agronomy

MDPI

Article

Maximizing Land Use Efficiency and Productivity of Soybean and Fodder Maize Intercrops through Manipulating Sowing Schedule and Maize Harvest Regime

Heba S. A. Salama * and **Mahmoud H. Abdel-Moneim**

Crop Science Department, Faculty of Agriculture (EL-Shatby), Alexandria University, Alexandria 21545, Egypt; mahmoudh3884@gmail.com

* Correspondence: heba.salama@alexu.edu.eg

Abstract: The incorporation of both food and forage crops in an intercropping system is receiving increasing attention, especially in developing countries with increasing populations and limited resources. In a two-year (2019–2020) field trial, conducted in Northern Egypt, productivity of soybean and fodder maize, as well as the quality of maize herbage, were investigated under three sowing schedules; soybean and maize sown together, and maize sown 15 and 30 days after soybean, in addition to soybean and fodder maize sown in pure stands, with maize harvested at green fodder maturity (GFM), and silage maturity (SM). Harvesting fodder maize at SM resulted in higher herbage yield than harvesting it at GFM, yet it negatively affected the soybean productivity. However, this negative impact was offset when fodder maize sowing was delayed 30 days after soybean sowing. Maize harvested at GFM was characterized by a higher leaf component, which was reflected in its higher crude protein content, yet the decline in quality with advanced maturity was to a great extent, counterbalanced by the presence of high-quality ears in maize harvested at SM. This was clear in its lower fiber and higher non-fiber carbohydrate contents. Land equivalent ratio (LER) demonstrated yield advantage with the delayed sowing of fodder maize (LER > 1), while the dry matter equivalent ratio (DMER) associated the yield advantage with the late harvesting of fodder maize at SM (DMER > 1), across all sowing schedules, which was more realistic for an additive intercropping model where the dry matter is the economic component. In a soybean-fodder maize intercropping system, whether fodder maize will be cultivated for green feeding or for silage production, it is recommended that sowing is delayed until 30 days after the soybean, in order to maximize yield advantage and land use efficiency.

Keywords: intercropping; soybean; fodder maize; maturity stage; sowing schedule; land equivalent ratio; dry matter equivalent ratio

Citation: Salama, H.S.A.; Abdel-Moneim, M.H. Maximizing Land Use Efficiency and Productivity of Soybean and Fodder Maize Intercrops through Manipulating Sowing Schedule and Maize Harvest Regime. *Agronomy* **2021**, *11*, 863. https://doi.org/10.3390/agronomy11050863

Academic Editors: Umberto Anastasi and Aurelio Scavo

Received: 4 April 2021
Accepted: 25 April 2021
Published: 28 April 2021

1. Introduction

The agricultural systems in developing countries are, nowadays, striving to reach sustainability in food production and food security under the existing high population pressure. Intercropping is a farming system, where two or more crops are cultivated together in the same field for a significant period of time during the growing season, even though the component crops are not necessarily sown or harvested simultaneously. It is one of the vital practices widely proposed to improve productivity and land use efficiency, especially in developing countries suffering from limited arable land and restricted agricultural inputs [1]. This is usually achieved by increasing the resource use efficiency [2].

Due to the pressing needs of the increasing populations, there has been escalating interest in the incorporation of both food and forage crops in the same farming system. Therefore, intercropping soybean (*Glycine max* [L.] Merr.), as a prominent oil crop, with fodder maize (*Zea mays* L.), as principle forage crop, increases the overall benefit from the farming practice, especially in the low input agricultural systems of the developing countries [3]. In a soybean-maize intercropping system, soybean can secure sufficient amounts of nitrogen through biological N fixation, thereby, enhancing soil quality [4]. There is evidence that nodulation and nodule longevity of soybean is generally improved in a soybean-maize intercropping system due to the improved microclimate that favors the growth of the nodular bacteria, in addition to the stimulation effect caused by the exudates produced from maize roots [4,5]. This will be positively reflected on the growth and productivity of both crops allowing them to mutually benefit from the intercropping system [3]. Soybean-maize intercropping is also encouraged in areas with limited water resources, like Egypt and other developing countries, due to its water-saving abilities [6]. This is mostly attributed to the root complementarity of both crops that increases their ability to capture soil water at different depths [7].

Previous studies have documented that maize is likely to dominate the soybean-maize intercropping system due to its higher competitive ability and relatively rapid initial growth [8], which suppresses the growth of soybean, especially when both crops are sown at the same time [9]. The early growth of the intercropped species is very important in determining their competitive abilities, which is reflected in their growth dynamics and final productivity [10]. Therefore, the interspecific competition between the intercrop components can be manipulated by adjusting the sowing schedule, i.e., varying the sowing dates of the different species (sometimes known as relay intercropping). This mechanism is expected to provide an advantage to the first sown crop by increasing its competitiveness, and thus, vigor [11]. Hence, achieving the maximum benefit from the soybean-maize intercropping system would be feasible only with the proper management of the intercropping component crops, especially in terms of sowing and harvesting adjustment, which would minimize competition and ensure complementarity in resources' utilization [12,13]. Many attempts were made to maximize the land use efficiency and productivity of intercropped soybean and maize by manipulating the row spacing [14,15], or sowing pattern and planting structure [4,5,9,16,17]. However, the variations in soybean and fodder maize productivity when different sowing/harvesting schedules are adopted is not yet exploited.

This study aimed at developing guidelines for intercropping soybean with fodder maize in Northern regions of Egypt, characterized by their arid Mediterranean climate. The main goal of the study was to develop practical recommendations about the appropriate sowing schedule for both crops in combination with the best harvest regime at which fodder maize should be removed in order to achieve optimum balance between soybean seed yield on the one hand and maize herbage productivity and quality on the other hand. It was hypothesized that consecutive sowing of both crops would interact with harvesting fodder maize at different stages of maturity in a way that alters the competition between the two crops. This would positively enhance their productivity and improve the land use efficiency. In this study, productivity of soybean and fodder maize, in addition to quality of maize herbage were investigated under variable sowing schedules, and maize harvest regimes. Land use efficiency and yield gain were also evaluated using the dry matter equivalent ratio (DMER), compared to the traditional land equivalent ratio (LER).

2. Materials and Methods

2.1. Field Trial

A two-year field trial was conducted at the experimental station of the Faculty of Agriculture, Alexandria University, Alexandria, Egypt (31°20′ N, 30° E), during 2019 and 2020 summer seasons. Texture of the experimental soil was sandy loam (54% sand, 30% silt, and 16% clay), with pH 8.15, 1.30 dS m^{-1} electrical conductivity, and 7.50% $CaCO_3$. The top 25 cm of soil contained 1.50% organic matter and 100, 4.80, and 290 mg kg^{-1} available N, P, and K, respectively. The experimental location is characterized by its hot, arid Mediterranean climate with zero precipitation during the summer season. Average monthly temperature and humidity during both experimental seasons are illustrated in Figures 1 and 2, respectively.

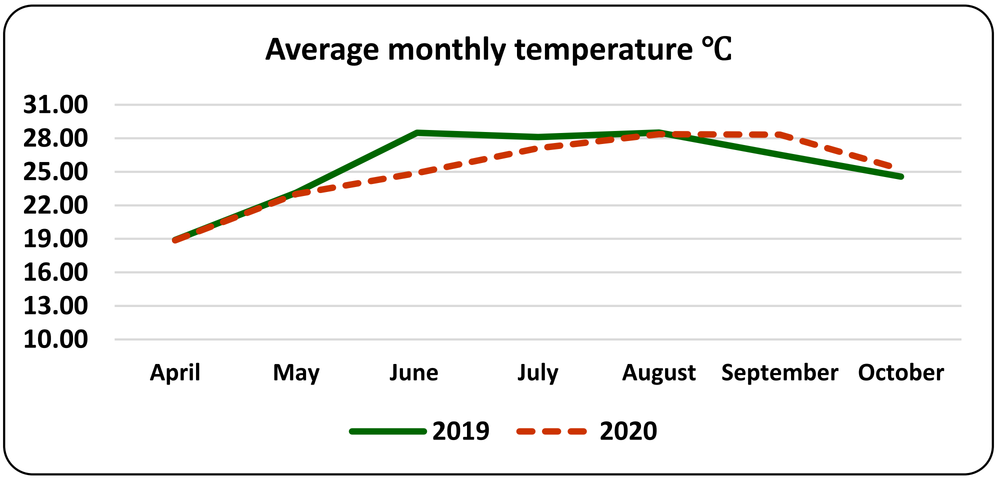

Figure 1. Average monthly temperature (°C) of the experimental site during summers 2019 and 2020.

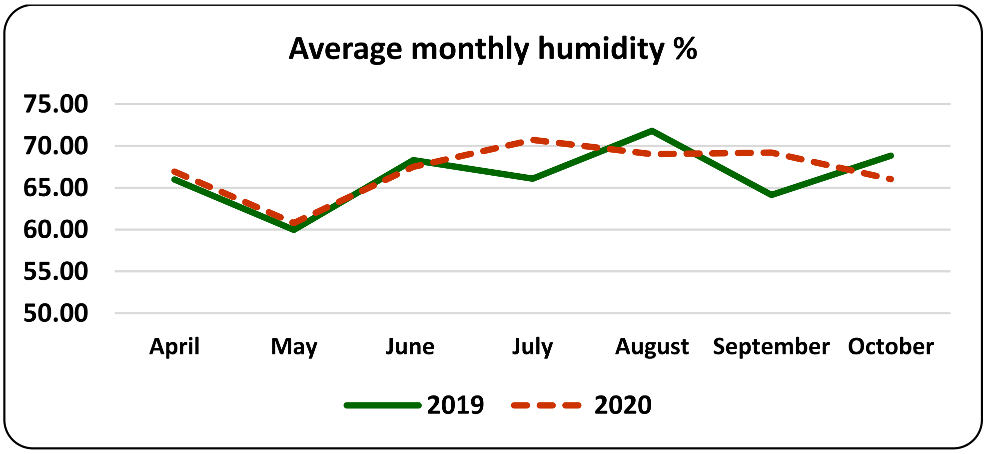

Figure 2. Average monthly humidity (%) of the experimental site during summers 2019 and 2020.

Soil preparation included plowing, disking, levelling and, finally dividing into experimental plots. Each experimental plot consisted of two adjacent wide beds, 60 cm apart. Each wide bed was 200 cm long and 120 cm wide, resulting in a total plot area of 6 m^2. On each wide bed, two border rows of maize, and three rows of soybean were sown at 30 cm intra-row spacing (Figure 3). A distance of 60 cm was left between each two experimental plots. Two seeds of the soybean and maize intercrops were sown in hills 15 and 30 cm apart, respectively. This sowing pattern was followed to maintain 75% plant density for soybean, in addition to 50% plant density for maize, in an additive intercropping model. Pure soybean and fodder maize stands were established during both seasons and were sown to 100% plant density for both crops.

A split-plot experimental design with four replications was employed, with the main plots assigned to the sowing schedule; 1. SS1: Soybean and maize sown together, 2. SS2: Maize sown 15 days after soybean, 3. SS3: Maize sown 30 days after soybean. 4. Pure stands of soybean and fodder maize. Sub-plots were dedicated to maize harvest regime; 1. HR1: Green fodder maturity (55 DAS), 2. HR2: Silage maturity (100 DAS). In both seasons, the maize three-way hybrid 368 and soybean cultivar Giza 111 were used. Soybean sowing was performed on 1 May and 20 April during 2019, and 2020, respectively, while maize sowing was done according to the investigated sowing schedules. Plant thinning was performed 21 days after sowing (DAS), by leaving 1 and 2 plants per hill for maize and soybean, respectively. To maintain adequate soil moisture and avoid induced drought stress, surface irrigation was scheduled on weekly basis. Based on the official recommendations of soybean and fodder maize production in the region, an amount of 200 kg ha^{-1} calcium monophosphate (15.5% P_2O_5) was applied once with seedbed preparation. In addition, a total amount of 144 kg N ha^{-1}, in the form of ammonium nitrate was split into three equal doses and applied with sowing of soybean (side-banded), then after 30 and 60 days (top dressing). The experimental plots were sprayed with 720 g Lannate ($C_5H_{10}N_2O_2S$) dissolved in 480 L water ha^{-1}, 30 days after maize sowing to protect against maize stem borers, while, weeds were hand-hoed when necessary.

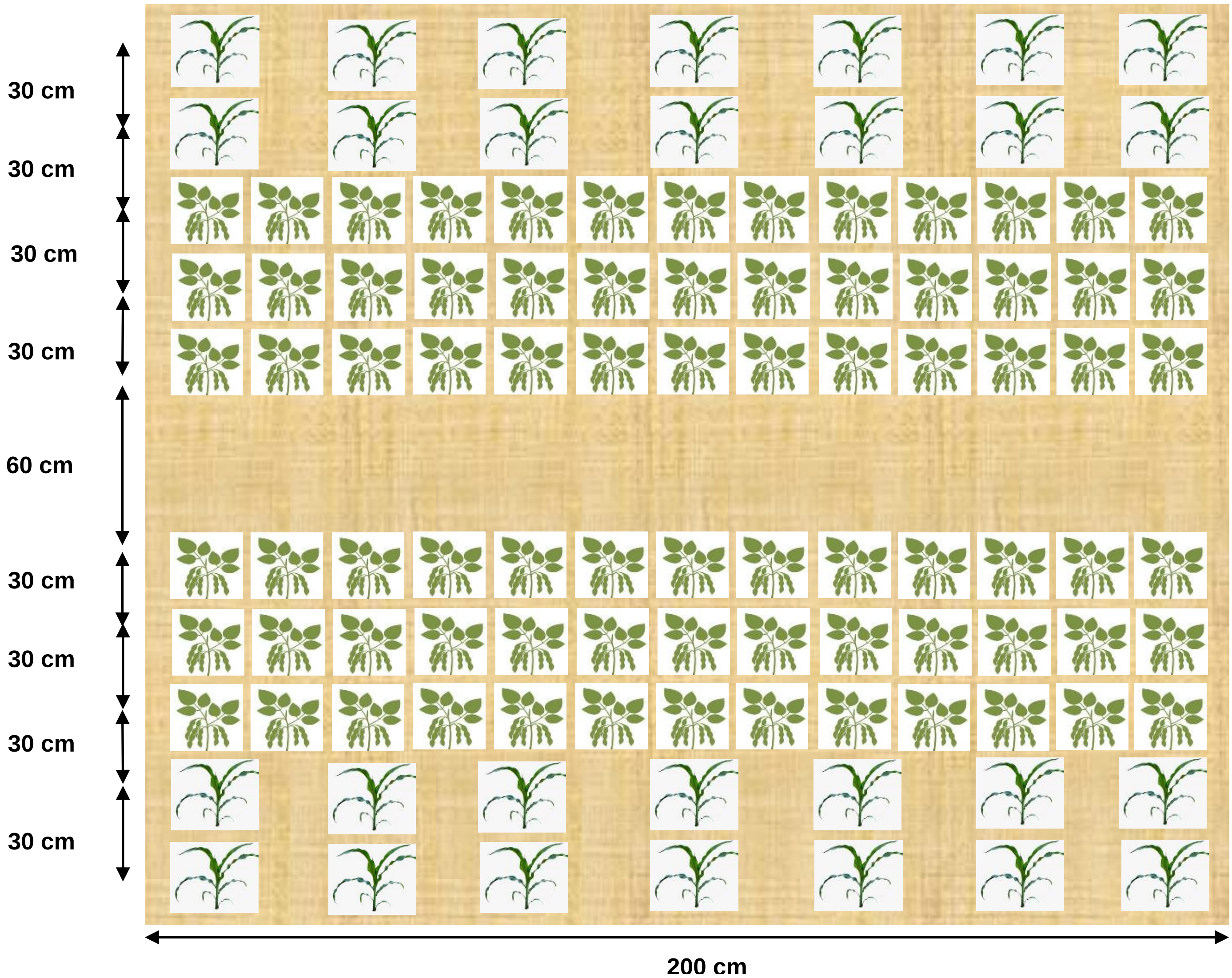

Figure 3. Experimental plot design illustrating the sowing pattern of the soybean and fodder maize on two adjacent wide beds.

2.2. Sampling and Measurements:

Maize was harvested at green fodder and silage maturity stages. Harvesting of green fodder maize was done after 55 DAS, which was supposed to provide the optimum balance between yield and fodder quality for green feeding as concluded in a previous study [18]. On the other hand, silage maturity was identified by the 1/2 milk line stage, which is considered to attain high silage nutritional quality [19]; this stage was reached at 100 DAS for the investigated cultivar. At harvesting, stalks were manually cut directly above ground level, and fresh matter yield (FMY) per plot was weighed immediately in the field. Plant height (cm), stem diameter (mm), plant weight (g), and leaf, stem and ear percentages, were determined as an average of five randomly chosen plants from each plot. To determine dry matter content (DMC) of the plant material, a subsample of approximately 1 kg was taken from each plot and oven-dried at 60 °C to constant weight. The dry matter yield (DMY) per plot was estimated based on the FMY and the DMC of the subsample. Prior to soybean harvesting, plant height was measured from the soil surface to the uppermost node with at least one pod, for 5 random plants from each plot. Plots were manually harvested and fresh biological yield (FBY) was weighed in the field; after that plants per plots were left to air-dry until constant weight was reached to determine the dry biological yield (DBY). Soybean plants were manually threshed and seeds were weighed to determine seed yield (t ha^{-1}) and then sieved to remove seed splits. Harvest index was calculated as seed yield divided by FBY and expressed as percentage. The 100-seed weight (g) was determined as an average of three random seed samples taken from each plot.

2.3. Laboratory Analyses

For maize quality analyses, the dried subsamples were milled to a 1 mm particle size. The contents of neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were sequentially determined using ANKOM^{200} Fiber analyzer (ANKOM Technology, Macedon, NY, USA) as described by [20]. The nitrogen (N) content was analyzed using the Kjeldahl procedure [21], then crude protein (CP) was calculated as N × 6.25. The crude ash (CA) content was determined by incinerating the samples in a muffle oven at 550 °C for 3 h [21]. The crude fat (CF) content in maize samples and oil content in soybean seed samples were determined using the Soxhlet procedure [21]. Non-fiber carbohydrates (NFC) content (g kg^{-1}) was calculated as follows:

$$NFC = 1000 - (CP + CF + NDF + CA). \tag{1}$$

2.4. Land Use Efficiency and Yield Advantage

Land equivalent ratio (LER): Determined as the sum of the fractions of the fresh biological yield (t ha^{-1}) of soybean and maize intercrops relative to their sole crop yields [22,23]:

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}. \tag{2}$$

where, *Yab* is yield of soybean "*a*" intercropped with maize "*b*", *Yaa* is pure stand yield of soybean "*a*", *Yba* is yield of maize "*b*" intercropped with soybean "*a*", *Ybb* is pure stand yield of maize "*b*".

Dry matter equivalent ratio (DMER): Determined as the sum of the dry yield of the main soybean crop and the maize companion crop relative to the *DM* yield of the sole main soybean crop [24,25]:

$$DMER = \frac{DMYab + DMYba}{DMYaa}. \tag{3}$$

where *DMYab* is *DMY* of soybean "*a*" intercropped with maize "*b*", *DMYba* is *DMY* of maize "*b*" intercropped with soybean "*a*", *DMYaa* is pure stand *DMY* of soybean "*a*".

2.5. Statistical Analyses

Analysis of variance (ANOVA) was conducted using Proc Mixed of SAS 9.4 [26], with only replicates considered random. The investigated variables (*V*) were analysed according to the following model:

$$V_{ijk} = \mu + R_i + SS_j + (R \times SS)_{ij} + HR_k + (SS \times HR)_{jk} + e_{ijk} \tag{4}$$

where μ is the overall mean, R_i is the replication (i = 1,2,3,4), SS_j is the sowing schedule effect (j = 1,2,3,4), $(R \times SS)_{ij}$ is the experimental error "a", HR_k is the maize harvest regime effect (k = 1,2), $(SS \times HR)_{ij}$ is the effect of the interaction between the sowing schedule and maize harvest regime, and e_{ijk} is the experimental error "b". The crop was not considered as an experimental factor, and the statistical analysis was conducted separately for each crop.

Data were presented in a combined analysis for the two growing seasons (2019 and 2020) upon homogeneity of variance's error [27]. Prior to the statistical analysis of the data, the harvest index was arcsine transformed and expressed as percentage. Mean comparisons were made using the least significant difference (L.S.D) procedure, with significances declared at $p < 0.05$.

3. Results

The main effects of sowing schedule and maize harvest regime will be presented and discussed only when their interaction is not significant.

3.1. Performance of Fodder Maize

The SS exerted a significant influence on fodder maize FMY, DMY, DMC, stem diameter and plant weight, which were all, in addition to plant height, significantly affected by the maize HR and by the interaction between the SS and HR (Table 1). The means presented in Table 2 revealed that harvesting maize at SM caused a significant increase in the above-mentioned parameters, except for the stem diameter, compared to harvesting at GFM. Obviously, maize harvested at SM produced highest significant FMY and DMY with the highest significant accumulated DMC, as well as the tallest and heaviest significant plants, with the least significant stem diameter except for SS2.

Table 1. p values for fresh matter yield (FMY), dry matter yield (DMY) as t ha^{-1}, dry matter content (DMC) as g kg^{-1}, plant height (cm), stem diameter (mm), and plant weight (g) for fodder maize, combined over 2019 and 2020 growing seasons.

S.O.V.	D.F.	FMY	DMY	DMC	Plant Height	Stem Diameter	Plant Weight
SS	3	<0.0001	<0.0001	0.0380	0.1398	0.0073	0.0278
HR	1	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SS * HR	3	<0.0001	<0.0001	0.0172	0.0001	0.0393	0.0150

S.O.V.: Source of variation, D.F.: Degrees of freedom, SS: Sowing schedule, HR: Harvest regime.

Table 2. Variations of the fresh matter yield (FMY), dry matter yield (DMY) as t ha^{-1}, dry matter content (DMC) as g kg^{-1}, plant height (cm), stem diameter (mm), and plant weight (g) for fodder maize, as affected by the interaction between sowing schedule (SS) and maize harvest regime (GFM and SM).

Treatment	FMY		DMY		DMC	
	GFM	SM	GFM	SM	GFM	SM
SS1	9.15 bB	49.95 aC	1.01 bA	17.12 aC	110.89 bA	343.67 aB
SS2	11.67 bB	39.32 aD	1.20 bA	17.63 aC	103.29 bA	447.41 aA
SS3	9.69 bB	66.03 aB	1.01 bA	28.07 aB	107.49 bA	423.74 aA
Pure	20.32 bA	88.40 aA	2.28 bA	32.17 aA	112.37 bA	363.59 aB
Treatment	**Plant height**		**Stem diameter**		**Plant weight**	
	GFM	**SM**	**GFM**	**SM**	**GFM**	**SM**
SS1	128.00 bB	259.83 aAB	24.42 aAB	16.03 bB	224.17 bB	1021.50 aA
SS2	102.08 bC	273.84 aA	22.43 aB	21.19 aA	154.17 bC	1233.83 aA
SS3	158.34 bA	246.25 aB	28.33 aA	20.78 bA	388.75 bA	979.17 aAB
Pure	131.33 bB	265.42 aAB	23.50 aB	16.07 bB	211.70 bB	608.14 aB

Means followed by different small letter(s) within the same row, and different capital letter(s) within the same column, for each studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

At SM, the pure maize stands were significantly superior to the tested sowing schedules concerning the FMY and DMY, with 88.40, and 32.17 t ha^{-1}, respectively, followed by SS3, with the least amount of decrease reaching 25.31 and 12.74% for FMY, and DMY, respectively. The SS2 and SS3 produced significantly higher DMC than SS1 and the pure maize stands. Moreover, SS2 was significantly superior to SS3 concerning plant height, while SS2 and SS3 produced the highest significant values for stem diameter, and SS1 and SS2 resulted in the heaviest plants. On the other hand, when maize was harvested at GFM, all the tested sowing schedules accumulated significantly similar amounts of DMC to the maize pure stands, which ranged from 103.29 to 112.37 g kg^{-1}. This was reflected on the significantly similar amounts of DMY produced, despite that the pure stands were characterized by the highest significant amount of FMY amounting to 20.32 t ha^{-1}. Nonetheless, when harvesting was done at GFM, SS3 was significantly superior to the other sowing schedules and to the maize pure stands, concerning plant height and weight and stem diameter.

Analysis of the variations in leaf, stem and ear% of fodder maize, in addition to its quality in terms of CP, fiber fractions (NDF, ADF, and ADL), and NFC, revealed that all the tested parameters, except ear percentage and ADL, were significantly affected by the SS, while, leaf and stem%, and the tested quality parameters were significantly affected by the HR (Table 3). The interaction between the two studied factors non significantly affected all the parameters. The pure maize stands where characterized by the highest significant leaf% that was significantly similar to SS1 and SS2, while SS3 was characterized by the highest significant stem% (Table 4). No significant variation was detected among the three tested sowing schedules with regard to the ear%. Maize harvested at GFM consisted of only leaves and stems, while maize harvested at SM consisted of leaves, stems and ears. Comparing both harvesting regimes revealed that early harvesting at GFM produced more leaves and stems than late harvesting at SM.

Table 3. *p* values for leaf, stem and ear percentages, crude protein (CP), fiber fractions (NDF, ADF, ADL) and non-fiber carbohydrates (NFC), expressed as g kg^{-1} for fodder maize, combined over 2019 and 2020 growing seasons.

S.O.V.	D.F.	Leaf%	Stem%	Ear%	CP	NDF	ADF	ADL	NFC
SS	3	0.0011	0.0466	0.9086	0.0331	0.0184	0.0006	0.6427	0.0016
HR	1	<0.0001	<0.0001	–	<0.0001	0.0047	<0.0001	<0.0001	<0.0001
SS * HR	3	0.0610	0.3258	–	0.2660	0.3494	0.0890	0.3564	<0.0001

S.O.V.: Source of variation, D.F.: Degrees of freedom, SS: Sowing schedule, HR: Harvest regime l.

Table 4. Variations of the leaf, stem and ear percentages, crude protein (CP), fiber fractions (NDF, ADF, ADL) and non-fiber carbohydrates (NFC) expressed as g kg^{-1} for fodder maize, as affected by the sowing schedule (SS) and maize harvest regime (GFM and SM).

Treatment	Leaf%	Stem%	Ear%	CP
Sowing schedule:				
SS1	28.30 ab	52.59 b	38.22 a	63.94 b
SS2	27.92 ab	53.41 ab	37.33 a	64.93 b
SS3	24.78 b	57.36 a	35.72 a	69.96 a
Pure	31.56 a	50.39 b	36.11 a	65.35 b
Maize harvest regime:				
GFM	40.45 a	59.55 a	-	74.65 a
SM	15.84 b	47.32 b	36.84	57.44 b
Treatment	**NDF**	**ADF**	**ADL**	**NFC**
Sowing schedule:				
SS1	618.85 a	284.05 a	40.95 a	180.97 b
SS2	617.34 a	277.49 a	40.15 a	182.74 b
SS3	613.21 a	290.88 a	41.70 a	188.08 ab
Pure	576.60 b	233.15 b	40.56 a	207.93 a
Maize harvest regime:				
GFM	622.14 a	295.51 a	47.54 a	135.65 b
SM	590.86 b	247.27 b	34.14 b	244.20 a

Means followed by different small letter(s) within the same studied factor for each parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

Regarding the fodder maize quality parameters, little, yet significant, variation was observed among the tested sowing schedules for the CP content, where SS3 was characterized by the highest significant CP content, amounting to around 7%, which was more than that produced from the pure stands, SS2 and SS1 by 0.5, 0.5, and 0.6%, respectively. On the other hand, a more pronounced variation was detected between the two maize harvest regimes, with harvesting at GFM producing around 7.5% CP, with 1.7% CP more than harvesting at SM. The three tested sowing schedules produced highest significant NDF and ADF contents compared to the maize pure stands, while no significant variation was detected for the ADL content. Similar to the CP content, harvesting at GFM produced highest significant amounts of the three fiber fractions than harvesting at SM. The difference between both harvest regimes amounted to 3.13, 4.82, and 1.34% for NDF, ADF, and ADL, respectively. The pure maize stands produced the highest significant NFC content followed by SS3, amounting to 207.93, and 188.08 g kg^{-1}, respectively. On the contrary, SS1 and SS2 were significantly inferior with 180.97, and 182.74 g kg^{-1}, respectively. As opposed to CP and fiber fractions, harvesting maize at GFM produced around half the amount of NFC that was produced when maize was harvested at SM, with 135.65 against 244.20 g kg^{-1} for GFM, and SM, respectively.

3.2. Performance of Soybean

Soybean fresh biological yield (FBY), dry biological yield (DBY), seed yield, plant height and 100-seed weight were significantly affected by the SS and HR, while HI was only variable among the tested sowing schedules. Meanwhile, non-significant variations were detected for the seed oil content. The interaction between the two studied factors was significant only in case of soybean FBY, DBY and 100-seed weight (Table 5). Early harvesting of the companion maize crop at GFM was accompanied with the highest significant soybean FBY and DBY for SS1 and SS2, while for SS3 difference between the two maize harvest regimes was non-significant (Table 6). The highest significant soybean FBY and DBY were produced from the pure stands, amounting to 41.94, and 21.34 t ha^{-1}, respectively. When maize was removed at GFM, no significant variation was detected between SS2 and SS3, while both were superior to SS1 for soybean FBY and DBY. However, in case of maize harvesting at SM, SS3 produced much higher soybean FBY and DBY, than SS1 and SS2. The SS3 was higher than SS1 and SS2 by 114.71, and 61.00% for FBY, respectively, and 113.56, and 54.77% for DBY, respectively. Pure soybean stands were superior to all the tested treatments in the production of the highest 100-seed weight, amounting to 17.81 g. Meanwhile, the three tested sowing schedules resulted in significantly similar 100-seed weight, yet slightly, but significantly, lower than the pure stands. At SS2 and SS3, harvesting maize at GFM and SM produced soybean with significantly similar 100-seed weight, while at SS1, soybean with highest significant 100-seed weight was produced when maize was harvested at GFM than when it was harvested at SM. As shown in Table 7, the highest significant soybean seed yield was produced from the pure stands (4.45 t ha^{-1}), followed by SS2 and SS3, while the least significant seed yield resulted from SS1 (1.78 t ha^{-1}). The HI followed the same trend of the seed yield, with the highest HI recorded for the pure stands that was at par with SS2 and SS3, while SS1 produced the least HI, with 6.67% less than the pure stands. Similarly, SS1 was accompanied with the shortest significant soybean plants, compared to the other sowing schedules and pure stands. Seed oil content was non-significantly affected by the SS, and reached 203.24 g kg^{-1}, in average for the three tested sowing schedules, against 206.17 g kg^{-1} for the soybean pure stands. When maize was harvested at GFM, soybean produced the highest significant seed yield, with the tallest significant plants compared to maize harvesting at SM. While, HI and seed oil content were not significantly variable among the two harvest regimes.

Table 5. *p* values for fresh biological yield (FBY) and dry biological yield (DBY) as t ha^{-1}, seed yield (t ha^{-1}), harvest index (HI%), plant height (cm), 100-seed weight (g), and seed oil content (g kg^{-1}) for soybean, combined over 2019 and 2020 growing seasons.

S.O.V.	D.F.	FBY	DBY	Seed Yield	HI	Plant Height	100-Seed Weight	Oil Content
SS	3	<0.0001	<0.0001	<0.0001	0.0240	0.0073	0.0088	0.6050
HR	1	0.0002	0.0002	0.0180	0.6493	0.0065	0.0005	0.8418
SS * HR	3	0.0079	0.0040	0.3207	0.9133	0.3288	0.0280	0.6190

S.O.V.: Source of variation, D.F.: Degrees of freedom, SS: Sowing schedule, HR: Harvest regime.

Table 6. Variations of the fresh biological yield (FBY) and dry biological yield (DBY) as t ha^{-1}, 100-seed weight (g) for soybean, as affected by the interaction between sowing schedule (SS) and maize harvest regime (GFM and SM).

Treatment	FBY		DBY		100-Seed Weight	
	GFM	**SM**	**GFM**	**SM**	**GFM**	**SM**
SS1	21.49 aC	14.48 bD	9.87 aC	7.45 bD	16.89 aB	16.16 bB
SS2	32.24 aB	19.31 bC	16.51 aB	10.28 bC	16.88 aB	16.81 aB
SS3	33.10 aB	31.09 aB	16.83 aB	15.91 aB	16.39 aB	16.63 aB
Pure	41.94 A	41.94 A	21.34 A	21.34 A	17.81 A	17.81 A

Means followed by different small letter(s) within the same row, and different capital letter(s) within the same column, for each studied parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

Table 7. Variations of the seed yield (t ha^{-1}), harvest index (HI%), plant height (cm), and seed oil content (g kg^{-1}) of soybean, as affected by the sowing schedule (SS) and maize harvest regime (GFM and SM).

Treatment	Seed Yield	HI	Plant Height	Oil Content
Sowing schedule:				
SS1	1.78 c	14.11 b	82.42 b	202.39 a
SS2	2.45 bc	18.87 ab	90.61 a	203.46 a
SS3	3.14 b	19.05 ab	92.50 a	203.87 a
Pure	4.45 a	20.78 a	97.29 a	206.17 a
Maize harvest regime:				
GFM	3.27 a	18.65 a	94.69 a	204.18 a
SM	2.64 b	17.75 a	86.72 b	203.77 a

Means followed by different small letter(s) within the same studied factor for each parameter, are significantly different according to the L.S.D. test at 0.05 level of probability.

3.3. Land Use Efficiency and Yield Advantage

Data of LER, presented in Table 8 and Figure 4, indicated that late sowing of fodder maize, in general, had a positive impact on land use resulting in a clear yield advantage. LER values for sowing fodder maize 15 days after soybean was 1.32 and 1.00, when harvesting was done at GFM, and SM, respectively. While, sowing maize 30 days after soybean resulted in LER values of 1.27 and 1.49 for the two respective fodder maize harvesting regimes. Determining the yield gain in terms of DMER (Table 8, Figure 4), showed an advantage only when fodder maize was harvested at SM associated with the three sowing schedules, while harvesting at GFM was accompanied with DMER values less than 1. Even though harvesting at SM caused a clear dry matter yield gain, the values of DMER progressively increased with later sowing of fodder maize, with the highest value (2.06) reached when fodder maize was sown 30 days after soybean and harvested at SM, indicating around 200% gain in the dry matter yield of the intercropping system compared to sole cropping of both crops. On the other hand, harvesting fodder maize at GFM resulted in a clear loss in the dry matter yield (DMER < 1), across all sowing schedules, with the most severe loss occurring when both crops were sown together at the same time (DMER = 0.51).

Table 8. Relative yields of the main soybean crop (La) and the companion fodder maize crop (Lb), land equivalent ratio (LER), and dry matter equivalent ratio (DMER) for the tested sowing schedules (SS) and maize harvest regimes (GFM and SM).

Sowing Schedule	Maize Harvest Regime	La	Lb	LER	DMER
SS1	GFM	0.51	0.45	0.96	0.51
	SM	0.35	0.57	0.92	1.15
SS2	GFM	0.74	0.57	1.31	0.83
	SM	0.56	0.44	1.00	1.31
SS3	GFM	0.79	0.48	1.27	0.84
	SM	0.74	0.75	1.49	2.06

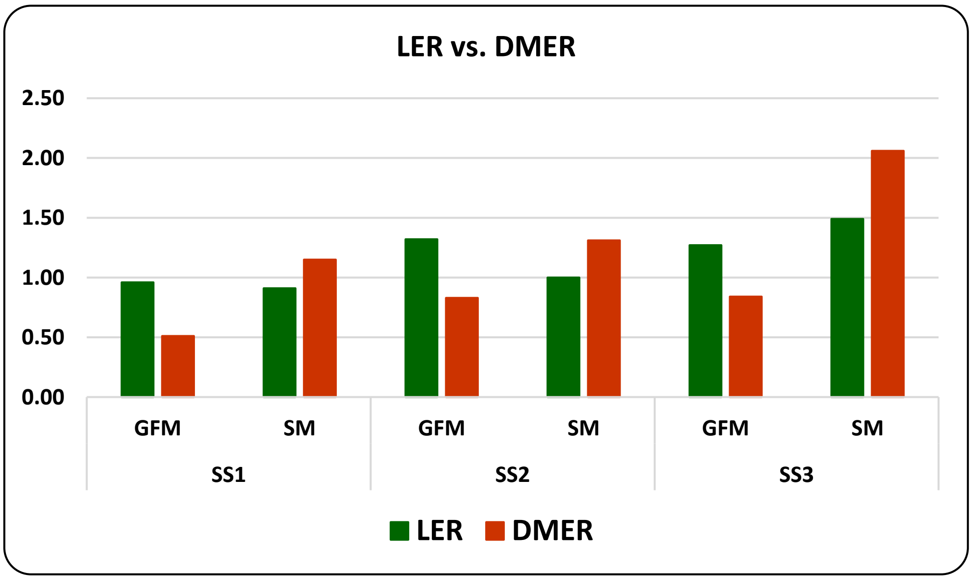

Figure 4. Variations in land equivalent ratio (LER) and dry matter equivalent ratio (DMER) in response to the tested sowing schedules (SS) and maize harvest regimes (GFM and SM).

4. Discussion

In an intercropping system, the best productivity from the component crops could be achieved if they vary in their growth duration so that their peak demand for growth resources can be reached at different periods [7,12]. The critical periods of yield definition for soybean and fodder maize occur usually at different timings along the growing season. Therefore, it is necessary to minimize the competition between both crops during these critical periods, which could be achieved by shifting the sowing/harvesting schedules of one or both crops.

The evaluated sowing schedules, in the current study, exerted a pronounced influence on the soybean and fodder maize performances, that was significantly dependent on the two tested maize harvest regimes. A stronger effect for the sowing schedule on both crops was observed when the fodder maize companion crop was harvested at SM, than when it was harvested at GFM. This was probably because harvesting fodder maize at SM acquired longer existence of maize crop neighboring soybean than harvesting it at GFM, which entailed longer period of interspecific competition between both crops. Meanwhile, each of the two crops showed different response to the sowing/harvesting treatments. While, fodder maize, harvested at SM, produced significantly higher fresh yield with higher dry matter content, resulting in higher dry matter yield than that harvested at GFM, an opposite impact was detected on soybean fresh, dry and seed yields.

A deep insight into the growth dynamics of both crops would help to explain their responses to the treatments. According to [28], the critical period of pod development and seed setting in soybean occurs between R4 and R7, which usually lasts for around 42 days in average approaching the end of the crop's growth cycle. Therefore, early harvesting of fodder maize at GFM terminates the competition between both crops before the beginning of the critical reproductive period of soybean. In addition, harvesting the fodder maize long before the canopy of the soybean matures permits light and air through the understory, which will be reflected on a healthier soybean canopy [7]. In similar studies, soybean plants were able to exhibit fast recovery growth after maize crop was harvested with good compensation to the previous severe competition that occurred during the intercropping period [29].

On the other hand, late harvesting of fodder maize at SM provides a longer period of competition between both crops during the soybean's critical period of development, which will not be in favor of the legume crop. In agreement with the current results [4], the differences in yield of soybean intercropped with maize were attributed to the stage of maturity of the maize companion crop. Cereals are generally characterized by vigorous plants with higher growth rates than legumes, thus, they often suppress the growth of accompanying legumes when intercropped together [13]. This was true for many legume-cereal intercropping systems, like soybean-maize and soybean-sorghum [30,31]. In their study of intercropping soybean and maize using variable patterns, the authors in [17] concluded that intercropping stimulated the growth of maize, which was negatively reflected on the growth of the accompanying soybean. In a similar soybean-maize intercropping system, the authors in [32] reported that fodder maize will be ready for harvesting and ensiling, while soybean is in the R7 developmental stage.

In addition to the vigorous growth nature of maize compared to soybean, the sowing pattern followed to establish the intercropping stands in the current study was in favor of fodder maize crop. Sowing fodder maize on the adjacent borders of the plots allowed it to benefit from the border-row effect [3,13,16,29] that was believed to increase sunlight capture by plants and improve photosynthesis [5], in addition to the use of the optimal intercropping arrangement of four maize rows: six soybean rows as recommended by [5]. This explains the vigorous growth and enhanced productivity of fodder maize achieved in the current study.

The negative impact of late harvesting of the companion fodder maize at SM on soybean crop was clearly offset by manipulating the sowing schedule of the companion crop. The worst impact on the productivity of both crops was achieved when they were sown together. It is well-known that the early growth of the intercrop component crops is very crucial in determining the competition dynamics between them [10]. Therefore, sowing both crops at the same time allowed the competition to begin very early in the season [7], negatively impacting both crops, with heavier impact on the legume component. This was clearly indicated by the significantly lowest soybean seed yield and HI. It was observed that late sowing of fodder maize, resulted in a soybean HI similar to that obtained from the soybean pure stands. While, sowing both crops together significantly decreased soybean HI, probably because the high competition associated with sowing both crops together at the same time significantly suppressed the ability of the soybean plant to convert the photosynthetic assimilates into the economic component, i.e., seed yield. In addition, the shortest soybean plants were produced when both crops were sown together, probably due to the high shading of the fast-growing fodder maize crop, reducing the light intensity reaching the lower soybean canopy, which resulted in stunted plants. In partial agreement with the current results, [33] reported that most soybean cultivars that grow under shade, induced by a taller neighbor plant like maize, exhibit yield reductions. They added, however, that, unlike the current study, shade might enhance stem elongation of soybean and, consequently increase the risk of lodging. On the other hand, delayed sowing of fodder maize allowed the establishment of soybean crop, increasing its competitiveness for when fodder maize was introduced. The best results arising from soybean and fodder maize yields were achieved when fodder maize was sown 30 days after soybean. Soybean plants at 30 DAS were in the third/fourth node developmental stage (V3/V4), thus, plants have already fully developed leaves beginning with the uni-foliolate nodes [28], in addition to the well-developed tap-root system, and are therefore, able to withstand the high competition associated with the introduction of fodder maize crop. Noticeably, the delayed sowing of fodder maize to 30 days after soybean sowing had also a better impact on the fodder maize fresh and dry matter yields, especially when it was harvested at SM. This result suggests that this consecutive sowing schedule ensured complementarity in resource-use in time driven by the different growth periods of both crops [29]. Yet, this delayed sowing of fodder maize resulted in taller maize plants, especially at early growth stages, probably because sowing maize 30 days after soybean (S3) encouraged the plant to strive for solar radiation by increasing stem elongation. This was clearly reflected on taller maize plants cut at GFM. On the other hand, later in the season, the speed of stem elongation slows down, ending up with maize sown early in the season (S1 and S2) and cut at SM having taller stems than late sown maize (S3).

In relation to the quality of the produced maize forage, it was observed that early harvested maize at GFM was characterized by higher significant CP content than late harvested maize at SM [34], which was directly proportional to the leaf component of the crop. Nonetheless, despite the lower leaf component of maize harvested at SM, it was characterized by the lowest significant fiber content (NDF, ADF, ADL) and highest significant NFC content. This might be attributed to the contribution of the ear to the resulting forage material, where the reduction in quality of the plant with advanced maturity is to a great extent compensated by the high quality ears [35,36]. During growth of the maize plant, carbohydrates are stored in the vegetative parts (leaves and stems) and whilst the plant is approaching maturity, the stored carbohydrates are translocated to the ear and deposited into the grains [37]. The importance of the maize grain content in determining its feeding value was well-documented in the early work of several researchers [38–41]. Little variation was detected for fodder maize quality among the evaluated sowing schedules, yet compared to the pure stands, intercropped maize was characterized with low leaf component and high stem component, especially with delayed fodder maize sowing. Maize in late sowing, was already surrounded with a 30 days old soybean canopy that obstructed light penetration into the newly emerging maize population and retarded its photosynthetic activity, resulting in the development of taller plants with smaller leaves and more stems. This was directly reflected on the higher NDF and ADF contents of the intercropped fodder maize compared to the pure stands. Meanwhile, intercropped fodder maize was characterized by higher CP content than pure maize. This result confirmed the ability of maize to benefit from the atmospheric fixed nitrogen by the soybean crop and convert it into higher protein content in the herbage [9].

In the present additive intercropping model, soybean and fodder maize were intercropped at 75% and 50% of the optimal plant densities, respectively, resulting in a total of 125% for both crops. It was, thus, obvious that the pure soybean and fodder maize stands, sown at the optimal (100%) plant density for each crop, were significantly more productive, compared to all the evaluated intercropping treatments, in terms of herbage and seed yields of fodder maize and soybean, respectively. These results agree with the findings of [15], who has reported higher yields for sole over intercropped soybean and maize. However, the analysis of land use efficiency and yield gain revealed that the LER values for the delayed sowing of fodder maize (15 or 30 days after sowing of soybean) were more than one, which indicated the advantage of intercropping soybean and fodder maize over the sole cropping of both crops. The maximum LER value (1.49) was obtained when fodder maize was sown 30 days after soybean and harvested at SM, indicating 49% yield gain over sole cropping. On the other hand, the lowest LER values were 0.91 and 0.96, achieved in case of sowing both crops together at the same time and harvesting fodder maize at GFM, and SM, respectively. In line with the current results, in experiments involving intercropping soybean and maize, high LER (more than one) were achieved [3,15,29,42]. The achieved yield gain in terms of high LER values could be attributed to the complementarity in utilization of above- and below-ground resources and farming inputs between the intercrop component crops [5], which was enhanced by the intercropping pattern used in the current study, by late sowing and harvesting of fodder maize. This intercropping model increased the overall resource use efficiency during the part of the growing season that was occupied by both crops together. Observing the relative yields of the two intercrops revealed that the high LER values were mainly caused by the high relative intercrop soybean yields, which confirms the assumption that the sowing schedules adopted in the current study were mostly in favor of the early sown (soybean) crop. Similarly, the authors in [3], in China, reported that soybean-maize intercropping significantly improved the productivity of soybean.

In addition to the LER, the DMER was used as a key index to gauge dry matter yield gain. A pronounced intercropping advantage in terms of high dry matter yield gain was observed when fodder maize was harvested at SM, noted by DMER values higher than one. This was attributed to the high dry matter contents (34% to 45%), reflected on high dry matter yields (17 to 28 t ha^{-1}) of fodder maize harvested at SM, compared to harvesting at GFM. Coupled with the previously reported advantage of late sowing of fodder maize, the highest DMER (around 200% dry matter yield gain) was reached when fodder maize was sown 30 days after soybean and harvested at SM. Therefore, as opposed to the LER, the productivity of the companion fodder maize crop was more important in determining the DMER than the productivity of the main soybean crop. This is due to the higher dry matter content of the fodder maize, especially when harvested at SM, in addition to the higher growth rate and competitive ability of maize as a cereal crop [15]. Nonetheless, several studies reported that land use efficiency and yield advantage were mainly caused by the subordinate rather than the dominant main crop [11,15]. Notably, the values of the DMER were more realistic in describing the yield gain of the intercropping system compared to sole cropping of both crops, than the LER, which confirms the assumptions raised by the authors in [2], that DMER is more adequate in determining the expected gain, in case of an additive intercropping model, especially in case of crops where the dry matter is the main economic component [43].

5. Conclusions

It has been demonstrated that the soybean-fodder maize additive intercropping practice might be beneficial for the low input agricultural systems of the developing countries. In the current study, the reduction in productivity of the main soybean crop, accompanied with late harvesting of fodder maize companion crop at silage maturity was counterbalanced with the delayed sowing of maize to 30 days after soybean. Late harvesting of fodder maize at silage maturity was not necessarily accompanied by reductions in herbage quality due to the presence of the high-quality ears. Although intercropping reduced the productivity of soybean and fodder maize compared to their pure stands, considering the LER revealed an intercropping advantage with the delayed sowing of fodder maize (LER > 1). On the other hand, the dry matter equivalent ratio (DMER) associated the yield advantage with the late harvesting of fodder maize at SM (DMER > 1), across all sowing schedules, which was more realistic for an additive intercropping model where the dry matter is the economic component. In a soybean-fodder maize intercropping system, whether fodder maize will be cultivated for green feeding or for silage production, it is recommended to delay its sowing to 30 days after soybean in order to maximize yield advantage and land use efficiency.

Author Contributions: Conceptualization, H.S.A.S.; methodology and investigation, H.S.A.S. and M.H.A.-M.; resources, H.S.A.S. and M.H.A.-M.; laboratory analyses, H.S.A.S.; data collection and statistical analysis, H.S.A.S. and M.H.A.-M.; writing—original draft preparation, H.S.A.S. and M.H.A.-M.; writing—review and editing, H.S.A.S. and M.H.A.-M.; supervision, H.S.A.S.; project administration, H.S.A.S. and M.H.A.-M.; funding acquisition, H.S.A.S. and M.H.A.-M. Both authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

SS	Sowing schedule
HR	Harvest regime
GFM	Green fodder maturity
SM	Silage maturity
FMY	Fresh matter yield
DMY	Dry matter yield
DMC	Dry matter content
CP	Crude protein
NDF	Neutral detergent fiber
ADF	Acid detergent fiber
ADL	Acid detergent lignin
NFC	Non-fiber carbohydrates
FBY	Fresh biological yield
DBY	Dry biological yield
HI	Harvest index

References

1. Salama, H.S.A.; Khalil, H.E.; Nawar, A.I. Utilization of thinned sunflower and soybean intercrops as forage: A useful strategy for small scale farms in intensive agricultural systems. *Int. J. Plant Prod.* **2020**, *14*, 487–499. [CrossRef]
2. Nawar, A.I.; Salama, H.S.A.; Khalil, H.E. Additive intercropping of sunflower and soybean to improve yield and land use efficiency: Effect of thinning interval and nitrogen fertilization. *Chil. J. Agric. Res.* **2020**, *80*, 142–152. [CrossRef]
3. Du, J.B.; Han, T.F.; Gai, J.Y.; Yong, T.W.; Xin, S.U.N.; Wang, X.C.; Feng, Y.; Jiang, L.; Kai, S.; Liu, W.G.; et al. Maize-soybean strip intercropping: Achieved a balance between high productivity and sustainability. *J. Integr. Agric.* **2018**, *17*, 747–754. [CrossRef]
4. Dolijanović, Ž.; Oljača, S.; Kovačević, D.; Simić, M.; Momirović, N.; Jovanović, Ž. Dependence of the productivity of maize and soybean intercropping systems on hybrid type and plant arrangement pattern. *Genetika* **2013**, *45*, 135–144. [CrossRef]
5. Zhang, Y.; Liu, J.; Zhang, J.; Liu, H.; Liu, S.; Zhai, L.; Wang, H.; Lei, Q.; Ren, T.; Yin, C. Row ratios of intercropping maize and soybean can affect agronomic efficiency of the system and subsequent wheat. *PLoS ONE* **2015**, *10*, e0129245. [CrossRef]
6. Ouda, S.A.; El Mesiry, T.; Abdallah, E.F.; Gaballah, M.S. Effect of water stress on the yield of soybean and maize grown under different intercropping patterns. *Aust. J. Basic Appl. Sci.* **2007**, *1*, 578–585.
7. Dowling, A.; Sadras, V.O.; Roberts, P.; Doolette, A.; Zhou, Y.; Denton, M.D. Legume-oilseed intercropping in mechanised broadacre agriculture—A review. *Field Crops Res.* **2021**, *260*, 107980. [CrossRef]
8. Kitonyo, O.M.; Chemining'wa, G.N.; Muthomi, J.W. Productivity of farmer-preferred maize varieties intercropped with beans in semi-arid Kenya. *Int. J. Agron. Agric. Res.* **2013**, *3*, 6–16.
9. Htet, M.N.S.; Soomro, R.N. Effect of different planting structure of maize and soybean intercropping on fodder production and silage quality. *Curr. Agric. Res.* **2016**, *4*, 125. [CrossRef]
10. Tofinga, M.P.; Paolini, R.; Snaydon, R.W. A study of root and shoot interactions between cereals and peas in mixtures. *J. Agric. Sci.* **1993**, *120*, 13–24. [CrossRef]
11. Andrade, J.F.; Cerrudo, A.; Rizzalli, R.H.; Monzon, J.P. Sunflower–soybean intercrop productivity under different water conditions and sowing managements. *Agron. J.* **2012**, *104*, 1049–1055. [CrossRef]
12. Ijoyah, M.O. Review of intercropping research: Studies on cereal-vegetable based cropping system. *Sci. J. Crop Sci.* **2012**, *1*, 55–62.
13. Belel, M.D.; Halim, R.A.; Rafii, M.Y.; Saud, H.M. Intercropping of corn with some selected legumes for improved forage production: A review. *J. Agric. Sci.* **2014**, *6*, 48. [CrossRef]
14. Kim, J.; Song, Y.; Kim, D.W.; Fiaz, M.; Kwon, C.H. Evaluating different interrow distance between corn and soybean for optimum growth, production and nutritive value of intercropped forages. *J. Anim. Sci. Technol.* **2018**, *60*, 1–6. [CrossRef]
15. Kamara, A.Y.; Tofa, A.I.; Ademulegun, T.; Solomon, R.; Shehu, H.; Kamai, N.; Omoigui, L. Maize–soybean intercropping for sustainable intensification of cereal–legume cropping systems in northern Nigeria. *Exp. Agric.* **2019**, *55*, 73–87. [CrossRef]
16. Sánchez, D.G.R.; Silva, J.E.; Gil, A.P.; Corona, J.S.S.; Wong, J.A.C.; Mascorro, A.G. Forage yield and quality of intercropped corn and soybean in narrow strips. *Span. J. Agric. Res.* **2010**, *8*, 713–721. [CrossRef]
17. Ariel, C.E.; Eduardo, O.A.; Benito, G.E.; Lidia, G. Effects of two plant arrangements in corn (*Zea mays* L.) and soybean (*Glycine max* L. Merrill) intercropping on soil nitrogen and phosphorus status and growth of component crops at an Argentinean Argiudoll. *Am. J. Agric. For.* **2013**, *1*, 22–31. [CrossRef]

18. Salama, H.S.A. Yield and nutritive value of maize (*Zea mays* L.) forage as affected by plant density, sowing date and age at harvest. *Ital. J. Agron.* **2019**, *14*, 114–122. [CrossRef]
19. Bal, M.A.; Coors, J.G.; Shaver, R.D. Impact of the maturity of corn for use as silage in the diets of dairy cows on intake, digestion, and milk production. *J. Dairy Sci.* **1997**, *80*, 2497–2503. [CrossRef]
20. Van Soest, P.J.; Robertson, J.B.; Lewis, B.A. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **1991**, *74*, 3583–3597. [CrossRef]
21. Association of Official Analytical Chemists (AOAC). *Official Methods of Analysis*, 19th ed.; Association of Official Analytical Chemists (AOAC): Gaithersburg, MD, USA, 2012.
22. De Wit, C.T. On competition. *Versl. Landbouwkd. Onderz.* **1960**, *66*, 1–82.
23. De Wit, C.T.; Van den Bergh, J.P. Competition between herbage plants. *Neth. J. Agric. Sci.* **1965**, *13*, 212–221.
24. Shaalan, A.M.; Khalil, H.E.; Nawar, A.I.; El-Salamouni, M.M. Intercropping of grain and fodder maize crops under different nitrogen levels and cutting dates. *Alex. Sci. Exch. J.* **2015**, *36*, 373–380.
25. Salama, H.S.A.; El-Karamity, D.E.; Nawar, A.I. Additive intercropping of wheat, barley, and faba bean with sugar beet: Impact on yield, quality and land use efficiency. *Egypt. J. Agron.* **2016**, *38*, 413–430. [CrossRef]
26. SAS Institute, Inc. *SAS/STAT User's Guide*; Version 9.1; SAS Institute: Cary, NC, USA, 2012.
27. Winer, B.J. *Statistical Principles in Experimental Design*, 2nd ed.; McGraw-Hill Kogakusha, Ltd.: Tokyo, Japan, 1971.
28. Fehr, W.R.; Caviness, C.E. *Stages of Soybean Development. Iowa Cooperative Extension Service, Iowa Agriculture and Home Economics Experiment Station Special Report Nr 80*; Iowa State University: Ames, IA, USA, 1977; Available online: https://lib.dr.iastate.edu/specialreports/87 (accessed on 12 January 2021).
29. Raza, M.A.; Khalid, M.H.B.; Zhang, X.; Feng, L.Y.; Khan, I.; Hassan, M.J.; Ahmed, M.; Ansar, M.; Chen, Y.K.; Fan, Y.F.; et al. Effect of planting patterns on yield, nutrient accumulation and distribution in maize and soybean under relay intercropping systems. *Sci. Rep.* **2019**, *9*, 1–14. [CrossRef] [PubMed]
30. Ghosh, P.K.; Tripathi, A.K.; Bandyopadhyay, K.K.; Manna, M.C. Assessment of nutrient competition and nutrient requirement in soybean/sorghum intercropping system. *Eur. J. Agron.* **2009**, *31*, 43–50. [CrossRef]
31. Echarte, L.; Della Maggiora, A.; Cerrudo, D.; Gonzalez, V.H.; Abbate, P.; Cerrudo, A.; Sadras, V.O.; Calvino, P. Yield response to plant density of maize and sunflower intercropped with soybean. *Field Crops Res.* **2011**, 423–429. [CrossRef]
32. Batista, V.V.; Adami, P.F.; Sartor, L.R.; Silveira, M.F.; Soares, A.B.; Oligini, K.F.; Kwiecinski, D.; Ferreira, M.L.; Camana, D.; Giacomel, C.L.; et al. Forage yield and silage quality of intercropped maize+ soybean with different relative maturity cycle. *J. Agric. Sci.* **2018**, *10*, 249–261. [CrossRef]
33. Liu, W.; Deng, Y.; Hussain, S.; Zou, J.; Yuan, J.; Luo, L.; Yang, C.; Yuan, X.; Yang, W. Relationship between cellulose accumulation and lodging resistance in the stem of relay intercropped soybean [*Glycine max* (L.) Merr.]. *Field Crops Res.* **2016**, *196*, 261–267. [CrossRef]
34. Millner, J.P.; Aver, R.V.; Hardacre, A.K. The yield and nutritive value of maize hybrids grown for silage. *N. Z. J. Agric. Res.* **2005**, *48*, 101–108. [CrossRef]
35. Thom, E.R.; Dorofaeff, F.D.; Dyson, C.B. Effect of plant population and time of harvest on yield and quality of maize (*Zea mays* L.) grown for silage: I. Yield and chemical composition, and sampling procedures for large areas. *N. Z. J. Agric. Res.* **1981**, *24*, 285–292. [CrossRef]
36. Phipps, R.H.; Wilkinson, M. *Maize Silage*; Chalcombe Publications: Great Britain, UK, 1985.
37. Daynard, T.B.; Tanner, J.W.; Hume, D.J. Contribution of stalk soluble carbohydrates to grain yield in corn (*Zea mays* L.). *Crop Sci.* **1969**, *9*, 831–834. [CrossRef]
38. Bunting, E.S. The question of grain content and forage quality in maize: Comparisons between isogenic fertile and sterile plants. *J. Agric. Sci. Camb.* **1975**, *85*, 455–463. [CrossRef]
39. Bunting, E.S. Effects of grain formation on dry matter distribution and forage quality in maize. *Exp. Agric.* **1976**, *12*, 417–428. [CrossRef]
40. Phipps, R.H. A note on the effect of genotype, density and row width on the yield and quality of forage maize. *J. Agric. Sci. Camb.* **1975**, *84*, 567–569. [CrossRef]
41. Phipps, R.H.; Weller, R.F.; Fulford, R.J. The development of plant components and their effects on the composition of fresh and ensiled forage maize 3. The effect of grain content on milk production. *J. Agric. Sci. Camb.* **1979**, *92*, 493–498. [CrossRef]
42. Matusso, J.M.M.; Mugwe, J.N.; Mucheru-Muna, M. Effects of different maize (*Zea mays* L.) soybean (*Glycine max* (L.) Merrill) intercropping patterns on yields and land equivalent ratio. *J. Cereals Oilseeds* **2013**, *4*, 48–57. [CrossRef]
43. Nawar, A.I.; Salama, H.S.A.; Shaalan, A.M.; Khalil, H.E. Land Equivalent Ratio Versus Dry Matter Equivalent Ratio: Adequacy for additive intercropping. In Proceedings of the 61st Annual conference of the German Society of Agronomy, Kiel, Germany, 8–9 October 2018; Volume 30, pp. 217–218.