recorded production by 26.19% and shortened flowering and harvest times by 6.77 and 8.14 days, respectively.

The factorial analysis revealed significant interactions between cropping system and management for plant height, leaf number, flowering time, and harvest time ($p < 0.001$), indicating that maize growth and phenological responses to management varied between monoculture and longan intercropping conditions. However, the interaction effect on recorded production was not significant ($p = 0.507$), demonstrating that the production response was better explained by the independent main effects of cropping system and management rather than a statistically supported synergistic interaction.

The principal scientific contribution of this study is the factorial evaluation of maize–longan intercropping and fertigation-based management, providing preliminary empirical evidence that cropping configuration can influence the magnitude of management responses in maize growth and phenology. These findings extend the agronomic discussion of intercropping beyond commonly investigated annual crop combinations to a young perennial fruit orchard system. Nevertheless, the interpretation remains conditional on verification of experimental-unit independence and primary measurement records. Further research incorporating standardized yield measurements, soil moisture,

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

Journal of Agriculture (JoA)
Volume: 05 | Number 03 | November 2026
E-ISSN: 2829-2421
https://doi.org/10.47709/JoA.v5n03.9938

nutrient availability, irrigation efficiency, longan productivity, and land equivalent ratio is required to establish the physiological mechanisms and overall productivity advantages of this cultivation system.

Acknowledgements

This work is associated with the 2026 Penelitian Dosen Pemula (PDP) research conducted by Universitas Rokania through the BIMA research reporting scheme. The authors should insert the verified official funding agency, grant contract number, and any formally acknowledged institutional assistance before submission. The authors are responsible for confirming the underlying field records and author contributions.

References

Adamo, T., Caivano, D., Colizzi, L., Dimauro, G., & Guerriero, E. (2025). Optimization of irrigation and fertigation in smart agriculture: An IoT-based micro-services framework. *Smart Agricultural Technology*, *11*, 100885. https://doi.org/10.1016/j.atech.2025.100885

Bian, Q., Dong, Z., Fu, Y., Zhao, Y., Feng, Y., Wang, Z., & Zhu, J. (2024). Optimizing irrigation strategies to improve yield and water use efficiency of drip-irrigated maize in southern Xinjiang. *Plants*, *13*(24), 3492. https://doi.org/10.3390/plants13243492

Bushnag, A., Ben Chaabane, S., Harrabi, R., Alharbi, L. A., Alshmrani, M., & Abuzneid, S. (2026). Smart agriculture: IoT-based smart irrigation with advanced fuzzy logic control. *Expert Systems with Applications*, *299*, 130168. https://doi.org/10.1016/j.eswa.2025.130168

Dong, Y., Werling, B., Cao, Z., & Li, G. (2024). Implementation of an in-field IoT system for precision irrigation management. *Frontiers in Water*, *6*, 1353597. https://doi.org/10.3389/frwa.2024.1353597

Gao, M., Wang, X., Chen, R., Gao, H., Wang, X., & Liu, H. (2025). Optimization of water and fertilizer management on the intercropping system between maize and mung bean to improve photosynthetic characteristics & water use and to increase plant yield. *Frontiers in Plant Science*, *16*, 1597198. https://doi.org/10.3389/fpls.2025.1597198

Ji, Z., Ren, M., Ye, J., Zhao, L., Dai, R., Zhang, T., Luo, Q., Tang, J., Hu, L., & Chen, X. (2024). The role of partner species in the crop cocultures: A meta-analysis. *Agriculture, Ecosystems & Environment*, *367*, 108992. https://doi.org/10.1016/j.agee.2024.108992

Kou, H., Liao, Z., Zhang, H., Lai, Z., Liu, Y., Kong, H., Li, Z., Zhang, F., & Fan, J. (2024). Grain yield, water-land productivity and economic profit responses to row configuration in maize-soybean strip intercropping systems under drip fertigation in arid northwest China. *Agricultural Water Management*, *297*, 108817. https://doi.org/10.1016/j.agwat.2024.108817

Li, C., Stomph, T.-J., Makowski, D., Li, H., Zhang, C., Zhang, F., & van der Werf, W. (2023). The productive performance of intercropping. *Proceedings of the National Academy of Sciences of the United States of America*, *120*(2), e2201886120. https://doi.org/10.1073/pnas.2201886120

Li, G., Liang, Y., Liu, Q., Zeng, J., Ren, Q., Guo, J., Xiong, F., & Lu, D. (2024). Enhancing production efficiency through optimizing plant density in maize–soybean strip intercropping. *Frontiers in Plant Science*, *15*, 1473786. https://doi.org/10.3389/fpls.2024.1473786

Morchid, A., Qjidaa, H., El Alami, R., Mobayen, S., Skruch, P., & Bossoufi, B. (2026). Smart irrigation-based internet of things and cloud computing technologies for sustainable farming. *Scientific Reports*, *16*, 5293. https://doi.org/10.1038/s41598-026-35810-0

Roy, S., & Chakraborty, R. S. (2025). Low-cost smart irrigation solution for efficient water use and requirement prediction. *Computers and Electrical Engineering*, *125*, 110420.

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

https://doi.org/10.1016/j.compeleceng.2025.110420

Sumarni, T., Nabil, N. A., & Anggoro, A. D. (2025). Growth and yield of sweet corn intercropping with caisim of different plant densities and planting times. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *53*(1), 44–53. https://doi.org/10.24831/jai.v53i1.60434

Žalac, H., Herman, G., Ergović, L., Jović, J., Zebec, V., Bubalo, A., & Ivezić, V. (2023a). Ecological and agronomic benefits of intercropping maize in a walnut orchard—A case study. *Agronomy*, *13*(1), 77. https://doi.org/10.3390/agronomy13010077

Žalac, H., Herman, G., Ergović, L., Jović, J., Zebec, V., Bubalo, A., & Ivezić, V. (2023b). Ecological and agronomic benefits of intercropping maize in a walnut orchard—A case study. *Agronomy*, *13*(1), 77. https://doi.org/10.3390/agronomy13010077

Zhao, Z., Li, Z., Li, Y., Yu, L., Gu, X., & Cai, H. (2024). Supplementary irrigation and reduced nitrogen application improve the productivity, water and nitrogen use efficiency of maize-soybean intercropping system in the semi-humid drought-prone region of China. *Agricultural Water Management*, *305*, 109126. https://doi.org/10.1016/j.agwat.2024.109126

This is an Creative Commons License This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License