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AGRONOMY | ORIGINAL ARTICLE

Effect of Cowpea Sowing Dates on the Yield Performance of Maize and Cowpea Under Additive Intercropping System

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ABSTRACT

The experiment was conducted at the Agronomy Field Laboratory of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh during the period from November 2023 to April 2024 to study the effect of sowing dates of cowpea on the productivity of maize-cowpea intercropping system. A local cowpea variety (V1) and Japanese cultivar (V2) was planted in a maize based intercropping system at different sowing dates. The experiment comprised two factors as-Factor A: (V1: Local cowpea variety, V2: Japanese cultivar); Factor B: (S1: Cowpea sown simultaneously with maize; S2: Cowpea sown 15 DAS of maize; S3: Cowpea sown 30 DAS of maize; S4: Cowpea sown 45 DAS of maize). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The result of the study showed that the growth and yield of maize was not affected by cowpea varieties and different sowing dates. Between the cowpea varieties the V2 (Japanese variety) showed better performance in relation to growth and yield potential. On the other hand, among the sowing dates, the cowpea varieties planted simultaneously with maize gave the best yield (8.36 ± 0.61 t ha^{-1}) compared to other treatments. Simultaneous sowing (S1) resulted in the tallest maize plants (200.67 cm) and the highest cowpea fresh pod yield (16.28 t ha^{-1}), indicating efficient resource sharing. The V2 (Japanese cultivar) gave best result for number of pods per plant (14.66 ± 3.11), pod length (36.09 ± 4.22 cm), fresh pod yield (13.54 ± 4.15 t ha^{-1}), stover yield (13.53 ± 4.15 t ha^{-1}). The S1 treatment showed best result for number of pods per plant (16.48 ± 2.79), pod length (35.67 ± 6.94 cm), number of seeds per plant (16.57 ± 1.77), fresh pod yield (16.28 ± 2.55 t ha^{-1}), stover yield (2.01 ± 0.12 t ha^{-1}). In most of the cases the S4 treatment gave lowest result. These results indicated that cowpea variety and its various sowing time do not affect the yield and yield contributing characters of maize and the Japanese cowpea variety performed best when planted simultaneously with maize.

1. Introduction

Intercropping, a conventional method of simultaneously farming multiple crops, is a strategic way to enhance resource usage and labor efficiency (Harati et al. 2023). With the increase in global food demands, intercropping has become an essential technique for improving food security and conserving natural resources (Yin et al. 2020). Diversified agricultural methods, such as intercropping, seek to enhance production stability by improving crop protection and augmenting productivity and profitability (Rosa-Schleich et al. 2019). Intercropping, a strategic agricultural method, seeks to enhance land use and resource efficiency by growing various crops concurrently in the same field (Stomph et al. 2020). This method not only improves overall output but also reduces risks related to crop failures. Multiple studies have shown that intercropping can exceed the yields obtained from solitary cropping. This strategy is based on the complementing characteristics of intercropped species, which effectively use resources including sunlight, water, and nutrients. By utilizing diverse ecological niches, these crops together enhance resource efficiency and yield potential in comparison to monoculture systems (Bybee-Finley and Ryan 2018).

Maize, a principal cereal crop in the worldwide agricultural economy, commonly known as corn, serves as both human sustenance and animal fodder (Erenstein et al. 2022). It is an extensively grown, highly nutritious, and rapidly growing crop characterized by a brief lifespan and significant potential for high yields. Maize ranks as the third most prolific cereal crop globally, behind rice and wheat (Ghimire and Gyawali 2023). In terms of yield,

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maize ranks first with an average of 10.2 t ha^{-1} (BWMRI 2023). Bangladesh's agro-climatic characteristics facilitate year-round maize cultivation, establishing it as a viable crop for the nation. Despite the annual increase in maize output in Bangladesh, which reached 3.60 million tons from 1.10 million acres in the fiscal year 2018-2019 (BBS 2019), the nation continues to depend on imports to satisfy its domestic consumption requirements. In 2021-22, 5.63 million tons of maize were produced from 0.55 million hectares, while the annual grain requirement is approximately 7.0 million tons (BWMRI 2023). The maize revolution, which first aligned with the growth of the poultry and fish feed sector, is now being redirected by the government to advocate for maize as a dual-purpose crop, appropriate for both feed and food use. Integrating maize as an intercrop within current cropping systems offers a promising option to boost productivity (Sahoo et al. 2023). In the last eleven years, maize production has increased over twelve times, propelled by strong local market demand.

Cowpea (*Vigna unguiculata* L.) has become a significant dual-purpose crop in many countries throughout the world, functioning as both fodder and seed source (Brasier et al. 2023). It offers a verdant canopy for livestock, and its seeds serve as a substantial protein supply for both people and animals. Darwesh et al. (2016) established that modest water scheduling (65% of accumulated pan evaporation) in both monoculture and intercropping systems does not adversely affect the yields of sunflower and feed cowpea. According to these data, a 1:2 intercropping arrangement of sunflower and cowpea seems to be a feasible agricultural approach. Legumes are an effective means to alleviate nitrogen deficit in soils and improve crop yields (Abd-Alla et al. 2023). Their fast proliferation facilitates efficient soil coverage, erosion mitigation, weed suppression, and atmospheric N_2 fixation (Kumawat et al. 2022). Moreover, they enhance pest and disease mitigation, labor efficiency, and optimal land use. Grain legumes, especially preferred by smallholder tropical farmers, provide food security, nutritional quality, and economic benefits. Intercropping with cereals enhances the yield of high-quality organic matter, leading to greater productivity than continuous maize monoculture.

The extensive spacing of maize crops allows for intercropping with legumes, either for green manuring or grazing, without detriment to yield (Kumawat et al. 2022; Mudare et al. 2022). It is suggested that non-legumes derive advantages from their interaction with legumes, resulting in improved nitrogen usage and less need on external inputs such as nitrogen fertilizers. Intercropping interactions enhance nitrogen utilization efficiency and reduce the global requirement for nitrogen fertilizers (Jensen et al. 2020). Grain legume crops can enhance subsequent cereal yields by an average of 29% (Mahmood et al. 2018). Maize cultivated alongside pea yielded a 144% increase in maize equivalent output compared to monoculture maize cultivation. This intercropping method exhibited a higher land equivalent ratio, gross and net returns, and overall profitability relative to solitary maize agriculture (Mudare et al. 2022). Dimande et al. (2024) and Kussie et al. (2024) found analogous findings, noting the best net revenue from intercropping maize with chickpea.

The productivity of intercropped systems is influenced by the length of component crops and their varying resource requirements. Staggered crop maturation can improve resource usage efficiency. Defoliating taller maize crops without reducing production can enhance light availability for shorter intercropped legumes, so alleviating competition for this essential resource. The timing of sowing within a certain intercropping arrangement significantly influences both the biological and practical aspects of crop growth and yield development, as it alters the competitive dynamics between the intercropped species. The primary cause of yield disparity associated with sowing dates across intercropped species is the variation in their respective competing powers at distinct sowing times (Huang et al. 2018). The competitive capacity of a species within a specific mixed cropping system is intricately linked to several morphological characteristics, such as canopy height and width, root depth and distribution, emergence timing, seed and seedling size, growth rate, and developmental stage (Huang et al. 2018). When a species characterized by a slow initial growth rate is intercropped with a species exhibiting rapid initial development, the latter can typically attain normal growth without a decrease in yield, owing to its superior ability to intercept light and assimilate other resources (Wang et al. 2017; Wang et al. 2021; Jin et al. 2024). This explains why earlier sown species may prevail in an intercropping system (Huang et al. 2018; Huang et al. 2017).

In view of the discussion above, this experiment was conducted (a) to study the effect of varieties of intercrop (cow pea) on growth and yield of maize and cowpea, (b) to assess the effect of sowing time of cowpea on growth and yield of maize-cowpea intercropping system, and (c) to find out the interaction effect of sowing dates and varieties of cowpea on the productivity of maize-cowpea intercropping system.

2. Materials and Methods

2.1. Experimental location

The experiment was carried out from November 2023 to April 2024 at the Agronomy Field Laboratory of the Department of Agronomy, Bangladesh Agricultural University (BAU), Mymensingh. The field was situated at 24°25′N latitude and 90°50′E longitude with an elevation of about 18 meters above sea level. The soil of the experimental site belonged to the Sonatola Series under the non-calcareous dark grey floodplain soils of the Old Brahmaputra alluvial tract (Agro-ecological Zone-9). The land was medium-low in elevation, fairly leveled, and had a silt loam texture with a soil pH of 7.3. The climate during the experimental period was characterized by a dry winter (November to April) with low rainfall, followed by a humid summer.

2.2. Experimental treatments and design

Maize, a tall-growing crop, was selected as the principal crop, and cowpea was chosen as the intercrop. The experiment comprised two factors, viz. cowpea variety, and sowing time of cowpea under the intercropping system. Two varieties of cowpea were used: a local variety

(V1) and a Japanese cultivar (V2). Seeds of both maize and cowpea (V1) were sourced from the Bangladesh Agricultural Research Institute. The Japanese variety (V2) of the cowpea was collected from a local market of Japan. Maize was sown on 20 November 2023, while cowpea was sown in four staggered intervals relative to maize sowing: simultaneously, and at 15, 30, and 45 days after maize sowing.Therefore, the experiment had eight treatment combinations involving the two cowpea varieties and four sowing times. It was arranged in a randomized complete block design (RCBD) with three replications. Each replication consisted of three main plots separated by 0.5 m spacing. Individual plot sizes were 2.5 m × 2 m, totaling 24 plots.

2.3. Agronomic management

The land was initially tilled on 18 November 2023 and prepared through multiple ploughings and laddering until a fine tilth was achieved. Fertilizers including urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, and zinc sulfate ($ZnSO_4$) were applied at the rates of 220, 110, 50, 125, and 10 kg ha^{-1}, respectively. All fertilizers except half of the urea were applied during final land preparation; the remaining urea was applied in two equal splits at 30 and 60 days after sowing. Maize seeds were dibbled at a spacing of 40 cm between rows and 30 cm between plants. Three seeds were sown per hill, later thinned to one seedling. Cowpea was sown in single rows between maize rows. Thinning and manual weeding were carried out twice at 30 and 45 days after sowing using a hand tool (khurpi). Light irrigation was applied after sowing for germination, followed by irrigations at 30, 60, and 90 days after sowing. Care was taken to prevent water flow between plots, and excess water was drained as necessary.

2.4. Data collection

Maize was harvested on 26 April 2024, which were then sun-dried, threshed, and weighed. Stover yield was recorded after sun drying for 15 days. Green cowpea pods (vegetable) was harvested in several stages starting from 20 March unitl 26 April 2024. After drying the harvested material for 10 days, cowpea stover weights were recorded. Data were collected on growth, yield, and yield components for both crops. For maize, the parameters recorded included plant height, number of cobs per plant, cob length and diameter, number of kernel rows per cob, number of seeds per row, thousand seed weight, grain yield, and stover yield. For cowpea, data included number of pods per plant, pod length, seeds per pod, fresh pods yield, and stover yield. Harvesting was done on a plot basis, and maize grains were dried to 12% moisture using a digital moisture meter before weighing.

2.5. Statical analysis

All data were statistically analyzed using the R statistical environment. Analysis of variance (ANOVA) was performed using the 'agricolae' package, and treatment means were compared using Tukey's post hoc test as outlined by Gomes and Gomes (1984).

3. Results and Discussion

3.1. Performance of maize

3.1.1. Plant height

Maize plant height was not significantly influenced by cowpea variety, sowing time, or their interaction. Although the tallest maize plants (199.3 ± 8.53 cm) were observed with the local cowpea variety (V1), and the shortest (195 ± 9.72 cm) with the Japanese variety (V2), the differences were statistically insignificant. The superior height in the V1 intercropped plot may reflect better compatibility between maize and the locally adapted cowpea, potentially enhancing mutual resource use and reducing interspecies competition (Harati et al. 2023). In contrast, V2 might have competed more intensely for limited resources.

Similarly, cowpea sowing time did not significantly affect maize height. The tallest maize plants (200.67 ± 5.15 cm) occurred with simultaneous sowing (S1), while the shortest (193.33 ± 11.34 cm) were observed when cowpea was planted 45 days later (S4). Early sowing likely facilitated resource partitioning during critical maize growth stages, consistent with findings that highlight the importance of synchronizing crop establishment to minimize interspecific competition (Áurea et al. 2017).

Combined effects of variety and sowing time also showed no significant variation in maize height. The tallest plants were recorded in treatments V1 × S1, V1 × S3, and V2 × S1, while the shortest (186.6 ± 12.8 cm) occurred in V2 × S4. This suggests that maize is relatively resilient to variations in intercropping arrangements, provided that competition is not excessive during early growth stages. These findings support earlier studies reporting the adaptability of maize in intercropping systems and its capacity to maintain growth across diverse conditions (Prasanna 2012; Adipala et al. 2002).

3.1.2. No. of cobs plant^{-1}

Maize cob number per plant was not significantly affected by cowpea variety, sowing time, or their interaction. Slightly higher cob numbers were recorded with the local cowpea variety (V1; 1.67 ± 0.26) compared to the Japanese variety (V2; 1.65 ± 0.26), possibly due to better ecological compatibility and reduced interspecific competition from the local cultivar. Local varieties are often better adapted to native agroecological conditions, facilitating more efficient resource sharing in intercropping systems (Dwivedi et al. 2015).

Sowing time of cowpea also showed no significant effect on cob number per maize plant. The highest cob count (1.8 ± 0.22) was observed with simultaneous sowing (S1), while the lowest (1.57 ± 0.2) occurred when cowpea was sown 45 days after maize (S4). Early sowing may reduce competition during critical maize development stages, consistent with evidence that intercropping benefits are maximized when component crops overlap in growth phases (Huang et al. 2017; Huang et al. 2018; Kumawat et al. 2022).

Table 1. Effect of sowing time of intercrop (cowpea), its variety, and their interaction on plant characters and yield related traits of maize

Treatment	PLH	NCP	CBL	CBD	KLC	NKL	WTG
Cowpea variety (V)							
V1	199.3 ± 8.53	1.67 ± 0.26	14.57 ± 0.79	4.51 ± 0.33	14.18 ± 0.73	28.59 ± 2.11	362.42 ± 25.62
V2	195.07 ± 9.72	1.65 ± 0.26	15.02 ± 1.29	4.53 ± 0.34	14.4 ± 1.74	30.23 ± 3.02	360.51 ± 26.23
Sig. level	NS	NS	NS	NS	NS	NS	NS
Cowpea sowing time (S)							
S1	200.67 ± 5.15	1.8 ± 0.22	14.8 ± 0.93	4.4 ± 0.28	14.05 ± 0.53	28.81 ± 1.87	368.92 ± 27.12
S2	195.93 ± 5.96	1.6 ± 0.28	15.08 ± 0.63	4.65 ± 0.39	13.65 ± 0.76	29.41 ± 3.28	363.88 ± 19.26
S3	198.8 ± 12.69	1.67 ± 0.3	14.27 ± 1.06	4.4 ± 0.34	13.93 ± 0.84	28.88 ± 2.57	365.35 ± 18.87
S4	193.33 ± 11.34	1.57 ± 0.2	15.03 ± 1.55	4.64 ± 0.27	15.54 ± 1.95	30.54 ± 3.13	347.71 ± 34.36
Sig. level	NS	NS	NS	NS	NS	NS	NS
Interaction (V × S)							
V1 × S1	200.8 ± 6.68	1.73 ± 0.31	14.62 ± 1.43	4.42 ± 0.24	14 ± 0.75	28.73 ± 2.83	378.97 ± 26.01
V1 × S2	195.67 ± 5.25	1.67 ± 0.42	15 ± 0.37	4.64 ± 0.57	14.03 ± 0.55	27.92 ± 2.76	353.68 ± 22.33
V1 × S3	200.67 ± 16.72	1.67 ± 0.23	14.16 ± 0.21	4.3 ± 0.23	13.81 ± 1.02	28.27 ± 1.1	370.03 ± 6.6
V1 × S4	200.07 ± 4.66	1.6 ± 0.2	14.49 ± 0.83	4.69 ± 0.18	14.88 ± 0.13	29.46 ± 2.35	347 ± 37.72
V2 × S1	200.53 ± 4.66	1.87 ± 0.12	14.98 ± 0.09	4.38 ± 0.38	14.11 ± 0.36	28.89 ± 0.85	358.88 ± 29.32
V2 × S2	196.2 ± 7.81	1.53 ± 0.12	15.15 ± 0.92	4.67 ± 0.23	13.26 ± 0.83	30.91 ± 3.54	374.08 ± 10.81
V2 × S3	196.93 ± 10.63	1.67 ± 0.42	14.39 ± 1.65	4.5 ± 0.45	14.06 ± 0.83	29.5 ± 3.77	360.67 ± 27.94
V2 × S4	186.6 ± 12.8	1.53 ± 0.23	15.57 ± 2.11	4.59 ± 0.39	16.19 ± 2.86	31.62 ± 3.94	348.42 ± 39.08
Sig. level	NS	NS	NS	NS	NS	NS	NS
CV (%)	4.85	16.7	7.91	7.87	8.43	9.72	7.53

Here, V1: Local cowpea variety, V2: Japanese cultivar; S1: Cowpea sown simultaneously with maize,S2: Cowpea sown 15days after sowing maize,S3: Cowpea sown 30 days after sowing maize,S4: Cowpea sown 45 days after sowing maize,PLH: Plant height (cm), NCP: No. of cobs/plant, CBL: Cob length (cm), CBD: Cob diameter (cm), KLC: No. of kernel lines/cob, NKL: No. of seeds per kernel line, WTG: Weight of 1000 grains; values are mean ± standard deviation, NS: Non-significant

Though the combined effects were statistically insignificant, the V2 × S1 treatment recorded the highest cob number (1.87 ± 0.12), suggesting that synchrony in planting enhanced resource use even with the Japanese variety. The lowest cob numbers in V2 × S2 and V2 × S4 imply that delayed sowing of this exotic cultivar reduced its complementarity with maize. These findings support the notion that both cultivar compatibility and planting synchrony are crucial in optimizing intercropping outcomes (Sahoo et al. 2023; Lanzavecchia et al. 2024).

3.1.3. Cob length

Maize cob length was not significantly affected by cowpea variety, sowing time, or their interaction. The longest cobs were recorded with the Japanese cowpea cultivar (V2; 15.02 ± 1.29 cm), while the shortest were observed with the local variety (V1; 14.57 ± 0.79 cm). The improved cob length under V2 may be linked to enhanced resource-use efficiency and growth synchronization in intercropping systems, as exotic cultivars often exhibit superior physiological traits under mixed cropping (Coulibaly et al. 2024). In contrast, the local variety may have introduced more competition, reducing resource availability during key development stages.

Cowpea sowing time also had no statistically significant effect on cob length. The highest values were observed under S2 and S4 (>15.0 cm), likely due to minimized competition during early or late maize growth phases. The lowest cob length was observed in S3 (14.27 ± 1.06 cm), which may have induced greater resource competition during maize's mid-growth phase. These findings align with studies showing that synchronized or delayed sowing can improve resource allocation efficiency in intercropped systems (Lanzavecchia et al. 2024; Sahoo et al. 2023).

Combined effects of variety and sowing time followed a similar trend. Cob length exceeded 15.0 cm in V1 × S2, V2 × S2, and V2 × S4 treatments, indicating that certain combinations may optimize spatial-temporal complementarity in intercropping. The V2 × S4 treatment, in particular, may have benefited from reduced early-stage competition due to staggered growth, promoting more efficient nutrient and moisture sharing. In contrast, combinations such as V1 × S1 and V1 × S3 resulted in shorter cobs, possibly due to overlapping growth phases and heightened competition. These outcomes reaffirm the importance of aligning crop phenology and resource demands for optimal intercropping performance (Lanzavecchia et al. 2024).

3.1.4. Cob diameter

Maize cob diameter was not significantly influenced by cowpea variety, sowing time, or their interaction. Although the highest cob diameter was observed with the Japanese cultivar (V2; 4.53 ± 0.34 cm) and the lowest with the local variety (V1; 4.51 ± 0.33 cm), the differences were marginal and statistically insignificant. The slightly superior result with V2 may reflect improved compatibility in growth dynamics or nutrient uptake efficiency, leading to marginally enhanced cob development. Such outcomes are consistent with findings that intercropping outcomes often depend on the resource-use complementarity of the component species (Coulibaly et al. 2024).

Sowing time also did not significantly affect cob diameter, although S2 (cowpea sown 15 days after maize) showed the highest value (4.65 ± 0.39 cm), followed by S4 (45 days after). The lowest diameter was found in S3 (4.40 ± 0.34 cm). Early or delayed cowpea sowing likely minimized interspecific competition during maize's cob formation period, allowing for better resource allocation. In contrast, S3 may have introduced competition during a more sensitive developmental phase.

The combined influence of variety and sowing time was similarly non-significant. The highest cob diameters were found in V1 × S4 (4.69 ± 0.18 cm), V2 × S4 (4.67 ± 0.23 cm), and V1 × S2 (4.64 ± 0.57 cm), while the lowest was observed in V1 × S3 (4.3 ± 0.23 cm). These results suggest that delayed sowing of cowpea—particularly in the S4 combination—may allow maize to develop with reduced interspecific stress, supporting more robust cob formation. However, the narrow range of variation indicates that environmental factors and maize's inherent resilience in intercropping systems played a more decisive role than the timing or variety of cowpea used.

3.1.5. Number of kernel lines cob^{-1}

The number of kernel rows per maize cob was not significantly influenced by cowpea variety, sowing time, or their interaction. Although V2 (Japanese cultivar) showed a slightly higher mean (14.4 ± 1.74) than V1 (local variety; 14.18 ± 0.73), the difference was statistically insignificant. The marginal advantage observed with V2 may stem from its better resource-use efficiency or physiological compatibility in intercropping, potentially enhancing pollination and kernel development (Harati et al. 2023).

Among sowing time treatments, a statistically significant difference was observed. The highest number of kernel lines (15.54 ± 1.95) was recorded in S4 (cowpea planted 45 days after maize), followed by S1 (14.05 ± 0.53), while the lowest occurred in S2 (13.65 ± 0.76). These findings suggest that delayed cowpea sowing reduces interspecific competition during maize's reproductive phase, thus supporting better kernel row development. Conversely, S2 may have imposed greater stress during early kernel formation due to overlapping resource demands, aligning with findings that sowing synchrony impacts kernel set and grain quality in intercropped maize (Ghosh 2004).

Despite these trends, the combined effect of variety and sowing time remained statistically insignificant. The highest number of kernel lines was observed in V2 × S4 (16.19 ± 2.86), followed by V1 × S4 (14.88 ± 0.13) and V2 × S1 (14.11 ± 0.36), whereas the lowest was found in V2 × S2 (13.26 ± 0.83). These results suggest that while specific combinations (e.g., V2 × S4) may offer favorable micro-environmental conditions for kernel formation, the overall lack of statistical significance implies that maize kernel development is largely resilient to cowpea intercropping under the tested conditions. Minor differences may be attributed to background environmental or soil fertility variation rather than treatment effects alone.

3.1.6. Number of seeds per kernel line

The number of seeds per kernel line in maize was not significantly affected by cowpea variety, sowing time, or their interaction. Although the Japanese cultivar (V2) produced a slightly higher number of seeds per line (30.23 ± 3.02) than the local variety (V1; 28.59 ± 2.11), the difference was statistically insignificant. This indicates that cowpea varietal differences had minimal influence on maize reproductive success in the intercropping system, suggesting a dominant role of maize's genetic potential in determining seed set (Harati et al. 2023).

Sowing time showed a similar pattern of nonsignificant variation. The highest seed count per kernel line was observed in S4 (30.54 ± 3.13), where cowpea was sown 45 days after maize. This time gap may have reduced competition for resources during maize's critical reproductive phase. Moderate values in S2 (29.41 ± 3.28) also reflect potential benefits of staggered sowing. Conversely, the lowest seed count occurred in S1 (28.81 ± 1.87), likely due to simultaneous sowing increasing interspecific competition for light, water, and nutrients during early development.

The interaction between cowpea variety and sowing time also produced no significant effects, although trends were evident. The highest number of seeds per line was recorded in V2 × S4 (31.62 ± 3.94), followed by V2 × S2 (30.91 ± 3.54), suggesting that delayed sowing combined with the Japanese cultivar may offer a marginal advantage. The lowest value was found in V1 × S2 (27.92 ± 2.76), implying that the local variety, when sown at 15 days, may impose more competitive pressure on maize development. Overall, the minimal differences across treatments underscore that maize seed formation was relatively stable and resilient across intercropping conditions, with genotype-driven traits likely playing a more critical role than interspecific interactions in influencing seed number per kernel line.

3.1.7. Weight of 1000 grains

The 1000-grain weight of maize was not significantly influenced by cowpea variety, sowing time, or their interaction. Maize intercropped with the local cowpea variety (V1) recorded a slightly higher grain weight (362.42 ± 25.62 g) than the Japanese cultivar (V2; 360.51 ± 26.23 g), though this difference was not statistically significant. This suggests that under the given experimental conditions, varietal differences in cowpea did not markedly affect maize grain development. Minor variations may reflect microclimatic effects, soil heterogeneity, or other uncontrolled environmental factors rather than intercropping dynamics (Gupta et al. 2014).

Similarly, cowpea sowing time showed no significant effect on maize 1000-grain weight. The highest weight was observed in S1 (368.92 ± 27.12 g), followed by S3 (365.35 ± 18.87 g), while the lowest occurred in S4 (347.71 ± 34.36 g). These trends indicate that simultaneous sowing (S1) may have fostered balanced resource competition during early development, while delayed sowing in S3 also allowed maize to establish adequately before cowpea emergence. In contrast, S4 may have introduced competition during late maize development stages, slightly suppressing grain filling. However, the absence of significant variation across treatments suggests maize grain weight is largely buffered against intercropping effects when environmental conditions are favorable (Coulibaly et al. 2024).

The interaction of cowpea variety and sowing time followed a similar pattern. The V1 × S1 combination yielded the highest 1000-grain weight (378.97 ± 26.01 g), followed by V2 × S2 (374.08 ± 10.81 g), while the lowest was recorded in V1 × S4 (347 ± 37.72 g). These results indicate that simultaneous planting of V1 with maize may offer optimal conditions for grain filling, but the lack of statistical significance reinforces that maize kernel weight is not strongly dependent on the cowpea intercropping configuration. The findings underscore the stability of this yield component across diverse intercropping treatments, likely driven more by maize genetics and environmental conditions than by cowpea variety or sowing schedule.

3.1.8. Grain yield

Maize grain yield was not significantly affected by cowpea variety, sowing time, or their interaction (Figure 1). While the highest yield (8.36 ± 0.61 t ha^{-1}) was observed with the local cowpea variety (V1), and the lowest with the Japanese cultivar (V2; 7.98 ± 0.81 t ha^{-1}), the difference was statistically insignificant. This suggests that both cowpea varieties exerted similar competitive effects on maize, and interspecific interactions did not vary substantially across varieties. The slightly higher yield in V1 plots may reflect local adaptation and more complementary growth dynamics with maize, although not at a level sufficient to produce a significant yield advantage (Coulibaly et al. 2024).

Cowpea sowing time also had no significant effect on maize grain yield. However, the highest yields were observed in S3 (30 days after maize; 8.6 ± 0.6 t ha^{-1}) and S4 (45 days; 8.5 ± 0.74 t ha^{-1}), while the lowest was in S2 (15 days; 7.54 ± 0.64 t ha^{-1}). The improved yields in S3 and S4 may be attributed to reduced interspecific competition during maize's critical vegetative and reproductive stages, allowing more efficient resource allocation. In contrast, early cowpea introduction in S2 may have led to increased competition for light and nutrients, slightly reducing yield potential.

The combined effect of cowpea variety and sowing time also did not significantly influence grain yield. The highest yield was recorded in V1 × S4 (8.98 ± 0.6 t ha^{-1}), followed by V2 × S3 (8.88 ± 0.62 t ha^{-1}) and V1 × S3 (8.32 ± 0.53 t ha^{-1}). The lowest yield was observed in V2 × S2 (7.11 ± 0.46 t ha^{-1}). These results indicate that optimal grain yield may be achieved when maize is intercropped with cowpea under delayed sowing schedules, especially with locally adapted varieties. Nevertheless, the statistical insignificance of these differences implies that maize yield is relatively stable across cowpea intercropping combinations, likely due to its robust growth characteristics and ability to withstand moderate competition under favorable environmental and management conditions.

3.1.9. Stover yield

Maize stover yield was not significantly influenced by the cowpea variety (Figure 2). When intercropped with the local cowpea (V1) or the Japanese cultivar (V2), maize produced comparable stover yields of 13.53 ± 0.98 t ha^{-1} and 13.5 ± 1 t ha^{-1}, respectively. This lack of significant variation indicates that varietal differences in cowpea had minimal effect on biomass partitioning in maize. The uniformity in stover yield suggests that both cowpea varieties exerted similar levels of interspecific competition or facilitation, and that stover accumulation in maize was more likely influenced by environmental conditions or sowing time than by cowpea varietal traits (Harati et al. 2023).

Although sowing time did not produce statistically significant differences in stover yield, trends were evident. The highest stover yield was recorded in S4 (14.27 ± 0.82 t ha^{-1}), followed by S3 (13.9 ± 0.85 t ha^{-1}), while S2 (12.95 ± 0.79 t ha^{-1}) produced the lowest yield. The superior performance in S4 (cowpea sown 45 days after maize) likely resulted from reduced interspecific competition during maize's critical vegetative stages, enabling greater biomass accumulation. The S3 and S2 treatments, with earlier cowpea sowing, may have introduced competition for light and nutrients during active maize growth, thus lowering stover production. Delayed cowpea sowing in S4 may have also allowed for better resource allocation and possible benefits from residual nitrogen fixation during later growth phases.

The interaction between cowpea variety and sowing time was also statistically insignificant. Nonetheless, the highest stover yield was found in the V2 × S4 treatment (14.32 ± 0.88 t ha^{-1}), followed closely by V1 × S4 (14.21 ± 0.95 t ha^{-1}), indicating that delayed cowpea sowing benefits maize biomass production regardless of the variety used. Conversely, the lowest yield (12.67 ± 0.81 t ha^{-1}) occurred in the V2 × S1 treatment, where simultaneous sowing may have resulted in early-stage competition for light and nutrients, reducing maize biomass accumulation. These results underscore the relative resilience of maize stover yield to varietal interactions and emphasize the importance of optimizing sowing time in intercropping systems for biomass productivity.

3.2. Performance of cowpea

3.2.1. Number of pods plant^{-1}

The number of pods plant^{-1} of the cowpea showed significant variation between the varieties (Table 2). The highest number of pods plant $^{-1}$ was recorded from V2 (14.66 ± 3.11) while the lowest number of pods plant $^{-1}$ was observed from V1 (11.85 ± 3.81). The higher number of pods per plant recorded in V2 compared to V1 may be attributed to the genetic potential of the Japanese cultivar (V2), which could have a greater reproductive capacity or better pod-setting ability under the experimental conditions. Additionally, V2 might possess traits that enhance its adaptability, such as more efficient nutrient utilization or better response to the intercropping system with maize, leading to increased pod production. In contrast, V1, the local cowpea variety, while more resilient to environmental stresses, might allocate more energy to vegetative growth, resulting in fewer pods per plant.

Considering cowpea sowing time, all the treatments were statistically significant among them for number of pods plant^{-1} of cowpea. However, the maximum number of pods per plant was recorded from S1 (16.48 ± 2.79), followed by S2 (13.62 ± 3.11), likely due to the optimal timing of cowpea planting in relation to maize. In the S1 treatment, where cowpea and maize were planted simultaneously, there was likely less competition for resources, allowing for better pod development. In contrast, the S4 treatment, where cowpea was planted 45 days after maize, experienced more intense competition for light, water, and nutrients, leading to reduced pod formation, as evidenced by the lower pod count ranging from 10.8 to 3.2. (Table 2) (Adipala et al. 2002)

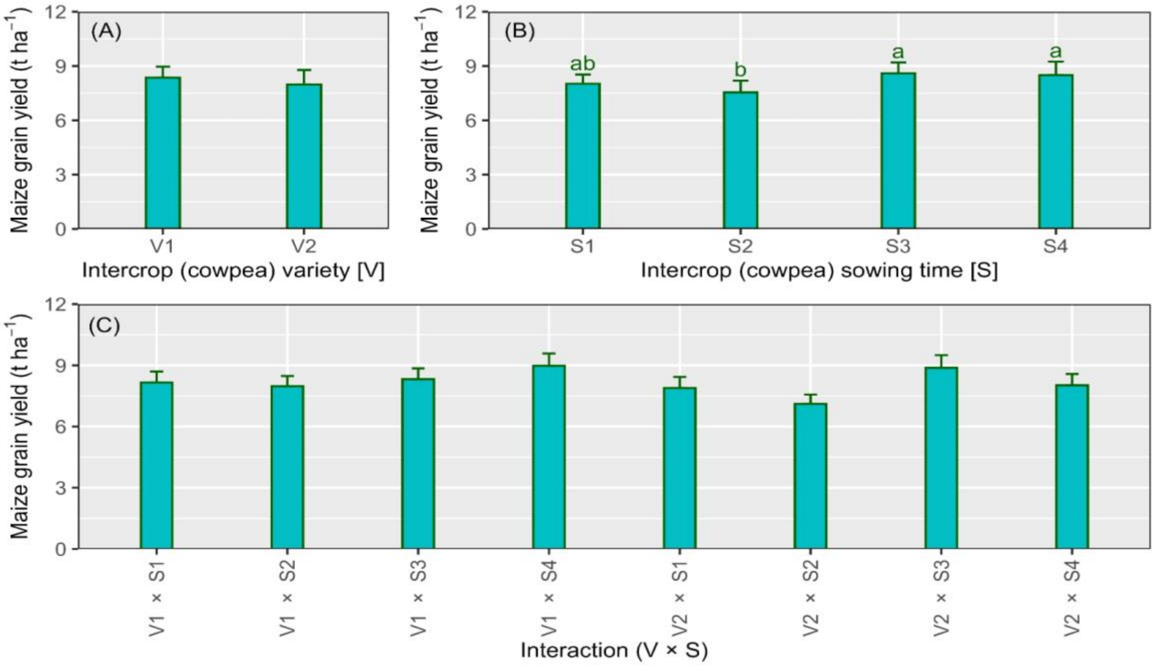

Figure 1. Effect of sowing time of intercrop (cowpea), its variety, and their interaction on grain yield of maize. Here, V1: Local cowpea variety, V2: Japanese cultivar; S1: Cowpea sown simultaneously with maize, S2: Cowpea sown 15 days after sowing maize, S3: Cowpea sown 30 days after sowing maize, S4: Cowpea sown 45 days after sowing maize

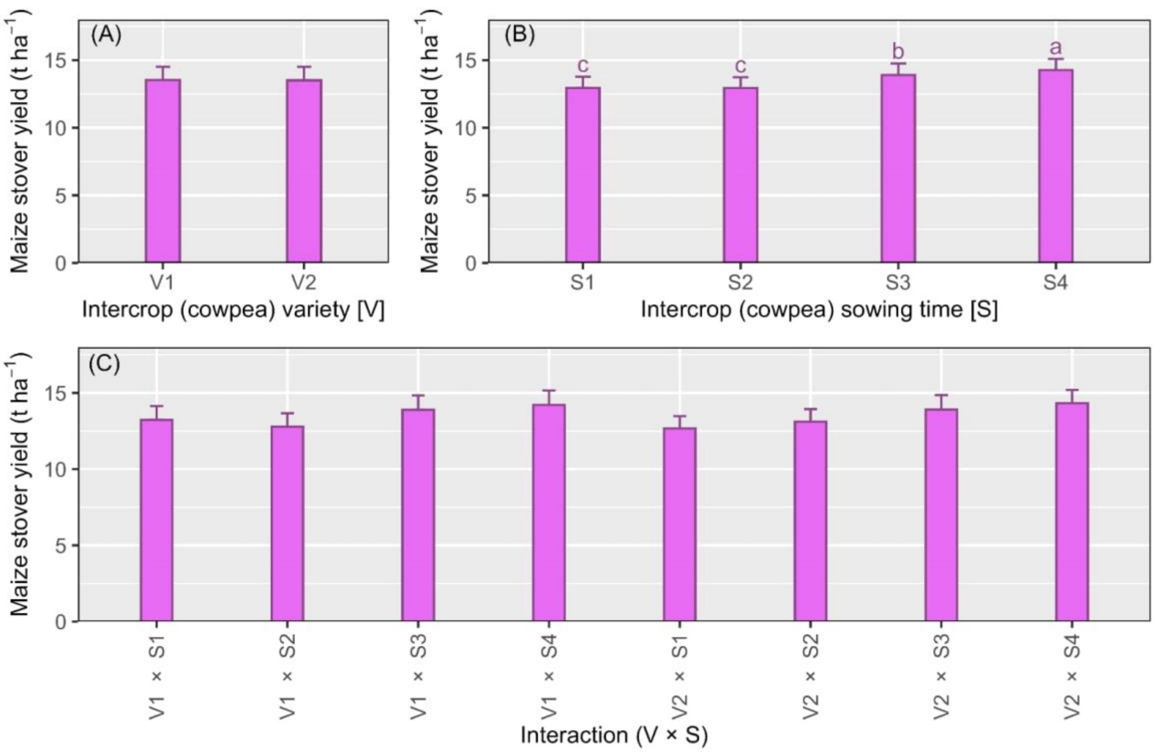

Figure 2. Effect of sowing time of intercrop (cowpea), its variety, and their interaction on Stover yield of maize. Here, V1: Local cowpea variety, V2: Japanese cultivar; S1: Cowpea sown simultaneously with maize, S2: Cowpea sown 15 days after sowing maize, S3: Cowpea sown 30 days after sowing maize, S4: Cowpea sown 45 days after sowing maize

For the combined effect of variety and sowing time the number of pods plant^{-1} of cowpea showed insignificant variations among all treatments. The highest number of pods per plant observed in the V2 × S1 (18.11 ± 3.1) treatment combination may be attributed to the Japanese cultivar (V2) thriving when planted simultaneously with maize (S1), as it could have benefited from optimal light and resource availability without much competition. In contrast, the second-highest pod count in the V2 × S2 (15.04 ± 2.42) combination suggests that planting cowpea 15 days after maize may have provided a balance between reduced competition and adequate resource access, leading to moderate pod production. The lowest pod count in the V1 × S4 (9.73 ± 4.46) treatment likely occurred because the local variety (V1) faced significant competition when planted 45 days after maize (S4), resulting in reduced plant vigour and lower pod production due to limited access to light and nutrients (Table 2).

3.2.2. Pod length

The pod length of the cowpea showed significant variation between the varieties (Table 2). The highest pod length was recorded from V2 (36.09 ± 4.22 cm) while the lowest pod length was observed from V1 (27.22 ± 2.39 cm). The highest pod length observed in V2 could be attributed to the genetic potential of the Japanese cultivar, which may have been bred for larger pod sizes as part of its agronomic traits. In contrast, V1, the local cowpea variety, might prioritize other growth traits such as plant height or stress resilience, resulting in a comparatively shorter pod length. Additionally, environmental factors, such as soil nutrients or temperature, could have favoured the development of longer pods in V2, while V1 may have been less responsive to these conditions.

When considering the sowing time of cowpea, all treatments showed statistically significant differences in pod length. However, the maximum pod length of cowpea was recorded in S1 (35.67 ± 6.94 cm) because planting the cowpea variety simultaneously with maize likely provided optimal conditions for pod development, as both crops may have benefited from synchronized growth patterns, reducing competition for light, water, and nutrients. In contrast, the slightly lower pod length in S2 (31.79 ± 4.24 cm) could be attributed to a moderate delay in planting, which may have led to some competition for resources, but still allowed adequate pod growth. The minimum pod length observed in S4 (29.21 ± 5.25 cm) suggests that the prolonged competition for resources, particularly light, between maize and cowpea, coupled with the 45-day delay in planting, significantly hindered pod formation and growth (Table2).

For the combined effect of maize and cowpea sowing time pod length of cowpea, all the treatments were showed insignificant variations among them. The top pod length in the V2 × S1 treatment combination (41.29 ± 4.94 cm) may be attributed to the Japanese cultivar's better ability to adapt to the simultaneous planting with maize, as this system likely provided an optimal balance of light, water, and nutrient availability.

The slightly reduced pod length in the V2 × S2 treatment combination (35.3 ± 2.59 cm) suggests that a 15-day delay in planting cowpea after maize may have resulted in less favourable growth conditions, although the cultivar still managed to produce longer pods than the local variety. In contrast, the V1 × S4 treatment combination (24.67 ± 1.18 cm) recorded the shortest pod length, possibly due to the local variety's reduced ability to compete effectively when planted 45 days after maize, a delayed planting time that may have imposed significant stress, leading to shorter pod development (Table 2) (Coulibaly et al. 2024)

3.2.3. Number of seeds pod^{-1}

The number of seeds per pod in cowpea exhibited no significant variation between varieties (Table 2). Among the varieties, V1 produced the highest number of seeds per pod (14.83 ± 1.38), while V2 recorded the lowest (14.38 ± 2.58). V1, the local cowpea variety, likely produced the highest number of seeds per pod due to its superior adaptation to local growing conditions, including better soil and climate compatibility. This genetic advantage may have enhanced its reproductive success, allowing it to allocate more resources to pod development and seed formation. In contrast, V2, the Japanese cultivar, may have struggled to perform optimally under the local environmental conditions, resulting in fewer seeds per pod due to lower fertility, less efficient resource allocation, or reduced pollination success.

In terms of sowing time, significant differences were observed across treatments for the number of seeds per pod. The highest number of seeds per pod was recorded in S1 (16.57 ± 1.77), likely because cowpea planted simultaneously with maize experienced optimal conditions for growth, such as adequate space, light, and nutrient availability. In contrast, the lower seed count in S4 (12.96 ± 1.53) suggests that planting cowpea 45 days after maize resulted in increased competition for resources, which likely limited the plant's reproductive capacity. The intermediate seed number in S2 (14.87 ± 1.39) indicates that a 15-day delay allowed for moderate competition, but not to the extent that it severely impacted pod formation and seed development (Table 2).

When considering the combined effect of maize and cowpea sowing time on the number of seeds per pod, no significant variations were observed among the treatment combinations. The highest number of seeds per pod in the V2 × S1 combination (16.62 ± 2.56) suggests that the Japanese cultivar (V2) performed well when planted simultaneously with maize (S1), possibly due to reduced competition for resources like light and nutrients, which allowed for optimal pod development. The V1 × S1 combination (16.52 ± 1.13) also showed a high seed count, indicating that the local cowpea variety (V1) thrives in the same planting system, potentially due to better local adaptation and effective resource utilization. In contrast, the V2 × S4 combination (12.42 ± 1.95) had the fewest seeds per pod, likely due to increased competition with maize when planted 45 days after, resulting in reduced pod formation and seed development (Table 2) ((Kussie et al. 2024)).

3.2.4. Fresh pod yield

The fresh pod yield of the cowpea showed significant variation between the varieties (Figure 3). The highest fresh pod yield of cowpea was recorded from V2 (13.54 ± 4.15 g) while the lowest fresh pod yield of cowpea was observed from V1 (11.07 ± 2.48 g). The highest fresh pod yield recorded from V2 could be attributed to the superior genetic characteristics of the Japanese cultivar, which may possess better pod-filling capacity and higher productivity under favourable conditions. In contrast, V1, the local cowpea variety, yielded less potentially due to its adaptation to local conditions that prioritize survival and growth rather than maximizing pod yield in a controlled environment. Additionally, factors such as the genetic vigour of V2, along with possible differences in disease resistance or pest tolerance, could have further enhanced its yield compared to the local variety.

When considering the cowpea sowing time, all treatments were statistically significant for the fresh pod yield of cowpea. The maximum fresh pod yield of cowpea was recorded in S1 (16.28 ± 2.55 g), where the cowpea variety was planted simultaneously with maize, suggesting that minimal competition for resources such as light, water, and nutrients allowed the cowpea plants to thrive. In contrast, the yield in S2 (13.86 ± 2.33 g), where cowpea was planted 15 days after maize, was slightly reduced, likely due to increased competition as maize plants began to establish themselves. The lowest yield was observed in S4 (8.11± 0.6 g), where cowpea was planted 45 days after maize, indicating severe competition for resources and possibly inadequate time for the cowpea plants to reach optimal growth before maize reached its full canopy (Figure 3).

For the combined effect of maize and cowpea sowing time fresh pod yield of cowpea, all the treatments were showed significant variations among them. The top fresh pod yield of cowpea in the V2 × S1 treatment combination (18.43 ± 1.26 g) can be attributed to the favourable interaction between the Japanese cultivar (V2) and the early planting with maize (S1), where the cowpea likely benefited from optimal growing conditions with minimal competition for resources. The second-highest yield observed in the V2 × S2 combination (15.78 ± 1.33 g) suggests that even with a 15-day delay in planting, the Japanese cultivar was still able to perform well, though not as optimally as in S1. In contrast, the lower yields recorded in the V1 × S4 (7.89 ± 0.87 g) and V2 × S4 (8.32 ± 0.02 g) combinations, statistically similar to each other, indicate that the prolonged planting delay (S4) severely reduced the growth potential of both cowpea varieties, likely due to increased competition for light, nutrients, and water from the maize crop (Figure 3).

3.2.5. Stover yield

The Stover yield of cowpea exhibited no significant variation between the varieties ($p<0.05$). The highest yield was observed in variety V2 (1.55 ± 0.55 t ha^{-1}), while the lowest yield was recorded for variety V1 (1.47 ± 0.5 t ha^{-1}) (Table 2). The higher yield observed in variety V2 (1.55 ± 0.55 t ha^{-1}) compared to V1 (1.47 ± 0.5 t ha^{-1}) may be attributed to the superior genetic traits of V2, such as its higher yield potential or better adaptability to environmental conditions, which may enhance overall productivity. Despite its slightly lower plant height, V2 might have demonstrated better resource allocation, especially in terms of photosynthesis and pod production, allowing for greater yield accumulation. Furthermore, V2's performance could have been improved by its potential resistance to pests or diseases, which would contribute to higher yield compared to V1, even under similar planting and intercropping conditions.

When analyzing the effect of sowing time, significant differences were noted among the treatments for cowpea Stover yield. The highest yield observed in treatment S1 (2.01 ± 0.12 t ha^{-1}) can be attributed to the simultaneous planting of cowpea with maize, which likely allowed for optimal resource utilization, as both crops could benefit from the same growth conditions without severe competition. Treatment S2 (1.99 ± 0.18 t ha^{-1}), where cowpea was planted 15 days after maize, also showed a high yield, as the delay likely reduced competition for light, water, and nutrients while still maintaining favourable growing conditions. In contrast, treatment S4 (0.96 ± 0.17 t ha^{-1}), where cowpea was planted 45 days after maize, recorded the lowest yield, likely due to significant light and resource competition, as maize had already established itself, resulting in reduced cowpea growth and productivity (Table 2).

Regarding the combined influence of maize and cowpea sowing times on Stover yield, no significant differences were observed among the treatment combinations. The highest Stover yield was observed in the V2 × S1 combination (2.03 ± 0.14 t ha^{-1}) due to the Japanese cultivar's better adaptability when planted simultaneously with maize, which likely facilitated more efficient resource utilization and reduced competition. The slightly lower yield in V2 × S2 (2.1 ± 0.15 t ha^{-1}) suggests that planting 15 days after maize still allowed sufficient growth, though with slightly more competition for resources. In contrast, the V1 × S4 combination (0.94 ± 0.2 t ha^{-1}) recorded the lowest yield, likely due to the local variety’s poorer performance under delayed planting (45 days after maize), which could have resulted in increased competition for light and nutrients, limiting growth (Table 2) (Sahoo et al. 2023)

Table 2. Effect of sowing time of intercrop (cowpea), its variety, and their interaction on plant characters and yield related traits of cowpea

Treatment	NPP	PDL	NSP	STY
Cowpea variety (V)				
V1	11.85 ± 3.81 b	27.22 ± 2.39 b	14.83 ± 1.38	1.47 ± 0.5
V2	14.66 ± 3.11 a	36.09 ± 4.22 a	14.38 ± 2.58	1.55 ± 0.55
Sig. level	<0.05	<0.001	NS	NS
Cowpea sowing time (S)				
S1	16.48 ± 2.79 a	35.67 ± 6.94 a	16.57 ± 1.77 a	2.01 ± 0.12 a
S2	13.62 ± 3.11 ab	31.79 ± 4.24 ab	14.87 ± 1.39 ab	1.99 ± 0.18 a
S3	12.12 ± 3.69 ab	29.95 ± 4.77 b	14.03 ± 1.82 ab	1.09 ± 0.14 b
S4	10.8 ± 3.2 b	29.21 ± 5.25 b	12.96 ± 1.53 b	0.96 ± 0.17 b
Sig. level	<0.05	<0.01	<0.05	<0.001
Interaction (V × S)				
V1 × S1	14.85 ± 1.55	30.04 ± 0.96	16.52 ± 1.13	1.99 ± 0.13
V1 × S2	12.21 ± 3.51	28.28 ± 1.06	15 ± 0.43	1.87 ± 0.12
V1 × S3	10.6 ± 4.75	25.89 ± 1.39	14.31 ± 0.65	1.09 ± 0.17
V1 × S4	9.73 ± 4.46	24.67 ± 1.18	13.51 ± 1.09	0.94 ± 0.2
V2 × S1	18.11 ± 3.01	41.29 ± 4.94	16.62 ± 2.56	2.03 ± 0.14
V2 × S2	15.04 ± 2.42	35.3 ± 2.59	14.73 ± 2.14	2.1 ± 0.15
V2 × S3	13.63 ± 2.14	34.02 ± 2.3	13.75 ± 2.76	1.08 ± 0.13
V2 × S4	11.86 ± 1.55	33.75 ± 2.35	12.42 ± 1.95	0.99 ± 0.17
Sig. level	NS	NS	NS	NS
CV (%)	23.72	7.68	12.25	10.14

Here, V1: Local cowpea variety, V2: Japanese cultivar; S1: Cowpea sown simultaneously with maize, S2: Cowpea sown 15days after sowing maize, S3: Cowpea sown 30 days after sown maize, S4: Cowpea sown 45 days after sowing maize, NPP: No. of podsplant-1, PDL: Pod length (cm), NSP: No. of seeds pod-1, STY: Stover yield (t ha-1); values are mean ± standard deviation. NS: Non-significant

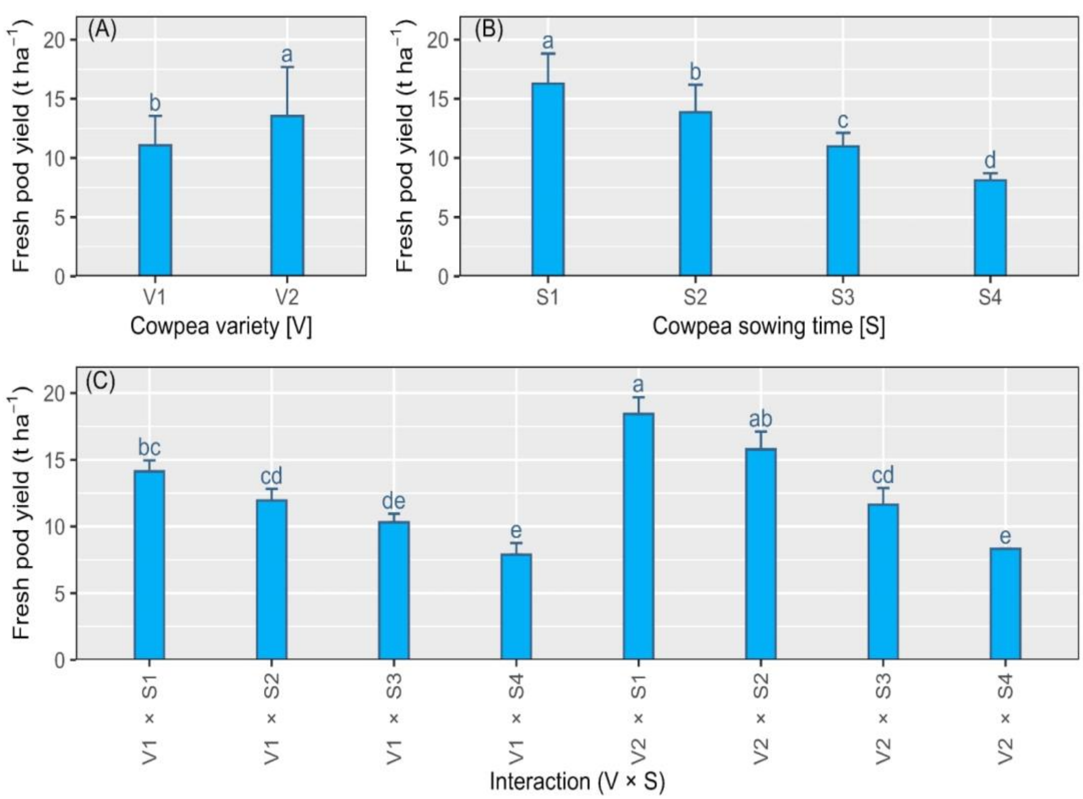

Figure 3. Effect of sowing time of intercrop (cowpea), its variety, and their interaction on Stover yield of cowpea. Here, V1: Local cowpea variety, V2: Japanese cultivar; S1: Cowpea sown simultaneously with maize, S2: Cowpea sown 15 days after sowing maize, S3: Cowpea sown 30 days after sowing maize, S4: Cowpea sown 45 days after sowing maize

4. Conclusion

The study demonstrates that while the maize component of the intercropping system remains unaffected by cowpea variety and sowing date, cowpea performance is significantly influenced by both factors. The Japanese cowpea variety (V2) exhibited superior growth and yield traits compared to the local variety. Among the sowing treatments, simultaneous planting of cowpea with maize (S1) proved most effective, resulting in the highest fresh pod and stover yields, as well as improved pod and seed characteristics. Delayed sowing (S4) consistently produced the poorest results. Therefore, for optimal productivity in a maize–cowpea intercropping system, simultaneous sowing using the Japanese cultivar is recommended.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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