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Effect of sowing dates and substitutive intercropping on growth and yield components of maize (*Zea mays* L.) in Qushtappa and Ankawa regions during the 2023–2024 growing season

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ABSTRACT

This study investigated how sowing date and substitutive intercropping ratios affect the growth and yield of maize (*Zea mays*) in two distinct agroecological regions of Iraq: Qushtappa and Ankawa which are located around 29 km apart, with Ankawa situated to the northwest of Erbil city and Qushtappa positioned to the southeast. Two sowing dates (15 July and 1 August) and five intercropping treatments (pure corn and 1:4 to 4:1 ratio of mungbean to corn) were evaluated in a randomized complete block design. Significant effects were found for plant height, stem diameter, number of leaves and nodes, biological yield, grain yield, and harvest index. The highest biological yield (16.78 t ha^{-1}) and grain yield (8.62 t ha^{-1}) were obtained in Ankawa on 15 July under the 2V:3C intercropping system. Conversely, pure corn yielded the highest harvest index (51.28%) under late sowing. The 2V:3C ratio demonstrated optimal balance between vegetative and reproductive growth. These results suggest that careful adjustment of planting date and crop ratio, tailored to site conditions, can enhance maize productivity in semi-arid regions.
KEYWORDS: Sowing dates; Growth; yield components; Maize-mungbean intercropping; sowing date; substitutive intercropping; harvest index.

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تأثير مواعيد الزراعة والزراعة البينية التعويضية على نمو ومكونات حاصل الذرة الصفراء (*Zea mays* L.) في منطقتي قوشتبة وعنكاوة خلال الموسم الزراعي 2023–2024

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الملخص

تحقّقت هذه الدراسة من تأثير مواعيد الزراعة ونِسَب الزراعة البينية الاستبدالية على نمو وإنتاجية الذرة الصفراء (***Zea mays***) في منطقتين زراعيتين مختلفتين بيئيًا في العراق: قشتبة وعينكاوة، واللتين تقعان على بُعد حوالي 29 كيلومترًا من بعضهما، حيث تقع عينكاوة شمال غرب مدينة أربيل، بينما تقع قشتبة إلى الجنوب الشرقي منها. تم تقييم موعدي زراعة (15 تموز و1 آب) وخمس معاملات زراعة بينية (زراعة الذرة منفردة، ونِسَب من 1:4 إلى 4:1 من الماش إلى الذرة) ضمن تصميم القطاعات العشوائية الكاملة. أظهرت النتائج تأثيرًا معنويًا على طول النبات، وقطر الساق، وعدد الأوراق والعقد، والمردود الحيوي، ومردود الحبوب، ودليل الحصاد. سُجل أعلى مردود حيوي (16.78 طن/هكتار) وأعلى مردود حبوب (8.62 طن/هكتار) في عينكاوة بتاريخ 15 تموز ضمن نظام الزراعة البينية بنسبة **2V:3C**. في المقابل، حققت زراعة الذرة المنفردة أعلى دليل حصاد (51.28%) عند الزراعة المتأخرة. وقد أظهرت نسبة **2V:3C** توازنًا مثاليًا بين النمو الخضري والتناسلي. وتشير هذه النتائج إلى أن التعديل الدقيق لموعد الزراعة ونسبة المحصول، بما يتلاءم مع ظروف الموقع، يمكن أن يعزز إنتاجية الذرة في المناطق شبه الجافة.
الكلمات المفتاحية: مواعيد الزراعة، النمو؛ مكونات الحاصل؛ الزراعة البينية بين الذرة والماش؛ الزراعة الاستبدالية؛ دليل الحصاد.

INTRODUCTION

A sustainable cropping method that maximizes land usage, boosts biodiversity, and increases agricultural output and resource efficiency is intercropping. Corn-mung-bean intercropping is one of the legume-cereal systems that shows the most promise in semi-arid areas. However, environmental factors including soil properties, temperature, and moisture availability frequently affect performance

Ro et al., (2023).

However, cultivating maize in this region poses specific challenges. A significant decision is determining the optimal time for planting. The timing of sowing may influence crop performance at various stages. Planting too early may subject young plants to lower temperatures, while planting too late could jeopardize the grain-filling phase during the summer's heat. Mahdi et al., (2024) examined three different sawing dates in June 25, July 10, and July 25. The study found that early sowing (June 25) led to significantly lower pollen moisture and vitality.

While sowing on July 10 and 25 produced maximum pollen moisture, pollen vitality and highest grain yields. However, as Li et al. (2024) observe, this timeframe is not universal; differing environmental conditions necessitate that farmers possess localized, pertinent knowledge to make informed decisions.

Another option is intercropping, particularly the substitutive type, where land is partially reallocated from maize to another crop, often a legume. This method can optimize space, reduce weed pressure, and enhance soil fertility over time. Although not novel, it is experiencing a resurgence in popularity as farmers pursue more sustainable agricultural practices to enhance productivity. Fu et al. discovered in their 2023 study that maize cultivated with legumes exhibits superior growth performance compared to maize grown in isolation. Furthermore, Wang et al. (2023) indicate that when this approach is integrated with mulching, the outcomes are significantly improved. Soil moisture rises, enabling plants to absorb greater quantities of nutrients, particularly nitrogen.

Despite growing evidence for the benefits of sowing date optimization and intercropping, there's still not much information about how they work together, especially under the environmental conditions unique to places like Qushtappa and Ankawa.

Thus, the purpose of this study was to assess the effects of two different agroecological settings, Ankawa and Qushtappa, as well as different sowing dates and intercropping ratios, on the development and yield of maize and mung-bean. The goal of the study is to determine the best combinations for sustainable production by examining soil and meteorological data in conjunction with plant performance.

MATERIALS AND METHODS

Study Locations: Describes the locations were the experiment achieved:

- **Ankawa**: Ankawa, which is situated in an area with silty clay loam soil, had a pH of 7.78, a low electrical conductivity (EC) of 0.4 dS/m, and a higher organic matter (0.93%), all of which were indicative of ideal growing conditions for crops.

- **Qushtappa**: Clay loam soil with a pH of 7.92, a slightly higher EC of 0.6 dS/m, and less organic matter (0.81%) are its defining characteristics.
- **Qushtappa and Ankawa** are located around 29 km apart, with Ankawa situated to the northwest of Erbil city and Qushtappa positioned to the southeast

Location	EC dS.$^{m-1}$	pH	N (%)	P (ppm)	K (ppm)	O.M (%)	Sand (%)	Silt (%)	Clay (%)	Soil Texture
Ankawa 36.244066, 43.998513	0.4	7.78	0.011	47.5	188	0.93	16.3	49.3	34.4	Silty Clay Loam
Qushtappa 36.008745, 44.023975	0.6	7.92	0.08	25.5	120	0.81	33.8	36.8	29.4	Clay Loam

*Analyzed at Ankawa experimental station – Ministry of Agriculture KRG – Iraq

Experimental Design

This experiment used a substitutive design to implement intercropping between corn (*Zea mays*) and green gram (*Vigna radiata*). The experiment followed a substitutive intercropping design as originally proposed by Willey (1979), where the total plant population remains constant while the proportion of each crop varies. This approach has been widely applied in cereal-legume systems, including maize–legume intercropping studies by Fu et al. (2023) and Ghanbari & Tusi (2020). Each experimental unit sized 3.5 meters wide and 3 meters long, with five planting rows spaced 70 cm apart. Under the substitutive model, the number of rows assigned to one crop is reduced in order to allocate more rows to the second crop, resulting in a constant total of five rows per plot. Table shows the row layouts for each therapy.

Treatment Code	Intercropping Ratio	Corn Rows (C)	Green Gram Rows (V)	Example Row Pattern
T1	5C : 0V(Control)	5	0	C - C - C - C - C
T2	0C : 5V (Control)	0	5	V - V - V - V - V
T3	4C: 1V	4	1	C - V - C - C - C
T4	3C : 2V	3	2	C - V - C - V - C
T5	2C : 3V	2	3	V - C - V - C - V
T6	1C : 4V	1	4	V - V - C - V - V

"C" = Corn (*Zea mays*), "V" = Green gram (*Vigna radiata*). Each plot consisted of 5 rows.

Intercropping treatments follow a substitutive design.

Each 3.5m × 3m plot has 5 rows. Within-row plant spacing is 15 cm for green gram (*Vigna radiata*) and 30 cm for corn (*Zea mays*). Using these spacings, the expected number of plants each row is as follows:

- "V" = Green gram (*Vigna radiata*): twenty plants each row.
- "C" = Corn (*Zea mays*): 10 plants each row.

To estimate the total number of plants per 3.5m x 3m plot under each treatment, multiply the number of rows by the number of plants per row for each crop based on the row arrangement in the substitutive intercropping system.

Agrometeorological Data

Crop development timeframes were impacted by the notable differences in monthly temperature and relative humidity between the two locations.

Month	Max Temp (°C)	Min Temp (°C)	Relative Humidity (RH) (%) Qushtappa	Relative Humidity (RH) (%) Ankawa
Novem/hhg	21.0 (Q) / 21.4 (A)	11.4 (Q) / 12.6 (A)	64.3	70.4
December	17.1 (Q) / 17.5 (A)	7.9 (Q) / 7.9 (A)	69.4	85.3
January	14.1 (Q) / 14.6 (A)	6.5 (Q) / 6.3 (A)	73.1	87.0
February	14.9 (Q) / 15.2 (A)	6.0 (Q) / 5.1 (A)	67.3	87.6
March	18.9 (Q) / 18.5 (A)	8.2 (Q) / 8.1 (A)	61.2	86.0
April	28.6 (Q) / 28.8 (A)	15.0 (Q) / 15.4 (A)	44.7	84.8
May	30.4 (Q) / 30.6 (A)	18.2 (Q) / 19.4 (A)	36.2	71.6
June	41.4 (Q) / 42.6 (A)	26.7 (Q) / 28.3 (A)	13.8	56.3
July	42.2 (Q) / 44.6 (A)	27.6 (Q) / 30.4 (A)	16.1	58.0
August	42.4 (Q) / 44.8 (A)	27.1 (Q) / 28.8 (A)	16.1	57.0
September	36.8 (Q) / 38.9 (A)	23.3 (Q) / 24.0 (A)	23.0	57.1

Data Collection and Statistical Analysis

Measurements were made of the growth factors (plant height, number of nodes and leaves, stem diameter) and yield components (biological yield, grain yield, and harvest index). To find significant changes between treatments, ANOVA and Tukey's HSD test were used to evaluate the data at $p < 0.05$. through the Opstat application (Sheoran and Kundu, 2024).

RESULTS AND DISCUSSION

Growth Parameters

Plant Height (Table 1) ; The results in Table 3 reveal that location influenced plant height, with maize grown at Ankawa generally taller than at Qushtappa. The mean plant height at Ankawa was 226.2 cm, while Qushtappa recorded 223.7 cm. This difference is attributed to Ankawa's better soil texture and higher organic matter content.

Regarding sowing date, plants sown on 15 July exhibited slightly taller growth (mean = 226.3 cm) compared to those sown on 1 August (mean = 223.0 cm), suggesting that early sowing favored vegetative development.In terms of intercropping ratio, the 1V:4C treatment led to the tallest plants (mean = 231.08 cm), followed by the 4V:1C and 2V:3C treatments. The shortest plants were recorded under the 2V:3C ratio at Ankawa (210.7 cm), indicating increased interspecific competition at that ratio. Higher levels of organic matter and better soil texture are thought to be responsible for the taller growth (Esmaeilzadeh and Ahangar, 2014). Although differences in height were visible across treatments, no statistically significant differences were observed at the 5% level based on Tukey's HSD test.

Table 1. Corn Plant height (cm) response of corn plant to sowing date (SDT) and corn (c) : Mung-bean (V) substitutive intercropping type at Qushtappa (QT) and Ankawa (AK) locations

Location	SDT	Intercropping treatments ratios (ICR)					Mean ICR
		Pure C	4v: 1C	3V:2C	2V:3C	1V:4C	
Qushtappa	15 JUL	222.667a	229.667a	222.333a	234.333a	213.333a	224.467a
	1 AUG	214.000a	226.333a	215.000a	222.333a	241.000a	223.733a
	Mean SDT	218.333a	228.000a	218.667a	228.333a	227.167a	
Ankawa	15 JUL	240.667a	232.333a	230.000a	208.333a	229.333a	228.133a
	1 AUG	223.667a	211.333a	222.667a	213.000a	240.667a	222.267a
	Mean SDT	232.167a	221.833a	226.333a	210.667a	235.000a	
Pooled Analysis	15 JUL	231.667a	231.000a	226.167a	221.333a	221.333a	226.300a
	1 AUG	218.833a	218.833a	218.833a	217.667a	240.833a	223.000a
	Mean SDT	225.250a	224.917a	222.500a	219.500a	231.083a	

Means with the same letter are not significantly different according to Tukey HSD for comparison of levels of SDT at same level of ICR and their interaction at p (0.05)

Number of Nodes (Table 2): The number of nodes per maize plant varied slightly between the two locations. Ankawa recorded a marginally higher average (mean = 12.53 nodes) compared to Qushtappa (12.30 nodes). This suggests that soil fertility and higher organic matter at Ankawa may have supported more vigorous stem development.

In terms of sowing date, plants sown on 15 July developed more nodes on average (12.70 nodes) than those sown on 1 August (11.43 nodes). This indicates that early planting promotes vegetative development, likely due to longer growth duration and more favorable initial temperatures.

Examining intercropping ratios, the 3V:2C and 1V:4C treatments produced the highest average number of nodes (both 13.08), whereas the 2V:3C treatment recorded a slightly lower mean (11.33 nodes). The Pure Corn treatment showed moderate node development (11.25 nodes).

While differences across treatments and factors were not statistically significant at the 5% level, the data suggest that early sowing combined with balanced or low-density mungbean intercropping tends to support enhanced stem node formation in maize.

Table (4) Number of nodes response of corn plant to sowing date (SDT) and corn (c) : Mung-bean (V) substitutive intercropping type at Qushtappa (QT) and Ankawa(AK) locations

Location	SDT	Intercropping treatments ratios (ICR)					Mean intercropping ratios (ICR)
		Pure C	4v: 1C	3V:2C	2V:3C	1V:4C	
Qushtappa	15 JUL	13.000a	13.333a	13.333a	12.333a	12.333a	12.867a
	1 AUG	10.333ab	13.000ab	15.000a	9.000b	11.333ab	11.733a
	Mean SDT	11.667a	13.167a	14.167a	10.667a	11.833a	
Ankawa	15 JUL	10.333a	11.333a	13.000a	13.000a	15.000a	12.533a
	1 AUG	11.333a	8.667a	11.000a	11.000a	13.667a	11.133a
	Mean SDT	10.833ab	10.000b	12.000ab	12.000ab	14.333a	
Pooled Analysis	15 JUL	11.667a	12.333a	13.167a	12.667a	13.667a	12.700a
	1 AUG	10.833a	10.833a	13.000a	10.000a	12.500a	11.433a
	Mean SDT	11.250ab	11.583b	13.083ab	11.333ab	13.083a	

Means with the same letter are not significantly different according to Tukey HSD for comparison of levels of SDT at same level of ICR and their interaction at p (0.05)

Number of Leaves (Table 5): Location had a noticeable effect on leaf number. Qushtappa had a slightly higher overall average (15.33 leaves per plant) compared to Ankawa (14.60 leaves), possibly due to better environmental conditions favoring leaf expansion, despite lower organic content.

With regard to sowing date, plants sown on 15 July produced more leaves (15.60) than those sown on 1 August (14.57), affirming that early planting supports more extensive vegetative growth.

Among the intercropping ratios, the Pure Corn treatment led in leaf production (16.75 leaves), followed by 1V:4C (15.58 leaves), while treatments with higher mungbean density, like 3V:2C and 2V:3C, showed reduced leaf numbers. The lowest values were recorded under the 4V:1C treatment.

These patterns suggest that lower mungbean competition and early planting favor optimal leaf development in maize. However, differences were not statistically significant.

Table 5. number leaves response of corn plant to sowing date (SDT) and corn (c) : Mung-bean (V) substitutive intercropping type at Qushtappa (QT) and Ankawa(AK) locations

Location	SDT	Intercropping treatments ratios (ICR)					Mean ICR
		Pure C	4v: 1C	3V:2C	2V:3C	1V:4C	
Qushtappa	15 JUL	17.333a	16.333a	15.333a	15.333a	17.000a	16.267a
	1 AUG	17.667a	14.000a	14.667a	12.667a	13.667a	14.533a
	Mean SDT	17.500a	15.167a	15.000a	14.000a	15.333a	
Ankawa	15 JUL	17.333a	16.333a	14.000a	13.000a	14.000a	14.933a
	1 AUG	14.667ab	10.667b	15.000ab	15.000ab	17.667a	14.600a
	Mean SDT	16.000a	13.500a	14.500a	14.000a	15.833a	
Pooled Analysis	15 JUL	17.333a	16.333a	14.667a	14.167a	15.500a	15.600a
	1 AUG	16.167a	12.333a	14.833a	13.833a	15.667a	14.567a
	Mean SDT	16.750a	14.333a	14.750a	14.000a	15.583a	

Means with the same letter are not significantly different according to Tukey HSD for comparison of levels of SDT at same level of ICR and their interaction at p (0.05)

Stem Diameter (Table 6): The average stem diameter of maize plants was slightly higher in Qushtappa (2.47 cm) than in Ankawa (2.46 cm), showing negligible location-related differences. However, early sowing in Qushtappa (15 July) recorded the highest diameter (up to 2.81 cm under 1V:4C).

Sowing date also influenced stem thickness: plants sown on 15 July had a slightly greater average diameter (2.48 cm) than those sown on 1 August (2.46 cm), highlighting a mild advantage of early planting in stem robustness.

For intercropping ratios, the Pure Corn and 4V:1C treatments both had the highest mean stem diameters (2.54 cm and 2.54 cm, respectively), while 3V:2C showed the lowest (2.36 cm), likely due to increased interspecific competition.

Although most differences were not statistically significant, the data suggest that low mungbean pressure and early sowing enhance stem development and structural integrity. Across all treatments, Qushtappa stems were generally thicker; however, late seeding (1 August) produced smaller diameters, maybe as a result of heat stress. (Rauf and Akop, 2018).

Table 6. Stem diameter (cm) response of corn plant to sowing date (SDT) and corn (c) : Mung-bean (V) substitutive intercropping type at Qushtappa (QT) and Ankawa(AK) locations

Location	**SDT**	**Intercropping treatments ratios (ICR)**					**Mean ICR**
		Pure C	**4v: 1C**	**3V:2C**	**2V:3C**	**1V:4C**	
Qushtappa	15 JUL	2.550ab	2.587ab	2.293b	2.590ab	2.810a	2.566a
	1 AUG	2.663a	2.520ab	2.110b	2.520ab	2.330ab	2.429a
	Mean SDT	2.607a	2.553a	2.202b	2.555a	2.570a	
Ankawa	15 JUL	2.720a	2.477a	2.370a	2.363a	2.003a	2.387a
	1 AUG	2.240a	2.580a	2.680a	2.450a	2.543a	2.499a
	Mean SDT	2.480a	2.528a	2.525a	2.407a	2.273a	
Pooled Analysis	15 JUL	2.635a	2.532a	2.332a	2.477a	2.407a	2.476a
	1 AUG	2.452a	2.550a	2.395a	2.485a	2.437a	2.464a
	Mean SDT	2.543a	2.541a	2.363a	2.481a	2.422a	

Means with the same letter are not significantly different according to Tukey HSD for comparison of levels of SDT at same level of ICR and their interaction at p (0.05)

Above-Ground Biological Yield (t ha^{-1}) of Corn(Table 7): Location had a clear impact on biological yield. Ankawa recorded a higher average (14.26 t/ha) compared to Qushtappa (13.06 t/ha), indicating that better soil fertility and organic matter at Ankawa promoted more vegetative biomass. The sowing date also affected yield: plants sown on 15 July produced a slightly higher mean biological yield (13.82 t/ha) than those sown on 1 August (13.66 t/ha), suggesting that early planting provided a longer vegetative period before senescence.

Regarding intercropping ratios, the 2V:3C treatment yielded the highest average (14.56 t/ha), even exceeding Pure Corn (14.15 t/ha). The 3V:2C treatment also performed well, while 1V:4C showed slightly lower performance (13.08 t/ha).

These findings suggest that moderate mungbean intercropping (particularly 2V:3C) and early sowing can enhance biomass accumulation. However, most differences were statistically nonsignificant.

Table (7) above ground Yield (t ha^{-1}) response of corn plant to sowing date (SDT) and corn (c): Mung-bean (V) substitutive intercropping type at Qushtappa (QT) and Ankawa (AK) locations

Location	SDT	Intercropping treatments ratios (ICR)					Mean ICR
		Pure C	4v: 1C	3V:2C	2V:3C	1V:4C	
Qushtappa	15 JUL	11.470a	15.277a	16.482a	13.766a	12.789a	13.957a
	1 AUG	14.214a	11.716a	13.550a	13.709a	12.117a	13.061a
	Mean SDT	12.842a	13.496a	15.016a	13.737a	12.453a	
Ankawa	15 JUL	14.101ab	12.588ab	10.526b	16.780a	14.439ab	13.687a
	1 AUG	16.811a	13.134a	14.415a	13.965a	12.955a	14.256a
	Mean SDT	15.456a	12.861a	12.470a	15.372a	13.697a	
	15 JUL	12.785a	13.932a	13.504a	15.273a	13.614a	13.822a

Pooled Analysis	1 AUG	15.513a	12.425a	13.982a	13.837a	12.536a	13.658a
	Mean SDT	14.149a	13.179a	13.743a	14.555a	13.075a	

Means with the same letter are not significantly different according to Tukey HSD for comparison of levels of SDT at same level of ICR and their interaction at p (0.05)

Grain Yield (Table 8): Grain yield was substantially influenced by location. Ankawa averaged a higher grain yield (6.37 t/ha) than Qushtappa (5.24 t/ha), attributed to richer soil conditions and slightly cooler microclimate.

Plants sown on 1 August outperformed those sown on 15 July in terms of grain yield (5.81 t/ha vs. 6.02 t/ha, respectively), particularly in Ankawa, suggesting that later sowing synchronized better with grain-filling stages.

The 2V:3C intercropping ratio yielded the highest mean grain yield (6.58 t/ha), followed by Pure Corn (6.28 t/ha). In contrast, 1V:4C and 4V:1C resulted in lower grain outputs.

The findings confirm that moderate intercropping levels and location-specific sowing timing are essential for maximizing grain yield under semi-arid conditions. Qushtappa produced the highest yields when seeded on August 1 and the V:4C ratio was set at 1V, most likely as a result of effective resource allocation for reproductive growth (Mohammed Ibrahim and Al-Aguidi, 2017)

Table 8. Grain Yield (t ha^{-1}) response of corn plant to sowing date (SDT) and corn (c): Mung-bean (V) substitutive intercropping type at Qushtappa (QT) and Ankawa(AK) locations

Location	**SDT**	**Intercropping treatments ratios (ICR)**					**Mean ICR**
		Pure C	**4v: 1C**	**3V:2C**	**2V:3C**	**1V:4C**	
Qushtappa	15 JUL	4.010a	7.464a	8.289a	5.816a	5.081a	6.132a
	1 AUG	6.264a	4.152a	5.591a	5.719a	4.493a	5.244a
	Mean SDT	5.137a	5.808a	6.940a	5.768a	4.787a	
Ankawa	15 JUL	6.204ab	4.830ab	3.332b	8.616a	6.514ab	5.899a
	1 AUG	8.657a	5.390a	6.498a	6.163a	5.142a	6.370a
	Mean SDT	7.431a	5.110a	4.915a	7.390a	5.828a	
Pooled Analysis	15 JUL	5.107a	6.147a	5.811a	7.216a	5.798a	6.016a
	1 AUG	7.461a	4.771a	6.045a	5.941a	4.817a	5.807a
	Mean SDT	6.284a	5.459a	5.928a	6.579a	5.307a	

Means with the same letter are not significantly different according to Tukey HSD for comparison of levels of SDT at same level of ICR and their interaction at p (0.05)

Harvest Index (table 9): The harvest index (HI) was slightly higher in Ankawa (43.30%) than in Qushtappa (39.57%), indicating that Ankawa conditions favored more efficient allocation of biomass to grains.

For sowing dates, 1 August produced a slightly lower HI (41.43%) than 15 July (41.94%), although the difference was marginal and not statistically significant.

In terms of intercropping ratios, 2V:3C showed the highest average HI (44.23%), followed by Pure Corn (42.96%). The lowest HI was observed under 4V:1C, likely due to excess vegetative growth and reduced grain allocation.

These findings highlight that intercropping strategies like 2V:3C, particularly when aligned with site-specific conditions, can enhance grain partitioning efficiency in maize production systems.

When Qushtappa was seeded on August 1 and the V:4C ratio was set at 1V, it yielded the best yields, most likely due to efficient resource allocation for reproductive growth (Chen et al 2022).

Table 9. Harvest index response of corn plant to sowing date (SDT) and corn (c): Mung-bean (V) substitutive intercropping type at Qushtappa (QT) and Ankawa (AK) locations.

Location	SDT	Intercropping treatments ratios (ICR)					Mean ICR
		Pure C	4v: 1C	3V:2C	2V:3C	1V:4C	
Qushtappa	15 JUL	34.590a	46.490a	50.253a	41.770a	38.717a	42.364a
	1 AUG	43.173a	35.363a	41.093a	41.590a	36.613a	39.567a
	Mean SDT	38.882a	40.927a	45.673a	41.680a	37.665a	
Ankawa	15 JUL	42.817ab	38.087ab	31.643b	51.187a	43.870ab	41.521a
	1 AUG	51.283a	39.793a	43.797a	42.390a	39.233a	43.299a
	Mean SDT	47.050a	38.940a	37.720a	46.788a	41.552a	
Pooled Analysis	15 JUL	38.703a	42.288a	40.948a	46.478a	41.293a	41.942a
	1 AUG	47.228a	37.578a	42.445a	41.990a	37.923a	41.433a
	Mean SDT	42.966a	39.933a	41.697a	44.234a	39.608a	

Means with the same letter are not significantly different according to Tukey HSD for comparison of levels of SDT at same level of ICR and their interaction at p (0.05)

DISCUSSION

1. **Effect of Location**

The results clearly demonstrate that location significantly influenced the growth and yield components of maize. Ankawa, characterized by silty clay loam soil and higher organic matter (0.93%), consistently outperformed Qushtappa across several parameters, including plant height, grain yield, and harvest index. This is in line with findings from Esmaeilzadeh & Ahangar (2014), who emphasized the role of soil organic content and texture in improving maize vegetative development. Additionally, Rauf et al. (2018) noted that higher soil fertility enhances stem robustness and biomass accumulation, which aligns with Ankawa’s higher above-ground yields.

Despite Ankawa’s advantage in biomass production, grain yield at Qushtappa was sometimes comparable, especially under optimal intercropping and sowing combinations. This may be attributed to slightly more favorable temperature-humidity dynamics at Qushtappa during grain-filling, as supported by Chen et al. (2021), who reported that moderate environmental stress can sometimes improve partitioning efficiency to reproductive organs.

2. **Effect of Sowing Date**

Sowing date had a substantial impact on both vegetative and reproductive traits. In both locations, 15 July sowing generally resulted in greater plant height, leaf number, and node count, suggesting a longer vegetative growth window and better early-season establishment. However, in terms of grain yield and harvest index, 1 August sowing often provided comparable or better results, particularly in Ankawa. This could be due to better synchronization between grain-filling and moderate post-anthesis conditions, reducing heat stress during the critical reproductive stages (Xu et al., 2022).

These findings are consistent with regional studies in Iraq that recommend mid-to-late July planting as optimal for maize. *Mahdi et al. (2024)* in Iraq confirmed that maize sown between mid- and late July performed best in terms of yield, fertility traits, and plant structure, especially under heat stress. Similarly, *Guo et al. (2024)* emphasize that optimal sowing date varies by environmental profile, with warmer and drier conditions requiring tighter alignment between vegetative and reproductive phases.

3. **Effect of Intercropping Ratio**

The intercropping ratio had a pronounced effect on both growth parameters and yield outcomes. The 2V:3C treatment consistently delivered high biological yield (14.56 t/ha), grain yield (6.58 t/ha), and harvest index (44.23%). This suggests that a moderate mungbean density supports resource complementarity, reducing intra-specific competition among maize while contributing nitrogen fixation and improved microclimatic conditions. Similar outcomes were documented by Fu et al. (2023) and Ghanbari & Tusi (2020), where substitutive intercropping involving legumes significantly improved maize productivity.

On the other hand, denser mungbean treatments like 3V:2C and 4V:1C often reduced maize performance, particularly in stem diameter and leaf count, likely due to increased below- and above-ground competition. This supports Chen et al. (2021) who found that while diversity can increase biomass, it may reduce harvest index due to biomass dilution in mixed cropping systems.

The Pure Corn treatment, while yielding high grain output in some instances, did not consistently outperform the 2V:3C system—indicating that intercropping can be both productive and resource-efficient when well-balanced.

4. **Interactions Between Factors**

Although this study emphasized the individual effects of the three main factors, some interactions stood out. For instance, the 2V:3C treatment under 15 July sowing in Ankawa produced the highest above-ground biomass (16.78 t/ha) and grain yield (8.62 t/ha), illustrating how optimal timing and crop ratio can amplify site-specific advantages. Conversely, late sowing in Qushtappa with the same ratio did not yield as well, underscoring the importance of matching intercropping design to location and sowing windows—a key recommendation in precision agronomy (Li et al., 2024).

CONCLUSION:

This study highlights the importance of tailoring cropping practices—particularly sowing dates and intercropping ratios—to local agroecological conditions. In general, Ankawa's higher organic matter content favored vegetative growth and biomass accumulation, while Qushtappa supported more efficient grain partitioning under specific treatment combinations. The 2V:3C intercropping ratio consistently produced superior outcomes in terms of biological yield, grain yield, and harvest index, especially when combined with optimal sowing dates. However, it is important to note that the outcomes observed in this study are specific to the maize and mungbean varieties used. Different maize cultivars may respond differently to planting dates and intercropping competition due to variability in genetic growth potential, heat tolerance, and maturity duration. Therefore, further research should investigate how different maize and legume varieties interact under similar environmental conditions to refine agronomic recommendations for broader application.

Based on the results of this single-season field study, the 2V:3C intercropping ratio appears to offer the most favorable balance between vegetative growth and grain yield efficiency. Additionally, tailoring sowing dates to site-specific environmental conditions—such as favoring early sowing in Qushtappa and slightly delayed sowing in Ankawa—enhanced productivity outcomes. However, since the current findings are limited to a single growing season, it is strongly recommended that the experiment be repeated over multiple seasons and possibly across additional locations. This would allow for a more reliable assessment of year-to-year variability and environmental interactions. Only after validating these results through multi-season trials, can a formal agronomic recommendation be confidently issued for wide-scale adoption.

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