Original Research Article

EFFECT OF MAIZE (*Zea mays* L.)- SOYABEAN (*Glycine max* (L.) Merrill) INTERCROPPING PATTERNS ON GROWTH AND YIELD PARAMETERS OF SOYABEAN (*Glycine max* (L.) Merrill) IN KAIMOSI, VIHIGA COUNTY KENYA

ABSTRACT

Cereal-legume combination is a common form of intercropping by most small-scale farmers in Western Kenya in general and Vihiga County in particular. This is due to small sizes of land owned by farmers. The practice maximizes on the land productivity and improve on food security for the otherwise overexploited and degraded soil. The adoption of technologies like intercropping and use of agricultural inputs such as certified seed varieties, and fertilizers have been promoted to boost crop production in western Kenya. This has however not appreciably improved the production particularly of soya bean that has remained at 0.2t ha^{-1} against potential of 2.5t ha^{-1}. Thus, other intercropping patterns need to be tried with a view to enhance productivity. The objectives of this study was therefore to; determine the effect of Maize- Soya bean intercropping patterns on growth and yield parameters of soya beans. The study was conducted in Kaimosi Friend's University (KAFU) research farm in Vihiga County. The experiment involved six treatment comprising; sole soya beans, sole maize, 1Maize-1Soybean (1M: 1S), 1Maize-2Soybean (1M: 2S), 2Maize-2Soybean (2M: 2S) and 2Maize-4Soybean (2M: 4S). Each treatment plot measured 3m x 3m and a space of 1m was left between treatments. They were replicated four times. 50% of each crop type were randomly tagged for data collection from each treatment and data collected after every 14 days from date of sowing. The study was carried out during the long and short rain seasons. Parameters such as soya bean height, number of leaves, leaf area index, pod length, pod number, and yield were determined from the tagged soya beans plants in each plot and collected data was analysed using GenStat statistical package version 15.2 to test for the significant differences between different intercropping patterns. Findings indicated that maize soya beans intercropping pattern had statistical significant impact on pod length, pod number and yields. Intercropping pattern had a significant effect on growth and yield parameters of soya bean. However, intercropping did not affect the height of soya bean despite 1maize:2Soya bean treatment recording the longest plants followed by 1M:2S and the least height recorded in 2M:4S which were also not significant at 70 days after planting. On the other hand, intercropping patterns significantly affected the number of leaves at 70 DAP with 1maize:2soya bean treatment recording the highest number while 2M:4S recording the least. In addition, intercropping pattern had significant effect on Leaf Area Index of soya bean ($P<0.001$). Intercropping pattern also had a significant effect on pod number and length with the longest pods observed in 1maize:2soya bean pattern as well as high number of pods. The maize-soybean intercropping patterns had significant effect on soya beans fresh and dry grain yields with 1M:2S recording statistically the highest yields among the intercrops and the least in 1M:1S in long rain with similar trends in the short rain. There was significantly strong positive relationship between yields and the growthand yield parameters ($p \leq 0.05$). The positive correlation could be due to availability of growth material for the intercrop. The findings from this suggest the 1M:2S intercropping pattern has potential for adoption due to high dry weight yields and efficiency in material utilization.

Key: soya bean, intercropping pattern, productivity and yield

INTRODUCTION

Soybean (Glycine max L. Merill) is continuously becoming an important grain legume food crop in Kenya and other parts of the world. It is extensively grown in arable lands, especially in Western Kenya. Soybean has the potential for improving human diet through supplying high quality protein as well as animal feed and serves as a source of raw material base for agro-industries.

Maize (*Zea mays L.*) is a major cereal crop in Kenya which is consumed by nearly all households. It is extensively cultivated in arable lands of Kenya, particularly in western and rift valley regions. The arable farmlands are under continuous cultivation and are dilapidated and prone to erosion. Thus, technologies like integrated soil fertility management (ISFM) practices such as intercropping of specific cereal crop with legumes are recommended (Karume *et al*., 2022). Intercropping guarantees farmers of good quality and yield (Bedoussac, *et al.*, 2015). Adoption of the right intercropping system that can guarantee increased food production and hence food availability is required.

Cereal-Legume intercropping system commonly practiced by small scale farmers ensures efficient use of resources such as land and inputs comprising labour, biological diversity within the system, insurance against crop failure, increased monetary returns and control of pests and diseases (Yilmaz *et al.*, 2008). The right intercropping pattern which ensures minimal competition for space, nutrients and solar radiation for optimum productivity is required.

Small scale farmers in in Western Kenya in general and in Vihiga county in particular extensively practice cereal-legume intercropping. The most intercropped crops are maize-common bean, maize-cowpea as well as maize-pigeon pea (Jaetzold*et al*., 2006). Soya beans is gradually gaining popularity by farmers of Western Kenya, due to its growing demand for food and fodder for livestock (Mugendi, *et al.*, 2010).

Soya bean is generally intercropped with maize using the conventional one row of maize and one row of soy bean (1M:1S). Modified version of intercropping pattern have been experimented on with mixed results. For instance, an intercropping pattern of two rows of maize and two rows of soya bean was found to significantly improve growth and yield of legumes while keeping the maize yield constant (Mongare *et al.*, 2020).

Earlier, Woomer *et al.* (2004) used a similar pattern which recorded higher productivity of soya bean and was attributed to more light penetration of nearly 20% to the soya bean component, compared to the conventional intercropping pattern. Other similar studies includeMuoneke*et al.*, (2007), Matusso*et al.* (2014), Baghdadi, (2015). From the foregoing, it is necessary to employ new intercropping patterns alongside the existing ones with a view to understand the performance and productivity of the legume partner. Innovative technologies may help to improve crop production as well as mitigate against soil degradation. Thus, the objective of this study was to determine the effects of intercropping patterns on growth and yield of soybeans in Kaimosi, Vihiga County, Kenya.

MATERIALS AND METHODS

The research was carried out atKaimosi Friends University (KAFU) research farm located in Vihiga County, Hamisi Sub-County (Fig. 1), Western Kenya from March to December 2021. It is located on longitude $34^0$50'E and latitude 0^0 07'N, the altitude is 1625m above sea level. Vihiga County is categorized into two main agro-ecological zones, the upper and lower midlands. These zones dictate land-use patterns and population settlement in the county. Kaimosi has a well-drained and fertile soils, which are mainly the red loamy sand soils derived from sedimentary and basalt rocks (Jaetzold*et al.*, 2010). The soils are hydric acrisols, deep well drained slightly acidic to alkaline. The area enjoys tropical type of climate with relief rainfall that ranges from 1500mm to 2000mm which is well distributed throughout the year. The rains are divided into two seasons; the long season and short season rainfall. The long season rains starts from March to July while short rains spread from August to November. The dry season extend from December to February (Republic of Kenya, 2008; M. Luvisi, 2018).

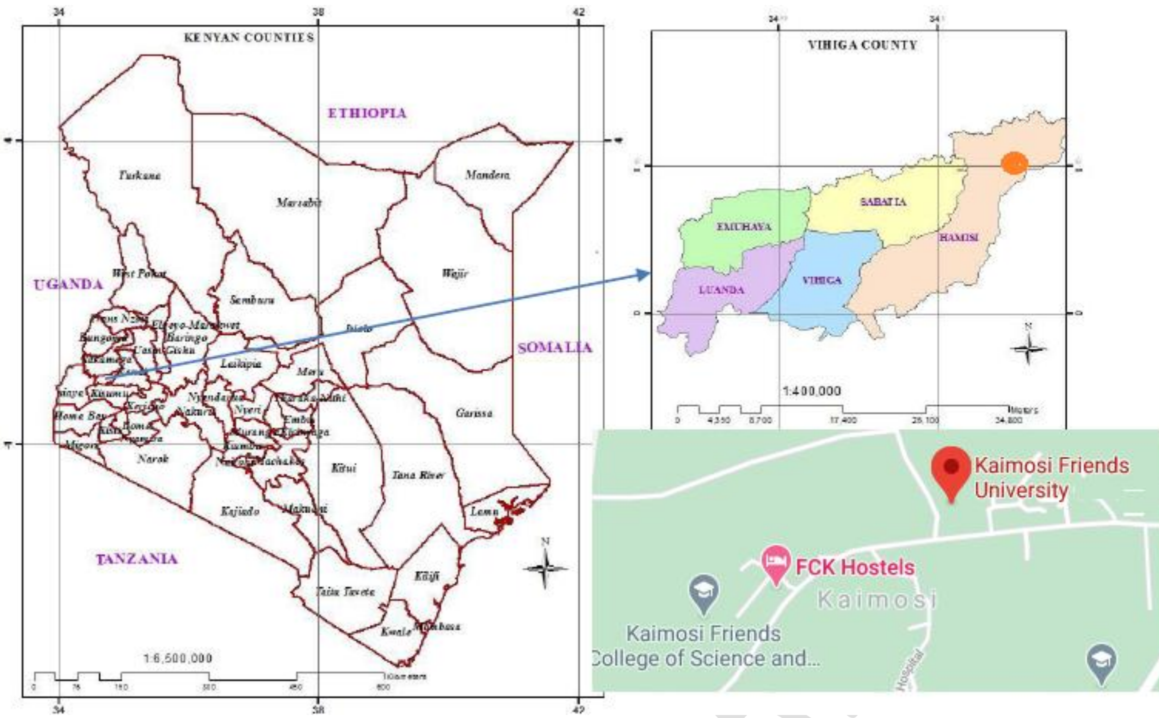

Figure 1: Location of Kaimosi Friend's University

The site was divided into 24 plots as experimental units each measuring 3m x 3m plots. Six treatments comprising sole soya beans, sole maize, one row of maize and one row of soybeans (1M:1S), one row of maize and two rows of soybeans (1M:2S), two rows of maize and two rows of soy beans (2M:2S(and two rows of maize and four rows of soybeans (2M:4S). These randomly assigned and replicated four times. The maize variety H513- soya bean variety SB19 were planted in the prepared plots at recommended depth according to the intercropping pattern at the onset of rains. Three seeds were planted per hole to cater for germination losses.

During planting DAP fertilizer was applied at the rate of 26kg Per acre and 75kgs per acre and CAN for top dressing at the rate of 45kg N per acre and 75kg N per acre according to the management practice recommended by KARI (2013). Thinning was done two weeks after sowing, retaining two plants per hole.

Data was collected on soya bean growth and yield parameters including height, number of leaves, leaf area index, pod length and number for all the five treatments for analysis.

The height was measured from the soil level at the base of the shoot apex using a meter rule while counting of green true leaves was done on the 50% randomly tagged plants in an x-manner to determine the leaf number.The determination of Leaf Area Index (LAI) was done using the inversion of transmitted PAR in the whole treatment, according to the equation of

Goudriaan (1988). The amount of PAR intercepted in a canopy brought by intercropping pattern is inversely proportional to the leaf area index of the plant.

$$L = \frac{\left[\left(1-\frac{1}{2K}\right)f_b - 1\right] \ln \tau}{A(1-0.47 f_b)}$$

Where, L is leaf area index; K is the extinction coefficient for the canopy, given as $k = \frac{1}{2\cos\theta}$ with Θ the zenith angle of the sun; f_b is the fraction of incident PAR; τ is the ration of PAR measured below the canopy to PAR above the canopy; A is given as

$$A = 0.283 + 0.785a - 0.159a^2$$

with the leaf absorptivity in the PAR band (typically around 0.9).

The number of pods per plant was physically counted as per the sampled plants (50% of the total soya bean population per treatment) in each treatment. The length of the pods was measured using a string from the sampled plants, which was then transferred to a meter rule and recorded. This was done when pods started forming to harvesting at 42 days after planting Soya bean was harvested 98 days after sowing in both seasons. This was done through uprooting of the whole plant drying them for a day and then crushing using a stick to break the pods and obtain the seeds. Afterwards, threshing was done to separate chaffs from the grain and measuring of fresh weight was done. Later the grains were dried for three days to attain the right moisture content of 13% confirmed by a moisture-meter, at that point dry weight was taken. Two weeks later maize was also harvested hand shelled dried and weighted. This data was then used in determining LER of the intercropping verses mono-cropping.

To evaluate the intercrop's performance, land equivalent ratio (LER) was calculated using the formula of Ofori and Stern, (1987) thus;

Land Equivalent Ratio (LER) = $(Y_{ij} / Y_{ii}) + (Y_{ji} / Y_{jj})$

Where, Y is the yield per unit area, Y_{ii} and Y_{jj} are sole crop yields of the component crops i and j, and Y_{ij} and Y_{ji} are intercropped yields.

The partial LER values L_i and L_j, represent the ratios of the yields of crops i and j when grown as intercrops. Thus,

Partial LER (L_i) = (Y_{ij} / Y_{ii})

Partial LER (L_j)= (Y_{ji} / Y_{jj})

LER is the sum of the two partial land equivalent ratios so that, LER = Partial LER (L_i) + Partial LER (L_j)

Data analysis

Data of soya bean, pod length, pod number and yield were subjected to analysis of variance (ANOVA) using GenStat statistical package version 15.2 to test for the significant differences between different intercropping patterns. LSD post hoc test at 95% confidence level was used to separate the means. The yield was subjected to t-student test at 5% of significance level ($p \leq 00.5$).

RESULTS

Plant height of soya beans

Soya bean height increased progressively from germination to maturity in all the treatments during data collection period. The intercropping pattern of maize and soya beans had no significant effect on height of soya beans during the study as shown in Table 1. At the end of the experimental period 1 row of maize and 2 rows of soya bean recorded the tallest plant height with a mean height of 64.50cm at 84 DAP followed by treatment with 1 line of maize and 1 line of soya bean and third was treatment with 2 line of maize and 2 line of soya bean with an average height of 57.75cm, the treatment with the least plant height was that with 2 line of maize followed by 4 lines of soya bean with a men height of 56.00cm.

Table 1: Mean soya beans height in (cm).

TREATMENTS	14 DAP	28 DAP	42 DAP	56 DAP	70 DAP	84 DAP
Sole soya bean	4.95^{a}	14.75^{a}	15.80^{b}	27.65^{a}	33.25^{a}	59.50^{a}
1M-1S	4.80^{ab}	15.00^{a}	18.90^{ab}	31.00^{a}	42.03^{a}	61.50^{a}
1M-2S	4.73^{b}	12.45^{a}	20.95^{a}	29.05^{a}	34.40^{a}	64.50^{a}
2M-2S	4.83^{ab}	16.68^{a}	21.10^{a}	31.95^{a}	39.10^{a}	57.75^{a}
2M-4S	4.83^{ab}	16.00^{a}	18.40^{ab}	26.90^{a}	32.75^{a}	56.00^{a}
LSD	**0.224**	**4.763**	**4.048**	**5.500**	**10.781**	**9.350**
***P-Vale* (*P*≤0.05)**	**0.358**	**0.725**	**0.078**	**0.262**	**0.251**	**0.395**

Treatments with same letter along the columns are not significantly different according to LSD at P≤0.05

Leaf number of soya beans

Intercropping pattern of maize and soya bean significantly affected the number of leaves at the end of the experimental period ($p>0.05$) (Table 2). Treatment with 1 line of maize followed by 2 lines of soya bean (T4) recorded significantly the highest number of leaves among the intercrops while sole soya bean had the overall significantly the highest number of leave in comparison to the rest of the treatments but had no statistical difference to 1M:2S pattern only. When intercrops were compared, pattern with 1 line of maize and 2 lines of soya bean had significantly the highest number of leaves of 60.0 followed by conventional pattern of 1 line of maize followed by 1 line of soya bean with a mean number of leaves of 48.25 and 2 line of maize and 2 lines of soya bean with a mean number of 46.5 leaves. The treatment with significantly the least number of leaves two line of maize and four lines of soya bean with an average of 32.75 number of leaves.

The results of the long rain season were different from the short season since in the long season intercropping pattern indicated a significant impact on number of leaves and this was not evidenced in the short rain period as intercropping had no significant impact on number of leaves throughout the study period (Table 3).

Table 2: Table showing mean number of leave for the long season

TREATMENTS	14 DAP	28 DAP	42 DAP	56 DAP	70 DAP	84 DAP
Sole soya bean	2.00[a]	9.00[ab]	14.50[a]	18.75[a]	26.00[b]	60.25[a]
1M-1S	2.00[a]	8.50[ab]	14.75[a]	28.75[b]	34.50[a]	48.25[ab]
1M-2S	2.00[a]	8.25[b]	15.25[a]	22.50[ab]	33.00[ab]	60.00[a]
2M-2S	2.00[a]	9.50[a]	14.00[a]	21.75[ab]	34.00[ab]	46.50[ab]
2M-4S	2.00[a]	8.50[ab]	15.25[a]	23.15[ab]	30.00[ab]	32.75[b]
LSD	**0**	**1.215**	**1.707**	**7.705**	**21.825**	**18.560**
***P-Vale (P*≤0.05)**	**-**	**0.242**	**0.501**	**0.142**	**0.325**	**0.001**

Treatments with same letter along the columns are not significantly different according to LSD at p≤0.05

Table 3**: Table showing mean number of leaves for the short season**

TREATMENTS	14 DAP	28 DAP	42 DAP	56 DAP	70 DAP
Sole soya bean	5.50[b]	8.75[a]	11.50[a]	17.25[a]	39.50[a]
1M-1S	6.00[ab]	8.75[a]	12.00[a]	18.50[a]	38.50[a]
1M-2S	6.00[ab]	9.00[a]	11.75[a]	20.00[a]	39.25[a]
2M-2S	6.00[ab]	9.00[a]	12.00[a]	18.00[a]	34.25[a]
2M-4S	6.75[b]	8.50[a]	11.75[a]	21.50[a]	36.25[a]
LSD	**0.933**	**0.826**	**0.613**	**6.838**	**13.448**
***P-Vale (P*≤0.05)**	**0.133**	**0.680**	**0.415**	**0.694**	**0.903**

Treatments with same letter along the columns are not significantly different according to LSD at p≤0.05

Leaf Area Index of soya beans

Intercropping pattern significantly affected the leaf area index (LAI) of soya bean during the study period (p≤0.05) (Table 4). Treatment with 2lines of maize and 4 lines of soya bean pattern recorded the highest leaf area index than both the sole crop and intercrop treatment though statistically not significant when compared to the intercrop treatments. This was followed by treatment with 2line of maize followed by 2 line of soya bean, then 1M:2S pattern and the least was 1M:1S patterns with the LAI of 0.50,0.43 and then 0.43 respectively at 84 DAP. There was no significant difference among all the treatments for both the sole and intercrop treatments except between sole soya bean with 2M:2S and 2M:4S pattern only. The result in the long rain had a similar trend to those of the short rains season.

Table 4: Table showing mean LAI of soya beans during the long season

TREATMENTS	42 DAP	56 DAP	70 DAP	84 DAP
Sole soya bean	0.08^{b}	0.11^{c}	0.15^{c}	0.33^{b}
1M-1S	0.13^{ab}	0.17^{bc}	0.18^{bc}	0.43^{b}
1M-2S	0.15^{a}	0.17^{bc}	0.22^{b}	0.43^{b}
2M-2S	0.15^{a}	0.20^{b}	0.21^{b}	0.50^{a}
2M-4S	0.19^{a}	0.26^{a}	0.29^{a}	0.55^{a}
LSD	**0.069**	**0.037**	**0.067**	**0.120**
P-Vale (P≤0.05)	**0.048**	**0.007**	**0.007**	**0.019**

Treatments with same letter along the columns are not significantly different according to LSD at p≤0.05

Pod length of soya beans

Intercropping pattern of maize and soya bean had a significance effect on the pod length of soya beans (p≤0.05) during the designated time of data collection as indicated in Table 6. By 84 DAP when different intercropping pattern were compared 1M:2S pattern recorded significantly the longest pods with an average of 3.84cm followed by 1M:1S, 2M:2S, and 2M:4S patterns respectively which were all significant. There was statistical significant difference among all the intercrops except between 1M:1S and 2M:2S intercropping patterns. 2M:4S pattern had significantly the least pod length of 2.26 as shown in the table below.

Table 5: Table showing mean pod length of soya beans

TREATMENTS	70 DAP	84 DAP
Sole soya bean	4.05^{a}	4.35^{a}
1M-1S	2.03^{d}	2.78^{c}

1M-2S	3.05[b]	3.84[b]
2M-2S	2.08[c]	2.65[c]
2M-4S	2.83[e]	2.26[c]
LSD	**0.441**	**0.386**
***P-Vale (P*≤0.05)**	**< 0.0001**	**< 0.0001**

Treatments with same letter along the columns are not significantly different according to LSD at p≤0.05

Pod number of soya beans

Intercropping pattern significantly affected the number of pods of soya beans (p≤0.05) during the study period with sole soya bean treatment recording significantly the highest number at both 70 and 84 DAP (Table 6). When intercrops were compared 2M:4S treatment had significantly the highest number of soya bean pods with an average of 45.5 pods per plant in the long rain period but with similar trend in the short rain, this was followed by 1M:2S, 1M:1S and significantly the fewest pods recorded in 2M:2S pattern with an average of 24.25 pods per plant. All the treatment indicated a statistical difference among them except between 1M:2S and 1M:1S.

Table 6: Table showing mean pod number of soya beans

TREATMENTS	70 DAP	84 DAP
Sole soya bean	28.50[b]	56.50[a]
1M-1S	14.50[c]	30.75[b]
1M-2S	13.25[c]	36.00[c]
2M-2S	14.00[c]	24.25[d]
2M-4S	35.75[a]	45.50[b]
LSD	**4.629**	**8.678**
***P-Vale (P*≤0.05)**	**< 0.0001**	**< 0.0001**

Treatments with same letter along the columns are not significantly different according to LSD at p≤0.05.

Yield of soya beans

Intercropping pattern of maize and soya beans significantly affected the yield of soya during the study period (Table 7). At harvesting of soya beans 98 DAP, intercropping significantly affected the fresh weight of soya bean. Sole soya bean recorded the highest fresh weight of 1.64g. However, among the intercrop patterns the highest fresh weight was recorded in the 2M:4S (1.408kgs) followed by 1M:2S (1.013kgs), then 2M:2S pattern (0.948kgs) and last 1M:1S (0.618kgs) respectively. The final yields which are the dry weight had sole soya bean recording significantly the highest yield in overall, while 1M:2S pattern recording significantly the highest weight of 0.913kgs among the intercrops followed by 2M:4S pattern and 2M:2S pattern respectively.

Table 7: Table showing mean yields of soya beans at 98 days after planting

TREATMENTS	FRESH WEIGHT(FW)	DRY WEIGHT/YIELDS(DW)
Sole soya bean	1.640^{a}	1.015^{a}
1M-1S	0.618^{c}	0.419^{c}
1M-2S	1.013^{b}	0.913_{a}
2M-2S	0.948^{b}	0.703^{b}
2M-4S	1.408^{a}	0.909^{a}
LSD	**0.373**	**0.146**
***P-Vale (P*≤0.05)**	**0.0001**	**0.0001**

Treatments with same letter along the columns are not significantly different according to LSD at p≤0.05.

Correlation of maize-soya beans intercropping patterns with the yield of soya beans

During the study all the parameters showed positive relationship with the yield of soya beans, with significantly strong relationship indicated by pod length and fresh weight as shown in table 8. Also, height, leaf area index, photosynthetic active radiation (PAR), pod length and pod number showed a positive relationship with yield ($p<0.05$). However, number of leaves had no significant relationship with the yield of soya ($p>0.05$).

Table 8: Table showing correlation analysis of growth parameters, PAR and yield parameters onyield of soya bean

Variables	Height	Leaf no.	LAI	PAR	Pod length	Pod number	Fresh weight	Dry weight
Height	1.000	0.185 *P=0.433*	0.525 *P=0.018*	0.666 *P<0.0001*	0.754 *P=0.0001*	0.828 *P<0.0001*	0.854 *P<0.0001*	0.611 *P=0.004*
Number of leaves	0.185 *P=0.434*	1.000	0.338 *P=0.145*	0.422 *P=0.064*	0.354 *P=0.126*	0.609 *P=0.005*	0.501 *P=0.024*	0.394 *P=0.085*
Leaf area index	0.525 *P=0.018*	0.338 *P=0.145*	1.000	0.501 *P=0.024*	0.551 *P=0.012*	0.609 *P=0.005*	0.501 *P=0.024*	0.535 *P=0.015*
PAR	0.666 *P<0.001*	0.501 *P=0.025*	0.501 *P=0.025*	1.000	0.607 *P=0.005*	0.739 *P=0.0002*	0.792 *P=0.0001*	0.621 *P=0.004*

Pod length	0.754 *P=0.0001*	0.551 *P=0.012*	0.551 *P=0.012*	0.607 *P=0.005*	1.000	0.811 *P<0.0001*	0.756 *P=0.0001*	0.669 *P=0.001*
Pod number	0.828 *P<0.0001*	0.609 *P=0.005*	0.609 *P=0.005*	0.739 *P=0.0002*	0.811 *P<0.0001*	1.000	0.902 P<0.0001	0.669 *P=0.004*
Fresh weight	0.854 *P<0.0001*	0.501 *P=0.024*	0.501 *P=0.024*	0.792 *P=0.0001*	0.756 *P=0.0001*	0.902 *P<0.0001*	1.000	0.669 *P=0.004*
Dry weight	0.611 *P=0.004*	0.394 *P=0.085*	0.535 *P=0.015*	0.621 *P=0.004*	0.669 *P=0.001*	0.669 *P=0.004*	0.669 *P=0.004*	1.000

DISCUSSION

Effect of maize-soya beans intercropping patterns on growth of soya bean

Plant height of soya beans

Soya bean height increased progressively from germination to maturity with the advancement of growth in all the treatments during data collection period and longer stem in the intercrops treatments than the sole treatment. This study shows that intercropping pattern did not affect the height of soya bean. Similar studies byMutusso*et al.*(2014) and Muoneke*et al.* (2007), did not find significant differences in plant height among intercropping patterns of maize and soya beans. Similarly, finding by Cai *et al.,* (2010), (Gao *et al*., 2010), and (Salama *et al.,* 2022)in other crop combination namely lentil- wheat intercrop, sorghum- cow peas intercrop and maize- cow peas intercropping pattern respectively were similar to the results of this study. Plant height is taken as a basic indicator used in morphological observation and reflects the growth and development of crops and the rate and robustness of plant growth (Verreynne*et al*., 2021). Increased height among the intercrops than sole soya bean was as a result of the degree of shading by maize. For instance, the soybean plant in 1M:2S were more shaded and they were the tallest while those in the 2M:4S pattern were more exposed to light and were the shortest. Thus, soya bean plant underwent a series of shading reaction to adapt to the shading stress, resulting in preferential supply of soya bean photosynthate to stem elongation, thus increasing soya bean height. Furthermore, height increase of soya bean may also have been due to positive phototropism where plants grow towards a light source in order to carry out photosynthesis. Maize dominateby lengthening their stem more than soya bean and covering them by forming a canopy on the understorey as growth and development period advances. This is because maize a C4 plant has a more competitive ability for resources like water, light and nutrients compared to soya beans a C3 plant.

It is noteworthy that intercropping maize and mung beans did not significantly affect the height of the mung beans Muhamad *et al*. (2020) contrary to our findings. However, the intercropping patterns were fewer in their study consisting of alternate double row pattern and convention system of alternating 1 to 1 row.

Leaf number of soya beans

Intercropping pattern significantly affected the leaf numbers of soya bean. However, the highest number of leaves were observed in treatment four with 1M;2S pattern among the intercrops. The findings of this study corroborates those of (Baker *et al.,* 2021), who reported significantly high number of leaves in both sorghum and cowpeas in sorghum cow peas intercropping pattern. (Mohamed *et al*., 2020) also reported more vegetative growth of cow peas under maize intercrop. The high number of leaves recorded in 1M:2S pattern could because maize minimizes the amount of infra-red radiation reaching the lower soya bean thus encouraging more branches and leave growth. Soya bean under 1M:2S pattern favorably adapt to shade brought by the overstorey maize either through tolerance or avoidance mechanism and continued with the normal physiological processes. Soya bean under the pattern could tolerate the shade enabling them to survive under low light condition and still increase light harvesting and light use efficiency enabling continuity in food manufacturing through the process of photosynthesis thus increasing vegetative growth of soya bean. Also, soya bean under 1M:2S pattern adapted to absorb and capture as much light as possible to optimize the photosynthesis output. This in turn may have help them to accelerate CO_2 fixation as well as accumulate carbohydrates to ensure physiological growth rate such as leaf multiplication is achieved (Wu *et al.,* 2017).

Therefore, intercropping pattern affect the leaf number of soya bean at a specific period of production as shown in the finding of this study when intercropping affected soya bean number of leaves at the end of production period but not at the beginning nor at the middle end.

Leaf area index of soya beans

This study shows that intercropping patterns have an influence on LAI. LAI for treatment of 2 line of maize and 4 line of soya bean intercropping pattern was the highest while the least LAI was recorded for 1 line of maize and 2 line of soya bean pattern. Similar findings were recorded by Thapa (2015) and (Khonde *et al.,* 2022), who also studied intercropping patterns of maize and soya beans. These findings are largely attributed tothe reduction of infra-red radiation (R:FR) ratio of photosynthetic active radiation at the top of the intercropping soya bean canopy that increased LAI of underneath soya bean (Liu et al.,2017). LAI of a canopy is key in forecasting crop growth and yields, a reasonable LAI is critical in keeping high photosynthetic rates and the yield. If the index is too low, not enough light will be absorbed and if too high, lower leaves will not receive enough light and will thus be a liability (Brintha & Seran, 2009). In the current study soya bean under intercrop treatment recorded the highest LAI than those under monocrop which agrees with the findings of Becham *et al*. (2018) who reported larger leaf areas index in maize-soya bean intercrops than sole crops. Contrary to this study Raza *et al*., (2021) in strip maize and soya bean intercropping reported low leaf are index in maize-soya bean intercrops than monocrop. This was because soya bean may have suffered from heavy maize shading and water stress in an intercropping system than sole soya bean affecting dry matter production and partitioning.Thus intercropping of maize and soya bean significantly affected the leaf area index (LAI) of soya bean throughout the period of data collection as a result of a reasonable LAI absorbed that led to increased light absorption for photosynthesis.

Effect of maize-soya beans intercropping patterns on yield parameters of soya beans

Pod length of soya beans

Intercropping pattern significantly affected the pod length of soya bean with the longest pod length observed in 1 row of maize and 2 rows of soya bean pattern with the pod length of 3.825cm. This was followed by conventional pattern of 1 row of maize and 1 row of soya bean with pod length of 2.275cm at 84DAP. However, sole soya bean recorded the longest pods amongst all treatments. These findings mirror those of Muhammad *et al.,* (2012)who found that different intercropping treatment of mung bean with maize significantly affected the length of mung bean pods and mung bean pods were also longest in the sole crop treatment. These results may be attributed to sufficient light interception during the reproductive stage which allowed higher rate of photosynthesis generating more biomass which accumulated to lengthen the pods. The optimum nutrient utilization may also have occurred in this pattern which led to increases length of pods of soya bean. The longest pods observed in sole soya bean than intercrop treatment could be attributed to availability of more nutrients that fostered the apical meristematic activities leading to vegetative growth and pod lengthening and less interspecific competition for available resourcesMuhammad *et al.,* (2012). As observed earlier (Matusso *et al.*, 2014), canopy which brings about 49-20% of ambient light leads to lengthening of internodes and increased lodging in soya bean plants. Whereas light enhancement beginning at early pod formation augments seed length from 8% to 23% in maize-soya bean intercrops (Mathew *et al.,* 2000). However, it is important to note that nutrient absorption through nitrogen fixation processes of the two crops in the intercropping treatments was not quantified in this study. Further studies are necessary to fill this gap.

Pod number of soya beans

Intercropping pattern significantly affected the number of pods of soya beans with the highest number of pods recorded in 2 line of maize and 4 line of soya bean among the intercrop treatment with an average of 45.5 pods per plant. Anan *et al.*, (2003) found that the number of pods per plant of peanut, soya beans and mug bean were similarly affected by the intercropping pattern. The result also agrees with Muhammad *et al.* (2012)who found that different intercropping treatments caused significant variation in pods per plant of mung bean. Other studies (Islam *et al*. 2006; Muhammad *et al.* 2012)with mung bean and maize intercrops also found a higher number of pods in sole mung bean as compared to intercropping treatments with maize. These findings may collectively be attributed to lack of inter specific competition and better utilization of nitrogen applied as a starter dose and fixed by the root nodules. Nevertheless, the phenomenon of biological nitrogen fixation appears to play an important role in soya bean pod production. It was however not determined in this study and should be part of future studies. The high number of pods recorded in 2 line of maize and 4 line of soya bean among the intercrop could be attributed to the optimum amount of leaf area index (LAI) reported elsewhere in this paper as it is key in determining the number of pods in soya bean in an intercropping pattern. The pattern also may have allowed for maximum light interception which reduces flower abortion and hence increasing the number of pods as the number of flower recorded in soya bean determines the amount of pods per plant. Light improvement at late vegetative or early flowering multiplies the number of pods which later improves its yield by encouraging more vegetative growth, flowering and increased podding in soya bean plant (Matusso*et al.*, 2014).

Yield of soya beans

Intercropping pattern significantly affected the yields of soya bean during the study with the highest fresh and dry yields being recorded in 2M:4S and 1M: 2S patterns, respectively. Matusso *et al* (2014), also found that intercropping pattern significantly affected the yield of soya beans. The highest yields of soya bean were recorded in sole treatment in this study and those of Mongare *et al* (2020) and Khonde et a. (2022). The reduction in soybean yields under intercrop treatment may be attributed to interspecific competition between the intercrop components for water, light, and nutrients, coupled with the aggressive growth effects of maize (C4 species) on soya bean, a C3 species. Furthermore, yield of soya beans could have reduced due to maize shading effects on soya bean, making the legume component to allocate its photosynthates to vegetative growth and height increasing in order to compete with taller maize (Ali *et al.,* 2012). In addition, (Papathanasiou *et al.,* 2022), also argued that low irradiance during flowering cause a high proportion of aborted flowers that leads to low number of pods per plant in common bean affecting the final yield. Matusso*et al*. (2014), on the other hand observed that higher LAI often cause no more increase in productivity rather decreases due to respiratory CO_2 losses from heavily shaded leaves and stems. Reduction in dry weight yield of soybean in 2M:4S pattern could be because pod did not fill fully at maturity bringing about inferior grains. Poor grain filling could be brought about by low nitrogen concentration and uptake from the soil possibly due to lack of native rhizobia to nodulate the legume which determines pod filling at maturity. Inferior pods may also be attributed to poor plant nutrition and other plant stresses that inhibit nitrogen fixation such as insufficient water, nutrients and light as they are key factors affecting productivity of a plant.

The finding where 1 row of maize and 2 rows of soya bean (1M:2S) pattern recorded the highest dry weight (yields) was possibly due to mature and healthy pod harvested as a result of availability of nutrients especially nitrogen and water absorption during flowering and maturity stage. The 1M:2S intercropping pattern allowed for sufficient PAR interception (data not shown). The pattern (1M:2S) also may have allowed for optimum soil cover that minimized the rate of evapotranspiration thus more water was available from soil for use in primary production.

During the study period, the parameters showed positive relationship with the yield of soya beans, with significantly strong relationship indicated by pod length and fresh weight. These parameters (leaf number, pod number and length) directly impact on final yield. Increased vegetative growth allows for proper light interception for photosynthesis thus more flower formation and development. The more flower a plant develops the more the pods and thus increase yield.

Begna *et al.,* (2020) established a positive correlation of height with yields parameters indicating that, taller plants produce heavy fruits, long fruit length and heavy grain in maize- soya bean intercropping system.

5.0 Conclusion.

In conclusion, this study has established that soya bean height was not significantly affected by intercropping although plants in intercrop treatments were taller, probably due to the shading effect of maize plants. The reduced number of leaves in intercrop treatments were as a result of adaptation of the understory soya beans to the light. LAI, pod length and number were affected by intercropping, which resulted in reduced final yield of soya bean in various intercropping patterns. The 2M:4S pattern appears to have performed better in final fresh weight yield but less effective in dry weight. The higher light exposure contributed to the favourable performance and has potential to be adopted, after further investigations.

REFERENCES

Baker, C., Modi, A. T., &Nciizah, A. D. (2021). Weeding Frequency Effects on Growth and Yield of Dry Bean Intercropped with Sweet Sorghum and Cowpea under a Dryland Area. *Sustainability*, *13*(21), 12328.

Begna, T. (2020). Major challenging constraints to crop production farming system and possible breeding to overcome the constraints. *International Journal of Research Studies in Agricultural Sciences (IJRSAS)*, *6*(7), 27–46.

Brintha, I., & Seran, T. H. (2009). *Effect of paired row planting of radish (Raphanus sativus L.) intercropped with vegetable amaranthus (Amaranthus tricolor L.) on yield components of radish in sandy regosol*.

Karume, K., Ayagirwe, R., Ibanda, A., Lina, A. A., Mubalama, M., Chuma, G., & Bagula, E. (2022). *Scoping study on existing CIS/CSA relevant units/engagements in Democratic Republic of Congo*.

Khonde, G. P., Tshiabukole, J.-P. K., Vumilia, R. K., Djamba, A. M., Kankolongo, A. M., Nkongolo, K. K., &Lukeba, J.-C. L. (2022). Simulation of the Growth and Leaf Dynamic in Quality Protein Maize and Soybean Intercropping Under the Southwestern Savannah Conditions of DR Congo. *Open Access Library Journal*, *9*(12), 1–18.

LUSIGI, M. (2018). *Analysis of adoption of modern Agricultural technologies by women in Luanda and Emuhaya sub-counties, VIhiga county, Kenya*. Maseno University.

Mohamed, A. M. E., Ibrahim, M. M., El-Said, M. A. A., & Mahdy, A. Y. (2020). Effect of intercropping cow pea with pearl millet on forage yield and competitive relationships. *Archives of Agriculture Sciences Journal*, *3*(3), 101–116.

Mongare, P. O. (2020). *Effect of Cropping System and Nitrogen on Maize and Soy Bean Yields in Western Kenya*.

Papathanasiou, F., Ninou, E., Mylonas, I., Baxevanos, D., Papadopoulou, F., Avdikos, I., Sistanis, I., Koskosidis, A., Vlachostergios, D. N., & Stefanou, S. (2022). The Evaluation of Common Bean (Phaseolus vulgaris L.) Genotypes under Water Stress Based on Physiological and Agronomic Parameters. *Plants*, *11*(18), 2432.

Raza, M. A., Yasin, H. S., Gul, H., Qin, R., MohiUd Din, A., Khalid, M. H. B., Hussain, S., Gitari, H., Saeed, A., & Wang, J. (2022). Maize/soybean strip intercropping produces higher crop yields and saves water under semi-arid conditions. *Frontiers in Plant Science, 13*, 1006720.

Salama, H. S., Nawar, A. I., & Khalil, H. E. (2022). Intercropping pattern and N fertilizer schedule affect the performance of additively intercropped maize and forage cowpea in the Mediterranean region. *Agronomy*, *12*(1), 107.

Wu, Y., He, D., Wang, E., Liu, X., Huth, N. I., Zhao, Z., Gong, W., Yang, F., Wang, X., & Yong, T. (2021). Modelling soybean and maize growth and grain yield in strip intercropping systems with different row configurations. *Field Crops Research*, *265*, 108122.

Bedoussac, I., Journet, E. P., Hauggaard-Nielsen, H., Naudin, C., Corre-Hellou, G., Jensen, E. S., . . . Justes, E. (2015). Ecological principles underlying the increase of productivity achieved by cereal-grain legume intercrops in organic farming: a review. *Agronomy Sustainable Development*, 35:911-935.

Jat, S. K., Shivay, Y. S., Parhar, C. M., & Meena, H. N. (2012). Evaluation of summer legumes for their economic feasibility, nutrient accumulation and soil fertility. *Journal of Food Legume*, 25(3):239-242.

Liu, B., Liu , X. B., Wang, C., Jin, J., & Harbert, S. (2010). Response of soybean yield and yield components to light enrichment and planting density. *International Journal of Plant Production*, 4 (1): 1-10.

Mathew, J. P., Herbert , S. J., Zhang, S., & Rautenkranz, A. A. (2000). Differential Response of Soybean Yield Components to the Timing of Light Enrichment. *Agronomy Journal*, 92: 1156-1161.

Matusso, J. M., Mugwe, J. N., & Mucheru-Muna, M. (2014). Effects of different maize (Zea mays L.)–soybean (Glycine max (L.) Merrill) intercropping patterns on yields light interception and leaf area index in two contrasting sites. *Agronomy Journal*, pp 77-86.

Muoneke, C. O., Ogwuche , M., & Kalu, B. (2007). Effect of Maize Planting Density on the Performance of Maize/Soybean Intercropping System in a Guinea Savannah Agro-ecosystem. *African Journal of Agricultural Research*, Volume 2 (12), pp. 667-677.

Ofori, F., & Stern, W. R. (1987). Cereal-legume intercropping systems. *Advances in Agronomy*, 40:41-90.

Reddy, T., & Reddi, G. (2007). Principles of Agronomy. *Kalyani Publishers*, 468-489.

Thapa, A. (2016). *On-farm evaluation of maize and legume intercropping for improved crop productivity in the mid hills of Nepal (Master's thesis).* Netherlands: Wageningen University.

Woomer, P., Langat, M., & Tungani, J. O. (2004). Innovative maize-legume intercropping results in above- and below-ground competitive advantages for understory legumes. *West African Journal of Applied Ecology*, 6:85–94.

Wu, Y., He, D., Wang, E., Liu, X., Huth, N. I., Zhao, Z., Gong, W., Yang, F., Wang, X., & Yong, T. (2021). Modelling soybean and maize growth and grain yield in strip intercropping systems with different row configurations. *Field Crops Research*, *265*, 108122

Yilmaz, S., Atak, M., & Erayman , M. (2008). Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean Region. *Turkish Journal of Agriculture*, 32:111-119.