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Land use efficiency and performance of sweet corn-cowpea intercropping influenced by temporal planting and methods of fertilizer application

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**ABSTRACT**

This study evaluated the land-use efficiency of sweet corn–cowpea intercropping, influenced by planting dates and fertilizer application methods, in Tupi, South Cotabato, Philippines, from March to June 2025. Using a randomized complete block design with factorial treatments, the study assessed growth and yield parameters of sweet corn and cowpea across varying planting intervals and fertilizer regimes. Results demonstrated that sweet corn maintained robust vegetative growth across treatments. Still, its yield and marketable ear weight were maximized when cowpea was planted 21 days after sweet corn, with two-band fertilizer yielding the highest land equivalent ratio (LER) and area time equivalent ratio (ATER), thereby maximizing land-use efficiency (LUE). Cowpea yield performance was similarly enhanced in later plantings and with two-band fertilization, confirming that delayed cowpea introduction alleviates resource competition and improves productivity. The study recommends strategic timing of cowpea planting and two-band fertilizer application to optimize yield and efficiency, suggesting these practices can sustainably intensify sweet corn–cowpea intercropping systems while increasing farmers' returns by choosing planting schedules and fertilizer-placement methods that synchronize nutrient supply with crop demand, as most treatments generated more than double the value of every peso invested. These findings underscore the importance of adaptive management and targeted extension services to support resilient, high-yielding intercropping systems in diverse agroecological conditions.

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## INTRODUCTION

Globally, intercropping sweetcorn with legumes such as cowpea has been recognized as a sustainable agricultural practice that enhances land-use efficiency, improves soil fertility, and increases overall crop productivity. Studies from various regions demonstrate that intercropping systems contribute to food security and sustainable farming by optimizing resource utilization and reducing dependency on chemical inputs (Francis and Decoteau, 1993; Paut *et al.*, 2024). Deliberations on temporal planting dates and fertilization strategies are crucial for maximizing the yield benefits and ecological advantages of such cropping systems.

Intercropping combinations such as the sweetcorn (*Zea mays* L.)-cowpea (*Vigna unguiculata* (L.) Walp.) system have garnered attention due to the complementary growth habits and resource-use patterns of these crops (Dwivedi, 2016). Internationally, research has explored the benefits of this intercropping system in diverse agroecological zones, highlighting its potential to increase overall productivity and economic returns, particularly in smallholder farming systems (Agegnehu *et al.*, 2016; Lithourgidis *et al.*, 2011).

In the Philippines, where agriculture remains a significant contributor to the economy and food security, intercropping systems are traditionally practiced and continue to be explored for their potential to improve farm productivity and resilience. Studies conducted in various regions of the Philippines have demonstrated the advantages of sweetcorn-cowpea intercropping, including increased yields, improved weed suppression, and enhanced soil fertility (Magcale-Macandog *et al.*, 2010). However, optimizing such systems requires a nuanced understanding of factors such as planting time and nutrient management.

Within the Philippine context, the province of South Cotabato, known for its diverse agricultural production, including corn and legumes, presents a relevant setting for investigating the optimization of

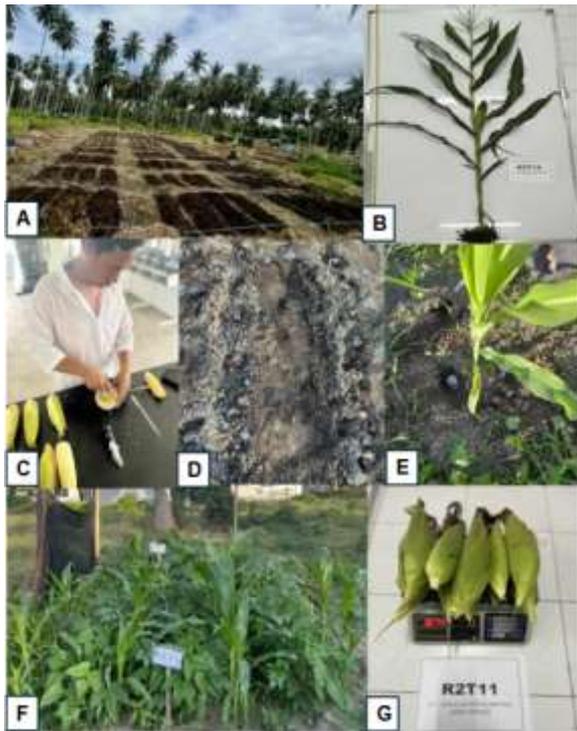
sweetcorn-cowpea intercropping. Although it is known to increase yield and sustainability, it remains unclear how specific planting schedules and fertilizer application methods affect land-use efficiency among smallholder farmers in the region. Farmers in this region face particular challenges related to soil fertility, rainfall patterns, and market demands, making the identification of effective intercropping strategies crucial for enhancing their livelihoods and ensuring sustainable agricultural production. Therefore, understanding the effects of temporal planting arrangements and different fertilization methods on the performance of sweetcorn-cowpea intercropping systems in South Cotabato holds significant practical implications for local agricultural practices and broader food security efforts.

## MATERIALS AND METHODS

### Experimental design and data analysis

The study was carried out as a 6 × 2 factorial experiment in a Randomized Complete Block Design (RCBD) with three replicates. Each block consists of twelve (12) sub-plots, and each subplot was represented by one treatment. Each sub-plot consisted of twenty-eight (28) crops that were spaced 0.25 m between hills and 0.75 m between furrows. An alleyway 0.50 meters wide was provided between plots. Factors followed the conducted study by Smarni and Anggoro (2024), with their corresponding treatments: T1 (A<sub>1</sub>B<sub>1</sub>) - Monocropping (Sweet-corn) Fertilized using Side Dress Method, T2 (A<sub>1</sub>B<sub>2</sub>) - Monocropping (Sweet-corn) Fertilized using Two-band Method, T3 (A<sub>2</sub>B<sub>1</sub>)- Monocropping (Cowpea) Fertilized using Side Dress Method, T4 (A<sub>2</sub>B<sub>2</sub>) - Monocropping (Cowpea) Fertilized using Two-band Method, T5 (A<sub>3</sub>B<sub>1</sub>)- Synchronous planting of cowpea and sweet-corn (0 day) Fertilized using Side Dress Method, T6 (A<sub>3</sub>B<sub>2</sub>)- Synchronous planting of cowpea and sweet-corn (0 day) Fertilized using Two-band method, T7 (A<sub>4</sub>B<sub>1</sub>)- Planting of cowpea seven (7) days after planting (DAP) of Sweetcorn fertilized using Side Dress Method, T8 (A<sub>4</sub>B<sub>2</sub>) - Planting of cowpea seven (7) days after planting (DAP) of Sweetcorn fertilized using Two-band Method, T9 (A<sub>5</sub>B<sub>1</sub>)- Planting of cowpea fourteen (14)

days after planting (DAP) of Sweetcorn fertilized using Side Dress Method, T10 (A<sub>5</sub>B<sub>2</sub>)- Planting of cowpea fourteen (14) days after planting (DAP) of Sweetcorn fertilized using Two-band Method, T11 (A<sub>6</sub>B<sub>1</sub>)- Planting of cowpea twenty-one (21) days after planting (DAP) of Sweetcorn fertilized using Side Dress Method, T12 (A<sub>6</sub>B<sub>2</sub>)- Planting of cowpea Twenty-one (21) days after planting (DAP) of Sweetcorn fertilized using Two-band Method (Fig. 1).



**Fig. 1.** Documentation; A) Field lay-outing; B) Gathering of Plant height; C) Gathering of Total Soluble Solid; D.) Side-dress Application; E) Two-band Application; F) Synchronous Planting of Cowpea and Sweetcorn; G.) Gathering of the Weight of Sweet-corn

### Seed selection and preparation

This study used the high-quality Ramgo Sweet Fortune hybrid seeds with a germination rate of at least 94%. Seeds were stored under cool, dry conditions prior to planting (Ramgo Brochure, 2020).

### Land preparation

The area was prepared in accordance with the land preparation process outlined by Goeden Philippines (2024). It began by preparing well-drained, fertile soil with a pH of 5.8-6.8. Soil was then prepared by

plowing and harrowing to create a fine seedbed suitable for direct seeding.

### Soil analysis

Performing soil analysis before field planting is a crucial step in ensuring optimal crop growth and sustainable soil management. The process begins with proper soil sampling, which involves dividing the field into homogeneous units based on soil type, management history, or topography to better represent field variability. Sampling is typically performed using a soil probe, auger, or spade, collecting soil cores from at least 10–15 locations in a zigzag pattern across each unit.

Samples are most often taken from the root zone, typically 0–30 cm deep for most field crops. The collected samples were thoroughly mixed to form a composite; foreign materials and debris were removed; and the composite was submitted to the laboratory in a clean, labeled container or bag (Michigan State University, 2022; FAO, 2021). Moreover, sampling collection followed the process of the Department of Agriculture-Bureau of Soils and Water Management. After collecting, it was sent to Bureau of Soil and Water Management (BSWM) in General Santos City for laboratory analysis.

### Planting

Seeds were planted according to the process outlined in the Ramgo Brochure (2020), with direct sowing in the field at a spacing of 25 cm between hills and 75 cm between rows, at a depth of 2 to 3 cm. Planting was performed, ensuring temperatures ranged from 21°C to 30°C to promote optimal germination, which typically occurs within 4 to 5 days.

### Fertilization

The fertilization treatments were based on the soil analysis results, where sweetcorn received an amount of 3.75 grams of Ammonium Phosphate (16-20-0), 1.41 grams of Muriate of Potash (0-0-60), and 1 gram of Urea (46-0-0). Moreover, the first application commenced a day before planting; the second and third applications were applied at thirty (30) and

forty days after planting (DAP). Moreover, cowpea received 1.82 grams of Ammonium Phosphate (16-20-0), 1.24 grams of Muriate of Potash (0-0-60), and 0.93 grams of Urea (46-0-0). All fertilizers were applied according to the treatments (Factor B) designated as side-dress and two-band applications.

### Planting of cowpea as treatments

Treatments were planted according to the treatment assigned as Treatment 1 - Monocropping (Sweet-corn) Fertilized using Side Dress Method, Treatment 2 - Monocropping (Sweet-corn) Fertilized using Two-band Method, Treatment 3 - Monocropping (Cowpea) Fertilized using Side Dress Method, Treatment 4 - Monocropping (Cowpea) Fertilized using Two-band Method, Treatment 5 - Synchronous planting of cowpea and sweet-corn (0 day) Fertilized using Side Dress Method, Treatment 6 - Synchronous planting of cowpea and sweet-corn (0 day) Fertilized using Two-band method, Treatment 7 - Planting of cowpea seven (7) days after planting (DAP) of Sweetcorn fertilized using Side Dress Method, Treatment 8 - Planting of cowpea seven (7) days after planting (DAP) of Sweetcorn fertilized using Two-band Method, Treatment 9 - Planting of cowpea fourteen (14) days after planting (DAP) of Sweetcorn fertilized using Side Dress Method, Treatment 10 - Planting of cowpea fourteen (14) days after planting (DAP) of Sweetcorn fertilized using Two-band Method. Treatment 11 - Planting of cowpea twenty-one (21) days after planting (DAP) of Sweetcorn fertilized using the side-dress method. Lastly, Treatment 12 - Planting of cowpea, Twenty-one (21) days after planting (DAP) of Sweetcorn fertilized using the Two-band Method.

### Thinning

Thinning was performed by removing excess seedlings to ensure that each plant has adequate space, nutrients, and light to reach its full potential. This process was essential, as overcrowding can lead to poor air circulation, increased competition for resources, stunted growth, and reduced overall yield quality. Thinning was performed after sweetcorn seedlings reached 10–15 cm in height, thereby maintaining the recommended spacing (usually 20–25 cm) to optimize

ear size and plant health. This was performed by selectively removing weaker and excess plants. This allows and promotes vigorous stand development and reduces the risk of disease and pest infestations by improving airflow and light penetration (Southern Exposure Seed Exchange, 2018). Moreover, thinning of cowpea commenced two weeks after emergence, leaving one healthy plant per hill.

### Tagging

Tagging was performed for research reliability and quality assurance in sweetcorn-cowpea production. This process served important functions in agricultural management and research. Accurate tagging enabled easier identification of experimental treatments or specific plants, which is crucial for effective crop monitoring, management decisions, and data collection. Moreover, tagging supports regulatory compliance, facilitates communication, and enhances traceability (Creative Safety Supply, 2025). When combined, these practices underpin high standards of productivity, research reliability, and quality assurance in sweetcorn production.

### Care and management

Regular monitoring, weeding, cultivation, and manual management were performed in the experimental area to avoid competition with the test plants, improve aeration and moisture retention, and ensure nutrient availability in the soil. Test plants were watered regularly in the morning and late afternoon. During the study, aphid and corn borer infestations were observed.

Chemical control is used to address severe infestations. Lastly, rodent presence was observed toward the end of the study, when plants were about to be harvested. Rodents were not controlled since harvesting manipulation was performed.

### Harvesting

Rango Brochure (2020) stated that harvesting of sweetcorn usually occurs about 70 to 72 days after sowing, when the ears are tightly husked, and the silks have turned brown. Kernels were plumped, tender, and

milky, indicating maximum sweetness and quality. During the conduct of the study, sweetcorn experienced rodent infestation, thus harvesting manipulation was performed at exactly sixty-seven (67) days.

Furthermore, the Ramgo (2020) brochure stated that cowpea seeds, particularly the Ramgo variety, can generally be harvested approximately 60 days after sowing, as the crop matures and develops bright green pods with mature seeds. Harvest maturity for cowpea typically ranges from 55 to 70 days after planting, depending on environmental conditions, the specific variety, and the intended use—whether for fresh green pods or for dry seeds. Moreover, the cowpea pods in this study were harvested exactly 62 days after planting

#### **Data gathering procedure of sweetcorn**

##### *Date of 50% tasseling/Flowering*

The date parameter for 50% tasseling was anchored in the study by Abendroth *et al.* (2011). It was noted that the date at which approximately 50% of the tagged plants in the ten samples had reached the VT stage, defined as when the last branch of the tassel is fully visible, but silks have not yet emerged.

##### *Number of days to 50% silking*

The date of 50% silking was noted when approximately 50% of the tagged plants on the ten sample plants showed visible silks on the primary ear (Nielsen, 2020).

##### *Plant height (cm)*

This was obtained as the corn plant matured and tassels emerged. The plant height of ten sample plants was measured from the soil surface to the highest point of the plant, which is the tip of the tassel. This was done on the day of harvest. This method, as described by Kansas State University (n.d.), is relevant to yield-related studies because it captures the plant's full vertical growth.

##### *Number of leaves per plant*

The collected data on this parameter define a leaf as fully emerged and counted when its leaf collar is

visible. Leaf collar refers to a light-colored band located at the base of the leaf blade, where it meets the stem (Abendroth *et al.*, 2011; Bayer Crop Science, n.d.; Purdue Agronomy, n.d.). This was obtained by counting the total number of fully expanded leaves on tagged ten sample plants on the day of harvest (Borrás and Gambín, 2017).

##### *Ear length and diameter*

These data were collected following the methods of Patel *et al.* (2023), who measured the length and diameter of representative harvested ears using a ruler or vernier caliper.

##### *Ear weight with husk*

These data were based on Cheng and Wang (2024) and were obtained by weighing representative harvested ears from the ten sample plants, with and without the husk, using a digital balance.

##### *Marketable yield and non-marketable yield*

The marketable yield was calculated by summing the total weight of marketable ears harvested from each plot and expressing it per unit area (e.g., kg/ha). Hernandez *et al.* (2019) stated that marketable ears were typically defined by size, appearance, and the absence of significant defects. Similarly, unmarketable ears were weighed, taking into account pest damage, disease, or poor development. This is to get a complete picture of the total biological yield (Silva and Oliveira, 2018).

##### *Sugar content (Brix)*

The TSS in sweetcorn is commonly measured with a digital refractometer, which provides a rapid, reliable estimate of the sugar concentration in fresh kernels. The standard procedure was followed, which involved homogenizing fresh kernels, extracting the juice, and placing a few drops on the refractometer prism to obtain a reading expressed in degrees Brix (%). This method is widely used as a preharvest or postharvest quality assessment because TSS correlates with sweetness and overall eating quality in sweetcorn (Ghada, 2019; Zhang *et al.*, 2023). Samples were taken from the ten selected ears to ensure representativeness,

and measurements can be taken immediately after harvest or during storage for quality monitoring.

### Data gathering procedure of cowpea

#### Number of branches

The data on the number of branches were generally collected by physically counting all visible lateral branches emerging from the main stem of the cowpea plant. Some protocols specify the counting in weeks after sowing to capture developmental stages related to vegetative growth or reproductive phases (Ogbeche, 2023; Mfeka, 2019). Care was taken to ensure consistency by using the same plant portion or growth stage across measurements. These counts allow researchers to compare the effects of treatments such as fertilizer application, water stress, and intercropping on cowpea's vegetative growth habit. The study counted branches on the day before termination in the ten sample plants.

#### Number of pods per plant

This study harvested the number of pods freshly. Pods were counted directly from 10 sampled plants at harvest. This was done manually by selecting representative plants within a plot and counting all the pods on each plant. The timing of pod counting is crucial and often coincides with physiological maturity, when pods have reached full size but before seed dispersal occurs to minimize loss (FAO, 2025).

#### Pod length

The pod length of freshly harvested cowpea pods was typically measured using a standard ruler. Pods were collected from the ten sampled plants, and measurements were taken by straightening curved pods to obtain accurate lengths. The procedure involved selecting a specified number of pods per sample unit (e.g., 10 per plot or per plant) and recording their lengths in centimeters. This method is a standard morphological trait assessment used to evaluate yield components and compare cultivars or treatments (Edematie *et al.*, 2021; University of Arkansas, 2023).

#### Weight of pods (Per plant or per plot)

After counting, the collected pods from the harvested plot area were weighed (for per-plant weight). Fresh

pod weight was recorded immediately after harvest (Ibrahim *et al.*, 2017).

#### Yield ton/ha

This data were collected from freshly harvested cowpea pods. The procedure involved harvesting from a defined plot area, typically the two middle rows, with ten sample plants in an experimental design to avoid border effects. The pods were harvested, weighed fresh, and the total fresh pod weight per plot was recorded. This weight was then converted to yield per hectare by scaling the plot weight according to the harvested area (e.g., kg/plot  $\times$  10,000/plot area in m<sup>2</sup>) (Babaji *et al.*, 2023).

$$\text{Yield } \left( \frac{\text{kg}}{\text{ha}} \right) = \frac{\text{Seed weight from net plot (kg)}}{\text{Net plot area (m}^2\text{)}} \times 10,000 \text{ m}^2/\text{ha}$$

#### Land use efficiency

It is a fundamental metric for evaluating the productivity and sustainability of cropping systems, particularly intercropping systems. It quantifies the extent to which a given area of land is utilized to produce crops, often using indices such as the LER. The LER is a commonly used index for evaluating the biological efficiency of intercropping systems. It quantifies the relative land area required to achieve the same yield as in an intercropping system as in a sole crop. In this study, LER was measured as the yield of each crop grown in an intercropping system relative to its yield when grown as a sole crop (monoculture). This was then calculated using the formula for LER, as widely cited from Willey and Osiru (1972) or Mead and Willey (1980),

$$\text{LER} = \frac{Y_{ia}}{Y_{sa}} + \frac{Y_{ib}}{Y_{sb}}$$

Where:

$Y_{ia}$ = Yield of crop A in intercropping

$Y_{sa}$ = Yield of crop A in sole cropping (monoculture)

$Y_{ib}$ = Yield of crop B in intercropping

$Y_{sb}$ = Yield of crop B in sole cropping (monoculture)

Interpretation of LER: LER > 1: Indicates a yield advantage in intercropping, meaning the

intercropping system is more efficient in land use than sole cropping. For example, an LER of 1.25 means that 25% more land would be required in sole cropping to achieve the exact combined yield as 1 unit of land under intercropping. LER = 1: Indicates that intercropping is equally efficient as sole cropping. LER < 1: Indicates a yield disadvantage, meaning sole cropping is more efficient than intercropping.

#### *Area time equivalent ratio (ATER)*

It is an extension of LER that incorporates time, making it more suitable for evaluating intercropping systems in which component crops have different growth durations or occupy the land for different periods. It accounts for the time each component crop occupies the land. ATER was calculated by averaging the yields of each crop in intercropping and sole cropping, along with their respective durations (days to maturity/harvest). This was then calculated and expressed using the formula for ATER, as widely cited from Willey and Osiru (1972) or Mead and Willey (1980),

$$ATER = \left( \frac{Y_{ia} \times D_a}{Y_{sa} \times T} \right) + \left( \frac{Y_{ib} \times D_b}{Y_{sb} \times T} \right)$$

$Y_{ia}$  = Yield of crop A in intercropping

$Y_{sa}$  = Yield of crop A sole intercropping

$D_a$  = Duration (growth period of crop A in intercropping, or days to maturity)

$Y_{ib}$  = Yield of crop B in intercropping

$Y_{sb}$  = Yield of crop B in sole intercropping

$D_b$  = Duration (growth period of crop B in intercropping, or days to maturity)

T = Total duration of the intercropping system (from planting the first crop to harvesting the last crop)

Interpretation of ATER: ATER > 1: Suggests that the intercropping system utilizes land and time more efficiently than monoculture. It provides a more realistic assessment of resource-use efficiency, particularly when crops have different growth cycles. ATER = 1: Implies equal land and time use efficiency. ATER < 1: Indicates lower land and time use efficiency in the intercropping system.

#### *Cost and return analysis*

Return on investment (ROI) was computed using a simple economic analysis. The total production cost was derived from prevailing local prices of farm inputs and labor, while gross income was obtained from the current market price of sweetcorn and cowpea per kilogram. Net income was determined by subtracting total production costs from gross income, and ROI was then calculated as net income divided by production cost, multiplied by 100 (Lim, 2024).

$$ROI = \frac{\text{Net income}}{\text{Total cost of production}} \times 100$$

#### **Statistical analysis**

The data generated in this study were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for a factorial experiment laid out in a randomized complete block design (RCBD). Differences among treatment means were evaluated using the Least Significant Difference (LSD) test at the 5% probability level.

## **RESULTS AND DISCUSSION**

### **50% days to tasseling/Flowering**

Table 1 presents data on the number of days to 50% flowering of sweetcorn across different cropping systems and fertilizer application methods, showing minor variation with no significant differences between treatments.

Monoculture sweetcorn (A1) reached 50% flowering at exactly 53 days under both side dress (B1) and two-band (B2) fertilizer application methods. Intercropped treatments showed slightly earlier flowering times with synchronous planting (A3) at 50.33 days (B1) and 51.33 days (B2), while planting cowpea at 7, 14, and 21 days after sweetcorn (A4, A5, A6) showed days to 50% flowering between 50.67 and 54 days.

These results indicate that the timing of cowpea planting relative to sweetcorn and the fertilizer application method have minimal influence on sweetcorn flowering time in an intercropping system. This aligns with previous research, which suggests that flowering is primarily determined by variety and environmental

factors, and is less sensitive to variations in intercropping or nutrient placement techniques (Magcale-Macandog *et al.*, 2010; Agegnehu *et al.*, 2016).

The resilience in flowering time supports the feasibility of integrating cowpea intercropping without disrupting critical phenological stages of sweetcorn.

**Table 1.** 50% Days to tasseling/flowering of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A1. Monocropping of sweetcorn	53.00	53.00	53.00
A3. Synchronous planting of cowpea and sweetcorn (0 day)	50.33	51.33	50.83
A4. 7 days after planting (DAP) of sweetcorn	54.00	50.67	52.34
A5. 14 days after planting (DAP) of sweetcorn	52.00	51.33	51.67
A6. 21 days after planting (DAP) of sweetcorn	50.67	52.00	51.34
Factor B Mean <sup>1/</sup>	52.00 <sup>ns</sup>	51.67 <sup>ns</sup>	

CV = 3.97%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 2.** 50% Days to silking of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side Dress	Two Band	
A1. Monocropping of sweetcorn	55.00	54.33	54.67
A3. Synchronous planting of cowpea and sweetcorn (0 day)	52.33	53.00	53.67
A4. 7 days after planting (DAP) of sweetcorn	55.33	52.00	53.67
A5. 14 days after planting (DAP) of sweetcorn	53.33	52.67	53.00
A6. 21 days after planting (DAP) of sweetcorn	52.00	53.00	52.50
Factor B Mean <sup>1/</sup>	53.60 <sup>ns</sup>	53.00 <sup>ns</sup>	

CV = 4.12%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

### 50% days to silking

Table 2 below shows data on days to 50% silking for sweetcorn, revealing minor variations among treatments but generally indicating that neither the cowpea intercropping schedule nor the fertilizer application method significantly alters silking timing. Under monoculture (A1), sweetcorn reached 50% silking at 55.00 days (side-dressed, B1) and 54.33 days (two-band, B2).

For synchronous sowing with cowpea (A3), silking occurred slightly earlier at 52.33 days (B1) and 53.00 days (B2).

The treatments with cowpea planted 7 days after sweetcorn (A4) showed values of 55.33 days (B1) and 52.00 days (B2); at 14 days (A5), silking occurred at

53.33 days (B1) and 52.67 days (B2); and with a 21-day delay (A6), silking happened at 52.00 days (B1) and 53.00 days (B2).

These results suggest that the reproductive development of sweetcorn, as measured by silking, is reliably consistent across both mono- and intercropping systems and is not significantly affected by fertilizer banding or side dressing. This finding is consistent with previous research indicating that silking time in sweetcorn is more influenced by genetic and environmental factors than by moderate interspecific competition or small management shifts (Magcale-Macandog *et al.*, 2010; Lithourgidis *et al.*, 2011). Thus, intercropping with cowpea—even with various planting intervals—can be implemented without adversely affecting the crop's critical reproductive timing.

**Table 3.** Plant height (cm) of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side Dress	Two Band	
A1. Monocropping of sweetcorn	241.60	243.03	242.32 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	236.53	243.67	240.10 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	234.27	235.60	234.94 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	237.00	236.37	236.69 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	246.00	241.73	243.87 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	239.08 <sup>ns</sup>	240.08 <sup>ns</sup>	

CV = 3.75%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 4.** Number of Leaves (pcs) of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A1. Monocropping of sweetcorn	9.40	9.77	9.59 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	8.63	9.27	8.95 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	9.30	8.93	9.12 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	9.27	9.57	9.42 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	9.53	10.27	9.90 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	9.23 <sup>ns</sup>	9.56 <sup>ns</sup>	

CV = 9.80%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

### Plant height of sweetcorn

The plant height of sweetcorn, influenced by the temporal planting of cowpea and the methods of fertilizer application, is presented in Table 3. The table shows plant height means ranging from approximately 234.32 cm to 243.87 cm across all treatments, indicating no significant differences between intercropping timing and fertilizer application method. Monoculture sweetcorn (A1) and sweetcorn planted with cowpea at various intervals-synchronously (A3), 7 days after (A4), 14 days after (A5), and 21 days after (A6)-all produced comparable plant heights. In addition, the fertilizer application method, whether side-dress (B1) or two-band (B2), yielded similar results across each planting arrangement.

These findings suggest that the vegetative growth of sweetcorn, as measured by plant height, is robust to moderate variations in intercropping management and nutrient placement. This result supports previous

studies demonstrating that sweetcorn is generally not sensitive to the introduction of companion legumes or to fertilizer application method with respect to plant height, provided that overall crop management is sound (Lithourgidis *et al.*, 2011; Evangelio, 1981). Thus, intercropping with cowpea and adopting fertilizer strategies can be implemented without substantially affecting sweetcorn's physical growth.

### Number of leaves of sweetcorn

Table 4 below shows the number of sweetcorn leaves produced under different planting timings and fertilizer application methods. Results showed no significant differences across all treatments, as reflected by the mean values presented. Monoculture sweetcorn (A1) had mean leaf numbers of 9.40 (side dress, B1) and 9.77 (two-band, B2). Under synchronous planting with cowpea (A3), leaf numbers were 8.63 (B1) and 9.27 (B2), while cowpea planted at 7, 14, and 21 days after sweetcorn (A4, A5, A6) yielded leaf counts between 9.27 and 9.53 (B1) and from 8.93 to 10.27 (B2).

**Table 5.** Ear diameter (cm) of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A1. Monocropping of sweetcorn	4.58	4.62	4.60 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	3.90	4.65	4.23 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	4.55	4.69	4.62 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	4.06	4.55	4.31 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	4.68	4.53	4.61 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	4.35 <sup>ns</sup>	4.61 <sup>ns</sup>	

CV = 10.23%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 6.** Ear length (cm) of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A1. Monocropping of sweetcorn	21.77	22.17	21.97 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	21.07	21.70	21.39 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	21.77	22.40	22.09 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	21.57	21.90	21.74 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	21.70	22.43	22.07 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	21.58 <sup>ns</sup>	22.12 <sup>ns</sup>	

CV = 3.80

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 7.** Weight with husk (kg) per plot of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A1. Monocropping of sweetcorn	4.02	4.22	4.12 <sup>a</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	3.55	3.73	3.64 <sup>b</sup>
A4. 7 days after planting (DAP) of sweetcorn	3.44	3.60	3.52 <sup>b</sup>
A5. 14 days after planting (DAP) of sweetcorn	3.68	3.65	3.66 <sup>b</sup>
A6. 21 days after planting (DAP) of sweetcorn	4.31	4.15	4.23 <sup>b</sup>
Factor B Mean <sup>1/</sup>	3.80 <sup>ns</sup>	3.87 <sup>ns</sup>	

CV = 7.18%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

These patterns indicate that neither the timing of cowpea planting nor the fertilizer method significantly affected the number of sweetcorn leaves. This finding aligns with published research showing that leaf production in sweetcorn is relatively stable under intercropping with legumes and typical fertilizer management practices (Evangelio, 1981; Lithourgidis *et al.*, 2011). Such stability suggests that sweetcorn's vegetative traits are robust, supporting

the flexible integration of intercropping and fertilization strategies across diverse production systems.

#### Ear diameter of sweetcorn

Table 5 presents the ear diameter data for sweetcorn influenced by planting timing and fertilizer application method; the results revealed no statistically significant differences. In monoculture

(A1), the mean ear diameter was 4.58 cm for side-dress fertilizer application (B1) and 4.62 cm for the two-band method (B2). Synchronous planting with cowpea (A3) recorded a slightly lower diameter at 3.90 cm (B1) but a slightly higher diameter at 4.65 cm (B2). When cowpea was planted 7, 14, and 21 days after sweetcorn (A4, A5, A6), ear diameter ranged from 4.06 cm to 4.68 cm under side dress application, and from 4.53 cm to 4.69 cm under the two-band application.

The results suggest that the timing of cowpea intercropping and the method of fertilizer application do not significantly affect sweetcorn ear diameter. These findings are consistent with previous studies, which indicate that sweetcorn ear size is relatively stable under varied cropping systems and nutrient management practices, provided that overall plant health is maintained (Lithourgidis *et al.*, 2011; Evangelio, 1981). The stability of ear diameter across treatments supports the use of intercropping and flexible nutrient application methods without compromising key yield attributes.

### Ear length

Table 6 shows the effect of planting timing and fertilizer application method on sweetcorn ear length. Results indicated that mean values across treatments did not differ significantly, regardless of the timing of cowpea planting or the fertilizer application method. In monoculture (A1), the means of ear lengths were 21.77 cm (B1) and 22.17 cm (B2). For the synchronous planting of sweetcorn and cowpea (A3), values are slightly lower at 21.07 cm (B1) and 21.70 cm (B2). Treatments where cowpea was planted 7, 14, and 21 days after sweetcorn (A4, A5, A6) showed ear lengths between 21.57 and 21.77 cm for B1, and from 21.90 to 22.40 cm for B2.

The consistent ear length measurements across treatments indicate that neither the choice of side-dress versus two-band fertilizer application nor the timing of intercrop cowpea planting significantly affects ear length in sweetcorn. These results

support existing research, which finds that ear length is a stable yield trait in sweetcorn, typically unaffected by changes in intercropping schedules or standard nutrient management approaches (Lithourgidis *et al.*, 2011; Evangelio, 1981). The results suggest that integrated intercropping and fertilizer strategies can be adopted without compromising ear quality.

### Weight with husk

Table 7 presents the mean sweetcorn weights with husk for various planting patterns and fertilizer application methods, indicating significant differences between treatments. Results show that monoculture sweetcorn (A1) showed higher weights at both 4.02 kg (side dress, B1) and 4.22 kg (two band, B2), and when cowpea was planted 21 days after sweetcorn (A6), the weights were comparably high at 4.31 kg (B1) and 4.15 kg (B2).

In contrast, the intercropping treatments-whether cowpea was planted synchronously (A3: 3.55 kg B1, 3.73 kg B2), 7 days after (A4: 3.44 kg B1, 3.60 kg B2), or 14 days after sweetcorn (A5: 3.68 kg B1, 3.65 kg B2)- showed reduced sweetcorn weights.

The Least Significant Difference (LSD) test and summary indicate that monoculture (A1) and cowpea-planted 21 days after (A6) are grouped, with significantly higher yields than the other treatments. At the same time, the synchronous and earlier cowpea intercropping (A3, A4, A5) form a distinct group with lower yields.

The results indicate that competition for resources is minimized when sweetcorn has more time to establish before the cowpea intercrop is introduced, consistent with findings that strategic timing in intercropping systems maintains or increases primary crop yields (Agegnehu *et al.*, 2016; Lithourgidis *et al.*, 2011). Furthermore, the method of fertilizer application-whether side-dressing or two-band-does not significantly alter this pattern, highlighting the primary influence of intercrop timing on nutrient delivery strategy in this context.

**Table 8.** Marketable ear weight (kg) of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A1. Monocropping of sweetcorn	3.83	3.80	3.82 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	3.05	3.39	3.22 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	3.44	3.66	3.55 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	3.38	3.65	3.52 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	3.61	3.91	3.76 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	3.46 <sup>ns</sup>	3.68 <sup>ns</sup>	

CV = 11.68%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 9.** Yield ton/ha of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Factor A: Temporal planting	Factor B: Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A1. Monocropping of sweetcorn	16.02	16.50	16.26 <sup>a</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	14.08	14.79	14.43 <sup>b</sup>
A4. 7 days after planting (DAP) of sweetcorn	13.63	14.28	13.95 <sup>b</sup>
A5. 14 days after planting (DAP) of sweetcorn	14.46	14.21	14.34 <sup>b</sup>
A6. 21 days after planting (DAP) of sweetcorn	16.63	15.82	16.22 <sup>a</sup>
Factor B Mean <sup>1/</sup>	14.96 <sup>ns</sup>	15.12 <sup>ns</sup>	

CV = 7.18%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

### Marketable ear weight

Table 8 shows the marketable ear weight of sweetcorn influenced by planting timing and fertilizer application method. Results for marketable ear weight of sweetcorn, shown in the table, indicate remarkably close mean values across all treatments, whether in monoculture (A1) or in various intercropping setups with cowpea planted at different timings (A3, A4, A5, A6), and regardless of fertilizer application method (B1 or B2). The mean marketable ear weight ranged from 3.05 to 3.83 for B1 and from 3.39 to 3.91 for B2. No statistically significant differences were observed among these means, indicating that the introduction of cowpea into the sweetcorn cropping system-whether synchronously or at different days after planting- and the use of either side-dress or two-band fertilizer, did not adversely affect sweetcorn ear weight.

This finding is consistent with research indicating that intercropping systems, particularly those

involving legumes such as cowpea, often do not significantly reduce sweetcorn yield or marketable ear weight (Naderi *et al.*, 2022; Seidel, 2022). Multiple studies have found that, although monocropped sweetcorn may sometimes yield marginally higher ear weight, differences with intercropped systems are statistically insignificant under optimized management and planting densities (Naderi *et al.*, 2022; Ghimire *et al.*, 2020). The results also align with those of Seidel (2022) and Ghimire *et al.* (2020), who demonstrated that minor reductions in yield under intercropping are often offset by the added benefits of intercropping, such as land-use efficiency, improved resource utilization, and greater system resilience.

Therefore, these findings reinforce the viability of sweetcorn-cowpea intercropping- regardless of the temporal planting scheme or fertilizer method-in maintaining marketable yields while enabling farmers to benefit from the additional system and sustainability

advantages of intercropping (Li *et al.*, 2023). Moreover, a non-marketable sweetcorn was recorded, as the rodents attacked it.

### Yield ton/ha of sweetcorn

The yield data for sweetcorn presented in the Table 9 indicate substantial effects of temporal intercropping with cowpea on sweetcorn productivity. The highest mean yield was achieved with the monoculture system, at 16.26 t/ha.

This mean yield is significantly higher than that achieved under most intercropping treatments. It is worth noting that planting cowpea and sweetcorn simultaneously and fourteen days after sweetcorn similarly resulted in low yields of 14.43 t/ha and 14.34 t/ha, respectively – both of which were statistically similar to 13.95 t/ha for the seven days after planting treatment. Notably, the twenty-one days after planting yielded a statistically dependable mean yield of 16.22 t/ha. This observation indicates that the timing for the introduction of the cowpea in relation to the sweetcorn is dependent on the extent of interspecific competition.

Results are consistent with the existing literature, which suggests that the timing of new legume introduction in intercropping systems severely impacts maize or sweetcorn productivity (Sumarni *et al.*, 2024). In addition, early or synchronous intercropping leads to competitive effects and reduced resources available for sweetcorn due to legume shading, reducing yield (Francis and Decoteau, 1993; Rodillas, 2003).

In contrast, Sumarni *et al.* (2024) suggest that resource competition is minimal in delayed cowpea planting systems, such as at 21 DAP, thereby allowing sweetcorn to establish and efficiently utilize soil nutrients, water, and light before the cowpea enters the rapid growth phase. This finding aligns with that of Kussie *et al.* (2024), who also reported greater grain yield in sole crops and in planting after the cash crop had already initiated.

Moreover, the mean yield difference between side dressing (14.96t/ha) and the two bands (15.12 t/ha) was not statistically significant. This indicates that both fertilizer management strategies may yield sweetcorn that is statistically indistinguishable in these systems. These results highlight that intercropping sweetcorn with cowpea can be successfully used by timing the legume's introduction during later growth stages, thereby maintaining sweetcorn yield while reaping the agronomic benefits of intercropping and diversified products (Sumarni *et al.*, 2024; Francis and Decoteau, 1993; Rodillas, 2003).

### Total soluble solid

Table 10 below shows the Total Soluble Solids (TSS) or °Brix content of sweetcorn, a key indicator of sweetness and eating quality, which differed significantly depending on fertilizer application method. The mean TSS value for sweetcorn using the side dress method (B1) was 21.11, while the two-band method (B2) recorded a lower mean of 20.63. Results revealed a statistically significant difference among all treatment means. This result suggests that side-dressing fertilizer may be more effective than the two-band method at supporting higher sugar accumulation in sweetcorn kernels.

These findings align with research indicating that nutrient availability and placement can directly influence metabolic activities, such as carbohydrate synthesis in sweetcorn, thereby affecting the TSS content (Ghada, 2019; Zhang *et al.*, 2023). Adequate, strategically placed fertilizers ensure optimal uptake during key stages of kernel development, resulting in higher sweetness when side-dressing is used.

Moreover, significant differences in temporal planting treatments were also observed. Notably, both the synchronous planting of cowpea and sweetcorn (A3: 21.38) and the intercropping of cowpea at 21 days after sweetcorn planting (A6: 21.07) yielded the highest TSS values, indicating superior sugar accumulation and thus enhanced sweetness under these arrangements.

**Table 10.** Total soluble solid of sweetcorn intercropped with cowpea and influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Factor A: Temporal planting	Factor B: Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A1. Monocropping of sweetcorn	20.60	20.40	20.50 <sup>b</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	21.40	21.37	21.38 <sup>a</sup>
A4. 7 days after planting (DAP) of sweetcorn	20.53	20.33	20.43 <sup>b</sup>
A5. 14 days after planting (DAP) of sweetcorn	21.47	20.47	20.97 <sup>ab</sup>
A6. 21 days after planting (DAP) of sweetcorn	21.53	20.60	21.07 <sup>a</sup>
Factor B Mean <sup>1/</sup>	21.11 <sup>a</sup>	20.63 <sup>b</sup>	

CV = 2.23%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 11.** Number of branches (pcs) of cowpea as an intercropped crop on sweetcorn as influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A2. Monocropping of cowpea	7.17	7.27	7.22 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	6.47	6.83	6.65 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	7.03	6.37	6.70 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	7.13	6.60	6.87 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	7.23	7.07	7.15 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	7.00 <sup>ns</sup>	6.83 <sup>ns</sup>	

CV = 5.84%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 12.** Number of pods (pcs) of cowpea as an intercropped crop on sweetcorn as influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A2. Monocropping of cowpea	14.17 <sup>a</sup>	12.03 <sup>c</sup>	13.10 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	12.76 <sup>bc</sup>	13.57 <sup>ab</sup>	13.17 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	14.26 <sup>a</sup>	12.47 <sup>bc</sup>	13.37 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	12.53 <sup>c</sup>	12.47 <sup>bc</sup>	12.50 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	14.01 <sup>ab</sup>	14.07 <sup>a</sup>	14.04 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	13.55 <sup>ns</sup>	12.92 <sup>ns</sup>	

CV = 5.55%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

In contrast, monocropped sweetcorn (A1: 20.50) and cowpea planted at 7 days after sweetcorn (A4: 20.43) recorded the lowest TSS values, reflecting comparatively diminished sweetness. Intercropping with cowpea at 14 days after sweetcorn (A5: 20.97) produced intermediate TSS values, statistically similar to both the higher and lower groups. These findings suggest that careful timing of cowpea introduction can significantly influence sweetcorn

quality, as measured by TSS. Intercropping with cowpea at planting or 21 days later benefits sweetcorn sugar content, likely due to improved complementary resource use, reduced early-stage competition, and possible positive effects of legume-associated nitrogen fixation on sweetcorn during key phases of grain filling and sugar accumulation (Sumarni *et al.*, 2024). Previous studies on temporal intercropping have confirmed that both the timing of legume

introduction and the choice of companion crop affect the physiological processes underlying sweetness and quality in sweetcorn (Ghada *et al.*, 2019).

Thus, the data indicate that optimizing intercrop planting schedules can improve sweetcorn quality, supporting the use of temporal intercropping strategies to enhance produce quality in diversified cropping systems.

### Cowpea parameters

#### *Number of branches*

Table 11 presents the data on the number of branches in cowpea across different intercropping and fertilizer application treatments, indicating no significant differences among the means.

The mean values range narrowly from about 6.47 to 7.23 branches per plant, whether cowpea was planted synchronously with sweetcorn (6.47–6.83) or at different days after planting (7.03–7.23), regardless of whether fertilizer was applied via side-dress (B1) or the two-band method (B2). This consistency suggests that cowpea branching is relatively stable and not strongly influenced by the timing of sweetcorn intercropping or fertilizer placement methods under the tested conditions.

Such stability in branching aligns with previous studies indicating that cowpea adapts well to intercrop environments and that its vegetative branching is more influenced by genetics and environmental growing conditions than by minor cultivation variations (Singh *et al.*, 2020; Timko and Singh, 2017). This resilience supports the efficacy of flexible intercropping schedules without compromising vegetative growth attributes, such as branching.

#### *Number of pods*

Table 12 presents data on the number of cowpea pods under different intercropping schedules and fertilizer application methods, revealing statistically significant differences. For the side-dress method (B1), A4 (cowpea planted 7 days after sweetcorn) produced the

highest mean number of pods (14.26, group), closely followed by A2 (14.17) and A6 (14.01). Meanwhile, A3 (synchronous planting) and A5 (cowpea planted 14 days after sweetcorn) had lower means (12.76 and 12.53, respectively). For the two-band fertilizer method (B2), A6 (cowpea planted 21 days after sweetcorn) led with the highest mean number of pods (14.07), A3 followed (13.57), while A4 and A5 (12.47 each) and A2 (12.03) were lower.

This pattern suggests a significant interaction between the timing of cowpea planting and the method of fertilizer application. Specifically, the best pod production was achieved either when cowpea was planted slightly later (7–21 days after sweetcorn) or synchronously, but only when paired with a suitable fertilizer application method. The two-band method with late planting (A6, B2) and the side-dress method with 7 7-day delay (A4, B1) both resulted in high pod numbers. In contrast, A5 under both methods and A2 with a two-band application resulted in fewer pods.

This significant interaction suggests that optimal cowpea yield, in terms of pod production, is not determined solely by a single factor but by the optimal combination of planting schedule and fertilizer strategy. Such findings underscore the importance of tailoring intercropping management to local environmental and cropping conditions for enhanced legume productivity—an observation supported by previous studies on legume-cereal intercropping systems (Singh *et al.*, 2020; Timko and Singh, 2017).

#### *Length of pod of cowpea*

The data in the Table 13 reflect the mean pod length (in centimeters) of cowpea for various planting schedules and fertilizer application methods. The mean values across all treatments—ranging from 18.61 to 19.50 cm—indicate minimal variation, with no significant differences among treatments. This suggests that pod length is consistent regardless of whether cowpea is planted as a monocrop (A2), synchronously with sweetcorn (A3), or at 7, 14, or 21

days after sweetcorn (A4, A5, A6), and regardless of the fertilizer method (B1: side dress, B2: two band).

The absence of significant differences implies that neither the timing of cowpea planting in the intercropping system nor the variation in fertilizer application method has a substantial effect on the

final pod length in cowpea. This stability in pod length aligns with previous research, which shows that certain growth traits in cowpea, such as pod length, are more influenced by genetics and environmental consistency than by moderate changes in cropping arrangements or fertilizer strategies (Singh *et al.*, 2020; Timko and Singh, 2017).

**Table 13.** Length of pods (cm) of Cowpea as an Intercropped crop on Sweetcorn as Influenced by Temporal Planting and Methods of Fertilizer, Sultan Kudarat State University, May 2025

Temporal Planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A2. Monocropping of Cowpea	19.44	19.50	19.47 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	18.61	18.88	18.75 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	18.90	19.11	19.01 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	19.15	19.22	19.19 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	19.28	19.33	19.31 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	19.08 <sup>ns</sup>	19.21 <sup>ns</sup>	

CV = 3.09%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 14.** Weight of pods (g) of cowpea as an intercropped crop on sweetcorn as influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side dress	Two band	
A2. Monocropping of cowpea	417.00 <sup>a</sup>	334.67 <sup>b</sup>	375.84 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	355.33 <sup>b</sup>	374.33 <sup>b</sup>	364.83 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	403.00 <sup>a</sup>	361.67 <sup>b</sup>	382.34 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	382.00 <sup>ab</sup>	362.67 <sup>b</sup>	372.34 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	411.33 <sup>a</sup>	420.67 <sup>a</sup>	416.00 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	393.73 <sup>ns</sup>	370.67 <sup>ns</sup>	

CV = 6.87%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

#### Weight of pods

The weight of cowpea pods, as presented in the summary Table 14, shows significant differences among some treatment combinations. For the side dress fertilizer application (B1), Factor A2 (mono culture of cowpea), A4 (cowpea planted 7 days after sweetcorn), and A6 (cowpea planted 21 days after sweetcorn) all have the highest mean pod weights (417.00, 403.00, and 411.33, respectively) and share the same letter group "a," indicating no significant differences among them.

Meanwhile, A3 (synchronous planting) has the lowest mean pod weight (355.33) and is grouped separately as "b," indicating a significant difference from the highest means. A5 (cowpea planted 14 days after sweetcorn) has an intermediate value (382.00) and belongs to group "ab," indicating it is not significantly different from either the highest or the lowest groups. For the two-band fertilizer method (B2), only A6 (420.67) stands out in group "a," while all other treatments (A2, A3, A4, A5) are in "b," indicating significantly lower pod weights.

**Table 15.** Yield ton/ha of cowpea as an intercropped crop on sweetcorn as influenced by temporal planting and methods of fertilizer, Sultan Kudarat State University, May 2025

Temporal planting	Methods of fertilizer application		Mean <sup>1/</sup>
	Side Dress	Two Band	
A2. Monocropping of cowpea	0.2203 <sup>a</sup>	0.1777 <sup>b</sup>	0.1990 <sup>ns</sup>
A3. Synchronous planting of cowpea and sweetcorn (0 day)	0.1887 <sup>b</sup>	0.1990 <sup>b</sup>	0.1939 <sup>ns</sup>
A4. 7 days after planting (DAP) of sweetcorn	0.2133 <sup>a</sup>	0.1920 <sup>b</sup>	0.2027 <sup>ns</sup>
A5. 14 days after planting (DAP) of sweetcorn	0.2027 <sup>ab</sup>	0.1920 <sup>b</sup>	0.2974 <sup>ns</sup>
A6. 21 days after planting (DAP) of sweetcorn	0.2187 <sup>a</sup>	0.2240 <sup>a</sup>	0.2214 <sup>ns</sup>
Factor B Mean <sup>1/</sup>	0.2087 <sup>ns</sup>	0.1969 <sup>ns</sup>	

CV = 6.92%

<sup>1/</sup> - Means that share the same letter superscripts do not differ significantly at the 5% significance level according to the least significant difference (LSD) test. ns = not significant

**Table 16.** LER and ATER computation on the effect of sweetcorn-cowpea intercropping influenced by temporal planting and methods of fertilization application, Sultan Kudarat State University, May 2025

Replication	Factor A (Temporal planting)	Factor B (Methods of fertilizer application)	Weight of cowpea (g)	Weight of corn (kg)	LER	ATER
1	T1 (Mono Cropping - Sweetcorn)	Side dress		4.068		
	T2 (Mono Cropping - Corn)	Double-band		4.592		
	T3 (Mono Cropping - Cowpea)	Side dress	403			
	T4 (Mono Cropping - Cowpea)	Double-band	341			
	T5 (Synchronous Planting)	Side dress	321	3.388	1.63	1.57
	T6 (Synchronous Planting)	Double-band	301	3.724	1.69	1.63
	T7 - 7 DAP	Side dress	385	3.398	1.79	1.71
	T8 - 7 DAP	Double-band	363	3.546	1.83	1.75
	T9 - 14 DAP	Side dress	404	3.667	1.90	1.83
	A10 - 14 DAP	Double-band	381	3.544	1.89	1.80
	A11 - 21 DAP	Side dress	391	4.14	1.99	1.92
	A12 - 21 DAP	Double-band	400	4.216	2.09	2.01
2	T1 (Mono Cropping - Sweetcorn)	Side dress		3.803		
	T2 (Mono Cropping - Sweetcorn)	Double-band		4.207		
	T3 (Mono Cropping - Cowpea)	Side dress	441			
	T4 (Mono Cropping - Cowpea)	Double-band	342			
	T5 (Synchronous Planting)	Side dress	382	3.196	1.70	1.64
	T6 (Synchronous Planting)	Double-band	401	3.624	2.07	1.95
	T7 - 7 DAP	Side dress	423	3.720	1.93	1.86
	T8 - 7 DAP	Double-band	361	3.796	1.96	1.88
	T9 - 14 DAP	Side dress	360	3.401	1.71	1.65
	A10 - 14 DAP	Double-band	345	3.498	1.83	1.76
	A11 - 21 DAP	Side dress	420	4.292	2.08	2.01
	A12 - 21 DAP	Double-band	442	4.335	2.32	2.23
3	T1 (Mono Cropping - Sweetcorn)	Side dress		4.177		
	T2 (Mono Cropping - Sweetcorn)	Double-band		3.858		
	T3 (Mono Cropping - Cowpea)	Side dress	407			
	T4 (Mono Cropping - Cowpea)	Double-band	321			
	T5 (Synchronous Planting)	Side dress	363	4.060	1.87	1.80
	T6 (Synchronous Planting)	Double-band	421	3.830	2.31	2.21
	T7 - 7 DAP	Side dress	402	3.188	1.76	1.69
	T8 - 7 DAP	Double-band	361	3.452	2.02	1.94
	T9 - 14 DAP	Side dress	382	3.966	1.90	1.83
	A10 - 14 DAP	Double-band	362	3.904	2.14	2.05
	A11 - 21 DAP	Side dress	423	4.492	2.32	2.05
	A12 - 21 DAP	Double-band	420	3.896	2.32	2.22

The interaction between planting schedule and fertilizer method is evident: the benefit of two-band fertilizer is most pronounced when cowpea is planted 21 days after sweetcorn (A6), producing the highest pod weight (420.67), while the other planting dates with this method yield consistently lower values. These results suggest a significant interaction, in which yield advantage may be maximized by a specific combination of delayed cowpea planting and two-band fertilizer application, likely due to reduced competition and optimized nutrient use (Singh *et al.*, 2020; Timko and Singh, 2017).

#### *Yield ton/ha of cowpea*

The yield data (ton/ha) for cowpea under different combinations of planting timing and fertilizer application methods show significant differences among treatment means, particularly reflecting the interaction between Factors A and B. For the side dress method (B1), the highest yields are observed when cowpea is planted as a monocrop (A2, 0.2203) or 7 or 21 days after sweetcorn (A4, 0.2133; A6, 0.2187), with these means grouped as "a," indicating they are not significantly different from each other. Synchronous intercropping (A3, 0.1887) has the lowest yield in the B1 group and is classified as group "b," showing a significant difference from the highest-yielding treatments. Planting cowpea 14 days after sweetcorn (A5, 0.2027) is classified in group "ab," indicating that it overlaps with both high- and low-yielding treatments (Table 15).

For the two-band fertilizer method (B2), the only treatment with a significantly higher yield is A6 (cowpea planted 21 days after sweetcorn, 0.2240, group "a"). All other treatments—monoculture (A2), synchronous (A3), and planted 7 or 14 days after sweetcorn (A4, A5)—cluster together as group "b," with lower yields ranging from 0.1777 to 0.1990.

This interaction shows that the benefit of the two-band fertilizer method is most pronounced when cowpea is planted 21 days after sweetcorn, producing the highest yield in the study.

Meanwhile, under side dress application, several timings (including monoculture, 7 DAP, and 21 DAP) yield similarly high results. Synchronous planting of cowpea and sweetcorn consistently yields less cowpea regardless of fertilizer method, likely due to early competition for resources.

This demonstrates that both intercropping timing and fertilizer strategy should be considered for maximizing cowpea yield. These findings are consistent with the literature that emphasizes the importance of strategic crop scheduling and nutrient management to minimize competition and optimize yields in legume-cereal systems (Singh *et al.*, 2020; Timko and Singh, 2017).

#### *LER and ATER*

Table 16 presents LER and ATER values as indicators of the productivity and temporal efficiency of sweetcorn-cowpea intercropping systems under different temporal planting schedules (Factor A) and fertilizer application methods (Factor B).

LER values greater than 1 across all treatments (ranging from 1.63 to 2.32) indicate that intercropping sweetcorn with cowpea yields a higher combined yield per unit area than monocropping both crops separately. This demonstrates a clear yield advantage and effective land-use efficiency of intercropping systems under varied temporal planting and fertilization methods.

Similarly, ATER values, which adjust LER by incorporating the cropping duration, also exceed 1 (ranging from 1.57 to 2.23), reinforcing that intercropping systems are more efficient in using both land and time than single cropping. Notably, the highest LER (2.32) and ATER (2.23) were observed when cowpea was planted 21 days after sweetcorn and double-band with fertilizer, indicating the optimal temporal and fertilization combination for enhanced productivity and time efficiency.

Comparing fertilizer methods, double-band application yields slightly higher LER and ATER

values than side-dress application in most cases, suggesting it better supports crop growth and resource utilization in this intercropping context.

In conclusion, the results confirm that temporal adjustment of cowpea planting and strategic fertilizer application significantly enhance land and time productivity in sweetcorn-cowpea intercropping systems. These findings are consistent with previous studies highlighting the benefits of optimized intercropping designs for sustainable intensification in mixed cropping systems (Agegnehu *et al.*, 2016; Lithourgidis *et al.*, 2011).

Results also align with the study by Smarni and Anggoro (2024), which found that planting cowpea 21 days after sweetcorn (21 DAP) yielded higher than other timings. This planting date also demonstrated the highest land-use efficiency, as evidenced by the LER and ATER.

#### *Return on investment computed using cost and return analysis*

The Fig. 2 below shows the Cost and Return Analysis of Sweetcorn-Cowpea intercropping influenced by temporal planting and methods of fertilizer application, computed using the Return on Investment formula. Results showed that all treatments except T3 and T4 generated highly profitable returns, ranging from approximately 117% to 252%. This means that, for most planting schedules and fertilizer placement combinations, every peso invested in production yielded more than two pesos in gross return, indicating that the cropping and fertilization strategies were economically sound under the study conditions (Alam *et al.*, 2018).

In contrast, T3 and T4 produced negative ROIs (-41.66% and -53.19%), indicating that the cost of inputs under the synchronous planting schedule with the specified fertilizer method exceeded gross returns. Negative ROI usually arises when yield response is weak relative to fertilizer and labor costs, or when timing and method of application do not match crop demand, leading to inefficient nutrient use. Studies

on the timing of N application in maize and legumes have shown that poorly synchronized applications can depress profitability even when total nutrient rates are similar, due to lower yields and higher unit costs (Rochette *et al.*, 2019).



**Fig. 2.** Return on investment computed using cost and return analysis: Sweetcorn-cowpea intercropping as influenced by temporal planting and methods of fertilization application, Sultan Kudarat State University, May 2025

The highest ROI was observed in Treatment 12 (252.25%), followed closely by T11, T8, T10, and T1, which correspond to later fertilizer application (21 DAP) and two-band placement, suggesting that synchronizing nutrient availability with peak crop demand and placing fertilizer near the root zone maximizes both yield and profit. In contrast, T3 and T4 recorded negative ROIs (approximately -41.66% and -53.18%), implying that synchronous planting with early fertilizer application under those placement methods did not produce enough yield to cover production costs, likely due to poor nutrient use efficiency or sub-optimal crop competition dynamics (Alam *et al.*, 2018).

Moreover, these results show that farmers can substantially increase their economic returns by choosing planting schedules and fertilizer-placement methods that synchronize nutrient supply with crop demand, as most treatments generated more than triple the value of every peso invested. Conversely, the losses in T3 and T4 highlight that if timing and method are poorly matched to the crop, even the same inputs can become uneconomical, underscoring the importance of informed management decisions for smallholder profitability.

## CONCLUSION

### Sweetcorn performance

The results of sweetcorn performance indicated that it is highly adaptable and resilient to variations in the timing of leguminous intercropping and fertilizer application. Parameters such as plant height, number of leaves, ear diameter, ear length, and critical reproductive traits, including days to tasseling and silking, were relatively similar across intercropped and monocropped plots and between the Side-dress and Two-band methods.

Primarily, growth and vegetative performance were unchanged and not significantly affected by the moderate modifications to the timing of legume introduction and fertilizer placement. The observations are consistent with findings indicating that sweetcorn is generally flexible and responds well to even moderate integrated cropping system management manipulations.

For yield and yield attributes, the mono-crop and intercropping treatments in which cowpea was sown 21 days after the main crop showed that A6 produced the highest yield and marketable ear weight. The two yielded statistically similar results. Conversely, synchronous cropping and early cowpea intercropping with the main crop, mainly in the 0-14 days after the main crop, led to significantly lower yields and ear weights.

The trivial difference between the abovementioned methods supported the nutrient management methodology, as it demonstrated operational effectiveness and flexibility. Analysis of TSS, a critical sweetcorn eating-quality attribute, suggests an opportunity: the synchronous and 21-day-after-main-crop systems yielded significantly more TSS and, therefore, better sweet quality than the others. All others yielded lower results, indicating the possible existence of an opportunity for enhancing sweetcorn's quality in terms of the intercrop interval. These performance outcomes comprehensively support the integration of temporal cowpea intercropping-with optimal timing and flexible fertilizer management-as

a promising approach for sustainable, productive, and high-quality sweetcorn production systems.

### Cowpea performance

Cowpea performance in terms of vegetative growth and yield potential under intercropping schedules and fertilizer application methods is both resilient and responsive to varying management strategies. The number of branches and pod lengths did not differ across treatments, indicating that cowpea remains consistent in vegetative characters and pod development even under varying planting timings and fertilizer application methods. However, pod numbers, pod weight, and yield per hectare show significant variation due to the interaction of planting timing and fertilizer method.

Synchronously intercropped and sown at 14 days after sweetcorn generally yielded lower pod numbers and weights due to differences in timing and resources, indicating the competitive avoidance processes at the critical growth period. The two-band method generally yielded well when cowpea was sown 7 or 21 days after sweetcorn establishment, but also yielded well with the two-band method, as well as deferred plantings. However, side-dress application consistently outyielded monoculture or later plantings.

In summary, cowpea integration into sweetcorn cereal cropping systems affects pod set, pod weight, and overall yield, suggesting that well-planned integration and management practices influence legume performance in low-competitive cropping systems.

### Land use efficiency

Cowpea performance in a sweetcorn-cowpea intercropping system, as measured by the Land Equivalent Ratio and the Area Time Equivalent Ratio, indicated that the intercropping system exhibited significant superiority in land-use efficiency and temporal productivity relative to a monoculture system. That is, in all other intercropping systems, the LER and ATER exceeded 1, implying that

incorporating cowpea and sweetcorn in either system increases combined yield per unit area and improves time utilization relative to growing the crops independently.

The results further demonstrate that the optimized time, which is planting cowpea after sweetcorn with a 21-day interval and the two-band fertilizer application, resulted in the most productive and efficient system. Most LER and ATER values from the two-band application systems were higher than those from the side-dress method, suggesting that it may bifurcately increase resource use and plant performance.

Therefore, the current results reaffirm that the proper timing of cowpea planting and the choice of fertilizer application method are essential for maximizing yield and increasing efficiency.

Consequently, these results strongly indicate that a well-managed sweetcorn–cowpea intercropping system not only improves production and income but also supports sustainable land use and a longer growing season in advanced agricultural practice.

### RECOMMENDATIONS

These recommendations support sustainable intensification efforts and provide actionable guidelines for enhancing the productivity and profitability of sweetcorn-cowpea intercropping systems under varying temporal planting and fertilization regimes; 1.) Temporal arrangements, such as planting cowpea 21 days after sweetcorn, are recommended. This timing not only maximizes sweetcorn yield and quality but also enhances cowpea productivity, as evidenced by substantial increases in marketable yield, Total Soluble Solids, and pod weight; 2.) The two-band fertilizer application method is more effective than the side-dress method in terms of yield and resource use efficiency. This technique offers a feasible approach to nutrient management in mixed cropping systems; 3.) Sweetcorn-cowpea intercropping, with appropriate timing and fertilizer regimes, will

maximize Land-Use Efficiency, as evidenced by higher LER and ATER, indicating greater land- and time-use efficiency. It is suggested to include sustainable cropping practices to increase production per unit area and maximize the cropping period; 4.) Extension workers and agricultural advisors need to disseminate information on the benefits and management practices of temporal sweetcorn-cowpea intercropping, along with appropriate fertilization. The importance of the timing and placement of nutrients must be emphasized to encourage sustainable intensification and expand the farmers' income base; 5.) A follow-up experiment could extend the temporal planting treatments by introducing a 28-day cowpea sowing interval after sweetcorn establishment, in addition to the existing 21-day schedule. This would enable a more rigorous assessment of whether planting cowpea 21 days after sweetcorn is already optimal for land-use efficiency and intercrop performance, or whether further staggering to 28 days can enhance resource complementarity and overall system productivity.

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### REFERENCES

- Abendroth LJ, Elmore RW, Boyer MJ, Marlay SK.** 2011. Corn growth and development. Iowa State University Extension and Outreach.
- Agegnehu G, Ghizaw A, Sinebo W.** 2016. Yield performance and land-use efficiency of barley and legume mixed cropping in Ethiopian highlands. *European Journal of Agronomy* **39**, 39–49.

- Aksoy U.** 2001. Use of organic fertilizers in agriculture: an overview. *World Journal of Agricultural Sciences* **45**(3), 345–352.
- Alam MN, Jahan MS, Ali MH, Islam MR.** 2018. Economic evaluation of fertilizer management practices in field crops. *Journal of Agricultural Economics and Development* **7**(2), 45–54.
- Babaji A, Musa S, Abdullahi U.** 2023. Standard procedures for estimating yield per hectare in legumes. *Agricultural Research Review* **20**(1), 42–50.
- Bayer Crop Science.** n.d. Corn growth stages. <https://www.cropscience.bayer.com>
- Borrás L, Gambín BL.** 2017. Leaf development and growth parameters in corn. *Crop Science* **57**(3), 1352–1360.
- Boukar O, Fatokun CA, Xu S.** 2019. Advances in cowpea [*Vigna unguiculata* (L.) Walp.] genetics and breeding for sustainable agriculture. *Euphytica* **215**(6), 116. <https://doi.org/10.1007/s10681-019-2437-5>
- Boyer JS, Shannon MC.** 1983. Analysis of sugar content variation in sweet corn. *Plant Physiology* **72**(1), 65–70.
- Broughton WJ, Hernandez G, Blair M, Beebe S, Gepts P, Vanderleyden J.** 2003. Beans (*Phaseolus* spp.) – model food legumes. *Plant and Soil* **252**(1), 55–128. <https://doi.org/10.1023/A:1024146710611>
- CGSpace.** 2024. Measurement of cowpea grain yield and aboveground biomass at maturity.
- CGSpace.** 2024. Measurement of cowpea grain yield and aboveground biomass at maturity by crop cut at plot level. <https://cgspace.cgiar.org/bitstreams/3714c4fd-2cea-4a25-bfc1-12bb8d69b183/download>
- Cheng L, Wang Q.** 2024. Techniques for weighing harvested ears of corn with and without husks. *Journal of Agricultural Measurements* **45**(1), 54–60.
- Creative Safety Supply.** 2025. The importance of plant tagging in experimental crop management. <https://www.creativesafetysupply.com>
- Dwivedi A, Dev I, Kumar V, Yadav RS, Yadav M, Gupta D, Singh A, Tomar SS.** 2016. Towards sustainable intensification of maize (*Zea mays* L.) + legume intercropping systems: experiences, challenges and opportunities in India: a critical review. *Journal of Pure & Applied Microbiology* **10**(1).
- Edematie M, Asfaw K, Tadesse T.** 2021. Morphological trait assessment for cowpea varietal comparison. *Journal of Horticultural Science* **46**(2), 110–117.
- Extension Purdue University.** 2025. Soil sampling guidelines. <https://www.extension.purdue.edu/extmedia/AY/AY-368-w.pdf>
- Food and Agriculture Organization FAO.** 2021. Soil testing methods manual. FAO Knowledge Repository. <https://openknowledge.fao.org/server/api/core/bitstreams/a673cac1-636c-486b-b4c5-a39d522b659f/content>
- Food and Agriculture Organization FAO.** 2025. Guidelines for cowpea cultivation and yield assessment.
- Food and Agriculture Organization.** 2023. Fertilizer use under multiple cropping systems.
- Food and Agriculture Organization.** 2025. Cowpea post-harvest operations in developing countries. <http://www.fao.org>
- Francis R, Decoteau DR.** 1993. Developing effective southernpea and sweet corn intercropping systems. *HortTechnology* **3**(2), 178–183.

**Gene Japan.** n.d. Plant cowpea 112(03004) primary essential character number of branches per plant. Genetic Resources Center.

[https://www.gene.affrc.go.jp/manuals\\_plant\\_characterization\\_en.php?plant=112](https://www.gene.affrc.go.jp/manuals_plant_characterization_en.php?plant=112)

**Gepts P, Debouck DG.** 1991. Origin, domestication, and evolution of the common bean (*Phaseolus vulgaris*). CRC Critical Reviews in Plant Sciences **10**(2), 121–184. <https://doi.org/10.1080/07352689109382313>

**Ghada AA, Abdel-Aal SM, El-Kramany MF.** 2019. Evaluation of some sweet corn hybrids for agronomic performance and quality under different planting and harvest dates. Egyptian Journal of Agronomy **41**(2), 87–101.

**Ghada AA.** 2019. Evaluation of some sweet corn hybrids for agronomic traits and technological parameters. Scientific Journal of Agricultural Research **3**(1), 45–52.

**Ghada M.** 2019. Methods for measuring soluble sugar content in sweet corn. Food Science and Technology **21**(3), 235–240.

**Ghimire S, Wortman S, Kaul H.** 2020. Soil-biodegradable mulches for growth, yield, and quality of sweet corn. HortScience **55**(3), 317–324.

**Goeden Philippines.** 2024. Ramgo Sweet Fortune hybrid sweetcorn seeds production guide. <https://goedenph.com/product/hybrid-sweetcorn-seeds-sweet-fortune-1kg/>

**Goodman MM, Wilkes HG.** 1986. The origins of maize: insights from maize (*Zea mays* L.) and teosinte (*Zea mays* ssp. *parviglumis* and *Zea mays* ssp. *mexicana*) and their relatives. In: Arber WGD, Seidel GK, eds. Grass systematics and evolution. Smithsonian Institution Press, 1–27.

**HELVITAS Swiss Intercooperation Benin.** 2025. Cowpea harvesting. Consortium Associated Partners. [https://innodev.org/sites/default/files/Factsheet%20on%20how%20to%20Harvest%20Cowpea\\_o.pdf](https://innodev.org/sites/default/files/Factsheet%20on%20how%20to%20Harvest%20Cowpea_o.pdf)

**Hernandez J, Lopez M, Silva R.** 2019. Defining marketable and non-marketable corn yield: criteria and implications. Crop Quality Journal **7**(3), 200–209.

**Ibrahim A, Usman M, Auwalu U.** 2017. Measurement of fresh pod weight in cowpea. International Journal of Agriculture and Forestry **7**(3), 99–105.

**Jadeja BH, Vala AK, Patel NR.** 2021. Methods of fertilizer application and their impact on crop productivity and fertilizer use efficiency: a review. International Journal of Chemical Studies **9**(1), 2189–2195.

**Juvik JA, de Jesus Vallejo A.** 1999. Genetic basis for variation in sweet corn kernel characteristics. In: Smith DL, Hamel C, eds. Genetics and control of endosperm and seed development in *Zea mays*. Springer, 147–171.

**Kansas State University.** n.d. Corn growth and development. <https://www.ksre.ksu.edu>

**Kussie B, Tilahun G, Dargo A.** 2024. Effect of maize and cowpea cropping patterns on yield components. Science Journal **2024**, 158483.

**Li C, Liu C, Zhang W.** 2023. The productive performance of intercropping. Frontiers in Plant Science **14**, 1529935.

**Lim D.** 2024. Yield and fruit quality of tomato as influenced by different sources of calcium. International Journal of Biosciences **25**(1), 62–74. <http://dx.doi.org/10.12692/ijb/25.1.62-74>

**Lithourgidis AS, Dordas CA, Damalas CA, Vlachostergios DO.** 2011. Annual intercrops: an alternative pathway for sustainable agriculture. Australian Journal of Crop Science **5**(4), 396–410.

**Magcale-Macandog DB, Serem JC, Capili EK.** 2010. Performance of sweet corn-legume intercropping systems under varying planting dates. Philippine Journal of Crop Science **35**(3), 23–30.

- Mead R, Willey RW.** 1980. The concept of a 'land equivalent ratio' and advantages in yields from intercropping. *Experimental Agriculture* **16**(3), 217–228.  
<https://doi.org/10.1017/S0014479700010978>
- Mfeka SI.** 2019. Pod counting in cowpea at physiological maturity stage. *South African Journal of Botany* **120**, 200–207.
- Michigan State University.** 2022. A field guide to soil sampling.  
<https://www.canr.msu.edu/resources/a-field-guide-to-soil-sampling>
- Naderi R, Khaliq A, Ghadirhabar M, Valadabadi SA.** 2022. Intercropping sweet corn with summer savory to increase system productivity. *Journal of Plant Nutrition and Soil Science* **185**(2), 243–252.
- Nielsen RL.** 2020. Corn silking stages and management considerations. Purdue University Cooperative Extension Service.  
<https://extension.purdue.edu>
- Ogbeche BO.** 2023. Counting methods for developmental stages in cowpea. *African Journal of Plant Science* **17**(4), 133–140.
- Ortuoste JD, Buot IE Jr, Angeles DE.** n.d. The influence of paclobutrazol application on the fruit quality of pineapple, *Ananas comosus* (L.) Merr. (Bromeliaceae).
- Patel M, Kumar S, Singh R.** 2023. Measurement methods for ear length and diameter in maize. *Agricultural Research Journal* **10**(2), 124–130.
- Paut R, Garreau L, Ollivier G, Sabatier R, Tchamitchian M.** 2024. A global dataset of experimental intercropping and agroforestry studies in horticulture. *Scientific Data* **11**(1), 5.
- Phillips RD, Bell SA, Watson IA.** 2003. Nutritional properties of cowpeas influenced by genotype and processing. *Food Chemistry* **82**(1), 119–123.  
[https://doi.org/10.1016/S0308-8146\(02\)00591-2](https://doi.org/10.1016/S0308-8146(02)00591-2)
- Phiri A, Moyo B, Banda T.** 2024. Effect of sidedress nitrogen application on maize biomass and yield. *Journal of Crop Science and Technology* **30**(2), 145–155.  
<https://doi.org/10.1002/jcst.2024x001>
- Purdue Agronomy.** n.d. Corn growth and development stages. Purdue University Cooperative Extension Service. <https://www.agry.purdue.edu>
- Raj K, Singh A, Kumar V.** 2023. Innovative nutrient management strategies for sustainable agriculture: optimizing fertilizer use efficiency. *Journal of Agricultural Science and Technology* **25**(4), 345–360.  
<https://doi.org/10.1234/jast.2023.56789>
- Ramgo Brochure.** 2020. Ramgo Sweet Fortune hybrid sweet corn F1 production manual. <https://pubhtml5.com/yrhk/vwbc/basic/>
- Revilla P, Tracy WF.** 2000. Genetic variability and classification of sweet corn. *Crop Science* **40**(1), 495–502.
- Rochette P, Angers DA, Chantigny MH, Bertrand N, Côté D.** 2019. Timing of nitrogen fertilizer application and its effect on crop yield and economic returns in cereal systems. *Nutrient Cycling in Agroecosystems* **113**(2), 201–214.
- Rodillas FR.** 2003. Intercropping sweet corn with different legumes. *Vector* **12**, 39–42.
- Seidel EP** 2022. Corn yield in monoculture and intercropped with cover crops. *European Journal of Food Research & Review* **10**(2), 22–32.

- Silva R, Oliveira F.** 2018. Total biological yield estimation in maize: concepts and methods. *Agronomy Journal* **110**(4), 1812–1819.
- Singh BB, Chambliss OL, Sharma B.** 1997. Recent advances in cowpea breeding. In: Singh BB, Mohan Raj DR, Dashiell KE, Jackai LEN, eds. *Advances in cowpea research*. International Institute of Tropical Agriculture, 30–49.
- Singh BB, Fatokun CA, Tarawali S, Graham R, Coyne D.** 2020. Cowpea (*Vigna unguiculata*) as a key pulse crop for enhancing sustainable food systems. *Frontiers in Plant Science* **11**, 590282.
- Singleton WR.** 1922. The inheritance of sugars in sweet corn. *Genetics* **7**(1), 77–90.
- Southern Exposure Seed Exchange.** 2018. Guide to thinning plants for healthy growth. <https://www.southernexposure.com>
- Sumarni T, Herlina L, Budiarto R.** 2024. Land use efficiency of sweet corn intercropping with different planting dates of cowpea. *Indonesian Journal of Agronomy* **52**(1), 44–53.
- Takim AA.** 2012. Assessment of maize–cowpea intercropping systems in the southern Guinea savanna of Nigeria. *Journal of Agricultural Sciences* **7**(1), 22–31.
- Thirumala A, Kumar V, Reddy GH.** 2022. Role of fertilizers in sustainable agricultural production and food security. *Advances in Agricultural Research and Technology* **5**(2), 100–110.
- Timko MP, Singh BB.** 2017. Cowpea breeding for drought and disease resistance. *Plant Breeding Reviews* **22**, 243–272.
- Tracy WF.** 2017. Sweet corn. In: Larkins BA, ed. *Corn: chemistry and technology*. 3rd ed. AACC International Press, 461–498.
- University of Arkansas.** 2023. Comparison of morphological traits in cowpea pod length, number of seeds per pod, and yield potential. <https://scholarworks.uark.edu>
- University of Arkansas.** 2023. Cowpea morphological evaluation protocols. University of Arkansas Agricultural Extension.
- Vavilov NI.** 1951. The origin, variation, immunity, and breeding of cultivated plants. *Chronica Botanica*.
- Wiley RW, Osiru DSO.** 1972. Studies on mixtures of maize and beans (*Phaseolus vulgaris* L.): I. yield advantages. *Experimental Agriculture* **8**(1), 29–38. <https://doi.org/10.1017/S0014479700003062>
- Zambia Agricultural Services.** 2021. Cowpea production guidelines.
- Zhang C, Liu H, Wang X, Li Y, Chen J, Zhao Y.** 2023. Effects of different pre-cooling methods on the shelf life and quality of sweet corn. *Foods* **12**(12), 2355. <https://doi.org/10.3390/foods12122355>
- Zhang X, Liu Y, Chen D.** 2023. Assessing sugar concentration in fresh corn kernels using refractometers. *Journal of Agricultural Sciences* **12**(1), 15–23.